U.S. Department of Homeland Security
Region 2
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New York, New York 10278-0002

FEMA

July 23, 2026

The Honorable Jenniffer González Colón
Governor of Puerto Rico
Post Office Box 9020082
San Juan, Puerto Rico 00902-0082

Reference: Designation of the 2026 Puerto Rico State Hazard Mitigation Plan as Approved

Dear Governor González Colón:

The U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA) Region 2 Mitigation Division, Resilience Branch has received and approved the adoption resolution for the 2026 Puerto Rico State Hazard Mitigation Plan. The plan is approved effective July 23, 2026, with an expiration date of July 22, 2031, in accordance with the planning requirements of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended, the National Flood Insurance act of 1968, as amended, and Title 44 Code of Federal Regulations (CFR) Part 201.

The State Mitigation Plan Review Tool, under separate cover, provides further details on the findings of this review, as well as opportunities for strengthening the plan as it is maintained and implemented over the coming years.

If we can be of assistance, please contact Jack Heide, Resilience Branch Chief at (202) 709-0671, or john.heide@fema.dhs.gov.

Sincerely,

PATRICK M TUOHY
Digitally signed by PATRICK M TUOHY
Date: 2026.07.24 10:19:17 -04'00'

William McDonnell
Director, Mitigation Division

cc María Marín Colón, Governor's Authorized Representative and State Hazard Mitigation Officer, Central Office for Recovery, Reconstruction and Resilience

Zuleika González Sánchez, Mitigation Director, Puerto Rico Emergency Management Bureau

Orlando (Landy) Olivera, Federal Emergency Management Agency Caribbean Area Office Coordinator

John (Jack) Heide, Federal Emergency Management Agency Region 2 Resilience Branch Chief

Placeholder Cover

2026 Puerto Rico State Hazard Mitigation Plan

May 26, 2026

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EXECUTIVE SUMMARY

Executive Summary

The 2026 Puerto Rico State Hazard Mitigation Plan (SHMP) identifies risks and develops mitigation measures to reduce vulnerability to natural and human-caused hazards. Hazard mitigation is defined as any sustained action taken to reduce or eliminate long-term risks from hazards to people or property. Hazard mitigation planning helps identify the Government of Puerto Rico's visions and goals for hazard mitigation across the island. Updating the hazard mitigation plan further ensures that Puerto Rico will remain eligible for pre- and post-disaster federal grant funding.

This plan update was developed through a collaborative and comprehensive planning process between May 2025 and July 2026. **130 plan participants** were actively engaged through three Planning Team meetings, biweekly Steering Committee meetings, and numerous emails, phone calls, and Subject Matter Expert stakeholder meetings. Over **65 agencies** attended at least one meeting, and **93% of stakeholders invited participated** in at least one type of engagement.

Authority

This plan was developed in accordance with the 2025 State Mitigation Planning Policy Guide and the Code of Federal Regulations, Part 201 (44 CFR Part 201 §201.1-201.5). In accordance with Law 20, the Puerto Rico Homeland Security Department Act, the Puerto Rico Emergency Management Bureau (PREMB) was responsible for preparing the SHMP update. The Steering Committee, which comprised PREMB, the Central Office for Recovery, Reconstruction and Resiliency (COR3), the Federal Emergency Management Agency (FEMA), and the planning consultant IEM, Inc., (IEM), also provided project management–level oversight of the plan development process.

Plan Update Priorities

Hazard mitigation plans are required to be updated and resubmitted for FEMA approval every five years. The structure and format of this update were revised to align with the updated mitigation planning guidance, which became effective in May 2025, as well as industry best practices. The stakeholder engagement was expanded to include a broader range of stakeholders and to add hazard-specific meetings in addition to Planning Team meetings. Additional hazards were added, expanding the count from 15 to 22. The mitigation goals and actions were revised to incorporate additional stakeholders, identify current priorities, expand outreach and community engagement, and emphasize hazard mitigation. Finally, the plan maintenance process was revised, including establishing, for the first time, a digital version of the SHMP.

Plan Schedule

The plan was updated between May 2025 and July 2026.

Step	Schedule
Planning Process	May to December 2025
Hazard Identification and Risk Analysis	August to December 2025
Capability Assessment	October to November 2025
Mitigation Strategy	November to December 2025
Draft Plan Review	January to May 2026
Plan Adoption	TBD: July 2026

Hazards Identified

The Planning Team evaluated all potential hazards that could impact the planning area. The Planning Team identified numerous hazards not previously listed in the prior plan. Moreover, the team ranked the following hazards:

	Hazards
High Risk	Coastal Erosion, Landslides, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Pandemic/Epidemic, Sargassum, Hazardous Materials
Medium Risk	Liquefaction, Heavy Rain, Invasive Species, Lightning, Rip Currents, Subsidence, Tornadoes, Tsunami, Wildfire, Dam Failure
Low Risk	Waterspouts

Mitigation Strategy

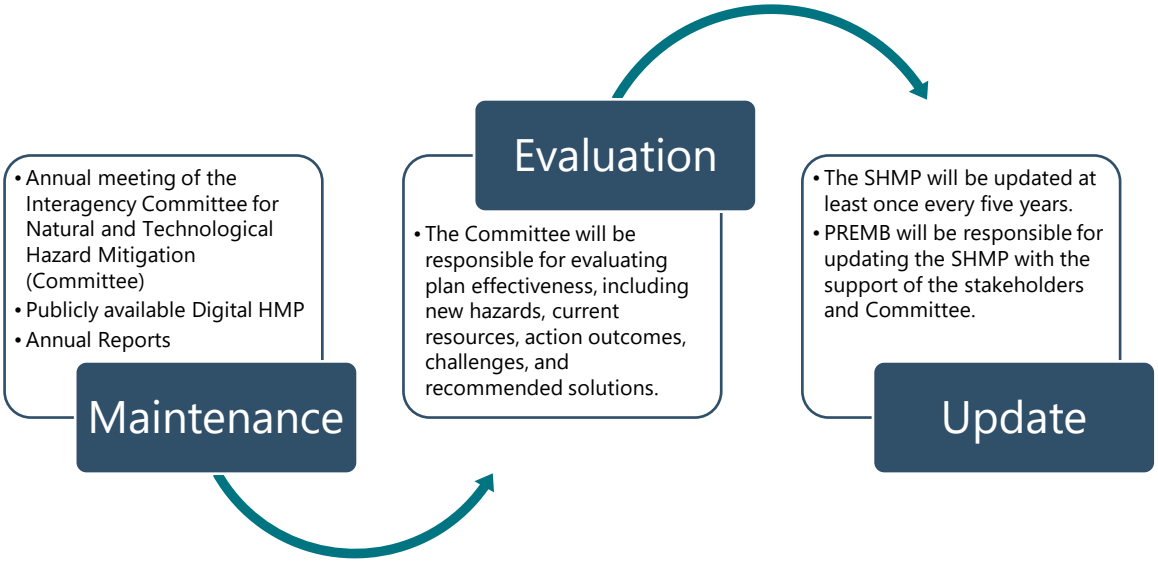
The plan participants identified the following goals to reduce Puerto Rico's long-term vulnerabilities to the identified hazards. The following table provides a list of the goals they developed.

Mitigation Goals	Description
Goal 1	Strengthen Puerto Rico's resilience to natural and non-natural hazards to reduce loss of life and protect property.
Goal 2	Prioritize mitigation for critical infrastructure and community lifelines to facilitate rapid recovery post-disaster.
Goal 3	Integrate risk mitigation and sustainable development into the foundation of land-use planning initiatives.
Goal 4	Preserve, enhance, and restore aspects of the natural environment that are beneficial for risk mitigation.

Mitigation Goals	Description
Goal 5	Support risk-based and community-informed mitigation planning and project development for the benefit of the community.
Goal 6	Increase whole-community awareness and support for hazard mitigation in Puerto Rico.

Plan Maintenance

The plan maintenance section includes information on how the plan will be monitored, evaluated, and updated moving forward. Plan maintenance ensures the SHMP remains practical, relevant, and aligned with current risks, priorities, regulations, and available resources. In addition, it encourages and refines plan implementation by providing multiple opportunities for plan participants to report out on progress and support ongoing mitigation efforts.



Plan Adoption

The hazard mitigation planning process is not complete until the plan has been adopted. The Government of Puerto Rico formally adopted the SHMP in July 2026.

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SECTION ONE

INTRODUCTION

Introduction

General Considerations

The 2026 Puerto Rico State Hazard Mitigation Plan (PRSHMP) reflects a proactive and strategic approach to minimizing risks to people and property through mitigation strategies tailored specifically to Puerto Rico's needs. This updated plan establishes a framework for assessing vulnerabilities within the island's geographic, economic, and regulatory context. Its goal is to enable informed decision-making in managing and reducing diverse hazard-related risks. By integrating best practices, the plan helps bridge gaps between mitigation efforts and local planning, align mitigation priorities with broader community development initiatives, and reduce risk to the whole community.

Purpose of the Plan

This plan promotes community resilience in alignment with federal mitigation planning guidelines, including the 2025 State Mitigation Planning Policy Guide. The main objective of the 2026 PRSHMP is to lessen the vulnerability to the impacts of natural hazards on Puerto Rico by collaboratively establishing a risk-based, capability-informed mitigation strategy. By planning for and implementing effective hazard mitigation programs, policies, and projects, Puerto Rico will be able to break the cycle of disaster damage, reconstruction, and repeated damage. The plan is also a requirement for certain federal assistance.

Conceptual Context

Emergency Management Principles

Emergency management is built upon four essential, interconnected phases: preparedness, response, recovery, and mitigation. Figure 1 presents an overview of the four phases.

Figure 1: Four Phases of Emergency Management

Preparedness refers to the ongoing process of planning, organizing, training, equipping, and exercising to ensure an effective and coordinated response to emergencies or disasters. This involves anticipating potential threats, identifying vulnerabilities, and developing strategies to mobilize and manage resources. These activities occur before a disaster strikes and are essential to strengthening the capacity of individuals, organizations, and communities to respond when an incident occurs. Preparedness also includes public education, the establishment of communication protocols, and the conduct of drills to enhance readiness and reduce impacts on life, property, and the environment.

The response phase involves immediate actions taken to respond to the direct impacts of a disaster. These efforts are centered on protecting lives, reducing the impact on property, and ensuring that all essential needs are met. Response efforts constitute the execution of plans developed during the preparedness phase of the emergency management cycle. Depending on the nature and severity of the disaster, the Puerto Rico Emergency Management Bureau (PREMB) will provide support to municipalities in accordance with the State Emergency Management Plan. This can include the activation of the appropriate Emergency Support Functions (ESFs) and coordination with federal, state, and local agencies as necessary to manage the incident.

The recovery phase of the emergency management cycle involves efforts to return to normal, which include rebuilding and restoring communities following a disaster. This stage includes both short-term and long-term actions. Restoring critical infrastructure is an example of a short-term action, while repairing non-critical infrastructure and supporting displaced populations are examples of long-term actions. Recovery may also incorporate strategies that align with mitigation goals to further enhance future safety.

The mitigation phase encompasses actions that prevent disasters, lessen the impacts of their occurrence, or minimize the impacts that cannot be avoided. These efforts focus on addressing risks in advance of a disaster and aim to lessen the impacts on disaster damage and recovery. Mitigation strategies are most effective when implemented before a disaster occurs and may include measures such as land use planning, building code enforcement, infrastructure improvements, and public education.

HAZARD MITIGATION PLANNING

FEMA defines hazard mitigation as cost-effective actions that reduce the risk of damage to facilities from future disasters.[1] These measures aim to prevent repetitive losses, minimize future impacts, and offer long-term solutions to the growing threat of natural hazards. The mitigation planning process encourages communities to integrate mitigation into their day-to-day decision making about land use planning, floodplain management, site design, and other functions. Among other key factors, it involves (1) organizing the planning process and resources, (2) assessing risks, (3) assessing capabilities, (4) developing a mitigation strategy, and (5) adopting and implementing the plan. State level plans take this analysis a step further to evaluate both state and local mitigation programs and priorities. Mitigation is an investment in the long-term safety and resiliency of the community. By proactively developing a hazard mitigation plan, communities can identify effective steps to minimize damage before a disaster strikes.

Legal Framework

DISASTER MITIGATION ACT OF 2000 (42USC §5133)

The Disaster Mitigation Act of 2000 amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act by creating a structural framework for disaster and hazard mitigation planning. It created a formal pre-disaster mitigation program while clarifying the administration of disaster relief efforts. Furthermore, it mandated that state, local, and tribal governments develop FEMA-approved hazard mitigation plans to receive certain types of federal disaster assistance and funding. A key goal of the Act was to help manage and reduce the escalating costs of federal disaster aid by encouraging proactive mitigation strategies.[2]

FEMA's State Mitigation Planning Policy Guide outlines the agency's policies and procedures for evaluating state hazard mitigation plans.[3] The guide underscores the importance of hazard mitigation plans as a demonstration of a state's commitment to reducing the impacts of natural hazards, and it informs how decisions on resources are directed to minimize those risks. The guide serves as a standard reference to ensure consistency in reviewing, approving, and updating state hazard mitigation plans.

[1] 44 Code of Federal Regulations (C.F.R.) § 206.201(e)
[2] Federal Emergency Management Agency, "The Disaster Mitigation Act of 2000," https://www.fema.gov/sites/default/files/2020-11/fema_disaster-mitigation-act-of-2000_10-30-2000.pdf.
[3] Federal Emergency Management Agency, "State Mitigation Planning Policy Guide," https://www.fema.gov/sites/default/files/documents/fema_hmd_state-mitigation-planning-policy-guide_05292025.pdf.

CODE OF REDERAL REGULATIONS, PART 201, SECTION 201.1 – 201.5 (44 CFR PART 201 §201.1-201.5) – MITIGATION PLANNING (CFR)

Title 44, Part 201 of the Code of Federal Regulations (CFR) outlines the policies and procedures for hazard mitigation planning by specifying the requirements that state, local, territorial, and tribal governments must meet to develop hazard mitigation plans in accordance with the Stafford Act. The main objectives per the CFR are to identify the natural hazards and associated risks that pose threats to the community, propose strategies to reduce potential losses, and establish a coordinated framework for implementing the strategies. Section 201.4 of the regulation mandates that states maintain a FEMA-approved hazard mitigation plan to be eligible for disaster assistance and other mitigation funding under the Stafford Act.[4]

PUERTO RICO HOMELAND SECURITY DEPARTMENT ACT – LAW NO. 20 OF APRIL 10, 2017

Chapter 6 of Law No. 20, which was enacted on April 10, 2017, established the PREMB to serve the emergency management needs of local and state government entities. The establishment of PREMB aligns with the provisions of the amended Stafford Act. PREMB is tasked with coordinating the response and recovery efforts of the Government of Puerto Rico (GPR) and the federal government during declared disasters. Under this law, a commissioner is appointed to lead and align Puerto Rico's disaster management strategies with those of the federal government. This coordination takes place through the Interagency Committee for the Mitigation of Natural and Technological Risks. This committee is charged with several key responsibilities, including a) preparing and implementing the State Mitigation Plan, b) prioritizing mitigation projects, and c) assessing the nature of emergency or disaster damage and recommending mitigation actions to reduce future damage.[5]

OE-2017-065 – CREATION OF THE PUERTO RICO CENTRAL OFFICE OF RECOVERY, RECONSTRUCTION, AND RESILIENCY (COR3)

On October 23, 2017, the Governor of Puerto Rico signed Executive Order OE-2017-065. This order was later amended by Executive Order 2017-069, which establishes the Central Recovery and Reconstruction Office (CRRO) as a division within the Public-Private Partnerships Authority, with all necessary authority, powers, and capability to fulfill its key responsibilities:

1. Identifying, procuring, and administering all state, federal, and/or private resources available to the GPR or any government entity to invest in the recovery
2. Coordinating and channeling all efforts and activities of the GPR and its entities in the recovery
3. Financing, implementing, or causing recovery-related infrastructure works and projects
4. Advising the Governor and offering assistance and technical advice to government entities on any matter of recovery[6]

[4] U.S. Government Publishing Office, "Code of Federal Regulations, Title 44, Part 201, Sections 201.1–201.5: Mitigation planning," 2020
[5] Puerto Rico Legislature, "Puerto Rico Homeland Security Department Act – Law No. 20 of April 10," 2017
[6] Puerto Rico Governor's Office, "Executive Order OE-2017-065: Creation of the Puerto Rico Central Office of," 2017

Subsequently, the CRRO was renamed the Central Office for Recovery, Reconstruction, and Resiliency (COR3). COR3 provides the centralized oversight and financial controls that the Government of Puerto Rico and the U.S. taxpayers expect for the recovery effort.

OE-2017-069 – INCORPORATION OF THE PARTICIPATION OF THE GOVERNOR'S AUTHORIZED REPRESENTATIVE

Executive Order OE-2017-69 was issued to amend and clarify various provisions of OE-2017-065. Section One formally establishes COR3 as a division within the Public-Private Partnership Authority (P3) with the following primary responsibilities:

1. Identifying and procuring all state, federal, and/or private resources available to government entities to invest in the recovery
2. Coordinating and channeling efforts and activities of governmental entities related to recovery
3. Financing and executing recovery-related infrastructure works and projects
4. Advising the Governor, providing assistance and technical advice to other government entities on the issue of recovery[7]

Section Two of the executive order states that COR3 operates under the authority of P3 with specific oversight mechanisms. Subsection N directs COR3 to work collaboratively with the State Coordinating Officer (SCO) and the Governor's Authorized Representative (GAR) to ensure coordinated efforts and minimize redundant responses. In addition, COR3 must integrate the participation of the SCO, GAR, and other relevant stakeholders into its administrative procedures.[8]

The amendment to Section Four designates the Executive Director of P3 as the head of COR3. Section Eight redefines "government entity" to encompass any current or future department, agency, board, office, public corporation, or other entity under the Executive Branch of the Government of Puerto Rico. Finally, the executive order nullifies any prior executive orders or provisions that conflict with its content.[9]

[7] Puerto Rico Governor's Office, "Executive Order OE-2017-069: Incorporated the participation of the Governor's Authorized Representative (GAR)," 2017
[8] Puerto Rico Governor's Office, "Executive Order OE-2017-069: Incorporated the participation of the Governor's Authorized Representative (GAR)," 2017
[9] Puerto Rico Governor's Office, "Executive Order OE-2017-069: Incorporated the participation of the Governor's Authorized Representative (GAR)," 2017

OE-2019-062 – REAFFIRMATION AND EXPANSION OF THE GOVERNMENT'S PUBLIC POLICY FOR THE EFFECTIVE AND TRANSPARENT MANAGEMENT OF FEDERAL FUNDS TO RECONSTRUCT THE ISLAND

This grants authority to the Puerto Rico Fiscal Agency and Financial Advisory Authority to implement oversight frameworks and enforce compliance measures to guarantee the proper and efficient management of federal funds.[10]

Administrative and Operational Context

The Puerto Rico Emergency Management Bureau (PREMB), established in 2017, plays a critical role in the island's disaster preparedness and response efforts. PREMB's mission encompasses a comprehensive approach to emergency management and covers all four phases of the emergency management cycle. PREMB is tasked with coordinating the resources of the government of Puerto Rico while collaborating with the private sector to deliver timely and effective emergency services that protect life and property. In accordance with Law No. 20 of April 10, 2017, PREMB operates under the direct and non-transferable authority of the Department of Public Safety. This legal framework reinforces PREMB's role as the central coordinating agency responsible for managing Puerto Rico's emergency response and preparedness efforts. PREMB's organizational framework is designed to support and manage the full range of actions necessary to respond to an emergency or a disaster. It consists of various offices, divisions, and operational areas that collectively ensure a coordinated and effective response.

PREMB provides its services across all of Puerto Rico, through a series of ten Operational Zones. These zones are grouped into three regions to promote faster response times and ensure services are accessible to local municipalities and communities. The regional division of the zones is as follows:

- Region I: San Juan, Caguas, Ceiba, and Humacao
- Region II: Aguadilla, Arecibo, and Vaga Baja
- Region III: Guayama, Ponce, and Mayagüez

Figure 2 displays a map of these zones, along with the municipalities that fall within each.

[10] Puerto Rico Governor's Office, "Executive Order OE-2019-062: Reaffirms and expands the government's public policy for the effective and transparent management of federal funds to reconstruct the island," 2019

Figure 2: Map of PREMB Operational Zones

Originally, PREMB was tasked with overseeing the management of funds dedicated to disaster response and mitigation efforts. The funds included Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA), and other programs. However, with the enactment of Act 211, the responsibility for administering FEMA funding was assigned to the GAR who acts on behalf of the Governor. The administration and staffing of the Hazard Mitigation Assistance (HMA) Office have been integrated into the Office of Management and Budget. This integration was necessitated by the financial management aspects involved in identifying and securing non-federal matching funds for programs such as HMA.

The establishment of the COR3 was initiated through an Executive Order in response to the following federally declared disasters: DR-PR-4336 (Hurricane Irma), DR-PR-4339 (Hurricane Maria), and DR-PR-4473. As part of its creation, COR3 incorporated the responsibilities of the GAR, which is housed within COR3 and is responsible for overseeing all mitigation initiatives funded through the Public Assistance Section 406, Hazard Mitigation Grant Program, and Pre-Disaster Mitigation program.

Organization of the Plan

The 2026 Puerto Rico State Hazard Mitigation Plan is organized into the following sections:

Table 1: Plan Contents

Section Number	Section
-	Executive Summary
Section 1	Introduction
Section 2	Puerto Rico State Profile
Section 3	Planning Process
Section 4	Risk Assessment
Section 5	State Mitigation Capabilities
Section 6	Local Mitigation Assessment
Section 7	Mitigation Strategy
Section 8	Plan Maintenance

Table 1 outlines the structure of the Hazard Mitigation Plan. The Executive Summary offers a concise overview of the plan's goals, purpose, and approach. Section 1 explains the background of the plan along with the legal and jurisdictional context in Puerto Rico. Section 2 details the unique characteristics of Puerto Rico, such as its geography, demographics, and economy. Section 3 outlines how the plan was developed and created, emphasizing stakeholder engagement and data analysis methods.

The core of the plan is covered in Section 4, which identifies the natural hazards impacting Puerto Rico. Section 5 reviews the state's existing resources, policies, and infrastructure and helps identify strengths and areas for improvement. Section 6 shifts focus to local efforts across all municipalities and examines the local capacity of governments to mitigate natural hazards. Section 7 outlines specific actions that can be taken to reduce or eliminate the risk associated with the identified hazards. Finally, Section 8 establishes how the plan will be regularly reviewed, updated, and adjusted based on new data.

Approval and Adoption of the Plan

The 2026 Puerto Rico State Hazard Mitigation Plan is a proactive and comprehensive strategy aimed at reducing risks from natural hazards. This updated plan integrates specific mitigation strategies tailored to Puerto Rico's geographic, economic, and political context. This document bridges the gap between mitigation efforts and local planning by aligning with broader objectives. The plan is built on a foundation of informed decision-making, resilience building, and resource planning, with the ultimate goal of enhancing Puerto Rico's ability to mitigate the impacts of natural hazards. In order to meet federal requirements, the plan and planning process will be reviewed and approved by FEMA.

Planning Process

The planning process for the 2026 PRSHMP ensured that input from all relevant stakeholders was incorporated into the final document. A key component of the process involved the engagement of stakeholders involved in interrelated areas, including representatives of the seven sectors of emergency management, economic development, land use and development, housing, health, education, and human services, infrastructure (including transportation and other community lifelines), and natural and cultural resources, as well as other relevant organizations. Feedback from these stakeholders helped shape the updated strategies and priorities identified in this plan.

Review and Approval

The hazard mitigation plan remains current, relevant, and actionable throughout its lifecycle. To achieve this, the plan must adapt to evolving conditions, statewide development trends, and shifting priorities while maintaining progress toward resilience objectives. Establishing a structured process for review, evaluation, and implementation demonstrates Puerto Rico's dedication to a dynamic, risk-informed strategy. This process promotes transparency, supports informed decision-making, and provides accountability for the effective execution of the mitigation actions identified in the plan.

The following subsections, Monitoring, Evaluating, and Updating, describe the methods, schedules, and responsibilities for tracking implementation, assessing effectiveness, and revising the plan as required by federal regulations (44 CFR §201.4). Together, these components ensure that mitigation efforts remain aligned with current risks and priorities, reinforcing Puerto Rico's commitment to proactive risk reduction and compliance with FEMA standards.

MONITORING

Monitoring is the ongoing process of tracking the implementation of mitigation actions and projects identified in the plan. Puerto Rico will establish a system to document progress on all mitigation activities, including those funded by FEMA and other sources. This system will define clear roles for agencies responsible for implementation, timelines for reporting, and mechanisms for verifying completion. Monitoring ensures accountability and provides a transparent record of actions taken to reduce risk, enabling stakeholders to identify successes and address delays promptly.

EVALUATING

Evaluation focuses on determining whether the mitigation plan is achieving its intended goals and objectives. Puerto Rico will conduct periodic reviews to assess the effectiveness of strategies and actions, using measurable criteria to gauge progress toward resilience goals. This process will consider changes in hazards, vulnerabilities, and development patterns, as well as lessons learned from recent disasters and stakeholder feedback. Evaluation ensures that the plan remains relevant and continues to guide risk-informed decision-making across all sectors.

UPDATING

Updating involves revising the plan to reflect new data, emerging hazards, and shifts in statewide priorities. In compliance with 44 CFR §201.4, Puerto Rico will update the plan at least every five years, or sooner if significant changes occur. Updates will integrate findings from monitoring and evaluation, incorporate stakeholder input, and align with federal and local planning frameworks. This process ensures that the plan remains current, actionable, and eligible for federal mitigation funding, reinforcing Puerto Rico's commitment to proactive risk reduction and long-term resilience.

Formal Adoption Documentation

Following the completion of the final review and the incorporation of any last revisions, the official adoption documents will be included within the Hazard Mitigation Plan. The plan update process will culminate with the plan receiving Approvable Pending Adoption (APA) status from FEMA. This signals that Puerto Rico has met the necessary requirements for federal hazard mitigation funding, and Puerto Rico will be officially recognized for its efforts in developing a comprehensive and strategic Hazard Mitigation Plan.

Formal adoption by Puerto Rico's highest elected official or designee will demonstrate the state's commitment to implementing the mitigation strategy and complying with federal requirements. The plan will also include assurances that Puerto Rico will manage and administer FEMA funding in accordance with applicable federal statutes and regulations and will update the plan as necessary to reflect changes in state or federal laws. These assurances reinforce accountability and ensure continued eligibility for federal mitigation assistance.

The adoption process is also aligned with the Disaster Mitigation Act of 2000 and 44 CFR Part 201, which mandates that states maintain an approved hazard mitigation plan to qualify for federal disaster assistance and funding. The final adoption documents and official approval of this plan by FEMA will confirm Puerto Rico's eligibility to receive these resources.

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SECTION TWO

PUERTO RICO STATE PROFILE

History

The first people to inhabit Puerto Rico were the Arawaks, an indigenous group originating from present-day Venezuela. They settled in Puerto Rico and the Dominican Republic and are known as the Taínos, which means "noble." They called the island "Borikén," and the people were referred to as Boricuas.[11]

The Spanish Crown claimed the island in 1493, shortly after Christopher Columbus's second voyage to America. Over the following 400 years, Spanish colonial rule fundamentally altered the island's demographics and culture, resulting in the near extermination of the Taíno population and the introduction of African slave labor.

In 1898, as part of the Treaty of Paris that ended the Spanish-American War, Puerto Rico was ceded to the U.S., marking a substantial shift in Puerto Rico's political status. The transition brought new governance and policies that would affect the island's residents. In 1917, Puerto Ricans were granted U.S. citizenship through the Jones–Shafroth Act. This change allowed them to participate in the U.S. democratic process by establishing a local government framework, including a bicameral legislature and an elected governor.[12]

Government

Puerto Rico is currently a territory of the United States, with an intricate political status. Although it has a degree of self-governance through its constitution and elected officials, it is not a fully sovereign nation. Puerto Ricans can elect their governor and legislature, and they have the authority to handle many local affairs. However, the U.S. federal government retains authority over areas such as immigration, foreign affairs, and national defense, including military matters. Residents of Puerto Rico cannot vote in U.S. elections and have limited representation in Congress.

Puerto Rico's government system is like that of the United States, with three independent and equal branches: executive, legislative, and judicial.[13]

- **Executive Power:** The governor has executive power and is elected every four years by the people, with no limits on how many times they can serve. The governor appoints a cabinet of secretaries confirmed by the Puerto Rico House of Representatives. Administrative agencies can create rules based on the powers given to them by the legislature.
- Puerto Rico does not have a lieutenant governor. Instead, the secretary of state acts as governor when the governor is unavailable. If the secretary of state is also unavailable, another cabinet secretary steps

[11] Hispanic Federation, "Puerto Rico History 101," https://www.hispanicfederation.org/wp-content/uploads/2024/07/Puerto-Rico-101.pdf.
[12] Encyclopædia Britannica. (n.d.).Jones-Shafroth Act. In Encyclopædia Britannica. Retrieved September 10, 2025, from https://www.britannica.com/event/Jones-Shafroth-Act.
[13] Library of Congress Blogs, "The Commonwealth of Puerto Rico and its Government Structure," https://blogs.loc.gov/law/2022/11/the-commonwealth-of-puerto-rico-and-its-government-structure/.

in as interim governor. The governor can issue executive orders and grant pardons and has the special power to cut or reduce specific items in budget bills.

- **Legislative Branch:** Puerto Rico's legislative branch has two parts: the House of Representatives and the Senate. Members are elected every four years, along with the governor. The House has 51 representatives, while the Senate has 27 members. Puerto Rico's constitution allows for more legislators if more than two-thirds of either chamber belongs to the same party.
- Puerto Rico is divided into 40 districts for representatives and eight districts for senators. Each district elects one representative or two senators. There are also 11 members elected at large in each house.
- Like the U.S. Congress, each legislative body creates its own rules. Members have parliamentary immunity, which means they cannot be arrested during sessions or for 15 days before or after sessions, unless it is for a serious crime.
- Only the legislative assembly can impeach the governor. The House starts the process, and the Senate conducts the trial.
- **Judicial Branch:** Judicial power in Puerto Rico is held by the Supreme Court and other lower courts created by the legislative assembly. This assembly can set up or eliminate courts, except for the Supreme Court. The judiciary has three levels: the Supreme Court, the Court of Appeals, and the Court of First Instance. It handles a wide range of cases. Judges at all three levels are appointed by the governor with approval from the Senate. Supreme Court judges do not have term limits, but they must retire at the age of 70. To remove a judge, impeachment is required. The U.S. Supreme Court can review cases from Puerto Rican courts, as it does in U.S. states.

Figure 3 provides general information on the structure of Puerto Rico's government.

Figure 3: Structure of the Puerto Rico Government[14]

Location

Puerto Rico, an unincorporated territory of the United States, is in the eastern Caribbean and is the smallest island in the Greater Antilles. It is an archipelago that includes the main island of Puerto Rico and several smaller islands, notably Vieques and Culebra to the east and Mona Island to the west.[15] The archipelago borders the Atlantic Ocean to the north and the Caribbean Sea to the south, lying approximately 50 miles east of the Dominican Republic and 40 miles west of the U.S. Virgin Islands. The island stretches 111 miles from east to west and 39 miles from north to south and occupies roughly 3,435 square miles, including the mainland and the municipal islands of Vieques and Culebra). San Juan, the capital of Puerto Rico, is also the most populous of its 78 municipalities. Figure 4 shows the archipelago's position and the outlined municipalities in its geographic scope.

[14] Poder Judicial de Puerto Rico, "Educational Guide: Our Government and Court System," https://poderjudicial.pr/documentos/Educo/Goverment-and-Court-System.pdf.
[15] Miller, G. L., & Lugo, A. E. (2009). Guide to the Ecological Systems of Puerto Rico (Gen. Tech. Rep. IITF-GTR-35). U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. https://data.fs.usda.gov/research/pubs/iitf/iitf_gtr_35.pdf.

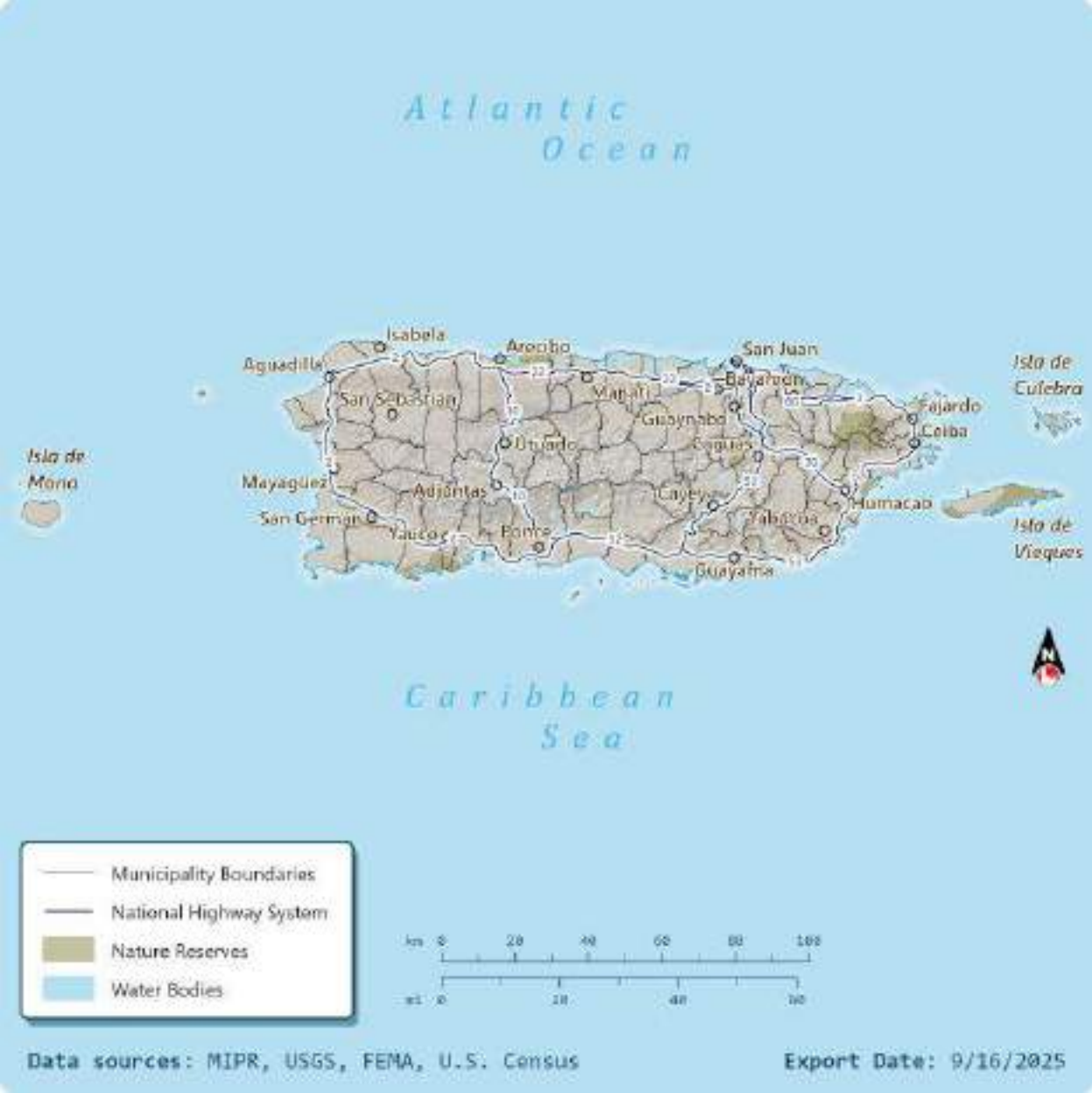


Figure 4: Puerto Rico Planning Area and Municipalities

Climate

Overview

Puerto Rico's climate is influenced by its tropical location, mountainous terrain, and position between the Atlantic Ocean and the Caribbean Sea. According to the Köppen–Geiger climate classification system, most of Puerto Rico falls under the tropical rainforest (Af) category, particularly in the northern and eastern regions. Af climates are hot and humid year-round with no dry season, supporting dense rainforest

ecosystems. In contrast, the southern and southwestern areas exhibit tropical savanna (Aw) characteristics due to lower annual rainfall. Aw climates maintain warm temperatures but have a distinct dry winter season, favoring grasslands and scattered trees instead of dense forests.[16] These climatic patterns produce consistently high temperatures and varied rainfall distribution. Northeastern areas like El Yunque experience high precipitation, while regions such as Guánica in the south are significantly drier due to the rain shadow effect of the Cordillera Central.[17] The island is increasingly affected by climate anomalies, including higher air and sea temperatures, more frequent intense rainfall events, and extended dry periods.[18] These shifts are influenced by broader systems, such as *El Niño* and *La Niña*, which affect the seasonal timing and intensity of rainfall across the Caribbean.[19] In recent decades, these trends have resulted in increased water stress, reduced reliability of water resources, and greater exposure to extreme weather, posing challenges to ecosystems, infrastructure, and public health.[20]

Puerto Rico's topography gives rise to a wide range of microclimates that significantly influence local climate conditions and hazard exposure. The island is divided by the Cordillera Central and the Sierra de Luquillo, which create sharp contrasts in temperature, rainfall, and humidity over relatively short distances.[21] Coastal areas in the north and east are generally warmer and more humid due to their proximity to the Atlantic Ocean and exposure to trade winds.[22] In contrast, the central mountain region experiences cooler temperatures and frequent rainfall, while the south and southwest are hotter and drier due to the rain shadow effect, leading to semi-arid conditions and recurring drought.[23] The western region, including Mayagüez and Rincón, is influenced by sea breezes and wind-driven weather patterns that moderate temperatures and affect local rainfall. Urban centers, such as San Juan, also are affected by the urban heat island effect, which raises localized temperatures.[24] These microclimatic variations are crucial considerations for hazard mitigation planning, as they determine specific vulnerabilities to heatwaves, flooding, droughts, and other climate-related impacts.

Table 2 outlines Puerto Rico's primary microclimate zones and their distinguishing characteristics.[25]

[16] Köppen Climate Classification Map of Puerto Rico, n.d.
[17] U.S. Forest Service, El Yunque National Forest, https://www.fs.usda.gov/elyunque/.
[18] National Centers for Environmental Information (NCEI), State Climate Summaries: Puerto Rico, NOAA, 2020, https://statesummaries.ncics.org/chapter/pr/.
[19] NOAA Climate Prediction Center, El Niño and La Niña Impacts on Caribbean Rainfall, https://www.cpc.ncep.noaa.gov/.
[20] T. López-Marrero, and B. Wisner, "Not in the Same Boat: Disasters and Differential Vulnerability in the Insular Caribbean," *Caribbean Studies,* 2012, 40(2), 129–168.
[21] U.S. Geological Survey (USGS), Hydrogeology and Hydrologic Conditions of Puerto Rico, 2017, https://pubs.usgs.gov/publication/sir20175023 .
[22] CariCOOS, Puerto Rico Coastal Observing System: Ocean and Climate Monitoring Data, https://www.caricoos.org/.
[23] National Centers for Environmental Information, State Climate Summaries: Puerto Rico, NOAA, 2020, https://statesummaries.ncics.org/chapter/pr/.
[24] T. López-Marrero, and B. Wisner, "Not in the Same Boat: Disasters and Differential Vulnerability in the Insular Caribbean," *Caribbean Studies,* 2012, 40(2), 129–168.
[25] Puerto Rico Climate Change Council (PRCCC), "Puerto Rico State of the Climate: Findings from the Puerto Rico Climate Change Council Working Group 1, San Juan, PR," 2015, https://www.pr-ccc.org/wp-content/uploads/2023/06/PR-State-of-the-Climate-FINAL_ENE2015.pdf.

Table 2: Microclimate Zones in Puerto Rico[26]

Zone	Microclimate Characteristics	Average Temperature
North Coast (e.g., San Juan, Arecibo)	Humid, frequent rainfall, influenced by trade winds from the Atlantic. Temperatures are warm year round.	77°F–84°F
South Coast (e.g., Ponce, Guayanilla)	Drier and hotter than the north, sometimes approaching semi-arid conditions. Less rainfall due to the rain shadow effect from the Cordillera Central.	80°F–90°F
Cordillera Central: Interior Mountains (e.g., Adjuntas, Jayuya)	Cooler temperatures, heavy rainfall in some areas, frequent fog, and lush vegetation. The climate is temperate compared to coastal zones.	65°F–75°F
East Coast (e.g., Fajardo, Humacao)	Humid with frequent rain showers, especially in the mornings. Heavily influenced by Atlantic trade winds.	77°F–85°F
West Coast (e.g., Rincón, Mayagüez)	Slightly drier than the east, but still tropical. Known for stable surf conditions in the winter and calmer waters in the summer.	78°F–86°F[1]
El Yunque Rainforest (Northeast Mountains)	Tropical rainforest microclimate with the highest rainfall in Puerto Rico. Cloud covers and mist are common.	70°F–79°F
Karst Region (Northwest) (e.g., Aguadilla, Isabela)	Characterized by limestone hills, caves, and sinkholes. The climate is humid with moderate rainfall and stable temperatures.	75°F–85°F
Dry Forest (Southwest) (e.g., Guánica)	One of the driest places in Puerto Rico and one of the best-preserved dry forests in the Caribbean. Minimal rainfall and high temperatures are typical.	80°F–92°F

Annual precipitation varies significantly, ranging from over 200 inches in the elevated areas of El Yunque National Forest to less than 40 inches in Ponce on the southern coast. During the wet season, which runs from May to October, much of the rainfall is credited to tropical cyclones and easterly waves that travel from east to west. In addition, elevated sea surface temperatures can provoke localized thunderstorm activity. In contrast, the dry season, which runs from November to April, typically sees rainfall driven by cold fronts that move from the west to the east.[27] The variability of the mean precipitation is visible in Figure 5.

[26] Adapted from NCEI (2020), USGS (2017), El Yunque National Forest (n.d.), CariCOOS (n.d.), and López-Marrero and Wisner (2012).

[27] U.S. National Oceanic and Atmospheric Administration (NOAA), "State Climate Summaries 2022 Puerto Rico and the U.S. Virgin Islands," https://statesummaries.ncics.org/chapter/pr/.

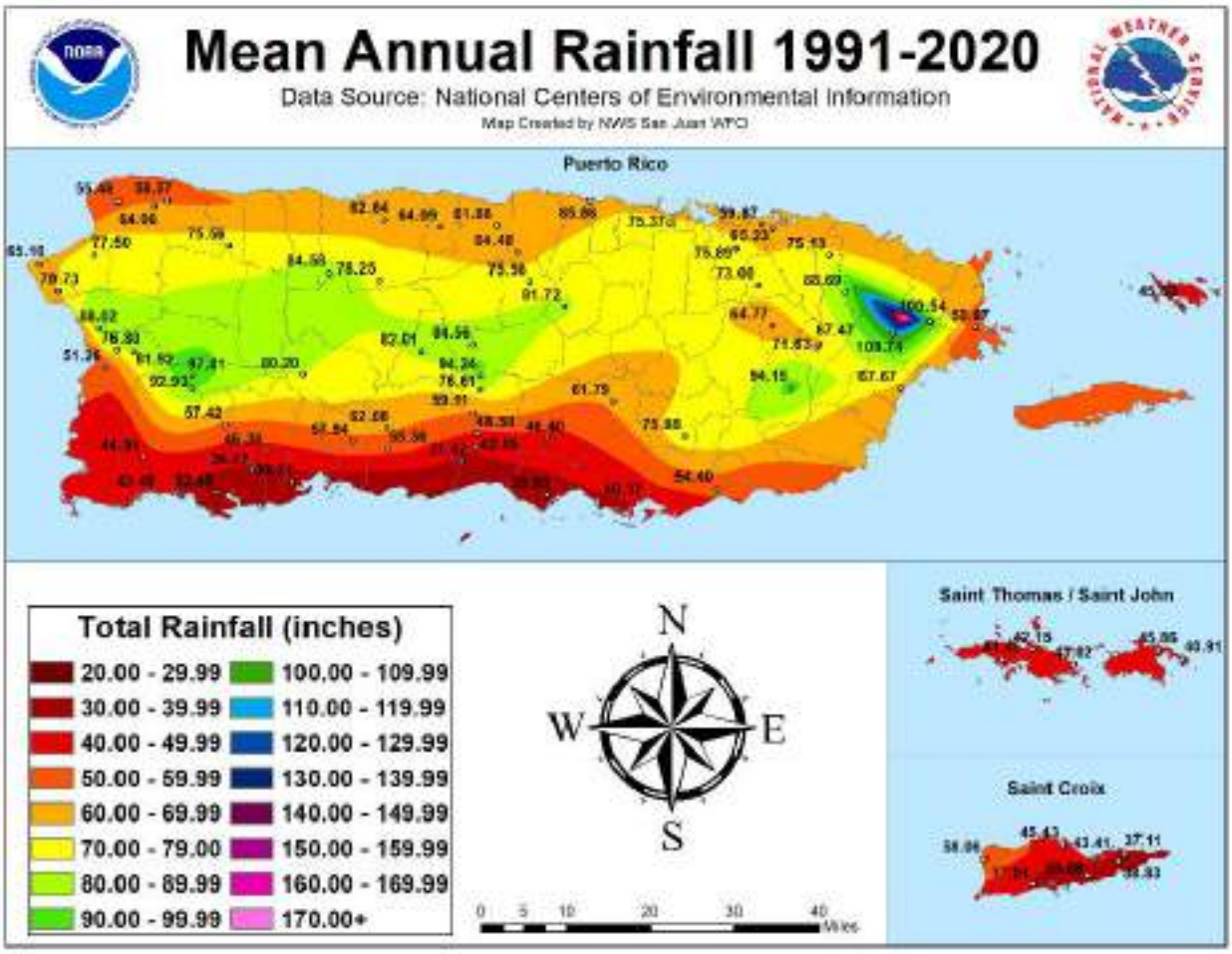


Figure 5: Mean Annual Rainfall in Puerto Rico, 1991–2020[28]

The region experiences consistently high relative humidity levels, ranging from approximately 57% to 92% throughout the year.[29] March is noted as the least humid month, with a relative humidity of 64%, while October registers the highest at 69%. Throughout the year, the average humidity is around 66%.[30]

Puerto Rico's tropical climate and varied microclimates create differential exposure to drought, flooding, heat, and storm hazards. These dynamics reinforce the need for targeted mitigation actions that reduce risk, safeguard critical systems, and enhance long-term resilience.

[28] NOAA National Weather Service PR and USVI Normals, Mean Annual Rainfall 1991–2020, https://www.weather.gov/sju/climo_pr_usvi_normals.
[29] Puerto Rico Advantage, "What's the Weather Like in Puerto Rico?" https://pradvantage.com/2018/09/whats-the-weather-like-in-puerto-rico/.
[30] Weather 7 Climate, "Average Humidity in Puerto Rico," https://weather-and-climate.com/average-monthly-Humidity-perc,puerto-rico,Spain.

Water Temperatures and Conditions

The sea temperatures in Puerto Rico typically range between 78°F and 84°F throughout the year.[31] The north coast, which includes areas, such as Arecibo, Hatillo, Vega Baja, and Dorado, is directly exposed to the powerful waves of the Atlantic Ocean. Direct exposure leads to consistently rough surf conditions, significant coastal erosion, and the presence of hazardous rip currents that pose risks to swimmers and beach recreational activities. Seasonal changes have a dramatic influence on water conditions. From November to March, cold fronts sweeping down from the North Atlantic generate large swells that can lead to extremely high waves, increasing the danger along the shore.

The East Coast, home to areas like Fajardo, Humacao, and Luquillo, experiences the influence of strong trade winds. These winds contribute to choppy seas and create an elevated risk of localized flooding and coastal storm impacts, especially during hurricane season, which typically runs from June to November, and during winter swells that can surge along the shoreline. The unique interplay of ocean currents and wind patterns makes this coast particularly susceptible to rapid changes in water conditions.

The south coast, encompassing cities, such as Ponce, Guayanilla, Lajas, and Salinas, faces the most sheltered waters of the Caribbean Sea. Here, the sea is generally calmer, providing a stark contrast to the north coast. This relative calm allows for more relaxing swimming conditions, supporting recreational activities, such as snorkeling and diving in coral-rich waters.

The West Coast presents unique challenges and characteristics due to its geographical orientation and seasonal exposure to Atlantic swells. Towns along this area encounter a mix of calmer and more turbulent waters influenced by both seasonal shifts and the interaction of local wind patterns.

Figure 6 shows significant wave heights and directions for December 7, 2017, based on the CariCOOS model. The map highlights how Puerto Rico's north and east coasts are directly impacted by large Atlantic swells, while the south coast remains relatively sheltered by the island's terrain.

[31] Sea Temperature, "Puerto Rico," https://seatemperature.net/country/puerto-rico.

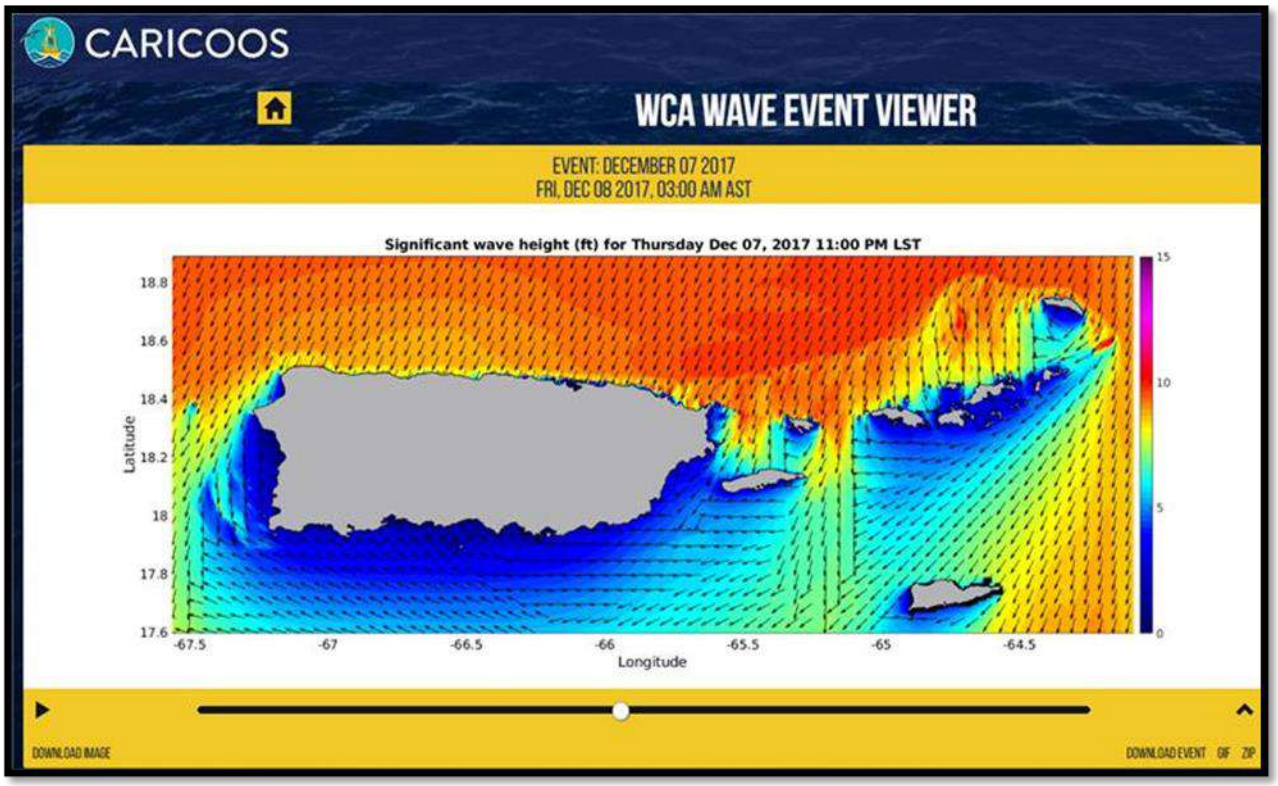


Figure 6: CARICOOS Model Output Showing Significant Wave Heights and Directions for December 7, 2017[32]

Geography

Puerto Rico's geography is structured by its mountainous interior, coastal plains, and northern karst regions, each shaping environmental risk and resilience.

The mountainous interior, including La Cordillera Central, extends east west across the island and contains peaks over 4,000 feet; Cerro de Punta, at 4,390 feet, is the highest point. This area features steep slopes, dense tropical forest cover, and rugged topography that influence landslide susceptibility, watershed dynamics, and ecological gradients.[33]

The coastal plains surround the central mountains. The southern coastal plain, such as the Ponce and Patillas alluvial plain, is characterized by drier climatic conditions and higher temperatures, while the northern coastal plain is more humid, with greater rainfall and fertile soils. Recent studies indicate that these plains

[32] CARICOOS. WCA Wave Event Viewer. https://www.caricoos.org/waveclimateatlas/calendar.
[33] Gould, W.A., Jiménez, M.E., Potts, G.S., Quiñones, M., & Martinuzzi, S. (2008). Landscape units of Puerto Rico: Influence of climate, substrate, and topography. USDA Forest Service, International Institute of Tropical Forestry, IITF-RMAP-06.

now sustain extensive urban and industrial expansion, replacing much of the agricultural land that historically dominated the lowlands.[34]

The northern karst region, spanning from the island's west to its northeastern tip, features classic karst geology: limestone formations, sinkholes, caves, and mogotes. Modern LIDAR data (2015–2017) provide fine-scale elevation models that reveal the extent of karst depressions and aquifer recharge areas.[35] These aquifers are highly productive but vulnerable to contamination and hydrological stress.

From a conservation geography perspective, Puerto Rico contains a mosaic of forests, shrublands, wetlands, and developed areas. The USDA Forest Service Landscape Units Map (Figure 7) integrates climate, geology, and topography to delineate 57 landscape units across the island. This classification shows that the moist and wet volcanic slopes of the Central and Luquillo Mountains represent about 40% of the island, moist plains 16%, dry plains 8%, and wetlands about 5%.[36] These patterns provide a geographic framework for understanding ecosystem diversity, hazard exposure, and land use pressures.

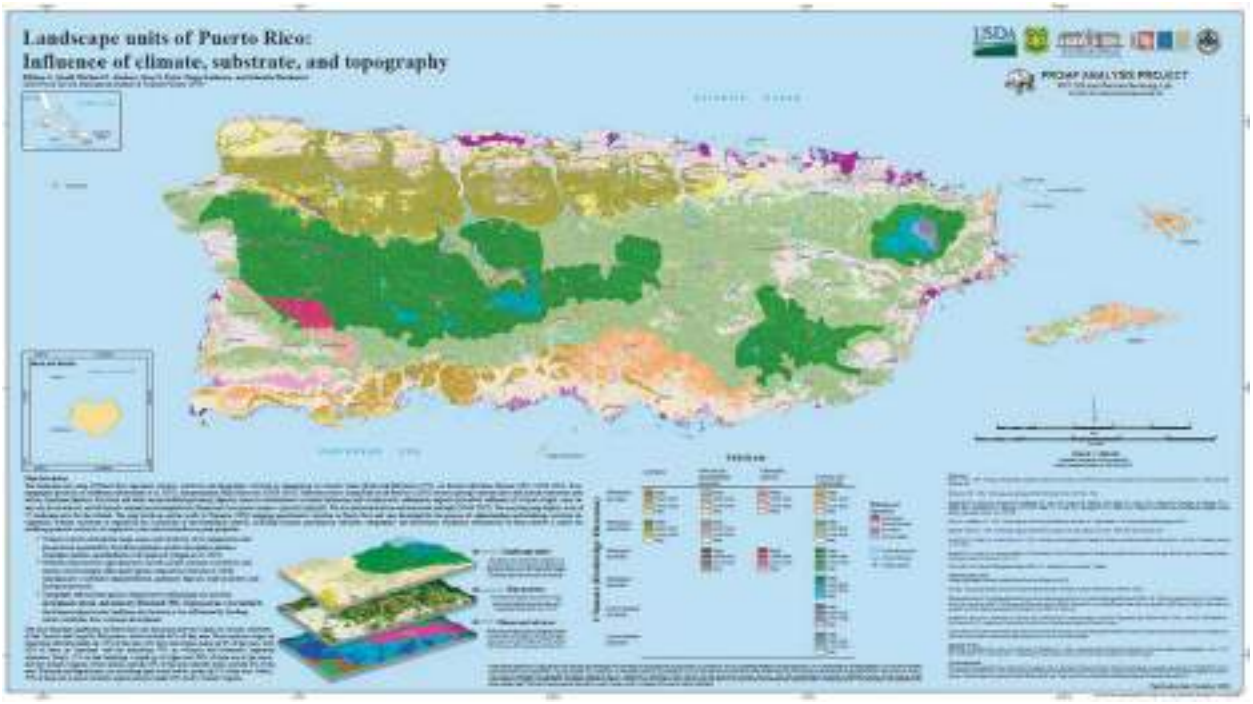


Figure 7: Landscape Units of Puerto Rico, Integrating Climate, Substrate, and Topography[37]

[34] Guzmán-Colón, C.R., et al. (2020). Conservation planning for island nations: Assessing land cover change and protection gaps in Puerto Rico. Global Ecology and Conservation, 23, e01153.
[35] USGS (2017). 2015–2017 LIDAR-derived imagery for karst areas in Puerto Rico, 1-meter resolution. U.S. Geological Survey Data Release.
[36] Helmer, E.H., Kennaway, T.A., Pedreros, D.H., Clark, M.L., Marcano-Vega, H., Tieszen, L.L., Ruzycki, T.S., Schill, S.R., & Carrington, C.M.S. (2008). Puerto Rico Gap Analysis Project. General Technical Report IITF-GTR-39. USDA Forest Service, International Institute of Tropical Forestry, Río Piedras, PR.
[37] USDA Forest Service, IITF-RMAP-06, 2008. https://data.fs.usda.gov/geodata/other_fs/IITF/pdf/IITF-RMAP-06_english.pdf.

Puerto Rico's land use includes various activities and challenges linked to its geography, climate, and economy. For instance, agriculture has historically been important in Puerto Rico, with major crops, such as sugarcane, coffee, and tobacco. Although the amount of agricultural land has decreased, some areas still grow fruits, vegetables, and coffee.[38] The government and local farmers are promoting sustainable practices to address problems such as soil erosion and changing atmospheric patterns.[39]

Urban development has grown substantially, especially in and around San Juan. This growth is due to the high population and tourism, which increases the need for homes, businesses, and infrastructure. Urban areas face problems such as housing shortages, transportation issues, and limited public services. The density of urbanization is shown in Figure 8. About 53% of Puerto Rico is forested, with many areas protected as national parks and nature reserves.[40] These forests support biodiversity, including unique species, and are essential for conservation efforts.

[38] USDA, "Puerto Rico Agriculture," https://www.nass.usda.gov/Publications/Highlights/2024/Census-of-Ag-22_HL_PuertoRico.pdf.
[39] Departamento de Recursos Naturales y Ambientales, "Nature-based Solutions for Coastal Systems," https://www.drna.pr.gov/wp-content/uploads/2024/11/CEH-Part-II-Nature-based-solutions-for-tropical-coastal-systems.pdf.
[40] Arcgis, "From Deforestation to Regeneration: The Story of Puerto Rico," https://storymaps.arcgis.com/stories/4b0caf082c754be88a7f5906942191ff.

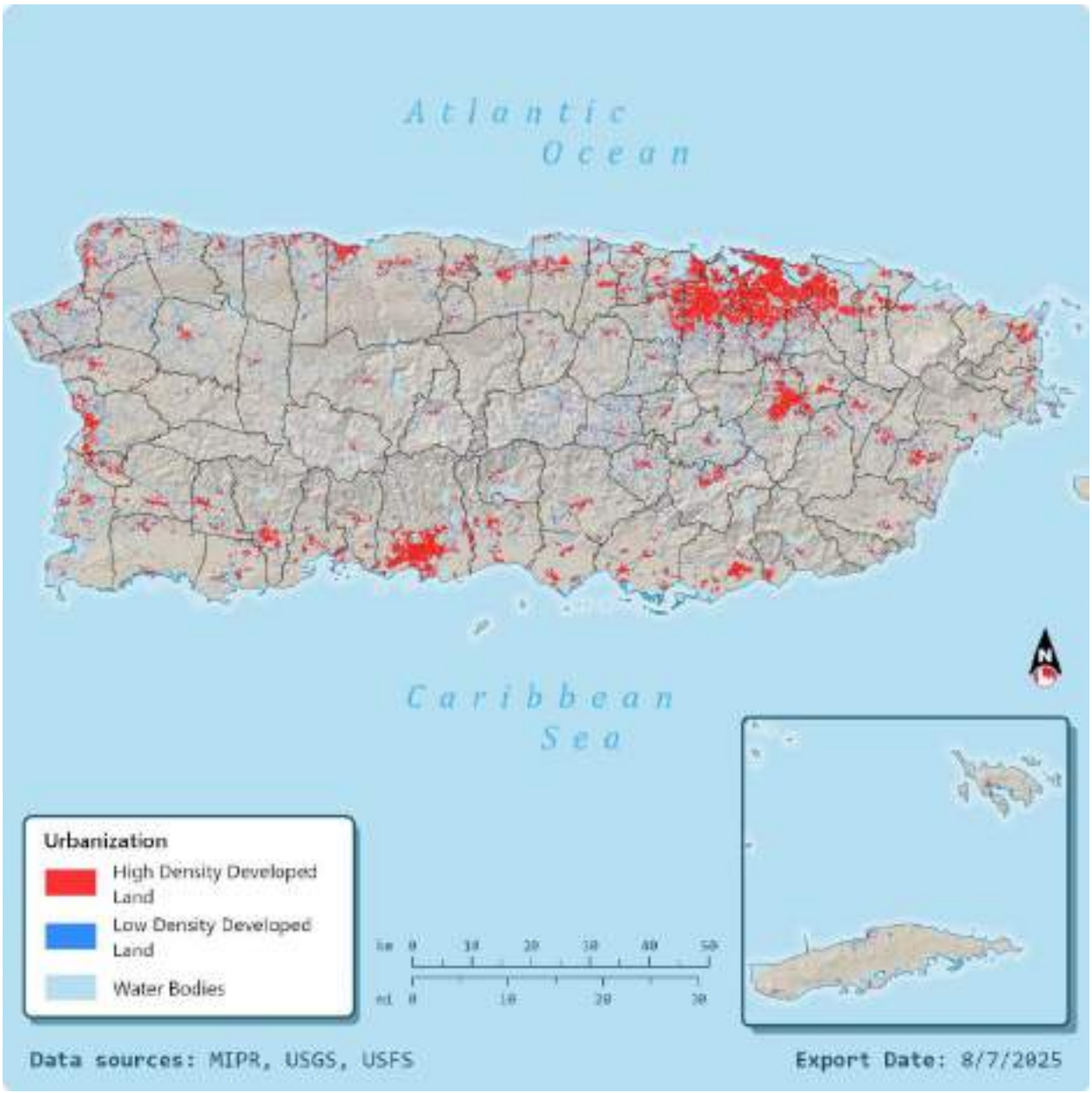


Figure 8: Urbanization in Puerto Rico

As tourism contributes to the economy, more resorts, hotels, and recreational areas are constructed. Coastal regions are affected, and efforts are underway to balance tourism development with environmental protection, especially for delicate marine ecosystems. Puerto Rico deals with environmental issues based on land use, including deforestation, urban sprawl, and pollution. The island is also vulnerable to changing atmospheric patterns, such as hurricanes and rising sea levels, which threaten both urban and rural areas.

The map in Figure 9, which shows land use across Puerto Rico, is based on the Landscape Change Monitoring System (LCMS), a remote sensing-based system for monitoring changes in land cover and land use over the past four decades. LCMS uses an ensemble of models as predictors to improve map accuracy

across a range of ecosystems and change processes.[41] LCSM can also be used to monitor vegetation loss or vegetation gain over time. Knowing where, when, and what factors create change across landscapes is critical to making sound land management decisions. Figure 10 shows areas of vegetation loss and gain in Puerto Rico.

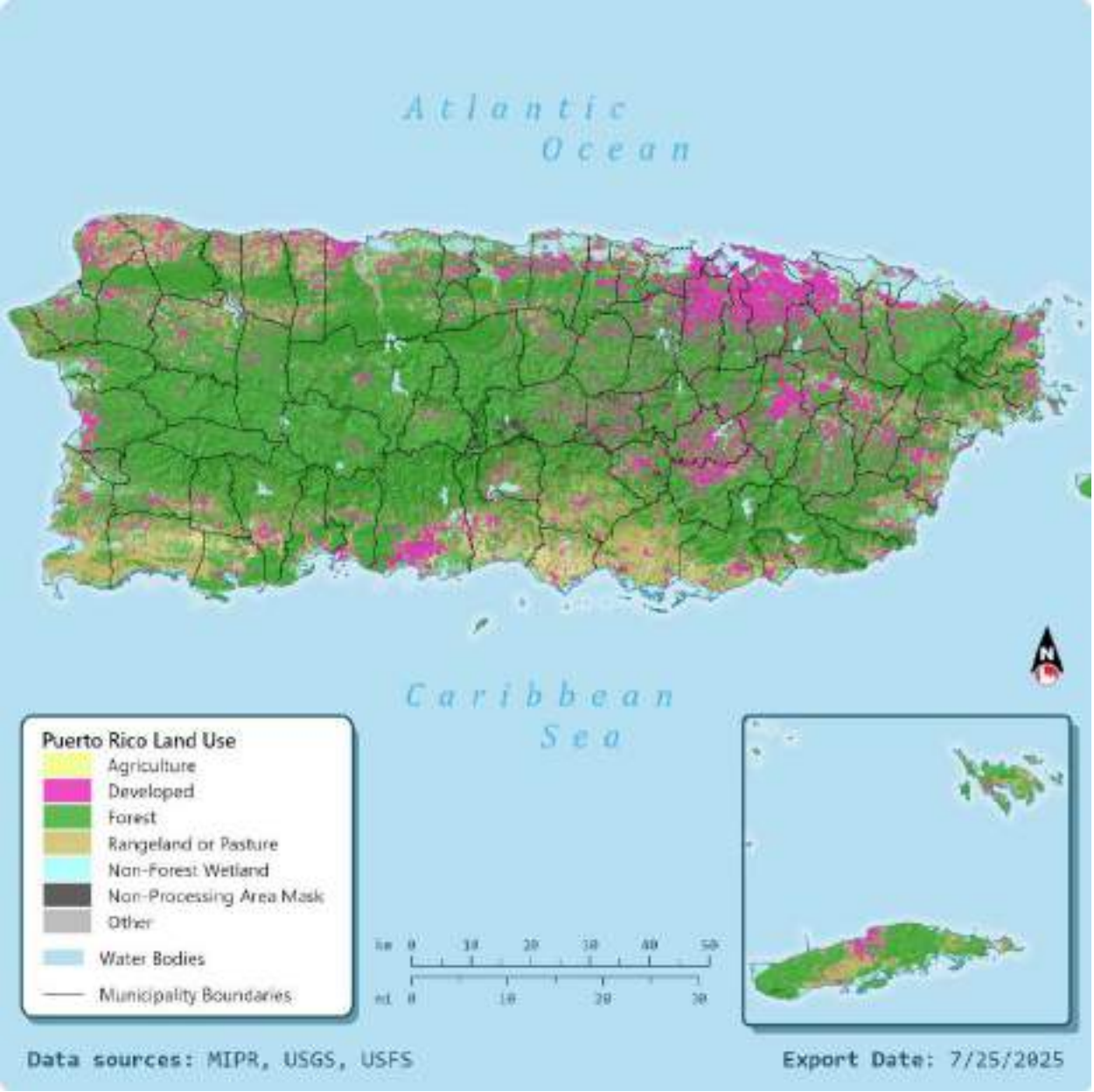


Figure 9: Land Use in Puerto Rico[42]

[41] LCMS, "Landscape Change Monitoring System (LCMS) Puerto Rico USVI Annual Landuse," U.S. Forest Service, https://data-usfs.hub.arcgis.com/datasets/usfs::landscape-change-monitoring-system-lcms-puerto-rico-usvi-annual-landuse/about.

[42] U.S. Forest Service. Landscape Change Monitoring System. 2023. https://data.fs.usda.gov/geodata/rastergateway/LCMS/index.php.

Figure 10: Land Use Change Detection in Puerto Rico

Ecosystems

Puerto Rico is a biodiversity hotspot, home to a mosaic of unique terrestrial, coastal, and marine ecosystems shaped by the island's topography, climate, and geologic history. Its natural landscapes include subtropical dry forests in the southwest, lush rainforests like El Yunque in the northeast, extensive mangrove systems, coral reefs, freshwater wetlands, karst regions, and montane cloud forests. Each of these ecosystems supports vital services, such as water filtration, flood control, carbon sequestration, erosion protection,

groundwater recharge, and biodiversity preservation services, which are critical not only for ecological integrity but also for disaster resilience and sustainable development.[43]

More than half of Puerto Rico is covered by forested or semi-forested lands, many of which have grown in abandoned agricultural areas. Forests from dry to moist lowlands to montane host high levels of endemism, particularly among amphibians and plants. These forested systems reduce surface runoff, improve infiltration, and stabilize slopes, providing essential protection against landslides and flash flooding. Mangrove ecosystems, found along the island's low-lying coasts in areas like Piñones and Jobos Bay, buffer storm surge and trap sediments, protecting shorelines and coastal communities. Wetlands and estuaries, such as those in the San Juan Bay Estuary store floodwaters, filter contaminants, and support fish nurseries. Meanwhile, Puerto Rico's fringing coral reefs, including those near La Parguera and Culebra, reduce wave energy before it reaches the coast, providing a natural breakwater that reduces erosion and storm damage.[44]

Puerto Rico's karst regions, especially in the north central municipalities of Camuy, Florida, and Arecibo, are ecologically and hydrologically significant. They contain limestone formations, sinkholes, and underground rivers that recharge some of the island's most important aquifers. These regions are sensitive to land clearing and development, and degradation can increase vulnerability to both drought and flooding. Similarly, montane cloud forests in areas, such as Maricao and the Luquillo Mountains, play a critical role in intercepting moisture, sustaining base flow for rivers, and stabilizing steep slopes prone to landslides.[45]

Despite their value, Puerto Rico's ecosystems face increasing stress due to anthropogenic activities and climatic pressures. Habitat fragmentation, unregulated land use, deforestation, pollution, and the spread of invasive species continue to degrade ecosystem health. These pressures are intensified by climate anomalies, such as prolonged droughts, extreme rainfall events, rising temperatures, sea-level rise, and increased storm frequency and intensity. Coastal ecosystems are experiencing accelerated erosion, saltwater intrusion, and coral bleaching. Mountainous and karst regions face higher risks of landslides and flash floods due to altered hydrology and the loss of vegetative cover.[46] Areas at the extremes of elevation or moisture, such as dry coastal zones, cloud forests, and low-lying wetlands, are particularly vulnerable to ecological shifts that could compromise the continued delivery of key services, such as water supply, storm buffering, and slope stabilization.

Real-world examples highlight the importance of ecosystem-based mitigation. After Hurricane María, mangrove belts in Loíza helped dissipate wave energy, reducing flood damage in adjacent communities.[47] Conversely, the degradation of coral reefs near Rincón has led to increased coastal erosion and diminished fisheries, exacerbating both environmental and economic vulnerabilities. Urban restoration efforts along

[43] Puerto Rico Climate Change Council (PRCCC), Working Group 2: Ecology and Biodiversity, "Puerto Rico State of the Climate 2013 Report, 2015, pp. 85–221, https://www.pr-ccc.org/en/publications/
[44] NOAA Coral Reef Conservation Program, "Coral Reefs Reduce Wave Energy and Coastal Risk," 2020, https://coralreef.noaa.gov/.
[45] USGS, "Landslide Susceptibility Maps of Puerto Rico. U.S. Geological Survey Fact Sheet," 2019, https://pubs.usgs.gov/fs/2019/3034/fs20193034.pdf.
[46] USGS, "Landslide Susceptibility Maps of Puerto Rico. U.S. Geological Survey Fact Sheet," 2019, https://pubs.usgs.gov/fs/2019/3034/fs20193034.pdf.
[47] NOAA Coral Reef Conservation Program, "Coral Reefs Reduce Wave Energy and Coastal Risk," 2020, https://coralreef.noaa.gov/.

the Río Piedras watershed demonstrate how community-driven tree planting and stormwater management can reduce flood risk and improve quality of life.[48]

Nature-based solutions are increasingly recognized as cost-effective and sustainable strategies for hazard mitigation. Mangrove and coral reef restoration, reforestation in fire-prone and landslide-susceptible areas, wetland conservation, and the expansion of urban green infrastructure can significantly reduce risk while supporting biodiversity and community resilience. These strategies also align with funding priorities under FEMA's Building Resilient Infrastructure and Communities, Hazard Mitigation Grant Program, and Flood Mitigation Assistance initiatives.[49]

A strong understanding of Puerto Rico's ecological zones, their vulnerabilities, and their protective functions is essential to integrate nature-based mitigation strategies into hazard mitigation planning. As the island faces increasingly complex environmental threats, the conservation and restoration of its ecosystems must be a central pillar of resilience planning. Table 3 summarizes the ecosystems of Puerto Rico, their representative locations, and their key hazard mitigation functions.

Table 3: Ecosystems of Puerto Rico and Their Hazard Mitigation Functions

Ecosystem	Representative Locations	Key Hazard Mitigation Functions
Forests (dry, moist, montane, cloud)	Guánica, El Yunque, Maricao, Luquillo	Stabilize slopes, reduce landslides, slow runoff, sustain river baseflows
Mangroves	Piñones, Jobos Bay, La Parguera	Dissipate wave energy, reduce storm surge flooding, protect coasts
Wetlands & Estuaries	San Juan Bay Estuary, Caño Tiburones	Store floodwaters, filter contaminants, support fisheries
Coral Reefs	La Cordillera, Culebra, Vieques, Rincón, La Parguera	Breakwaves, reduce erosion, protect coastal communities, support fisheries & tourism
Karst Regions & Aquifers	Camuy, Florida, Arecibo	Recharge aquifers, drought resilience, regulate groundwater, reduce flooding

The coral reef ecosystems surrounding Puerto Rico serve as a vital component of the island's natural infrastructure, offering both ecological and hazard mitigation benefits. Puerto Rico's coral reefs generate over $1.4 billion annually in tourism revenue from more than 1 million visitors.[50] These biodiverse systems prominently located along the eastern coast (La Cordillera Reef near Fajardo), the southern shelf (including Salinas, Guánica, and La Parguera), the north coast (notably in Dorado, San Juan, and Vega Baja), the western

[48] Estuario.org, "Restoration Projects in the San Juan Bay Estuary," San Juan Bay Estuary Program, 2020, https://estuario.org.
[49] FEMA, "Nature-Based Solutions: A Guide for Local Communities," 2021, https://www.fema.gov/sites/default/files/documents/fema_riskmap-nature-based-solutions-guide.pdf.
[50]The Nature Conservancy: https://www.nature.org/content/dam/tnc/nature/en/documents/Caribbean-Puerto-Rico-Fact-Sheet.pdf.

marine reserves (such as Rincón's Tres Palmas), and offshore islands (Culebra, Vieques, and Mona) function as natural barriers that attenuate wave energy and reduce the impact of coastal hazards.

Forests

Puerto Rico's landscape supports a wide variety of forests that play a critical role in reducing natural hazard risks (see Figure 11). Shaped by trade winds, steep mountains, and diverse geology, the island's ecosystems are distributed across wet and dry zones, coastal plains, and high mountain peaks. These forests provide essential services, such as water storage, soil stabilization, slope protection, and natural buffering against storms. Their conservation and restoration are central to hazard mitigation planning.

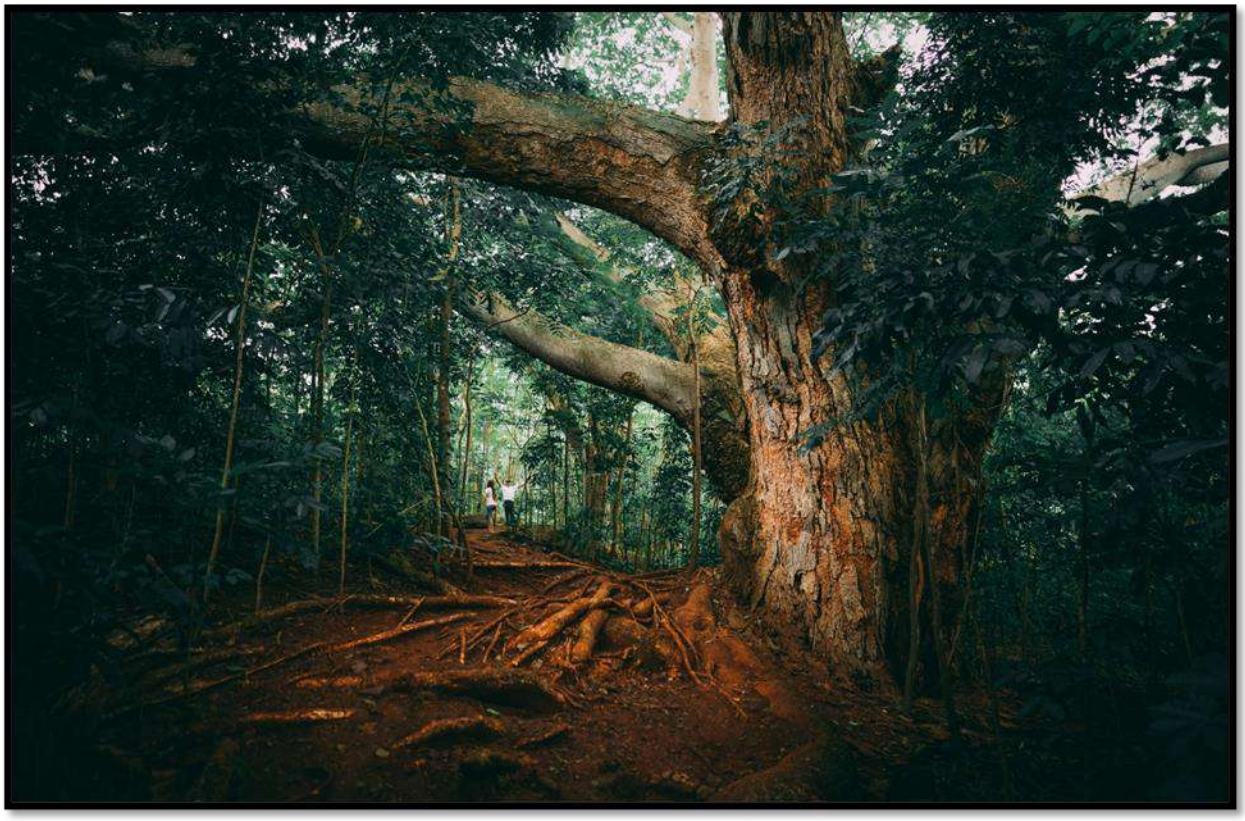


Figure 11: Boquerón State Forest, Cabo Rojo, Puerto Rico

Figure 12 is a map of land cover classifications. It shows the distribution of forests, wetlands, cultivated areas, and developed lands. It highlights the extensive moist forests in the north and central mountains, the dry forests concentrated in the southern coastal plain, and montane forests at higher elevations.

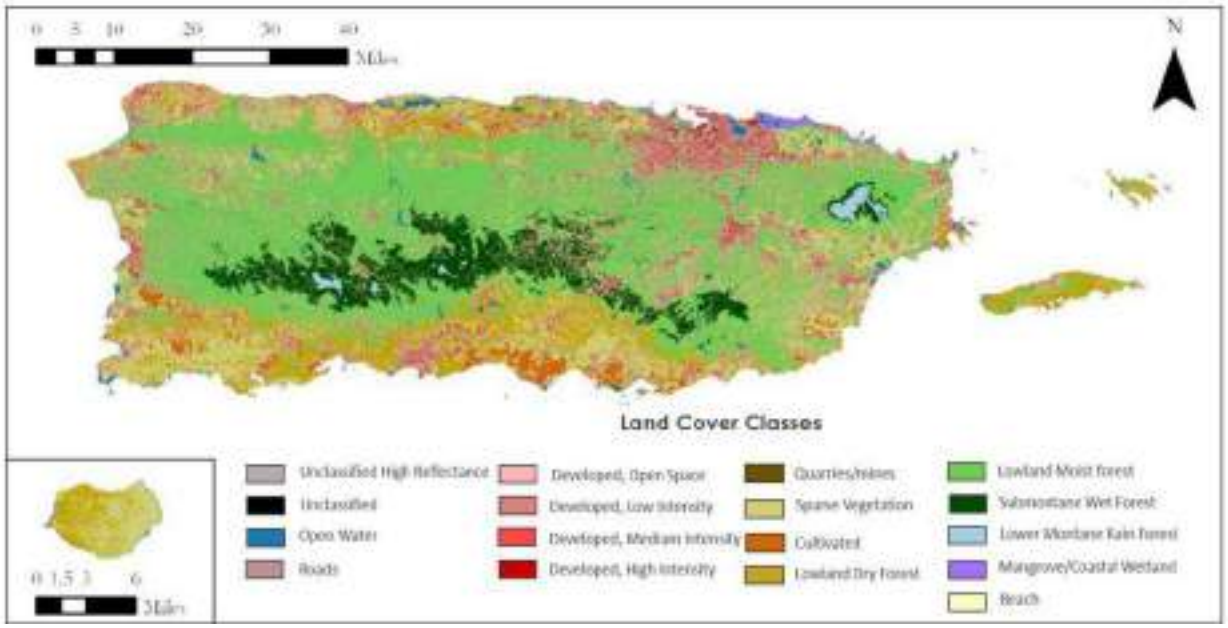


Figure 12: Land Cover Classification Map of Puerto Rico, 2023–2025[51]

Puerto Rico's forests vary depending on rainfall, topography, and geology. Moist forests are most extensive in the northern and central regions, while dry forests dominate the southern coastal plain. At higher elevations, montane and cloud forests capture water and stabilize steep slopes. Each of these forest types contributes to hazard mitigation by reducing flooding, erosion, drought impacts, wildfires, and landslides. Table 4 summarizes their key ecological functions and hazard mitigation benefits.

Table 4: Ecological and Hazard Mitigation Functions of Puerto Rico's Forest Types

Forest Type	Location	Ecological Functions	Hazard Mitigation Benefits
Moist Forests	Northern, eastern, and central regions; offshore islands (Mona, Vieques, Culebra, Desecheo, Caja de Muertos)	Dense canopies, high biodiversity, water infiltration	Reduce flooding by storing rainfall; protect soils from erosion; recharge rivers and aquifers
Dry Forests	Southern coastal plain (rain shadow of central mountains)	Drought-adapted vegetation; seasonal leaf drop	Control erosion in drought-prone areas; buffer against wildfires and extreme heat impacts
Montane & Cloud Forests	Sierra de Luquillo, Cordillera Central (high elevations)	Capture cloud moisture; regulate streamflow; stabilize steep slopes	Maintain water supply during droughts; reduce landslide risk; slow runoff velocity during storms

[51] Rubin, E., et al. (2025). Puerto Rico Ecological Conservation Technical Paper. NASA Technical Reports Server.

Forest Type	Location	Ecological Functions	Hazard Mitigation Benefits
State Forests & Protected Areas	Over 20 designated forests (e.g., Guánica, Río Abajo)	Habitat protection; water quality preservation; sediment reduction	Provide managed buffers for coastal storms, floods, and slope failures; reduce hazard exposure

Puerto Rico has an extensive network of protected areas that includes state forests, national forests, wildlife refuges, nature reserves, and private conservation lands. These areas preserve biodiversity, safeguard water resources, and provide critical buffers against natural hazards. Table 5 lists the main categories of protected areas, their extent, and their role in reducing environmental and community vulnerabilities.

Table 5: Protected Areas of Puerto Rico [52]

Category	Examples	Approx. Area (acres)	% of Puerto Rico's Land Area	Hazard Mitigation Role
Commonwealth Protected Areas	State forests (Guánica, Río Abajo, Carite, Boquerón), Nature Reserves	~400,000	~12%	Maintain water quality, reduce erosion, buffer coastal zones
Federal Protected Areas	El Yunque National Forest, Vieques National Wildlife Refuge, Desecheo, Cabo Rojo, NOAA reserves	~160,000	~5%	Flood & storm surge protection, biodiversity corridors
NGO/Private Easements	Para la Naturaleza conservation easements, private reserves	~60,000	~2%	Connect fragmented ecosystems, reduce development exposure
Marine Protected Areas	Tres Palmas, La Parguera, Mona Island coastal reserves	~22,000 (marine only)	n/a	Protect coral reefs, fisheries, and coastal buffers

Puerto Rico's protected areas represent a critical layer of conservation that overlaps with the island's broader land cover patterns. The land cover classification map of Puerto Rico (Figure 12) provides a spatial overview of how forests, wetlands, cultivated lands, and developed areas are distributed across the island. This map was developed through collaboration between the USDA Forest Service International Institute of Tropical Forestry (IITF), the Puerto Rico Department of Natural and Environmental Resources (DRNA), and research partners supported by NASA ecological mapping efforts.[53] It highlights the ecological diversity of Puerto

[52] Gould, W.A., et al. (2019). A Comprehensive Inventory of Protected Areas and Other Land Conservation Mechanisms in Puerto Rico. USDA Forest Service, International Institute of Tropical Forestry, General Technical Report IITF-GTR-50.
[53] Rubin, E., Mateski, J., Montalbano, N., Gibbs, J., et al. (2025). Puerto Rico Ecological Conservation: Mapping Land Cover to Inform Endangered Frog and Bird Species Distribution and Conservation Planning in Puerto Rico. NASA Technical Reports Server.

Rico and underscores how land use patterns interact with hazard exposure, particularly in flood-prone valleys, drought-affected southern plains, and landslide-susceptible mountain regions.

Figure 13: Protected Natural Areas of Puerto Rico[54]

[54] Rubin, E., Mateski, J., Montalbano, N., Gibbs, J., et al. (2025). Puerto Rico Ecological Conservation.

Hydrography and Hydrology

Puerto Rico and its outlying islands support diverse surface and groundwater systems that are central to water supply, ecosystems, and hazard exposure. The Cordillera Central and Sierra de Cayey create a hydrologic divide between the humid north and the semi-arid south, producing sharp rainfall contrasts from more than 150 inches annually in the Luquillo Mountains to less than 30 inches in Guánica.[55] Over 40 perennial rivers flow across the island, with most draining northward to the Atlantic Ocean. Major reservoirs, such as La Plata, Carraízo, and Guajataca, regulate supply but also influence flood risk. Coastal hydrography includes estuaries, wetlands, and mangroves that act as natural buffers against storm surge and sea level rise.

The island's northern karst region contains unique hydrographic and hydrologic features, most notably the Río Camuy, one of the largest underground river systems in the world. Flowing through the limestone karst belt, the river has carved the extensive Camuy Cave System (Sistema de Cuevas de Camuy), composed of caverns, sinkholes, and subterranean passages. Figure 14 shows the Rio Tanama in a picture taken from inside such a cave. This illustrates the interaction between surface and groundwater in Puerto Rico's geology and highlights how karst dynamics, such as rapid infiltration, underground drainage, and sinkhole formation, shape hazard exposure and water management challenges.

Figure 14: Cueva Ventana View of the Río Tanama. Utuado, Puerto Rico

[55] Gómez-Gómez, F., Rodríguez-Martínez, J., & Santiago, M. (2014). Hydrogeology of Puerto Rico and the Outlying Islands of Vieques, Culebra, and Mona. U.S. Geological Survey.

Groundwater is concentrated in two principal aquifer systems: the North Coast Limestone Aquifer (~2,000 km^2) and the South Coastal Alluvial Plain Aquifer (~181 mi^2).[56] These systems have historically supported agriculture and public water supply, although reliance has shifted heavily toward surface water, which now accounts for about 90% of public withdrawals.[57] Since the 1980s, USGS has documented long-term declines in groundwater levels, particularly in the South Coastal Plain aquifer, where intensive irrigation and multiyear droughts have led to persistent drawdowns and saltwater intrusion. In contrast, the North Coast karst aquifer has been more stable, although it remains vulnerable to contamination and rapid infiltration during extreme rainfall events. Secondary aquifers in Lajas Valley, Caguas, Juncos, and other areas remain locally important but face challenges, such as drought sensitivity, contamination, and saltwater intrusion.[58]

Taken together, Puerto Rico's hydrography and hydrogeology illustrate the island's reliance on limited water resources and its vulnerability to hazards. Effective management of rivers, reservoirs, and aquifers is critical for reducing flood impacts, safeguarding water supply during drought, and preparing for climate-driven extremes.

Figure 15 identifies the island's major groundwater systems, including the North Coast Limestone aquifer, the South Coastal Plain aquifer, and minor aquifers and non-aquifer zones. This is essential for understanding groundwater extraction zones and recharge vulnerabilities.

[56] USGS Water Resources of Puerto Rico – Reservoir and surface hydrology datasets.
[57] USGS. (2018). Estimated Public-Supply Water Withdrawals in Puerto Rico. Data.gov.
[58] Torres-González, S. et al. (2020). Aquifer Sustainability in the South Coastal Plain of Puerto Rico. Sinkhole Conference, Univ. of South Florida.

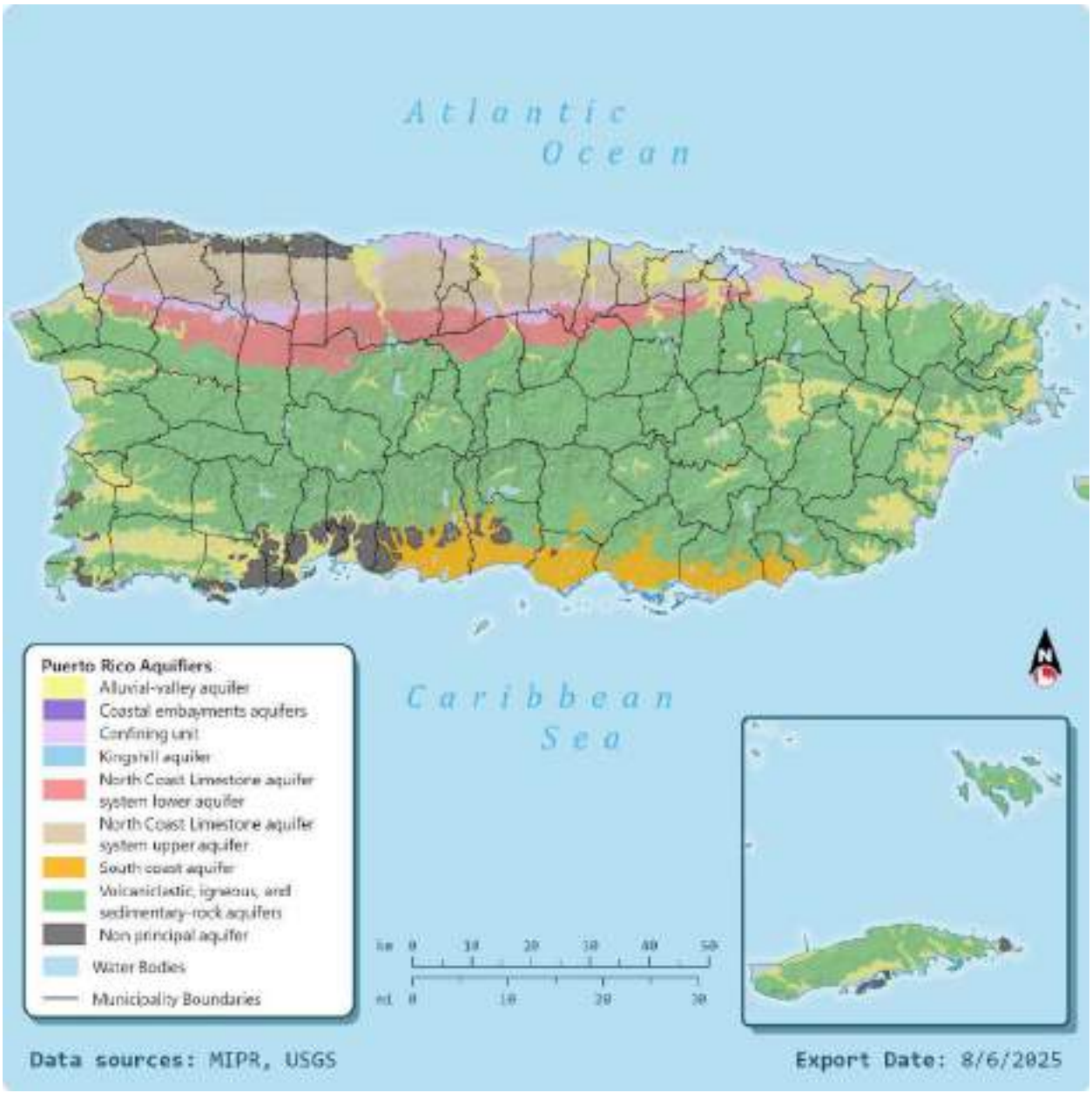


Figure 15: Principal Aquifers of Puerto Rico[59]

Figure 16 delineates the island's karst zones, mountainous interior, and coastal plains. These physical divisions influence precipitation patterns, groundwater recharge potential, and aquifer type and structure.

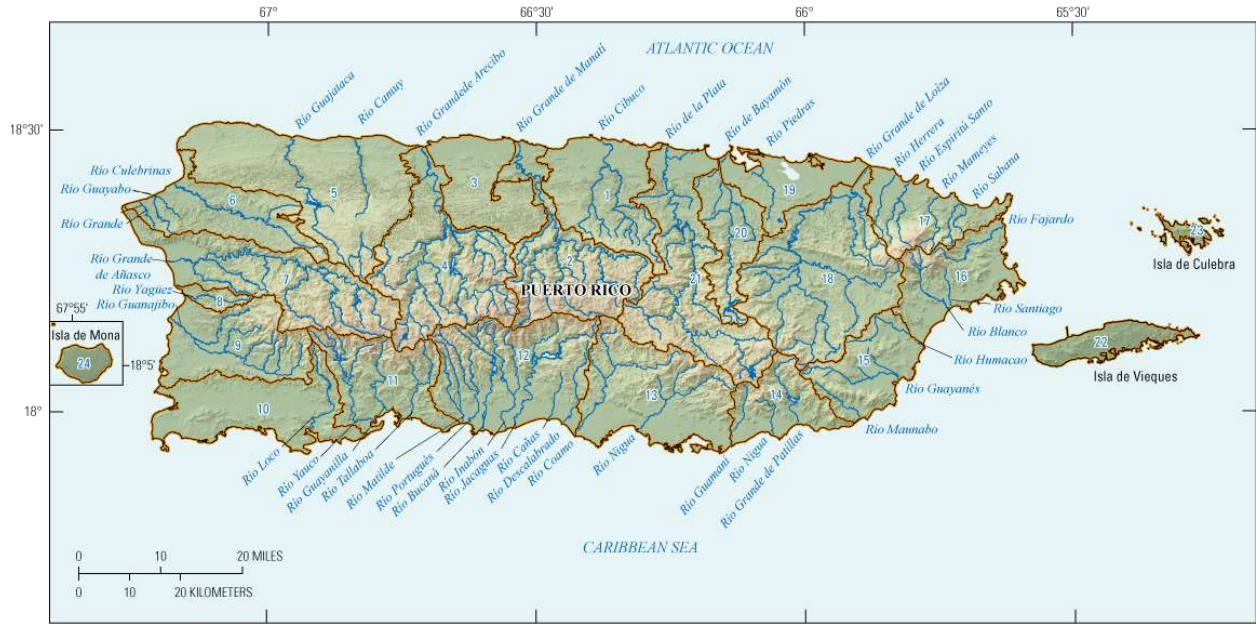
[59] U.S. Geological Survey, modified from Gómez-Gómez et al., 1987.

Figure 16: Hydrogeographic Regions of Puerto Rico[60]

Rivers

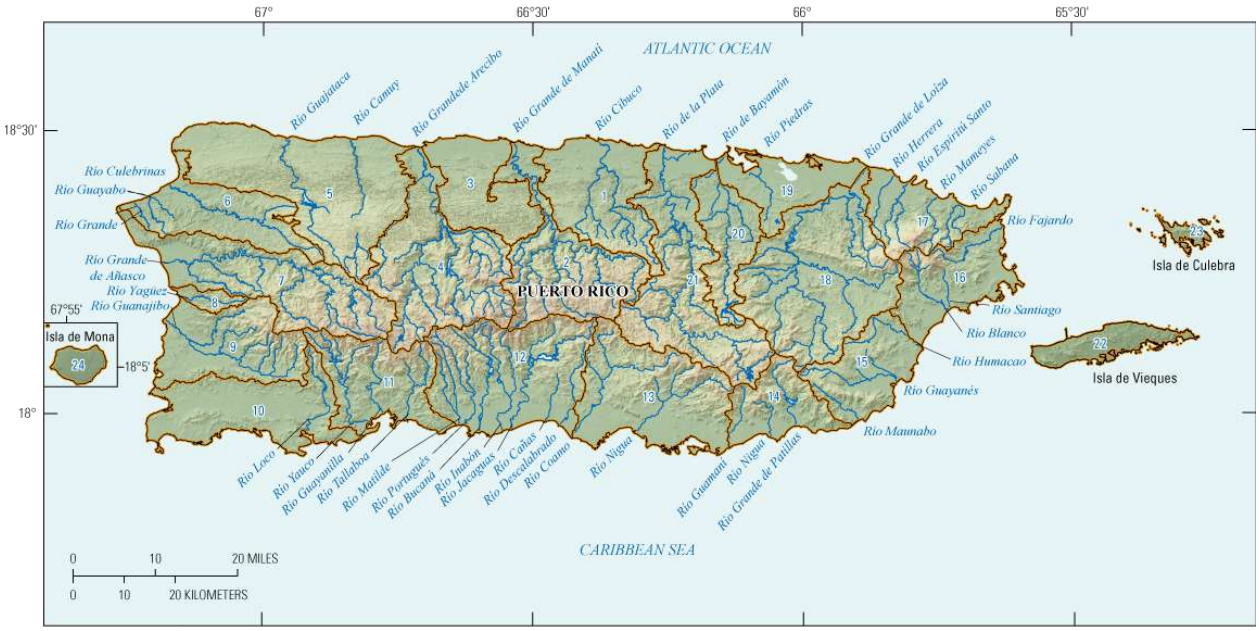
Puerto Rico has more than 224 rivers, of which about 50 are considered major perennial systems (see. From mountain headwaters in Adjuntas and El Yunque to large basins like the Río la Plata and Río Grande de Loíza, these rivers shape the landscape, sustain ecosystems, and provide essential water resources for communities. Managed through watershed frameworks, river basins also serve as the foundation for flood risk assessment and hazard mitigation planning.

[60] E.D. Swain, J.C. Bellino, "Insight into Hurricane Maria Peak Daily Streamflows from the Development and Application of the Precipitation-Runoff Modeling System (PRMS): Including Río Grande de Arecibo, Puerto Rico, 1981–2017," *Hydrology,* 2022, 9(11):205, https://doi.org/10.3390/hydrology9110205.



Index number	10-digit hydrologic unit code and watershed name
1	2101000201 Río Cibuco watershed
2	2101000202 Río Grande de Manatí watersheds
3	2101000203 Caño Tiburones Coastal watershed
4	2101000204 Río Grande de Arecibo watershed
5	2101000205 Quebrada Los Cedros to Río Camuy watersheds
6	2101000301 Río Culebrinas watershed
7	2101000302 Río Grande de Añasco watershed
8	2101000303 Río Yaguez watershed
9	2101000304 Río Guanajibo watershed
10	2101000401 Quebrada Boquerón to Río Loco watersheds
11	2101000402 Río Yauco to Río Tallaboa watersheds
12	2101000403 Río Matilde to Río Descalabrado watersheds
13	2101000404 Río Coamo to Río Seco watersheds
14	2101000405 Río Guamaní to Río Jacaboa watersheds
15	2101000501 Río Maunabo to Río Humacao watersheds
16	2101000502 Río Antón Ruíz to Río Fajardo watersheds
17	2101000503 Río Herrera to Las Cabezas de San Juan Coastal watersheds
18	2101000504 Río Grande de Loíza watershed
19	2101000505 San Juan Bay Estuary watershed
20	2101000506 Río de Bayamón to Río Hondo watersheds
21	2101000507 Río de la Plata watershed
22	2101000601 Isla de Vieques
23	2101000602 Isla de Culebra
24	2101000603 Isla de Mona

Figure 17: Majors Rivers in Puerto Rico



Base from U.S. Geological Survey digital data, 1:25,000
Shaded relief from U.S. Geological Survey 30-meter digital elevation model data
Lambert Conformal Conic projection
North American Datum of 1983

EXPLANATION

Elevation, in feet above Puerto Rico mean sea level
High : 4,357
Low : 0

Watershed and index number

Index number	10-digit hydrologic unit code and watershed name
1	2101000201 Río Cibuco watershed
2	2101000202 Río Grande de Manatí watersheds
3	2101000203 Caño Tiburones Coastal watershed
4	2101000204 Río Grande de Arecibo watershed
5	2101000205 Quebrada Los Cedros to Río Camuy watersheds
6	2101000301 Río Culebrinas watershed
7	2101000302 Río Grande de Añasco watershed
8	2101000303 Río Yaguez watershed
9	2101000304 Río Guanajibo watershed
10	2101000401 Quebrada Boquerón to Río Loco watersheds
11	2101000402 Río Yauco to Río Tallaboa watersheds
12	2101000403 Río Matilde to Río Descalabrado watersheds
13	2101000404 Río Coamo to Río Seco watersheds
14	2101000405 Río Guamaní to Río Jacaboa watersheds
15	2101000501 Río Maunabo to Río Humacao watersheds
16	2101000502 Río Antón Ruíz to Río Fajardo watersheds
17	2101000503 Río Herrera to Las Cabezas de San Juan Coastal watersheds
18	2101000504 Río Grande de Loíza watershed
19	2101000505 San Juan Bay Estuary watershed
20	2101000506 Río de Bayamón to Río Hondo watersheds
21	2101000507 Río de la Plata watershed
22	2101000601 Isla de Vieques
23	2101000602 Isla de Culebra
24	2101000603 Isla de Mona

River basins across the island face increasing threats from extreme hydrologic events, sedimentation, aging infrastructure, and unregulated development in floodplains. Historic floods demonstrate that these systems have been repeatedly affected for decades. The 1931 San Felipe II hurricane caused catastrophic flooding in the Loíza basin, destroying communities and crops. In 1985, heavy rains triggered flash floods and landslides across the central mountains, resulting in more than 100 fatalities. More recently, Hurricane Georges (1998) produced widespread river flooding, while Hurricane María (2017) caused catastrophic inundation and near-failure of the Guajataca Dam, forcing mass evacuations.[61] Hurricane Fiona (2022) again brought island-wide flash flooding and infrastructure breakdowns.

Taken together, these events reveal a long history of hazard exposure in the island's river basins. Flooding is not an isolated consequence of single storms but a chronic and escalating threat. Without stronger watershed management, resilient infrastructure, and land use controls, these systems will continue to place communities, critical facilities, and ecosystems at risk under present and future climate conditions.

Multiple agencies are involved in monitoring, managing, and mitigating river-related hazards. These include DRNA, USGS, the Puerto Rico Aqueduct and Sewer Authority (PRASA), and the U.S. Army Corps of Engineers,

[61] FEMA Region 2, Discovery Report: Río Grande de Loíza Watershed, https://feedback.region2coastal.com/Region2/Discovery/RioGrandeDeLoiza/. The Guardian, Puerto Rico Evacuates 70,000 as Dam Fails in Hurricane Maria's Wake, 2017, https://www.theguardian.com.

supported by nonprofit and citizen science programs, such as the San Juan Bay Estuary Program[62] and EarthEcho Water Quality Monitoring Day.[63] These entities play vital roles in water quality monitoring, flood modeling, community education, and long-term planning.

Effective hazard mitigation must prioritize integrated watershed management approaches that include reforestation, slope stabilization, structural rehabilitation of flood control infrastructure, and the integration of real-time monitoring systems. These actions are critical to building a resilient and adaptive river system that protects life, property, and ecological functions across Puerto Rico's diverse landscapes.

Table 6 highlights selected major rivers in Puerto Rico, their geographic reach, and the primary hazards associated with each.

Table 6: Major Rivers in Puerto Rico[64]

River Name	Length (miles)	Main Municipalities	Key Hazards
Río Grande de Loíza	40	Loíza, Trujillo Alto, San Lorenzo	Flooding, sedimentation
Río Grande de Arecibo	55	Arecibo, Utuado	Flooding, aging flood control
Río Guajataca	25	San Sebastián, Quebradillas, Isabela	Dam breach risk, flooding
Río Yagüez	15	Mayagüez	Urban flash floods
Río Culebrinas	22	Aguada, Aguadilla	Riverbank erosion
Río de la Plata	45	Toa Alta, Toa Baja, Dorado	Flooding, infrastructure risk
Río Bayamón	25	Bayamón, Cataño	Urban flooding
Río Espíritu Santo	12	Río Grande	Flash floods, landslides
Río Blanco	24	Naguabo	Flooding, deforestation
Río Grande de Manatí	45	Ciales, Manatí	Flooding, sedimentation

Puerto Rico's water security depends on a network of managed reservoirs and dams that provide potable water, irrigation, and limited flood regulation. Key systems include Lago La Plata, Lago Loíza also known as Carraízo, Lago Toa Vaca, and Lago de Cidra, which are managed by the Puerto Rico Aqueduct and Sewer Authority. Other important reservoirs, such as Lago Guajataca, Lago Caonillas, Lago Dos Bocas, and Lago Guayabal, are managed by the Puerto Rico Electric Power Authority. Although originally designed for multiple purposes, most reservoirs today serve primarily as drinking water sources for urban and drought-

[62] Estuario, "Water Quality Monitoring Program," https://estuario.org/water-quality/.
[63] EarthEcho International, "Water Quality Monitoring Day in Puerto Rico," https://www.monitorwater.org.
[64] Recursos Agua Puerto Rico, "Hidrografía de Puerto Rico," https://www.recursosaguapuertorico.com.

sensitive regions.[65] Table 7 lists the main rivers and representative municipalities in the watersheds of Puerto Rico.

Table 7: Rivers by Watershed Region in Puerto Rico[66]

Watershed Region	Main Rivers	Representative Municipalities
Río Grande de Loíza	Río Grande de Loíza, Gurabo, Turabo	Loíza, Trujillo Alto, Caguas, San Lorenzo
Río Grande de Arecibo	Río Grande de Arecibo, Vacas, Tanamá	Arecibo, Utuado, Adjuntas
Río de la Plata	Río de la Plata, Usabón, Hondo	Toa Baja, Dorado, Barranquitas
Río Guajataca	Río Guajataca	San Sebastián, Isabela, Quebradillas
Río Grande de Añasco	Río Cañas, Guaba, Lajas	Las Marías, Mayagüez
Río Culebrinas	Río Culebrinas	Aguada, Aguadilla
Río Yagüez	Río Yagüez	Mayagüez
Río Bayamón	Río Bayamón	Bayamón, Cataño
Río Grande de Manatí	Río Grande de Manatí	Manatí, Ciales
Northeastern Coastal/ El Yunque	Río Espíritu Santo, Sabana, Mameyes, Fajardo	Río Grande, Luquillo, Naguabo

These systems face chronic challenges from sedimentation and water quality degradation. For example, Lago Loíza had lost nearly half of its original storage by the mid-1990s, and Lago Caonillas continues to lose capacity from sediment accumulation. DRNA monitoring confirms that turbidity, nutrient enrichment, and algal blooms remain water quality concerns.

Recent extreme events have further highlighted vulnerabilities. Hurricane María (2017) triggered massive sediment inflows and turbidity spikes, while Hurricane Fiona (2022) caused record rainfall and infrastructure breakdowns and left over 760,000 customers without water. The near-failure of Guajataca Dam in 2017 underscores the risks posed by aging infrastructure. Strengthening watershed management, sediment control, and dam safety is essential to safeguard Puerto Rico's reservoirs under future climate extremes.

As Puerto Rico confronts increasingly variable precipitation patterns and hydrologic extremes, maintaining and upgrading its reservoir infrastructure becomes a strategic priority. The resilience of Puerto Rico's water supply system depends on the performance and longevity of its reservoirs and dams. These critical infrastructures, while foundational to public health and economic stability, are vulnerable to sedimentation, structural aging, and hydrologic stress from extreme weather. A proactive hazard mitigation approach must include sediment management, dam rehabilitation, and the protection of upstream watersheds to safeguard

[65] PRASA, Informe de Situación Operacional y Capacidad de Almacenamiento de Embalses Potables, 2021.
[66] USGS, "Watershed Boundaries for Puerto Rico," 2022, https://pubs.er.usgs.gov/publication/sir20225040.

water availability during both drought and hydroelectric status. Table 8 shows the status of the reservoirs in Puerto Rico in 2020.

Table 8: Reservoir Status, 2020[67]

Reservoir	Municipality Area	Operator	Primary Use	Year Built	Remarks
Lago La Plata	Bayamón/ Naranjito/ Toa Alta	PRASA	Potable water (San Juan metro area)	1973	Major drinking water source.
Lago Loíza	Trujillo Alto	PRASA	Potable water	1953	Reduced capacity due to sedimentation.
Lago de Cidra	Cidra	PRASA	Potable water	1946	Local water supply.
Lago Toa Vaca	Villalba and surrounding towns	PRASA	Potable water	1972	Serves central municipalities.
Lago Carite	Guayama	PRASA	Potable water and irrigation	1913	Originally hydroelectric (Carite Plant); currently no power generation.
Lago Guajataca	San Sebastián/ Isabela/ Quebradillas	PREPA	Multi-use (potable, irrigation, recreation)	1928	Hydroelectric turbines are decommissioned, currently not generating power.
Lago Caonillas	Utuado	PREPA	Former hydroelectric and water supply	1948	Infrastructure in place, technically active capacity but currently inactive.
Lago Dos Bocas	Arecibo/ Utuado	PREPA	Former hydroelectric and water supply	1942	Infrastructure in place, technically active capacity but currently inactive.
Lago Guayabal	Juana Díaz	PREPA	Irrigation and backup water supply	1913	Supports irrigation and flood management.
Laguna Tortuguero	Vega Baja/ Manatí	DRNA	Ecological reserve/ flood regulation	Natural	Protected area.

[67] DRNA = Department of Natural and Environmental Resources, PRASA = Puerto Rico Aqueduct and Sewer Authority, PREPA = Puerto Rico Electric Power Authority.

Historical and Cultural Resources

Defining cultural resources can be challenging, as existing laws for cultural preservation help identify what is historically or culturally important. Historic properties and archeological sites are two categories that are clearly distinguished based on where they are included in or eligible for official registers. In Puerto Rico, there are two lists of historic places: one at the national level and one at the Commonwealth. The recognition of historic sites in Puerto Rico began in February 1949, when the San Jan historic site was recognized under the Historic Sites Act of 1935. The National Register of Historic Places was created in 1966, and the San Juan area later became the San Juan National Historic Site.[68]

It is important to understand that being listed in the National Register or the Puerto Rican Cultural Institute (Instituto de Cultura Puertorriqueña, ICP) requires a formal nomination. This means that neither register represents all eligible properties. Therefore, they should not be seen as complete lists of Puerto Rico's historic or archaeological resources.

In recent years, the impacts of hurricanes such as Hurricane Maria in 2017 have posed significant threats to these irreplaceable resources. The devastation caused by these storms has resulted in the loss of historical sites, damage to museums, and the erosion of cultural practices as communities struggle to rebuild. The aftermath reveals the precarious nature of preserving Puerto Rico's heritage in the face of climate change and natural disasters. Still, the ongoing challenges highlight the urgent need for proactive preservation efforts and sustainable practices to ensure that Puerto Rico's historical treasures endure for future generations.[69]

Currently, 383 properties are listed in the National Register of Historic Places for Puerto Rico, which include buildings, structures, archeological sites, and districts.

Suggested Narrative:

Historic and cultural resources include buildings, archeological sites, landscapes, and districts that reflect Puerto Rico's heritage. Their recognition and protection are guided by both federal and Commonwealth preservation laws that establish formal criteria for significance. At the federal level, the National Historic Preservation Act of 1966 created the National Register of Historic Places, the official list of properties worthy of preservation.[70] At the Commonwealth level, ICP, through the State Historic Preservation Office, maintains Puerto Rico's own register of historic properties. Importantly, not all eligible properties are listed, since inclusion requires a formal nomination and review process.

[68] Rand, "Natural and Cultural Resources Recovery Planning in Puerto Rico Natural and Cultural Resources Sector Report, Volume II,"
https://www.rand.org/content/dam/rand/pubs/research_reports/RR2800/RR2859/RAND_RR2859.pdf.
[69] Rand, "Natural and Cultural Resources Recovery Planning in Puerto Rico Natural and Cultural Resources Sector Report, Volume II,"
https://www.rand.org/content/dam/rand/pubs/research_reports/RR2800/RR2859/RAND_RR2859.pdf.
[70] National Historic Preservation Act of 1966, Public Law 89-665.

The preservation of historic places in Puerto Rico began with the designation of the San Juan Historic Site in 1949 under the Historic Sites Act of 1935. This site, which includes the city's defensive walls and fortifications, was later incorporated into the National Register and is today managed as the San Juan National Historic Site, a UNESCO World Heritage Site. As of 2024, 383 properties are listed in the National Register of Historic Places in Puerto Rico, including individual buildings, structures, archeological sites, and historic districts.[71]

These resources are not only important for heritage and tourism but are also vulnerable to natural hazards. Hurricane María in 2017 caused severe damage to historic buildings, museums, and community landmarks, highlighting the fragility of cultural resources in the face of extreme weather. The loss of sites and cultural practices in the aftermath of storms underscores the urgent need to integrate preservation into hazard mitigation planning. Protecting these resources requires proactive measures, such as resilient retrofits, community education, and emergency preparedness for cultural institutions.[72]

Currently, 383 properties are listed in the National Register of Historic Places for Puerto Rico. They include buildings, structures, archeological sites, and districts.

Transportation

Puerto Rico has a diverse and intricate transportation system that links its residents and visitors to the island's distinctive landscapes, cities, and landmarks. The network incorporates various modes of transportation, including public buses, a rapid transit system, taxis, rideshare services, car rentals, ferries, and air travel. According to the Federal Highway Administration's Highway Statistics 2022, Puerto Rico has approximately 16,435 miles of public roads,[73] including 15 major highways and 3 major interstates.

Challenges to inter-island transportation include traffic congestion in the San Juan metro area, along with the poor condition of the island's roads. According to the federal government, only 13% of Puerto Rico's highways are classified as being in good condition. In San Juan, drivers spend an average of 58 hours each year stuck in traffic, which costs each driver approximately $1,150. Contributing to this congestion is the fact that many residents rely on personal vehicles rather than public transportation, such as trains.[74]

[71] National Park Service, National Register of Historic Places Database (NPGallery): Puerto Rico, 2024.
[72] FEMA. Integrating Historic Property and Cultural Resource Considerations Into Hazard Mitigation Planning (FEMA 386-6), 2000.
[73] Federal Highway Administration. (2023). *Highway Statistics 2022: Table HM-18 – Public road length, by ownership, and federal-aid highways*. U.S. Department of Transportation. https://www.fhwa.dot.gov/policyinformation/statistics/2022/hm18.cfm.
[74] Financial Oversight & Management Board of Puerto Rico, "Working Group on Transportation Sector Reform Established," https://oversightboard.pr.gov/working-group-on-transportation-sector-reform-established-2/.

Interstates/Highways

Puerto Rico's three interstates are I-PR-1, covering 71.08 miles; I-PR-2, covering 138.13 miles; and I-PR-3, covering 40.56 miles, totaling 249.77 miles.[75] These roads are important for transportation across the island, connecting different regions, improving access, and supporting the economy.

Interstate PR-1 runs along the full length of PR 52, known as Autopista (toll road) Luis A. Ferré, between Ponce and San Juan. It also follows Primary Route 18, which connects to Primary Route 22 in San Juan. PR 52 is part of the toll roads operated by the Metropistas Group.

PR 52 mainly took over as the primary route from Ponce to Juana Diaz, Santa Isabel, and Salinas. Both routes cross the central mountain range, known as the Cordillera Central, from Salinas to Cayey. The toll road becomes more urban as it enters Caguas, featuring reversible dynamic toll lanes from Exit 15 at PR 1/30 to San Juan. The dynamic toll lanes continue north from PR 52 onto PR 18 and reach PR 22, also known as Autopista José de Diego. I-PR-1 ends at PR 22, which is also I-PR-2 and I-PR-3.[76]

Interstate PR 2 circles the western part of Puerto Rico, starting from San Juan and going west to Aguadilla, south to Mayagüez, and east to Ponce. This route runs alongside Primary Route 22, which goes from San Juan to Arecibo, and Primary Route 2, which continues from Arecibo to Ponce.

I-PR-2 is a limited-access road that runs along PR 22, also known as the Autopista Jose de Diego toll road. It starts from PRI-3 and PRI-1/PR 18 in San Juan. From Arecibo to Hormigueros, PR 2 is a regular road. East of Secondary Route 100, PR 2 is a controlled-access expressway to San Germán. From there to Ponce, it becomes a limited-access freeway. This section connects PR 52 and PR 9 in Ponce.[77]

Interstate PR-3 is a road that runs north from Humacao to Fajardo and west from Luquillo to San Juan in northeastern Puerto Rico. The southern part of the route is along PR 53 (Autopista Dr. Jose Celso Barbosa), which goes north from PR 30 in Humacao to the end of the toll road at PR 3 in Fajardo. PRI-3 follows PR 3, a main route heading west to Rio Grande, where it connects to PR 66 (Autopista Roberto Sanchez Vilella), which goes south.

The toll road on PR 66 offers a fast route around Rio Grande, Canóvanas, and Trujillo Bajo, while PR 3 serves as the main road north. PRI-3 then joins PR 26, a limited-access freeway that runs northwest from Carolina into San Juan. PRI-3 stays on PR 26 until it reaches PR 22 in the Minillas neighborhood. From there, PRI-3 heads south along PR 22 to a shared ending point with PRI-2 (PR 22) and PRI-1 (PR 18).

[75] U.S. Department of Transportation, "FHWA Route Log and Finder List," https://www.fhwa.dot.gov/planning/national_highway_system/interstate_highway_system/routefinder/table01.cfm.
[76] AAroads, "Puerto Rico Interstate 1," https://www.aaroads.com/interstate-guide/i-pr001/.
[77] AARoads, "Puerto Rico Interstate 2," https://www.aaroads.com/interstate-guide/i-pr002/.

Construction for Corredor del Este (East Corridor), the toll road for PR 66, began in 2003. After it was finished, PR 3 to the north was downgraded from a main road to a rural inter-municipal route.[78]

Figure 18 is a map of expressways and toll roads traversing Puerto Rico.

Figure 18: Puerto Rico Expressways and Toll Roads[79]

[78] AARoads, "Puerto Rico Interstate 3," https://www.aaroads.com/interstate-guide/i-pr003/.
[79] AARoads, "Puerto Rico Interstate 1," https://www.aaroads.com/interstate-guide/i-pr001/.

In Puerto Rico, the speed limits on highways typically range from 50 to 65 miles per hour, similar to many U.S. states. Highways are classified into three distinct categories, each serving a different traffic need:[80]

- **Expressways**: These highways are designed to facilitate mostly uninterrupted traffic flow. They are constructed without traffic lights, railroad crossings, or other obstacles that can hinder the movement of vehicles. Expressways are ideal for long-distance travel across the island, allowing for consistent speed.
- **Freeways:** Unlike expressways, freeways offer completely uninterrupted access to vehicles. These highways have no access points that interfere with traffic flow, such as at-grade intersections or stop signs. Drivers on freeways can expect a smoother and faster journey, as these roads are designed to minimize delays and maximize efficiency.
- **Autopistas** (**toll roads):** These are specialized highways that qualify as freeways; however, they require drivers to pay a toll. Although expressways provide similar benefits in terms of uninterrupted travel, the toll requirements differentiate them from freeways. They are often maintained to a higher standard and may offer additional services or features, such as rest areas or enhanced safety measures.
- **zzz**

Public Transit

Puerto Rico features a diverse public transit system that includes the Tren Urbano rail network, which connects key areas in the San Juan metropolitan region, and an extensive bus system operated by the Autoridad de Transporte Marítimo. In addition, multiple international airports, such as Luis Muñoz Marín International Airport, facilitate air travel to and from the island. These systems provide essential transportation options that enhance mobility.

- **Rail System:** Tren Urbano is a rapid transit system that features a single line stretching 10.7 miles. The system serves the municipalities of San Juan, Bayamón, and Guaynabo. The Tren Urbano has 16 strategically located stations designed to facilitate easy access for riders. It includes a vehicle maintenance and storage facility to ensure the upkeep of its fleet of 74 rail cars.

  Integral to the operations of the Tren Urbano is an operations center, equipped with advanced technology for managing train schedules and ensuring passenger safety. The system also relies on traction power, train control systems, and communications technology to maintain efficient and reliable service.[81]

  Most of the transit system is elevated, with a notable 1.1-mile segment running through a tunnel in the Rio Piedras district. The project was initiated as a proactive solution to the growing volume of vehicle traffic in the San Juan metropolitan area.

[80] Puerto Rico Car Transport, "All You Need to Know About Puerto Rico's Highways," https://www.puertoricocartransport.com/news/need-know-puerto-ricos-highways/.
[81] U.S. Department of Transportation, "Tren Urbano," https://www.transportation.gov/buildamerica/projects/tren-urbano.

- **Bus System:** The Autoridad Metropolitana de Autobuses (AMA) is a public bus service established on May 11, 1959. It became part of the Department of Transportation and Public Works in 1973 and later joined the Integrated Transit Authority in 2014. AMA is the second-oldest public transport authority in the United States, after New York's Metropolitan Transportation Authority.

  AMA has 149 buses and provides transportation to the San Juan metropolitan area, which includes San Juan, Guaynabo, Bayamón, Trujillo Alto, Cataño, Toa Baja, and Carolina. It operates 30 fixed bus routes with a daily ridership of approximately 35,000 passengers.[82]

- **Airports:** Puerto Rico is home to a diverse network of over 10 airports (Figure 19), which includes four major international airports and several regional and island airports. The primary hubs in the region are the Luis Muñoz Marín International Airport (SJU) in San Juan, Rafael Hernández Airport (BQN) in Aguadilla, and Mercedita Airport (PSE) in Ponce. Luis Muñoz Marín International Airport stands out as the primary and busiest airport on the island, for both international and domestic travelers, and handles millions of passengers annually. BQN and PSE also serve domestic and international flights for passengers and cargo.

  Besides the major airports, Puerto Rico has several regional airports which include, the José Aponte de la Torre Airport (CPB/RVR) in Ceiba for travelers heading to the Vieques and Culebra islands, Arecibo Airport (ABO), primarily used for smaller aircraft; Mayagüez Airport (MAZ), which caters to domestic flights; Fajardo Airport (FAJ/X95), servicing charter flights; and Humacao Airport (HUC/X63), which also supports smaller aircraft operations.

  Another significant regional airport is Fernando Luis Ribas Dominicci Airport, commonly called Isla Grande Airport. Located near San Juan, this airport mainly focuses on general aviation and offers services for charter flights, private aircraft, and some regional airline services.[83]

[82] Alcheron, "Puerto Rico Metropolitan Bus Authority," https://alchetron.com/Puerto-Rico-Metropolitan-Bus-Authority#Background.
[83] Discover Puerto Rico, "Puerto Rico Airports," https://www.discoverpuertorico.com/transportation/airports.

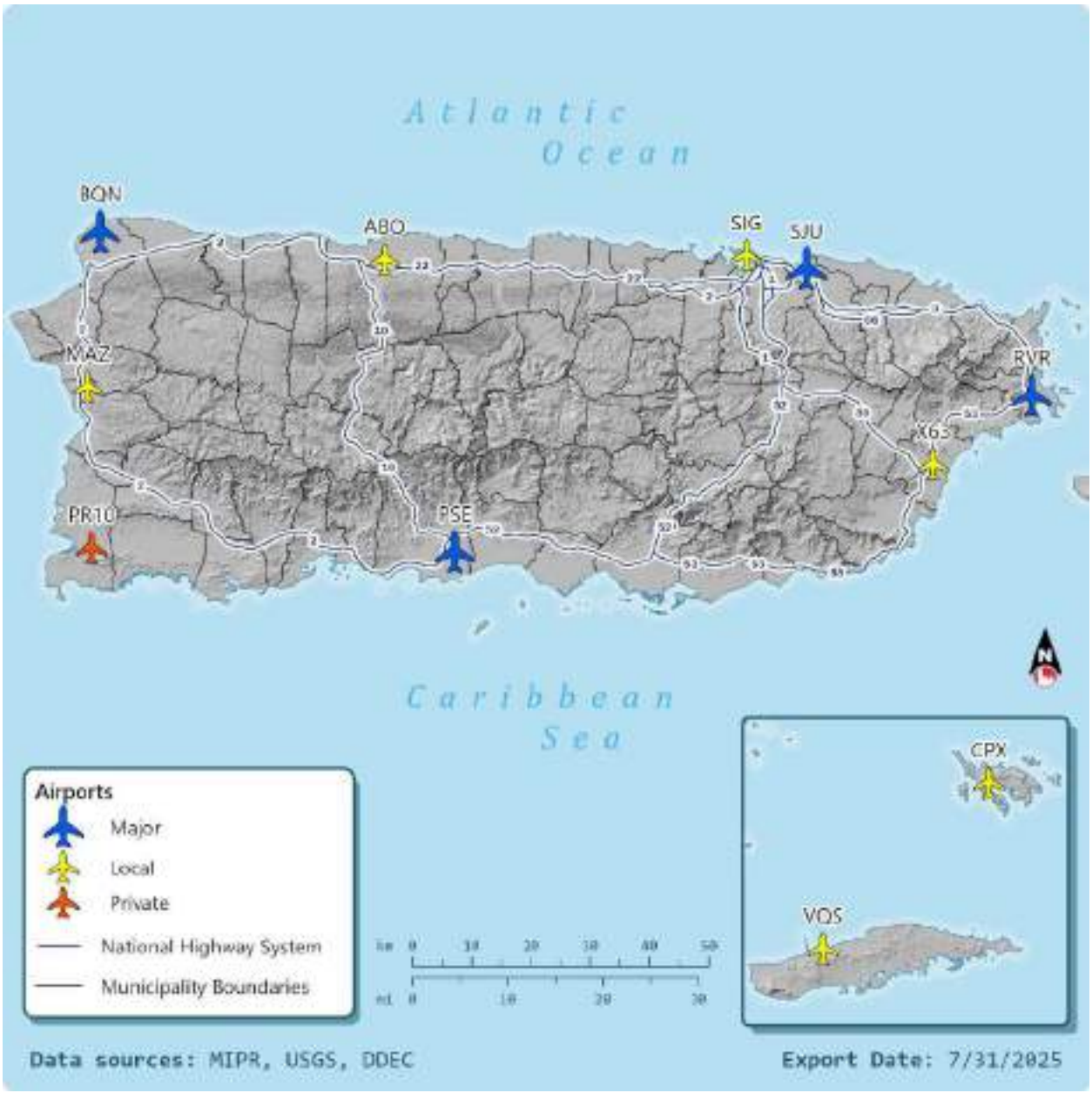


Figure 19: Major Airports in Puerto Rico

Bridges

Puerto Rico is currently home to 2,385 bridges, of which 332, or approximately 13.9%, are classified as structurally deficient. This classification implies that one or more key elements of these bridges are in poor or worse condition. This has increased from 282 structurally deficient bridges reported in 2020.

The deck area of the structurally deficient bridges represents 11.8% of the deck area across all bridge structures in Puerto Rico. Thirty-nine of these bridges are situated on the Interstate Highway System. A

substantial 76.5% of the deficient bridges are located off the National Highway System, which includes critical routes that connect major airports, ports, and rail and truck terminals.

In terms of safety measures, 833 bridges are currently posted for load, which may impose restrictions on the size and weight of vehicles traversing these structures. Puerto Rico has identified necessary repairs for 1,722 bridges, a slight decrease from the 1,726 bridges that required attention in 2020.[84] Between 2020 and 2024, the number of bridges in need of repair, including those classified as structurally deficient, remained relatively stable. In 2020 and 2021, 1,726 bridges needed repair. The number rose slightly to 1,727 in 2022, before declining to 1,715 in 2023. By 2024, the number rose again to 1,722.[85]

Demographics

Population

According to the latest census data, the population of Puerto Rico presents a unique demographic landscape shaped by historical events, economic factors, and social changes. Understanding these population dynamics is essential for addressing the challenges and opportunities facing the island today. As shown in Figure 20, population density is highest in the region around San Juan and a few other urban centers.

[84] American Road & Transportation Builders Association, "National Bridge Inventory: Puerto Rico," https://artbabridgereport.org/state/profile/PR.
[85] American Road & Transportation Builders Association, "National Bridge Inventory: Puerto Rico," https://artbabridgereport.org/state/profile/PR.

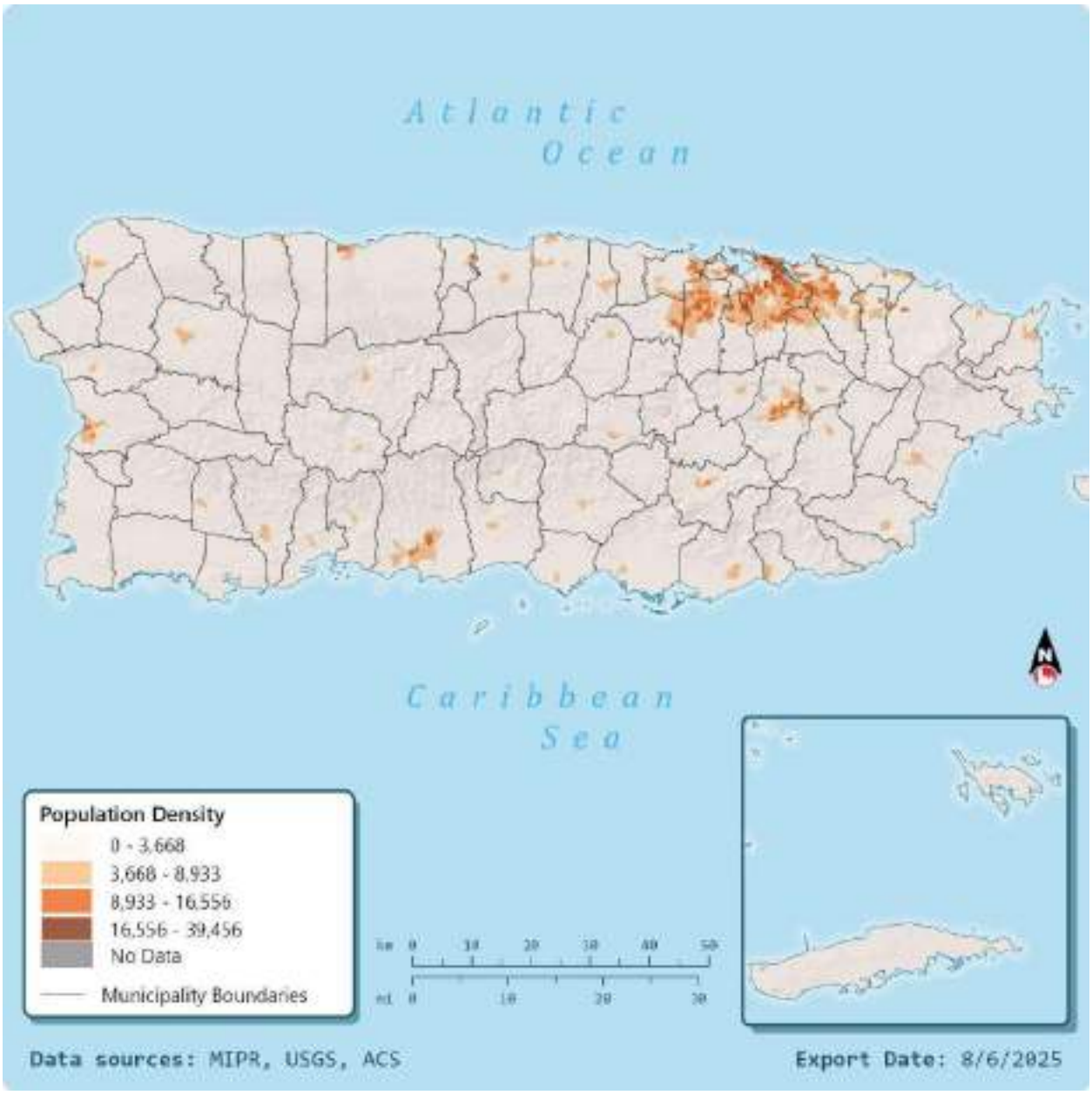


Figure 20: Population Density in Puerto Rico

Puerto Rico's population has experienced a decline over the past few decades (see Figure 21). As of the 2024 census estimates, the population is approximately 3,203,295, down from 3,285,874 in 2020. This represents a decrease of approximately 2.5% over a four-year period.[86]

Decennial population trends showed a rise in population from 1980 through 2020, followed by a downward turn since then. The distribution of areas that have experience population decline or growth between 2010 and 2020 is visible in Figure 22.

[86] U.S. Census Bureau, "Quick Facts Puerto Rico," https://www.census.gov/quickfacts/fact/table/PR/PST045224.

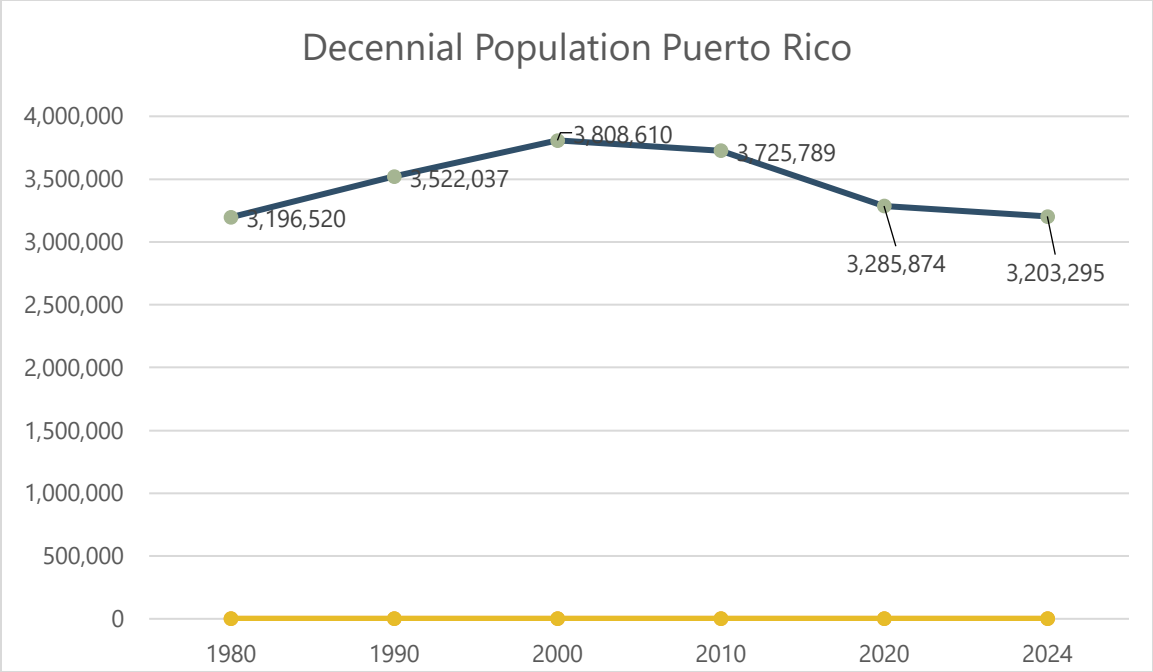


Figure 21: Decennial Population Trends, Puerto Rico[87]

[87] Centro, "2020 Population Decennial Analysis," https://centropr.hunter.cuny.edu/reports/puerto-ricos-2020-population-decennial-analysis/.

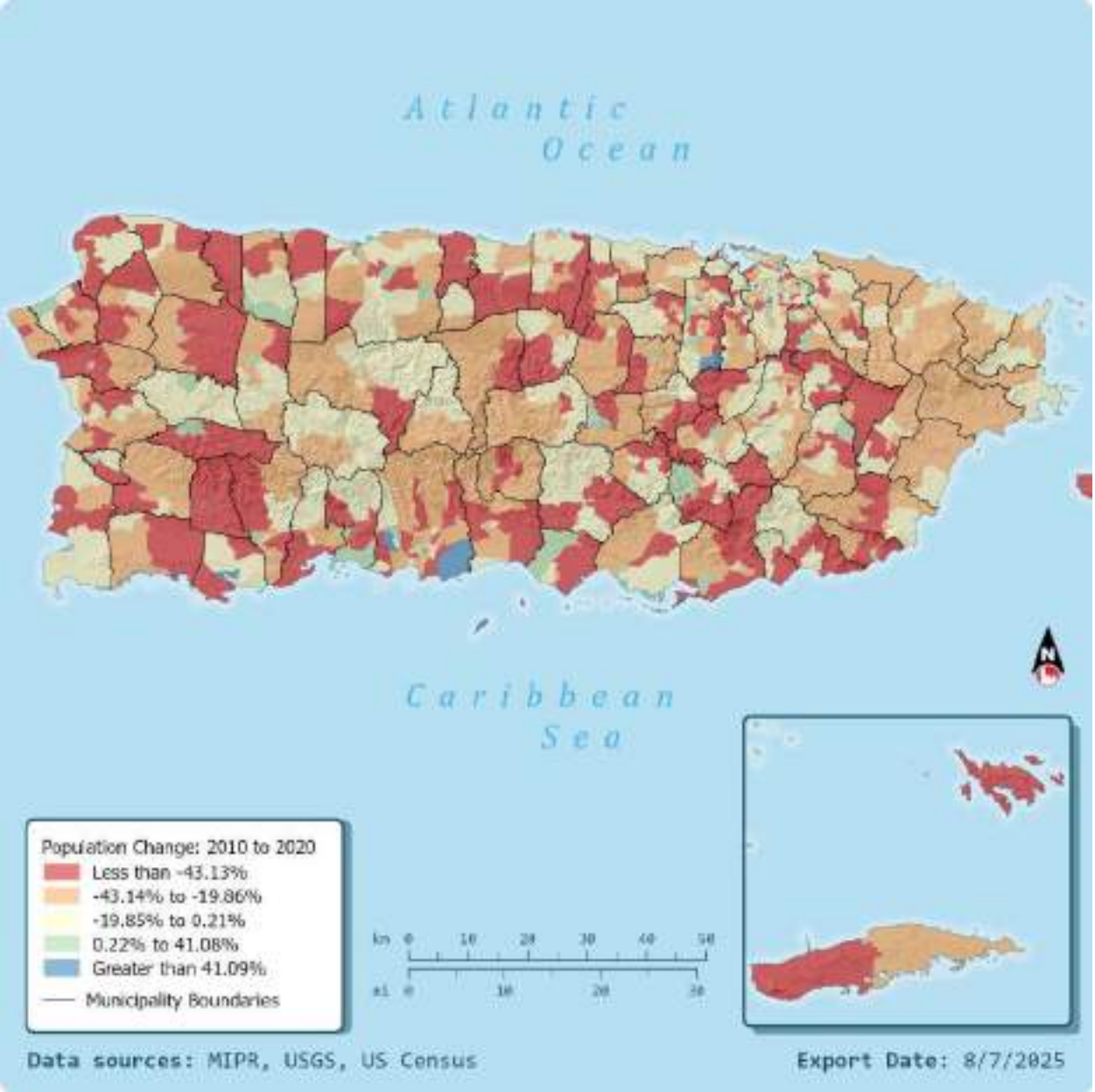


Figure 22: Population Change 2010–2020

The population reduction can be attributed to several factors, including economic challenges, outmigration, and demographic trends. Many Puerto Ricans have moved to the mainland United States, especially following Hurricane Maria in 2017.[88]

[88] Federal Reserve Bank of New York, "The Causes and Consequences of Puerto Rico's Declining Population," https://www.newyorkfed.org/medialibrary/media/research/current_issues/ci20-4.pdf.

The six highest reductions in population from April 01, 2020, to July 01, 2024, were for the municipalities of Guánica (-12.1%), Loíza (-6.9%), Guayanilla (-6.5%), Yauco (-6.2%), Guayama (-6.1%), and Yabucoa (-6.1%). Detailed information on population changes per municipality can be found in Table 9.

Table 9: Population Change by Municipality Over the Past Five Years[89]

Municipality	2020	2021	2022	2023	2024	Cumulative Change 2020–2024
Adjuntas	18,008	18,026	17,896	17,887	17,981	-0.2
Aguada	38,109	38,004	37,647	37,509	37,523	-1.6
Aguadilla	55,046	54,613	53,877	53,592	53,557	-2.8
Aguas Buenas	24,189	23,974	23,521	23,260	23,125	-4.5
Aibonito	24,633	24,674	24,537	24,586	24,751	0.5
Añasco	25,569	25,414	25,003	24,796	24,689	-3.5
Arecibo	87,638	87,122	86,023	85,579	85,971	-2.0
Arroyo	15,820	15,606	15,273	15,062	14,944	-5.7
Barceloneta	22,669	22,630	22,406	22,354	22,413	-1.1
Barranquitas	28,981	29,076	28,927	29,006	29,281	1.0
Bayamón	184,952	183,983	181,509	180,751	181,152	-2.2
Cabo Rojo	47,122	47,098	46,695	46,646	46,820	-0.7
Caguas	127,069	126,610	125,085	124,539	124,628	-2.1
Camuy	32,819	32,883	32,599	32,603	32,765	-0.2
Canóvanas	42,326	42,140	41,613	41,488	41,512	-1.9
Carolina	154,559	153,508	151,495	150,777	150,679	-2.7
Cataño	23,110	22,810	22,344	22,099	21,971	-5.1
Cayey	41,593	41,316	40,774	40,513	40,389	-3.0
Ceiba	11,284	11,147	10,923	10,840	10,783	-4.6
Ciales	16,975	16,939	16,729	16,684	16,698	-1.7
Cidra	39,960	39,905	39,482	39,390	39,478	-1.2
Coamo	34,604	34,351	33,875	33,644	33,514	-3.3
Comerío	18,868	18,861	18,618	18,595	18,613	-1.4
Corozal	34,551	34,580	34,293	34,318	34,476	-0.3

[89] U.S. Census Bureau, "Puerto Rico Municipios Population Totals: 2020–2024," https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-puerto-rico-municipios.html.

Municipality	2020	2021	2022	2023	2024	Cumulative Change 2020–2024
Culebra	1,790	1,783	1,769	1,762	1,759	-1.8
Dorado	35,902	35,936	35,646	35,699	35,867	0
Fajardo	32,087	31,812	31,352	31,149	31,043	-3.4
Florida	11,682	11,651	11,485	11,418	11,425	-2.3
Guánica	13,686	13,273	12,790	12,408	12,117	-12.1
Guayama	36,472	35,625	35,252	34,753	34,386	-6.1
Guayanilla	17,738	17,478	17,060	16,801	16,628	-6.5
Guaynabo	89,758	89,721	89,011	88,995	89,405	-0.4
Gurabo	40,588	40,500	40,052	39,959	40,039	-1.4
Hatillo	38,449	38,379	37,997	37,927	38,034	-1.2
Hormigueros	15,618	15,567	15,405	15,327	15,290	-2.3
Humacao	50,820	50,520	49,886	49,659	49,616	-2.5
Isabela	42,941	42,985	42,728	42,761	43,033	0.2
Jayuya	14,771	14,708	14,488	14,424	14,440	-2.3
Juana Díaz	46,498	46,401	45,940	45,895	46,045	-1.1
Juncos	37,031	36,996	36,652	36,668	36,796	-0.6
Lajas	23,278	23,215	22,934	22,862	22,888	-1.9
Lares	28,089	27,982	27,759	27,713	27,734	-1.3
Las Marías	8,856	8,820	8,703	8,668	8,674	-2.3
Las Piedras	35,181	35,143	34,802	34,739	34,890	-0.8
Loíza	23,607	23,235	22,652	22,299	22,047	-6.9
Luquillo	17,766	17,684	17,442	17,383	17,387	-2.2
Manatí	39,450	39,260	38,738	38,631	38,637	-2.2
Maricao	4,752	4,679	4,571	4,521	4,486	-5.7
Maunabo	10,580	10,527	10,368	10,270	10,248	-3.2
Mayagüez	72,847	71,927	70,580	69,741	69,044	-5.5
Moca	37,463	37,515	37,279	37,322	37,543	0.2
Morovis	28,706	28,597	28,270	28,182	28,230	-1.7
Naguabo	23,384	23,278	22,960	22,826	22,820	-2.4

Municipality	2020	2021	2022	2023	2024	Cumulative Change 2020–2024
Naranjito	29,244	29,341	29,182	29,265	29,516	0.9
Orocovis	21,431	21,421	21,225	21,209	21,260	-0.8
Patillas	15,940	15,806	15,516	15,335	15,216	-4.8
Peñuelas	20,347	20,140	19,758	19,566	19,453	-4.6
Ponce	137,153	134,745	132,091	130,153	129,659	-5.7
Quebradillas	23,619	23,544	23,328	23,251	23,301	-1.4
Rincón	15,205	15,332	15,306	15,420	15,625	2.9
Río Grande	47,007	46,576	45,820	45,554	45,297	-3.7
Sabana Grande	22,700	22,624	22,337	22,189	22,183	-2.4
Salinas	25,721	25,472	24,990	24,706	24,504	-5.0
San Germán	31,826	31,582	31,169	30,970	30,980	-2.8
San Juan	341,672	339,296	334,591	332,789	332,454	-2.9
San Lorenzo	37,671	37,632	37,245	37,242	37,363	-0.9
San Sebastián	39,311	39,276	38,953	38,899	38,999	-0.9
Santa Isabel	20,273	20,112	19,802	19,675	19,651	-3.1
Toa Alta	66,845	66,715	66,020	65,918	66,100	-1.1
Toa baja	75,096	74,195	72,732	71,838	71,332	-5.3
Trujilo Alto	67,690	67,516	66,762	66,655	66,816	-1.4
Utuado	28,226	27,973	27,514	27,236	27,155	-4.0
Vega Alta	35,366	35,201	34,764	34,617	34,658	-2.1
Vega Baja	54,356	54,229	53,662	53,506	53,709	-1.3
Vieques	8,236	8,166	8,036	7,988	7,966	-3.4
Villalba	22,040	21,818	21,456	21,268	21,197	-4.1
Yabucoa	30,326	29,936	29,282	28,876	28,580	-6.1
Yauco	34,045	33,596	32,881	32,387	32,057	-6.2

Age

Puerto Rico's population has experienced a decline over the past few decades (see Figure 21). As of the 2024 census estimates, the population is approximately 3,203,295, down from 3,285,874 in 2020.[90] This represents a decrease of approximately 2.5% over a four-year period. The current population of Puerto Rico is categorized by age as shown in Figure 23.

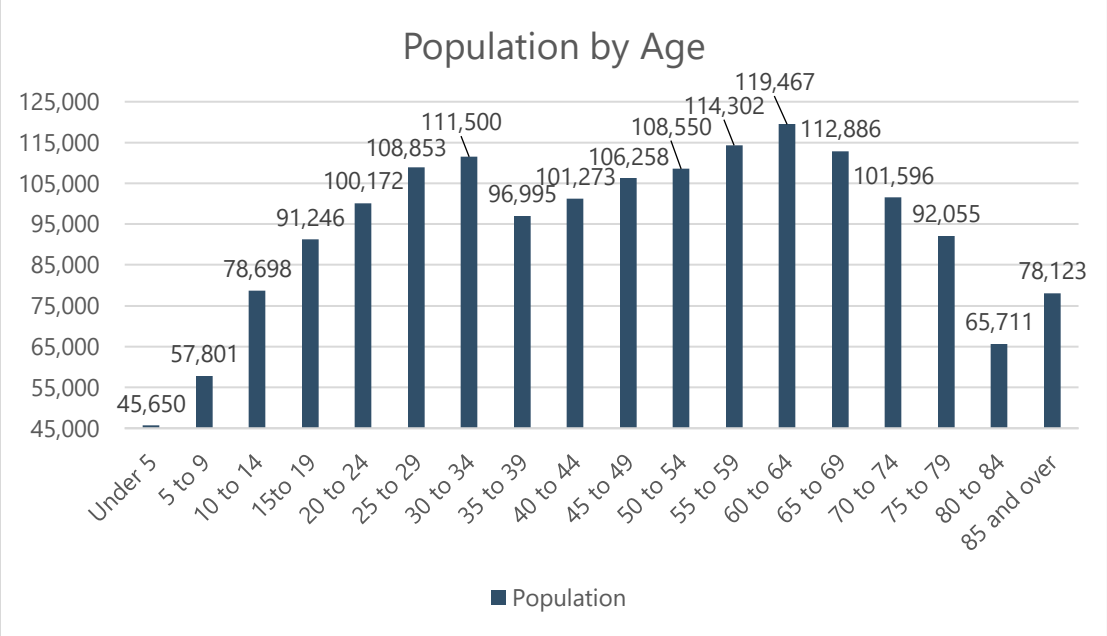


Figure 23: Population by Age[91]

The demographic shifts also reveal an aging population (see Figure 24) with more people dying, and fewer infants being born on the island. Figure 25 shows areas where higher percentages of older populations are located.

[90] United States Census Bureau, "Quick Facts Puerto Rico." https://www.census.gov/quickfacts/fact/table/PR/PST045224

[91] U.S. Census Bureau, "Puerto Rico Commonwealth population by Characteristics: 2020–2024," https://www.census.gov/data/tables/time-series/demo/popest/2020s-detail-puerto-rico.html.

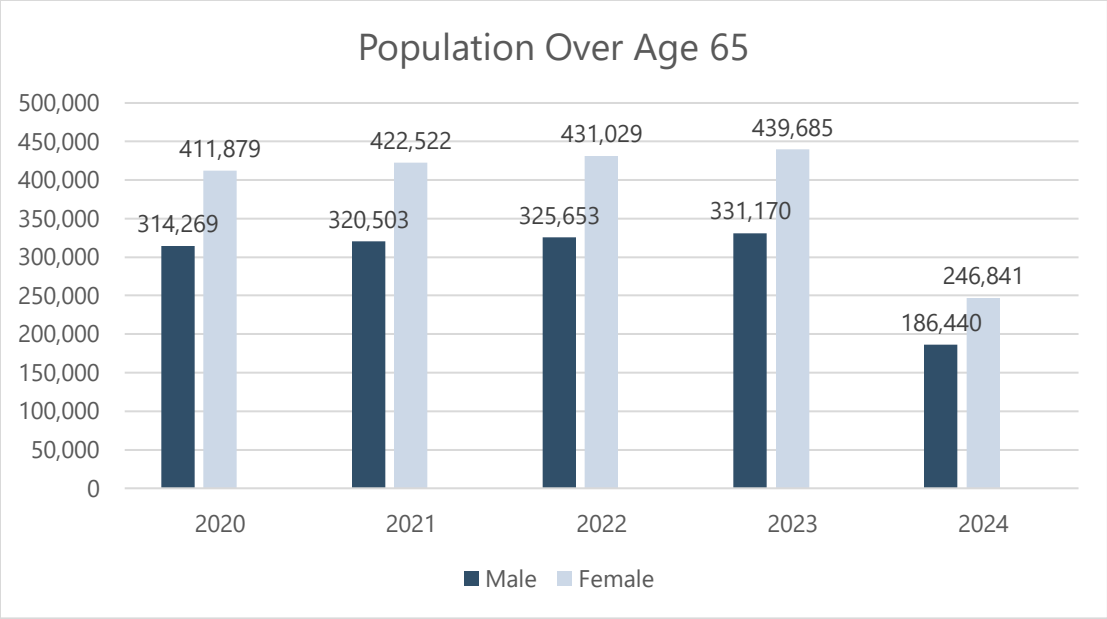


Figure 24: Population Over Age 65[92]

92

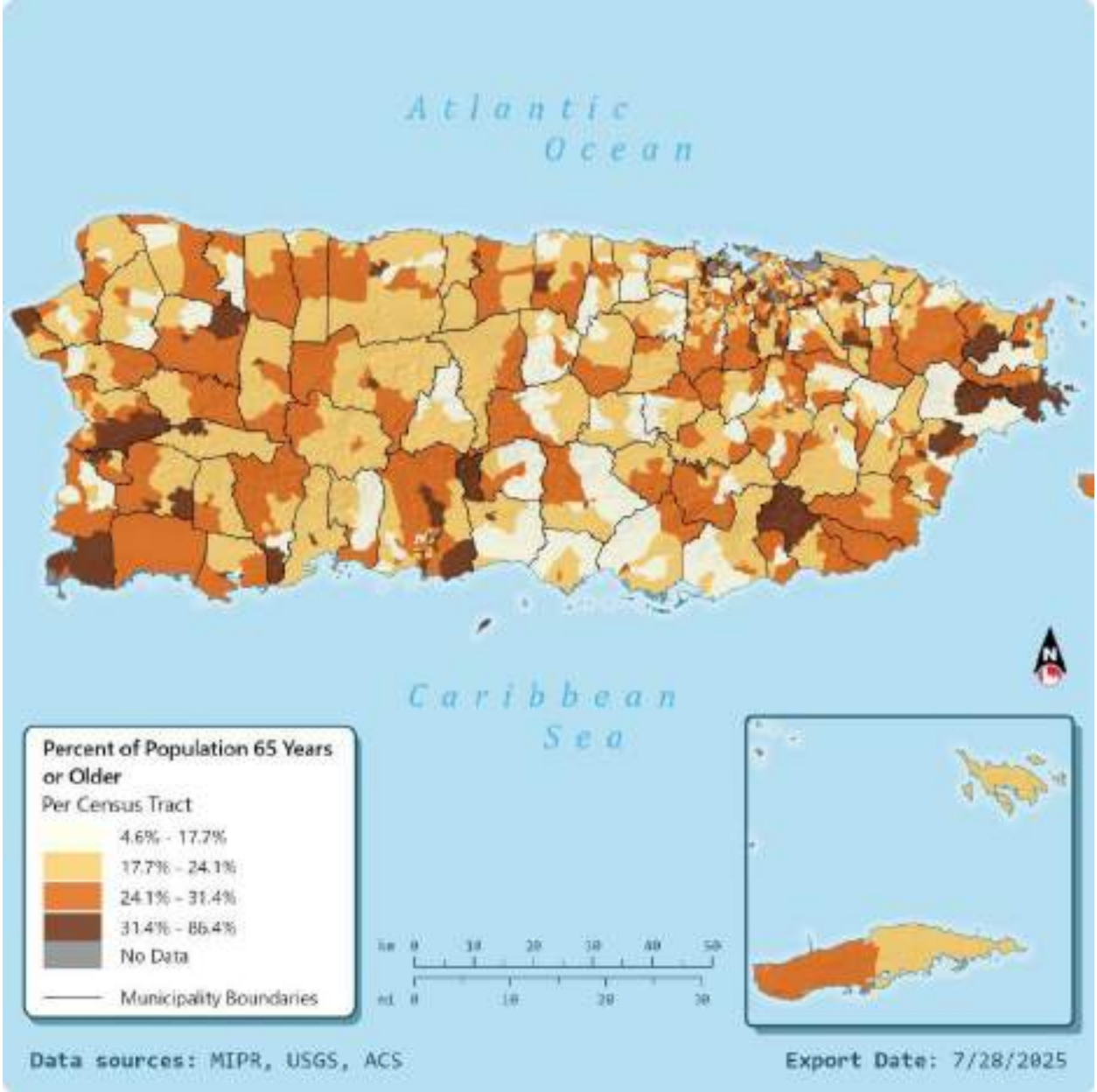


Figure 25: Population Over the Age of 65, 2020–2024[93]

Race and Ethnicity

Race is determined by self-identification in census surveys, where individuals choose the race that they feel represents them. The Other races category includes Asians, Native Hawaiian or Other Pacific Islander, and write-in responses like "multiracial" and "mixed."[94] Ethnicity is classified as either Hispanic or Latino, and

[93] U.S. Census Bureau, "Puerto Rico Commonwealth Population by Characteristics: 2020–2024," https://www.census.gov/data/tables/time-series/demo/popest/2020s-detail-puerto-rico.html.
[94] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.

non-Hispanic or Latino. The federal government treats race and ethnicity as distinct; Hispanics and Latinos can belong to any race.

Disparities in health, exposure to pollution, and vulnerability to natural disasters are closely linked to race and ethnicity. Research shows that minority populations often live near hazardous facilities and face higher pollution rates. They typically have limited access to parks, nutritious food, and stable housing, making them more susceptible to disasters and extreme heat due to barriers like language and community isolation.

Table 10 displays race and ethnicity statistics for Puerto Rico.

Table 10: Race and Ethnicity, Puerto Rico

Race and Ethnicity	Population	Percent of Total
White Alone	1,146,311	35.2
All Other Races	2,108,574	64.8
Black or African American	237,762	7.3
American Indian	5,598	0.2
Other Races	1,865,214	57.3
Hispanic Ethnicity	3,215,824	98.8
Non-Hispanic Ethnicity	39,061	1.2

Puerto Rico's foreign-born population has also declined in recent American Community Survey (ACS) estimates. Individuals who are not U.S. citizens at birth are considered part of the foreign-born population. This includes those who have gained U.S. citizenship through naturalization, lawful permanent residents, temporary migrants (such as foreign students), humanitarian migrants (refugees and asylees), and other migrants. Areas where a higher percentage of foreign residents are born are visible in Figure 26.

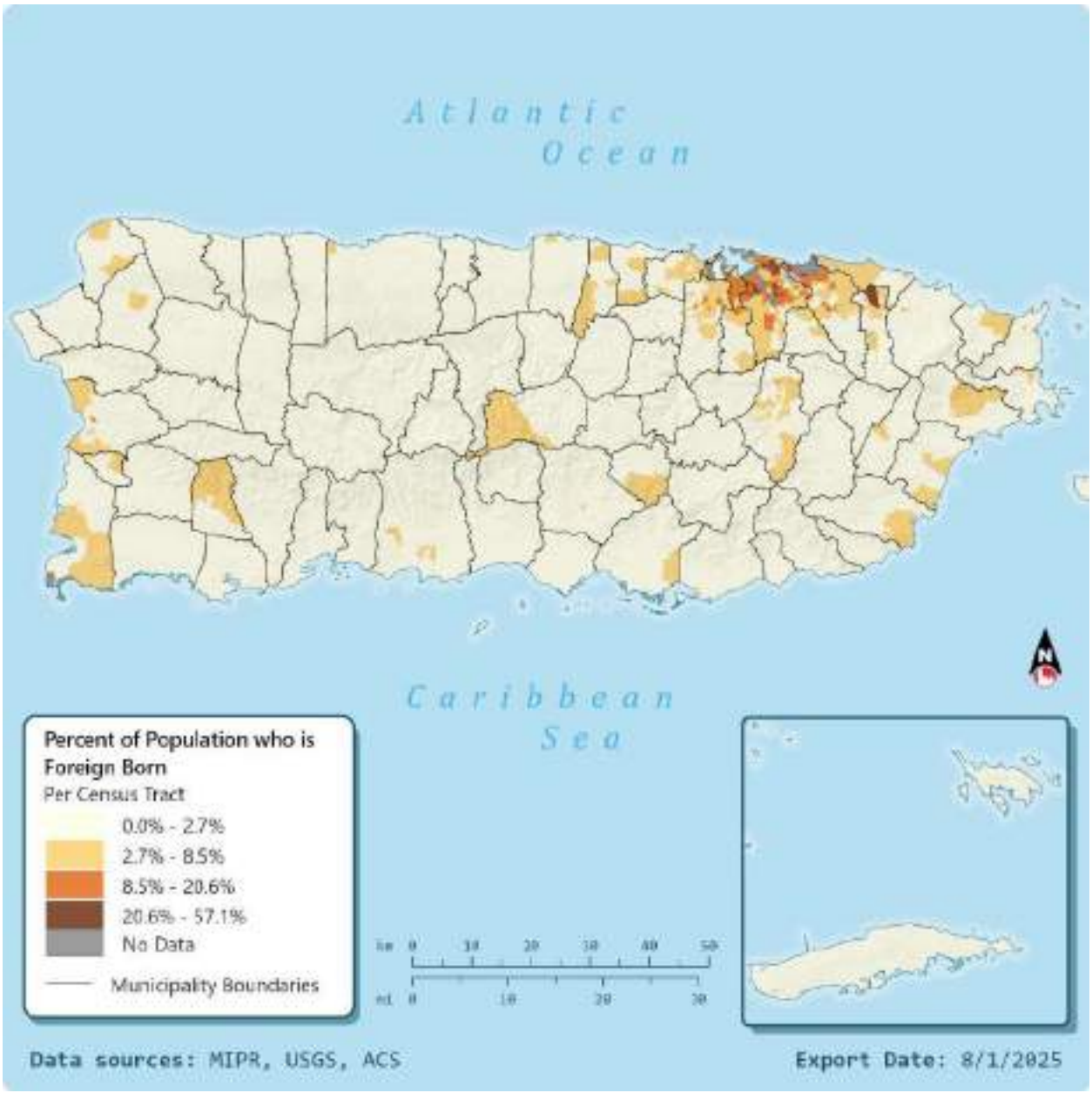


Figure 26: Percent of Foreign Born Population

Language

Puerto Rico's history as a Spanish colony and later a U.S. territory has shaped its unique language. The island's first inhabitants, the Taíno Indians, established communication systems that transformed with the arrival of Spanish settlers. Despite attempts to suppress the Taíno language during centuries of Spanish rule, elements of it persist in Puerto Rico Spanish, blending with influences from the African languages introduced by enslaved Africans.

The Spanish-American War marked a second wave of colonization, leading to substantial changes in the island's linguistic landscape. The United States initially established English as the official language and medium of instruction. Still, after resistance from the Puerto Rican people, Spanish became the primary language of instruction, with English taught as a required subject. Today, both Spanish and English are official languages in Puerto Rico.[95]

The total population of Puerto Ricans over the age of 5 who speak English "not well" is 1,874,158, or 59.5%.[96] This is also visualized in Figure 27. Limited English-speaking ability is notable in many of the interior municipalities.

[95] Library of Congress, "Yo Soy (I am): The Historical Trajectory of Language in Puerto Rico," https://guides.loc.gov/language-in-puerto-rico.
[96] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.

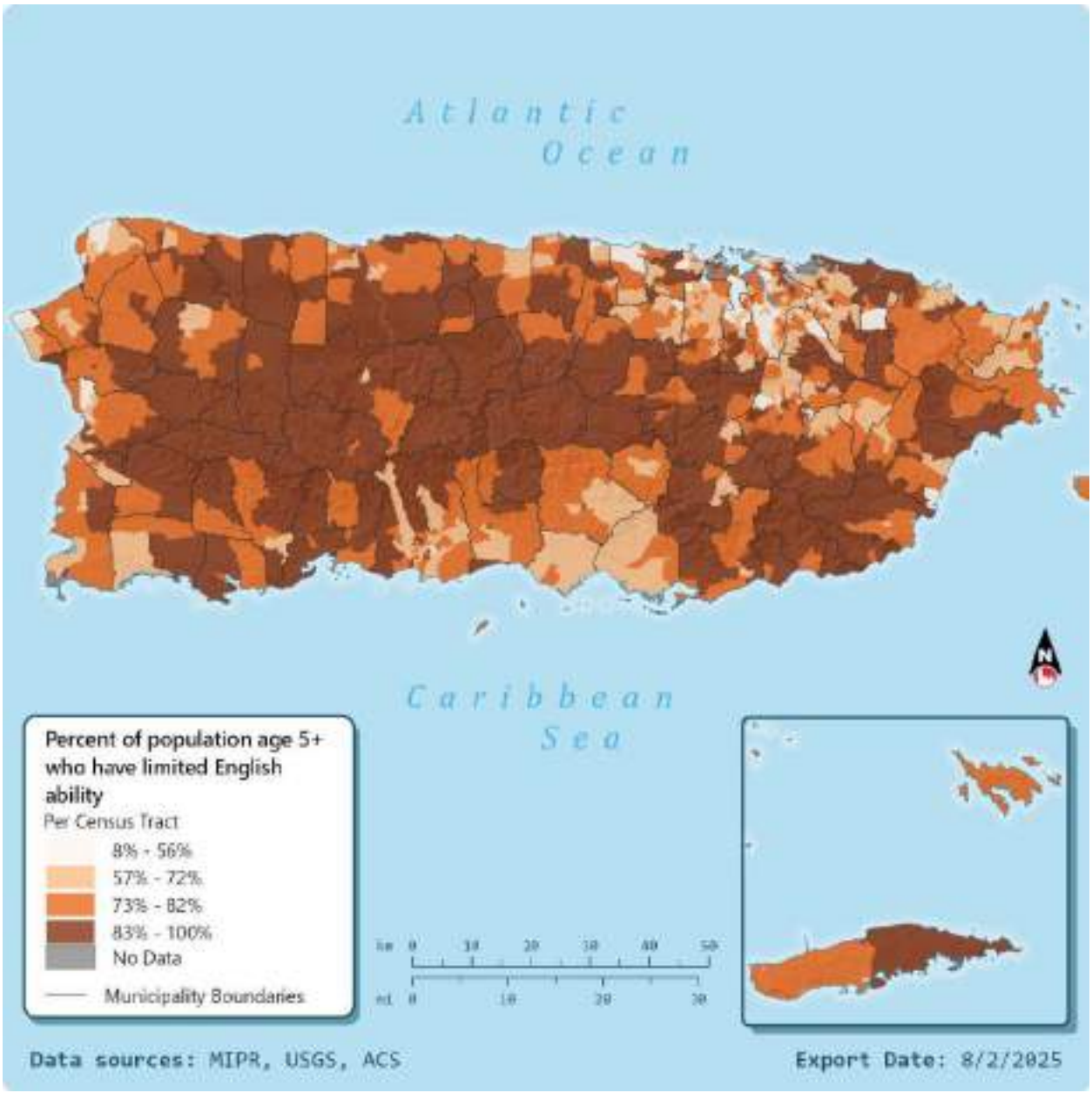


Figure 27: Percent of Population Who Have Limited English Language Ability

Education

The education system in Puerto Rico is modeled after the American school system, with Spanish as the primary language of instruction in public schools. Education is mandatory for children ages 5 to 18, with the first six grades completed in primary school.

Secondary schooling consists of the remaining six years of the pre-tertiary education program. Vocational and adult education are mainly provided by private organizations, offering various programs in larger urban areas.

Puerto Rico also has a diverse selection of post-secondary colleges and universities. Some of these institutions are state-controlled, while others are privately owned. The oldest public college in Puerto Rico is the University of Puerto Rico, established in 1906 in Río Piedras, San Juan.[97]

The U.S. Census reports a total school enrollment population of 62.1% for those in kindergarten to 12th grade in Puerto Rico, which is below the mainland U.S. enrollment population of 67.8%. In addition, 30.8% of Puerto Ricans have attained a bachelor's degree or higher, compared with 36.2% of the mainland U.S. population.[98]

The detailed educational attainment statistics for those 25 and over in Puerto Rico are shown in Figure 28. Furthermore, Figure 29 shows the spatial distribution of the percentage of those age 25 and over whose highest level of education completed is less than high school.

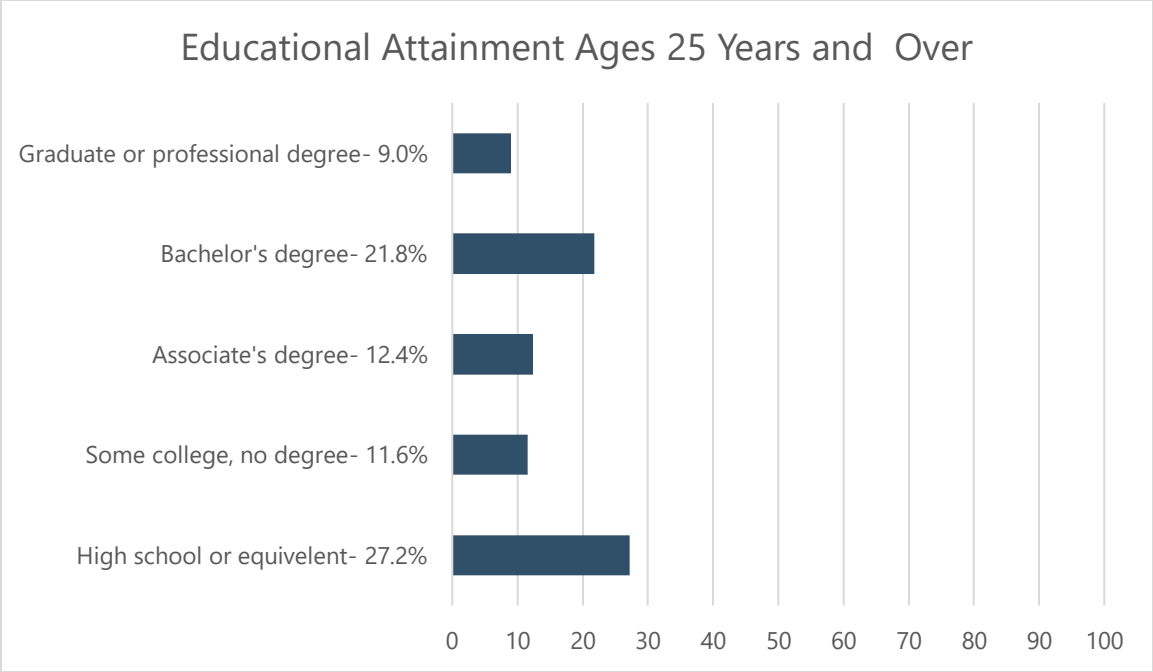


Figure 28: Education Attainment in Puerto Rico

In Puerto Rico, educational attainment reflects a diverse range of qualifications among its residents. The statistics indicate that 9% of the population holds a graduate or professional degree, while 21.8% have earned a bachelor's degree. Additionally, 12.4% hold an associate's degree, and 11.6% have completed some college coursework without earning a degree. The proportion of individuals with a high school diploma or equivalent stands at 27.2%. Overall, these figures illustrate a significant portion of the population with varying levels of education, highlighting both achievements and opportunities for further educational development.

[97] Scholaro Database, "Education System in Puerto Rico," https://www.scholaro.com/db/countries/puerto-rico/education-system.
[98] U.S. Census Bureau, "Puerto Rico," https://data.census.gov/profile/Puerto_Rico?g=040XX00US72.

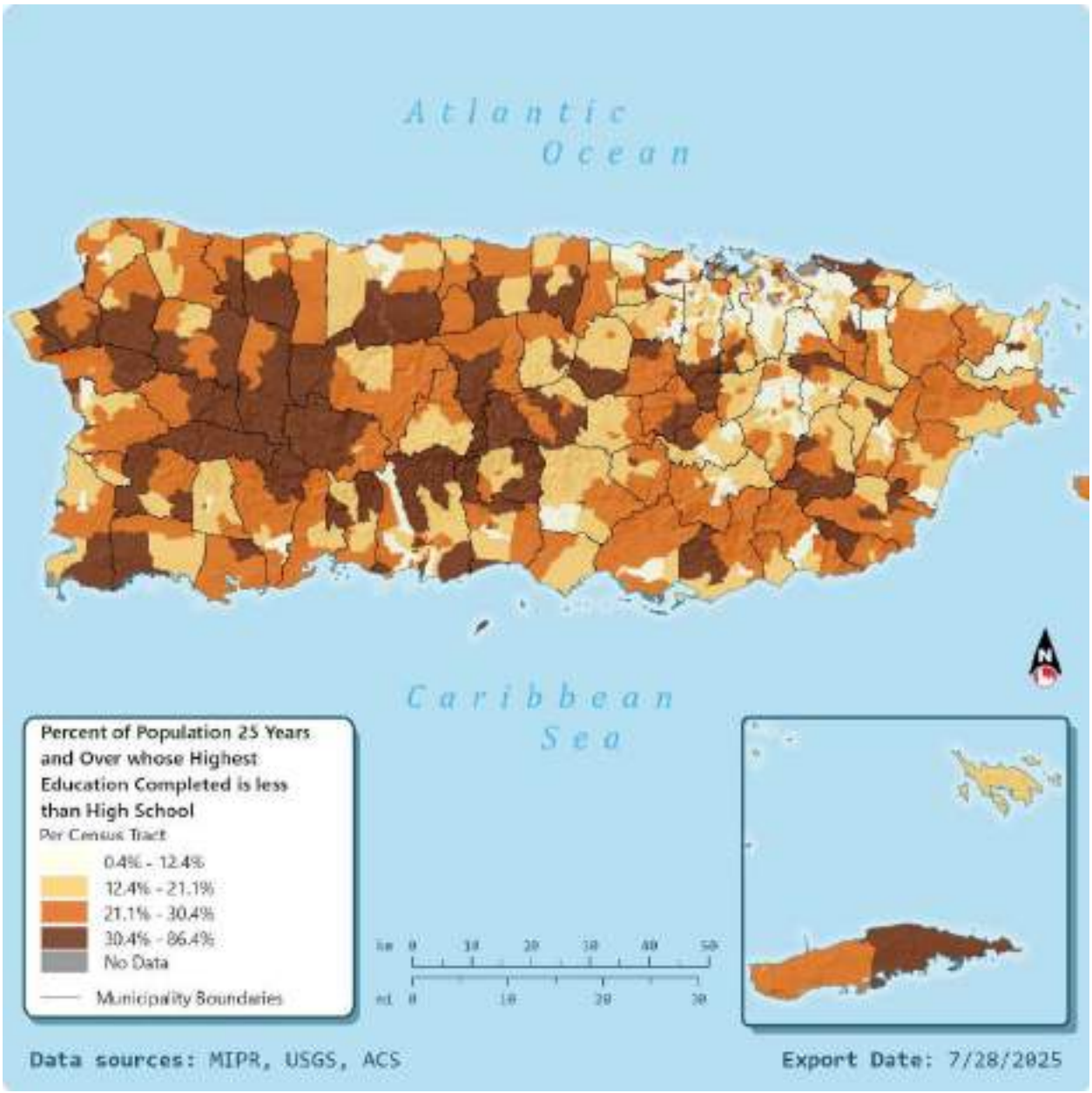


Figure 29: Percent of Population with less than High School Education

School enrollment data shows a varied distribution of students over the age of 3 across different education levels. Approximately 62% of the population is enrolled in kindergarten through 12th grade.

In addition, about 4% of children attend nursery or preschool. In higher education, roughly 27% of the population is enrolled in undergraduate programs, while around 6% of people are in graduate or professional school. Detailed statistics are shown in Figure 30.[99]

[99] U.S. Census Bureau, "Puerto Rico," https://data.census.gov/profile/Puerto_Rico?g=040XX00US72.

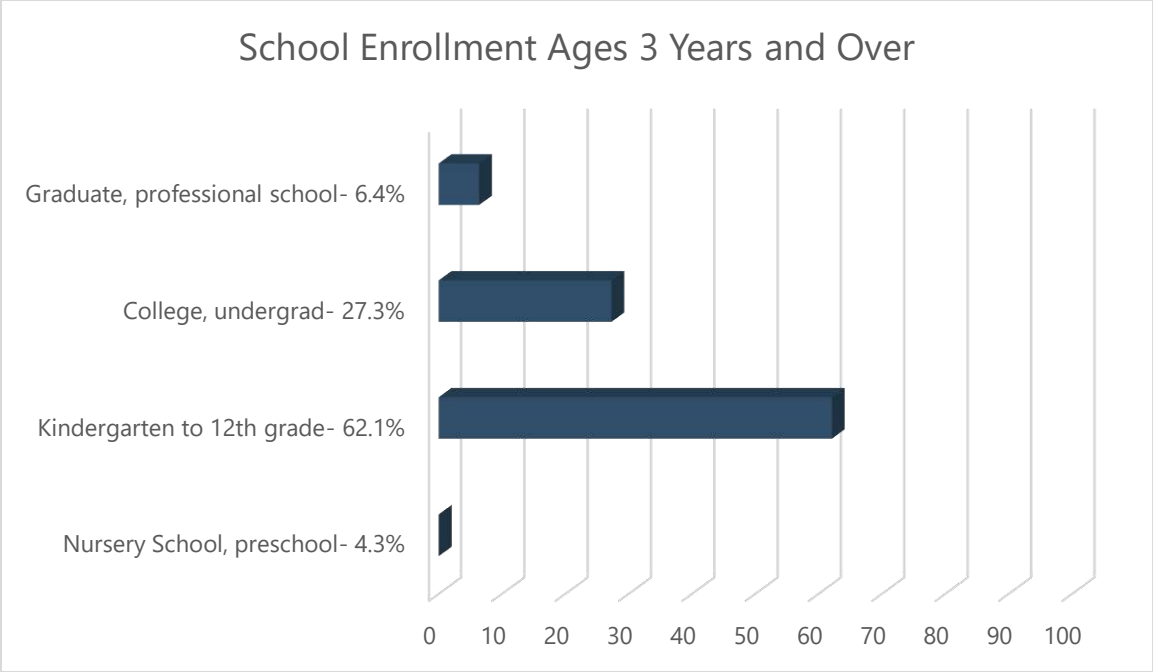


Figure 30: School Enrollment Over the Age of Three in Puerto Rico

A recent report revealed that since 2007, 673 schools in Puerto Rico had closed, representing approximately 44% of the island's schools. In addition, a survey conducted by the nonprofit organization El Puente found that 470 of the closed school buildings are now abandoned in various communities. The government intends to sell the school buildings to generate revenue for the county's public debt. Some are currently being used to shelter the unhoused.[100]

Income and Poverty

Puerto Rico's median household income was $25,621. Median income levels varied by household type, reaching $32,091 for families, $42,665 for married-couple families, and $15,409 for non-family households. Figure 31 displays the median household income by census tract for Puerto Rico. This shows that higher median incomes are concentrated in smaller areas, particularly in the northwest.

[100] Refinery29, "Why are so Many Puerto Rico Public Schools in Disrepair?" https://www.refinery29.com/en-us/2024/04/11707238/puerto-rico-students-tiktok-videos-public-schools#:~:text=A%20recent%20report%20found%20that,sentenced%20to%20prison%20for%20corruption.

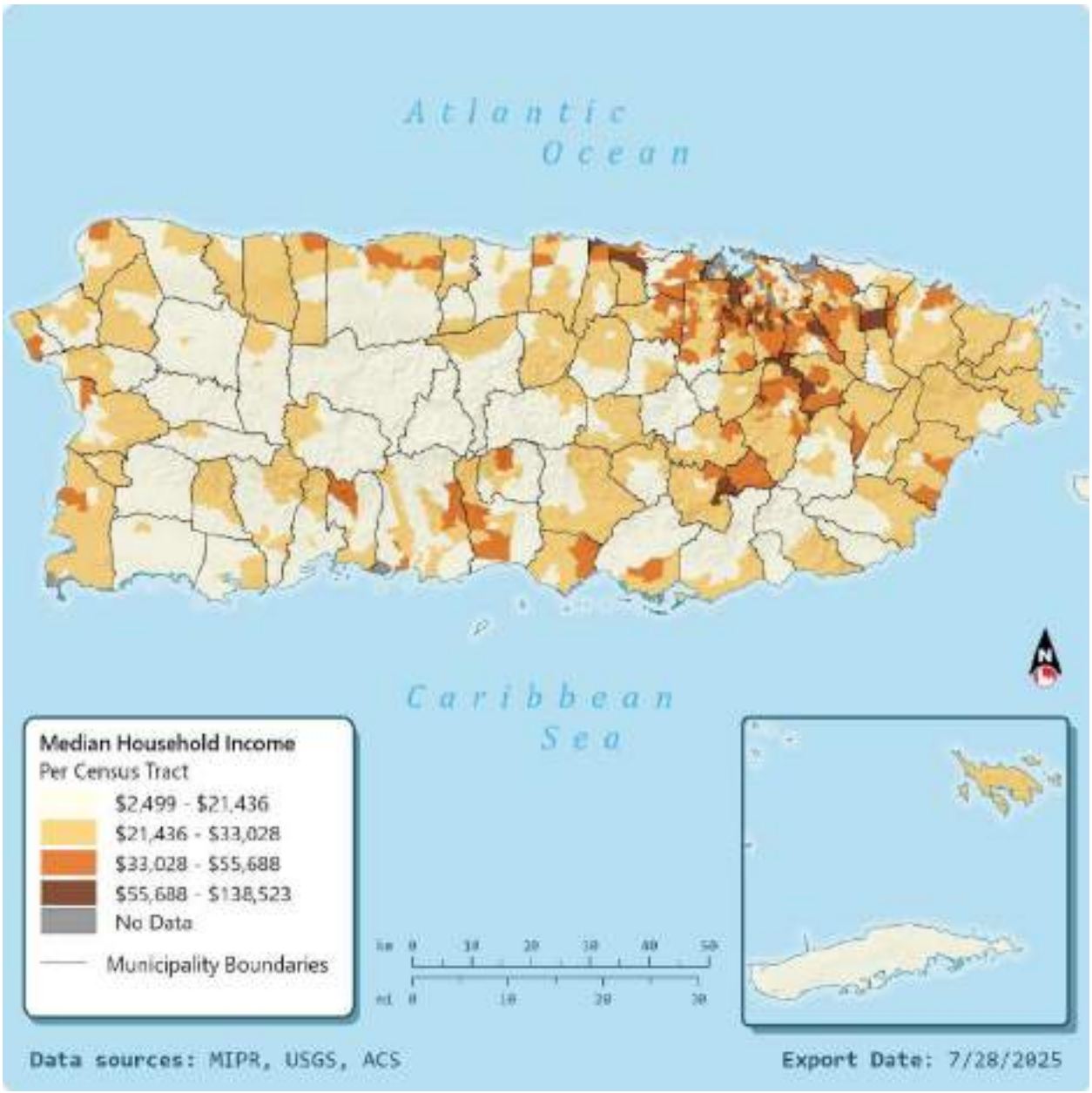


Figure 31: Median Household Income

The employment rate in Puerto Rico in 2023 was 42.7% compared with 60.6% on the mainland.[101] Workers by class are displayed in Figure 32.[102]

[101] Filantropía Puerto Rico, "Puerto Rico Social Indicators" Puerto Rico Social Indicators - Filantropia Puerto Rico
[102] U.S. Census Bureau, "Puerto Rico," https://data.census.gov/profile/Puerto_Rico?g=040XX00US72#employment.

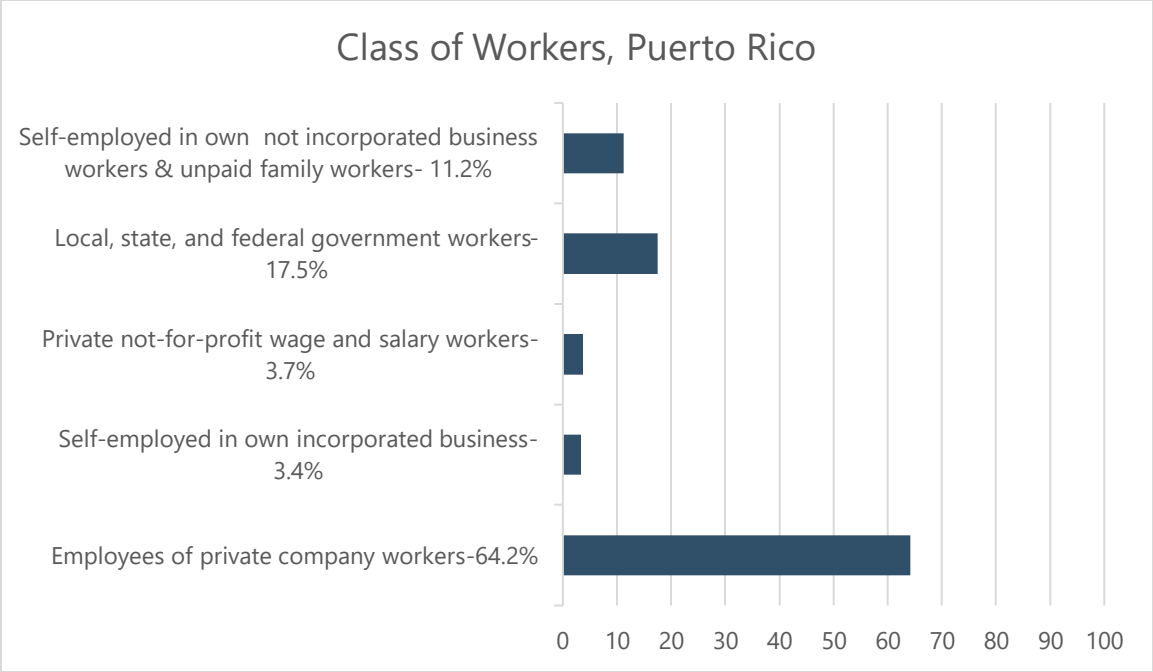


Figure 32: Classes of Workers, Puerto Rico

The population between the ages of 16 and 24 was 2,047,528. Out of this group, 890,174 individuals did not participate in the workforce, representing 43.5 percent of the population in this age range. This highlights a significant portion of young people who were not engaged in employment during the reporting period.

Poverty statistics reveal the number of people living in poverty, deep poverty, and seniors aged 65 and older who are affected by poverty. Poverty statistics exclude people in institutions, military housing, college dorms, or homes with unrelated people under 15 years old. The total population in Puerto Rico for whom poverty status is determined is 3,226,312.[103]

The Census Bureau defines poverty based on income levels that vary by family size. A person or family is considered "below the poverty level" if their income is less than this amount. The Administration for Children and Families, Office of Community Services, Division of Energy Assistance, has developed a method to adjust the U.S. Department of Health and Human Services poverty guidelines for use in the Commonwealth of Puerto Rico when determining income eligibility for the Low-Income Home Energy Assistance Program. This method uses median income data from the ACS and the Puerto Rico Community Survey to modify the federal poverty guidelines applicable to the continental United States. These adjusted figures are based on the most recent estimate of median income for a four-person family in Puerto Rico.[104]

[103] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.
[104] The Administration for Children and Families, "LIHEAP IM 2024-02 Federal Poverty Guidelines for Puerto Rico," https://acf.gov/sites/default/files/documents/ocs/COMM_LIHEAP_IM%202024-02_Att3FPGTable_PR.pdf.

The Federal Poverty Guidelines for Puerto Rico for fiscal year 2025 are displayed in Table 11.[105] The percentage of population below poverty level by census tract is shown in Figure 33. The areas of higher percentage of poverty aligns with areas of lower median household income shown in Figure 31.

Table 11: Federal Poverty Guidelines for Puerto Rico

Household Size	100% Poverty Guidelines	110% Poverty Guidelines	150% Poverty Guidelines
1	$5,872	$6,460	$8,808
2	$7,499	$8,249	$11,248
3	$9,126	$10,039	$13,689
4	$10,753	$11,829	$16,129
5	$12,380	$13,618	$18,570
6	$14,007	$15,408	$21,010
7	$15,634	$17,198	$23,451
8	$17,261	$18,988	$25,891
9	$18,888	$20,777	$28,332
10	$20,515	$22,567	$30,772
11	$22,142	$24,357	$33,213
12	$23,769	$26,146	$35,653

[105] The Administration for Children and Families, "LIHEAP IM 2024-02 Federal Poverty Guidelines for Puerto Rico," https://acf.gov/sites/default/files/documents/ocs/COMM_LIHEAP_IM%202024-02_Att3FPGTable_PR.pdf.

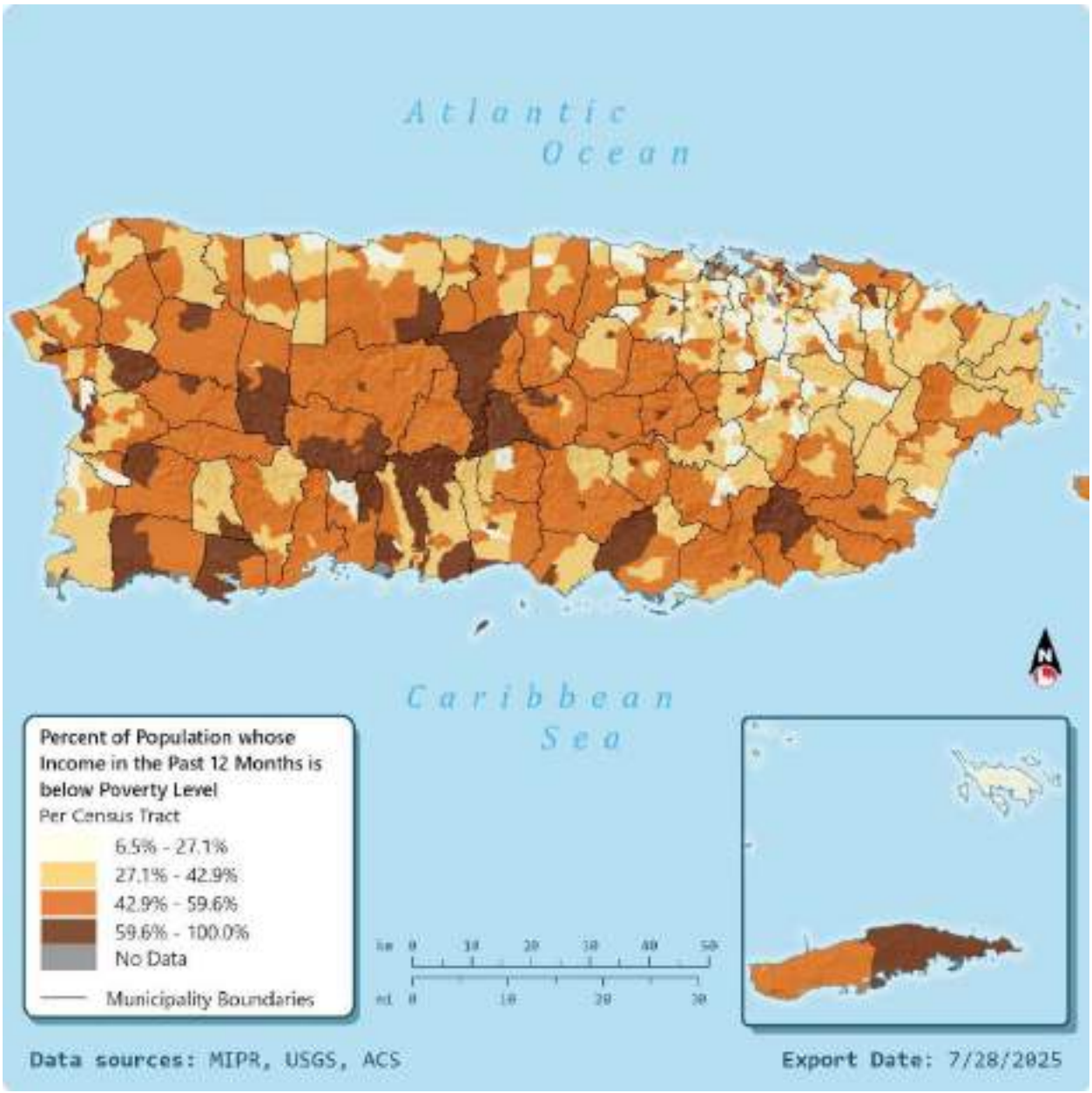


Figure 33: Percent of Population Below Poverty Level

Low income is closely linked to poor health and difficulties in recovering from disruptions, such as extreme weather and environmental problems. During natural disasters, low-income individuals are especially vulnerable because of inadequate housing, limited evacuation options, and increased emotional stress. They are more likely to live or work near environmental hazards and face greater future risks to natural hazards. The link between low income and poor health is particularly strong among the poorest, with even small increases in income leading to significant health benefits.

Income inequality in communities exacerbates health disparities. People in low-income neighborhoods tend to suffer from worse physical and mental health problems, like asthma and depression. They also face higher rates of preventable hospitalizations due to poor access to primary healthcare. They are less likely to have

health insurance, which worsens health outcomes linked to environmental risks.[106] Table 12 provides statistics on people in Puerto Rico living in poverty, deep poverty, and those over 65 living in poverty. Deep poverty is defined as that of those whose total cash income is below 50% of the poverty threshold.[107]

Table 12: Poverty Data[108]

Poverty Data	Population	Percentage
People in Poverty	1,340,637	41.6
People in Deep Poverty	683,535	21.2
Both in Poverty and Over 65	286,478	8.9
Families in Poverty	304,614	38.2
Families with Children in Poverty	156,587	19.6
Single-Mother Families in Poverty	100,278	12.6
Households Receiving Supplemental Social Security Income	5,372	0.4
Households Receiving Cash Public Assistance Income	51,370	4.1
Households Receiving Nutrition Assistance Program	580,584	46.8

Persons with Disabilities

Puerto Rico defines disability as a condition that substantially limits an individual's ability to perform one or more major daily living activities. This definition applies to individuals with a history of the condition or those who are considered to have a disability, even if they do not currently exhibit it. Disabilities can be physical, mental, or sensory in nature. A sensory disability significantly impacts one or more of the senses, including hearing, sight, touch, smell, or speech. In addition, morbid obesity is defined as a condition where a person's weight exceeds their health and recommended weight by 100% according to general medical standards.[109]

Forty-two percent of adults in Puerto Rico have a disability.[110] The total population of non-institutionalized Puerto Ricans who are diagnosed with a disability is 734,989. Figure 34 shows the percentage of population with a disability grouped by census tract.

[106] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.
[107] Center for Poverty & Inequality, "What is Deep Poverty?" https://poverty.ucdavis.edu/faq/what-deep-poverty.
[108] Headwaters Economics, "Puerto Rico." https://headwaterseconomics.org/tools/populations-at-risk/.
[109] Justia U.S. Law, "2024 Laws of Puerto Rico Title One- The Commonwealth (§§ 1 — 5289) Chapter 21- Discrimination Against Disabled Persons Prohibited (§§ 501 — 511b) § 501 – Definitions," https://law.justia.com/codes/puerto-rico/title-one/chapter-21/501/#:~:text=%E2%80%94%20Shall%20mean%20any%20person%20with,with%20or%20without%20reasonable%20accommodation.
[110] Filantropía Puerto Rico, "Data Facts for Systemic Change," https://filantropiapr.org/data-facts-for-systemic-change/#:~:text=Homeless%20Population%3A%20Recent%202024%20data,homeless%20individuals%20in%20Puerto

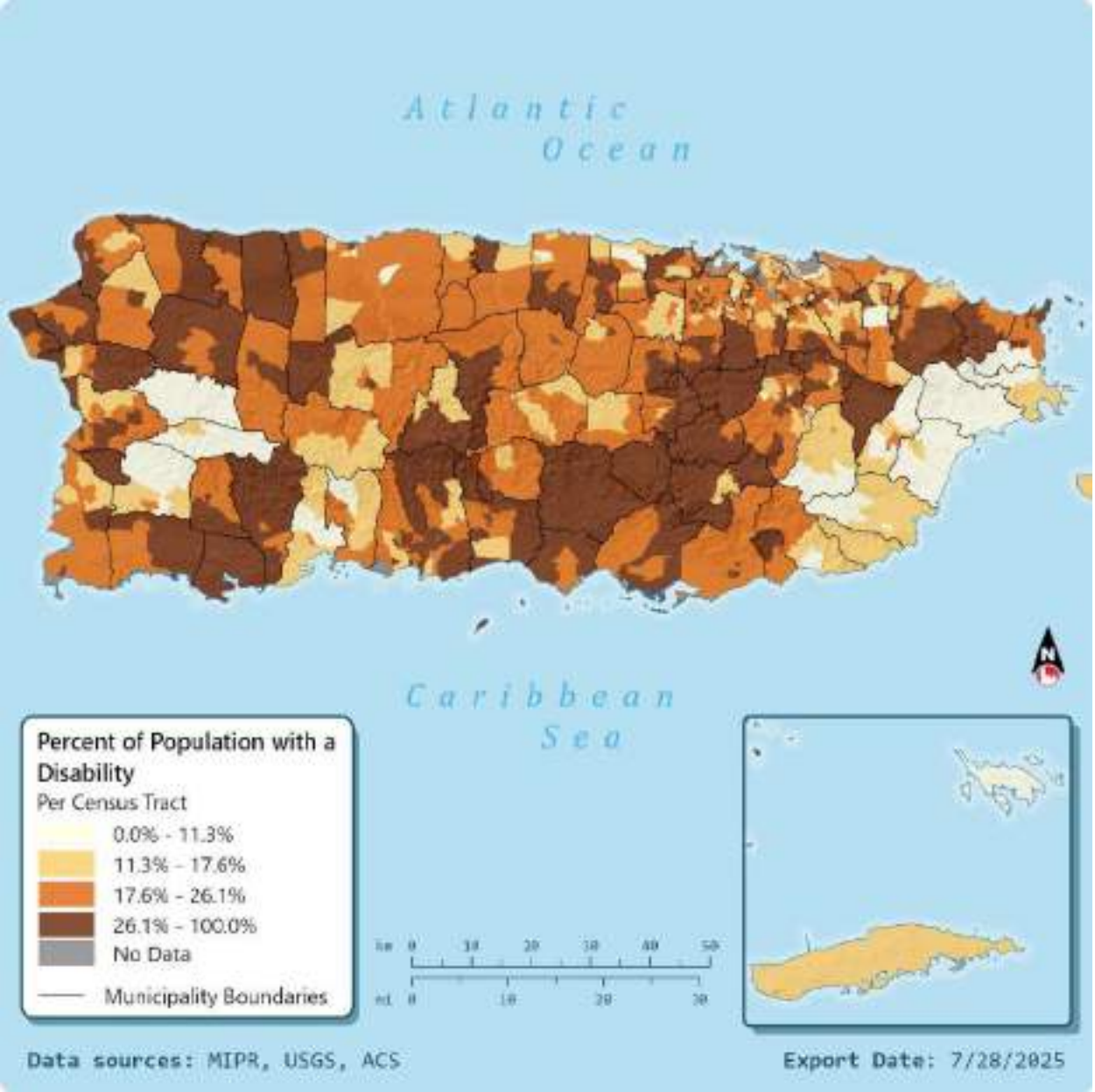


Figure 34: Percent of Population with a Disability[111]

Disabled people are less likely to have health insurance due to factors, such as limited employment opportunities, lower incomes, systemic discrimination, and lack of awareness about available options, making them more vulnerable than their non-disabled counterparts. The challenges multiply for those who are confined to a bed, as they are at a heightened risk of heat-related mortality, particularly during extreme

%20Rico.&text=San%20Juan%20Homeless%20Population%3A%20The,the%20homeless%20population%20during%202024.

[111] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.

weather conditions. In addition, natural disasters can severely restrict access to medical care, worsening existing health issues, and placing individuals with disabilities in a precarious situation.

Housing

In Puerto Rico, the housing landscape is diverse, comprising a wide range of residential types. The most prevalent housing type is single-family detached homes, which number approximately 1,268,421. Multi-family homes are also significant, including duplexes, triplexes, and quadplexes, totaling 88,647 units. There are 68,531 multi-family dwellings with 5-9 units, as well as 79,782 units in the 10-49 category. High-rise buildings with 50 or more units account for 66,549 residences. Additionally, there are 4,100 mobile homes and 75 unconventional living arrangements, including boats, RVs, and vans. Overall, Puerto Rico has a total of 1,575,105 housing units, reflecting a diverse residential environment that accommodates various living preferences.[112]

The interplay of natural disasters, economic decline, and policy failures has led to extensive property abandonment. Currently, Puerto Rico has the highest number of vacant properties in the United States, with nearly 30% of housing units either abandoned or off the market.

Puerto Rico's housing crisis is rooted in a mixture of long-standing displacement and property challenges. An extensive barrier to recovery is that many Puerto Ricans lack formal deeds, often due to generational land subdivisions and verbal agreements that were never officially recorded. This has resulted in many being denied disaster relief aid, making it difficult to rebuild and worsening housing instability. This instability is reflected in the housing unit change map shown in Figure 35.

[112] U.S. Census Bureau. (n.d.). Units in structure: Table B25024, American Community Survey 5-Year Estimates. U.S. Department of Commerce. Retrieved September 19, 2025, from https://data.census.gov/table/ACSDT5Y2023.B25024?q=B25024:+Units+in+Structure&g=040XX00US72

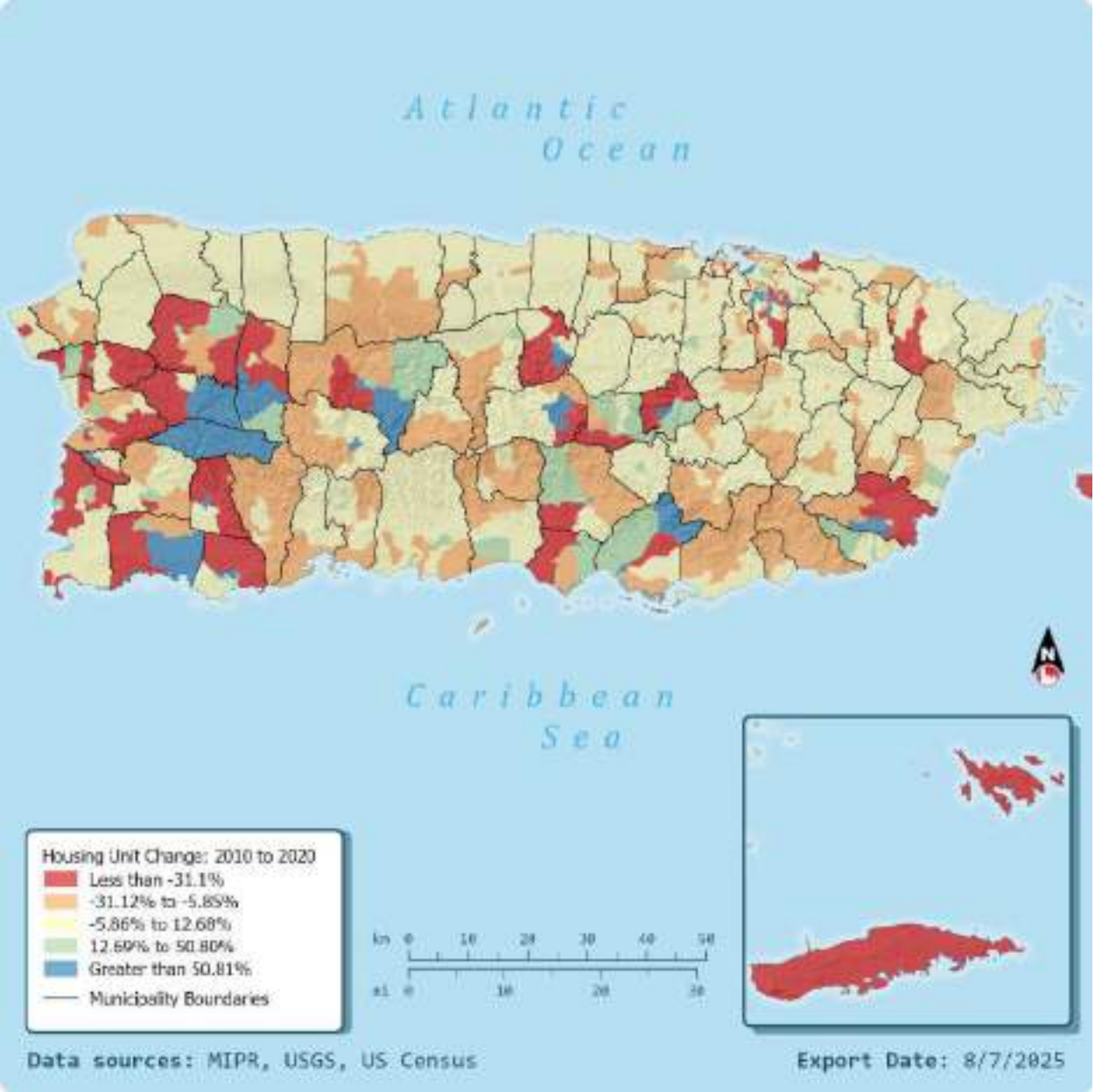


Figure 35: Housing Unit Change 2010–2020

In 2024, average home prices rose by 15%, with the typical home now costing $221,824. Newly constructed homes increased by 20%, reaching an average price of $351,407. Meanwhile, Puerto Rican families earn only 61% of the income needed to qualify for a mortgage, with a median household income at $25,621.[113]

The government defines families as "housing-cost burdened" if they spend more than 30% of their income on housing. Table 13 provides a breakdown of housing statistics for Puerto Rico. Figure 36 shows the distribution of areas where percentage of home ownership is high, whereas Figure 37 shows areas of high

[113] Reason Foundation, "Puerto Rico's Housing Crisis is no Accident—It's by Design," https://reason.org/commentary/puerto-ricos-housing-crisis-is-no-accident-its-by-design/.

numbers of renters. In addition, there are 1,293,243 total occupied housing units in Puerto Rico; 395,015 (31.9%) are rental units, and 2,410 (0.2%) are mobile homes.[114] Figure 38 is a map of mobile home density showing that the southwest corner of the state has the highest concentration of mobile homes.

Table 13: Housing Affordability, Puerto Rico, 2023[115]

	Owner-Occupied Mortgaged Homes	Renter-Occupied Homes	Cost-Burdened Households	Percentage of Cost-Burdened Households	Median Monthly Housing Costs (Mortgage/ Gross Rent)
Homeowners	316,605	-	120,141	37.9%	$974
Home Renters	-	395,015	116,038	29.4%	$579

[114] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.
[115] Headwaters Economics, "Puerto Rico," https://headwaterseconomics.org/tools/populations-at-risk/.

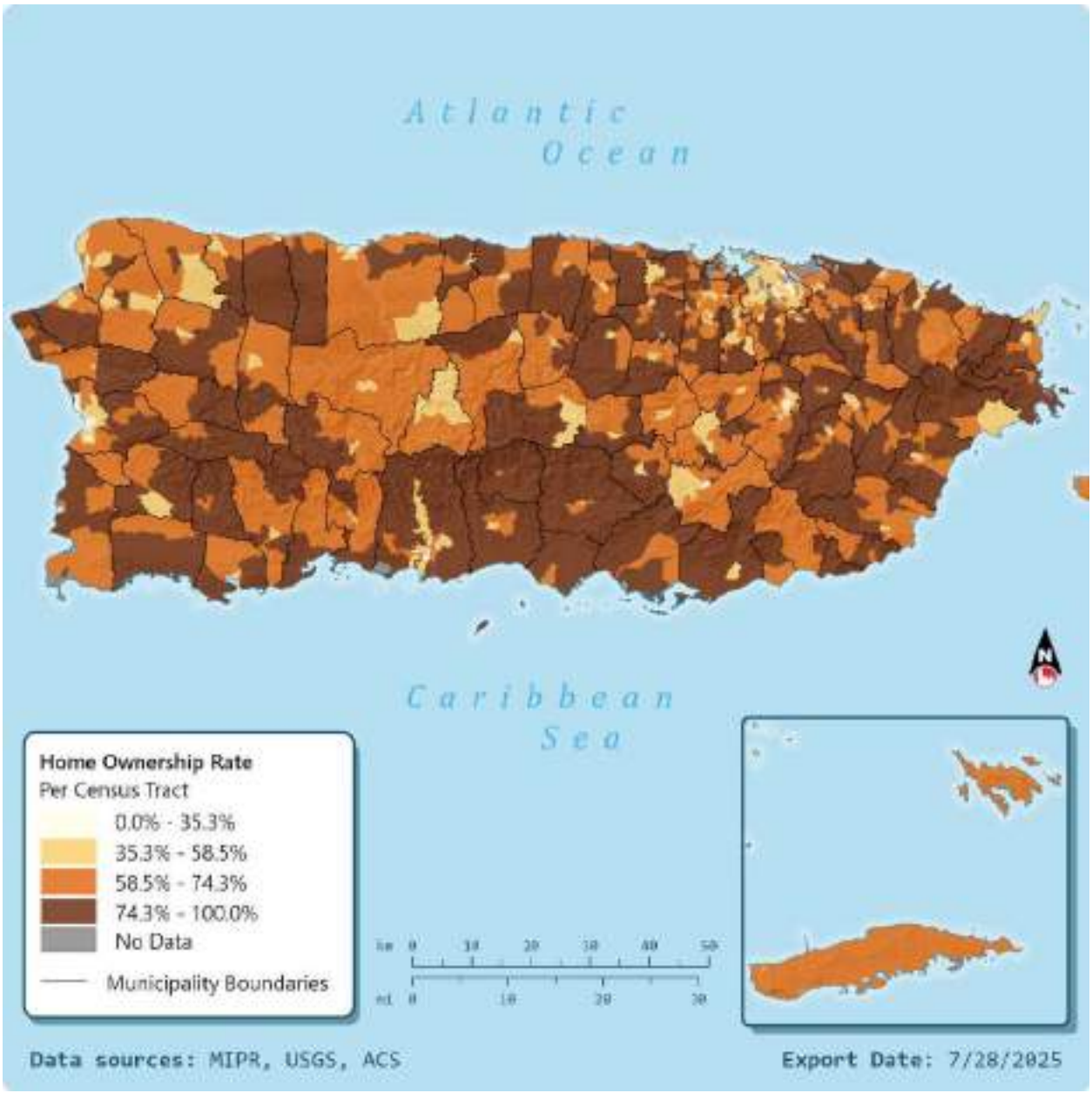


Figure 36: Home Ownership Rate

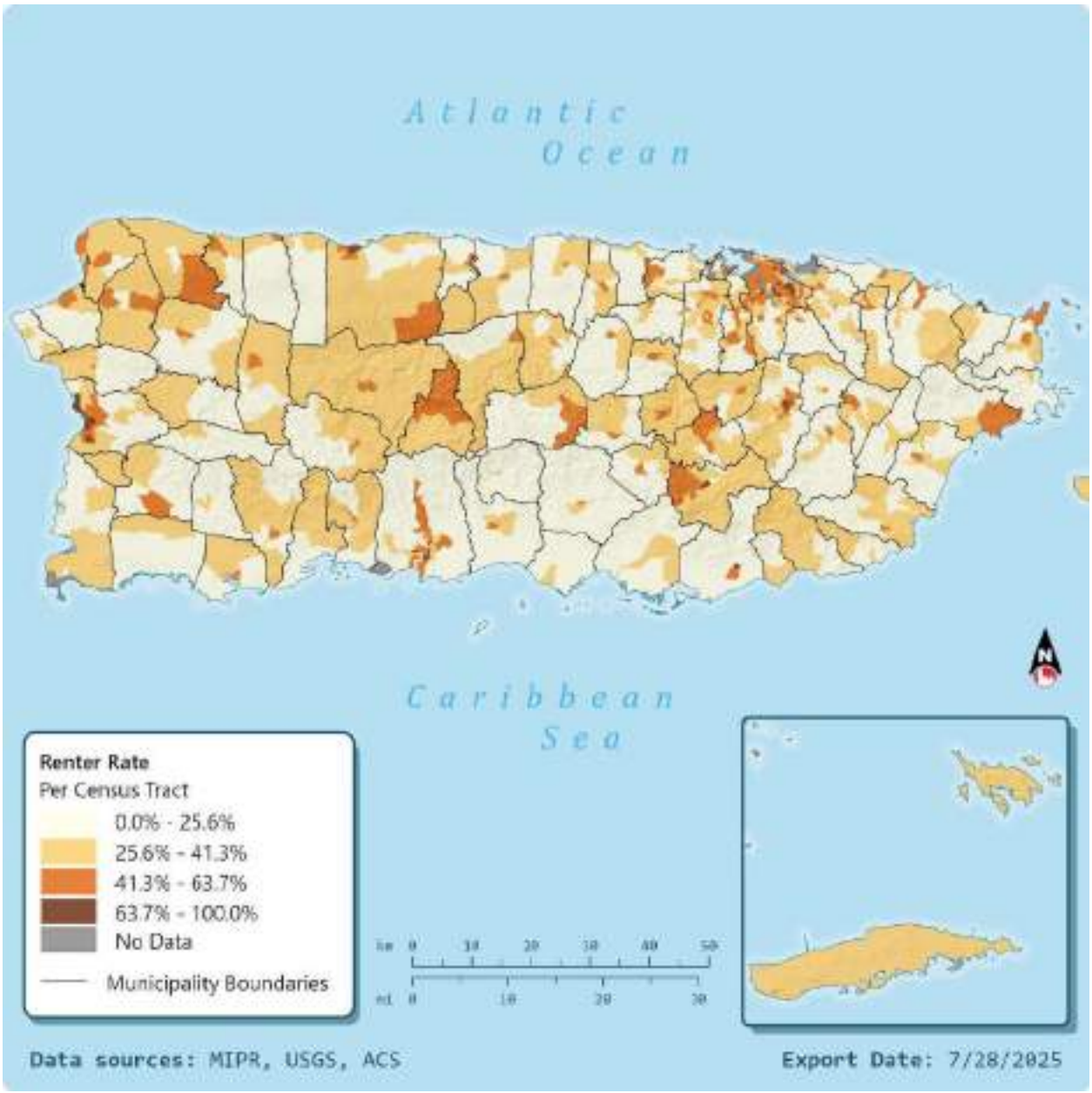


Figure 37: Renter Rate

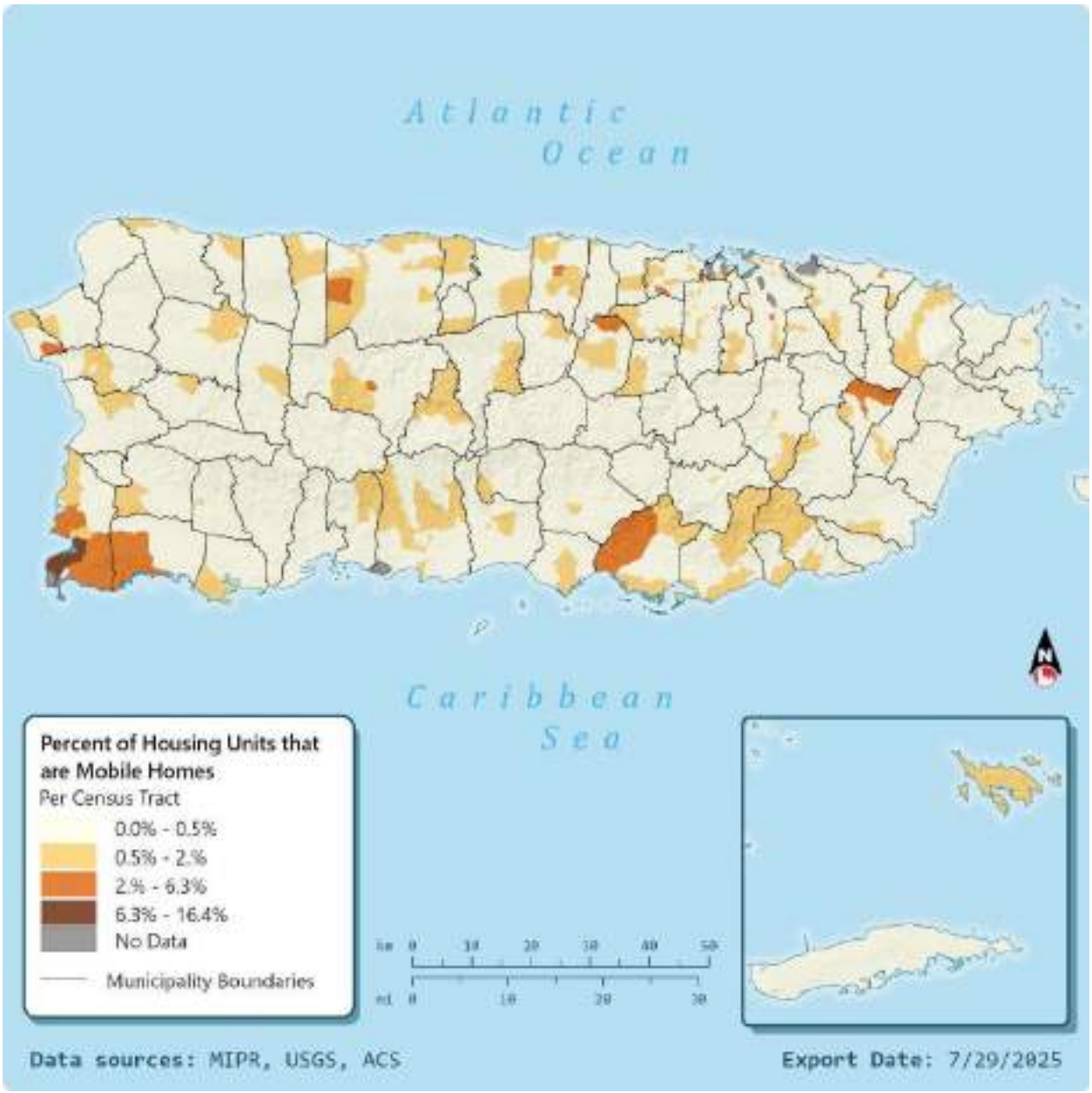


Figure 38: Percentage of Housing Units as Mobile Homes

Homelessness

According to 2024 survey data, there are 2,096 homeless individuals in Puerto Rico. The municipality of San Juan accounts for 25.8% of the homeless population. In addition, 55.8% of the participants in the survey reported facing homelessness for the first time.[116] Despite a slight decrease compared with 2022, the percentage of people experiencing homelessness for the first time has risen.

[116] Filantropía Puerto Rico, "Data Facts for Systemic Change," https://filantropiapr.org/data-facts-for-systemic-change/#:~:text=Homeless%20Population%3A%20Recent%202024%20data,homeless%20individuals%20in%20Puerto

Technology Access

Communities with more access to communication services, such as internet, telephone services, and other tools, fare better during a disaster. Availability and accessibility of hazard information promotes risk awareness and provides vital information regarding appropriate actions for maintaining personal safety during a disaster.

A "digital divide" occurs when some households have little to no connectivity to high-speed internet. For instance, 35% of the population in Puerto Rico does not have sufficient access to telecommunications, and the gaps are associated with gender, age, income level, education, and residence in rural communities.[117] Smartphones are the preferred method of accessing the internet for many Puerto Rico residents, and 95% have access to a smartphone. This is often sufficient for personal use but created limitations for business and government services.[118] The Census Bureau ACS provides information on access to technology. The percent of households that have only access to a smartphone are shown in Figure 39. Figure 40 shows the distribution of households without access to computers or similar technology. Higher concentrations of households with limited computer access are visible in the west and south areas of the island. Households without internet access are displayed in Figure 41, which shows higher percentages in the western area of the island.

%20Rico.&text=San%20Juan%20Homeless%20Population%3A%20The,the%20homeless%20population%20during%202024.

[117] "Digital gap amount 55+, 65+ population in Puerto Rico persists, SME study shows," 2021, https://newsismybusiness.com/digital-gap-among-55-65-population-in-puerto-rico-persists-sme-study-shows/.

[118] Puerto Rico Report, "U.S Treasury to Invest $158 Million in Puerto Rico Broadband," 2023, https://puertoricoreport.com/u-s-treasury-to-invest-158-in-puerto-rico-broadband/.

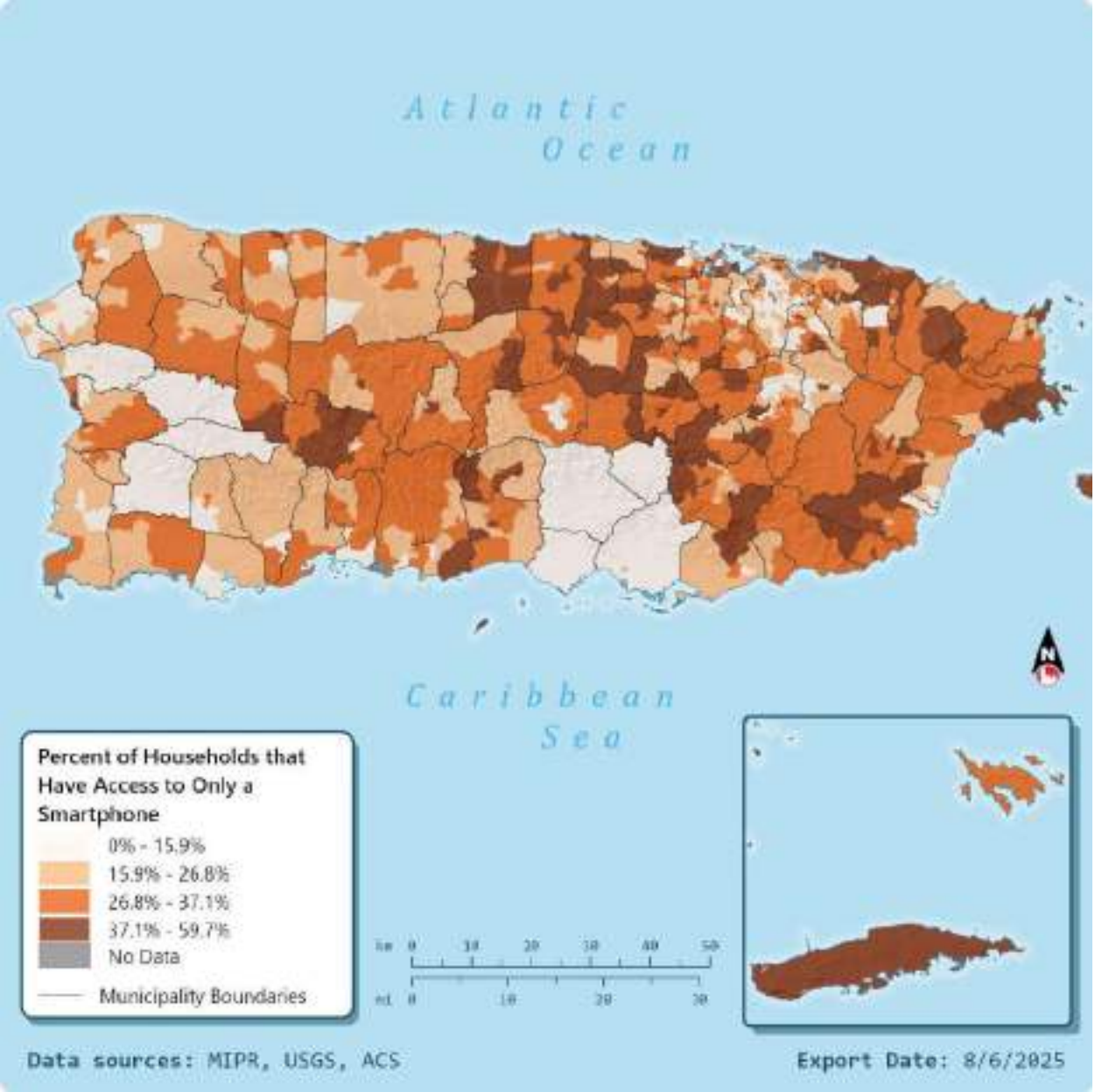


Figure 39: Households with Only Smartphone Access

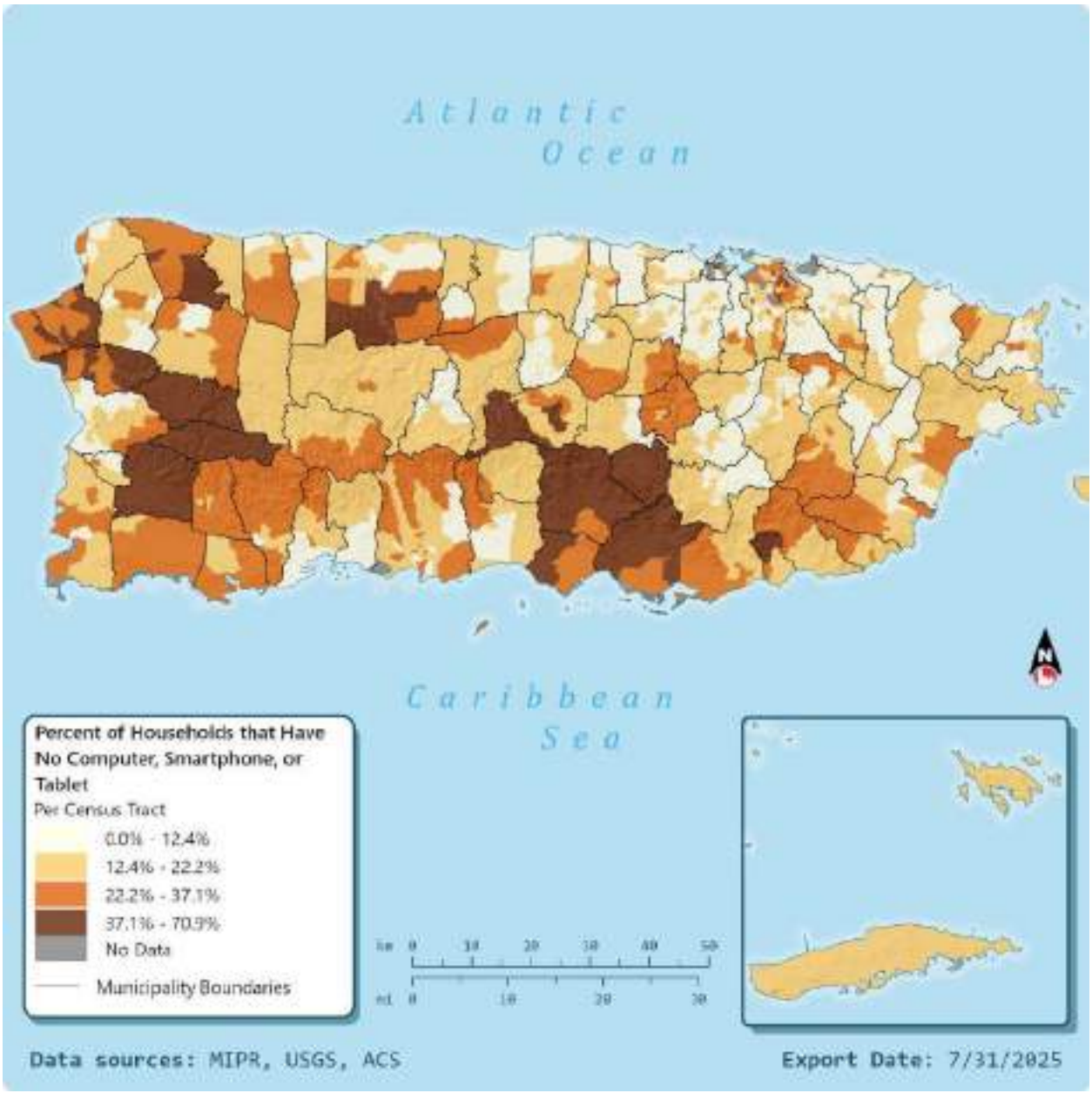


Figure 40: Puerto Rico Households with No Computer, Smartphone, or Tablet

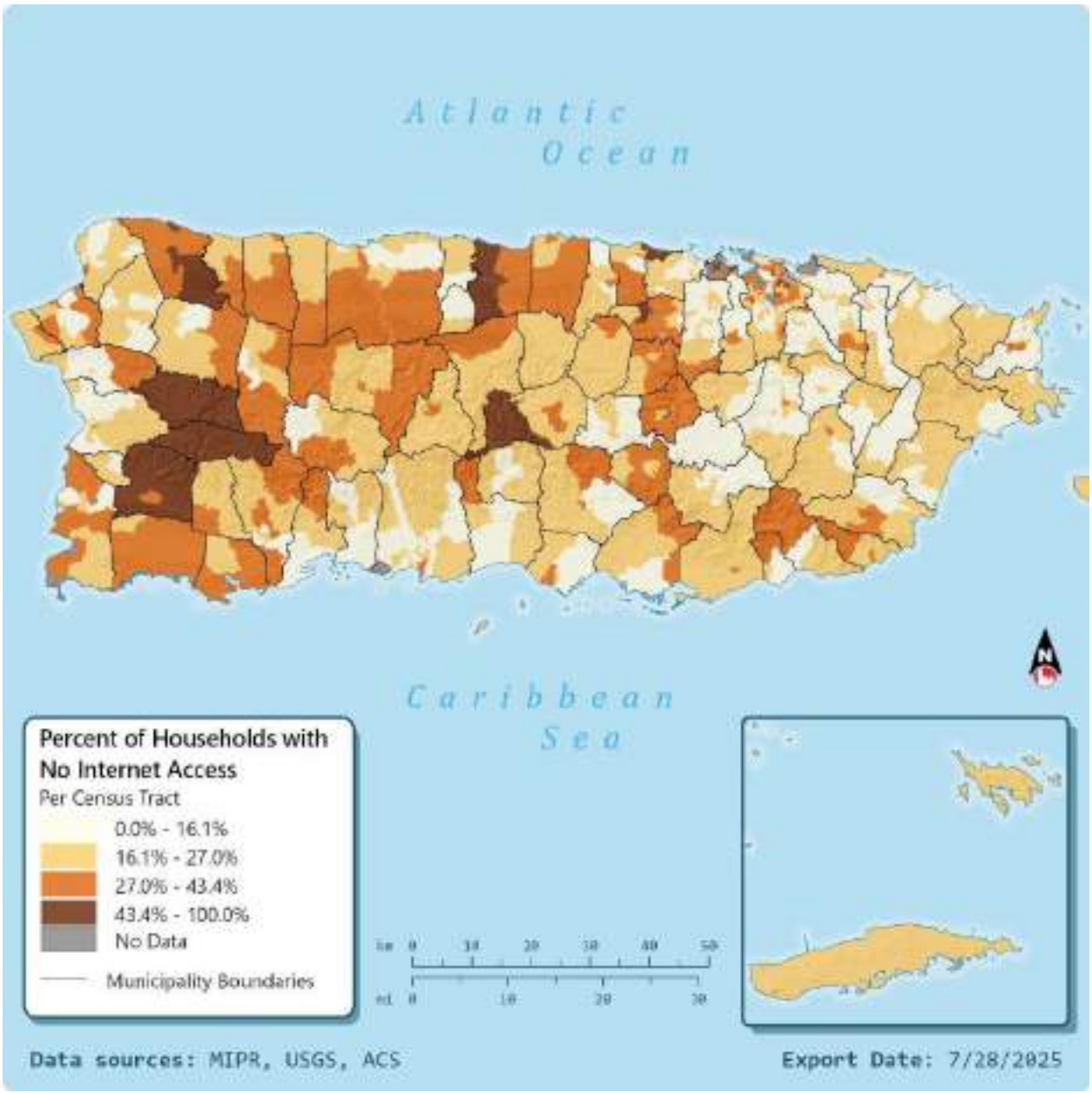


Figure 41: Puerto Rico Households with No Internet Access

Puerto Rico is working toward bridging the digital divide by expending broadband infrastructure, providing public Wi-Fi hotspots, promoting digital literacy and skills development, and improving internet access in low-income communities.[119] For example, the Puerto Rico Broadband Program seeks to coordinate,

[119] USCIS Guide, "Government Initiatives to Bridge the Digital Divide in Puerto Rico," https://www.uscisguide.com/living/government-initiatives-to-bridge-the-digital-divide-in-puerto-rico/.

authorize, and execute the disbursement of local and federal funds for the construction of broadband infrastructure on the island.[120]

Vehicle Ownership

During emergencies, natural disasters, and extreme weather events, the absence of a car can have devastating consequences. Individuals without access to a vehicle are less likely to evacuate when necessary and may struggle to reach emergency response centers, putting their safety at risk. During extreme heat events, individuals without access to vehicles face additional challenges. They are often unable to reach community cooling centers or find cooler areas, which can pose serious health risks. Figure 42 shows areas where higher percentages of households without vehicle access are located, which are concentrated in small areas across the island.

[120] Government of Puerto Rico, "Some of Our Projects Aimed to Close Puerto Rico's Digital Gap," https://www.smartisland.pr.gov/en-us/sobre-nosotros.

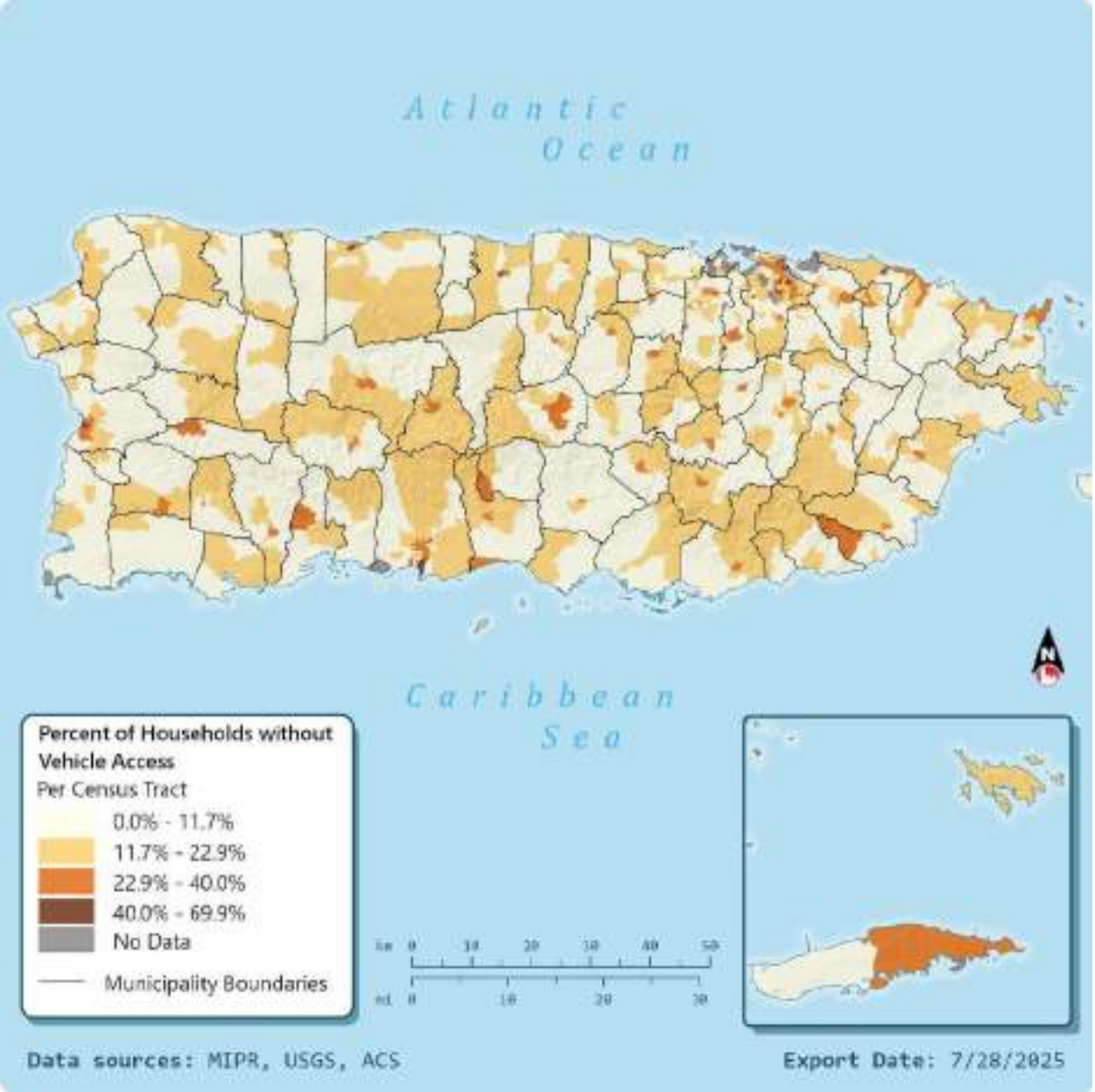


Figure 42: Percent of Households Without Vehicle Access

Economy

In 2023, Puerto Rico's gross domestic product (GDP) reached $117.90 billion U.S. dollars, showing a growth increase of 3.82% since 2022.[121] Figure 43 displays the GDP growth rate from 2020 through 2023 for Puerto Rico and the United States.[122]

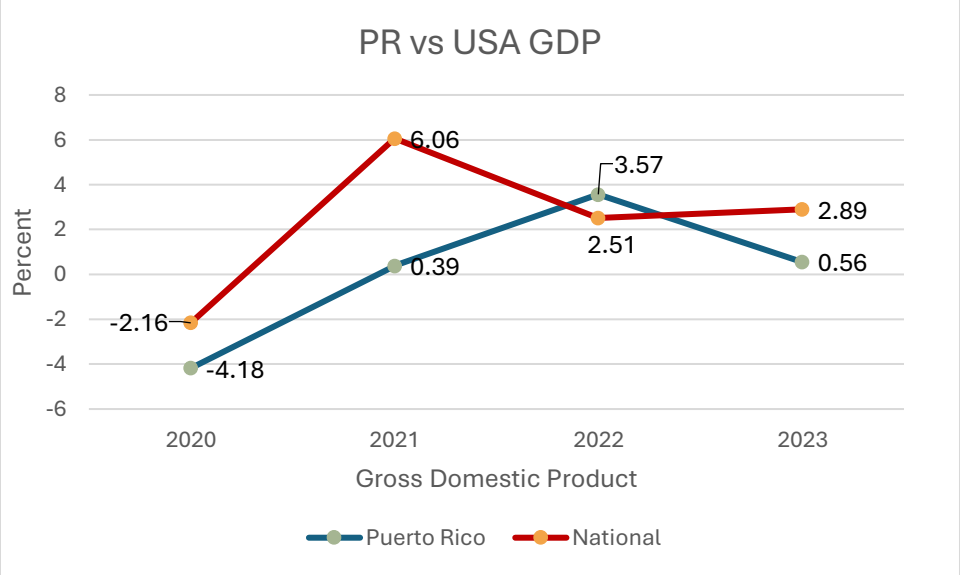


Figure 43: GDP Growth Rate, Puerto Rico vs. Nationally

The sectors of manufacturing, real estate and rental, and retail trade were the top three contributors to Puerto Rico's GDP, accounting for 66.5%. Table 14 displays the sectors contributing the most value-added in terms of gross output and intermediate input to Puerto Rico's economy and how the economy shifted from 2023 to 2024.

Table 14: Puerto Rico Gross Domestic Product by Major Industrial Sector 2024[123]

Sector	Economic Activity in Millions	Percentage of GDP	Percent Change 2023–2024
Manufacturing	$55,632	44	8
Real Estate and Rental	$19,735	16	6.5
Retail Trade	$8,241	6.5	6

[121] Macrotrends, "Puerto Rico GDP," https://www.macrotrends.net/global-metrics/countries/pri/puerto-rico/gdp-gross-domestic-product.
[122] Macrotrends, "Puerto Rico GDP," https://www.macrotrends.net/global-metrics/countries/pri/puerto-rico/gdp-gross-domestic-product; Macrotrends, "U.S. GDP Growth Rate," https://www.macrotrends.net/global-metrics/countries/usa/united-states/gdp-growth-rate#:~:text=U.S.%20gdp%20growth%20rate%20for,a%204.75%25%20decline%20from%202019.
[123] Junta de Planificación, "2024 Economic Report to the Governor and to the Legislative Assembly," https://jp.pr.gov/wp-content/uploads/2025/06/PRs-Economy-2024.pdf.

Sector	Economic Activity in Millions	Percentage of GDP	Percent Change 2023–2024
Finance and Insurance	$3,838	3	6
Government	$6,908	5.5	-3.4*
Health Care and Social Services	$5,459	4	4
Wholesalers Trade	$3,799	3	7
Professional, Scientific, and Technical Services	$4,319	3	8
Accommodation and Food Services	$3,079	2	13
Information	$3,385	3	4
Utilities	$2,671	2	7

*Decreases are shown in red.

The top industries for the civilian population 16 years and over are displayed in Figure 44 as of 2024.[124]

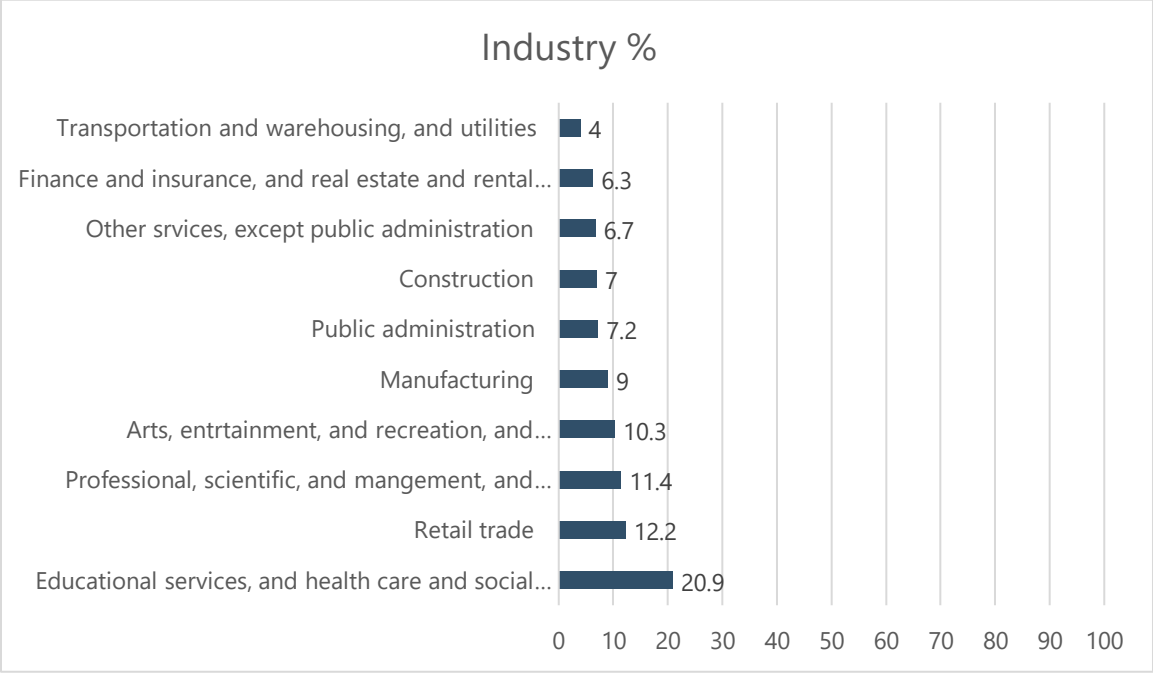


Figure 44: Percentage of Civilian Population Aged 16 and Over in Various Employment Industries

[124] U.S. Census Bureau, "Puerto Rico," https://data.census.gov/profile/Puerto_Rico?g=040XX00US72#employment.

In May 2025, the unemployment rate for Puerto Rico was 5.5%. Puerto Rico has the second-highest unemployment rate among U.S. states.[125] Figure 45 illustrates the fluctuating unemployment rate percentages for the period from 2020 to 2025.[126] In 2020, there was an unprecedented rise in unemployment caused by the COVID-19 pandemic. Between March 16 and March 30, 2020, approximately 76,928 Puerto Ricans applied for unemployment benefits.[127] By July 2020, 300,000 Puerto Ricans had filed unemployment claims directly linked to the COVID-19 pandemic.[128]

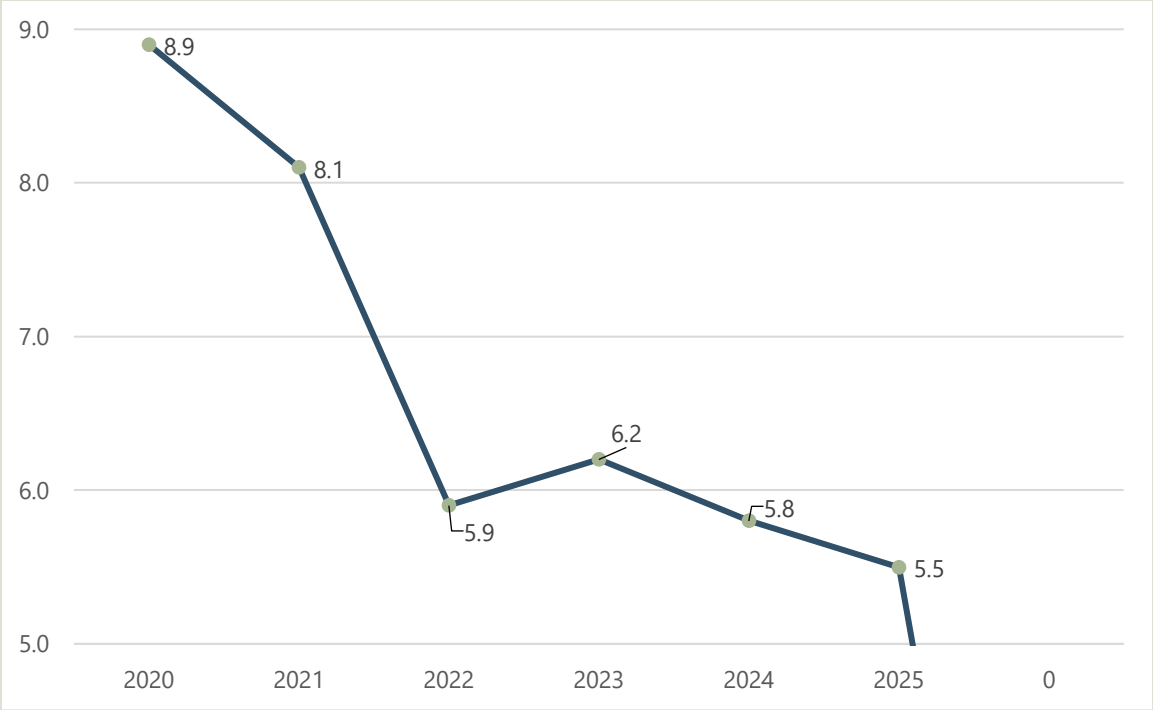


Figure 45: Puerto Rico Unemployment Rates 2020–2025[129]

Puerto Rico's unemployment rate has shown a substantial decrease since 2023, largely due to various factors contributing to economic recovery and growth. One of the most prominent influences has been the easing of pandemic restrictions, which allowed businesses to reopen and operate at full capacity. This resurgence led to increased demand for labor, resulting in more job opportunities across various sectors and an increase in employment by 9.2%.[130]

[125] Data Commons, "Ranking by Unemployment Rate," https://datacommons.org/ranking/UnemploymentRate_Person/State/country/USA?unit=%25.
[126] U.S. Bureau of Labor Statistics, "Databases, Tables & Calculators by Subject," https://data.bls.gov/pdq/SurveyOutputServlet.
[127] American University, "The Impact of the Covid-19 Pandemic in Puerto Rico," https://www.american.edu/cas/news/catalyst/covid-19-in-puerto-rico.cfm#:~:text=Puerto%20Rico%20has%20been%20hit,Ricans%20applied%20for%20unemployment%20benefits.
[128] New York Times, "Pandemic Plunges Puerto Rico into Yet Another Dire Emergency," https://www.nytimes.com/2020/07/08/us/coronavirus-puerto-rico-economy-unemployment.html.
[129] American Community Survey, 5-year estimates, 2023.
[130] PR51st, "Is Puerto Rico Experiencing Economic Recovery?" https://www.pr51st.com/is-puerto-rico-experiencing-economic-recovery/.

Federal assistance has also played a crucial role in this recovery. Increased funding stimulus programs provided by both local and federal governments have supported businesses in retaining and hiring staff. These initiatives allowed companies to navigate the challenges of the economic landscape, enabling them to invest in workforce growth and stability. Alongside this support, private sector employment is at an all-time high, with various infrastructure and development projects having created jobs in construction and related industries, further contributing to the reduction in unemployment rates.

Besides these factors, Puerto Rico has experienced a push to boost its tourism sector, a vital component of the local economy. As travel restrictions were lifted, the return of tourists led to a surge in job opportunities in the hospitality and related services sectors. This influx not only benefited businesses directly tied to tourism but also had a ripple effect on the overall economy, enhancing employment across multiple sectors. Furthermore, workforce development initiatives aimed at enhancing skills and training have prepared residents for available positions, making it easier for job seekers to find work.

Considering these combined efforts, the decrease in unemployment rates in Puerto Rico since 2023 reflects a broader trend of economic recovery and growth, positioning the territory for a more stable and resilient future.

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SECTION THREE

PLANNING PROCESS

Planning Process

The 2026 plan was prepared in compliance with the Disaster Mitigation Act of 2000 (DMA 2000), Title 44 of the Code of Federal Regulations (44 CFR), and FEMA's State Mitigation Planning Policy Guide. In 2025, FEMA released a new version of the Policy Guide; therefore, this plan was designed to meet the most recent criteria. A robust planning process ensures that each update incorporates the most current and reliable data, reflects local capabilities and priorities, and establishes a comprehensive approach to reducing the impacts of hazards on lives, property, and livelihoods. Figure 46 highlights the process used to update the island's hazard mitigation plan.

Figure 46: Plan Update Process Steps

Through a collaborative and inclusive process, stakeholders from the Commonwealth of Puerto Rico not only evaluated hazards and impacts to community lifelines but also identified, assessed, and prioritized mitigation actions. These efforts aim to reduce risks from future hazard events and ensure the island remains resilient.

This section provides a high-level overview of the activities that shaped the development of the plan.

Plan Update Methodology

The plan update methodology was developed by the planning consultant IEM and The Steering Committee. The process began in May 2025 with an administrative kickoff meeting to review changes in requirements according to the latest FEMA policy guidance, expectations for the plan update, and identification of the agencies involved in the Steering Committee. The Plan Update Schedule was developed, and the team began to identify existing resources and the best available data for incorporation into the draft plan, including the latest GIS mapping layers, island assets, and local research. This approach incorporates the best available data at the time, along with existing resources, into the plan and also ensures alignment with ongoing initiatives and planning documents.

Furthermore, a key element of the plan update was effective coordination with the Interagency Committee for Natural and Technological Hazard Mitigation (the Committee). Coordination with the Committee was essential for ensuring that mitigation strategies are aligned across federal, state, and local partners.

The collaboration was further expanded to include additional stakeholders, such as academic institutions, which offer research expertise and modeling capabilities, and dam owners, who provide critical operational insights and on-the-ground perspectives. By integrating these voices into the planning process, the Government of Puerto Rico can better assess vulnerabilities, strengthen risk reduction measures, and prioritize investments that protect community lifelines, such as water, energy, transportation, and communications systems, ultimately enhancing resilience and safeguarding the continuity of essential services.

Together, the plan participants and plan developer updated the plan in accordance with the latest guidelines, updated data analysis, and local Puerto Rico priorities, resources, research, and recommendations. Stakeholders contributed invaluable information to each section of the plan, including the risk and vulnerability analysis, capabilities assessment, the review of the prior mitigation actions, and the mitigation strategy as outlined in Coordination with Agencies and Stakeholders.

Plan Update Schedule

The Plan Schedule outlines the key milestones, timelines, and responsibilities that guide the development, review, adoption, and maintenance of the Hazard Mitigation Plan. Establishing a clear schedule ensures that each phase of the planning process is completed in an organized and timely manner, supports compliance with FEMA requirements, and facilitates meaningful participation from all relevant parties, including agencies, stakeholders, and the public. By defining when major tasks occur—such as data collection, risk assessment updates, stakeholder engagement, drafting, review periods, and final approval—the schedule provides transparency and accountability throughout the planning process. Furthermore, Table 15 includes a summarized description of the structured timeline and milestones that supported the coordination of efforts across departments and partners, ensuring that the plan was updated, actionable, and ready to support Puerto Rico's long-term mitigation goals.

Table 15: Plan Development Schedule and Milestones

Step	Schedule	Description
Planning Process	May – December 2025	A comprehensive range of Puerto Rico agencies and stakeholders had the opportunity to participate in the plan update. The draft Introduction, Puerto Rico Profile, and Planning Process sections were updated to outline the process and requirements associated with the islandwide plan update.
Kickoff Meeting: *August 15, 2025*		
Hazard Identification and Risk Analysis	August – December 2025	The hazard profiles were updated to reflect the impacts and the role of community lifelines, as well as previous occurrences, federal or local declarations, and significant events. Potential severity of events,

Step	Schedule	Description
		probability of future hazards, and vulnerability assessments were also analyzed. These updates ensured that demographic, social, and infrastructure data aligned with the realities of emerging risks and vulnerabilities across Puerto Rico. Meetings were held with subject matter experts (SMEs) to gather critical insights, data, and feedback to support the hazard identification and risk analysis process. During these sessions, SMEs contributed their technical knowledge, operational experience, and local perspectives to help validate hazard profiles, refine risk assumptions, and identify emerging threats. The discussion focused on reviewing available data sources, assessing the accuracy and completeness of existing hazard information, and identifying gaps requiring further analysis or action recommendations. Feedback from SMEs was incorporated into the hazard assessment to ensure that the resulting analysis reflects current conditions and the most up-to-date understanding of vulnerabilities across the island. Results were presented at the subsequent planning team meetings.
Subject Matter Expert Meetings: *September – December 2025*		
Capability Assessment	October – November 2025	The plan update included a comprehensive evaluation of existing Puerto Rico laws, regulations, policies, and programs, as well as a full review of all 78 local mitigation plans. As part of this process, hazards and capabilities for each municipality were analyzed, and the results of these assessments were incorporated directly into the updated plan.
Capability Assessment Meeting: *October 1, 2025*		
Mitigation Strategy	November – December 2025	A review of mitigation goals, objectives, and actions was conducted to identify how to address all hazards in the updated 2026 plan. The Planning Team evaluated the actions from the prior plan and determined which to

Step	Schedule	Description
		retain, modify, or mark as completed. After the review, a comprehensive set of strategies was considered, including recommendations developed by the planning consultant, ensuring that both broad initiatives and participant-specific actions were developed to reflect the unique capacities and concerns of Puerto Rico.
Mitigation Strategy Meeting: *November 4, 2025*		
Draft Plan Review	January – May 2026	The active stakeholder participation, thorough risk analysis, detailed capability assessments, and comprehensive mitigation strategy, as well as a strategic approach to plan maintenance, were compiled into the complete draft plan and submitted for FEMA review. The draft plan review was conducted in two stages. First, FEMA conducted a rolling courtesy review while the plan was being drafted. Then, the plan was formally submitted for FEMA approval.
Plan Adoption	TBD: July 2026	The Government of Puerto Rico formally adopted the plan once FEMA declared the plan "Approvable-Pending-Adoption". The plan was also translated into Spanish for public access. Additionally, the plan was converted into a digital HMP and shared publicly to further engage stakeholders and the public throughout the five-year lifecycle of this plan update.

The Steering Committee

The Steering Committee served as the central body guiding the development and implementation of the Hazard Mitigation Plan. It provided strategic direction, subject-matter expertise, and decision-making support throughout the planning process. The Steering Committee comprised representatives from key agencies and stakeholder groups, including PREMB, COR3, FEMA, and the selected contractor for this plan update, IEM. The committee ensured the plan incorporated diverse perspectives, aligned with existing initiatives, and complied with federal requirements and local priorities.

Through regular meetings, review of draft materials, and collaborative dialogue, the Steering Committee shaped the plan's goals and evaluated proposed mitigation strategies. Their leadership and active

participation were critical to producing a plan designed to strengthen community resilience and advance long-term risk reduction.

Table 16: Steering Committee Members

Agency/Stakeholder Name	Name	Title
PREMB	Zuleika González Sánchez	Mitigation Director
	Sarimar Hiraldo Principe	Executive Official - Mitigation Area
	Víctor A. Osorio Cepeda	Administrative Officer
	Maritza N. Sanabria Jarquín	Senior Emergency Management Officer
COR3	Daphne Diaz Burgos	Project Development Associate Director
	Natalie Rexach López-Merino	Project Manager
	Nelson Rivera Calderón	HM Project Management Lead
	Jorge González Ayala	Project Manager
	Rafael Castillo Navarro	Program Associate Director for HMGP and IA
	Alejandro Olmedo Borja	Project Development Deputy Director
	William Guzmán	Project Manager
	Carel Velazquez Pola	HMGP Project Lead
	Javier Cadilla Candelaria	Project Manager
	Luis Berrios Orlandi	Project Specialist
FEMA	Omar Visbal-Castro	HM Project Officer
	Idania Rodríguez	HM Planning Specialist
	Héctor M. González	Floodplain Management and Insurance Specialist
IEM	Casey Garnett	Project Manager
	Carlos Santos-Rivera	Deputy Project Manager
	Juan Lugardo	Hazard Mitigation Specialist

Coordination with Agencies and Stakeholders

Effective mitigation relies on intentional, well-structured coordination across a broad network of agencies, organizations, and community partners. No single entity holds all the resources, authority, or expertise needed to address complex incidents—especially those requiring swift decisions, cross-jurisdictional collaboration, and the continuity of critical services. Establishing clear communication channels, shared goals, and defined responsibilities allows stakeholders to implement mitigation strategies.

Table 16 lists the agencies and stakeholders invited to participate in a collaborative framework that united local, island, federal, nonprofit, and private-sector partners in a common approach. These participants represent a wide range of stakeholders from fields involved in hazard mitigation, including emergency management, economic development, land use and development, housing, health, education, and human services, infrastructure, and natural and cultural resources. Further, they reflect community lifelines—the most fundamental services in the community—and specific hazard subject matter expertise. Ultimately, coordinated partnerships enhance the implementation of mitigation strategies by ensuring all participants operate from a shared understanding and pursue common mitigation priorities.

Figure 47: Presentation at the Mitigation Strategy Meeting

The list below contains the agencies and stakeholders Invited to Participate in the Planning Process:

- 9-1-1 Government System Bureau
- American Red Cross
- Automobile Accident Compensation Administration
- Bureau of 9-1-1 Emergency Systems
- Bureau of Firefighters
- Capital Superintendent
- Caribbean Coastal Ocean Observing System
- Caribbean Collaborative Action
- Long-Term Recovery Group
- LUMA Energy
- Mental Health and Addiction Services Administration
- Metropolitan Bus Authority
- Mitigation/Interagency Coordination
- Municipality of Comerío
- National Oceanic and Atmospheric Administration (NOAA)
- National Weather Service

- Central Office for Recovery, Reconstruction, and Resiliency
- Department of Agriculture
- Department of Correction and Rehabilitation
- Department of Economic Development and Commerce
- Department of Education
- Department of Health
- Department of Housing
- Department of Justice
- Department of Labor and Human Resources
- Department of Natural and Environmental Resources
- Department of Public Safety
- Department of Public Works
- Department of Recreation and Sports
- Department of State
- Department of the Family
- Emergency Management Bureau
- Federal Emergency Management Agency (FEMA)
- Genera PR
- General Services Administration
- IEM
- Integrated Transportation Authority
- International Tsunami Information Center
- Office for Persons with Disabilities
- Office of Management and Budget
- Office of Principal Human Resources
- Office of the Advocate for Persons
- Office of the Governor
- Office of the Women's Advocate
- Planning Board
- Ports Authority
- Public Buildings Authority
- Public Housing Administration
- Public-Private Partnerships Authority
- Puerto Rico Aqueduct and Sewer Authority
- Puerto Rico Department of Health
- Puerto Rico Electric Power Authority
- Puerto Rico Fire Department Bureau
- Puerto Rico Institute of Forensic Sciences (or Intelligence Bureau)
- Puerto Rico National Guard
- Puerto Rico Seismic Network
- Puerto Rico Telecommunications Bureau
- U.S. Geological Survey (USGS)
- University of Puerto Rico
- UPR-M
- UPR-RP

AGENCIES AND STAKEHOLDERS THAT PARTICIPATED

In 2025, Puerto Rico's State Hazard Mitigation Plan was updated through a series of coordinated meetings that collectively shaped the island's resilience strategy. Table 19 provides a list of the participants, agencies they represented, and the actions undertaken by each participant.

The process began with the official launch on August 15, 2025, at the Puerto Rico Emergency Management and Disaster Administration Bureau office in Guaynabo. Stakeholders identified a wide range of ecological

and environmental challenges alongside human vulnerabilities. Concerns included ecological issues such as bees, snakes, and sargassum blooms, as well as hazards like hurricanes, tornadoes, lightning, and extreme winds. Regional vulnerabilities were highlighted, such as drought in the south affecting elderly, homeless, and agricultural communities; flooding in coastal and rural areas, straining emergency services; and landslides linked to poor construction practices, underscoring the need for stronger seismic infrastructure. Extreme heat, coastal erosion, tsunamis, wildfires, and pandemics were also highlighted, with participants stressing the fragility of the power grid and the importance of effective evacuation procedures. The session highlighted the importance of community collaboration in strengthening resilience against these diverse risks.

Plan stakeholders were invited to participate in the Capabilities Assessment Meeting, held on October 1, 2025, at the Puerto Rico Emergency Management and Disaster Administration Bureau. During the meeting, participants assessed their resources and competencies to ensure alignment with identified threats. Using a hybrid format that combines in-person and virtual participation, attendees reviewed mitigation actions from the 2021 State Plan and decided whether to adopt, modify, eliminate, or retain them. To foster collaboration, participants rotated through thematic stations dedicated to Planning and Regulatory; Administrative and Technical; Financial; and Education and Community Outreach capabilities. Written feedback and suggestions collected at each station fostered cross-agency dialogue and generated actionable insights to inform the development of stronger future mitigation strategies.

Figure 48: Open Discussion on the Progress of the 22 Identified Hazards

The process culminated with the Mitigation Strategy Meeting on November 4, 2025, at the PREMB office in Guaynabo. This session provided updates on the mitigation plan and explored new strategies to address all risks, including hazards such as hurricanes, floods, earthquakes, tsunamis, and forest fires. Agencies and experts contributed technical knowledge to establish priorities and strengthen inter-institutional coordination for more effective emergency management. A key feature was the presentation of 22 posters,

each focused on a specific hazard, offering summaries of collected data, key definitions, and maps of the most affected areas in Puerto Rico. These visual tools enhanced understanding of the scope of threats and supported informed decision-making and strategic planning for risk reduction.

Beyond formal Steering Committee sessions and stakeholder workshops, targeted meetings were held with subject-matter experts (SMEs) as captured in Table 17, to provide specialized knowledge and validate technical aspects of the plan. These consultations offered deeper insight into hazard dynamics, infrastructure vulnerabilities, emergency response capacity, and evolving mitigation practices. SME contributions were especially valuable in refining risk assessments, shaping feasible mitigation actions, and ensuring the plan reflects current science, regulatory requirements, and operational realities. Their expertise enhanced the accuracy, relevance, and practicality of the overall planning process.

Table 17: Subject Matter Expert Meetings

Name	Email	Agency	Topic
Andre Amador	andre.amador@upr.edu	CARICOOS	Coastal Erosion
Andya Aponte Acosta	aponte_a1@jp.pr.gov	Puerto Rico Planning Board	Flooding
Carmen I. Jorge de Salamán	cijorge@jrsp.pr.gov	Transportation and Other Public Services Office	HAZMAT
Edward Cruz	edward.cruz1@upr.edu	UPR	Sargassum
Efrain Cardona	Efrain2987@hotmail.com	Firefighter	Wildfire
Emanuel Rodríguez	emanuel.rodriguez@noaa.gov	NOAA	Lightning, Wildfire, Tornadoes, Hurricanes, Extreme Heat
Ernesto Rodríguez	ernesto.rodriguez@noaa.gov	NOAA	Lightning, Wildfire, Tornados, Hurricanes, Extreme Heat
Felix E. Burgos Hernández	fburgos@dsp.pr.gov	Fire Department	Wildfire
Glorymar Gómez Pérez	glorymar.gomez1@upr.edu	UCAR-Contractor	Tsunami
Isabella Camara Torres	isabella.camara@upr.edu	UPR-M.	Landslides
Jaime Lafuente	Jlafuente@jrsp.pr.gov	Commissioner, Transportation and Other Public Services Office	HAZMAT

Name	Email	Agency	Topic
Juan Mendez	Jmendez@drna.pr.gov	Department of Natural Resources	HAZMAT
Julio Morell	julio.morell@upr.edu	CARICOOS, UPR	Coastal Erosion, Sargassum
Liza Millan	liza.millan@salud.pr.gov	Department of Health	Pandemic/Epidemic
Lorna Jaramillo	lorna.jaramillo@upr.edu	UPR-RP	Coastal Erosion
Lt. Joel R. Figueroa	Jfigueroa@dsp.pr.gov	Director DHS/Wildfires Division Director, Puerto Rico Fire Department	HAZMAT
Luis E. Lamboy Torres	lamboy_le@jp.pr.gov	Puerto Rico Planning Board	Flooding
Maite M. Soto-Colorado	maite.soto@prepa.pr.gov	PREPA Program Manager	Dam Failure
Mariluz Melendez	mariluz.melendez@salud.pr.gov	Department of Health	Pandemic/Epidemic
Miguel Canals	miguel.canals@upr.edu	CARICOOS	Coastal Erosion
Odalys Martínez-Sánchez, Ph.D.	odalys.martinez@noaa.gov	NOAA	Lightning, Tornadoes
Pablo Méndez	pablo.mendez1@upr.edu	UPR-RP	Extreme Heat
Patricia Chardon Maldonado	patricia.chardon@upr.edu	CARICOOS, UPR	Coastal Erosion, Sargassum
Pedro Matos Lavano	pedro.matos4@upr.edu	UPR-M.	Landslides
Rene Esteves	rene.esteves@upr.edu	CARICOOS	Coastal Erosion
Stephen Hughes	kenneth.hughes@upr.edu	UPR-M.	Landslides
Victor Huerfano	victor.huerfano@upr.edu	UPR-M	Earthquake, Liquefaction

Overall, the three meetings and stakeholder engagement established a comprehensive framework of local input, data, and perspectives essential for updating Puerto Rico's hazard mitigation plan. Table 19 highlights the various participants who came together, reinforcing the importance of collaboration, adaptability, and proactive planning in building a resilient future for the island.

Table 18: Participating Agencies and Stakeholders

Name	Agency	Title	Participation
Abner Martínez	LUMA	Manager, Federal Office	Provided hazards and risk analysis input Supported the analysis of existing mitigation strategies Provided feedback via surveys Provided input for the overall plan development
Alejandro Olmedo Borja	COR3	Project Development Deputy Director	Participated in Steering Committee Meetings
Alexander Rullan	PREPA	Assistant Engineer - Blue Coast District	Participated in stakeholder meetings
Alexandro Reyes Otero	JRSP	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Alexies Rosario	Metropolitan Bus Authority	Interagency Coordinator	Participated in the Capability Assessment Meeting Participated in the Mitigation Strategy Meeting Provided feedback via surveys Provided input for the overall plan and action development
Amanda González	Department of Housing	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Amarilis Rivera Márquez	Department of Housing	Interagency Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Andre Amador	CARICOOS	Assistant Professor	Participated in stakeholder meetings
Andya Aponte Acosta	Puerto Rico Planning Board	Engineer, NFIP Specialist, Permit Auditor	Participated in stakeholder meetings

Name	Agency	Title	Participation
Angel Jimenez Colon	PREMB	PREMB Commissioner	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Angela Moreno	IEM	Hazard Mitigation Specialist	Participated in stakeholder meetings Collected and gathered input Participated in the Mitigation Strategy Meeting
Ann Ventura Payan	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Design Director	Participated in the Mitigation Strategy Meeting Participated in stakeholder meetings Provided hazards and risk analysis input Provided input for the overall plan development
Ann Ventura Payan	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Design Director	Participated in stakeholder meetings Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Anthony Yrimia Herrera	Puerto Rico Telecommunications Bureau	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development

Name	Agency	Title	Participation
Antonio Morales Rivera	Department of Housing	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Antonio Pardo Rosado	PRASA	Emergency Technical Advisor	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
Antonio Pardo Rosado	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Emergency Technical Advisor	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Arlene Rodríguez	Federal Emergency Management Agency (FEMA)	Emergency Management Specialist - Mitigation	Participated in the Capability Assessment Meeting
Armin J Cintron Torres	Department of Public Works	International Emergency Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Arnaldo Hernández Santos	General Court of Justice	Assistant security marshal/Alternate emergency management coordinator.	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Axel L Torres Serrano	Public Buildings Authority	Director of Strategic Partnerships	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Carel Velazquez Pola	COR3	HMGP Project Lead	Participated in Steering Committee Meetings

Name	Agency	Title	Participation
Carlos Santos-Rivera	IEM	Deputy Project Manager	Led Steering Committee, Kickoff, Capability Assessment, and Mitigation Strategy Meetings Facilitated Stakeholder Meetings Led efforts to collect and incorporate input Supported final plan drafting and reviewing
Carmen I. Jorge de Salamán	Transportation and Other Public Services Offices	Coordinator	Participated in stakeholder meetings
Carmen Reyes	Ports Authority	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Casey Garnett	IEM	Project Manager	Led Steering Committee, Kickoff, Capability Assessment, and Mitigation Strategy Meetings Participated in Stakeholder Meetings Led efforts to collect and incorporate input Supported final plan drafting and reviewing
Chante Santana	Luma	Program Manager	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Christina Arce Seda	Department of Corrections	Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Claribel Méndez	PREPA	Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Cristian González	IEM	Planner	Participated in the Mitigation Strategy Meeting Attended Subject Matter Expert meetings

Name	Agency	Title	Participation
Cristóbal Zamora Vazquez	Department of Housing	Alternate Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys
Daniel Horta Nieves	Department of Justice	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys
Daniel Reyes Arce	COR3	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Supported the analysis of existing mitigation strategies
Daphne Diaz Burgos	COR3	Associate Director Project Development	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Darilyn M. Amador	Puerto Rico Planning Board	Alternate Coordinator - External Resources	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys
Dennis A Arroyo Robles	Office of the Women's Advocate	Administrative Services Manager	Participated in the Capability Assessment Meeting Provided feedback via surveys
Digno Cartagena	Genera PR	Director of Emergency Management Corporate Security	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development

Name	Agency	Title	Participation
Edgardo Serrano Rivera	Capitol Superintendent	Interagency Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Supported the analysis of existing mitigation strategies
Edwin Malavet	DRNA	Manager, Environmental Emergency Response Area	Participated in stakeholder meetings
Efrain Cardona	Puerto Rico Fire Department Bureau	Firefighter	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the wildfire meeting on 9/9/2025
Eliaris Rivera	Administration of Mental Health and Anti-Addiction Services (ASSMCA)	Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Ely J. Padilla Perez	Department of Labor and Human Resources	Alternate Emergency Management Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Emanuel Rodríguez	NOAA	Meteorologist	Participated in stakeholder meetings
Emilio Garay Vega	Department of Public Works	Chief Executive Officer	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development

Name	Agency	Title	Participation
Ernesto Morales	National Weather Service	Advisement Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Provided feedback on the risk assessment. Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Ernesto Rodríguez	NOAA National Weather Service San Juan	Meteorologist In Charge	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Ezequiel Mecerdes Rincón	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Engineer	Participated in stakeholder meetings
Felix E. Burgos Hernández	Puerto Rico Fire Department Bureau	Fire Sergeant	Participated in stakeholder meetings. Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Fernando Osorio	PREPA	Senior Management Engineer	Participated in stakeholder meetings
Frank Lugo	Department of Agriculture	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys

Name	Agency	Title	Participation
Gerardo Rodríguez	Department of Economic Development	State Energy Program Manager	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Gisela Rosario Otero	PREMB	Executive Officer	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Glorymar Gómez Pérez	International Tsunami Information Center Caribbean Office	NOAA Blind Populations: Project Manager	Participated in stakeholder meetings Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Harry Marrero	PREMB	Director of Planning	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Héctor L. Rivera Román	Office of the Advocate for Persons with Disabilities	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Héctor M. González	FEMA	Risk Mitigation	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Participated in the Capability Assessment Meeting
Héctor M. González	FEMA	Floodplain Management and Insurance Specialist	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Participated in the Capability Assessment Meeting Participated in the Mitigation Strategy Meeting

Name	Agency	Title	Participation
Idania Rodríguez	FEMA	HM Community Planner	Participated in the Steering Committee Meetings Participated in the Kickoff Meeting Participated in the Capabilities Assessment Meeting Provided input for the overall plan and action development Provided FEMA courtesy review feedback
Ignacio Soto Quiñones	Department of Housing	Alternate Emergency Management Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Ileana Rodríguez Martínez	Mental Health and Addiction Services Administration (ASSMCA)	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys
Isabella Camara Torres	UPR-M.	Assistant Researcher	Participated in stakeholder meetings
Israel Rivera Nieves	Puerto Rico Planning Board	Interagency Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Itsa Collazo Torres	Puerto Rico Department of Health	Corresponding Director	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Ivelisse Esquilin	Puerto Rico Long-Term Recovery Group	Interagency Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Ivette Colón Meléndez	Puerto Rico Planning Board	Senior Professional Land Use Planner	Participated in stakeholder meetings Provided input for the overall plan development

Name	Agency	Title	Participation
Javier Aponte Machado	Public Buildings Authority	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Javier Cadilla Candelaria	COR3	Project Manager	Participated in Steering Committee Meetings
Javier E. Pietri	Puerto Rico Electric Power Authority	DFMO Project Specialist	Participated in the Capability Assessment Meeting Provided feedback via surveys
John A. Uphoff Figueroa	Governors' Office	Advisor for the Governor's Office	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Jorge González Ayala	COR3	Project Manager	Participated in Steering Committee Meeting Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Jorge Marcano Dipiní	Department of Recreation and Sports	Assistant Secretary of Administration	Participated in the Capability Assessment Meeting Provided feedback via surveys
José A Quiñones Negron	General Court of Justice	Assistant General Bailiff	Participated in the Capability Assessment Meeting Provided feedback via surveys
José F. Agostini Rodríguez	General Services Administration	Assistant General Sheriff	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development

Name	Agency	Title	Participation
José Fernández	Metropolitan Bus Authority	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Josean Nazario Torres	DRD	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Joshua Ortiz Ginés	Governors' Office	Administrator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Juan Espina	American Red Cross	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Juan Lugardo	IEM	Project Staff	Participated in Stakeholder meetings Collected and gathered input
Juan O. Ramirez Rivera	Public Service Regulatory Board	Public Service Regulatory Board	Participated in the Capability Assessment Meeting Provided feedback via surveys
Juan Ortiz Giro	Department of Health	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Julia Lisa Melendez Datimy	Department of Health	Mitigation/Interagency Coordinator for Guayama Zone	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development

Name	Agency	Title	Participation
Julieta Gómez	USGS	Civil Engineer	Participated in the Kickoff Meeting Provided hazards and risk analysis input
Julio A Menéndez Hernández	Public Housing Administration	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Julio Irizarry	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Senior QC & EHC Leader	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
Julio Morell	CARICOOS	Executive Director and Principal Investigator	Participated in stakeholder meetings
Kheyris Nieves	COR3	HMGP Deputy Director	Participated in Biweekly Meeting 10-15-2025 Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Leidin Pabon Chevere	Department of Education	Special Assistant	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys
Leticia Martinez Almonte	9-1-1 Services	Director of Calls	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Lina Cintrón Lorenzo	LUMA	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys

Name	Agency	Title	Participation
Lincoln H Acevedo Valle	Department of Labor and Human Resources	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys
Liza Millan	Department of Health	Planning Manager / DOC Manager	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
Lorna Jaramillo	UPR-RP	Professor, Researcher	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
Lt Col Raul Nieves	National Guard of Puerto Rico	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Supported the analysis of existing mitigation strategies
Lt. Joel R. Figueroa	Negociado de Cuerpo de Bomberos de Puerto Rico	Director DHS/Wildfires Division Director	Participated in stakeholder meetings
Luis A Cintrón	GeneraPR	Emergency Management Lead	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Supported the analysis of existing mitigation strategies
Luis A. Mateo Rivera	Puerto Rico National Guard	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys
Luis Berrios Orlandi	COR3	Project Specialist	Participated in Steering Committee Meetings

Name	Agency	Title	Participation
Luis E. Lamboy Torres	Puerto Rico Planning Board	National Flood Insurance Program Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings Provided NFIP data
Luis R Rivera Molina	Bureau of 9-1-1 Emergency Systems	Interagency Emergency Management Coordinator	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Luis R. Medero Merrero	Metropolitan Bus Authority	Planning Technician and Evaluator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Luis Ramos	Integrated Transportation Authority	Interagency Coordinator	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys
Maira Encarcion	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Emergency Coordinator	Participated in stakeholder meetings
Maite M. Soto-Colorado	PREPA	PREPA Program Manager	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys

Name	Agency	Title	Participation
Maria Angelis-Solis	PREPA	Chief Engineer	Participated in stakeholder meetings
Maria Davila Colon	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Engineer	Participated in stakeholder meetings
Mariluz Meléndez	Department of Health	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Maritza N. Sanabria Jarquín	PREMB	Senior Emergency Management Officer	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings Reviewed the draft plan and provided feedback
Meghan Wren	FEMA	Hazard Mitigation Planning Lead	Participated in the Capability Assessment Meeting
Miguel Canals	CARICOOS	Co-Principal Investigator	Participated in stakeholder meetings

Name	Agency	Title	Participation
Natalie Rexach López-Merino	COR3	Project Manager	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development
Nelson Rivera Calderón	COR3	HM Project Management Lead	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Nestor D. Monserrate Perez	DRNA	Office of Recovery and Mitigation Director	Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Odalys Martínez-Sánchez	NOAA	Science and Operations Officer	Participated in stakeholder meetings Reviewed the draft plan and provided feedback
Pablo Méndez	UPR-RP	Associate Professor	Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
Paloma Alaniz	IEM	Mitigation Manager	Participated in the Kickoff Meeting Participated in the Mitigation Strategy Meeting Participated in stakeholder meetings Supported plan development and data collection

Name	Agency	Title	Participation
Patricia Chardon Maldonado	CARICOOS	Deputy and Technical Director, Co-Principal Investigator	Participated in stakeholder meetings
Pedro Ayala	9-1-1 Government System Bureau	Alternate Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys
Pedro Matos LLavano	UPR-M.	Assistant Researcher	Participated in stakeholder meetings
Rafael Castillo Navarro	COR3	Program Associate Director for HMGP and IA	Participated in Steering Committee Meetings Participated in the Capability Assessment Meeting Provided feedback via surveys
Rene Esteves	CARICOOS	Contractor	Participated in stakeholder meetings
Rogelio Gonzalez Sanchez	Puerto Rico Planning Board	Geographic Information System Director	Participated in stakeholder meetings Provided GIS and state asset data Provided input for the overall plan development
Sarimar Hiraldo Principe	PREMB	Executive Official – Mitigation Area	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings Reviewed the draft plan and provided feedback
Selenia Ayala Martínez	Municipality of Comerio	Office of Federal Programs and Economic Development	Participated in stakeholder meetings

Name	Agency	Title	Participation
Shakyra Meléndez Ambert	Puerto Rico Aqueduct and Sewer Authority (PRASA)	Investigator	Participated in stakeholder meetings
Stephen Goicochea	PREPA	Assistant Engineer	Participated in stakeholder meetings
Stephen Hughes	UPR-M.	Professor	Participated in stakeholder meetings
Víctor A. Osorio Cepeda	PREMB	Administrative Officer	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings
Victor Huerfano	UPR-M	Director, Research Professor	Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in stakeholder meetings
William Guzmán	COR3	Project Manager	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input
Yaritza Pagán Rodríguez	Office of Management and Budget	Senior Government Budget Analyst	Participated in the Capability Assessment Meeting Provided feedback via surveys

Name	Agency	Title	Participation
Zuleika González Sánchez	PREMB	Mitigation Director	Participated in Steering Committee Meetings Participated in the Kickoff Meeting Provided hazards and risk analysis input Participated in the Capability Assessment Meeting Provided feedback via surveys Participated in the Mitigation Strategy Meeting Provided input for the overall plan and action development Participated in stakeholder meetings Reviewed the draft plan and provided feedback
Zulma L. Canales López	Office of Management and Budget	Interagency Coordinator	Participated in the Capability Assessment Meeting Provided feedback via surveys

HIGH HAZARD POTENTIAL DAMS STAKEHOLDERS

High Hazard Potential Dams (HHPDs) pose substantial risks to public safety, critical infrastructure, and the environment due to the severe consequences that could result from a failure. In Puerto Rico, owners of HHPDs have a heightened responsibility to ensure their facilities are properly planned, maintained, and operated in accordance with territorial and federal emergency management requirements. Consistent with the planning framework and guidance established by FEMA, dam owners must actively adhere to relevant federal regulations, territorial laws, and FEMA planning standards, particularly those governing hazard mitigation planning. Meetings with key stakeholders, including the dam safety agency and HHPD dam owners, as showcased in Table 19, were conducted to gather critical information on dam conditions, operations, maintenance practices, and emergency preparedness. These discussions provided valuable insight into potential failure scenarios, downstream impacts, and existing coordination procedures between operators and local emergency management agencies. Stakeholder input helped identify vulnerabilities, clarify roles and responsibilities, and strengthen the integration of dam-related risks into the overall hazard mitigation planning process. The engagement ensured that the plan reflects accurate, up-to-date information and supports collaborative strategies to enhance public safety and reduce long-term risk.

Table 19: Participating High Hazard Potential Dam Stakeholders

Participants	Title	Agency
Alexander Rullan	Assistant Engineer - Blue Coast District	PREPA
Ann Ventura Payan	Design Director	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Antonio Pardo Rosado	Emergency Technical Advisor	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Ezequiel Mecerdes Rincón	Engineer	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Fernando Osorio	Senior Management Engineer	PREPA
Julio Irizarry	Senior QC & EHC Leader	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Maira Encarcion	Emergency Coordinator	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Maite M. Soto-Colorado	Program Manager	PREPA
Maria Angelis-Solis	Chief Engineer	PREPA
Maria Davila Colon	Engineer	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Nestor D. Monserrate Perez	Office of Recovery and Mitigation Director	DRNA

Participants	Title	Agency
Selenia Ayala Martínez	Office of Federal Programs and Economic Development	Municipality of Comerio
Shakyra Meléndez Ambert	Investigator	Puerto Rico Aqueduct and Sewer Authority (PRASA)
Stephen Goicochea	Assistant Engineer	PREPA

How to Read This Plan

This Hazard Mitigation Plan is structured to lead readers from foundational context through detailed analysis to practical strategies. It is organized into eight core sections with supporting appendices. The plan opens with an Executive Summary and Introduction, which define its scope, purpose, and the FEMA guidance shaping the update. An updated Puerto Rico State Profile follows, along with a description of the planning process that highlights stakeholder engagement, meetings, surveys, and expert consultations.

The Risk Assessment section delivers comprehensive hazard analyses informed by updated datasets and modeling tools. Subsequent sections on State Mitigation Capabilities and Local Mitigation Assessment outline the Commonwealth's regulatory, administrative, fiscal, and municipal capacities. The Mitigation Strategy presents revised goals and actions designed to strengthen resilience, while the Plan Maintenance section details how progress will be monitored, evaluated, and updated over time.

Supporting appendices provide additional technical resources, currently covering human-caused hazards (Dam Failure and Hazardous Materials), as well as a more detailed analysis of the National Risk Index (NRI). A reference table accompanies this chapter, summarizing each section's purpose and mapping it to FEMA-required elements. This design enables users, reviewers, and auditors to navigate the plan efficiently and verify compliance. Overall, the structure ensures a logical progression of information, supports both strategic and technical review, and enhances usability for practitioners, policymakers, and stakeholders. Furthermore, Table 20 provides information on how each section is related to FEMA's Policy Guide.

Table 20: Sections of the Hazard Mitigation Plan

Section	Description	Element
Executive Summary	Provides a clear snapshot of the plan's purpose, goals, and anticipated benefits, helping stakeholders quickly understand how the plan supports long-term community resilience.	S1, S2, S19, HHPD3
1. Introduction	Expanded discussion on the purpose and scope of the SHMP to reflect updated FEMA guidance.	S1
2. Puerto Rico State Profile	Updated demographic, economic, and infrastructure profiles using the most recent U.S. Census and the Puerto Rico Planning Board.	S7

Section	Description	Element
3. Planning Process	The plan update process followed a structured and transparent approach that detailed how the plan was prepared, the schedule and timeline for completion, and the key milestones and activities carried out throughout the effort. The update incorporated input from a wide range of agencies and stakeholders, including state departments, local governments, and subject matter experts, who contributed through meetings, workshops, and coordinated review sessions.	S1, S2, HHPD1
4. Risk Assessment	Updated hazard profiles using new datasets, including updated tsunami inundation modeling, wildfire risk maps, dam failure inundation mapping, and NOAA Atlas 14 precipitation data (where applicable).	S3, S4, S5, S6, S7, HHPD1, HHPD2, FMAG1
5. State Mitigation Capabilities	Updated description of the Government of Puerto Rico's regulatory, administrative, and fiscal capabilities, including opportunities and challenges.	S8, S14, S15, S16, HHPD3, HHPD4, HHPD5, HHPD6
6. Local Mitigation Assessment	A thorough assessment of local policies and programs, along with a complete review of all 78 local mitigation plans. As part of this effort, hazards for each municipality were evaluated, along with capabilities such as funding opportunities. The findings from these analyses were integrated directly into the updated plan.	S13, S6, S7
7. Mitigation Strategy	Revised goals and objectives were developed to reflect a more resilient approach. Furthermore, all mitigation actions from the previous plan were reviewed, and their implementation status, effectiveness, and continued relevance were assessed to inform updates and guide the development of new or refined actions.	S9, S10, S11, S12, S15, HHPD7, FMAG2
8. Plan Maintenance	Strengthened monitoring and evaluation procedures, developing a checklist to ensure the plan remains a living document, capturing programmatic updates via checklists.	S17, S18, S20
Appendices	Descriptions of human-caused hazards (Dam Failure, Hazardous Materials) and analysis of National Risk Index findings for Puerto Rico.	S6

Significant Updates Since the 2021 Plan

The 2026 Puerto Rico State Natural Hazard Mitigation Plan (SHMP) incorporates substantial updates across all major planning sections to reflect new data, lessons learned from recent disasters, evolving capabilities,

and islandwide mitigation priorities. Since the 2021 plan, the island has continued to rebuild from previous natural disasters and endure new ones, thereby focusing priorities on increasing resiliency.

The updated plan incorporates a new format and methodology, placing stronger emphasis on stakeholder engagement and the development of meaningful mitigation actions. It integrates locally sourced data with newly available sets to ensure a more accurate and comprehensive understanding of risk. The update also reflects recent changes in federal policy and capabilities, aligning the plan with current national guidance. In addition, the plan enhances the use of GIS, including the development of a digital version of the plan to improve hazard analysis, visualization, and decision-making throughout the mitigation planning process. To ensure the plan remains current, the plan maintenance section was revised to enable stakeholders to incorporate programmatic updates through the use of a checklist, capturing updates directly into the plan.

The plan has also been revised to align with federal changes outlined in FEMA's State Mitigation Planning Policy Guide, effective 2025. Because this guidance evolved during the drafting process, some information—particularly regarding federal programs—was retained even though it may no longer apply. As federal programs continue to change over the plan's five-year cycle, readers are encouraged to verify available resources at the time of use.

Key updates are:

- Broader stakeholder engagement across the various sections throughout plan development.
- Expanded risk assessment from 15 to 22 natural hazards.
- Revised hazard list, separating severe weather into specific categories to meet new FEMA requirements.
- Hazard risk profiles were updated using the latest Hazus data and modeling outputs to ensure more accurate estimates of potential losses and impacts, enhancing the precision of hazard profiles and supporting data-driven mitigation planning.
- Hazard profiles linked to community lifelines, identifying risks to essential services.
- Expanded capabilities assessment, including evaluations of opportunities to strengthen current systems.
- Revised wide goals, reflecting updated priorities and greater involvement of stakeholders.
- Identified new plan maintenance approach, incorporating expanded monitoring and digital HMP capabilities to ensure ongoing implementation of mitigation measures.

This update reflects a more focused, accessible, and adaptable plan that strengthens resilience, improves usability, and supports long-term hazard mitigation efforts.

Grant Funding

This planning effort was funded by a FEMA Hazard Mitigation Assistance grant (Hazard Mitigation Grant Program for DR 4482 in fiscal year 2020). PREMB was the applicant agent for the grant. The grant funded the selected consultant for this plan update, IEM, Inc. (IEM). IEM was responsible for facilitating meetings,

collecting data from the plan participants, stakeholders, and the public, conducting loss estimates, and developing the draft plan.

Conclusion

The planning process for this Hazard Mitigation Plan update represents a comprehensive, collaborative, and data-driven effort to enhance Puerto Rico's resilience to natural hazards. Through a blend of in-person and virtual stakeholder meetings, targeted outreach, surveys, and expert consultations, the process captures diverse perspectives, local knowledge, and technical expertise at every stage of development.

This inclusive approach strengthens the accuracy and relevance of hazard analyses and mitigation strategies while fostering shared ownership among agencies, municipalities, community organizations, and residents. By documenting engagement activities and directly integrating feedback, the Commonwealth has established a transparent, repeatable framework for future updates.

The resulting plan is more robust, better aligned with community needs, and consistent with FEMA guidance—positioning Puerto Rico to make informed, equitable, and sustainable mitigation decisions in the years ahead.

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SECTION FOUR

RISK ASSESSMENT

Risk Assessment Introduction

This section identifies and analyzes hazards that pose a threat to Puerto Rico; evaluates their potential impacts on people, property, and critical infrastructure; and provides a foundation for developing effective mitigation strategies. It supports evidence-based decision-making and prioritization of actions that reduce long-term vulnerability and enhance resilience. The assessment outlines the natural hazards that may affect Puerto Rico and describes the methodologies used to evaluate the risks these hazards pose to the Government of Puerto Rico, its citizens' health and safety, property, economy, and natural resources. A key component of the assessment is the vulnerability analysis, which examines the assets at risk such as people, buildings, critical facilities and infrastructure, community lifelines, essential services, and natural, historic, and cultural resources and evaluates the potential consequences of hazard events on these assets. This analysis directly informs the selection and prioritization of mitigation measures aimed at reducing risk and enhancing resilience.

In alignment with FEMA's State Mitigation Planning Handbook and 44 CFR §201.4(c)(2), the risk assessment follows a five-step process:

1. **Identify Hazards:** Specify what hazards may occur in the planning area
2. **Describe Hazards:** Discuss where hazards have occurred or could occur, provide historical information about past occurrences, describe the possible severity or magnitude of hazards, and estimate the probability of future hazard events
3. **Identify Community Assets:** Examine which assets are most vulnerable to loss during a hazard
4. **Analyze Impacts:** Describe how each hazard could affect the assets of each community
5. **Summarize Vulnerability:** Draw conclusions from the analyses to guide development of strategy and reduce future losses

The state and local governments share responsibility for hazard identification and risk assessment. While local governments focus on hazards, vulnerabilities, and risks at the local or regional scale, the government of Puerto Rico evaluates the broader regional and island wide implications of those hazards. This section integrates historical data, scientific research, stakeholder input, and geospatial analysis to provide a comprehensive understanding of Puerto Rico's hazard landscape. It serves as the analytical backbone of the mitigation plan, guiding the selection of actions that address the most pressing risks.

Hazard Identification

For the purpose of this plan, the Puerto Rico Emergency Management Bureau (PREMB), in coordination with the Steering Committee and the Planning Committee, identified a comprehensive set of hazards that pose a threat to the safety, health, and welfare of Puerto Rico's residents. A total of 20 natural hazards were profiled and included in the Risk Assessment section of this plan.

Two additional anthropogenic (human-caused) hazards were identified: Dam Failure and Hazardous Materials. While these are not considered natural or climate-related hazards, they were deemed significant enough to warrant inclusion. As such, they are addressed in a dedicated annex to this plan and follow the same structure and methodology as that used in the main Risk Assessment. Dam Failure is not classified as a natural hazard, but its potential consequences, such as severe flooding and infrastructure damage, justify its inclusion due to the high risk it poses to communities. Hazardous Materials incidents are anthropogenic in nature and can result in serious public health and environmental impacts. Both hazards are presented in the annex to ensure comprehensive coverage and to support informed mitigation planning. The full list of hazards is presented below.

- Coastal Erosion
- Landslides
- Liquefaction
- Droughts
- Earthquakes
- Extreme Heat
- Extreme Winds / Hurricanes / Tropical Storms
- Faults and Fissures
- Flooding
- Heavy Rain
- Invasive Species
- Lightning
- Pandemic / Epidemic
- Rip Currents
- Sargassum
- Subsidence
- Tornadoes
- Tsunami
- Waterspouts
- Wildfire
- Dam Failure (annex)
- Hazardous Materials (annex)

Figure 49: Hazards Identified by Puerto Rico

Disaster Declarations

Puerto Rico has experienced a wide range of natural disasters, including hurricanes, floods, landslides, mudslides, and biological disasters. Historical records indicate that hurricanes have been one of the most recurring and impactful hazards, with major disaster declarations affecting most or all of the island. Severe storms and flooding have also posed significant threats, with multiple large-scale events requiring disaster declarations.

Figure 50: Disaster Declarations in Puerto Rico 1956–2024

From 1956 to 2024, Puerto Rico has experienced 51 federally declared disasters, reflecting a strong predominance of weather-related hazards. Hurricanes account for the largest share with 20 declarations, followed by floods and severe storms with 11 each. Other hazards include biological events (2), droughts (2), earthquakes (2), and isolated occurrences of fire, tropical storm and miscellaneous events. This distribution underscores the island's high vulnerability to tropical cyclones and secondary flooding impacts, while also highlighting the presence of less frequent but significant hazards such as seismic activity and drought. The historical pattern emphasizes the need for robust mitigation strategies focused on hurricane resilience, flood management, and multi-hazard preparedness.

Table 21: Presidential Disaster Declarations for Puerto Rico

Disaster	Year	Declaration Title	Incident Type	Counties/ Municipios
DR-4850-PR	2024	Tropical Storm Ernesto	Tropical Storm	38
EM-3610-PR	2024	Tropical Storm Ernesto	Severe Storm	79
DR-4805-PR	2024	Severe Storms, Flooding, Landslides, Mudslides	Flood	13
DR-4671-PR	2022	Hurricane Fiona	Hurricane	78
EM-3583-PR	2022	Tropical storm Fiona	Hurricane	78
DR-4649-PR	2022	Severe Storm, Flooding, Landslides	Flood	5
DR-4571-PR	2020	Severe Storm and Flooding	Flood	1
DR-4560-PR	2020	Hurricane Isaias	Hurricane	4
EM-3537-PR	2020	Tropical Storm Laura	Hurricane	78
EM-3532-PR	2020	Potential Tropical Cyclone 9	Hurricane	78

Disaster	Year	Declaration Title	Incident Type	Counties/ Municipios
DR-4493-PR	2020	Covid-19 Pandemic	Biological	78
EM-3452-PR	2020	COVID-19	Biological	78
DR-4473-PR	2020	Earthquakes	Earthquake	34
EM-3426-PR	2020	Earthquakes	Earthquake	78
EM-3417-PR	2019	Tropical Storm Dorian	Severe Storm	78
DR-4339-PR	2017	Hurricane Maria	Hurricane	78
EM-3391-PR	2017	Hurricane Maria	Hurricane	78
DR-4336-PR	2017	Hurricane Irma	Hurricane	32
EM-3384-PR	2017	Hurricane Irma	Hurricane	10
DR-4040-PR	2011	Tropical Storm Maria	Hurricane	3
DR-4017-PR	2011	Hurricane Irene	Hurricane	56
EM-3326-PR	2011	Hurricane Irene	Hurricane	78
DR-4004-PR	2011	Severe Storms, Flooding, Mudslides, and Landslides	Severe Storm	13
DR-1946-PR	2010	Severe Storms, Flooding, Mudslides, and Landslides associated with TS Otto	Severe Storm	21
DR-1919-PR	2010	Severe Storms and Flooding	Severe Storm	10
EM-3306-PR	2009	Explosions and Fire	Fire	5
DR-1798-PR	2008	Severe Storms and Flooding	Severe Storm	26
DR-1613-PR	2005	Severe Storms, Flooding, Landslides, and Mudslides	Severe Storm	17
DR-1552-PR	2004	Tropical Storm Jeanne, Landslides, Mudslides	Severe Storm	78
DR-1501-PR	2003	Severe Storms, Flooding, Mudslides, and Landslides	Severe Storm	31
DR-1396-PR	2001	Severe Storms, Flooding, Mudslides, and Landslides	Severe Storm	13
DR-1372-PR	2001	Severe Storms, Flooding, and Mudslides	Severe Storm	15
EM-3151-PR	1999	Hurricane Lenny	Hurricane	78
DR-1247-PR	1998	Hurricane Georges	Hurricane	79
EM-3130-PR	1998	Hurricane George (Direct Federal Assist First 72 hours)	Hurricane	1
EM-3124-PR	1996	Gas Leak Explosion	Other	1

Disaster	Year	Declaration Title	Incident Type	Counties/ Municipios
DR-1136-PR	1996	Hurricane Hortense	Hurricane	71
DR-1068-PR	1995	Hurricane Marilyn	Hurricane	14
DR-931-PR	1992	Severe Storms and Flooding	Flood	35
DR-842-PR	1989	Hurricane Hugo	Hurricane	57
DR-805-PR	1987	Severe Storms and Flooding	Flood	32
DR-768-PR	1986	Heavy rains, Flooding, and Mudslides	Flood	31
DR-746-PR	1985	Severe storms, Flooding, Mudslides	Flood	48
DR-736-PR	1985	Storms, Mudslide, Landslide, Flooding	Flood	20
DR-597-PR	1979	Hurricane David	Hurricane	72
DR-483-PR	1975	Tropical Storm Eloise	Flood	78
DR-455-PR	1974	Flooding	Flood	52
EM-3002-PR	1974	Drought	Drought	24
DR-296-PR	1971	Heavy Rains and flooding	Flood	60
DR-170-PR	1964	Extreme Drought Conditions	Drought	Statewide
DR-62-PR	1956	Hurricane	Hurricane	Statewide

Risk Assessment Methodology

As required by 44 CFR §201.4(c)(2)(i), the plan must include an evaluation that provides the basis for identifying proposed activities that aim to reduce losses for the identified hazards. The risk assessment should provide enough information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses related to the identified hazards.

Data Collection

To conduct a risk assessment, planners must access data from multiple sources. These include information on the location and extent of hazards, historical records of past events and their impacts on communities, and datasets identifying populations, structures, facilities, and other assets at risk from these hazards.

An extensive effort was made to gather complete information for updating the available data, including databases, maps, technical data, demographic information, and studies and analyses carried out in response to disasters and emergencies that have occurred. Sources of information included Puerto Rico and federal government agencies, academia, and private entities. Data was collected through emails or phone calls, in-person and virtual meetings with government officials and technical staff, and identification of technical studies conducted through FEMA, PREMB/COR3, or other partners.

Records of past hazard events were compiled from multiple sources, including disaster declaration documentation and the NOAA National Centers for Environmental Information (NCEI) Storm Events Database, which provides natural hazard data from 1950 to the present. Additional historical data was obtained from geological records maintained by the U.S. Geological Survey (USGS) and the Puerto Rico Division of Geology, along with other sources cited within the individual hazard profiles.

Demographic data related to population and housing were obtained from the U.S. Census Bureau and American Community Survey reports. Various state government agencies provided critical infrastructure data, such as the Department of Economic Development and Commerce (DEDC), Puerto Rico Planning Board (PRPB), and Puerto Rico Department of Housing.

Where applicable, information contained in approved LHMPs was incorporated to support setting priorities and formulating mitigation strategies. The review of local government plans focused on the following areas:

- Natural hazards that may affect municipalities
- An estimate of potential losses associated with the identified risks
- Mitigation goals or objectives established
- Mitigation activities or projects proposed by local jurisdictions to address identified natural hazards

Geospatial analysis is an essential component in identifying hazard-prone areas and assets exposed to hazards. Geographic Information System (GIS) software was used to (1) map the spatial footprint of natural hazards with known geographic areas of probable occurrence and (2) overlay data asset information (such as population centers, infrastructure, and critical facilities) to assess impacts. For hazards that do not have a defined extent, maps of past occurrences can provide a reference for general risk in the planning area. For some hazards, the scenario-based modeling tool Hazus was used to generate potential loss estimates. These maps supported the development of targeted mitigation actions to reduce risk and visually communicate risk to stakeholders.

Critical Facilities and Infrastructure

Critical facilities and infrastructure, such as hospitals, emergency response services, power plants, water treatment facilities, and utility networks, were identified and mapped to assess their exposure and vulnerability to natural hazards. Particular attention was given to assets that provide essential services during and after disasters, as their continued operation is vital for community resilience. The analysis included an evaluation of facility locations relative to hazard zones and considered building and content replacement costs in the event of a disaster. DEDC and PRPB provided most of the infrastructure information, which was used for both overlay analysis and integrated into Hazus modeling.

Hazus

Hazus is a nationally standardized risk modeling methodology that can be used to estimate potential damage, economic loss, and social impacts from natural hazards. The Hazus 6.1 software is built on Esri ArcGIS for Desktop and includes nationwide GIS datasets and models for each of the four natural hazards:

earthquake, flood, tsunami, and extreme winds. Hazus 6.1 was used for this analysis because the latest version, Hazus 7.1, does not incorporate the tsunami or earthquake modules. The model results can support the risk assessment portion of mitigation planning by providing loss estimates and other information regarding potential impacts on community assets.

The models estimate the amount of damage that could be expected for different building occupancies, critical facilities, transportation systems, and utilities from these events. Hazus offers different levels of analysis, depending on the data used. By default, Hazus is packaged with datasets that include baseline building and infrastructure inventories for the entire United States. A Level 1 analysis relies on the default baseline inventory datasets provided within the software, which include general building inventory, population characteristics, and basic economic data across the United States. For more detailed assessments, a Level 2 analysis incorporates locally sourced datasets to update the inventory, particularly for essential facilities and critical infrastructure. For each Hazus model, the baseline inventory was updated with critical infrastructure provided by local sources to conduct a Level 2 analysis. The updated infrastructure includes fire stations, police stations, hospitals, Emergency Operations Centers, schools, airports, ports, communication networks, and utility systems. Additionally, all critical infrastructure was modeled as a user-defined facility to include damage and replacement costs for assets that are not included in the Hazus named facilities.

Hazus generates outputs that include estimations of direct physical damage to buildings, essential facilities, and transportation and utility networks; secondary impacts, such as debris production; indirect losses due to business interruption; and social effects, including displaced households and sheltering requirements.

For this plan update, Hazus 6.1 was used to estimate potential losses for multiple hazard scenarios. For flooding, scenarios were modeled using 1% annual chance flood and 0.2% annual chance floods, based on both the FEMA FIRM boundaries and Advisory Base Flood Elevation (ABFE) flood depth grids. ABFE products were developed for Puerto Rico after Hurricane Maria in 2017 to determine the accuracy of the current 1% annual chance flood analysis and to determine stronger construction parameters within the floodplain. The ABFE products resulted in a 20% increase in area within the 1% annual flood boundary.[131] Analyzing the potential losses using both datasets provides an opportunity to better understand how the ABFE dataset may provide new insight into potential impacts from flooding.

Two earthquake scenarios were also evaluated with Hazus. One was based on the 6.4 magnitude earthquake that occurred offshore of southwest Puerto Rico on January 7, 2020. Another was based on a probabilistic 8.5 magnitude earthquake located near the Puerto Rico Trench north of the island. This allows for comparison between an actual event and a possible worst-case event.

Hurricanes were evaluated using probabilistic scenarios rather than historical incidents. The hurricane model produces estimates for multiple return periods, including 10-, 20-, 50-, 100-, 200-, 500-, and 1000-year intervals. Hazus contains a database of simulated storms that intersect the study region and are

[131] Advisory Coastal Flood Hazard Mapping – Puerto Rico. Simposio Sobre Manejo de Riesgos Costeros. 2019. https://staging.pr-ccc.org/wp-content/uploads/2023/06/5-Shudipto-Rahman-Ing.-Naomy-Peres-Nuevos-Mapas-de-Inundacion-FEMA-ABFE-Maps.pdf.

characterized by varying wind speeds. The losses from each of these simulated events are ranked to determine a scenario for each annual chance event. The wind speeds of that hurricane are then used as the basis to determine wind speed values and losses at the individual census tract level across the study region. Higher return intervals are typically associated with higher wind speeds and higher total losses; however, this may vary at the census tract level.[132]

Tsunami scenarios can be based on near-source or far-source earthquake ground shaking that would precede a tsunami. Local, or near-source, tsunamis are generated by earthquakes within 100 kilometers of the study region, and ground shaking is likely to be felt as a natural warning that a tsunami may occur. Distant, or far-source, tsunamis are generated by earthquakes occurring more than 1,000 kilometers away from the study region, and no ground shaking is likely to be felt prior to the tsunami arrival. This type of tsunami would arrive several hours after the source earthquake, and this would provide time for authorities to issue notifications through tsunami warning systems. For this plan, a far-source generating event was modeled using a 28-foot runup onto the land, which represents the elevation of the most landward extent of the tsunami with respect to the initial sea level. This height was set according to the recommendation of local tsunami subject matter experts from the Seismic Network of Puerto Rico.

High Hazard Potential Dams (HHPDs)

Risk from HHPDs was assessed using data from the National Inventory of Dams (NID). According to Puerto Rico Electric Power Authority (PREPA), there are 37 dams in Puerto Rico, of which 36 are classified as HHPDs. Where available, inundation maps were used to identify potential vulnerabilities and impacts to downstream population and infrastructure. NID identifies 36 state-regulated HHPDs in Puerto Rico. The high-hazard designation does not indicate the condition of a dam or likelihood of a dam failure; rather, it indicates the potential for loss of life if a dam were to fail. To supplement the NID data, additional information was requested from dam owners in Puerto Rico, including the Department of Natural and Environmental Resources (DNER), Puerto Rico Electric Power Authority (PREPA), Puerto Rico Aqueduct and Sewer Authority (PRASA), Municipality of Comerío, and private owners.

In alignment with FEMA's HHPD Grant Program requirements, this section focuses on eligible state entities that qualify for federal funding under the program. According to FEMA, only states and territories with an authorized dam safety program and a FEMA-approved hazard mitigation plan that includes dam risk are eligible to apply for HHPD grants.[133] In Puerto Rico, the Puerto Rico Electric Power Authority (PREPA) actively implements dam safety and rehabilitation projects as the recipient of FEMA's High Hazard Potential Dam (HHPD) Grant Program funds. PREPA leads technical efforts on the ground, but the responsibility for applying for and administering federal funding lies with the State Administrative Agency (SAA). The DNER serves as Puerto Rico's designated State Administrative Agency (SAA) for the HHPD Grant Program. PREPA may receive and manage HHPD funds to carry out dam safety improvements, but only the designated SAA

[132] FEMA. Hazus 6.1 Hurricane Model User Guidance. 2024. https://www.fema.gov/sites/default/files/documents/fema_hazus-6.1-hurricane-model-user-guidance.pdf.
[133] FEMA. Who Can Apply for the High Hazard Potential Dam Grant Program? May 9, 2025. https://www.fema.gov/grants/mitigation/learn/dam-safety/rehabilitation-high-hazard-potential-dams/apply.

can formally engage FEMA. Importantly, private dam owners are excluded from direct eligibility under the HHPD Grant Program and must work through public or nonprofit entities to access funding.

Failure of an HHPD in Puerto Rico could have severe consequences for critical infrastructure and community safety. Potential impacts include disruption to roads, bridges, electrical systems, and aqueducts, as well as damage to densely populated areas and strategic assets.

To assess the risk of dam failure in Puerto Rico, we relied not only on national datasets but also on direct engagement with dam owners and operators across the island. Their collaboration was essential in providing localized, technical, and operational data often not captured in national inventories. The information gathered from these entities included Emergency Action Plans (EAP), flood inundation maps, inspection and maintenance records, and hydrologic and hydraulic (H&H) analyses, which were used to model potential dam-break scenarios and evaluate downstream impacts. We also incorporated technical studies from the U.S. Geological Survey (USGS) and guidance documents from FEMA, which helped contextualize local data within broader risk assessment frameworks.

Data Limitations

Despite these efforts, the assessment faced notable data limitations. Many dams lack up-to-date structural condition assessments, and in several cases, sedimentation studies have not been conducted in recent years. This creates uncertainty around the actual storage capacity of reservoirs and the structural stability of aging infrastructure. Additionally, geotechnical evaluations and comprehensive risk analyses are incomplete or outdated for a number of dams.

For instance, loss estimates, exposure assessments, and hazard vulnerability descriptions were based on the most reliable data and methodologies available. However, there are inherent uncertainties in any loss estimation process due to limitations in the understanding of natural hazards and the ability to model their impacts on the built environment. Several factors contribute to these uncertainties, including:

- The need to make approximations and simplifications during analysis and modeling
- Gaps or outdated information in building inventory, demographic, or economic data
- The unique and unpredictable characteristics of each hazard, including its extent and severity
- The effectiveness of existing mitigation measures that may reduce potential losses
- The amount of warning time available for residents to prepare for and respond to a hazard

The NCEI Storm Events Database is a source of a significant amount of data for historic occurrences of natural hazards. This database does not record all events but only occurrences with sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. Also, event types recorded have changed over time. From 1950 to 1954, the dataset only contains information on tornado events. From 1955 to 1996, thunderstorm, wind, and hail events were added. All 48 event types from NWS Directive 10-1605 have been recorded from 1996 to the present. Property and crop damage estimates are best-guess estimates based on data available at the time of the event publication.

The FEMA National Risk Index is a dataset and online tool that helps illustrate areas most at risk from 18 different natural hazards. It offers a comprehensive composite score that serves as a baseline risk measurement at the county and census tract levels. The risk scores can provide risk-based comparisons at the state and national level. Data is not available for Puerto Rico for Community Resilience, which is one of the primary indicators used to generate the overall risk for these hazards. This reduces the effectiveness of using this tool for analyzing hazard risk in Puerto Rico. This tool was evaluated as part of the risk assessment development process. However, due to concerns that the tool may underestimate risk in Puerto Rico, it is used sparingly throughout the plan.

Geographic Database Sources

National, state, and local data sources were reviewed to locate available spatially based data relevant to this planning effort. When such datasets were available, maps were produced using geographic information system (GIS) software to show the spatial extent and location of hazards and analyze potential exposure to assets. These maps are included in the hazard profile sections. This section describes the sources for the various data used in the risk assessment.

BUILDING AND COST DATA

Building replacement cost is the cost to replace the entire structure with one of equal quality and utility. Replacement cost is based on industry-standard cost-estimation models published in RSMeans Square Foot Costs. It is calculated using the RSMeans square foot cost for a structure, which is based on the building occupancy class (i.e., multi-family residential or commercial retail trade), multiplied by the square footage of the structure from the tax assessor data. The construction class and number of stories for single-family residential structures also factor in determining the square foot costs.

Replacement cost values, detailed structure information, and census data are included within Hazus 6.1. The default data for building stock inventory and replacement cost was used for overall economic loss estimates from earthquake and flood.

Updated data provided by PRPB and other local entities was used in place of the Hazus defaults for critical facilities and infrastructure. This local data was added to the Hazus analysis as user-defined facilities to ensure all facilities were represented accurately. The building occupancy class was used to generate replacement cost values for these datasets.

GIS DATA SOURCE SUMMARY

Table 22: GIS Data Source Summary

Organization	Additional Source Details	Description	Date	Format
U.S. Census Bureau	ACS 5 Year Community Estimates Esri Living Atlas, esri_demographics: Census Bureau's API for American Community Survey	Variables: Place of birth (foreign born), population density, population over 65, median household income, households with no vehicle, language/limited English ability, percent of population with a disability, household size (average housing rental rate), household internet connectivity (no internet connection, no computer or smartphone, smartphone only), housing units in structure (mobile homes), adults over 25 who have not graduated high school, population with income below the federal poverty line, dependent population (65+ or <18), Data.census.gov, https://www.census.gov/data/developers/data-sets.html#accordion-a8ec3eb6f0-item-e2df35399d, https://esri.maps.arcgis.com/home/index.html	2019–2023	Feature Services
	ACS B07001	Geographical Mobility in the Past Year by Age for Current Residence in the United States Data.census.gov	2019–2023	Spreadsheet
	DP1: Profile of General Population	Change in housing units 2010–2020 https://data.census.gov/table/DECENNIALDP2020.DP1?d=DEC+Demographic+Profile&g=040XX00US72$0500000	2020	File download
	Indicadores.pr Change in Population	Annual Population Estimates for Puerto Rico and its municipalities https://indicadores.pr/dataset/estimados-anuales-poblacionales	2020–2024	Spreadsheet

Organization	Additional Source Details	Description	Date	Format
USDA Forest Service	National Land Cover Database	Tree Canopy Cover Data https://imagery.geoplatform.gov/iipp/rest/services/Vegetation/USFS_EDW_NLCD_TCC_PRUSVI/ImageServer https://imagery.geoplatform.gov/iipp/rest/services/Vegetation/USFS_EDW_NLCD_TCC_PRUSVI/ImageServer	2023	Image Service
	Landscape Change Monitoring System	Land Use https://data-usfs.hub.arcgis.com/datasets/usfs::landscape-change-monitoring-system-lcms-puerto-rico-usvi-annual-landuse/about Land Use Change Detection https://data.fs.usda.gov/geodata/rastergateway/LCMS/index.php	2024	TIF download
	Puerto Rico Gap Analysis Project	Land Cover Change – Urbanization https://data.fs.usda.gov/geodata/other_fs/IITF/index.php	2008	SHP download
	Wildland-Urban Interface	Defining and Mapping the Wildland-Urban Interface of Puerto Rico and the U.S. Virgin Islands. 2010 Distribution and Implications. Population and Housing units within WUI. https://data.fs.usda.gov/research/pubs/iitf/gtr_iitf_2025_001.pdf	2025	Data tables
Global Land Analysis & Discovery	Global Forest Change	Deforestation – Forest Loss https://glad.earthengine.app/view/global-forest-change#bl=off;old=off;dl=6;lon=-66.46996703116544;lat=18.190591937577672;zoom=10;	2024	TIF Download
Global Forest Watch	Tree Mortality	Gross Forest Cover Loss https://glad.earthengine.app/view/global-forest-change#bl=off;old=off;dl=6;lon=-66.46996703116544;lat=18.190591937577672;zoom=10;	2024	Image Service

Organization	Additional Source Details	Description	Date	Format
United States Geological Survey		Karst Map of Puerto Rico https://pubs.usgs.gov/of/2010/1104/	2010	File download
	Data.gov Data Catalog	Principal aquifers of Puerto Rico and the U.S. Virgin Islands https://www.sciencebase.gov/catalog/item/6314057ad34e36012efa2cba	2025	File Download
	Shoreline Change	Shorelines for Vieques, Culebra, and Puerto Rico from 1900s to 2018 https://www.sciencebase.gov/catalog/item/6149f75fd34e0df5fb96fbe9	2023	SHP Download
	Landslide	Landslide Inventories Across the United States – version 3 https://www.sciencebase.gov/catalog/item/671eef1fd34ed0f827ea9f12	2019, revised 2025	SHP Download
	Landslide following Hurricane Maria	Concentration of landslides caused by Hurricane Maria in Puerto Rico https://www.sciencebase.gov/catalog/item/59de6459e4b05fe04ccd39d8	2017	SHP download
	Caribbean-Florida Water Science Center	30-year Normal Precipitation distribution maps for Puerto Rico https://www.usgs.gov/media/images/30-year-normal-precipitation-distribution-maps-puerto-rico	2010	File download
GloH2O	Climate	Koppen Climate Classification https://www.gloh2o.org/koppen/	2020	Tif download
U.S. Drought Monitor (USDA, NDMC, NOAA)		Current Drought Conditions https://droughtmonitor.unl.edu/DmData/GISData.aspx and https://droughtmonitor.unl.edu/DmData/DataDownload/StatisticsbyThreshold.aspx	2025	SHP Download

Organization	Additional Source Details	Description	Date	Format
NOAA	Natural Hazard Viewer	Earthquake epicenters and tectonic plate boundaries https://www.ncei.noaa.gov/maps/hazards/, https://noaa.maps.arcgis.com/home/item.html?id=3b013773d0194605aaa659fdec4402a3	2025	Feature Service
	Past Weather	Extreme Heat – Average Annual Temperatures and Maximum Temperature Recorded by Station NOAA Stations https://www.ncei.noaa.gov/access/past-weather/puerto%20rico	2025	CSV Download
	National Hurricane Center	National Storm Surge Risk Maps – version 4 https://www.nhc.noaa.gov/nationalsurge/	2025	TIF Download
	Marine Beach Forecast - Rip Currents	Rip Currents – Surf Fatalities https://mapservices.weather.noaa.gov/vector/rest/services/outlooks/marine_beachforecast/MapServer/108	2025	Map Server
	GIS for Climate – Esri Federal User Community	Tornado Tracks https://climate-arcgis-content.hub.arcgis.com/datasets/e75412d18bdc469dbf89bf7e929475cc_0/about	2024	SHP Download
	National Weather Service – TsunamiReady Communities	Tsunami Ready in Puerto Rico/U.S. Virgin Islands https://www.weather.gov/tsunamiready/pr-tr	2024	File Download
	National Centers for Environmental Information	International Best Track Archive for Climate Stewardship (IBTrACS) – Hurricane Tracks v4r01 https://services2.arcgis.com/FiaPA4ga0iQKduv3/ArcGIS/rest/services/IBTrACS_ALL_list_v04r00_lines_1/FeatureServer	2024	Feature Service
	National Weather Service - Storm	SVRGIS Severe Report Database – Historic Wind Events https://www.spc.noaa.gov/gis/svrgis/	2024	File Download

Organization	Additional Source Details	Description	Date	Format
	Prediction Service Center			
USDA	Caribbean Climate Hub for Tropical Forestry and Agriculture	Annual Average Precipitation 1991–2020 https://farm.caribbeanclimatehub.org/data-viewer/		Feature service
USDA Natural Resources Conservation Service	Soil Survey Geographic Database (SSURGO)	USA Soils Map Units – Soil Order https://www.arcgis.com/home/item.html?id=52002402ebec486eaabc4b59e3c34d86	2018, revised 2025	Feature Service
	USA SSURGO	Soil Potential Subsidence https://www.arcgis.com/home/item.html?id=3a1100ca5f6d4bd99a93601e156479bf	2024	Feature Service
U.S. Fish and Wildlife Service	Caribbean Island Habitat	Invasive Species https://gis-fws.opendata.arcgis.com/maps/fws::caribbean-island-habitat-southeast-blueprint-indicator-2023/about	2023	Feature Service
Estadisticas.PR	COVID-19	COVID-19 Indicators Platform https://estadisticas.pr/en/covid-19	2023	File Download
Department of Health	Dengue	Arboviral Disease Surveillance (Dengue, Chikungunya, and Zika) July 30, 2025 https://datos.salud.pr.gov/arbovirus/publications	2025	PDF Download
	Mpox	Monkeypox (Mpox) in Puerto Rico, June 10, 2025 https://datos.salud.pr.gov/mpox/publications	2025	PDF Download
Sea Grant Puerto Rico (NOAA, UPR, VIMAS)	Sargassum – Sargassum Project	A Pilot Sargassum Management Prioritization Index, Sargassum Natural Impact Ranking https://uprm.maps.arcgis.com/apps/webappviewer/index.html?id=4ea1bdad90d64cb1a1946e11d87a1fd6 ,	2023	Feature Service

Organization	Additional Source Details	Description	Date	Format
		https://seagrantpr.org/investigacion/proyectos-de-investigacion/proyecto-sargazo/		
NASA	Jet Propulsion Laboratory – California Institute of Technology	Projections of Saltwater Intrusion in Coastal Watersheds by 2100 https://www.jpl.nasa.gov/images/pia26491-projections-of-saltwater-intrusion-in-coastal-watersheds-by-2100/	2025	TIFF download
FEMA	Planning Board	ABFE Flood Depth Grids - HECRAS Models for the PR Advisory Maps https://sige.pr.gov/server/rest/services/PuertoRico_Advisory/MapServer	2018	SHP Download
	Flood Map Service Center	FIRM – Flood Insurance Rate Map https://msc.fema.gov/portal/search?AddressQuery=Puerto%20Rico	2009	SHP Download
	Tsunami	Estimated Average Annualize Tsunami Losses for the United States, FEMA P-2426 https://www.fema.gov/sites/default/files/documents/fema_hazus_p-2426_estimated-average-annualized-tsunami-losses-united-states_092025.pdf	2025	PDF Download
	Floodsmart	Historical NFIP Claims Information and Trends https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=2000&maxy=2024&county=&gtype=tstate	2024	CSV Download
University of Puerto Rico Mayaguez	Tsunami Program	Puerto Rico Tsunami Program Map Tool – Tsunami Flood Zones https://maptool.uprm.edu/	2012	GDB Download
U.S. Army Corps of Engineers	National Inventory of Dams	Dam Locations https://nid.sec.usace.army.mil/nid/#/	2025	CSV Download

Organization	Additional Source Details	Description	Date	Format
PRPB	Critical Facilities and Infrastructure	ABFE- 1% and 0.2% Annual Chance Flood Zones Deslizamientos – Landslide, Liquefaction Erosion Risk FIRMs Storm Surge Sea Level Rise Tsunami Flood Zones and Evacuation Zones Wind Zones Airports CDTC – Health and Medical Centers Fire Stations Heliports Hospitals Hospital Heliports Municipal Emergency Management Offices Police Stations Potential Landing Sites Coastal Evacuation Zones PREMB Zone EOCs Seaports Cable Take Off Cellular Antennas AM Antennas FM Antennas Land Mobile Broadcast Towers Land Mobile Commercial	2025	CSV and Excel File Download, Geodatabase, Feature Services

Organization	Additional Source Details	Description	Date	Format
		Communication Towers Substations Surface Water Taps Drinking Water Wells Livestock Companies Landfill System RCRA Facilities Underground Storage Tanks EMS Hospitals Universities Churches Schools Tolls Wastewater pump stations AAA Aqueducts		
PRPB	Wildfire Susceptibility	Georisk – Forest Fire Susceptibility Level https://sige.pr.gov/server/rest/services/MIPR/Georiesgo_v10B/MapServer		Map Server Raster Layer
	Earthquake Susceptibility	Georisk– Earthquake Susceptibility https://sige.pr.gov/server/rest/services/MIPR/Georiesgo_v10B/MapServer/45		Feature Layer
	Earthquake	Georisk – Liquefaction https://sige.pr.gov/server/rest/services/MIPR/Georiesgo_v10B/MapServer/44		Feature Layer

Hazard Profiles

The evaluation of hazards that may affect Puerto Rico is fundamental for this plan. Its purpose is to identify potential physical, economic, and social impacts and to establish a mitigation strategy that reduces the likelihood and consequences of emergencies and disasters. Also, the evaluation of hazards helps prioritize the allocation of human, technical, and financial resources required at the state and local levels. The following sections profile each hazard identified in the analysis and assess the associated risks. Each risk assessment considers the following attributes:

1. **Hazard Description:** A brief introduction to the mechanisms behind the hazard.
2. **Location:** An indication of geographic areas most likely to experience the hazard, based on where they have occurred or may occur.
3. **Previous Occurrences:** A chronological history of recent or significant hazard occurrences, along with the extent of damage or associated costs, if available. Any incidents receiving federal disaster declarations are described.
4. **Potential Severity of Event:** A description of the potential magnitude and extent of the hazard, accompanied by a scale that describes the range or intensity of the hazard.
5. **Probability of Future Hazard Events:** Likelihood of this type of event occurring or reoccurring in Puerto Rico. It may be defined in historical frequencies, statistical probabilities, or return intervals. When applicable, a brief overview indicates ways in which the frequency of occurrence may change over time.
    a. **Low:** Hazards occurring less than once every five years
    b. **Moderate:** Hazards occurring at least once every five years
    c. **High:** Hazards occurring at least once a year
6. **Vulnerability Assessment:** A description of the assets at risk from each hazard, including their locations, populations, structures, and community lifelines. Vulnerability may be expressed in quantitative (such as replacement cost) or qualitative value (such as the type of structure), depending on available data.
7. **Impact Assessment:** An analysis of the potential consequences of a hazard event. It includes an analysis of potential losses to the identified vulnerable assets.
8. **Community Lifelines:** A description of the potential impacts to community lifelines from the specific hazard. The eight FEMA Community Lifelines are shown in Figure 51.
9. **Changes in Development:** Description of changes in vulnerability to each hazard since the 2021 plan. This may include land use or changes in the built environment, economic changes, changes in population patterns (migration, density, and makeup of socially vulnerable populations), or other changing conditions. Each is classified according to whether its vulnerability increased, decreased, or remained the same.
10. **Mitigation Success Stories:** Completed or ongoing projects or efforts to reduce risk to a hazard, where applicable.

Figure 51: FEMA Community Lifelines

Risk Ranking and Hazard Prioritization

The planning participants in the Kickoff meeting were given a survey regarding the various hazards that may occur in Puerto Rico. Table 23 shows a visual summary of the responses. Participants ranked flooding as the highest vulnerability in terms of the percentage of Puerto Rico that is vulnerable and the vulnerability of critical infrastructure. The population is considered most vulnerable to extreme winds, hurricanes, and tropical storms.

Table 23: Priority Ranking of Hazards

Hazard	Likelihood This Hazard Will Affect Puerto Rico	Vulnerability of Critical Infrastructure	Vulnerability of Population	Areas Most Vulnerable	Prioritization of This Hazard
Coastal Erosion	High	High	High	Regionalized	High
Landslides	High	High	High	Regionalized	High
Liquefaction	Medium	High	Medium	Regionalized	Medium
Drought	High	High	High	All the island	High
Earthquakes	High	High	High	All the island	High
Extreme Heat	High	High	High	All the island	High
Extreme Winds / Hurricanes / Tropical Storms	High	High	High	All the island	High

Hazard	Likelihood This Hazard Will Affect Puerto Rico	Vulnerability of Critical Infrastructure	Vulnerability of Population	Areas Most Vulnerable	Prioritization of This Hazard
Faults and Fissures	Medium	High	High	Regionalized	High
Flooding	High	High	High	All the island	High
Heavy Rain	Medium	High	Medium	All the island	Medium
Invasive Species	Medium	High	Medium	Regionalized	Medium
Lightning	Medium	Medium	High	All the island	Medium
Pandemic / Epidemic	Medium	High	High	All the island	High
Rip Currents	Medium	Medium	Medium	Regionalized	Medium
Sargassum	Medium	High	High	Regionalized	High
Subsidence	Low	Medium	Medium	Localized	Low
Tornadoes	Medium	Medium	Medium	All the island	Medium
Tsunami	Medium	High	High	Regionalized	Medium
Waterspouts	Low	Low	Medium	Localized	Low
Wildfire	Medium	Medium	Medium	Regionalized	Medium
Dam Failure (annex)	Medium	Medium	High	Regionalized	Medium
Hazardous Materials (annex)	Medium	High	High	Regionalized	High

As part of the risk assessment process, hazards were evaluated based on five key criteria: likelihood of occurrence, vulnerability of critical infrastructure, vulnerability of the population, geographic extent of vulnerability, and overall prioritization. This evaluation provides a foundation for targeted mitigation strategies and resource allocation.

The analysis identified several high-priority hazards that pose significant threats across the island. These include droughts, earthquakes, extreme heat, hurricanes and tropical storms, flooding, and pandemics/epidemics, all of which have a high likelihood of occurrence and affect both infrastructure and population across the island. Additionally, coastal erosion, landslides, faults and fissures, sargassum events, and hazardous materials incidents were also prioritized due to their high impact, despite being more regionally concentrated.

Liquefaction, heavy rain, invasive species, lightning, rip currents, tornadoes, tsunamis, wildfires, dam failure, and other hazards were classified as medium priority. These threats tend to be more localized or have

moderate likelihood and impact but still warrant attention due to their potential to disrupt communities and infrastructure in specific areas. Subsidence and waterspouts were identified as low-priority hazards, primarily due to their limited geographic scope and lower likelihood of occurrence. However, their inclusion in the assessment ensures that even localized risks are considered in the broader mitigation framework. The integration of dam failure, hazardous materials, and other annexed hazards further highlights the importance of cross-sector coordination and preparedness for cascading impacts.

Meetings with Hazard Subject Matter Experts

More than 15 meetings have been held with experts from various institutions to strengthen the hazard profiles for the Puerto Rico State Hazard Mitigation Plan. Table 24 contains a summary of the participants and topics discussed.

Table 24: Technical Consultations on Local Hazard Profiles

Entity / Institution	Topics Covered
Puerto Rico Seismic Network	Earthquakes, faults and fissures, subsidence
Puerto Rico Fire Department	Wildfire, Hazardous Materials
UPR-Mayagüez	Landslides, subsidence
Puerto Rico Department of Health	Pandemic / Epidemic
Puerto Rico State Forester	Wildfires
PREMB Tsunami Program Manager	Tsunami
Puerto Rico Planning Board	Land use, regulatory coordination
COREPi / UPR-Río Piedras	Coastal erosion
CARICOOS	Sargassum, coastal erosion
Caribbean Collaborative Action Network (CCAN)	Extreme heat
Puerto Rico Aqueduct and Sewer Authority (PRASA)	Dam failure
Puerto Rico Electric Power Authority (PREPA)	Dam failure
Puerto Rico Department of Natural and Environmental Resources (DNER)	Dam failure
Municipality of Comerío	Dam failure

SECTION 4.1

COASTAL EROSION

Coastal Erosion

COASTAL EROSION DEFINITION

Coastal erosion is generally defined as the gradual loss of beaches, dunes, or cliffs due to the action of waves, flowing water, and wind. Severe storms can accelerate this process rapidly, leading to dramatic changes along the shoreline.[134]

Coastal erosion is a long-term natural hazard that is exacerbated by both natural events and human activities. Unlike episodic hazards such as earthquakes or floods, which typically originate from a single source like a river or an earthquake epicenter, coastal erosion is a gradual process driven by the cumulative effects of wave action, sea-level rise, and sediment transport imbalances.

This distinction makes coastal erosion not only a hazard in its own right, but also a critical factor in hazard mitigation efforts, particularly for flooding and hurricanes. Coastal features such as dunes, beaches, and wetlands act as natural buffers, dissipating wave energy and reducing the impact of storm surges on inland areas. For example, coral reefs and vegetated shorelines have been shown to significantly reduce flood depths and structural damage during hurricanes.

Coastal erosion is a dynamic process influenced by both natural forces and human interventions (see Figure 52). Agencies such as the Federal Emergency Management Agency (FEMA) and the U.S. Geological Survey (USGS) have developed methodologies to measure and assess erosion, which are critical for hazard mitigation planning and coastal infrastructure design. FEMA distinguishes between two primary types of coastal erosion:

[134] Federal Emergency Management Agency (FEMA), *Coastal Hazards & Flood Mapping: A Visual Guide*, https://www.fema.gov/sites/default/files/documents/fema_coastal-glossary.pdf.

- **Episodic (Storm-Induced) Erosion:** This occurs during high-intensity weather events such as hurricanes and tropical storms. These events can cause rapid and severe changes to the coastline, including dune breaching, bluff collapse, and sediment displacement.[135]
- **Chronic Erosion:** This refers to long-term shoreline retreat driven by factors such as sea-level rise, sediment supply changes, and land subsidence. Chronic erosion is typically gradual but can have significant cumulative impacts over time.[136]

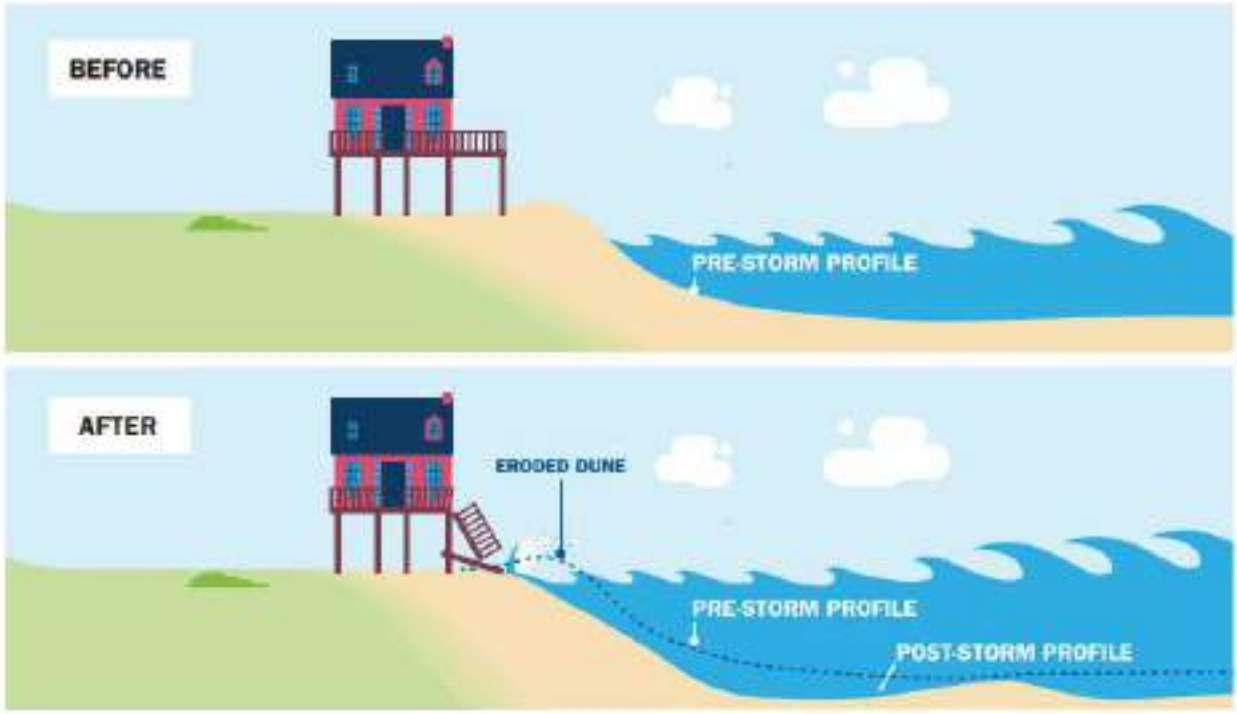


Figure 52: Coastal Erosion Triggered by a Storm Event[137]

To understand the occurrence of coastal erosion in Puerto Rico, it is essential to classify the types of shorelines found across the island. Bracero-Marrero et al. (2021), as cited in the USGS Data Report 1191, categorized the shoreline of Puerto Rico—including its five main coastal regions (North, East, South, West, and Northwest) and the islands of Culebra and Vieques—into four distinct types: beach, vegetation, rocky shoreline, and human-engineered (see Figure 54).[138]

[135] FEMA, *Coastal Construction Manual*, August 2011, https://www.fema.gov/sites/default/files/2020-08/fema55_voli_combined.pdf.
[136] FEMA, *Coastal Construction Manual*, August 2011, https://www.fema.gov/sites/default/files/2020-08/fema55_voli_combined.pdf.
[137] FEMA, *Coastal Hazards & Flood Mapping: A Visual Guide*, https://www.fema.gov/sites/default/files/documents/fema_coastal-glossary.pdf.
[138] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.

- Beach shorelines refer to areas primarily composed of unconsolidated sediment such as sand, which are shaped by wave and tidal action.
- Vegetation shorelines are those dominated by coastal plant life, such as mangroves or other salt-tolerant species, which play a role in stabilizing sediment and buffering wave energy.
- Human-engineered shorelines include structures like seawalls, revetments, and other coastal defenses built to protect infrastructure and reduce erosion.
- Rocky shorelines are naturally occurring solid rock formations along the coast, and are generally more resistant to erosion but less dynamic in terms of sediment movement.

Location

Puerto Rico is a U.S. Commonwealth located in the heart of the Caribbean, between latitudes 18° 31′ and 17° 55′ N and longitudes 65° 37′ and 67° 17′ W, bordered by the Atlantic Ocean and the Caribbean Sea. In addition to the main island, the Commonwealth includes five smaller nearby islands.[139] The coast of the main island of Puerto Rico was divided into five regions for the shoreline change analysis: North, East, South, West, and Northwest, as shown in Figure 53.[140] The division was based on two main factors: general geographic location and the prevailing wave energy conditions.

Due to Puerto Rico's geographic location and exposure to varying wave energy across all coastal regions, every shoreline of the island is at risk of coastal erosion. This ongoing hazard threatens natural coastal defenses and increases vulnerability to flooding and hurricanes, making erosion a critical concern for long-term hazard mitigation planning.

[139] M. Barreto-Orta, R. Méndez-Tejeda, E. Rodríguez, N. Cabrera, E. Díaz, and K. Pérez, "The State of the Beaches at Puerto Rico after Maria," *ResearchGate*, March 2019, https://www.researchgate.net/publication/332061474_The_state_of_the_beaches_at_Puerto_Rico_after_Maria.
[140] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.

Figure 53: Geographic Location of Puerto Rico and Shoreline Classifications[141]

From Figure 54, it is evident that the North region, which includes the metropolitan area of San Juan, has the highest concentration of beach and human-engineered shoreline types. This pattern reflects the region's high level of economic development and urbanization, which has led to both the preservation of recreational beach areas and the construction of engineered coastal defenses designed to protect infrastructure from erosion and storm impacts.

[141] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.

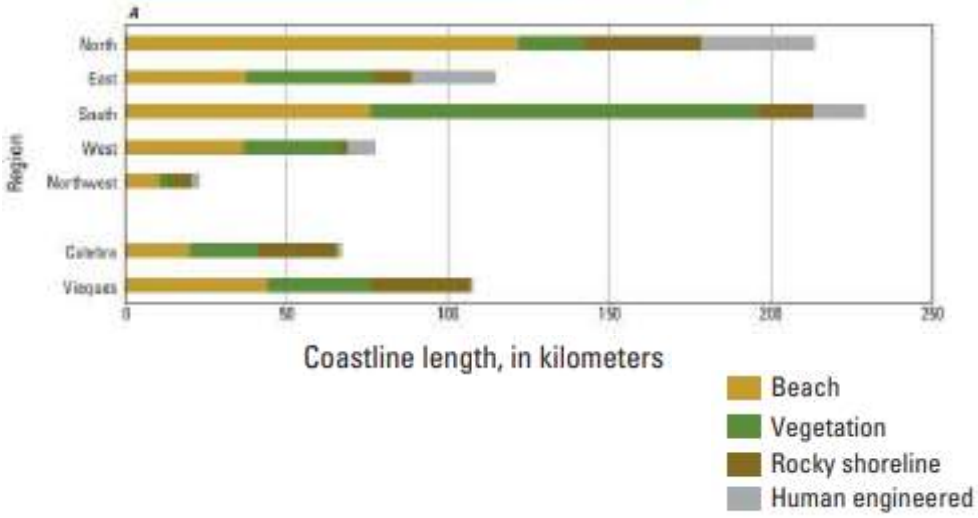


Figure 54: Shoreline Classification for Puerto Rico, Culebra, and Vieques[142]

Previous Occurrences

According to the most recent studies, the average long-term coastal erosion rate for Puerto Rico is approximately –0.24 meters per year, based on shoreline position data collected from the early 1900s to 2018. This value represents the mean rate of shoreline retreat across the island and its two island municipalities, Vieques and Culebra, and was calculated using the Digital Shoreline Analysis System (DSAS). The negative value indicates landward movement of the shoreline, meaning erosion—not accretion. In other words, Puerto Rico's coastlines are, on average, losing sediment rather than gaining it.[143]

This rate of –0.24 meters per year is an average annual change, meaning that each year, the shoreline retreats inland by approximately 24 centimeters. However, this rate can vary significantly depending on local conditions such as wave energy, sediment supply, and human activity.

Historical shorelines for this study were compiled from a variety of sources such as orthophotos, aerial photos, and lidar data and were analyzed in the USGS Digital Shoreline Analysis System to calculate rates of change. Records of historical shoreline position to monitor change over time enable researchers to identify areas most vulnerable to change.[144] Figure 55 shows areas of change measured by this process from 1901 to 2018.

[142] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.
[143] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.
[144] Henderson, R.E., Heslin, J.L., and Himmelstoss, E.A., 2021, Puerto Rico shoreline change — A GIS compilation of shorelines, baselines, intersects, and change rates calculated using the Digital Shoreline Analysis system version 5.1

Figure 55: Coastal Erosion Shoreline Changes by Year

Accretion, the opposite of erosion, refers to the natural or artificial process of sediment accumulation that causes the shoreline to advance seaward. According to the USGS, accretion can occur due to factors such as longshore sediment transport, riverine sediment input, or coastal restoration efforts including beach nourishment. In areas experiencing accretion, the shoreline moves seaward, indicating a net gain of sediment over time.[145]

Table 25: Regional Breakdown of Long-Term Shoreline Change Rates, 1900s–2018

Region	Rate (m/yr) ± Uncertainty	Interpretation
North	+0.04 ± 0.03	Net shoreline gain (accretion)
Northwest	+0.10 ± 0.09	Accretion
West	+0.10 ± 0.05	Accretion
East	+0.06 ± 0.04	Accretion
Vieques	+0.02 ± 0.06	Slight accretion
South	–0.05 ± 0.03	Erosion
Culebra	+0.08 ± 0.08	Accretion

These rates reflect the net change in shoreline position, with positive values indicating accretion and negative values indicating erosion. Contrary to earlier assumptions, the North region shows a slight net shoreline gain, which may be influenced by localized sediment deposition or coastal engineering. The South region is the only area with a net erosional trend, likely due to lower wave energy and sediment supply, as well as limited natural buffering features.[146]

The report identifies several key factors contributing to erosion across Puerto Rico:

- **Wave Energy:** Regions with higher wave power density, such as the North and Northwest, are more susceptible to shoreline change.
- **Storm Impacts:** Hurricanes Irma and Maria (2017) significantly destabilized shorelines, accelerating erosion in many areas.
- **Sediment Supply and Vegetation Loss:** Areas with limited sediment input or degraded coastal vegetation (e.g., mangroves) are more vulnerable to erosion.
- **Human Development:** Urbanized and engineered shorelines can disrupt natural sediment transport, increasing erosion in adjacent areas.

[145] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.
[146] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.

While the USGS Data Report 1191 emphasizes long-term averages, it also includes short-term erosion rates (1970s–2018). In some regions, these short-term rates show slower erosion or even temporary accretion, possibly due to coastal stabilization efforts, natural variability, or changes in storm frequency. However, the overall trend remains erosional in high-energy coastal zones, especially where natural buffers have been degraded.[147]

The report was developed in part as a response to the 2017 hurricanes Irma and Maria, which had a profound impact on Puerto Rico's coastal systems. These storms prompted the need for updated shoreline data and more comprehensive hazard assessments. The Supplemental Appropriations for Disaster Relief Requirements Act of 2018 funded this effort, recognizing the importance of understanding how extreme events accelerate coastal change.[148]

NOAA's South Atlantic Coastal Study Environmental Sensitivity Index monitors a variety of shoreline criteria such as exposure to wave and tidal energy, shoreline settling, substrate composition and permeability, development, and stabilization structures and characterizes it for purposes of identifying potential coastal storm risk management strategies.[149] Figure 56 shows trends of coastal erosion or accretion according to this analysis.

[147] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.
[148] FEMA, *Hurricanes Irma and Maria in Puerto Rico*, October 2018, https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf.
[149] NOAA South Atlantic Coastal Study Environmental Sensitivity Index, SACS NOAA ESI Shoreline Puerto Rico, March 2024. https://data-sacs.opendata.arcgis.com/datasets/SACS::sacs-noaa-esi-shoreline-puerto-rico/about.

Figure 56: Puerto Rico Coastal Shoreline Trends

According to the FEMA P-2020 Mitigation Assessment Team Report, Hurricane Irma (Category 5) and Hurricane Maria (Category 4) caused widespread destruction, including storm surge exceeding 6 feet, rainfall over 35 inches, and wind gusts over 140 mph. These forces led to severe erosion, dune loss, and infrastructure damage, especially in low-lying and unprotected coastal areas like Culebra, Vieques, and the northeastern coast.[150] Figure 57 confirms this trend, showing the beach changes before and after Hurricane Maria.

Figure 57: Aerial Photographs of a Beach in Rincón, Puerto Rico[151]

FEDERAL DISASTER DECLARATIONS

Coastal erosion is a long-term process driven by a combination of natural and human-induced factors. While gradual changes such as sea level rise and sediment supply play a role, the primary drivers of erosion in Puerto Rico are hydrometeorological hazards, including hurricanes, tropical storms, and flooding events. These high-energy storm events accelerate shoreline retreat and sediment loss.

Because these hazards are the main contributors to coastal erosion, federal disaster declarations related to coastal impacts are typically issued under the categories of storms, flooding, and other hydrometeorological events, rather than under erosion-specific classifications.

Although there are no disaster declarations specifically labeled as "Coastal Erosion," Table 26 presents recent disaster declarations related to tropical storms. This information is provided for reference only, as the inventory of these declarations is organized within the appropriate sections of the report, such as

[150] FEMA, *Hurricanes Irma and Maria in Puerto Rico*, October 2018, https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf.

[151] *(Left)* 1930s Aerial Showing the Beach with No Development; (*Center)* Pre-Irma and -Maria Aerial; *(Right)* Post-Irma and Maria Aerial Showing Storm-Induced Erosion
Storlazzi, et al., *Rigorously Valuing the Impact of Hurricanes Irma and Maria on Coastal Hazard Risks in Florida and Puerto Rico*, Open-File Report 2021–1056 (Reston, VA: U.S. Geological Survey, 2021), https://doi.org/10.3133/ofr20211056.

flooding or hurricanes. As previously mentioned, storms are among the most significant drivers of coastal change, whether through erosion or accretion.

Table 26: Federal Disaster Declarations Including Coastal Erosion

Disaster Number	Declaration Date	Incident Period	Description	Location
DR-4850-PR	11/27/24	8/13/24–8/16/24	Tropical Storm Ernesto	Aguas Buenas, Aibonito, Añasco, Barranquitas, Canóvanas, Ceiba, Coamo, Comerío, Corozal, Hormigueros, Jayuya, Las Marías, Loíza, Manatí, Maricao, Maunabo, Mayagüez, Naguabo, Orocovis, San Lorenzo, San Sebastián, Santa Isabel, Vega Alta, Vieques, Villalba, and Yabucoa.
EM-3610-PR	8/13/24	8/13/24–8/16/24	Tropical Storm Ernesto Emergency protective measures	All 78 municipalities
DR-4805-PR	7/23/24	4/29/24–5/10/24	Puerto Rico Severe Storms, Flooding, Landslides, and Mudslides	Adjuntas, Guánica, Lajas, Las Marías, Luquillo, Maricao, Naranjito, Orocovis, Sábana Grande, San Sebastián, Toa Alta, Utuado, and Yauco Municipalities for Public Assistance.
DR-4649-PR	3/29/22	2/4/22–2/6/22	Puerto Rico Severe Storm, Flooding, and Landslides	Cataño, Dorado, Toa Baja, Vega Alta, and Vega Baja

Although coastal erosion has not triggered a formal FEMA disaster declaration, its impacts have been documented by federal agencies. FEMA's Mitigation Assessment Team and the USGS have observed significant erosion-related damage following Hurricanes Irma and Maria, including the loss of beaches and dunes, increased vulnerability of infrastructure, and long-term shoreline retreat.[152]

PUERTO RICO DISASTER DECLARATIONS

Puerto Rico has not received a federal disaster declaration from FEMA specifically for coastal erosion. However, the Government of Puerto Rico has independently declared a state of emergency due to coastal erosion.

[152] U.S. Geological Survey, *Assessment of Coastal Hazards in Puerto Rico*, https://www.usgs.gov/supplemental-appropriations-for-disaster-recovery-activities/assessment-coastal-hazards-puerto-rico; and John McCarthy, "FEMA Funds First-of-Its-Kind Effort to Rebuild Puerto Rican Coral Reefs," *Virgin Islands Free Press*, July 29, 2023, https://vifreepress.com/2023/07/fema-funds-first-of-its-kind-effort-to-rebuild-puerto-rican-coral-reefs/.

In April 2023, the Governor issued Executive Order OE-2023-009, declaring a state of emergency due to the escalating impacts of coastal erosion.[153] This declaration identified coastal erosion as one of the most imminent risks to Puerto Rico, driven by changing climatic conditions and sea level rise.[154] The order cites incalculable economic and patrimonial losses (i.e., losses involving property, infrastructure, and cultural assets) affecting critical infrastructure, entire coastal communities, natural coastal barriers, and beaches and tourism assets. In conjunction with the emergency declaration, the Government of Puerto Rico allocated $105 million in federal funds to implement nearly two dozen mitigation measures aimed at reducing erosion impacts.[155] These include the relocation of vulnerable homes, the construction of artificial reefs, mangrove restoration, and beach nourishment projects.

SIGNIFICANT EVENTS

Hurricanes are the primary natural force that most significantly impacts coastal areas and rapidly drives coastal change. They bring not only strong winds, but also heavy rainfall, storm surges, and high waves—all of which pose serious hazards to coastlines. The magnitude of coastal changes caused by hurricanes depends on both the storm's category and its path. As shown in Figure 58, Hurricane Georges (1998, Category 2–3), Hurricane Maria (2017, Category 4), and Hurricane Hugo (1989, Category 3) have had the greatest impact on coastal infrastructure, resulting in millions of dollars in economic losses and substantial changes to the coastline. For example, Figure 59 illustrates the shoreline changes at a beach in the municipality of Rincón between 2006 (prior to Hurricane Maria) and 2018 (after the hurricane). The dramatic sediment movement is clearly visible, highlighting the significant transformation of the beach.[156] Another example is the shoreline changes observed in Cabo Rojo (see Figure 60).

[153] AP, "Puerto Rico Declares State of Emergency on Coastal Erosion," https://apnews.com/article/puerto-rico-coastal-erosion-state-emergency-1cb74408d61a3feab6480efa69f94d0f; and US Harbors, "Puerto Rico Declares State of Emergency on Coastal Erosion," April 14, 2023, https://www.usharbors.com/2023/04/puerto-rico-declares-state-of-emergency-on-coastal-erosion/.
[154] Government of Puerto Rico, *Executive Order OE-2023-009: Declaring an Emergency as a Result of the Effects of Coastal Erosion*, April 11, 2023, https://docs.pr.gov/files/Estado/OrdenesEjecutivas/2023/OE-2023-009.pdf.
[155] US Harbors, "Puerto Rico Declares State of Emergency on Coastal Erosion," April 14, 2023, https://www.usharbors.com/2023/04/puerto-rico-declares-state-of-emergency-on-coastal-erosion/.
[156] U.S. Geological Survey, *Shoreline Changes in Puerto Rico*, https://geonarrative.usgs.gov/puertoricoshorelinechange/.

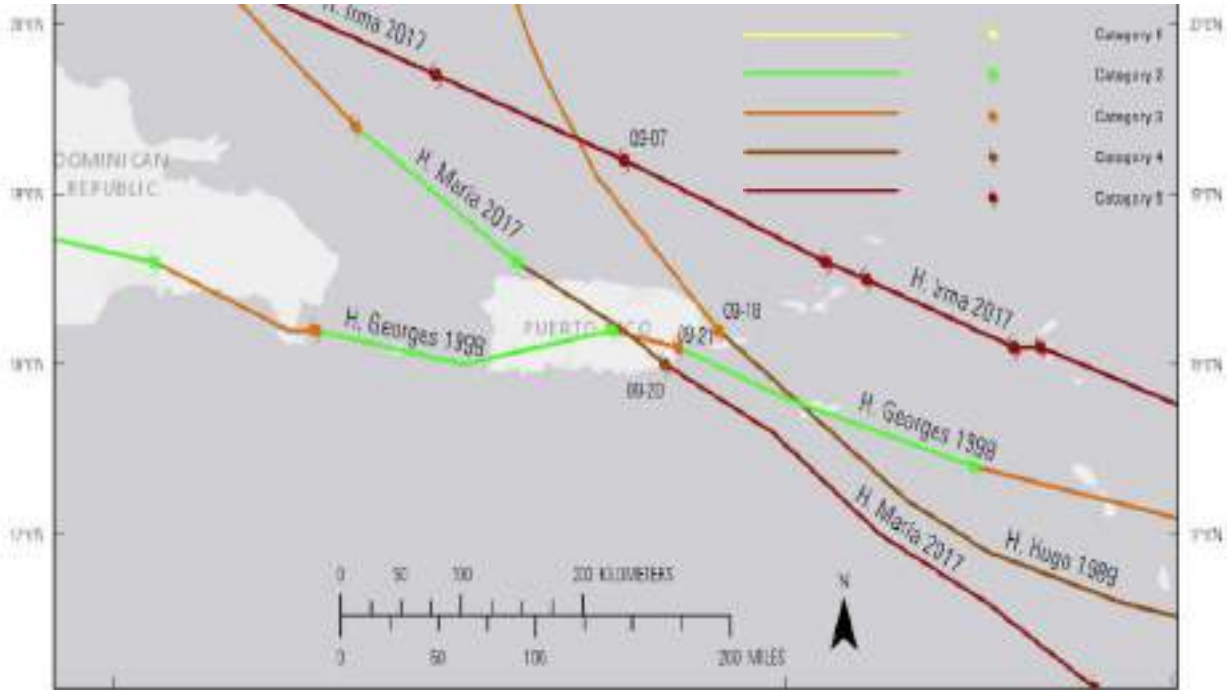


Figure 58: Hurricane Historic Tracks in Puerto Rico for Hugo, Georges, Maria, and Irma[157]

Figure 59: Rincón Beach, 2006 (*Top*); Rincón Beach After Hurricane Maria, 2018 (*Bottom*)[158]

[157] U.S. Geological Survey, *Shoreline Changes in Puerto Rico*, https://geonarrative.usgs.gov/puertoricoshorelinechange/.

[158] U.S. Geological Survey. (2025). *Puerto Rico shoreline change geonarrative*. U.S. Department of the Interior. Retrieved September 26, 2025, from https://geonarrative.usgs.gov/puertoricoshorelinechange/.

Figure 60: *(Left)* Cabo Rojo Beach, 2006; *(Right)* Cabo Rojo Beach After Hurricane Maria, 2018[159]

Puerto Rico has endured several devastating hurricanes that have shaped its approach to hazard mitigation and floodplain management. Hurricanes Hugo, Georges, Irma, and Maria each caused widespread destruction, particularly in coastal areas. Hugo (Category 2) destroyed 80% of wooden structures on Culebra and Vieques and displaced over 30,000 people. Georges (also Category 2) revealed the vulnerability of informally constructed buildings and led to the adoption of the 1997 Uniform Building Code and the New Secure Housing Project, which relocated homes from flood-prone areas and built 1,647 code-compliant units that later proved resilient during subsequent storms.[160]

[159] U.S. Geological Survey. (2025). *Puerto Rico shoreline change geonarrative*. U.S. Department of the Interior. Retrieved September 26, 2025, from https://geonarrative.usgs.gov/puertoricoshorelinechange/.
[160] FEMA, *Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials*, FEMA Publication No. 480 (2005), https://www.fema.gov/sites/default/files/documents/fema-480_floodplain-management-study-guide_local-officials.pdf.

Figure 61: Puerto Rico Landscape Ravaged by Hurricane Maria[161]

Hurricanes Irma and Maria in 2017 were especially catastrophic. Irma, a Category 5 storm, skirted Puerto Rico, causing wind gusts of over 120 mph and heavy rainfall. Just two weeks later, Maria made direct landfall as a Category 4 hurricane, bringing sustained winds of 155 mph, 38 inches of rain, and a storm surge over 6 feet. The combined impact left most of the island without power for months and severely damaged infrastructure and housing. These hurricanes highlighted the importance of resilient building practices and reinforced the need for effective floodplain management strategies, especially in coastal zones where erosion and storm surge amplify flood risks.[162]

Mangroves have historically played a vital role in protecting Puerto Rico's coastline by acting as natural buffers that stabilize soil, reduce erosion, and mitigate the impact of storm surges. However, over the past decades, these critical ecosystems have faced significant degradation due to urban development, pollution, and extreme weather events—most notably Hurricane Maria in 2017. The destruction of mangrove forests has directly contributed to increased coastal erosion and heightened vulnerability for shoreline communities.

Recognizing the importance of mangroves in coastal resilience, Puerto Rico has initiated restoration efforts aimed at replanting and rehabilitating these habitats. These initiatives not only help reduce erosion and

[161] NASA Earth Observatory, "Puerto Rico Landscape Ravaged by Hurricane Maria," September 26, 2017, https://earthobservatory.nasa.gov/images/91030/puerto-rico-landscape-ravaged-by-hurricane-maria.
[162] FEMA, *Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials*, FEMA Publication No. 480 (2005), https://www.fema.gov/sites/default/files/documents/fema-480_floodplain-management-study-guide_local-officials.pdf.

protect infrastructure but also improve water quality and enhance carbon sequestration, contributing to broader climate mitigation goals.

Coastal erosion, as detailed in FEMA's floodplain management study guide, is a significant hazard in flood-prone areas like Puerto Rico. It results from the dynamic interaction of waves, currents, and storm surge, which can undermine foundations and alter floodplain boundaries over time. FEMA emphasizes that erosion control is a natural and beneficial function of floodplains, but development in these areas must consider erosion risks. The study guide outlines strategies such as modifying human susceptibility to flood damage and preserving natural resources to mitigate these impacts. Puerto Rico's hurricane experiences underscore the critical role of integrating erosion considerations into floodplain management and building codes to enhance long-term resilience.[163]

Coastal erosion is a persistent and long-term hazard shaped by both natural forces—such as wave action, tides, and storm surges—and human activities like shoreline development and infrastructure placement. In Puerto Rico, this hazard became especially evident following Hurricanes Irma and Maria, which exposed the vulnerability of coastal communities to erosion and wave-induced damage. This profile focuses exclusively on coastal erosion; therefore, the only type of flooding considered is coastal flooding—specifically how wave energy contributes to shoreline change. Inland flooding is excluded from this analysis, as the intent is to understand and mitigate the direct impacts of oceanic forces on coastal landforms and infrastructure.[164]

Potential Severity of Event

To estimate the severity of coastal erosion, FEMA and USGS employ both empirical and process-based models to quantify erosion.

- **Empirical Geometric Models:** These rely on historical beach profiles and storm data to estimate erosion extents. Some of the geospatial tools and remote sensing technologies used include the following:
  - **DSAS:** A GIS-based tool that calculates shoreline change rates using historical data. Key metrics include the following:
    - End Point Rate (EPR): Measures the change between two shoreline positions over time.
    - Linear Regression Rate (LRR): Uses a best-fit line through multiple shoreline positions to determine the average change.

[163] FEMA, *Hurricanes Irma and Maria in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance*, FEMA P-2020 (October 2018), https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf.
[164] FEMA, *Hurricanes Irma and Maria in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance*, FEMA P-2020 (October 2018), https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf; and *National Flood Insurance Program (NFIP) Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials*, FEMA 480 (2005), https://www.fema.gov/sites/default/files/documents/fema-480_floodplain-management-study-guide_local-officials.pdf.

    - Weighted Linear Regression (WLR): Similar to LRR but accounts for positional uncertainty.
    - Remote Sensing and CoastCams: Provide real-time monitoring of coastal features such as sandbars and bluffs.[165]
- **Process-Based Models:** These simulate physical processes such as wave action, storm surge, and sediment transport to predict erosion outcomes.[166]

In long-term hazards such as coastal erosion, magnitude is typically assessed through long-term shoreline change rates and vulnerability to sea-level rise. The USGS Coastal Change Hazards Portal and related programs provide tools and data to assess these risks, helping planners and communities make informed decisions to enhance coastal resilience.

Estimating intensity from magnitude in coastal erosion is challenging, as intensity is more closely associated with storm-related variables, while magnitude reflects slower, long-term processes. For example, a high-intensity hurricane may cause less severe erosion in areas with robust mitigation structures, while a lower-intensity storm could result in significant damage in poorly protected regions.[167]

To measure shoreline change, the study used thousands of transects—straight lines drawn perpendicular to a baseline that runs parallel to the general trend of the coast. These transects intersect historical shoreline positions, allowing researchers to calculate how far the shoreline has moved landward (erosion) or seaward (accretion) over time. Each transect serves as a fixed measurement point, and the change in shoreline position along these lines is used to compute erosion or accretion rates. This method provides a consistent and spatially distributed framework for analyzing shoreline dynamics across different regions.

Transects are critical because they allow for a standardized, repeatable method of measuring shoreline movement across time and space. By anchoring measurements to fixed baselines and intersecting them with historical shoreline data, scientists can quantify change rates with high spatial resolution. This approach is especially valuable in regions like Puerto Rico, where coastal morphology varies significantly and localized erosion patterns can differ from broader trends (see Figure 62).

[165] U.S. Geological Survey, *Open-File Report 2021–1056: Rigorously Valuing the Impact of Hurricanes Irma and Maria on Coastal Hazard Risk in Florida and Puerto Rico*, 2021, https://pubs.usgs.gov/of/2021/1056/ofr20211056.pdf.
[166] FEMA, *Coastal Construction Manual*, August 2011, https://www.fema.gov/sites/default/files/2020-08/fema55_voli_combined.pdf.
[167] FEMA, *Hurricanes Irma and Maria in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance*, FEMA P-2020 (October 2018), https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf.

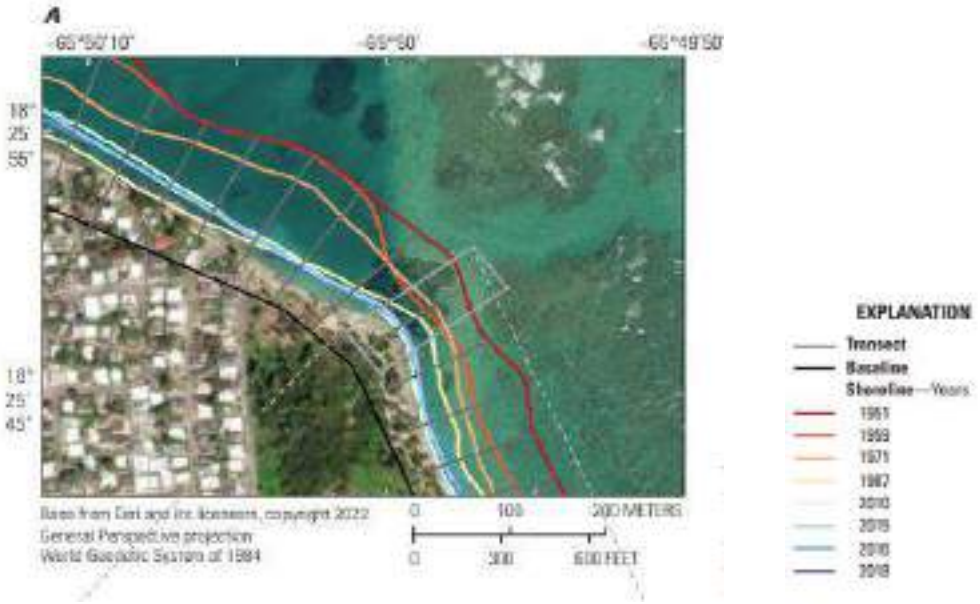


Figure 62: Shoreline Change at Punta Uvero, Loíza[168]

Figure 63 from the FEMA report illustrates the concept of 30-year and 60-year erosion limits, which are used to estimate future shoreline retreat due to long-term erosion processes. These limits are calculated by multiplying the annual average erosion rate by either 30 or 60 years, depending on the planning horizon. For example, if a coastal area experiences an average erosion rate of 2 feet per year, the 30-year erosion limit would be 60 feet inland from the current shoreline, and the 60-year limit would be 120 feet. These projections help identify areas at risk of future erosion and inform land-use planning, building setbacks, and hazard mitigation strategies. The figure visually represents how these erosion limits are mapped inland from the current shoreline to delineate zones of potential future loss, guiding decisions about construction and development in coastal hazard areas.

[168] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (2024), https://doi.org/10.3133/dr1191; and U.S. Geological Survey, *Shoreline Changes in Puerto Rico*, https://geonarrative.usgs.gov/puertoricoshorelinechange/.

Figure 63: 30- and 60-Year Erosion Zones in Rincon[169]

In addition to hurricanes, tides play an important role in the natural process of erosion. The Moon has the greatest influence on ocean tides, especially when it is closest to Earth—a phenomenon known as lunar perigee. When lunar perigee coincides with the alignment of the Earth, Moon, and Sun, it generates higher-than-normal tides called *perigean spring tides*. These elevated tides can intensify wave action and accelerate shoreline retreat, as illustrated in areas like Playa de la Boca (see Figure 64). Another factor that can affect the rate of coastal erosion is the local geology, including topography, rock structure, and the type of sediment that composes the beach.[170]

[169] FEMA, *Hurricanes Irma and Maria in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance*, FEMA P-2020 (October 2018), https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf; and M. Barreto-Orta, R. Méndez-Tejeda, E. Rodríguez, N. Cabrera, E. Díaz, and K. Pérez, "The State of the Beaches at Puerto Rico after Maria," *ResearchGate*, March 2019, https://www.researchgate.net/publication/332061474_The_state_of_the_beaches_at_Puerto_Rico_after_Maria.
[170] U.S. Geological Survey, "Plate 2: Coastal Change Hazards—Hurricanes and Extreme Storms," n.d., retrieved September 8, 2025, from https://pubs.usgs.gov/unnumbered/32506/plate-2.pdf.

Figure 64: Coastal Damage at Playa de la Boca, Barceloneta[171]

Figure 65 illustrates one of the worst-case scenarios that could occur in Puerto Rico: the aftermath of Hurricane Maria and its devastating impact on the Barceloneta shoreline. The storm caused severe erosion, loss of beach width, and damage to coastal infrastructure—highlighting the vulnerability of this area to extreme weather. Similar impacts are likely during the next major storm that approaches the island.[172]

Figure 65: Shoreline Changes at Playa La Boca, Barceloneta, March–September 2017[173]

Probability of Future Hazard Events

Long-term progressive hazards such as coastal erosion require different approaches to measure frequency of occurrence, since intensity and magnitude are not strictly linked to coastal erosion but instead result from the cumulative effects of many different natural hazards over extended timeframes. Unlike flooding or earthquakes, which are episodic and often abrupt, coastal erosion is typically a gradual and cumulative

[171] CoRePI-PR, "El estado de las playas de Puerto Rico Post-María," https://corepipr.uprrp.edu/.
[172] CoRePI-PR, "El estado de las playas de Puerto Rico Post-María," https://corepipr.uprrp.edu/.
[173] CoRePI-PR, "El estado de las playas de Puerto Rico Post-María (Grupo 1)," https://storymaps.arcgis.com/stories/dfb5b1a22af6440b809cde3aac482b42.

process. It lacks a discrete "event" that can be modeled with return periods or exceedance probabilities however, given the long-term and gradual nature which unfolds over time, this hazard has a **high** probability of occurring in the future in Puerto Rico.

For example, the coastal erosion approach in the *USGS Data Report 1191* for Puerto Rico is analyzed using a spatial and temporal shoreline change methodology.[174] The report compiles historical shoreline positions from the early 1900s to 2018 using aerial imagery, lidar data, and topographic surveys. These shorelines are processed through the DSAS to calculate erosion and accretion rates across different regions.[175]

The study divides Puerto Rico into five coastal regions plus the islands of Vieques and Culebra (as seen earlier in Figure 53), and classifies shorelines into four types: beach, vegetation, rocky, and human-engineered. The erosion rates are influenced by factors such as wave energy, coastal development, and storm impacts—especially from Hurricanes Irma and Maria. This approach helps identify vulnerable areas and supports hazard mitigation planning. The Puerto Rico Planning Board provided data for 30 year and 60 year risk projections for coastal erosion. These projections, shown in Figure 66, show that most of the coastline is expected to experience effects of coastal erosion in the next 30-60 years.

[174] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.
[175] R. E. Henderson, J. L. Heslin, E. A. Himmelstoss, and M. Barreto-Orta, *National Shoreline Change—Summary Statistics for Vector Shorelines from the Early 1900s to the 2010s for Puerto Rico*, U.S. Geological Survey Data Report 1191 (Reston: VA: U.S. Geological Survey, 2024), https://doi.org/10.3133/dr1191.

Figure 66: Coastal Erosion Risk Projections

With over 1,225 beaches spread across 44 coastal municipalities, Puerto Rico is a paradise shaped by the sea—but also threatened by it. Once viewed as a slow-moving hazard, coastal erosion has become a daily reality for thousands of residents living just meters from the shoreline. The beaches that once offered protection, recreation, and ecological richness are now shrinking, retreating, and, in some cases, disappearing. Figure 67 illustrates shoreline change in Punta Uvero, Loíza, between 1950 and 2015.[176]

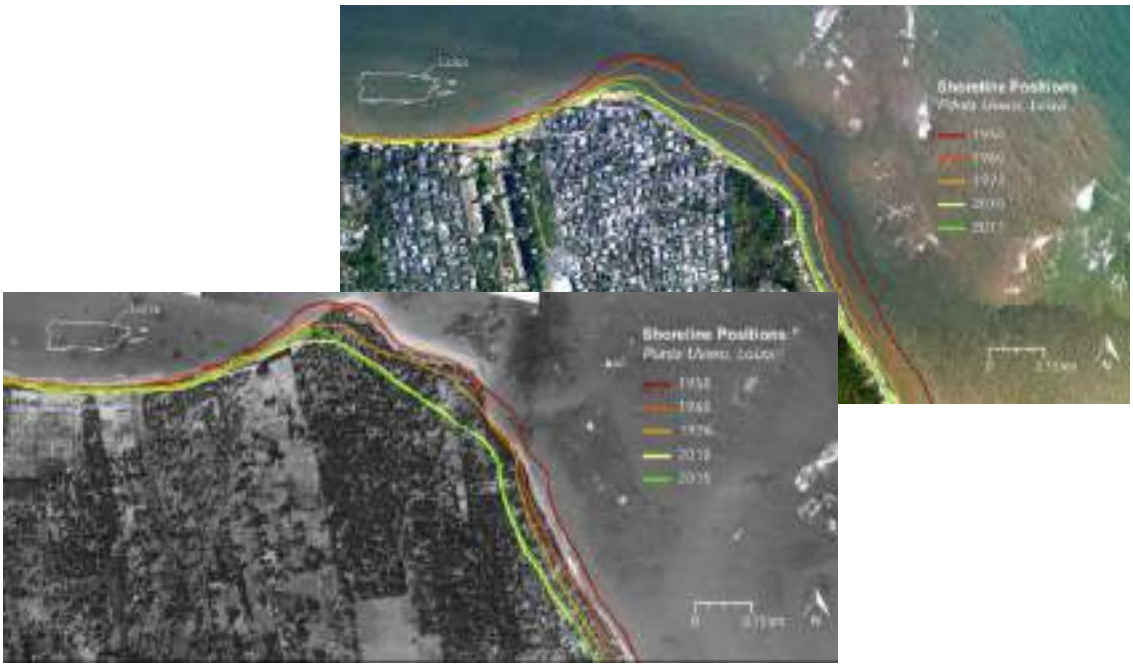


Figure 67: 2015 Shoreline Changes in Loíza (*top*); 1950 Aerial Photo Shoreline (*bottom*)

In response to the growing crisis of coastal erosion, the Coastal Research and Planning Institute of Puerto Rico (CoRePI-PR) launched a comprehensive project to assess the geomorphic conditions of the island's beaches following Hurricane Maria in 2017. Supported by FEMA's Hazard Mitigation Grant Program (HMGP FEMA-4339-DR-PR), the project analyzed beach changes across Puerto Rico using high-resolution mapping and field data collected between September 2017 and July 2018. The study categorized shorelines into four groups, applied across the five previously identified coastal regions.

Vulnerability Assessment

Coastal infrastructure, communities, and shorelines in Puerto Rico are highly exposed to erosion. Figure 68 confirms Puerto Rico's shoreline vulnerability, illustrating significant changes across nearly all time periods over the past century. As noted earlier, this is due to a variety of factors outlined in this section.

[176] U.S. Geological Survey, *Coastal Change*, https://www.usgs.gov/centers/pcmsc/science/coastal-change; and *Shoreline Changes in Puerto Rico*, https://geonarrative.usgs.gov/puertoricoshorelinechange/.

Figure 68: Coastal Changes in Puerto Rico from 1901 to 2018[177]

Given that this hazard mitigation plan operates at the statewide scale, the vulnerability of coastal communities and infrastructure is addressed primarily through other natural hazards—namely flooding and hurricanes. These hazards are not only the main contributors to coastal erosion, but also the primary threats facing communities and infrastructure in Puerto Rico. Therefore, in this context, vulnerability will be described in terms of shoreline characteristics that can help reduce the rate of erosion.

Additionally, the type and rate of coastal erosion largely depend on the characteristics of the shoreline, which typically fall into two categories: sandy coasts and rocky coasts. Sandy coasts are more vulnerable to sea-level rise, wave action, and storm events. In contrast, rocky coasts are more resistant to these forces, which slows the pace of erosion. However, because coastal erosion is a long-term process, it continues to occur even in rocky areas—just at a slower rate.[178]

[177] U.S. Geological Survey, *Shoreline Changes in Puerto Rico*, https://geonarrative.usgs.gov/puertoricoshorelinechange/.
[178] U.S. Geological Survey, "Plate 2: Coastal Change Hazards—Hurricanes and Extreme Storms," n.d., https://pubs.usgs.gov/unnumbered/32506/plate-2.pdf.

Figure 69: Coastal Types in Puerto Rico[179]

Figure 70 depicts the impact of a storm on a barrier island. As expected, the extent of the impact depends on the magnitude and intensity of storm characteristics—such as storm surge and wave height—as well as the barrier island's elevation. Figure 70 outlines four stages of coastal storm impact, each determined by the severity of the storm and the elevation of the shoreline. The four stages are defined as follows[180]:

- **Swash:** Total water levels remain below the dune base.
- **Collision:** Total water levels exceed the base of the dune.
- **Overwash:** Total water levels exceed the dune crest, causing erosion.
- **Inundation:** Storm surge and tides exceed the dune crest, completely altering the shoreline's morphology.

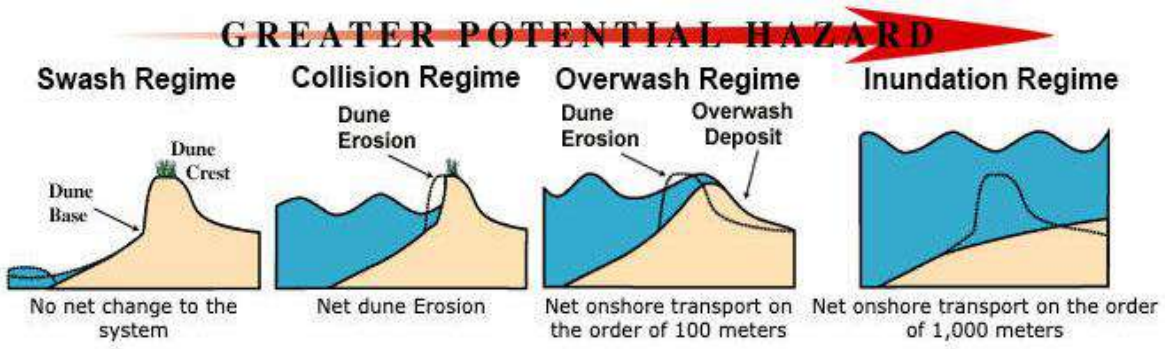


Figure 70: Coastal Storm Impact Regimes[181]

[179] CoRePI-PR, "El estado de las playas de Puerto Rico Post-María (Grupo 1)," https://storymaps.arcgis.com/stories/dfb5b1a22af6440b809cde3aac482b42; and U.S. National Park Service, *Coastal Processes—Erosion*, https://www.nps.gov/articles/coastal-processes-erosion.htm.

[180] U.S. Geological Survey, *Storm-Impact Scale*, n.d., https://www.usgs.gov/centers/spcmsc/science/storm-impact-scale.

[181] *(Left)* Sandy Coast – Playa Flamenco, Culebra; *(Right)* Rocky Coast – Maunabo, Puerto Rico

To expand on the role of shoreline characteristics in coastal vulnerability, research by the USGS and the National Oceanic and Atmospheric Administration found that hurricanes caused significant damage to coral reefs, which serve as natural barriers against wave energy. The loss of reef structure resulted in a measurable increase in coastal flooding risk, with more people, buildings, and infrastructure exposed to storm surge hazards. For example, in eastern San Juan, the 100-year floodplain expanded due to reef degradation, increasing coastal community vulnerability.[182]

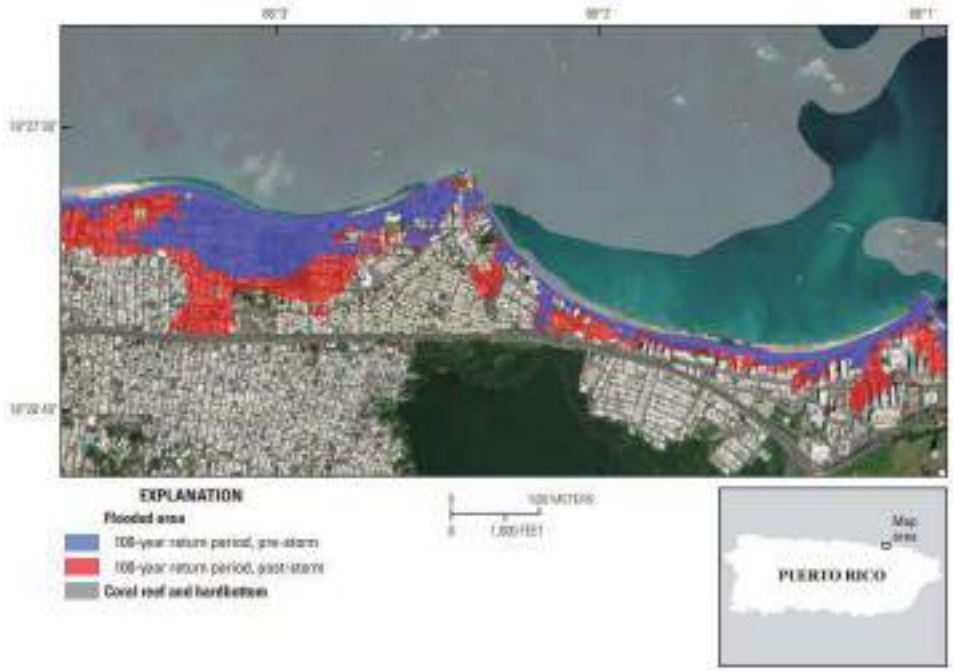


Figure 71: 100-Year Floodplains for Pre- and Post-Storm Coral Reef Conditions, Eastern San Juan[183]

In sum, coastal vulnerability depends on several factors that can reduce the severity of erosion, including the type of coastline, existing infrastructure, and coastal recovery programs. These programs not only slow the pace of erosion but also help mitigate the impacts of other hazards, such as flooding.

LOCATIONS

As an island, the entire territory of Puerto Rico is highly vulnerable to hydrometeorological hazards. Figure 72 shows that multiple critical infrastructure assets are located along the coast, where exposure to flooding and storm surge is more likely. Although the VE Zone—a coastal flood zone with additional hazard from wave action—is largely undeveloped, the proximity of critical infrastructure to flood-prone areas highlights

U.S. Geological Survey, *Storm-Impact Scale*, n.d., https://www.usgs.gov/centers/spcmsc/science/storm-impact-scale.
[182] C. D. Storlazzi, B. G. Reguero, T. S. Viehman, K. A. Cumming, A. D. Cole, J. B. Shope, S. H. Groves, C. L. Gaido, B. A. Nickel, and M. W. Beck, *Rigorously Valuing the Impact of Hurricanes Irma and Maria on Coastal Hazard Risks in Florida and Puerto Rico*, Open-File Report 2021–1056 (U.S. Geological Survey, 2021), https://doi.org/10.3133/ofr20211056.
[183] C. D. Storlazzi, B. G. Reguero, T. S. Viehman, K. A. Cumming, A. D. Cole, J. B. Shope, S. H. Groves, C. L. Gaido, B. A. Nickel, and M. W. Beck, *Rigorously Valuing the Impact of Hurricanes Irma and Maria on Coastal Hazard Risks in Florida and Puerto Rico*, Open-File Report 2021–1056 (U.S. Geological Survey, 2021), https://doi.org/10.3133/ofr20211056.

the importance of preserving and improving coastal health systems. Strengthening these systems can provide more defensive elements against hurricanes and flooding, enhancing overall community resilience.

Figure 72: Critical Facilities in Coastal Erosion Risk Areas[184]

[184] Government of Puerto Rico, *MIPR GIS Portal*, https://gis.jp.pr.gov/mipr/.

POPULATIONS

In Puerto Rico, where 62% of the population resides in coastal municipalities, the threat of coastal erosion is not just environmental—it is deeply social and economic. Rising sea levels, coastal development, and weakened environmental protections have left thousands exposed to flooding, infrastructure loss, and displacement.[185]

Figure 73 shows the predominant categories of social vulnerability across municipalities, based on 2022 Community Resilience Estimate data for Puerto Rico.[186] Areas shaded in dark orange represent populations experiencing three or more components of social vulnerability, while yellow areas indicate one to two components. This widespread vulnerability, especially in regions with limited infrastructure, underscores the urgent need for a multi-risk reduction approach.

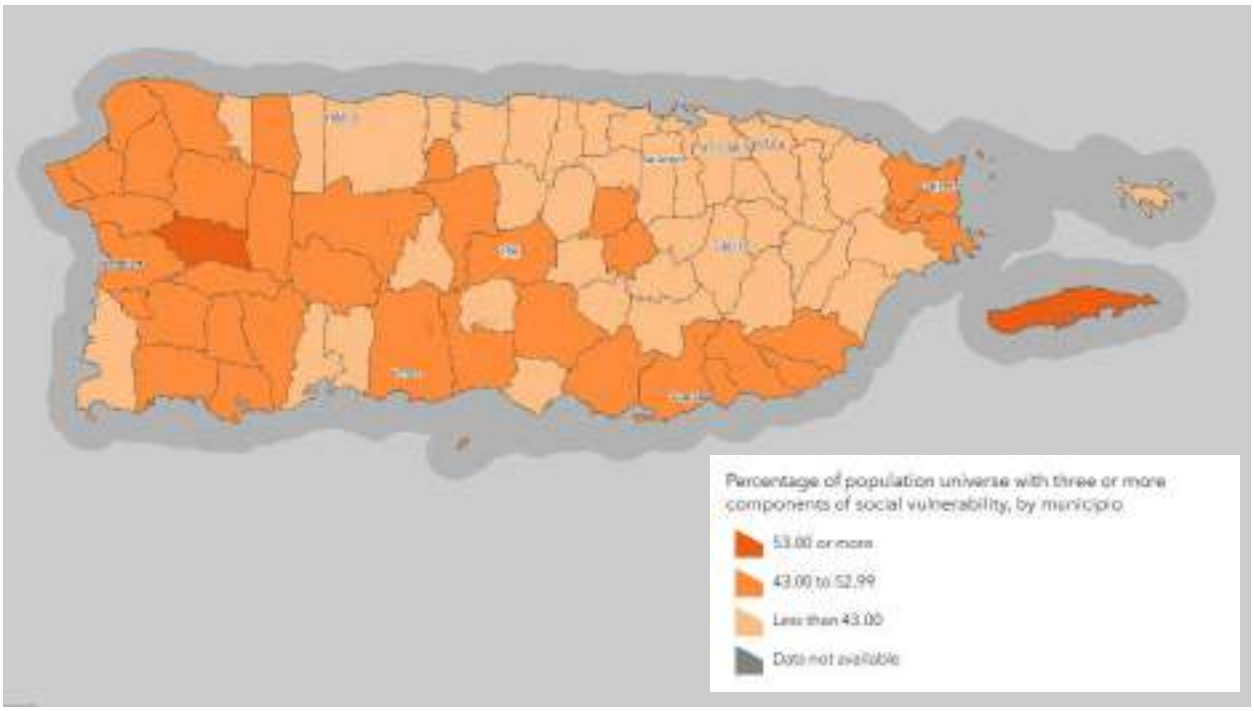


Figure 73: Social Resilience in Puerto Rico by Municipio

Puerto Rico's limited adaptive capacity, exacerbated by high poverty rates, under-resourced institutions, and aging infrastructure, makes the island particularly vulnerable to natural hazards such as hurricanes, earthquakes, floods, and coastal erosion. Coastal erosion, driven by different types of hydrometeorological storms, poses a growing threat to densely populated shoreline communities and critical lifeline infrastructure, including transportation, water systems, and healthcare facilities. These risks are compounded by socioeconomic vulnerabilities and uneven access to resources, which hinder recovery and

[185] International Collective in Support of Fishworkers, "Erosion Threatens Western Puerto Rico Region's Postal Communities,". (n.d.), https://icsf.net/newss/erosion-threatens-western-puerto-rico-regions-coastal-communities/.
[186] US Census Bureau, "Community Resilience Estimates for Puerto Rico Viewer," 2023, https://mtgis-portal.geo.census.gov/arcgis/apps/experiencebuilder/experience/?id=e851575739ca4b4281037d92cc62cbd4.

resilience efforts. Addressing these overlapping social, environmental, and infrastructural challenges is essential to reduce future economic losses, protect public health, and safeguard human lives.[187]

A recent article from *El Nuevo Día* emphasizes this concern, noting that 44 coastal municipalities in Puerto Rico are facing the reality that "the sea is rising and it's not going to stop." Experts warn that some structures already impacted by erosion may need to be abandoned or rebuilt entirely, highlighting the urgency of proactive planning and mitigation.[188]

Coastal municipalities, where a significant portion of the population resides, tend to be socially vulnerable. While this analysis does not directly measure vulnerability to coastal erosion, the high levels of social vulnerability in these areas underscore the need for further studies focused on erosion-related risks. The Community Resilience Estimates developed by the U.S. Census Bureau show that nearly half of Puerto Rico's population has three or more risk factors that make recovery from disasters, including damage from coastal erosion, more difficult. These include poverty status, unit-level crowding, lack of vehicle access, and lack of broadband internet. All municipalities—and 87% of census tracts—across the island exhibit higher social vulnerability than the U.S. average.

STRUCTURES INCLUDING CRITICAL FACILITIES

Figure 72, located earlier in the section, highlights the shoreline locations of critical communication, transportation, and public safety infrastructure, which are essential to Puerto Rico's economy. Figure 74 shows the locations of hospitals and power plants, many of which are near the coast. While these assets are assessed in other sections of the report, their placement along the coast underscores the importance of protecting Puerto Rico's coastal zones. Coastal erosion can also result as a cascading hazard as a result of flooding, high-winds, or storm surge which may intensify impacts on already vulnerable structures and infrastructure.

[187] International Collective in Support of Fishworkers, "Erosion Threatens Western Puerto Rico Region's Postal Communities,". (n.d.), https://icsf.net/newss/erosion-threatens-western-puerto-rico-regions-coastal-communities/.
[188] Pérez, Sharon Minelli, "'The sea is rising and it won't stop': a call for a climate change summit in Puerto Rico," El Nuevo Dia, March 11, 2025, https://www.elnuevodia.com/english/business/notas/the-sea-is-rising-and-it-wont-stop-a-call-for-a-climate-change-summit-in-puerto-rico/.

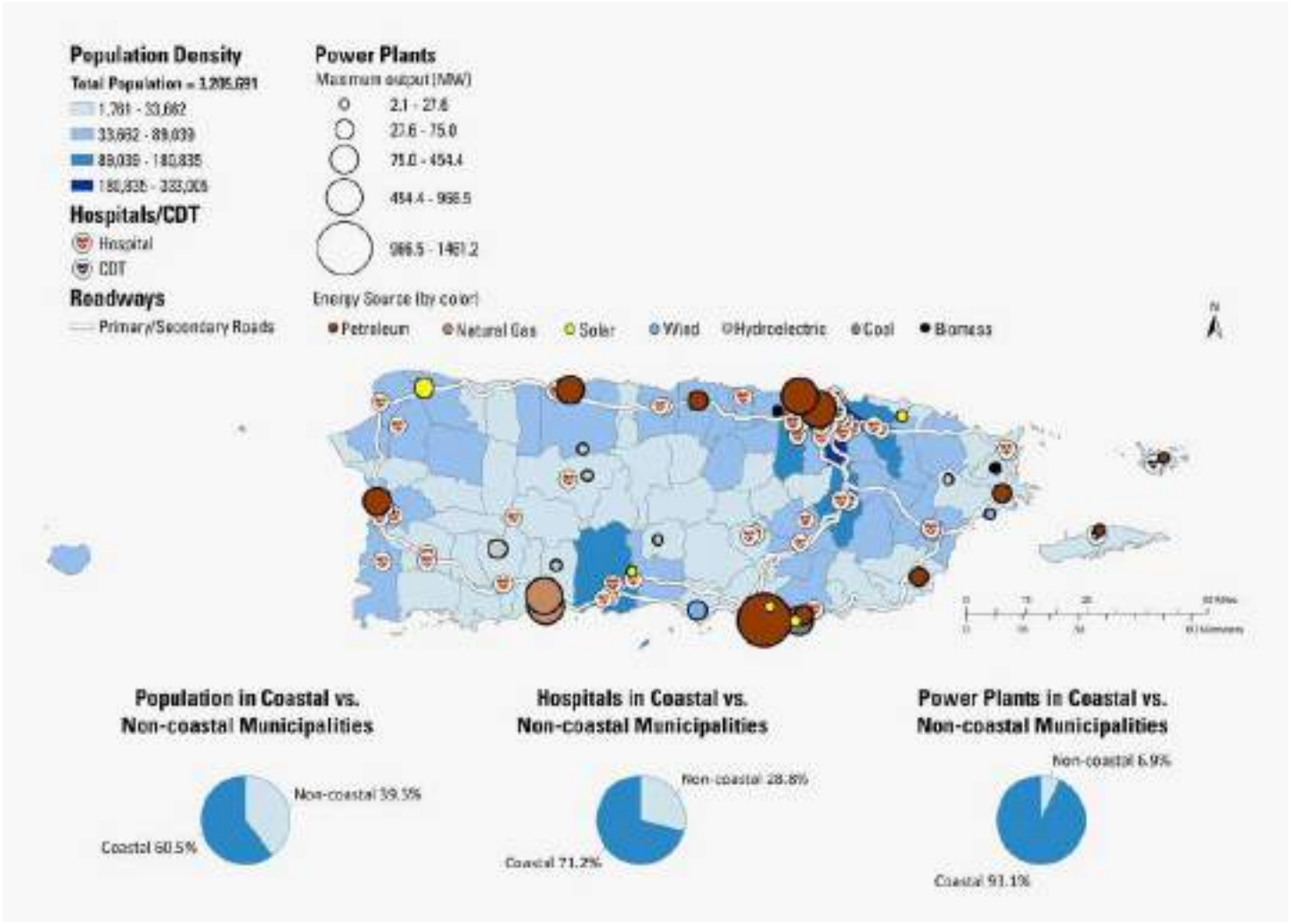


Figure 74: Coastal Vulnerability and Critical Infrastructure Distribution in Puerto Rico[189]

[189] U.S. Geological Survey, "Puerto Rico Coastal Vulnerability Map," https://www.usgs.gov/media/images/puerto-rico-coastal-vulnerability-map.

INFRASTRUCTURE AND COMMUNITY LIFELINES

As an island, Puerto Rico's shorelines serve as the first line of defense against natural hazards such as coastal flooding and hurricanes. These hazards frequently impact the island due to its geographic location in the Caribbean, making coastal resilience a vital concern. Moreover, the infrastructure located along the shoreline and nearby areas is highly valuable. A significant portion of Puerto Rico's Gross Domestic Product (GDP) is generated in these coastal zones, through sectors such as tourism, energy, transportation, and commerce.

Figure 74 presents a detailed map of Puerto Rico showing the distribution of population density, hospitals/CDTs (Diagnostic and Treatment Centers), power plants, and roadways. By comparing coastal and non-coastal municipalities, it is evident that vulnerability in coastal Puerto Rico is high. The clustering of hospitals, power plants, and dense populations in vulnerable coastal areas underscores the urgency of effective hazard mitigation planning.[190]

The figure provides a comprehensive overview of key infrastructure and population distribution, with a particular emphasis on coastal areas. Puerto Rico has a total population of 3,205,691, with density varying significantly across regions—from sparsely populated zones with 1,761 residents to highly concentrated areas reaching up to 333,005, such as the San Juan metro area.

Energy infrastructure is mapped by power plant output, ranging from 2.1 MW to 1461.2 MW, and categorized by energy sources: petroleum (brown), natural gas (yellow), solar (orange), wind (green), hydroelectric (blue), coal (black), and biomass (purple). Healthcare facilities are marked with symbols distinguishing hospitals (red hearts) and CDTs (blue hearts). The transportation network is represented by primary and secondary roadways.

At the bottom of the map, three pie charts highlight the concentration of infrastructure in coastal municipalities:

- **Population:** 60.5% of residents live in coastal areas.
- **Hospitals:** 71.2% are located in coastal municipalities.
- **Power Plants:** A striking 93.1% are situated near the coast.

This data points to a critical insight: Puerto Rico's physical infrastructure is highly vulnerable to coastal hazards, including hurricanes, flooding, and ongoing coastal changes. While these infrastructures may not be directly affected by coastal erosion, their proximity to the shoreline makes them susceptible to indirect impacts such as service disruptions, limited access, and increased exposure to extreme weather events. This underscores the urgent need to integrate coastal dynamics into hazard mitigation and infrastructure planning to enhance resilience and reduce risk.

[190] U.S. Geological Survey, "Puerto Rico Coastal Vulnerability Map," https://www.usgs.gov/media/images/puerto-rico-coastal-vulnerability-map.

Impact Assessment

Figure 75 illustrates the economic vulnerability of Puerto Rico's coastal zones by estimating the replacement cost of assets located in areas at risk of shoreline retreat. Regions with dense development, such as the North and metropolitan San Juan show the highest exposure, reflecting the concentration of housing, infrastructure, and critical facilities near the coast. These values underscore the need for resilient construction standards and nature-based mitigation strategies to reduce future economic losses.

STATE ASSETS

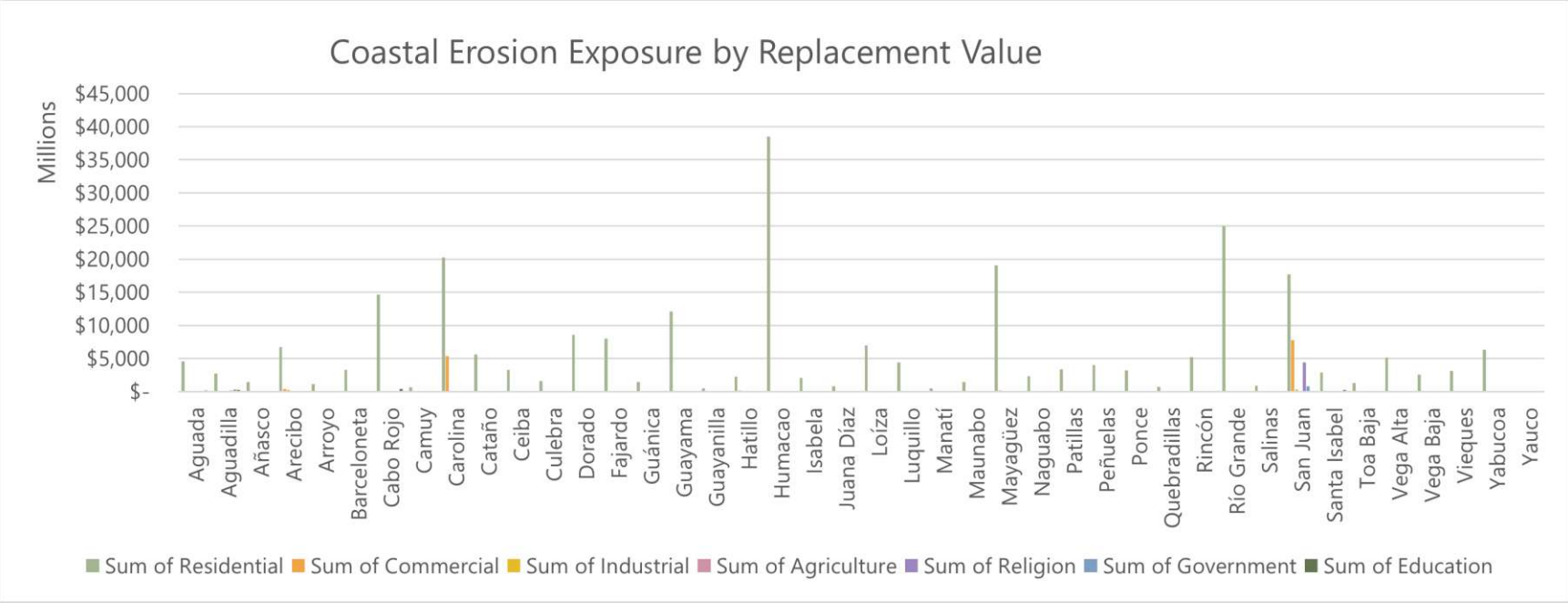


Figure 75: Coastal Erosion Replacement Value by Municipality

In addition to traditional assets, coral reefs are an important resource that can help reduce coastal erosion. The degradation of coral reefs poses a significant threat to Puerto Rico's coastal resilience, with serious implications for economic stability and public safety. Coral reefs act as natural breakwaters, dissipating wave energy before it reaches the shore. Without these vital ecosystems, flood risks increase dramatically. A 1-meter loss in reef height could expand the 100-year floodplain across the United States by 104 km^2, placing an additional 51,000 people and $5 billion in property and economic activity at risk. In Puerto Rico alone, coral reefs annually protect $184 million worth of buildings and economic activity. Their absence would expose coastal communities to more frequent and severe flooding, compounding the economic burden from storm damage and recovery costs.[191]

Coral reefs in Puerto Rico play a critical role in reducing coastal erosion and flood risk, especially during storms and hurricanes. Acting like submerged breakwaters, they dissipate wave energy offshore, significantly lowering the impact on coastal infrastructure and communities.[192] According to the USGS, coral reefs annually protect over 4,200 people and help avert $184 million in damages to buildings and economic activity across Puerto Rico and contribute to $1.8 billion in flood protection benefits nationwide. The coral reef protection is in specific areas of the commonwealth:[193]

- **Puerto Rico (Main Island):** $65.9 million in building protection, $117.3 million in economic activity protected.
- **Culebra:** $148,502 in building protection, $286,275 in economic activity.
- **Vieques:** $94,075 in building protection, $9,710 in economic activity.

The degradation of coastal reefs increases flood risk and exposes coastal populations to greater harm. However, while coral reefs are a highly effective natural solution, their protective function should be complemented by other measures in areas where infrastructure and population density are high, including the following:

- Sand beach restoration
- Wave breakers
- Seawalls or other engineered barriers

The following data illustrates the potential consequences of coral reef degradation on flood risk and economic vulnerability in Puerto Rico.

- A 1-meter loss in reef height could expand the 100-year floodplain by 32 km^2, putting 17,000 more people and $767 million in property and economic activity at risk.

[191] U.S. Geological Survey, "The Value of U.S. Coral Reefs for Risk Reduction," https://www.usgs.gov/centers/pcmsc/value-us-coral-reefs-risk-reduction.
[192] U.S. Geological Survey, "The Value of U.S. Coral Reefs for Risk Reduction," https://www.usgs.gov/centers/pcmsc/value-us-coral-reefs-risk-reduction.
[193] U.S. Geological Survey, "Puerto Rico Coral Reefs and Coastal Hazard Risk Reduction," https://www.usgs.gov/media/images/puerto-rico-coral-reefs-and-coastal-hazard-risk-reduction.

- Damage from hurricanes like Irma and Maria (2017) significantly reduced reef protection, increasing flood risks and economic losses.[194]

Combining natural and engineered solutions ensures a more resilient coastal defense system, especially in Puerto Rico, where much of the island's GDP and critical infrastructure are concentrated near the shoreline.

LOCAL ASSETS

Local assets across Puerto Rico's coastal municipalities are increasingly vulnerable to the impacts of coastal erosion, threatening housing, infrastructure, livelihoods, and cultural heritage.

MUNICIPAL INFRASTRUCTURE AND HOUSING

Coastal erosion has already displaced communities in municipalities such as Arecibo, where wave surges have destroyed homes and blocked roads. In Rincón, erosion is consuming approximately 1.84 meters of coastline per year, prompting local governments to consider building bans and land-use restrictions to protect vulnerable areas. [195]Critical infrastructure such as roads, bridges, wastewater systems, and public buildings in coastal zones are at risk of damage or loss due to shoreline retreat and storm surge.[196]

COMMUNITY-BASED ORGANIZATIONS AND LOCAL INITIATIVES

Local organizations are leading efforts to restore and protect coastal ecosystems. In San Juan, the Coalition for the Restoration of Santurcean Ecosystems (CRES) has implemented nature-based solutions such as mangrove reforestation and dune restoration in Punta Las Marías to combat erosion and promote climate justice. [197] In Yabucoa, the Del Monte al Mar initiative by The Nature Conservancy engages residents in watershed management and coastal protection to reduce erosion and improve water quality. [198]The nonprofit Conservación Costera Puerto Rico (CoCoPR) is also active in community-led restoration, notably in the Guajataca Tunnel area, where it promotes sustainable tourism and environmental education.

TOURISM, CULTURAL SITES, AND LIVELIHOODS

Tourism-dependent communities are particularly vulnerable. Erosion threatens beaches that serve as economic engines for municipalities such as Loíza, Isabela, and Cabo Rojo, where local businesses rely on

[194] U.S. Geological Survey, "The Value of U.S. Coral Reefs for Risk Reduction – Puerto Rico, 2," https://www.usgs.gov/media/images/value-us-coral-reefs-risk-reduction-puerto-rico-2.
[195] Rodríguez Velázquez, V. (2024, August 6). *Displaced by the waves: Communities in Arecibo battle coastal erosion*. Centro de Periodismo Investigativo. https://periodismoinvestigativo.com/2024/08/displaced-communities-arecibo-coastal-erosion/.
[196] Chase, V., Hernández, R., & Lugo, A. E. (2011). *Assessing critical infrastructure in Puerto Rico's coastal zone*. Florida Institute of Technology. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/latin-america-and-caribbean/puerto-rico-usvi-bvi/Chase-et-al.--2011.--Assessing-Critical-Infrastructure-in-Puerto-Rico-Coastal-Zone..pdf; Environmental Justice Atlas. (2023, April 25). *Building ban to face coastal erosion, Rincón, Puerto Rico*. EJAtlas. https://ejatlas.org/conflict/coastal-erosion.
[197] Climate Tracker Caribbean. (2023, October 12). *Communities lead coastal restoration in San Juan, Puerto Rico*. https://climatetrackercaribbean.org/climate-justice/communities-lead-coastal-restoration-in-san-juan-puerto-rico/
[198] The Nature Conservancy. (n.d.). *Puerto Rico: From ridge to reef*. https://www.nature.org/en-us/about-us/where-we-work/caribbean/stories-in-caribbean/puerto-rico-ridge-to-reef/.

coastal access and scenic value.[199] The loss of beaches and recreational areas not only affects tourism revenue but also undermines cultural identity and community cohesion.

LOCAL GOVERNMENT AND PLANNING CAPACITY

Many coastal municipalities lack the technical capacity and financial resources to implement long-term erosion mitigation strategies. The Sea Grant Program at the University of Puerto Rico is working to bridge this gap by providing scientific data and training to local decision-makers through the CENECCA project, which supports climate adaptation planning.[200] Other local assets including visitors and residents, structures, and infrastructure are vulnerable to coastal erosion. Additional economic and environmental impacts can fundamentally change coastal communities impacted by coastal erosion. One example of the impacts of coastal erosion on local communities and assets which reflects local concerns across Puerto Rico is found in Barceloneta.

The Municipality of Barceloneta, located on Puerto Rico's northern coast, features a shoreline that plays a vital role in the region's economy and tourism. Known for its sandy beaches and coastal ecosystems, the area attracts visitors and supports local businesses. More importantly, Barceloneta is home to key industrial operations, including pharmaceutical manufacturing and chemical production, which are part of Puerto Rico's broader economic backbone. With approximately 32% of the island's critical infrastructure situated within low-elevation coastal zones, the municipality's proximity to the shoreline makes it particularly vulnerable to coastal erosion and flooding.[201] These environmental threats could result in costly disruptions to both local livelihoods and island-wide economic stability.

Barceloneta's coastline spans 8.6 km, with beaches making up about 65% of its coastal area. Around 3.3% consists of hardened structures like ramps, bulkheads, piers, rip-rap, and seawalls. After Hurricane Maria, the beaches experienced both erosion (46%) and accretion (54%), with most erosion occurring in the western sections and accretion near Punta Palmas Alta. Ten months later, erosion decreased in areas east of Palmas Altas, including Playa Las Palmitas and Sector Verdum, but increased in La Boca and Las Criollas. Significant beach migration was observed in La Boca, with inland waterline shifts also noted in Playa Barceloneta, Las Criollas Beach, the coast near Barceloneta Pier, Isla Roque, and the beach in front of Capilla Santa María del Mar.

Figure 76 illustrates Barceloneta's coastline, showing that most of the shore is sandy (marked by an orange line). However, some sections feature engineered infrastructure along the beach—around 3.3% of Barceloneta's coastline (indicated by a red line).[202]

[199] United States Congressman Jared Huffman, "Resident Commissioner Introduces Bill to Evaluate the Impacts of Coastal Erosion," https://huffman.house.gov/media-center/in-the-news/resident-commissioner-introduces-bill-to-evaluate-the-impacts-of-coastal-erosion.
[200] Sea Grant Puerto Rico. (n.d.). *Resilience, planning and coastal development*. University of Puerto Rico Sea Grant Program. https://seagrantpr.org/en/marine-outreach/resilience-planning-and-coastal-development/.
[201] CoRePI-PR, "El Estado de las Playas de Puerto Rico Post-María (Grupo 1)," https://storymaps.arcgis.com/stories/dfb5b1a22af6440b809cde3aac482b42.
[202] CoRePI-PR, "El Estado de las Playas de Puerto Rico Post-María (Grupo 1)," https://storymaps.arcgis.com/stories/dfb5b1a22af6440b809cde3aac482b42.

Figure 76: Coastal Area Types in Barceloneta

COMMUNITY LIFELINES

Community Lifelines are the most essential services that support the daily functioning of society and are critical to human health, safety, and economic security. According to FEMA, a lifeline enables the continuous operation of critical government and business functions. When these lifelines are disrupted during a disaster, rapid stabilization is necessary to prevent cascading impacts and to support recovery efforts.

FEMA developed the lifelines framework to help emergency managers reframe incident information, communicate impacts clearly, and prioritize response actions. Lifelines are used not only during response but across the entire preparedness and recovery cycle, making them a cornerstone of resilience planning. The critical facilities in Puerto Rico overlaid with the areas of projected coastal erosion risk. Three facility types are identified in areas at risk as shown in Figure 72. Development along these shores has been driven by both necessity and opportunity. Ports and airports are strategically placed on coastal plains, making them essential yet vulnerable components of the island's infrastructure. These hubs support a diverse economy rooted in manufacturing (pharmaceuticals, textiles, petrochemicals, electronics) and a robust service sector, including finance, insurance, real estate, and tourism.

Tourism alone draws millions of visitors annually, contributing hundreds of millions of dollars to the local economy. But beyond leisure, the coast supports industries that are deeply intertwined with Puerto Rico's survival—food imports, energy distribution, and transportation all rely on coastal access. In fact, over 60% of Puerto Rico's economy is tied to service-related industries linked to the ocean and tourism.[203]

[203] U.S. Climate Resilience Toolkit, "Economy," https://toolkit.climate.gov/economy.

This coastal dependency comes at a cost. Rising sea levels, storm surges, and coastal erosion threaten not only the physical infrastructure but also the economic stability of the island. A sea level rise of just 1.6 feet could impact over 8,000 structures; a rise of 6.5 feet could affect more than 50,000. [204]

SAFETY AND SECURITY

Law enforcement, emergency services, and public safety operations is essential in Puerto Rico's response to coastal erosion, a hazard that increasingly threatens lives, infrastructure, and communities. This lifeline supports efforts such as evacuating residents from high-risk zones, restricting access to unstable coastal areas, and coordinating emergency response when erosion damages roads, homes, or public facilities.

Puerto Rico's vulnerability is acute: over 67% of the population lives in coastal municipalities, and more than 99 kilometers of shoreline have migrated inland in recent years due to erosion. This has led to the loss of homes, businesses, and critical infrastructure such as hospitals and wastewater treatment plants. In response, in 2023 Puerto Rico issued Executive Order OE-2023-009, declaring a state of emergency and mandating the implementation of prevention, mitigation, adaptation, and resiliency measure.[205]

FOOD, HYDRATION, AND SHELTER

The Food, Hydration, and Shelter lifeline, as defined by FEMA, ensures access to essential resources for survival, especially during disasters. In Puerto Rico, coastal erosion poses a growing threat to this lifeline. As erosion damages roads, homes, and public infrastructure in vulnerable coastal communities like Arecibo, access to food distribution points, clean water, and emergency shelters become increasingly strained[206]

Following events like Hurricane Fiona, over one million residents were left without potable water, highlighting how erosion and storm surges can disrupt supply chains and critical services. In some cases, entire neighborhoods have been displaced, forcing families to relocate and rely on temporary shelter solutions that may not be adequately prepared for long-term erosion risks.

HEALTH AND MEDICAL

The Health and Medical lifeline, which ensures access to medical care and public health services, faces growing challenges in Puerto Rico due to coastal erosion. As erosion accelerates along the island's shores, it threatens critical infrastructure such as hospitals, clinics, and emergency response facilities, especially in low-lying coastal zones.

Events like Hurricanes Irma and Maria caused extensive damage to beaches and dunes, increasing the vulnerability of shoreline communities and placing medical facilities at risk of flooding and structural failure. In some cases, erosion has disrupted access routes to hospitals, delaying emergency response and the

[204] U.S. Climate Resilience Toolkit, "Economy," https://toolkit.climate.gov/economy.
[205] Government of Puerto Rico, Administrative Bulletin Number: OE-2023-009, April 11, 2023, https://docs.pr.gov/files/Estado/OrdenesEjecutivas/2023/OE-2023-009%20English.pdf.
[206] Velázquez, Víctor Rodríguez, "Displaced by the Waves: Communities in Arecibo Battle Coastal Erosion," Centro de Periodismo Investigativo, August 6, 2024, https://periodismoinvestigativo.com/2024/08/displaced-communities-arecibo-coastal-erosion/.

delivery of medical supplies. With over 60% of Puerto Rico's population living in coastal municipalities, the potential for erosion-related health emergencies is significant. Maintaining the Health and Medical lifeline requires resilient infrastructure, updated hazard assessments, and coordinated planning to ensure continuity of care during and after coastal hazard events.

ENERGY

The Energy lifeline, which ensures access to power and fuel, is increasingly vulnerable in Puerto Rico due to coastal erosion. As erosion accelerates along the island's shores, it threatens critical energy infrastructure such as power plants, substations, and transmission lines, especially in low-lying coastal areas like Costa Sur and Aguirre, which supply much of the island's electricity.[207]

Recent events, including breakdowns at these facilities, have led to island-wide outages, disrupting not only residential power but also emergency services and healthcare operations. Coastal erosion, compounded by rising sea levels and intensified storms, increases the risk of flooding and structural damage, which can further destabilize the grid and delay recovery efforts.

Maintaining the Energy lifeline amid coastal erosion requires strategic investment, community-led solutions, and adaptive infrastructure planning to ensure reliable power delivery during and after climate-related disasters.

COMMUNICATIONS

The Communications lifeline, which ensures access to emergency communication systems and public information, is increasingly at risk in Puerto Rico due to coastal erosion. As erosion intensifies along the island's shores, it threatens critical infrastructure such as cell towers, fiber-optic lines, and emergency broadcast systems, especially in low-lying coastal municipalities where over 60% of the population resides.[208]

During hurricanes like Maria and Fiona, erosion and storm surges damaged beaches and dunes, disrupting communication networks and leaving thousands without access to emergency alerts or coordination systems. These disruptions can delay response times, hinder evacuation efforts, and isolate vulnerable communities from life-saving information.

FEMA and local partners have promoted Nature-Based Solutions such as dune restoration and shoreline stabilization—to help protect infrastructure and maintain access to lifeline services. However, maintaining the Communications lifeline will require resilient design, strategic planning, and community engagement to ensure continuity during coastal hazard events.

[207] Congressional Research Service, "Electric Reliability and Resiliency in Puerto Rico," February 19, 2025, https://www.congress.gov/crs_external_products/IF/PDF/IF12913/IF12913.3.pdf.
[208] International Collective in Support of Fishworkers, "Erosion Threatens Western Puerto Rico Region's Postal Communities," (n.d.), https://icsf.net/newss/erosion-threatens-western-puerto-rico-regions-coastal-communities/.

TRANSPORTATION

The Transportation lifeline, which ensures the availability of safe and reliable transportation services, is increasingly threatened in Puerto Rico due to coastal erosion. Many key roads—such as PR-1 in Salinas, PR-3 in Humacao, and PR-681 in Barceloneta—are located dangerously close to the shoreline and are vulnerable to rising sea levels, storm surges, and erosion-related damage.

For example, after Hurricane María, the PR-1 segment was rendered impassable due to pavement destruction and guardrail collapse, leaving nearly 700 residents isolated. This road is the only access route for the community, highlighting how erosion can disrupt emergency response, evacuation, and the delivery of essential supplies.[209]

Figure 77: PR-1 Road, Las Ochenta Section

A study by the Coastal Research and Planning Institute identified 101 segments of state roads at risk of coastal erosion, with 46 segments vulnerable to storm surge flooding. Despite this, long-term relocation or elevation projects are lacking, and many municipalities are relying on short-term fixes like placing rocks or installing storm drains.[210] Without resilient transportation infrastructure, communities face increased vulnerability to other hazards, including delayed medical response, disrupted supply chains, and limited

[209] González, L.J.M. and G. Carrasquillo, "Puerto Rico's Coastal Roads Ill-Prepared for Flooding," Centro de Periodismo Investigativo, March 11, 2025, https://periodismoinvestigativo.com/2025/03/puerto-rico-coastal-roads-flooding-preparation/.
[210] González, L.J.M. and G. Carrasquillo, "Puerto Rico's Coastal Roads Ill-Prepared for Flooding," Centro de Periodismo Investigativo, March 11, 2025, https://periodismoinvestigativo.com/2025/03/puerto-rico-coastal-roads-flooding-preparation/.

evacuation options. FEMA and local agencies have emphasized the need for hazard mitigation planning, including road redesigning, elevation, and nature-based solutions to protect these lifelines.

HAZARDOUS MATERIALS

The Hazardous Materials lifeline, which involves the safe management of chemical, biological, and radiological substances, faces increasing risks in Puerto Rico due to coastal erosion. As erosion intensifies along the island's shores, it threatens industrial facilities, fuel storage sites, and wastewater treatment plants located near vulnerable coastlines.

During Hurricane Fiona, for example, widespread flooding and erosion damaged infrastructure and raised concerns about contaminants entering surface and groundwater systems, especially in areas with aging or exposed facilities. Sediment runoff from eroded coastal zones can carry pollutants into reservoirs and offshore reef ecosystems, increasing water treatment costs and posing long-term environmental and public health risks.

WATER SYSTEMS

The Water Systems lifeline, which includes freshwater reservoirs, potable water distribution networks, and wastewater treatment facilities, is increasingly threatened in Puerto Rico due to coastal erosion. As erosion accelerates along the island's shores, it puts critical infrastructure—such as wastewater treatment plants near low-lying coastal zones—at risk of flooding, contamination, and structural damage.

During Hurricane Fiona, over one million residents lost access to potable water, highlighting how erosion and storm surges can disrupt water services and contaminate supply systems. The USGS has identified that erosion of beaches and dunes contributes to long-term hazards for both natural and populated shorelines, increasing vulnerability to future disasters and economic losses. FEMA has allocated funding to restore damaged water infrastructure, including projects by the Puerto Rico Aqueduct and Sewer Authority (PRASA) aimed at replacing water pipes and improving system resilience.[211]

Changes in Development

Puerto Rico's coastal municipalities face increasing challenges due to beach erosion, particularly in the aftermath of Hurricane Maria. According to CoRePI-PR, several municipalities have experienced significant losses in beach width, which poses risks not only to natural ecosystems but also to local economies and infrastructure. Among the most affected are Vieques, Culebra, Isabela, Loíza, Luquillo, Patillas, Humacao, Dorado, Ponce, and Yabucoa. These areas are not only popular tourist destinations but also host critical industries—such as pharmaceuticals, manufacturing, and fishing—that contribute substantially to Puerto

[211] NimB Staff, "FEMA allocates $22.6M to restore water infrastructure in Puerto Rico," NimB 15: News Is My Business, July 29, 2024, https://newsismybusiness.com/fema-allocates-22-6m-to-restore-water-infrastructure-in-puerto-rico/.

Rico's economy. The degradation of these shorelines could result in costly impacts for the island, making coastal erosion a pressing issue for both environmental and economic planning.[212]

A clear example of how coastal development has exacerbated erosion in Puerto Rico can be seen in Ocean Park, San Juan. According to a report by *Para la Naturaleza*, recent erosion events have severely impacted the beach area, with up to 12 feet of vertical loss over a horizontal distance of 110 feet, leading to the collapse of numerous palm trees now overtaken by the sea, as confirmed by Figure 78.[213]

Figure 78: Coastal Erosion Intensified by Urban Development in Ocean Park, San Juan, 2022[214]

Historically, erosion had been documented near Parque Celso Barbosa (also known as *El Último Trolley*), but the current damage is occurring closer to Condado, in areas not previously affected. Experts from the University of Puerto Rico are investigating whether this is a cyclical phenomenon or a new development, using tools like ground-penetrating radar to analyze sediment layers. This case highlights how coastal construction and urban development, especially in densely built areas like Ocean Park, can disrupt natural sediment flow and increase vulnerability to erosion. It underscores the need for coastal planning and regulation.

[212] Maritza Barreto, "Using Geospatial Analysis to Assess Post-María Beach Changes in Puerto Rico," presentation at the NOAA Hydrographic Services Review Panel Spring Meeting, 2023, https://nauticalcharts.noaa.gov/hsrp/meetings/2023/spring/presentations/03+01+02+Maritza+Barreto_UPRRP_PR_Using+Geospatial+analysis+to+asses+Post+Maria+beach+changes+at.pdf.
[213] Para la Naturaleza, "Examinarán la Erosión Costera en Ocean Park," Archivo Para la Naturaleza, Retrieved September 26, 2025, from https://archivo.paralanaturaleza.org/examinaran-la-erosion-costera-en-ocean-park/.
[214] Para la Naturaleza. "Examinarán la erosión costera en Ocean Park," Archivo Para la Naturaleza, Retrieved September 26, 2025, from https://archivo.paralanaturaleza.org/examinaran-la-erosion-costera-en-ocean-park/.

To determine whether infrastructure is exposed to flooding hazards, it is essential to understand FEMA's flood zone designations—particularly Zone V, which is specifically associated with coastal areas subject to high-velocity wave action from storms or hurricanes. Although Zone V is referenced broadly in exposure assessments, it is important to note that the nomenclature belongs to FEMA's flood hazard classification system and is used primarily to identify areas at greatest risk from coastal flooding. Recognizing the presence of Zone V helps planners and decision-makers assess potential vulnerabilities in coastal infrastructure. Importantly, these designations are part of FEMA's Flood Insurance Rate Maps (FIRMs), which serve as the official source for identifying flood-prone areas and guiding land use, insurance requirements, and mitigation planning. While Zone V is used here to highlight potential coastal exposure, it is part of a broader flood hazard classification system that underpins FEMA's mapping and regulatory framework.

Although construction codes are primarily designed to address various types of flooding and earthquakes, this section briefly highlights important zones located near the shoreline. As illustrated in Figure 79, projected erosion suggests that areas adjacent to the shoreline should be considered for inclusion in V Zones or Coastal A Zones (CAZs).[215]

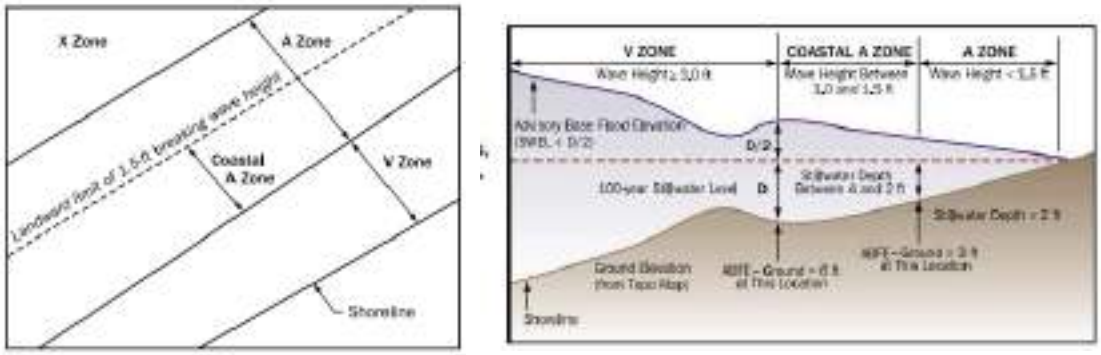


Figure 79: Plan View Showing Coastal A Zone Landward of V Zone[216]

With the adoption of the 2018 International Building Code (IBC) and International Residential Code (IRC) in Puerto Rico, buildings located in CAZs must now comply with V Zone construction standards, indicating decreased risks to structures built since the building code has been updated. This is because:

- Local building officials are required to enforce V Zone standards in CAZs.
- Designers and builders must identify CAZs using FEMA's Limit of Moderate Wave Action (LiMWA) or local designations.
- Flood insurance premiums may be reduced for compliant structures due to increased resilience.

Under the 2018 IBC and IRC, buildings in CAZs must meet the following V Zone standards:

1. **Open Foundations:** Use piles or piers that allow water to flow beneath the structure.

[215] FEMA, "Design and Construction in Coastal A Zones (Hurricane Katrina Recovery Advisory)," December 2005, https://www.fema.gov/pdf/rebuild/mat/coastal_a_zones.pdf.
[216] FEMA, "Design and Construction in Coastal A Zones (Hurricane Katrina Recovery Advisory)," December 2005, https://www.fema.gov/pdf/rebuild/mat/coastal_a_zones.pdf.

2. **Elevation:** Elevate the bottom of the lowest horizontal structural member above the Base Flood Elevation (BFE) + 1 foot or the Design Flood Elevation.
3. **Breakaway Walls:** Install breakaway walls with flood openings below elevated buildings.
4. **Flood-Resistant Materials:** Use flood-resistant materials below the BFE.
5. **Utility Placement:** Ensure equipment and utilities are not mounted on or penetrate breakaway walls.

Figure 80 highlights the devastation along Zone V and VE shores following Hurricane Maria, underscoring the importance of taking FEMA guidance seriously to save lives and reduce economic losses. Coastal FIRMs serve not only as mapping tools but also as regulatory instruments that inform construction standards aimed at reducing economic and human losses. In Puerto Rico, updated codes now require that even buildings in CAZs meet Zone V standards, reflecting the reality that wave action—even below three feet—can cause significant damage. For example, in areas like Punta Santiago (Humacao), FEMA observed that structures built without proper elevation or erosion-resistant design were severely compromised according to standards outlined in ASCE 24-14 and ASCE 7-16, which aim to create safer, more resilient coastal communities that can better withstand future storm events and long-term shoreline change.[217]

Figure 80: Ground-Level and Aerial Views of Storm-Induced Beach Erosion in Punta Santiago Following Hurricane Maria[218]

FIRMs classify zones based on flood risk. Among these, Zone V and VE are of particular relevance to coastal erosion, as they denote Coastal High Hazard Areas subject to breaking waves of 3 feet or more. These zones are critical because they directly correlate with areas most vulnerable to erosion and storm surge. The designation "V" stands for velocity, indicating the presence of high-energy wave action. Structures in these zones must adhere to stricter building codes, including elevated foundations and open designs, to withstand the dynamic forces of coastal flooding (shown in orange in Figure 81).[219]

[217] Federal Emergency Management Agency, "Highlights of ASCE 24-14 Flood Resisitant Design and Construction," 2015, https://www.fema.gov/sites/default/files/2020-07/asce24-14_highlights_jan2015.pdf.
[218] FEMA, "Hurricanes Irma and Maria in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance, FEMA P-2020," October 2018, https://www.fema.gov/sites/default/files/2020-07/mat-report_hurricane-irma-maria-puerto-rico_2.pdf.
[219] FEMA, "Design and Construction in Coastal A Zones (Hurricane Katrina Recovery Advisory)," December 2005, https://www.fema.gov/pdf/rebuild/mat/coastal_a_zones.pdf.

The BFE plays a key role in this context, as it determines the minimum elevation for construction to reduce flood risk. While BFE does not directly measure erosion, it is influenced by coastal processes and helps ensure that buildings are sited above anticipated flood levels, accounting for erosion-related ground loss.[220] The LiMWA is a delineation on FEMA's FIRMs that marks the inland extent where wave heights during the base flood event reach 1.5 feet. This area lies between Zone V (Coastal High Hazard Area) and Zone A, and is referred to as the Coastal A Zone,[221] as shown in Figure 81.

Figure 81: Mapped FEMA Zone VE Areas in Puerto Rico[222]

Although not subject to the same high-energy wave action as Zone V (which experiences breaking waves of 3 feet or more), the CAZ still faces moderate wave impacts that can cause significant damage to buildings and foundations. As such, FEMA and local authorities often recommend or require that structures within the LiMWA area follow similar construction standards to those in Zone V, including elevated foundations and flood-resistant design practices.

Mitigation Success Stories

PR-250 IN CULEBRA

Between October 2022 and August 2023, a transformative project was undertaken to strengthen the resilience of Culebra's coastal communities—specifically along the vulnerable stretch of PR-250. Protectores de Cuencas Inc., in partnership with the Municipality of Culebra and Puerto Rico's Department of Natural

[220] Federal Emergency Management Agency, "Highlights of ASCE 24-14 Flood Resistant Design and Construction," 2015, https://www.fema.gov/sites/default/files/2020-07/asce24-14_highlights_jan2015.pdf.
[221] Federal Emergency Management Agency, "Highlights of ASCE 24-14 Flood Resistant Design and Construction," 2015, https://www.fema.gov/sites/default/files/2020-07/asce24-14_highlights_jan2015.pdf.
[222] Government of Puerto Rico, *MIPR GIS Portal*, https://gis.jp.pr.gov/mipr/.

and Environmental Resources spearheaded the initiative, which embraced nature-based and hybrid engineering solutions to safeguard both infrastructure and ecosystems.[223]

In response to mounting environmental challenges, the project represents a bold and proactive commitment to resilience, sustainability, and community protection. It began with the stabilization of PR-250—a vital coastal lifeline. More than just a roadway, PR-250 connects residents, supports local commerce, and ensures critical access for emergency services.

The vision extended beyond infrastructure. Project leaders addressed erosion and flooding with urgency, recognizing the serious threats these hazards pose to homes, livelihoods, and the integrity of the coastal community. These interventions did more than defend—they restored balance and reinforced natural resilience. The project revitalized the landscape, enhancing its ecological health and scenic beauty.

Finally, the project took decisive action to protect marine ecosystems. By intercepting sediment and polluted runoff, it safeguarded fragile coastal waters from degradation, preserving biodiversity and ecological integrity for generations to come.

Figure 82: Relocated Stone Structure Above Mean High Tide in Culebra[224]

[223] Protectores de Cuencas Inc., "Engineering with Nature along PR-250 to Build Coastal Communities Resilience in Culebra: Final Report," August 2023, https://1380b568-4b5b-4ffa-9b5f-465b7c75be6c.usrfiles.com/ugd/1380b5_1a1411cc4fa1404bb951a519a258490e.pdf.
[224] Protectores de Cuencas Inc., "Engineering with Nature along PR-250 to Build Coastal Communities Resilience in Culebra: Final Report," August 2023, https://1380b568-4b5b-4ffa-9b5f-465b7c75be6c.usrfiles.com/ugd/1380b5_1a1411cc4fa1404bb951a519a258490e.pdf.

Faced with the relentless forces of coastal erosion and rising seas, the project delivers a deliberate and layered defense of the shoreline—transforming vulnerability into resilience. Through a suite of targeted interventions, the initiative reshapes, reinforces, and reclaims the coastal edge.

It begins with regrading and rock relocation, where engineers recontoured the seaside bank and repositioned stone to stabilize areas worn down by time and tide. Next, they relocated revetments, elevating protective stone structures above the mean high tide line to better absorb and dissipate wave energy—turning passive barriers into active shields (see Figure 82).

To complement these structural measures, the project introduced native vegetation, planting resilient, coastal-adapted species that form a living buffer. These plants not only anchor the soil but also restore ecological function, inviting biodiversity back to the shoreline. Finally, the installation of geotextile fabric adds a hidden layer of protection, a barrier that separates soil from water, slowing erosion and preserving the integrity of the land (see Figure 83).

Together, these interventions form a cohesive and intelligent system—one that deflects wave energy, curbs sediment loss, and enhances the shoreline's durability. The result is a coast not only fortified against environmental stressors but also revitalized in its ecological richness, offering enduring benefits to both the community and the natural world.[225]

Figure 83: Installing Geotextile Fabric

[225] Protectores de Cuencas Inc., "Engineering with Nature along PR-250 to Build Coastal Communities Resilience in Culebra: Final Report," August 2023, https://1380b568-4b5b-4ffa-9b5f-465b7c75be6c.usrfiles.com/ugd/1380b5_1a1411cc4fa1404bb951a519a258490e.pdf.

Erosion is not just a natural process; it's a persistent threat to coastal infrastructure, ecological integrity, and community safety. The project report identifies erosion as a critical challenge and responds with a suite of targeted, sustainable interventions designed to mitigate its impact. Key erosion control strategies included the following:

- **Non-Woven Geotextile Fabric:** Strategically installed to absorb the erosive force of water while allowing stormwater to infiltrate, reducing surface runoff and soil displacement.
- **Sediment Control Traps:** Deployed during construction to intercept sediment before it could reach and damage sensitive marine habitats.
- **Layered Soil and Rock Placement:** Engineered to resist erosive forces and simultaneously support the establishment of native vegetation.
- **Coco Liners:** Biodegradable materials placed to further stabilize the soil, enhance water infiltration, and promote root growth. These measures reflect a clear understanding: erosion control is not optional—it is foundational to long-term coastal resilience.

By integrating natural and engineered solutions, the project not only protects the shoreline but also reinforces the ecological and infrastructural stability of Culebra's coast (see Figure 84).

Figure 84: Relocated Revetment Above Mean High Tide in Culebra

SECTION 4.2

DROUGHT

Drought

DROUGHT DEFINITION

Drought is a deficiency of precipitation over an extended period of time (usually a season or more), resulting in a water shortage.[226]

Types of Droughts

According to the United States Geological Survey, there are five different types of droughts. They may be thought of in terms of stages of the same drought event.

- **Meteorological Drought:** Dry weather patterns persist in a localized area. There is some departure of precipitation from normal for a particular location. The conditions at this stage include any precipitation shortfall of 75 percent of normal totals for three months or longer. This criterion can be misleading if all of the precipitation falls in a very short time period and results in floods.
- **Hydrological Drought:** A notable decrease in the water supply in water systems has been observed. Surface and subsurface water supplies are below normal. The reduction in stream flow (inflow) to reservoirs and lakes is the most obvious sign that a serious drought is in progress.
- **Agricultural Drought:** The impact of drought on crops occurs where the amount of moisture in the soil no longer meets the needs of a particular crop. Soil moisture is deficient to the point where plants are stressed and biomass (yield) is reduced.

[226] National Oceanic and Atmospheric Administration, National Integrated Drought Information System, "Drought Basics," 2025, https://www.drought.gov/what-is-drought/drought-basics.

- **Ecological Drought:** The impact of drought on ecosystems is beyond thresholds of vulnerability. This leads to reduced plant growth (either seasonally or permanently), a decline or extinction of local species, and significant landscape changes, such as the conversion of forests to non-forested vegetation. The latter, in turn, can diminish soil water retention, alter freshwater ecosystem flow patterns, raise water temperatures, and ultimately degrade water quality.
- **Socioeconomic Drought:** The impact of drought on supply chains of commodities represents the final stage of drought effects. This stage occurs when the physical water shortage begins to affect people. If dry conditions persist long enough and become severe enough, they impact sectors beyond the agricultural community, such as community drinking supply and other social and economic enterprises.

Location

All of Puerto Rico can be impacted by the various characteristics and stages of drought conditions. Figure 85 shows drought locations in Puerto Rico as of the time of this plan update.

Figure 85: U.S. Drought Monitor Puerto Rico, Drought Intensity Map and Legend (July 2025)

Previous Occurrences

Puerto Rico has experienced several major droughts since the 1950s. These droughts have affected the entire population dependent on water resources from precipitation. The following provides information on previous occurrences of drought and includes federal drought disaster declaration information from the United States Department of Agriculture, the most recent Puerto Rico State of Emergency declarations for drought, and reports of local drought events from the National Centers for Environmental Information (NCEI) database.

FEDERAL DISASTER DECLARATIONS

The United States Department of Agriculture designates disaster declarations for states and counties experiencing prolonged drought. Table 27 provides available information on the latest drought disaster declarations for Puerto Rico from 2015 to 2022. No federal drought declarations were declared in 2023, 2024, or 2025.

Table 27: US Department of Agriculture Drought Disaster Declarations for Puerto Rico[227].

Disaster Number	Declaration Date	Begin Date	End Date	Municipalities
S5260	8/15/2022	6/21/2022	N/A	Aibonito, Barranquitas, Corozal, Cidra, Coamo, Comerio, Morovis, Naranjito, Orocovis, Toa Alta, Vega Alta
S4754	8/24/2020	6/9/2020	N/A	Adjuntas, Jayuya, Juana Diaz, Peñuelas, Ponce, Utuado
S4523	9/9/2019	7/2/2019	N/A	Adjuntas, Jayuya, Juana Diaz, Peñuelas, Ponce, Utuado
S3955	2/17/2016	12/29/2015	N/A	Aibonito, Arroyo, Barranquitas, Caguas, Cayey, Cidra, Coamo, Guayama, Juana Díaz, Maunabo, Orocovis, Patillas, Salinas, San Lorenzo, Santa Isabel, Villalba, Yabucoa
S3969	3/23/2016	1/1/2016	N/A	Aguas Buenas, Aibonito, Barranquitas, Bayamón, Caguas, Canóvanas, Carolina, Cayey, Cidra, Coamo, Comerio, Corozal, Guaynabo, Gurabo, Humacao, Juncos, Las Piedras, Maunabo, Naguabo, Naranjito, Orocovis, Patillas, San Juan, San Lorenzo, Trujillo Alto, Vieques, Yabucoa
S3852	7/15/2015	7/7/2015	N/A	Aguas Buenas, Caguas, Canóvanas, Carolina, Cayey, Cidra, Gurabo, Juncos, Las Piedras,

[227] United States Department of Agriculture, "Disaster Designation Information (2015, 2020, 2023)," 2025, https://www.fsa.usda.gov/resources/disaster-assistance-program/disaster-designation-information.

Disaster Number	Declaration Date	Begin Date	End Date	Municipalities
				Patillas, San Juan, San Lorenzo, Trujillo Alto, Yabucoa
S3860	8/5/2015	7/23/2015	N/A	Aibonito, Arroyo, Cayey, Coamo, Guayama, Patillas, Salinas, Santa Isabel
S3863	8/12/2015	7/30/2015	N/A	Aguas Buenas, Aibonito, Arroyo, Barranquitas, Caguas, Canóvanas, Carolina, Cayey, Ceiba, Cidra, Comerio, Fajardo, Guayama, Gurabo, Humacao, Juncos, Las Piedras, Loíza, Luquillo, Maunabo, Naguabo, Patillas, Rio Grande, Salinas, San Juan, San Lorenzo, Trujillo Alto, Yabucoa
S3870	8/19/2015	8/11/2015	N/A	Toa Alta, Barranquitas, Corozal, Morovis, Naranjito, Orocovis, Vega Alta
S3880	9/2/2015	8/20/2015	N/A	Toa Alta, Aguas Buenas, Aibonito Barranquitas, Bayamón, Caguas, Canóvanas, Carolina, Catano, Cayey, Ceiba, Cidra, Coamo, Comerio, Corozal, Dorado, Fajardo, Guaynabo, Humacao, Juana Diaz, Las Piedras, Loíza, Luquillo, Morovis, Naguabo, Naranjito, Orocovis, Rio Grande, Salinas, San Juan, Santa Isabel, Toa Baja, Trujillo Alto, Vega Alta, Vega Baja, Villalba
S3896	9/23/2015	7/28/2015	N/A	Aibonito, Barranquitas, Cidra, Coamo, Comerio, Corozal, Naranjito, Orocovis

PUERTO RICO DISASTER DECLARATIONS

In June 2020, in the midst of the coronavirus pandemic, the Governor of Puerto Rico declared a State of Emergency due to severe drought conditions affecting 26% of the island and moderate drought conditions impacting 60%, according to the U.S. Drought Monitor. The drought impacted 21 of the 78 municipalities of Puerto Rico. Due to reduced water levels, the Puerto Rico Water and Sewer Authority (PRASA) implemented daily water rationing and restrictions impacting 140,000 customers island wide. The water rationing measures specifically impacted PRASA customers connected to the Carraízo reservoir, one of 11 operated by Puerto Rico's government.[228]

[228] Associated Press, "Worsening Drought Forces State of Emergency in Puerto Rico," June 29, 2020, https://apnews.com/article/485aa49fc349decdbbef5e663d92dc74.

SIGNIFICANT EVENTS

Table 28 shows the NCEI database reports related to local drought events in Puerto Rico. According to NCEI, 25 drought events were recorded from 2014 to 2025, resulting in a total of $5 million in property damage[229]. No drought events were reported in the database from 2024 to 2025.

Table 28: NCEI Data for Drought

Dates	Location	Description	Damages
7/25/2023–7/31/2023	North Central, Northwestern, Western Interior	As the month progressed, heavy rain did not occur across the extreme northwest of Puerto Rico, where the Guajataca Basin is located. The basin stayed at observational levels. Additionally, rivers were well below normal, the soil was dry, and the rainfall deficit was increasing as well. The lack of significant rains created a water deficit for the Guajataca Basin.	$0 in property and crop damage.
7/1/2023–7/4/2023	North Central, Northwestern, Western Interior	The lack of significant rains across northwestern Puerto Rico resulted streams being well below normal throughout the area. Additionally, the Guajataca Basin was at observational levels throughout much of the period. This resulted in the area experiencing Severe Drought (D2) conditions.	$0 in property and crop damage.
6/20/2023–6/30/2023	North Central, Northwestern	The lack of wetting rain caused streamflow to run from below to much below normal for northwestern Puerto Rico. Additionally, the Guajataca Basin received less rain than usual, resulting in the reservoir reaching observational levels.	$0 in property and crop damage.
9/1/2022–9/6/2022	Southeast, Ponce and vicinity, Eastern interior, Central interior,	The precursor to Hurricane Earl brought above-normal rainfall to the eastern half of Puerto Rico during the first few days of the month. These rains resulted in drought improvement below Severe Drought (D2) criteria. By the middle to latter part of the month, additional rainfall, mainly due to Hurricane Fiona, resulted in the removal of all drought categories across the territory.	$0 in property and crop damage.

[229] National Centers for Environmental Information. (n.d.). Storm events database: Puerto Rico drought events (2014–2025). National Oceanic and Atmospheric Administration. https://www.ncei.noaa.gov/access/search.

Dates	Location	Description	Damages
7/01/2022–8/31/2022	Central interior, Southeast, Eastern interior, Ponce and vicinity	The rainfall deficit across the southeast of Puerto Rico resulted in the continuation of drought conditions, with Severe Drought (D2) persisting across the Southeast. The 28-day average streamflow from the USGS river gauge network indicated some streamflows running below normal across the eastern interior and southeast Puerto Rico. Although the drought is gradually improving, lingering effects are still causing increasing water demands as well as stressed pastures, crops, and native vegetation.	$0 in property and crop damage.
6/14/2022–6/22/2022	Northeast, Central interior, Southeast, Eastern interior, Ponce and vicinity	The rainfall deficit across east and south of Puerto Rico resulted in drought conditions deteriorating, with Severe Drought (D2) introduced. The dry spell caused mandatory water restrictions in the interior and northeast Puerto Rico, including Aibonito, Loiza, Canóvanas, Rio Grande, Loiza, and Las Piedras. Reservoir levels continued to recede for Carraízo, Cidra, La Plata, Carite, Guajataca, Toa Vaca, and Cerrillos. The 28-day average streamflow from the USGS river gauge network indicated streamflows running below normal or well below normal across most of Puerto Rico. This drought was of concern to agricultural interests, as hot and dry conditions increased water demands and stressed pastures, crops, and native vegetation.	$0 in property and crop damage.
6/01/2014–6/30/2014	Southeast	During the past several months, local islands have been experiencing abnormally dry to drought conditions (D1) with just 25 to 50 percent of normal rainfall. Rainfall deficit has been noted across most of the island except in portions of the western interior. During the second and third weeks of August, significant rainfall accumulations were noted across Puerto Rico, although the rainfall deficit continues. However, the deficit decreased to 50 to 90% and was confined to east Puerto Rico.	$0 in property and crop damage.

Potential Severity of Event

The Palmer Drought Severity Index (PDSI), developed by Wayne Palmer in 1965, measures drought severity using temperature, precipitation, and soil moisture. Because the PDSI is standardized across various climates, it has become the "semi-official" drought index. It uses zero as normal and assigns a number between 6 and -6, with dry periods expressed as negative numbers and wet periods as positive numbers:[230]

Table 29: Palmer Drought Severity Index Classification and Range

Range	Palmer-Classification
4.0 or more	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

The extent of drought can be classified by levels of intensity. Figure 86 shows U.S. Drought Monitor (USDM) drought classifications that identify and label areas of drought by intensity. The four categories of drought which could occur in Puerto Rico range from D1—the least intense—to D4, the most. The D0 category is used to indicate abnormally dry areas that may be entering or recovering from drought. In addition, Figure 86 shows drought ranges determined by the Palmer Drought Severity Index, the Climate Prediction Center Soil Moisture Model, United States Geological Survey Weekly Streamflow, Standardized Precipitation Index.[231]

[230] United States Drought Monitor, "Palmer Drought Severity Index," 2025, https://droughtmonitor.unl.edu/ConditionsOutlooks/CurrentConditions.aspx.
[231] United States Drought Monitor, "Drought Classification," 2025, https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx.

CAT	DESCRIPTION	POSSIBLE IMPACTS	RANGERS				
			PALMER DROUGHT SEVERITY INDEX (PDSI)	CPC SOIL MOISTURE MODEL (Percentile)	USGS WEEKLY STREAMFLOW (Percentile)	STANDARDIZED PRECIPITATION INDEX (SPI)	OBJECTIVE DROUGHT INDICATOR BLENDS (Percentile)
D0	Abnormally Dry	Going into drought: - Short-term dryness slowing planting, growth of crops/pastures Coming out of drought: - Some lingering water deficits - Pastures/crops not fully recovered	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7	21 to 30
D1	Moderate Drought	- Some damage to crops, pastures - Streams, reservoirs, or wells low, some water shortages developing or imminent - Voluntary water-use restrictions requested	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	- Crop/pasture losses likely - Water shortages common - Water restrictions imposed	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	- Major crop/pasture losses - Widespread water shortages or restrictions	-4.0 to -4.9	6 to 10	6 to 10	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	- Exceptional and widespread crop/pasture losses - Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

Figure 86: U. S. Drought Classifications

In addition to the U.S. Drought Classifications and the U.S. Drought Monitor data, the Puerto Rico Aqueduct and Sewer Authority (PRASA) closely monitors water levels at its 11 main reservoirs to determine the extent of hydrological drought in its operational regions. The values are reported in meters above sea level daily. A chart similar to that shown Figure 87 indicates the current alert status for each reservoir: Overflow, Secure, Observation, Adjustments, Control, or Out of Service.[232]

[232] Puerto Rico Aqueduct and Sewer Authority, "Aqueducts-Reservoir Levels," 2025, https://www.acueductos.pr.gov/infraestructura/niveles-de-los-embalses.

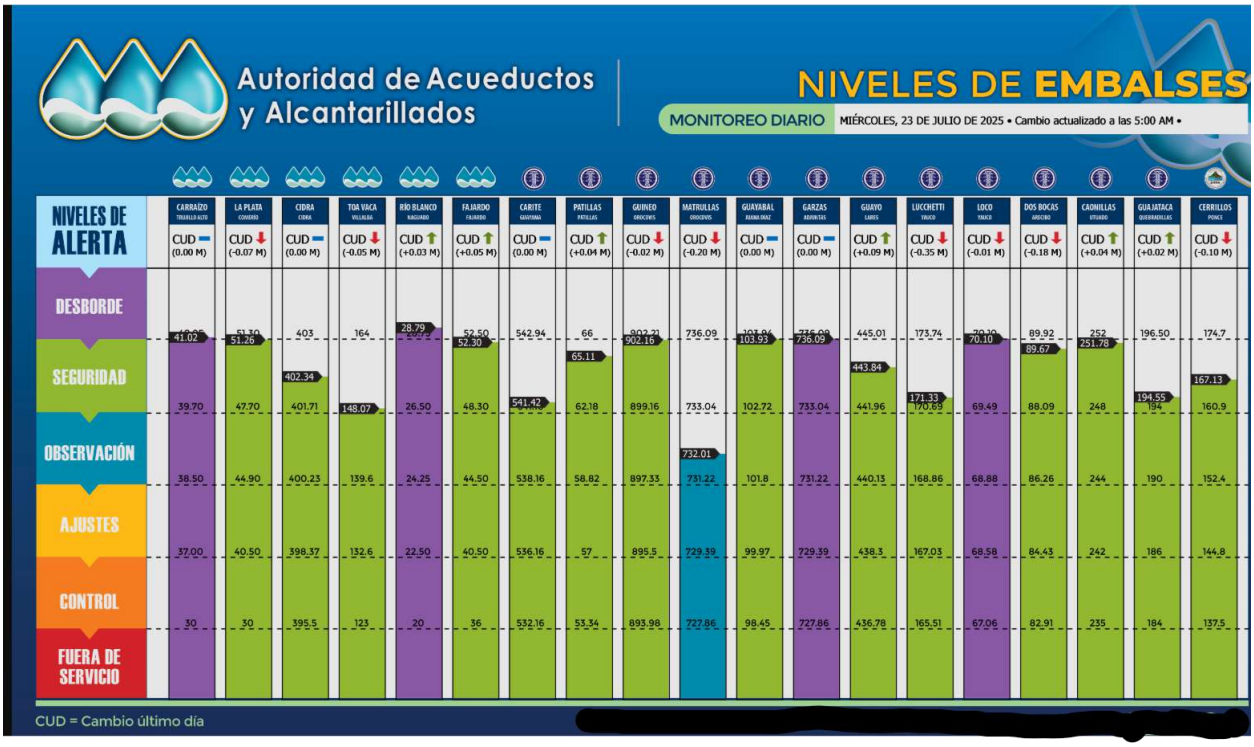


Figure 87: PRASA Reservoir Levels Monitor July, 2025[233]

Probability of Future Hazard Events

Puerto Rico's tropical marine climate has moderately high temperatures and high humidity throughout the year. December to March is the dry season and followed by an early rainy season during April and May. June and July feature a midsummer dry period and a late rainy season. August through November brings the wet fall season with frequent tropical storms and hurricanes that can cause significant rainfall and flooding. The Puerto Rico dry season is known for its sunny and warm weather with relatively low levels of precipitation. The climate of Puerto Rico varies significantly across the main island due to its diverse topography and location. The coastal regions are generally warmer than the interior and mountainous areas, which experience more rainfall and lower temperatures. Based on the frequency of previous drought events in Puerto Rico from 2000 to 2025, with variations between D1 and D0 drought classifications or moderate conditions, the probability of drought events can be considered **moderate**, as episodes of drought can occur but not annually.[234] For more details, see Figure 88.

[233] Puerto Rico Aqueduct and Sewer Authority, "Aqueducts-Reservoir Levels," 2025, https://www.acueductos.pr.gov/infraestructura/niveles-de-los-embalses.
[234] National Oceanic and Atmospheric Administration, National Integrated Drought Information System, Drought.gov, "Drought in Puerto Rico," https://www.drought.gov/states/puerto-rico.

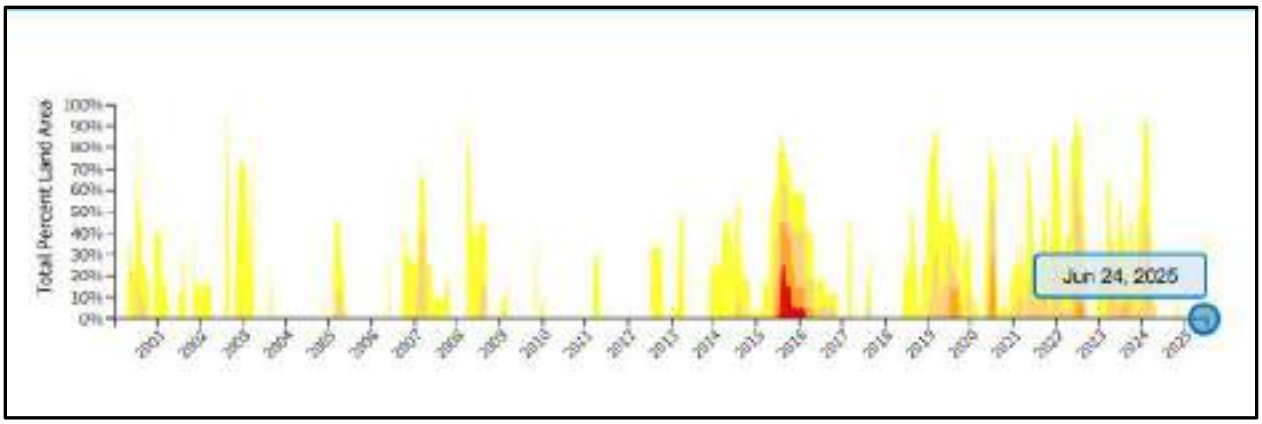


Figure 88: Time Series of Drought Conditions for Puerto Rico (2000-2025)[235]

In addition to previous events indicating probability of future drought events, researchers have concluded that the annual occurrence of the trans-Atlantic Saharan Air Layer (SAL) can be a contributing factor to high-impact drought conditions in Puerto Rico[236]. Over the 40-year study period, the island experienced consistently below-average summer rainfall, which coincided with the seasonal presence of Saharan dust plumes in the atmosphere. During the same timeframe, there was a 10% increase in the number of Saharan Air Layer (SAL) days.[237]

Research indicates that changing future conditions can increase the probability of future drought events. Warmer temperatures enhance evaporation, which reduces surface water, dries out soil and vegetation, and makes periods with low precipitation drier than they would be in cooler conditions. Also, warming temperatures increase precipitation variability and lead to increases in secondary hazards, such as flooding and landslides. This results in longer periods of both extreme precipitation and drought and increases the need for expanded water storage during drought years.[238]

Climate is the main factor that controls the hydrology of Puerto Rico, directly affecting the availability of water resources. A 2014 vulnerability study by the Puerto Rico Aqueduct and Sewer Authority concluded that future increases in precipitation are likely to impact infrastructure. However, one positive impact

[235] National Oceanic and Atmospheric Administration, National Integrated Drought Information System, Drought.gov, "Historic Data and Conditions Map and Time Series for Puerto Rico (2000-2025)," https://www.drought.gov/historical-information?state=puerto-rico&dataset=0&selectedDateUSDM=20250617.
[236] Miller, P. W., & Ramseyer, C. (2024). The relationship between the Saharan air layer, convective environmental conditions, and precipitation in Puerto Rico. Journal of Geophysical Research: Atmospheres, 129(1), e2023JD039681. https://doi.org/10.1029/2023JD039681.
[237] Miller, P. W., & Ramseyer, C. (2024). The relationship between the Saharan air layer, convective environmental conditions, and precipitation in Puerto Rico. Journal of Geophysical Research: Atmospheres, 129(1), e2023JD039681. https://doi.org/10.1029/2023JD039681.
[238] Center for Climate and Energy Solutions, "Drought and Climate Change," 2025, https://www.c2es.org/content/drought-and-climate-change/.

increased precipitation could cause faster recharge of the aquifer, which would facilitate the availability of drinking water from wells reducing the impact of drought.[239]

Vulnerability Assessment

Puerto Rico's critical infrastructure assets have experienced significant impacts from drought events, underscoring vulnerabilities in water and energy systems. Following the severe drought of 1994, the Commonwealth invested approximately $1 billion in the development of the Super aqueduct, a strategic infrastructure project designed to improve water supply reliability for the San Juan metropolitan region[240]. Despite this investment, recurring droughts, such as the 2020 event, have triggered water rationing measures, revealing persistent vulnerabilities.

Puerto Rico's annual dry season in particular makes it vulnerable to the different types and stages of drought. A strong reliance on normal precipitation rates and groundwater supply increases its vulnerability to hydrological drought. The agricultural economy is vulnerable to drought, as it depends on irrigation systems that rely on the availability of groundwater to maintain productive crop yields. In recent years, the island's drought conditions have improved, but vulnerability to drought remains a reality.

LOCATIONS

The entirety of the island has experienced drought conditions. However, certain regions have been more susceptible to drought conditions. In Puerto Rico, abnormal dryness develops along the northwest and south-central coasts, where short-term precipitation deficits persist, stressing crops and decreasing groundwater levels. The National Risk Index (NRI) includes data on the expected annual losses to individual natural hazards, historical loss, and overall risk at a county and Census tract level. However, for drought, there is insufficient information to calculate the risk index score for Puerto Rico when compared to the rest of the U.S.

POPULATIONS

All populations across Puerto Rico are vulnerable to drought conditions, which bring on a scarcity of freshwater resources. People in rural areas, as well as people in metropolitan areas, do experience drought conditions. This vulnerability is exacerbated by rising temperatures and aging infrastructure, which together amplify the challenges posed by prolonged drought events.

STRUCTURES INCLUDING CRITICAL FACILITIES

Prolonged drought compromises critical infrastructure such as hydroelectric power, water treatment, and wastewater systems by limiting the consistent water supply they need to function effectively and deliver essential services to communities. Of the 38 reservoirs in Puerto Rico, 11 supply water to the island's 3.5

[239] Authoridad de Aqueductos Y Alcantarillados, "Climate Change Vulnerability Study," 2014, https://www.acueductos.pr.gov/infraestructura/cambio-climatico-estudio-de-vulnerabilidad.
[240] Five Year Strategic Plan-Puerto Rico Aqueduct and Sewer Authority (PRASA): https://docs.pr.gov/files/AAA/Nuestra%20AAA/Documentos/PRASA%20Strategic%20Plan%202020-2025.pdf.

million inhabitants. The reservoirs collect water directly from the river channel, or in-stream. As the flowing water enters the reservoir, velocity slows and suspended sediment settles and accumulates over time.[241]

INFRASTRUCTURE AND COMMUNITY LIFELINES

Puerto Rico's water and wastewater systems have faced extreme crises during years of moderate to abnormally dry drought conditions, requiring mitigation strategies to address anticipated negative impacts on their infrastructure. Puerto Rico's agricultural ecosystem and hydration water systems depend on rainfall to maintain adequate levels in the water supply. When drought persists at the abnormally dry D0 level for 13.57% of the island,[242] these systems become vulnerable. This situation impacts the groundwater levels and, in turn, crop yields and the availability of drinking water for the population.[243]

Figure 89: PRASA At a Glance[244]

PROBLEM STATEMENTS

- Drought can increase vulnerability of water system infrastructure, potentially disrupting services in extreme circumstances or causing economic losses. Recent drought conditions and the aftermath of damage from Hurricane María, Hurricane Fiona, and a series of earthquakes in 2019 and 2020, have all had serious impacts on Puerto Rico's infrastructure. The island continues to face challenges in providing critical services to the population.

[241] Holupchinski Ordahl, E., "Exploring drought and annual rainfall in Puerto Rico (Doctoral dissertation)," 2022, https://repositorio.upr.edu/handle/11721/3025.
[242] USA Today, U.S. Drought Monitor, "Puerto Rico Drought Monitor," June 26, 2025, https://data.usatoday.com/drought/puerto-rico/72/.
[243] United States Drought Monitor, "National Drought Summary-Caribbean," June 24, 2025, https://droughtmonitor.unl.edu/Summary.aspx.
[244] Puerto Rico Aqueduct and Sewer Authority, "PRASA at a Glance-Fiscal Plan as certified by the Financial Oversight and Management Board (FOMB) for Puerto Rico on June 29, 2020," 2025, https://docs.pr.gov/files/AAA/Nuestra%20AAA/Documentos/PRASA%20Strategic%20Plan%202020-2025.pdf.

- Aguadilla, Arroyo, Camuy, Coamo, Guayama, Humacao, Isabella, Mayagüez, Ponce, Juana Diaz, Quebradillas, Salinas, Santa Isabel, and other municipalities located in the western, southwestern, and southeastern parts of the island have consistently experienced vulnerability to D1 moderate drought conditions during the dry season.
- The high rate of withdrawals and the reduction in recharge had lowered the water table of the aquifer below sea level, allowing seawater contamination (saline intrusion) from the Caribbean Sea.
- The lowering of water supply levels brought on by dry season drought conditions can impact crop yields and may require voluntary water use restrictions.[245] Communities with higher levels of exposed agriculture are at greater risk.
- Island-wide demand for scarce freshwater supplies by populations dependent on reservoir systems and potable water systems, as well as the competition for those resources from the agrarian economy, put increased strain on those resources during drought events.
- The island's water distribution systems depend on electricity for pumps to provide water through the system, which has been challenged by service disruptions from frequent power outages.
- Sedimentation from previous landslide events found in Puerto Rico's freshwater reservoirs presents a critical challenge for maintaining reservoir resources. Much of the island's total reservoir storage capacity is compromised, and this creates a strain during drought events.
- Droughts can impact water systems and hydroelectric power generation due to reduced water levels in reservoirs and rivers, leading to water and energy shortages. They can also affect cooling systems in power plants that rely on water, potentially leading to reduced power output.
- Drought imposes additional chronic stresses by reducing recharge to coastal aquifers. These coastal aquifers are recharged by direct rainfall and streamflow from central Puerto Rico; the decreased precipitation and net infiltration in those areas constrain water availability during drought.[246]

Impact Assessment

STATE ASSETS

Drought is unlikely to directly impact state-owned and -operated structures. However, it can impact infrastructure and critical infrastructure efficiency, including energy and water infrastructure systems. Drought conditions can also significantly impact energy infrastructure, particularly systems reliant on water resources. In Puerto Rico, hydroelectric generation is especially vulnerable to reduced water availability

[245] USA Today, U.S. Drought Monitor, "Puerto Rico Drought Monitor," June 26, 2025, https://data.usatoday.com/drought/puerto-rico/72/.
[246] F. D. Moraes, T. L. Mote, & T. C. Rasmussen, "The Role of Physical Geography on Puerto Rico's Water Budget," *Journal of Hydrology: Regional Studies* 47 (2023): 101382, https://www.sciencedirect.com/science/article/pii/S2214581823000691.

during prolonged droughts.[247] This shift contributes to estimated annual economic losses of $10–$15 million,[248] reflecting both:

- Diminished renewable energy output, especially from hydroelectric sources,[249] and
- Increased operational costs due to fuel purchases, maintenance, and emergency logistics.[250]

These impacts show the interdependence between water availability and energy production, particularly in regions where hydroelectricity comprises a substantial portion of the energy mix. The cascading effects of drought on energy systems may also exacerbate vulnerabilities in other lifeline sectors, including water supply, healthcare, power plants, and communications. These losses reflect both diminished renewable energy output and increased operational costs, highlighting the interdependence between water availability and energy production.[251]

The overall replacement costs for hydroelectric dams and all other water infrastructure are shown in Table 30. Where asset types differ between municipalities, no state assets were identified among the excluded types. There are 17 hydroelectric dams throughout Puerto Rico, totaling approximately $4.1 billion in replacement costs. These dams are located in the municipalities of Guayama, Arecibo, Ciales, Patillas, Isabela, Jayuya, Orocovis, Trujillo Alto, and Utuado; two dams each are located in Comerío and Lares, and four dams in Adjuntas. The costliest replacements, at $1 billion each, are for the Guajataca Dam in Isabela and the Loiza Dam in Trujillo Alto.

Additionally, there is a total of $670 million in replacement costs for water infrastructure, as seen in Table 30. For the purposes of this plan update, Puerto Rico identified water infrastructure-related assets, including aqueducts, water pump stations, wastewater treatment plants, and water treatment plants. Aqueducts are the most common asset, comprising 63% of all asset records; they cost $166 million in replacement. All but

[247] Federal Emergency Management Agency, Central Office for Recovery, Reconstruction and Resilience (COR3), *FEMA 5-Year Plan: Fiscal Years 2024–2029*, https://recovery.pr.gov/documents/Energy%205%20Year%20Plan%20-%20June%202024_20241212T153644.042Z.pdf.

[248] Puerto Rico Electric Power Authority (PREPA). *Notice of Disputes to LUMA Energy, LLC and LUMA Energy ServCo, LLC under Article 15 of the Transmission and Distribution Operation and Maintenance Agreement (T&D OMA)*, https://ftp.prepa.pr.gov/public/folder/dnoldz8kxks-v-kj0qy9nw/Annexes%20-%20%20Notice%20of%20Disputes%20to%20LUMA%20Energy%2C%20LLC%20and%20Luma%20Energy%20ServCo%2C%20LLC%2C%20under%20Article%2015%20of%20the%20T%26D%20OMA/Notice%20of%20Disputes%20to%20LUMA%20Energy%2C%20LLC%20and%20LUMA%20Energy%20ServCo%2C%20LLC%2C%20%20under%20Article%2015%20of%20the%20T%26D%20OMA.pdf [requires login].

[249] Government of Puerto Rico, Public-Private Partnerships Authority, "Hydroelectric Power Plants Revitalization Project," https://www.p3.pr.gov/energy/hydroelectric-power-plants-revitalization-project.

[250] Government of Puerto Rico, Public Service Regulatory Board, Puerto Rico Energy Bureau, "In Re: Electric System Priority Stabilization Plan," https://energia.pr.gov/wp-content/uploads/sites/7/2025/07/20250704-MI20240005-Resolution-and-Order.pdf.

[251] Puerto Rico Electric Power Authority (PREPA), *Notice of Disputes to LUMA Energy, LLC and LUMA Energy ServCo, LLC under Article 15 of the Transmission and Distribution Operation and Maintenance Agreement (T&D OMA)*, https://ftp.prepa.pr.gov/public/folder/dnoldz8kxks-v-kj0qy9nw/Annexes%20-%20%20Notice%20of%20Disputes%20to%20LUMA%20Energy%2C%20LLC%20and%20Luma%20Energy%20ServCo%2C%20LLC%2C%20under%20Article%2015%20of%20the%20T%26D%20OMA/Notice%20of%20Disputes%20to%20LUMA%20Energy%2C%20LLC%20and%20LUMA%20Energy%20ServCo%2C%20LLC%2C%20%20under%20Article%2015%20of%20the%20T%26D%20OMA.pdf [requires login].

10 municipalities have at least one aqueduct, and most have multiple. The highest individual asset in water infrastructure cost is an aqueduct in Cabo Rojo—the Carros Públicos Aqueduct—costing $30.3 million for replacement. However, most other aqueducts cost less than $1 million each.

Water pump stations are the second most common asset, representing 16.6% of all assets, but have almost double the total replacement cost of aqueducts: $271 million. Individual water pump stations tend to cost almost $2 million each. Water and wastewater treatment plants are less common, but each is still very costly. The most expensive water treatment plant is Los Filtros Guaynabo, costing $25.7 million in Guaynabo. The most expensive wastewater treatment plant is the San Sebastián WWTP, which costs much less, at about $5.8 million. Together, the two separate treatment types make up 18.4% of the overall assets, with a combined replacement cost of $232 million—significantly more than the most common asset, aqueducts.

Table 30: Replacement Cost for Hydroelectric Dam and Water Infrastructure State Assets Potentially Vulnerable to Drought by Location

Municipality	Asset Type	Asset Count	Total Cost
Adjuntas		22	$618,991,055.00
	Water Pump Stations	3	$5,530,320.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	10	$4,378,170.00
	Water Treatment Plants	4	$3,686,880.00
	Hydroelectric Dams	4	$604,358,750.00
Aguada		11	$2,995,590.00
	Aqueducts	10	$1,958,655.00
	Water Treatment Plants	1	$1,036,935.00
Aguadilla		6	$4,723,815.00
	Aqueducts	4	$2,880,375.00
	Water Treatment Plants	2	$1,843,440.00
Aguas Buenas		14	$5,760,750.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	11	$2,880,375.00
	Water Treatment Plants	2	$1,843,440.00
Aibonito		15	$10,687,868.44
	Wastewater Treatment Plants	1	$5,450,630.39
	Aqueducts	12	$3,393,798.04
	Water Treatment Plants	2	$1,843,440.00

Municipality	Asset Type	Asset Count	Total Cost
Añasco		1	$921,720.00
	Water Treatment Plants	1	$921,720.00
Arecibo		59	$538,911,651.82
	Water Pump Stations	13	$22,236,495.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	40	$4,608,600.00
	Water Treatment Plants	4	$11,029,621.82
	Hydroelectric Dams	1	$500,000.00
Arroyo		10	$1,152,150.00
	Aqueducts	10	$1,152,150.00
Barceloneta		10	$2,073,870.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	9	$1,036,935.00
Barranquitas		28	$24,736,310.17
	Water Pump Stations	11	$18,549,615.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	13	$2,384,600.17
	Water Treatment Plants	3	$2,765,160.00
Bayamón		3	$2,880,375.00
	Water Pump Stations	1	$1,843,440.00
	Aqueducts	1	$115,215.00
	Water Treatment Plants	1	$921,720.00
Cabo Rojo		11	$33,925,750.34
	Aqueducts	10	$33,004,030.34
	Water Treatment Plants	1	$921,720.00
Caguas		53	$82,378,725.00
	Water Pump Stations	40	$73,737,600.00
	Wastewater Treatment Plants	2	$2,073,870.00
	Aqueducts	9	$1,036,935.00
	Water Treatment Plants	2	$5,530,320.00

Municipality	Asset Type	Asset Count	Total Cost
Camuy		12	$2,304,300.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	11	$1,267,365.00
Canóvanas		2	$1,843,440.00
	Water Treatment Plants	2	$1,843,440.00
Carolina		6	$7,604,190.00
	Water Pump Stations	4	$7,373,760.00
	Aqueducts	2	$230,430.00
Cataño		1	$1,036,935.00
	Wastewater Treatment Plants	1	$1,036,935.00
Cayey		17	$15,721,240.00
	Water Pump Stations	6	$11,060,640.00
	Aqueducts	9	$2,817,160.00
	Water Treatment Plants	2	$1,843,440.00
Ceiba		6	$10,170,920.00
	Water Pump Stations	5	$9,217,200.00
	Aqueducts	1	$953,720.00
Ciales		7	$7,389,035.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	1	$921,720.00
	Water Treatment Plants	4	$3,686,880.00
	Hydroelectric Dams	1	$1,743,500.00
Cidra		6	$2,419,515.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	4	$460,860.00
	Water Treatment Plants	1	$921,720.00
Coamo		1	$921,720.00
	Water Treatment Plants	1	$921,720.00
Comerío		8	$6,778,265.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	4	$460,860.00

Municipality	Asset Type	Asset Count	Total Cost
	Water Treatment Plants	1	$921,720.00
	Hydroelectric Dams	2	$4,358,750.00
Corozal		6	$3,226,020.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	3	$345,645.00
	Water Treatment Plants	2	$1,843,440.00
Culebra		2	$1,958,655.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	1	$921,720.00
Dorado		15	$22,995,618.98
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	14	$21,958,683.98
Fajardo		3	$3,802,095.00
	Water Pump Stations	1	$1,843,440.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Water Treatment Plants	1	$921,720.00
Florida		9	$1,036,935.00
	Aqueducts	9	$1,036,935.00
Guánica		12	$3,110,805.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	11	$2,073,870.00
Guayama		18	$10,565,085.00
	Water Pump Stations	2	$3,686,880.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	12	$1,382,580.00
	Water Treatment Plants	2	$1,843,440.00
	Hydroelectric Dams	1	$2,615,250.00
Guayanilla		12	$3,110,805.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	10	$1,152,150.00
	Water Treatment Plants	1	$921,720.00

Municipality	Asset Type	Asset Count	Total Cost
Guaynabo		2	$25,845,365.23
	Aqueducts	1	$115,215.00
	Water Treatment Plants	1	$25,730,150.23
Gurabo		16	$13,825,800.00
	Water Pump Stations	6	$11,060,640.00
	Aqueducts	9	$1,843,440.00
	Water Treatment Plants	1	$921,720.00
Hatillo		7	$2,419,515.00
	Aqueducts	5	$576,075.00
	Water Treatment Plants	2	$1,843,440.00
Hormigueros		7	$806,505.00
	Aqueducts	7	$806,505.00
Humacao		4	$4,723,815.00
	Water Pump Stations	1	$1,843,440.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	1	$921,720.00
	Water Treatment Plants	1	$921,720.00
Isabela		7	$1,004,032,525.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	3	$1,152,150.00
	Water Treatment Plants	2	$1,843,440.00
	Hydroelectric Dams	1	$1,000,000,000.00
Jayuya		20	$18,019,324.64
	Water Pump Stations	5	$9,217,200.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	10	$2,384,779.64
	Water Treatment Plants	3	$2,765,160.00
	Hydroelectric Dams	1	$2,615,250.00
Juana Díaz		20	$2,304,300.00
	Aqueducts	20	$2,304,300.00

Municipality	Asset Type	Asset Count	Total Cost
Juncos		29	$36,062,295.00
	Water Pump Stations	18	$33,181,920.00
	Aqueducts	10	$1,958,655.00
	Water Treatment Plants	1	$921,720.00
Lajas		6	$4,116,525.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	4	$2,157,870.00
	Water Treatment Plants	1	$921,720.00
Lares		5	$504,689,120.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	1	$115,215.00
	Water Treatment Plants	1	$921,720.00
	Hydroelectric Dams	2	$502,615,250.00
Las Marías		5	$3,957,310.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	3	$1,998,655.00
	Water Treatment Plants	1	$921,720.00
Las Piedras		5	$1,382,580.00
	Aqueducts	4	$460,860.00
	Water Treatment Plants	1	$921,720.00
Loíza		1	$1,036,935.00
	Wastewater Treatment Plants	1	$1,036,935.00
Luquillo		5	$2,189,085.00
	Aqueducts	4	$1,267,365.00
	Water Treatment Plants	1	$921,720.00
Manatí		22	$8,756,750.17
	Aqueducts	22	$8,756,750.17
Maricao		4	$3,802,095.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Water Treatment Plants	3	$2,765,160.00

Municipality	Asset Type	Asset Count	Total Cost
Maunabo		7	$3,341,235.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	4	$460,860.00
	Water Treatment Plants	2	$1,843,440.00
Mayagüez		11	$5,415,105.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	8	$2,534,730.00
	Water Treatment Plants	2	$1,843,440.00
Moca		9	$1,036,935.00
	Aqueducts	9	$1,036,935.00
Morovis		20	$28,212,460.00
	Water Pump Stations	12	$22,121,280.00
	Wastewater Treatment Plants	2	$2,073,870.00
	Aqueducts	4	$2,173,870.00
	Water Treatment Plants	2	$1,843,440.00
Naguabo		8	$6,623,255.00
	Aqueducts	5	$3,858,095.00
	Water Treatment Plants	3	$2,765,160.00
Naranjito		4	$5,645,535.00
	Water Pump Stations	2	$3,686,880.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Water Treatment Plants	1	$921,720.00
Orocovis		7	$8,379,000.00
	Wastewater Treatment Plants	2	$2,073,870.00
	Aqueducts	1	$925,720.00
	Water Treatment Plants	3	$2,765,160.00
	Hydroelectric Dams	1	$2,615,250.00
Patillas		10	$561,621,985.69
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	7	$1,663,330.69
	Water Treatment Plants	1	$921,720.00

Municipality	Asset Type	Asset Count	Total Cost
	Hydroelectric Dams	1	$558,000,000.00
Peñuelas		10	$6,912,900.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	3	$345,645.00
	Water Treatment Plants	6	$5,530,320.00
Ponce		48	$13,873,800.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	39	$5,463,105.00
	Water Treatment Plants	8	$7,373,760.00
Quebradillas		3	$1,152,150.00
	Aqueducts	2	$230,430.00
	Water Treatment Plants	1	$921,720.00
Rincón		13	$2,304,300.00
	Aqueducts	13	$2,304,300.00
Rio Grande		6	$13,739,301.19
	Water Pump Stations	1	$1,843,440.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	1	$921,720.00
	Water Treatment Plants	3	$9,937,206.19
Sabana Grande		7	$2,419,515.00
	Aqueducts	5	$576,075.00
	Water Treatment Plants	2	$1,843,440.00
Salinas		22	$2,534,730.00
	Aqueducts	22	$2,534,730.00
San Germán		17	$5,427,850.08
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	15	$3,469,195.08
	Water Treatment Plants	1	$921,720.00
San Juan		19	$3,110,805.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	18	$2,073,870.00

Municipality	Asset Type	Asset Count	Total Cost
San Lorenzo		13	$16,758,175.00
	Water Pump Stations	6	$11,060,640.00
	Aqueducts	4	$2,932,375.00
	Water Treatment Plants	3	$2,765,160.00
San Sebastián		5	$8,804,536.74
	Wastewater Treatment Plants	2	$6,845,881.74
	Aqueducts	1	$115,215.00
	Water Treatment Plants	2	$1,843,440.00
Santa Isabel		13	$2,419,515.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	12	$1,382,580.00
Toa Baja		10	$1,152,150.00
	Aqueducts	10	$1,152,150.00
Toa Alta		5	$13,852,937.74
	Water Pump Stations	3	$5,530,320.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Water Treatment Plants	1	$7,285,682.74
Trujillo Alto		2	$1,010,167,297.45
	Water Treatment Plants	1	$10,167,297.45
	Hydroelectric Dams	1	$1,000,000,000.00
Utuado		18	$21,753,581.39
	Water Pump Stations	8	$13,147,151.39
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	3	$345,645.00
	Water Treatment Plants	5	$4,608,600.00
	Hydroelectric Dams	1	$2,615,250.00
Vega Alta		7	$1,871,619.28
	Water Pump Stations	2	$373,824.28
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	4	$460,860.00

Municipality	Asset Type	Asset Count	Total Cost
Vega Baja		18	$4,608,600.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	15	$1,728,225.00
	Water Treatment Plants	2	$1,843,440.00
Vieques		20	$3,226,020.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	19	$2,189,085.00
Villalba		8	$4,990,245.00
	Aqueducts	4	$1,303,365.00
	Water Treatment Plants	4	$3,686,880.00
Yabucoa		17	$12,937,400.18
	Water Pump Stations	2	$3,686,880.00
	Wastewater Treatment Plants	1	$5,217,995.18
	Aqueducts	12	$2,189,085.00
	Water Treatment Plants	2	$1,843,440.00
Yauco		6	$4,032,525.00
	Wastewater Treatment Plants	1	$1,036,935.00
	Aqueducts	2	$230,430.00
	Water Treatment Plants	3	$2,765,160.00
Grand Total		**914**	**$4,852,431,519.53**

Figure 90 shows where critical water infrastructure and hydroelectric dams are located throughout Puerto Rico. A total of 638 facilities are located in low-risk areas (indicated as very low or low susceptibility to drought on the map), while 259 facilities are located within high-risk areas (indicated as high or very high susceptibility to drought).

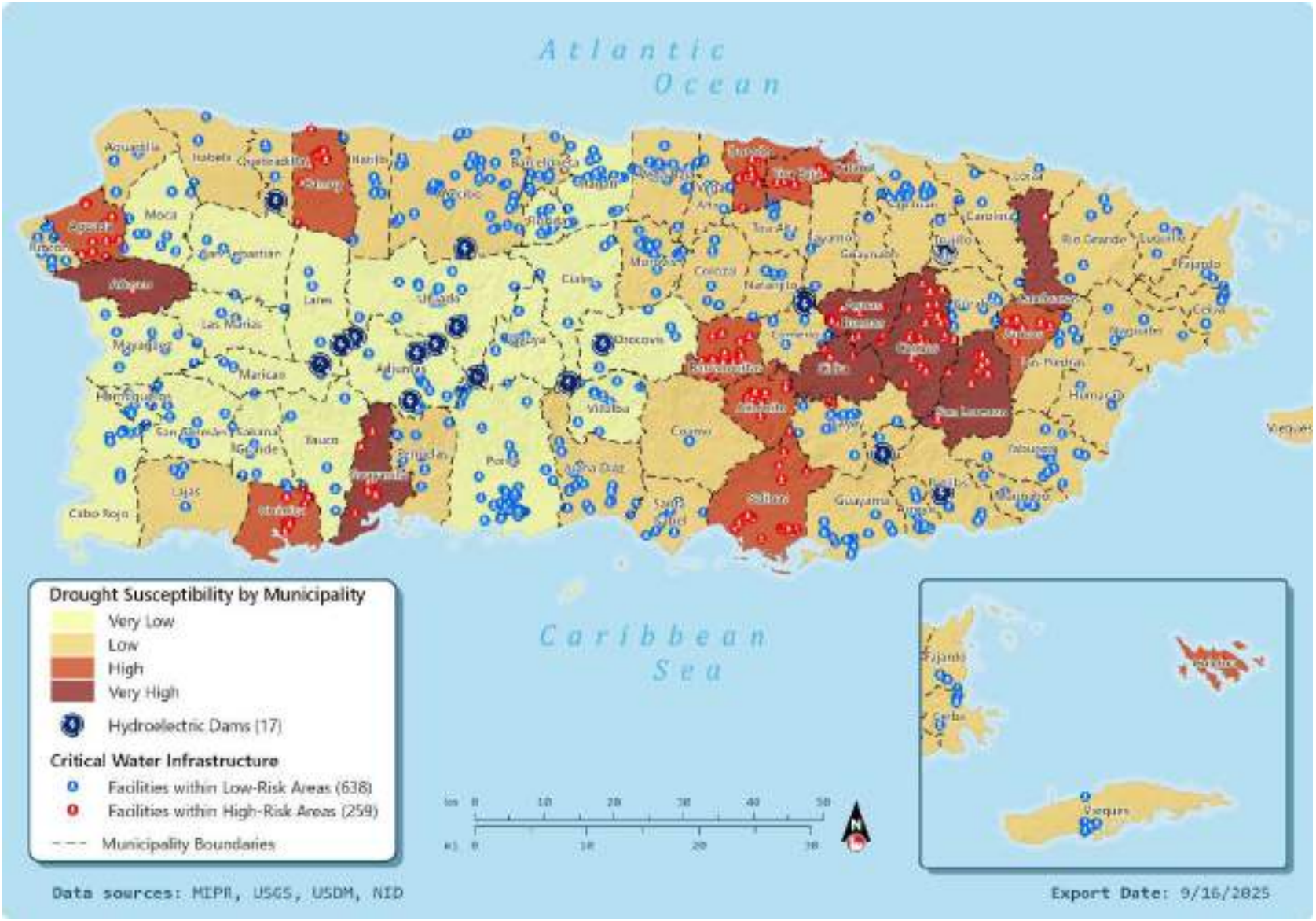


Figure 90: Drought Susceptibility by Municipality – Critical Water Infrastructure

In addition to direct impacts on state-funded assets, drought conditions in Puerto Rico pose significant threats to both the economy and public health. Water shortages can severely hinder agricultural productivity, which in turn affects food security, employment, and revenue generation. Puerto Rico's agricultural sector, while small comprising less than 1% of the island's GDP in 2020, remains vital for local livelihoods and exports[252]. Crops such as coffee, cacao, bananas, and irrigated vegetables are particularly vulnerable to drought stress. For example, recent dry conditions in the eastern interior and northeast regions have led to cracked soils, yellowing cacao leaves, and reduced yields. [253]

Coffee farming, a dominant land use in the central highlands, continues to be a key economic activity despite past hurricane damage. It provides employment for thousands and contributes significantly to agricultural exports. However, drought can delay harvests, reduce bean quality, and increase susceptibility to pests and fungi, as seen in recent years.

Beyond agriculture, droughts also impact critical public services. Schools and emergency management facilities may face clean water shortages, increasing vulnerability during disasters. Historical data show that severe droughts (D2–D3) in Puerto Rico have led to altered school schedules, business closures, and even mosquito-borne disease outbreaks due to stagnant water conditions. [254]

Businesses reliant on water, especially in the food and beverage sector, are heavily affected. These cascading impacts illustrate how drought can trigger a trickle-down effect, beginning with water supply disruptions and culminating in broader economic and social vulnerabilities.

LOCAL ASSETS

The effects of drought conditions are reflected relatively quickly in regional agriculture. The majority of crops in the U.S. Caribbean are not irrigated and, therefore, rely heavily on rainfall for moisture. Agricultural production in Puerto Rico is important for the islands' economy, food security, and rural livelihoods. Agricultural drought is a major concern in Puerto Rico, as 90% of the farmland in Puerto Rico relies on adequate levels of precipitation. The 2014–2016 drought had its most prolonged impact on the eastern half of the island, which experienced up to 80 weeks of moderate drought conditions.[255] In 2015, drought conditions heavily impacted the livestock sector (62.2% of all reported economic losses), followed by the

[252] Kenner, B., Russell, D., Valdes, C., Sowell, A., Pham, X., Terán, A., & Kaufman, J. (2023). *Puerto Rico's agricultural economy in the aftermath of Hurricanes Irma and Maria: A brief overview* (AP-114). U.S. Department of Agriculture, Economic Research Service. https://ers.usda.gov/sites/default/files/_laserfiche/publications/106261/AP-114_Summary.pdf?v=16759.

[253] National Integrated Drought Information System (NIDIS). (2025, September 11). *Drought update for Puerto Rico and the U.S. Virgin Islands*. Drought.gov. https://www.drought.gov/drought-status-updates/drought-update-puerto-rico-and-us-virgin-islands-2025-09-11.

[254] Pugh, B., & Rippey, B. (2025, September 11). *U.S. Drought Monitor: Puerto Rico*. National Drought Mitigation Center, University of Nebraska–Lincoln. https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?PR.

[255] Álvarez-Berríos, N. L., Soto-Bayó, S., Holupchinski, E., Fain, S. J., & Gould, W. A. (2018). Correlating drought conservation practices and drought vulnerability in a tropical agricultural system. Renewable Agriculture and Food Systems, 33(3), 279-291. https://www.cambridge.org/core/blog/2018/07/03/confronting-drought-impacts-in-puerto-rico/.

plantain sector (22%).[256] The remaining 10% of the losses were attributed to a wide variety of 21 crops, including bananas, root and tuber crops, herbs, fruits, and coffee.[257]

Table 31 provides examples of short-term and long-term impacts of drought on crops in Puerto Rico.

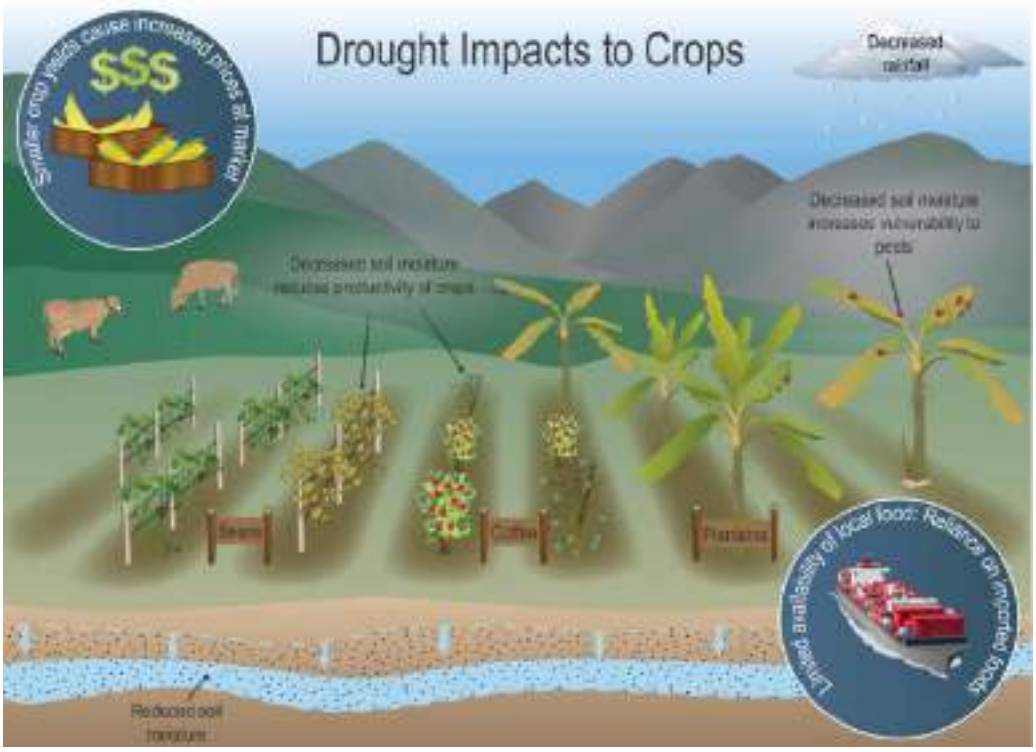


Figure 91: Drought Impacts to Crops in U.S. Caribbean[258]

[256] Álvarez-Berríos, N. L., Soto-Bayó, S., Holupchinski, E., Fain, S. J., & Gould, W. A. (2018). Correlating drought conservation practices and drought vulnerability in a tropical agricultural system. Renewable Agriculture and Food Systems, 33(3), 279-291. https://www.cambridge.org/core/blog/2018/07/03/confronting-drought-impacts-in-puerto-rico/.

[257] Álvarez-Berríos, N. L., Soto-Bayó, S., Holupchinski, E., Fain, S. J., & Gould, W. A. (2018). Correlating drought conservation practices and drought vulnerability in a tropical agricultural system. Renewable Agriculture and Food Systems, 33(3), 279-291. https://www.cambridge.org/core/blog/2018/07/03/confronting-drought-impacts-in-puerto-rico/.

[258] United States Geological Survey, "Drought Impacts to Crops in the U.S. Caribbean," 2025, https://www.usgs.gov/programs/climate-adaptation-science-centers/drought-impacts-crops-us-caribbean.

Table 31: Short- and Long-Term Impacts of Drought on Crops in Puerto Rico[259]

Short-Term Impacts	Long-Term Impacts
Produce Quality: Drought can stunt growth and result in produce that is smaller and of lower quality.	**Local Food Availability:** As staple crops are impacted, there will be a reduction in the availability of local food. Imported food is often less fresh and has lower nutritional value.
Higher Prices: Lower yields and higher operating costs can mean higher prices for consumers.	**Saltwater Intrusion:** Overuse of groundwater for irrigation could lead to more salt-water intrusion into aquifers.
Vulnerability to Pests: As soil moisture decreases, crops dry out and become more vulnerable to insects.	**Coffee Production:** Coffee production may be reduced due to less optimal conditions and an increase in pests.

Figure 92 indicates drought susceptibility by municipality based on historical drought occurrences and losses. While all of Puerto Rico is somewhat vulnerable to drought, municipalities particularly in the south and southeast portions of Puerto Rico have typically been more susceptible to drought impacts. Most of the western side of the island has very low susceptibility to drought with most municipalities across Puerto Rico having low susceptibility to this hazard.

[259] United States Geological Survey, "Drought Impacts to Crops in the U.S. Caribbean," 2025, https://www.usgs.gov/programs/climate-adaptation-science-centers/drought-impacts-crops-us-caribbean.

Figure 92: Drought Susceptibility by Municipality

COMMUNITY LIFELINES

Prolonged drought conditions can impact food, hydration, shelter, health and medical systems, energy systems, and water and wastewater systems. Most crops and animals require water to thrive and grow; without water, they stress and ultimately die. Structures and infrastructures are also affected as prolonged drought can severely damage structural integrity as the soil pulls away from beams, buildings, bridges, and other structures.

FOOD, HYDRATION, AND SHELTER

The Food, Hydration, Shelter lifeline provides access to basic needs for those impacted by prolonged drought. The Puerto Rico agricultural system is part of the food distribution for the island's population and is directly impacted by reduced crop yields, losses of livestock, and increased food prices during prolonged periods of drought. Prolonged drought may also lead to water shortages that impact the drinking water supply and require the implementation of water restrictions. Puerto Rico's sheltering program can be strained as it provides support to populations in crisis under prolonged drought conditions, when food and water supplies are impacted.[260]

HEALTH AND MEDICAL

The Health and Medical lifeline, which provides medical care and public health services, may be impacted by drought, because it exacerbates health problems related to poor air quality (due to dust from the Sahara Air Layer) and limited water for hygiene.

ENERGY

The Energy lifeline focuses on providing power and fuel to the affected communities. Drought may impact hydroelectric power generation due to reduced water levels in reservoirs and rivers, leading to energy shortages. Drought can also affect cooling systems in Puerto Rico's power plants that rely on water, potentially leading to reduced power output.

WATER SYSTEMS

The Water Systems lifeline includes freshwater reservoirs, potable water distribution infrastructure, and wastewater treatment plants. This infrastructure may be impacted when drought-induced reduction in water supply disrupts the water distribution system. Infrastructure degradation, particularly sedimentation in reservoirs, can and has reduced water storage capacity and operational efficiency.

HAZARDOUS MATERIALS

The Hazardous Materials lifeline involves the management of hazardous materials spills and exposure of the water systems to contaminants. Drought conditions can concentrate pollutants in groundwater supplies,

[260] United States Geological Survey, "Drought Impacts to Crops in the U.S. Caribbean," 2025, https://www.usgs.gov/programs/climate-adaptation-science-centers/drought-impacts-crops-us-caribbean.

increasing the risk of exposure to hazardous materials in the drinking water supply. In response, desalination, water recycling, or the implementation of water restrictions may be required.

Changes in Development

The Puerto Rico Aqueduct and Sewer Authority has taken several initiatives since the most recent plan update, which focused on improving water quality and availability to reduce the impacts of drought on the population, the agriculture economy, and the water supply systems. For example, in 2020, PRASA faced a new dry season during which 50% of the Island experienced moderate to severe drought conditions. The implemented water rationing plan affected approximately 140,000 clients served by the Carraízo system from July 2 to July 27, 2020.

In addition, after the 2017 hurricanes, PRASA's Capital Improvement Program (CIP) was adjusted by adding an objective for system recovery and resiliency.[261] One initiative of the CIP involved addressing concerns related to runoff and silt in reservoirs. Although rainfall is abundant generally from April to November, roughly two thirds of this rainwater was not available, because runoff evaporates from land or transpires through vegetation. In addition, raw water reservoirs have accumulated silt and sand at the bottom, affecting the amount of volume stored. In response, the Puerto Rico Aqueduct and Sewer Authority (PRASA) has implemented approximately $1 billion in mitigation measures through its Capital Improvement Program (CIP).[262] These include silt removal operations, system modernization, and upgrades to enhance resilience against future drought conditions. As a result of PRASA's implementation of several CIP initiatives, Puerto Rico's vulnerability to drought conditions has **decreased.**

LAND USE AND BUILT ENVIRONMENT CHANGES

Through Senate Bill (PS) 939, signed into law in June 2024, PRASA, Puerto Rico Permit Management Office, and the Department of Agriculture began implementing procedures to comply with the public policy of promoting rain harvesting throughout Puerto Rico. This initiative is projected to reduce consumption from reservoirs and the risk of water rationing during periods of drought. PRASA is currently conducting a study to measure outcomes from rain harvesting initiatives. This type of human-made change in the environment will decrease Puerto Rico's vulnerability to hydrological drought.

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

The Puerto Rico Aqueduct and Sewer Authority Five Year Strategic Plan (2021-2025) includes initiatives for its Capital Improvement Program (CIP), focused on water quality improvements to modernize and maintain PRASA infrastructure. The CIP identifies six categories for projected future growth and redevelopment:

- **Mandatory Compliance:** Projects to comply with current regulations, including the Consent Decree with EPA and the Agreement with PRDOH.

[261] Puerto Rico Aqueduct and Sewer Authority, "PRASA Five Year Strategic Plan (2021-2025)," 2025, https://docs.pr.gov/files/AAA/Nuestra%20AAA/Documentos/PRASA%20Strategic%20Plan%202020-2025.pdf.
[262] Severe Drought in Puerto Rico Prompts State of Emergency, Water Rationing | Weather.com https://weather.com/safety/news/2020-06-30-severe-drought-puerto-rico-state-of-emergency.

- **Non-Mandatory Compliance:** Projects with a high risk of non-compliance with environmental regulations that may convert into Mandatory Compliance projects.
- **Quality:** Projects focused on quality in service reliability as well as water quality areas.
- **Renewal & Replacement:** Equipment and infrastructure renewal and replacement to allow for the provision of a reliable, quality service.
- **Emergency and Recovery:** Projects to address situations requiring immediate actions to allow for continuous service provision in compliance with water quality regulations.
- **Resiliency:** Projects to allow for improved system resiliency to address a new reality of increased impact from climate changes in PRASA's system.

POPULATION CHANGES

The population of Puerto Rico has decreased 2.5% since the last plan update. Although small percentage wise, less demand on water systems can help alleviate the impacts of drought. Water conservation is a typical measure implemented to reduce the strain on water systems during periods of drought. However, it is complicated. Drought can also contribute to the population decline. When water is turned off due to drought or crops are lost, this can lead to migration both within and outside of the island.

Mitigation Success Stories

PRASA Five Year Strategic Plan (2021-2025) has begun to address ongoing challenges as they face a new reality from natural disasters (such as droughts, hurricanes, and earthquakes) and other threats to the island's water and wastewater treatment systems. PRASA has focused strategic planning on infrastructure design and development as well as investment in technology to ensure recovery and enhance resiliency. After the 2017 Hurricanes, PRASA's Capital Improvement Program was adjusted by adding an objective for system recovery and resiliency.[263]

SALINAS WATER SUPPLY SYSTEM MITIGATION PROJECT ($27,012,343.17 HMGP GRANT)

The Salinas coastal plain is an important agricultural area in southern Puerto Rico. The Salinas Aquifer is located on the southern coast of Puerto Rico, in one of the driest regions of the island. Groundwater levels at the Salinas Aquifer (which is part of the South Coast Aquifer) have declined in recent years due to an imbalance caused by limited surface recharge and high rates of water extraction. The high rate of withdrawals and the reduction in recharge have lowered the water table of the aquifer below sea level, allowing seawater contamination (saline intrusion) from the Caribbean Sea.

The Salinas Water Supply System Mitigation Project (HMGP-4339-0020), completed on June 30, 2025, constructed a 4-MGD conventional water treatment plant (WTP) at a private parcel behind the Salinas Plaza

[263] Puerto Rico Aqueduct and Sewer Authority, "PRASA Five Year Strategic Plan (2021-2025)," 2025, https://docs.pr.gov/files/AAA/Nuestra%20AAA/Documentos/PRASA%20Strategic%20Plan%202020-2025.pdf.

Shopping Center close to the Patillas irrigation channel and State Road PR-52. The water treatment plant receives raw water from two intakes:

- A 4-MGD gravity intake with a lift pump station constructed at the Patillas irrigation canal close to the plant site
- A 4-MGD gravity intake constructed at the Juana Díaz irrigation canal at Sector Las Ochenta, at a high point near Las Flores and Girasol streets

Both intakes have the capacity to deliver up to 4 MGD to guarantee water sustainability when either one of the irrigation canals is out of service for maintenance or during an emergency.

COMMUNITY FACILITIES FOR ENERGY AND WATER RESILIENCE PROGRAM ($395,000,000 HUD GRANT)

On January 26, 2024, the Government of Puerto Rico and the Puerto Rico Department of Housing launched an initiative under the Community Facilities Program for Energy and Water Supply Resilience (CEWRI), funded by CDBG-DR. The U.S. Department of Housing and Urban Development (HUD) allocated $395 million to support the initiative, which aims to provide photovoltaic energy systems and water storage solutions to selected participants of the Repair, Reconstruction, or Relocation (R3) Program. The program will address power and water system vulnerabilities by providing single-family homeowners with energy and water efficiency improvements and promoting resilience through the installation of battery-powered photovoltaic systems for critical loads and water storage systems.[264]

[264] Recuperacion.pr.gov, "Community Facilities for Energy and Water Supply Resiliency Program," 2025, https://recuperacion.pr.gov/download/instalaciones-comunitarias-para-la-resiliencia-energetica-y-de-abastecimiento-de-agua/.

SECTION 4.3

EARTHQUAKES

Earthquakes

EARTHQUAKE DEFINITION

The U.S. Geological Survey (USGS) defines an earthquake as "what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane." It further explains that "the location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface is the epicenter."[265]

For context, energy is stored when two edges of faults are stuck together and continue pressing against each other, creating friction. When the movement overcomes the friction between the edges of the fault, all the stored energy is released in all directions in the form of seismic waves that reach the surface, causing the ground to shake.

Earthquakes can be measured in two ways: magnitude and intensity. Magnitude is measured using a seismograph, which tracks the amount of energy released at the source of the earthquake and is represented on the Richter scale. Meanwhile, intensity refers to the effect of an earthquake in different locations.

The earthquake begins at the hypocenter located below the earth's surface and can be felt at the epicenter located directly above it on the main fault plane. Foreshocks can be felt before a major earthquake or main shock. Aftershocks can follow a major earthquake and may continue for weeks, months, or years after the main shock.

[265] U.S. Geological Survey (USGS), "The Science of Earthquakes," accessed August 29, 2025, https://www.usgs.gov/programs/earthquake-hazards/science-earthquakes.

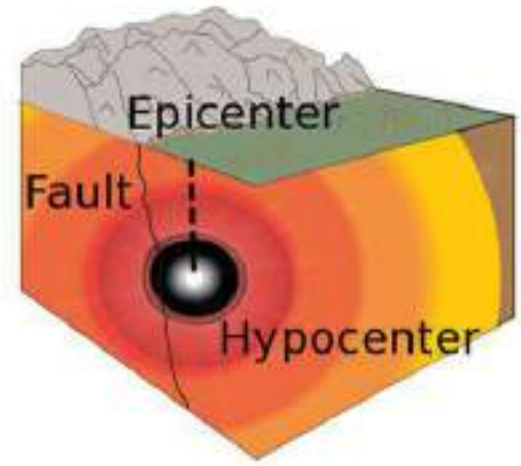


Figure 93: Earthquake Hypocenter (Focus) and Epicenter[266]

Types of Plate Boundaries

Tectonic plate movements around Puerto Rico occur along the boundary between the North American Plate and the Caribbean Plate, and are classified into three main types: convergent, divergent, and transform. In this region, convergent boundaries are represented by the subduction of the North American Plate beneath the Caribbean Plate, particularly along the Puerto Rico Trench, which can generate large megathrust earthquakes and tsunamis. Divergent activity is observed in zones like the Mona Passage, where crustal extension leads to normal faulting and moderate seismicity. Transform boundaries are present in structures such as the Septentrional Fault Zone and the Enriquillo-Plantain Garden Fault, where plates slide past each other laterally, producing strike-slip earthquakes. These tectonic interactions result in complex deformation across Puerto Rico and contribute to its significant seismic hazard, shaping the island's geological landscape and posing risks to infrastructure and communities.[267]

Figure 94: Types of Tectonic Plate Movements

[266] Puerto Seismic Network, "What Is an Earthquake," https://redsismica.uprm.edu/english/education/earthquake_information.php.
[267] Mueller, C., Frankel, A., Petersen, M., & Leyendecker, E. (2010). *New seismic hazard maps for Puerto Rico and the U.S. Virgin Islands*. Earthquake Spectra, 26(1), 169–185. https://doi.org/10.1193/1.3277667.

Location

The Mona Canyon, Puerto Rico Trench, and Sombrero Seismic Zone are key fault zones forming part of the complex tectonic boundary between the North American Plate and the Caribbean Plate. Puerto Rico lies at the northeastern corner of the Caribbean Plate, where tectonic interactions have produced large-magnitude earthquakes and devastating tsunamis as Figure 95 states. The region contains approximately 504 identified faults, both on land and underwater, contributing to its high seismic hazard. Subduction is most prominent in the Puerto Rico Trench, where the North American Plate is being forced beneath the Caribbean Plate. This subduction zone generates deep seismic activity and poses significant tsunami hazards, as evidenced by historical events and ongoing geophysical studies conducted by the USGS[268].

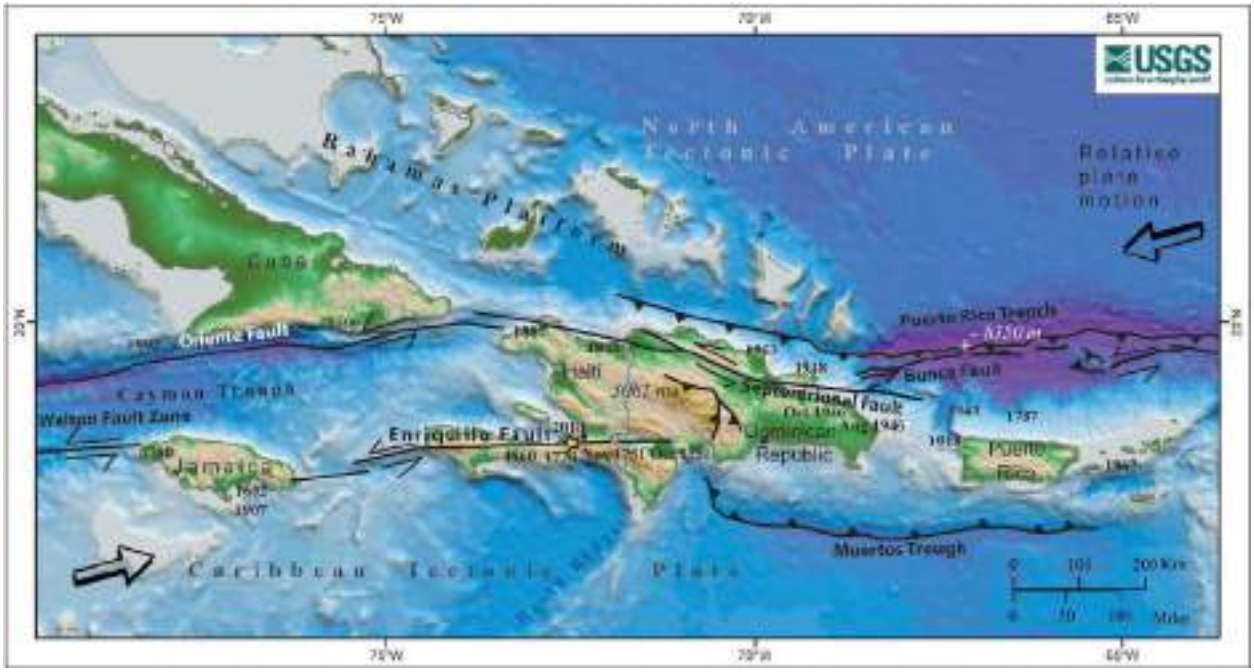


Figure 95: Caribbean Tectonic Plate Boundary

Additionally, Puerto Rico and the surrounding region experience frequent seismic swarms, which are clusters of small to moderate earthquakes occurring over a short period of time. These swarms, along with the presence of major fault zones, highlight the region's vulnerability to significant geological hazards such as earthquakes, tsunamis, and land subsidence.[269]

[268] Woods Hole Coastal and Marine Science Center. (2010, January 20). *Map of the North American–Caribbean tectonic plate boundary*. U.S. Geological Survey. https://www.usgs.gov/media/images/regional-map-puerto-rico.
[269] López, A. M., Hughes, K. S., & Vanacore, E. (2020, January 7). *Puerto Rico's Winter 2019–2020 seismic sequence leaves the island on edge*. Temblor. https://doi.org/10.32858/temblor.064.

In Figure 96, the map also highlights earthquake epicenters in relation to the boundaries of tectonic plates, providing insight into the geodynamic context of the region and emphasizing areas of heightened seismic risk and the interaction between major geological structures.[270]

[270] López, A. M., Hughes, K. S., & Vanacore, E. (2020). *Puerto Rico's Winter 2019–2020 seismic sequence leaves the island on edge*. Temblor. http://doi.org/10.32858/temblor.064.

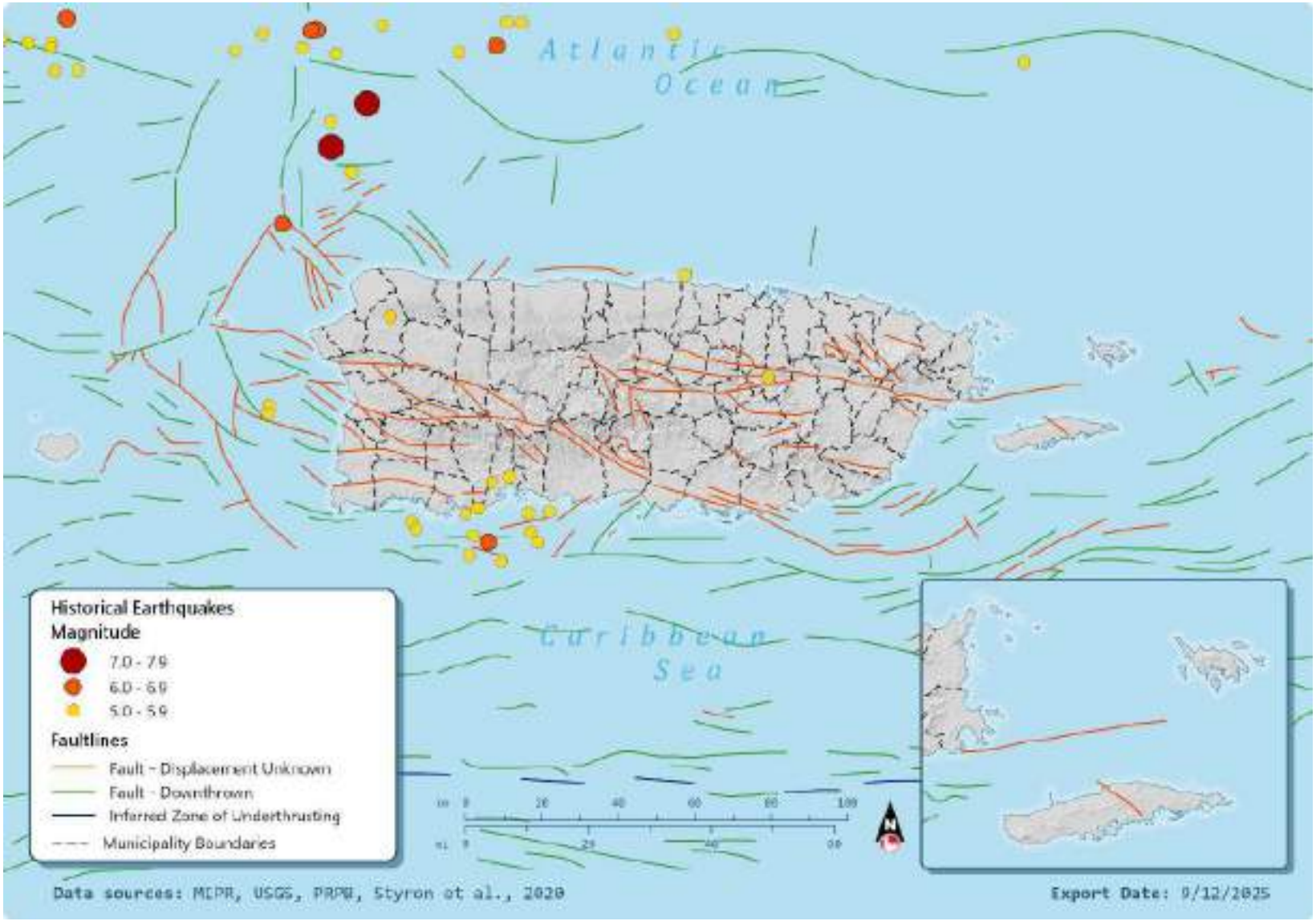


Figure 96: Historic Earthquakes with Fault Lines

According to the USGS, this region is geologically active and capable of generating high-intensity earthquakes, making it one of the most seismically dynamic areas in the Caribbean.[271] At-risk seismic zones in Puerto Rico include the following:

- The northern region of Puerto Rico
- The Muertos Trench (south)
- The Anegada Trench (east)
- The Mona Canyon zone (west)

Table 32 provides more detailed information on the most significant faults near Puerto Rico, including their estimated potential magnitudes. *Potential magnitude* refers to the maximum expected strength of an earthquake that a fault can produce, typically measured using the Moment Magnitude Scale (Mw):

Table 32: Faults Near Puerto Rico with Locations and Estimated Magnitudes

Fault Name	Relative Location	Absolute Location	Potential Magnitude
Anegada Fault	South-Southeast	(17.91°N, -64.39°W) to (17.72°N, -66.49°W)	7.7
Mona Fault (East)	Northwest	(19.10°N, -67.32°W) to (18.52°N, -67.26°W)	7.5
Mona Fault (West)	Northwest	(18.98°N, -67.50°W) to (18.42°N, -67.64°W)	7.5
Great Northern Fault Zone	Center-east	(18.18°N, -65.72°W) to (18.31°N, -66.30°W)	6.8
Great Southern Fault Zone	Midwest	(18.05°N, -66.51°W) to (18.28°N, -67.09°W)	6.6
Failure of the Dead	South	(17.45°N, -64.16°W) to (17.23°N, -68.30°W)	7.6
Puerto Rico Trench	North	(19.72°N, -63.23°W) to (19.59°N, -68.38°W)	8.5
Northern Fault	Northwest	(18.99°N, -67.48°W) to (19.10°N, -68.35°W)	7.8
Hat Failure	Southeast-southwest	(18.86°N, -63.69°W) to (17.94°N, -65.42°W)	7.7

[271] USGS, "2025 Puerto Rico and U.S. Virgin Islands Long-term National Seismic Hazard Model, Earthquake Hazards Program," March 17, 2025, https://www.usgs.gov/programs/earthquake-hazards/science/2025-puerto-rico-and-us-virgin-islands-long-term-national.

Previous Occurrences

Puerto Rico is located at the active boundary between the North American Plate and the Caribbean Plate, making it one of the most seismically active regions in the Caribbean. Due to this tectonic setting, it is completely normal for the island to experience hundreds to thousands of earthquakes each year, most of which are too small to be felt by people. However, several earthquakes have been strong enough to be perceptible and have caused significant damage, such as the 2020 southwestern Puerto Rico earthquake sequence. These events highlight the importance of understanding seismic hazards and implementing mitigation strategies to reduce risk.[272]

Figure 97 illustrates the intense seismic activity recorded across Puerto Rico, underscoring the island's vulnerability to future seismic hazards.[273]

[272] Mueller, C., Frankel, A., Petersen, M., & Leyendecker, E. (2010). *New seismic hazard maps for Puerto Rico and the U.S. Virgin Islands*. Earthquake Spectra, 26(1), 169–185. https://doi.org/10.1193/1.3277667.
[273] A. M. López, K. S. Hughes, and E. Vanacore, "Puerto Rico's Winter 2019-2020 Seismic Sequence Leaves the Island on Edge," Temblor, 2020, http://doi.org/10.32858/temblor.064.

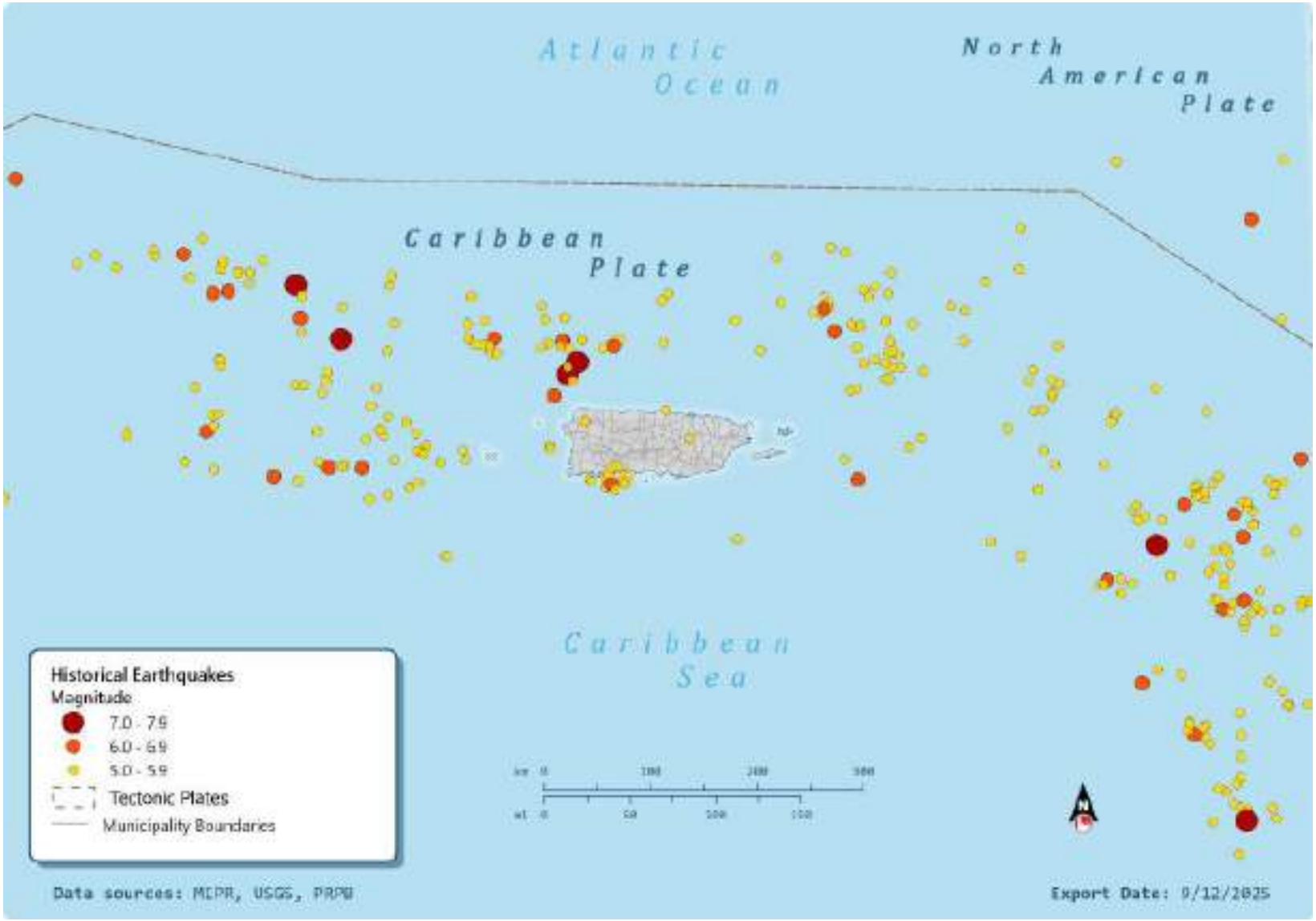


Figure 97: Recent Earthquakes with Epicenters and Tectonic Plate Boundaries

Puerto Rico has long been vulnerable to seismic activity due to its location near the complex tectonic boundaries of the Caribbean region. This vulnerability was highlighted between December 2019 and January 2020, when a series of powerful earthquakes struck the island, causing widespread damage, displacing thousands of residents, and prompting both federal and local emergency responses. While the National Centers for Environmental Information (NCEI) storm database serves as a key source of historical hazard data referenced in this plan, it does not include records of seismic events. To address this gap, seismic activity data has been sourced from the USGS and the Puerto Rico Seismic Network, both of which provide comprehensive and authoritative information on earthquakes affecting the region.

Table 33 presents a descending list of significant earthquakes impacting Puerto Rico from 1990 to 2023, highlighting the intense seismic activity of early 2020, when multiple high-magnitude events—peaking at 6.4—struck the island in rapid succession.

Table 33: USGS Database of Earthquakes Impacting Puerto Rico, 1990–2025

Date	Location (Latitude/Longitude)	Magnitude
1/7/2020	4 km SSE of Indios, Puerto Rico (17.9578/-66.8113)	6.4
1/11/2020	5 km SE of Maria Antonia, Puerto Rico (17.949/-66.8508)	5.9
1/6/2020	14 km S of Indios, Puerto Rico (17.8675/-66.8193)	5.8
5/16/2010	4 km E of Moca, Puerto Rico (18.4/-67.07)	5.8
1/7/2020	0 km NW of Magas Arriba, Puerto Rico (18.0223/-66.776)	5.6
1/7/2020	11 km S of Tallaboa, Puerto Rico (17.8919/-66.7217)	5.6
5/2/2020	6 km S of Tallaboa, Puerto Rico (17.937/-66.7266)	5.4
7/3/2020	9 km SSE of La Parguera, Puerto Rico (17.8995/-67.0048)	5.3
1/15/2020	Puerto Rico Region (17.9155/-67.0171)	5.2
1/11/2020	19 km S of Indios, Puerto Rico (17.8238/-66.7941)	5.2
1/10/2020	4 km S of Maria Antonia, Puerto Rico (17.935/-66.883)	5.2
12/17/2011	19 km SW of Stella, Puerto Rico (18.188/-67.37)	5.2
12/17/2011	21 km SW of Stella, Puerto Rico (18.172/-67.371)	5.1
12/24/2010	3 km W of Aguas Buenas, Puerto Rico (18.26/-66.135)	5.1
2/4/2020	15 km SSE of Guánica, Puerto Rico (17.8388/-66.8751)	5
1/25/2020	1 km N of Indios, Puerto Rico (18.0105/-66.8188)	5
1/7/2020	7 km SE of Tallaboa, Puerto Rico (17.9418/-66.6754)	5
1/7/2020	14 km S of Tallaboa, Puerto Rico (17.8685/-66.7029)	5
12/29/2019	10 km SSE of Guánica, Puerto Rico (17.8846/-66.864)	5
7/3/2020	5 km SE of La Parguera, Puerto Rico (17.9443/-67.0035)	4.9

Date	Location (Latitude/Longitude)	Magnitude
1/12/2020	2 km S of Maria Antonia, Puerto Rico (17.9556/-66.8865)	4.9
1/6/2020	Puerto Rico Region (17.9075/-66.799)	4.9
10/8/2021	13 km SE of Esperanza, Puerto Rico (18.0105/-65.3871)	4.8
12/24/2020	6 km SE of Maria Antonia, Puerto Rico (17.9331/-66.8451)	4.8
8/7/2020	2 km SSE of Magas Arriba, Puerto Rico (17.995/-66.7606)	4.8
6/28/2020	5 km SW of Guánica, Puerto Rico (17.9396/-66.9415)	4.8
1/11/2020	3 km E of Indios, Puerto Rico (17.9923/-66.7946)	4.8
12/24/2020	Puerto Rico Region (17.9461/-66.8385)	4.7
1/8/2020	8 km S of Tallaboa, Puerto Rico (17.915/-66.7035)	4.7
1/7/2020	4 km SSW of Guánica, Puerto Rico (17.9315/-66.927)	4.7
1/7/2020	9 km SSE of Tallaboa, Puerto Rico (17.9128/-66.6898)	4.7
1/3/2020	10 km S of Indios, Puerto Rico (17.9006/-66.8261)	4.7
12/29/2019	7 km SSW of Indios, Puerto Rico (17.9308/-66.83630)	4.7
12/28/2019	5 km SSE of Maria Antonia, Puerto Rico (17.9371/-66.8661)	4.7
10/1/1990	1 km W of Juncos, Puerto Rico (18.229/-65.932)	4.7
5/2/2020	5 km SSE of Tallaboa, Puerto Rico (17.9508/-66.6981)	4.6
1/20/2020	4 km WSW of Tallaboa, Puerto Rico (17.9748/-66.7528)	4.6
1/14/2020	13 km SSE of Guánica, Puerto Rico (17.8548/-66.8686)	4.6
1/11/2020	6 km SSW of Indios, Puerto Rico (17.9423/-66.8395)	4.6
1/7/2020	3 km SSW of Indios, Puerto Rico (17.9645/-66.8256)	4.6
1/7/2020	9 km SSW of Tallaboa, Puerto Rico (17.9206/-66.767)	4.6
3/12/2019	3 km SSW of Jobos, Puerto Rico (17.93/-66.1798)	4.6
12/5/2016	9 km S of Emajagua, Puerto Rico (17.919/-65.8795)	4.6
8/13/2014	37 km NNE of Culebra, Puerto Rico (18.6263/-65.18450	4.6
7/19/1998	18 km WSW of Charlotte Amalie, U.S. Virgin Islands (18.303/-65.098)	4.6
9/13/1994	7 km E of Pole Ojea, Puerto Rico (17.98/-67.116)	4.6
4/9/2023	Puerto Rico Region (17.955/-66.9518)	4.5
6/28/2020	5 km SW of Guánica, Puerto Rico (17.9443/-66.9495)	4.5
6/13/2020	Puerto Rico Region (17.9601/-66.9471)	4.5
1/25/2020	6 km SSW of Guánica, Puerto Rico (17.9245/-66.9401)	4.5

Date	Location (Latitude/Longitude)	Magnitude
1/20/2020	4 km SW of Tallaboa, Puerto Rico (17.9618/-66.7425)	4.5
1/20/2020	3 km SW of Tallaboa, Puerto Rico (17.977/-66.7408)	4.5
1/13/2020	3 km S of Indios, Puerto Rico (17.9638/-66.8131)	4.5
1/12/2020	8 km SSE of Guánica, Puerto Rico (17.9033/-66.8765)	4.5
1/2/2020	8 km S of Indios, Puerto Rico (17.9148/-66.8333)	4.5
7/22/2010	15 km N of Charlotte Amalie, U.S. Virgin Islands (18.483/-64.949)	4.5
6/12/2002	32 km S of Charlotte Amalie, U.S. Virgin Islands (18.045/-64.927)	4.5
2/19/1990	17 km SE of Esperanza, Puerto Rico (17.983/-65.3560)	4.5

Table 34 and Figure 98 presents annual earthquake counts and magnitudes in Puerto Rico from 2019 to 2025, clearly illustrating that 2020 stands out both in terms of the number of seismic events and the frequency of high-magnitude earthquakes. That year alone recorded over 11,500 earthquakes, including 126 events of magnitude 4.5 or greater, a stark contrast to the significantly lower figures in subsequent years. However, while these numbers reflect short-term seismic activity, they do not alter the long-term probability of hazard in terms of intensity or magnitude. As emphasized by López et al. (2020), the 2019–2020 seismic sequence was exceptional but episodic, and Mueller et al. (2010) remind us that probabilistic seismic hazard assessments rely on decades of historical data, fault behavior, and ground motion models—not recent clusters alone.[274]

Table 34: Earthquake Magnitudes in Puerto Rico, 2019–2025[275]

Year	Total Earthquakes	Significant Events	Magnitude 4.5+	Magnitude 2.5+	Magnitude 1.0+	Magnitude <1.0
2025	1,734	0	0	774	960	0
2024	2,232	1	9	1,225	997	0
2023	3,139	0	2	1,505	1,632	0
2022	5,207	0	1	1,548	3,649	9
2021	3,166	0	7	1,896	1,257	6
2020	11,557	18	126	7,323	4,068	22
2019	4,937	6	35	2,260	2,586	50

[274] A. M. López, K. S. Hughes, and E. Vanacore, "Puerto Rico's Winter 2019-2020 Seismic Sequence Leaves the Island on Edge," Temblor, 2020, http://doi.org/10.32858/temblor.064
[275] USA Today, "Earthquakes in Puerto Rico Graph from 1994 to 2025," 2025, https://data.usatoday.com/earthquake/past-hour/puerto-rico/2025/#eqchart.

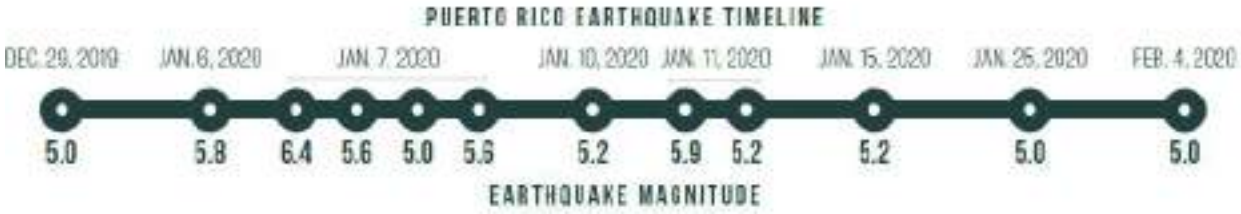


Figure 98: Puerto Rico Earthquake Timeline, 2019–2020[276]

FEDERAL DISASTER DECLARATIONS

DISASTER NUMBER DR-4473-PR – JANUARY 16, 2020

On January 16, 2020, the federal government issued Disaster Declaration DR-4473-PR, marking a pivotal moment in Puerto Rico's response to the devastating earthquake sequence that began in late December 2019. This declaration authorized the Federal Emergency Management Agency (FEMA) to provide critical aid to six municipalities—Guánica, Guayanilla, Peñuelas, Ponce, San Germán, and Yauco—through both the Public Assistance (PA) and Individual Assistance (IA) programs. These communities, located in the island's southwestern region, bore the brunt of the seismic impacts, with widespread structural damage and thousands of residents displaced.

As the aftershocks continued and damage assessments expanded, the declaration was amended on March 11, 2020, to include additional municipalities: Adjuntas, Jayuya, Juana Díaz, Lajas, Las Marías, Mayagüez, Sábana Grande, San Germán, and Utuado. Ultimately, a total of 33 municipalities were designated under DR-4473-PR, making them eligible for federal assistance to support recovery and rebuilding efforts.

This declaration not only unlocked vital resources but also underscored the scale of the disaster and the federal commitment to supporting Puerto Rico's resilience. The inclusion of both PA and IA programs ensured that assistance reached not only public infrastructure but also individual households, reinforcing the importance of coordinated emergency management in the face of complex and cascading hazards.

[276] U.S. House Committee on Natural Resources, "House Committee on Natural Resources Report on Puerto Rico's Earthquakes," February 2020, https://democrats-naturalresources.house.gov/imo/media/doc/KS_PUERTORICO_earthquakesreport.pdf.

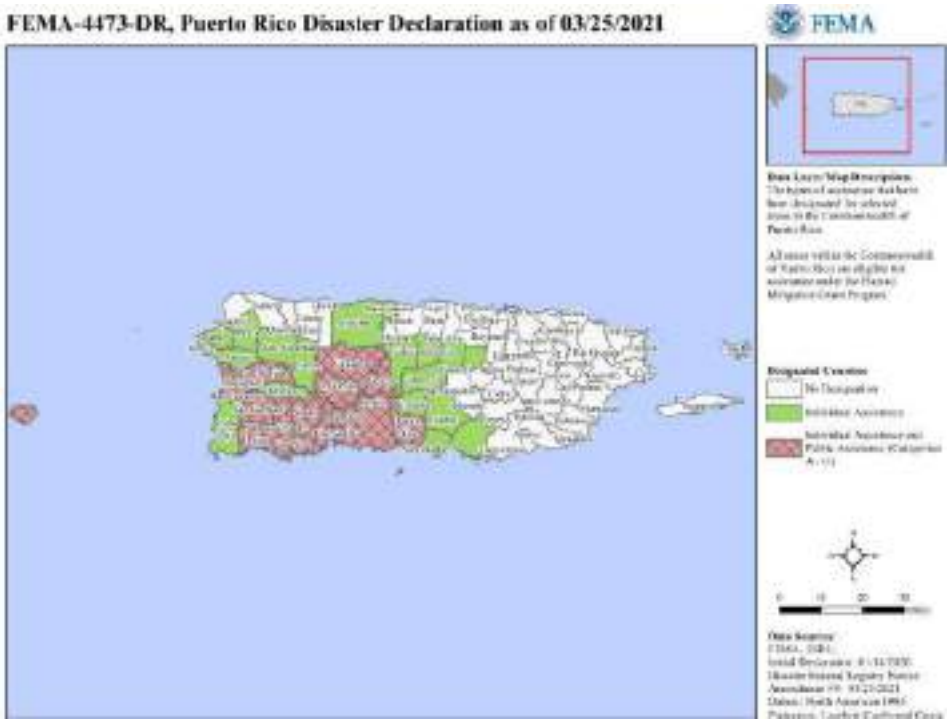


Figure 99: FEMA DR-4473–Puerto Rico Disaster Declaration Map Showing Designated Municipalities[277]

PUERTO RICO DISASTER DECLARATIONS

DISASTER NUMBER OE-2020-001, JANUARY 7, 2020

On January 7, 2020, in the early hours following a powerful magnitude 6.4 earthquake near Guayanilla, the Governor of Puerto Rico, Hon. Wanda Vázquez Garced, issued Executive Order OE-2020-001, declaring a state of emergency across the entire island. This decisive action was taken in response to the escalating seismic activity that had already caused significant damage to critical infrastructure, homes, schools, and public services[278].

The order empowered government agencies to activate emergency procurement procedures, enabling rapid acquisition of essential materials and services. It also called for a coordinated response plan among all relevant agencies to address the immediate threats to life, property, and public safety. The declaration recognized the gravity of the situation—not only the initial earthquake but also the ongoing aftershocks that continued to destabilize communities and threaten vital systems.

By invoking the authority granted under Puerto Rico's Constitution and the Department of Public Safety Act (Law 20-2017), the Governor ensured that emergency resources could be mobilized swiftly. The order also

[277] Federal Emergency Management Agency, "DR-4473-PR Puerto Rico Earthquakes Disaster Designated Areas Map," 2025, https://www.fema.gov/disaster/4473/designated-areas.
[278] Executive Order No. OE-2020-001, https://www.lexjuris.com/ordenes/OE-2020-001.pdf.

authorized the use of emergency reserve funds and established a working group led by the State Coordinator Officer to oversee response and recovery efforts.

This executive action was not merely procedural—it was a critical step in safeguarding the island's residents and infrastructure during one of the most disruptive seismic episodes in recent history. It laid the foundation for federal assistance, including FEMA's Public Assistance and Individual Assistance programs, and underscored the importance of proactive governance in the face of cascading hazards

In response to the state of emergency declaration, Puerto Rico's Financial Oversight and Management Board (FOMB) authorized the utilization of Emergency Reserve funds from fiscal years 2019 and 2020, totaling $260 million in aggregate funds, as needed by the Government of Puerto Rico for the earthquake-related expenses.[279]

SIGNIFICANT EVENTS

The historical record of seismic activity in Puerto Rico dates to 1615, when an earthquake originating in the Dominican Republic caused damage on the island.[280] Subsequent events include a magnitude 7 earthquake on August 30, 1740, which directly impacted Puerto Rico, notably destroying the Guadalupe Church in the municipality of Ponce. According to the Puerto Rico Seismic Network, four major and destructive earthquakes have occurred between 1670 and 1918—in the years 1670, 1787, 1867, and 1918. This pattern underscores the island's ongoing exposure to seismic hazards, as evidenced by the January 7, 2020, earthquake in Guánica. It is crucial to recognize that the Puerto Rico microplate, the Puerto Rico Trench, and the Virgin Islands plate are integral components of the region's national seismic risk profile.

1787 EARTHQUAKE

Possibly the strongest earthquake to have affected Puerto Rico since the beginning of colonization occurred on May 2, 1787. It was felt intensely across the entire island and is estimated to have reached a magnitude of 8.0 on the Richter scale.[281] The epicenter was located to the north, in the Puerto Rico Trench. The tremor was strongly felt throughout the island. The earthquake caused the collapse of the church in Arecibo, along with the chapels of El Rosario and La Concepción, and damaged the main churches in Bayamón, Toa Baja, and Mayagüez. It also inflicted considerable damage on the San Felipe del Morro and San Cristóbal forts in Old San Juan, where cisterns, walls, and guardhouses were cracked or destroyed.

[279] Financial Oversight and Management Board for Puerto Rico, Statement – January 7, 2020, https://drive.google.com/file/d/1FWhHxEDMLMZcffJfwU1uHIQcJk1AtVt2/view. Note that FY2019 Emergency Reserve of $130 million was fully utilized to cover costs associated with Dorian Storm and the January earthquakes. FY2020 Reserve balance as of May 8, 2020, was approximately $46.8 million.
[280] Puerto Rico Seismic Network, "Significant Earthquakes in Puerto Rico," https://redsismica.uprm.edu/english/education/earthquakes/significant.php.
[281] Puerto Rico Seismic Network, "Significant Earthquakes in Puerto Rico," https://redsismica.uprm.edu/english/education/earthquakes/significant.php.

1867 EARTHQUAKE

The earthquake of November 18, 1867, with a magnitude of 7.3, struck the Anegada Passage between Saint Thomas and Saint Croix in the Virgin Islands, causing widespread damage in both the Virgin Islands and Puerto Rico. A resulting tsunami reached wave heights of up to 20 feet in the Virgin Islands and impacted Puerto Rico's southern and western coasts, with waves penetrating up to 492 feet inland in low-lying areas such as Yabucoa.

1918 SAN FERMÍN EARTHQUAKE

The 1918 San Fermín earthquake was a major seismic event that struck Puerto Rico on October 11, 1918, with a magnitude of 7.1 to 7.2, originating in the Mona Canyon.[282] The earthquake triggered a significant tsunami, causing widespread destruction on the island's western coast, with waves up to 20 feet high, and resulting in 116 deaths and approximately $4 million in damages.

Figure 100: La Mallorquina Building Damaged by the 1918 Earthquake in Mayagüez[283]

[282] Puerto Rico Seismic Network, "Significant Earthquakes in Puerto Rico," https://redsismica.uprm.edu/english/education/earthquakes/significant.php.
[283] Wilbert Pagán Ayala, "A 105 años del terremoto de San Fermín | Parte I," El Vocero de Puerto Rico, https://www.elvocero.com/habitat/a-105-a-os-del-terremoto-de-san-ferm-n-parte-i/article_4f150af2-630f-11ee-a8d3-bbf352ab145e.html.

Figure 101: Damage from the October 11, 1918, San Fermín Earthquake[284]

1943–1946 EARTHQUAKE

Powerful magnitude 7.6-7.8 earthquake struck off the northwestern coast of Puerto Rico, near the Mona Puerto Rico's seismic hazard is influenced by its position along the boundary between the North American and Caribbean plates, where subduction zones, strike-slip faults, and extensional regions interact. The Mueller et al. (2010) study integrates historical earthquake catalogs, GPS-based deformation rates, and fault-specific parameters to model potential seismic scenarios. Among these, the 1943 earthquake near Mona Canyon stands out as a significant event. With a magnitude of Mw 7.6–7.8, it originated from the subduction interface of the Puerto Rico segment. The quake was felt island-wide, with intense shaking in Aguadilla, Mayagüez, San Juan, and Ponce, prompting widespread panic and temporary evacuations[285].

Another major event considered is the 1946 earthquake off northeastern Hispaniola, with a magnitude of Mw 7.8–8.0. Although centered near the Dominican Republic, its effects reached Puerto Rico, where shaking intensity reached VI in Mona Island and western regions, and V elsewhere. A tsunami with wave heights of

[284] Puerto Rico Seismic Network, "1918 Earthquake," 2025, https://redsismica.uprm.edu/english/education/earthquakes/1918earthquake.php.
[285] Mueller, C., Frankel, A., Petersen, M., & Leyendecker, E. (2010). *New seismic hazard maps for Puerto Rico and the U.S. Virgin Islands*. Earthquake Spectra, 26(1), 169–185. https://doi.org/10.1193/1.3277667.

about 2 feet was observed along Puerto Rico's northern and western coasts. While structural damage was minor, the event highlighted the island's vulnerability to regional seismic activity and associated tsunamis[286].

2019–2020 EARTHQUAKES

On December 28, 2019, a first in a series of earthquakes struck Puerto Rico, including 12 events ranging from magnitude 5.0 to magnitude 6.4 in early January, with one confirmed fatality and island-wide power outages. The earthquakes destroyed more than 76 homes, and 173 homes had major structural damage, displacing an estimated 6,407 individuals.[287]

Figure 102: Earthquake Damage to Ponce's Massacre Museum[288]

The 2020 earthquakes significantly affected the southwestern region of Puerto Rico, causing damage to various structures including homes, schools, municipal buildings, roads, and bridges. Widespread power outages occurred, and approximately 300,000 households were left without access to potable water.

The magnitude 5.8 earthquake led to the collapse of Punta Ventana, a natural rock arch and popular tourist attraction in the Municipality of Guayanilla (see Figure 103). The seismic events also resulted in multiple physical injuries, one fatality in the Municipality of Ponce, and a major island-wide blackout.

[286] Puerto Rico Seismic Network, "Significant Earthquakes in Puerto Rico," https://redsismica.uprm.edu/english/education/earthquakes/significant.php.
[287] U.S. House Committee on Natural Resources, "House Committee on Natural Resources Report on Puerto Rico's Earthquakes," February 2020, https://democrats-naturalresources.house.gov/imo/media/doc/KS_PUERTORICO_earthquakesreport.pdf.
[288] Coraly M. Cruz Mejías, "Earthquakes May Shutter Schools After Virus," Global Press Journal, November 26, 2020. https://globalpressjournal.com/americas/puerto-rico/earthquakes-may-shutter-puerto-rican-schools-even-pandemic/.

Figure 103: Punta Ventana Before and After the 6:35 a.m. Earthquake on January 6, 2020[289]

Figure 104: January 2020 Earthquake Destroyed Historic Parish in Guayanilla[290]

[289] BBC News Mundo, "Sismos en Puerto Rico: Punta Ventana, la icónica maravilla natural que se derrumbó tras uno de los terremotos que han sacudido a la isla," https://www.bbc.com/mundo/noticias-51020394.
[290] Dánica Coto, "Puerto Rico Earthquake Aftermath Deepens as Govt Seeks Help," NBC Boston, January 9, 2020, https://www.nbcboston.com/news/national-international/puerto-rico-earthquake-aftermath-deepens-as-govt-seeks-help/2059832/.

Potential Severity of Event

Understanding the severity of an earthquake requires more than just identifying the hazard—it demands a clear assessment of impact and risk, both of which are shaped primarily by a region's vulnerability. While hazard refers to the potential for ground shaking, it is the vulnerability of infrastructure, population, and systems that ultimately determines the scale of damage and disruption. In Puerto Rico, where seismic hazard levels place the region in Seismic Design Category C, the potential severity of earthquakes is considered **Moderate**, meaning the island could experience very strong shaking, with significant risk of damage to buildings and infrastructure, especially in vulnerable areas[291].

To quantify severity, planners and engineers rely on a combination of standardized metrics and scales. Among the most widely used are:

- **Modified Mercalli Intensity (MMI):** A qualitative scale that captures how seismic energy is experienced by people and structures, ranging from barely perceptible tremors (MMI I) to total destruction (MMI XII).
- **Peak Ground Acceleration (PGA):** A quantitative, engineering-based measure expressed as a fraction of gravity (g), indicating how violently the ground moves. PGA is critical for designing resilient buildings, bridges, and lifelines.
- **Moment Magnitude (Mww):** A scale that quantifies the total energy released at the earthquake's source, offering a consistent measure across different types of seismic events.

While MMI reflects the human and structural experience of shaking, PGA provides the technical basis for seismic design, and Mww anchors the event's magnitude. Together, these metrics offer a comprehensive view of earthquake severity.[292]

According to USGS seismic hazard maps, parts of Puerto Rico—particularly the southwestern and northern coastal regions—can experience PGA values exceeding 0.3g, with some areas reaching 0.5g or more during major events. These levels correspond to MMI values of VIII to X, indicating severe to extreme shaking capable of causing partial or total building collapse, foundation shifts, and widespread infrastructure.[293]

Later in this document, the Impact Assessment section presents results from in-house Hazus modeling, where two earthquake scenarios—magnitude 6.4 and magnitude 8.5—were simulated to estimate potential economic losses across Puerto Rico. These models focus on critical infrastructure and residential assets, providing insight into how severity translates into tangible consequences.

[291] U.S. Geological Survey. (2019). *U.S. Seismic Hazard Maps – Puerto Rico and the U.S. Virgin Islands, Samoa and the Pacific Islands, and Guam and Northern Mariana Islands*. Earthquake Hazards Program. https://doi.org/10.3133/ofr03379.
[292] U.S. Geological Survey. (2019). *U.S. Seismic Hazard Maps – Puerto Rico and the U.S. Virgin Islands, Samoa and the Pacific Islands, and Guam and Northern Mariana Islands*. Earthquake Hazards Program. https://doi.org/10.3133/ofr03379.
[293] Mueller, C., Frankel, A., Petersen, M., & Leyendecker, E. (2010). *New seismic hazard maps for Puerto Rico and the U.S. Virgin Islands*. Earthquake Spectra, 26(1), 169–185. https://doi.org/10.1193/1.3277667.

To contextualize the 6.4 scenario, it is important to note that the largest earthquake in Puerto Rico's modern history occurred on January 7, 2020, registering a moment magnitude (Mw) of 6.4. According to the USGS event page, this earthquake struck 4 km SSE of Indios, with a depth of 6.0 km, and produced intensities reaching MMI VIII in affected areas.

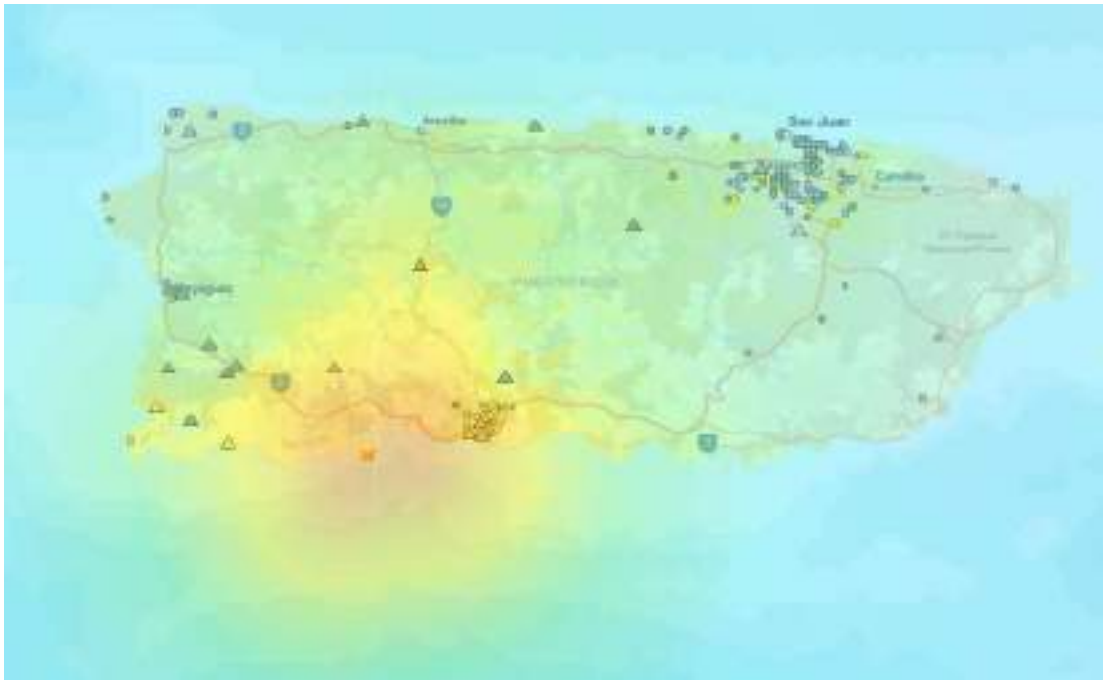


Figure 105: Epicentral ShakeMap of M6.4 Earthquake – 4 km SSE of Indios, Puerto Rico

The corresponding ShakeMap in Figure 106 shows Peak Ground Acceleration (PGA) values exceeding 0.5g in southwestern municipalities such as Guayanilla and Peñuelas, which aligns with the regions that experienced the most severe damage. These PGA values are translated into Modified Mercalli Intensity (MMI) levels—specifically MMI VIII to IX, indicating severe to violent shaking (orange circle in Figure 106). While Mww remains constant for the event (M6.4), MMI varies spatially and is derived from instrumental data like PGA and community reports. The ShakeMap's intensity contours thus provide a localized representation of shaking severity, helping to explain the concentration of damage in these municipalities.

Figure 106: USGS 6.4 Mw ShakeMap Event in 2020

This ShakeMap served as the basis for the deterministic Hazus model used in the 6.4 scenario. It is important to clarify that this approach is not fully probabilistic. Deterministic modeling simulates the impact of a specific event—in this case, the January 2020 earthquake—using fixed parameters such as magnitude, epicenter, depth, and ground motion attenuation. It does not account for recurrence intervals or the full range of possible future events, which are essential components of probabilistic hazard assessments.

The M6.4 earthquake that struck near Indios, Puerto Rico, prompted a yellow alert for fatalities and an orange alert for economic losses, indicating that while some casualties were possible, significant damage was likely and potentially widespread. The estimated economic losses ranged from 0–2% of Puerto Rico's GDP, a level that historically has required a regional or national response. In terms of population exposure, approximately 5.7 million people experienced shaking, with the largest groups exposed to MMI IV (light) and MMI V (moderate) intensities. Notably, 224,000 people felt strong shaking (MMI VI), and 165,000 experienced very strong shaking (MMI VII). Cities such as Tallaboa (MMI VIII), Indios, Magas Arriba, Guayanilla, Maria Antonia, Palomas, and Ponce (MMI VII) were among the most affected, while San Juan (MMI IV), Bayamon (MMI V), and Carolina (MMI V) also felt notable impacts.[294]

[294] U.S. Geological Survey. (2020, January 7). *M 6.4 - 4 km SSE of Indios, Puerto Rico* [PAGER report]. USGS Earthquake Hazards Program. https://earthquake.usgs.gov/earthquakes/eventpage/us70006vll/pager.

Figure 107: Estimated Population Exposure to Earthquake Shaking

The PAGER system (Prompt Assessment of Global Earthquakes for Response) is an automated tool developed by the USGS to rapidly estimate the human and economic impacts of significant earthquakes worldwide. Within about 30 minutes of an event, PAGER provides estimates of fatalities, economic losses, and population exposure to shaking, using seismic data, population models, and historical loss data. It assigns color-coded alerts—green, yellow, orange, or red—based on the severity of expected impacts, helping emergency responders and decision-makers prioritize actions.

PAGER's methodology compares the population exposed to each level of shaking intensity (using the Modified Mercalli Intensity scale) with vulnerability models derived from past earthquakes, enabling a fast and informed response even before ground-truth reports are available.[295] Figure 108 shows the USGS PAGER report's estimated economic losses for the 2020 M6.4 Puerto Rico earthquake. It shows that the estimated economic losses fall within the orange alert level, which indicates that significant damage is likely. This assessment is supported by the "Significant Events" section, which documents substantial impacts across affected areas. The histogram in Figure 108 shows a 35% probability that the actual economic losses would fall within a specific range—likely between $100 million and $1 billion. In PAGER methodology, this percentage reflects the likelihood that the losses will be within that range, based on modeled data and historical comparisons.[296]

[295] U.S. Geological Survey. (2020, January 7). *M 6.4 - 4 km SSE of Indios, Puerto Rico* [PAGER report]. USGS Earthquake Hazards Program. https://earthquake.usgs.gov/earthquakes/eventpage/us70006vll/pager.
[296] U.S. Geological Survey. (2020, January 7). *M 6.4 - 4 km SSE of Indios, Puerto Rico* [PAGER report]. USGS Earthquake Hazards Program. https://earthquake.usgs.gov/earthquakes/eventpage/us70006vll/pager.

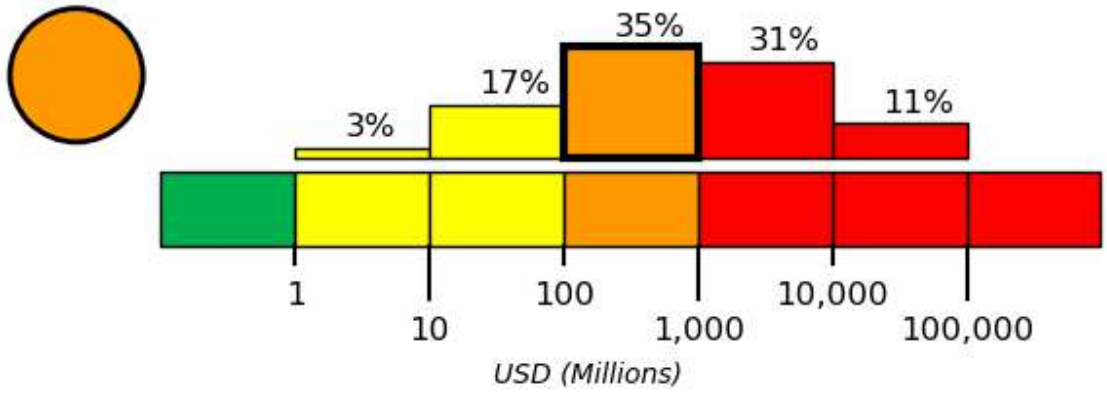


Figure 108: USGS PAGER Estimated Economic Losses

Probability of Future Hazard Events

Puerto Rico has a **high** probability of experiencing future earthquake events, based on its geological setting and historical seismicity. This assessment pertains specifically to hazard probability, which refers to the likelihood of ground shaking occurring due to seismic activity—not to be confused with risk, which incorporates exposure and vulnerability of people, infrastructure, and assets.

The Puerto Rico Seismic Network and the U.S. Geological Survey (USGS) identify Puerto Rico as one of the most seismically active regions in the Western Hemisphere. This is due to its location on the Puerto Rico–Virgin Islands microplate, which is compressed between the North American Plate and the Caribbean Plate. This tectonic interaction has produced numerous large earthquakes historically, including events with magnitudes exceeding 7.0.

According to Mueller et al. (2010), probabilistic seismic hazard maps developed for Puerto Rico show elevated ground motion values across the island, indicating a significant probability of strong shaking within typical design return periods (e.g., 475 years, corresponding to a 10% chance of exceedance in 50 years.

This hazard probability is reflected in Puerto Rico's classification under Seismic Design Category (SDC) C, as defined by the International Building Code (IBC) and ASCE 7 standards. SDC C indicates a moderate to strong seismic hazard, requiring buildings to be designed to withstand substantial ground motion. This classification is based on probabilistic seismic hazard analyses, which consider local faults, offshore subduction zones, and historical earthquake data.

The SDC system ranges from A (very low hazard) to E/F (very high hazard). SDC C implies expected shaking intensities typically between Modified Mercalli Intensity (MMI) V and VII, which can cause moderate to considerable damage depending on building quality. Understanding Puerto Rico's SDC designation is essential for hazard mitigation planning. It ensures that critical facilities—such as hospitals, schools, and emergency centers—are constructed with appropriate seismic resistance, aligning design standards with the realistic probability of earthquake hazards, not just theoretical risk.

While both Peak Ground Acceleration maps and Seismic Design Category maps are derived from probabilistic seismic hazard analyses, they serve different but complementary purposes. PGA maps show the expected ground acceleration at a site during a specific return period (e.g., 475 years), providing a direct measure of ground shaking intensity. In contrast, SDC maps translate that ground motion data—along with soil conditions and building occupancy—into design requirements for structures. Both are scenario-based tools that incorporate uncertainties in earthquake sources, fault behavior, and ground motion prediction models.

This probabilistic approach is considered the most reliable method for estimating seismic hazard levels. It allows decision-makers to plan and design infrastructure based on realistic risk scenarios rather than worst-case or historical-only events. By integrating historical seismicity, GPS-based deformation data, and fault slip rates, these maps support informed hazard mitigation and resilient construction strategies[297].

The following hazard maps were developed using a probabilistic seismic hazard methodology by the USGS. This approach incorporates historical seismicity, fault slip rates, Global Positioning System (GPS)–based deformation data, and ground motion prediction models to estimate the likelihood of various levels of ground shaking occurring at a site over a given period. It also accounts for uncertainties in earthquake sources and ground motion behavior.

Figure 109 shows PGA values for a 2% probability of exceedance in 50 years, which corresponds to a 2,500-year return period—a rare but potentially catastrophic event. Figure 110 also presents PGA values for a 10% probability of exceedance in 50 years, or a 500-year return period—more frequent and still damaging.

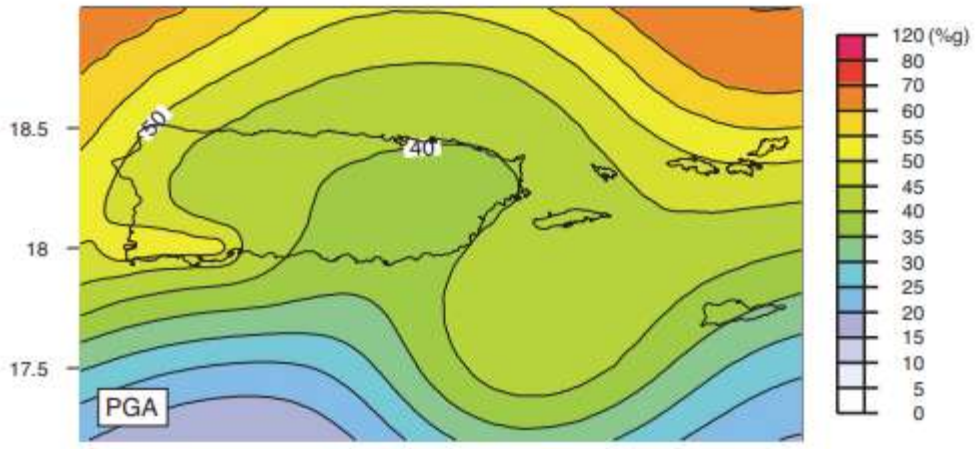


Figure 109: Peak Ground Acceleration for 2% Probability of Exceedance in 50 Years

[297] Mueller, C., Frankel, A., Petersen, M., & Leyendecker, E. (2010). *New seismic hazard maps for Puerto Rico and the U.S. Virgin Islands*. Earthquake Spectra, 26(1), 169–185, https://onlinelibrary.wiley.com/doi/10.1193/1.3277667.

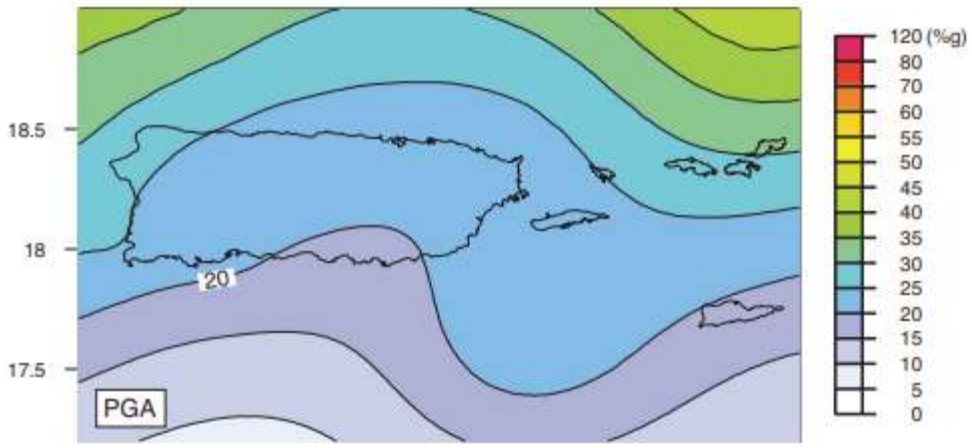


Figure 110: Peak Ground Acceleration for 10% Probability of Exceedance in 50 Years

Figure 109 and Figure 110 indicate that southwestern Puerto Rico (near the Mona Passage and South Lajas Fault) and the northern coastal region (near the Puerto Rico Trench) exhibit PGA values exceeding 0.3g (30% of gravity). These areas are located near active fault zones and subduction interfaces, which are capable of generating large earthquakes

Vulnerability Assessment

Puerto Rico's seismic vulnerability stems from its tectonic setting at the boundary between the North American and Caribbean plates, where active fault systems and the nearby Puerto Rico Trench contribute to frequent and potentially severe earthquakes. In hazard analysis, vulnerability refers to the susceptibility of physical assets—such as buildings and infrastructure—to damage when exposed to seismic forces. This is influenced by factors like construction type, age, soil conditions, and adherence to building codes. Exposure, on the other hand, refers to the quantity and value of assets (e.g., number of buildings, population, infrastructure) located in hazard-prone areas. The interaction between exposure and vulnerability determines the potential impact of an earthquake: highly vulnerable structures in highly exposed areas result in greater expected losses.

FEMA's Hazus Earthquake Model focuses specifically on physical vulnerability, using engineering-based fragility curves and inventory data to estimate damage to buildings, lifelines, and essential facilities. It does not account for social vulnerability, which includes factors like income, age, disability, and access to resources that affect a community's ability to prepare for, respond to, and recover from disasters. In Puerto Rico, Hazus modeling shows that even moderate seismic events can cause widespread physical damage due to the high exposure of residential structures and critical infrastructure. However, to fully understand the human impact, social vulnerability must be assessed separately using tools like CDC's Social Vulnerability Index or local demographic data.

IN-HOUSE HAZUS MODEL: EXPOSURE

Table 35 summarizes the percentage exposure of different building types and uses based on in-house Hazus inventory data and damage distribution:

Table 35: Percentage of Total Building Value by Building Type

Building Type / Use	% of Total Buildings	% of Total Building Value	Notes
Residential (Single Family)	89.3%	92%	Most exposed and vulnerable.
Other Residential	6.7%	6.8%	Includes multi-family units.
Commercial	1.8%	1.3%	Includes retail, office, etc.
Industrial	0.6%	0.4%	Factories, warehouses.
Education	0.2%	0.2%	Schools, universities.
Government	0.1%	0.1%	Municipal buildings.
Religion	0.1%	0.1%	Churches, temples.
Agriculture	0.1%	0.1%	Barns, silos, etc.

Table 36 and Table 37 provide a focused overview of Puerto Rico's critical infrastructure exposure, highlighting the municipalities and occupancy types with the greatest share of total asset value at risk from seismic events.

Table 36 presents the distribution of critical infrastructure value by municipality, emphasizing those jurisdictions with the highest concentration of exposed infrastructure. While the full dataset includes all municipalities, only those with the most significant shares are shown here to illustrate priority areas for mitigation planning.

Table 36: Distribution of Critical Infrastructure Value by Municipality

City	% of Total Infrastructure Value
San Juan	16.7
Carolina	6.3
Guaynabo	5.6
Arecibo	5.1
Juana Díaz	3.6
Ponce	3.3
Bayamón	3.0
Caguas	2.8

City	% of Total Infrastructure Value
Añasco	2.7
Moca	2.6
Cayey	2.5
Vega Baja	2.3
Salinas	2.2
Juncos	1.9
Cabo Rojo	1.8
Mayagüez	1.8
Humacao	1.7
Peñuelas	1.6
Jayuya	1.6
Vieques	1.4
Barranquitas	1.2
Aguadilla	1.2
Lajas	1.1
Manatí	1.1
Isabela	1.0

Table 37 illustrates critical infrastructure exposure by occupancy type, based on Hazus inventory data. The table confirms that industrial facilities, particularly light industrial and food/drug/chemical sectors, represent the largest share of total assets by count—together accounting for over 40% of the total infrastructure units modeled. This concentration underscores the vulnerability of Puerto Rico's industrial base to seismic disruption and the importance of targeted retrofitting and resilience strategies.

Table 37: Critical Infrastructure Exposure by Occupancy Type

Occupancy Type	Count	Percentage of Total Assets (%)
IND2 – Light Industrial	1797	21.4
IND3 – Food/Drugs/Chemicals	1716	20.4
EDU1 – Grade Schools	1683	20.0
IND4 – Metals/Minerals Processing	847	10.1
GOV1 – General Services	522	6.2
IND6 – Construction	467	5.6

Occupancy Type	Count	Percentage of Total Assets (%)
GOV2 – Emergency Response	399	4.8
IND5 – High Technology	391	4.7
COM7 – Medical Office/Clinic	299	3.6
COM4 – Professional/Technical Services	188	2.2
COM6 – Hospital	72	0.9
EDU2 – Colleges/Universities:	17	0.2

LOCATIONS

Puerto Rico's location within an active seismic zone contributes to its high probability of future earthquake events. Its position on the Puerto Rico–Virgin Islands microplate—between the North American and Caribbean plates—makes it especially vulnerable to high-intensity ground shaking, as confirmed by the USGS and the Puerto Rico Seismic Network.

POPULATIONS

Based on in-house modeling using FEMA Hazus for earthquakes, the following Table 38 identifies the areas in Puerto Rico where impacts would likely be greatest in the event of a major seismic event 6.4 and 8.5. These counties have the highest combination of population density and building replacement value, which Hazus uses to estimate potential damage, displacement, and economic loss. The estimated vulnerable population reflects those most at risk due to exposure, structural fragility, and soil conditions:

Table 38: Population and Exposed Value

County	Population	Building Value (Billion USD)
San Juan	342,259	70.8
Bayamón	185,187	30.5
Ponce	137,491	22.4
Carolina	154,815	24.2

STRUCTURES INCLUDING CRITICAL FACILITIES

Many of Puerto Rico's historic structures and critical facilities located in the seismic hazard zones of the island are prone to severe damage from ground shaking from major earthquake events. The Costa Sur natural gas power plant in Guayanilla generates more than 25% of Puerto Rico's electricity. The 6.4 magnitude earthquake caused structural and infrastructure damage to the power plant facilities, resulting

in a reduction in power generation and triggering island-wide blackouts for several days, impacting millions of customers (see Figure 111).[298]

Figure 111: Damage to Costa Sur Power Plant from January 2020 Earthquake[299]

INFRASTRUCTURE AND COMMUNITY LIFELINES

Puerto Rico's critical infrastructure and community lifeline systems may be uniquely vulnerable to seismic hazards due to the island's topography and geography, which limit access to neighboring jurisdictional support for life-sustaining operations during hazard events.

PROBLEM STATEMENTS

- Puerto Rico is located in a seismic hazard area where the potential for damage and loss from earthquake/liquefaction events is increased for municipalities located near identified active faults. Buildings with poor structural integrity that do not meet the 2018 International Residential Code or the 2018 International Building Code standards for seismic retrofitting of unreinforced masonry structures could experience severe damage if a magnitude 7.0 or greater earthquake with extensive ground shaking were to occur.
- Residential and business communities located on or near identified active fault lines are most vulnerable to significant fatalities and injuries, and structural damage in areas where unreinforced masonry buildings pose a risk of collapsing as a result of a major earthquake event. The 2020 earthquakes caused an island-wide power outage, destroyed homes and schools, disrupted businesses and caused $110 million in damage to 559 structures.
- The potential for damage to structures and critical facilities from earthquake events is increased for municipalities located near identified active faults, heightening the vulnerability of state assets that may

[298] U.S. House Committee on Natural Resources, "House Committee on Natural Resources Report on Puerto Rico's Earthquakes," February 2020, https://democrats-naturalresources.house.gov/imo/media/doc/KS_PUERTORICO_earthquakesreport.pdf.
[299] U.S. House Committee on Natural Resources, "House Committee on Natural Resources Report on Puerto Rico's Earthquakes," February 2020, https://democrats-naturalresources.house.gov/imo/media/doc/KS_PUERTORICO_earthquakesreport.pdf.

not meet current seismic retrofit building standards. New building codes are usually adopted by the local jurisdictions through phased approaches and grandfather clauses, which can delay uniform compliance with updated standards.

- Any disruption to Puerto Rico's proprietary transportation, energy, health and medical, safety and security, communications, or water systems from a major seismic event could result in prolonged operational loss of these critical systems and require major long-term recovery efforts. Historically, full-service restoration has taken months to years.

Impact Assessment

In the context of earthquake risk assessment, impact refers to the measurable consequences of an earthquake event, including physical damage to infrastructure, economic losses, casualties, and disruptions to essential services. Hazus, FEMA's GIS-based loss estimation tool, defines impact as the result of the interaction between three core components: hazard, exposure, and vulnerability[300].

- Hazard represents the probability and intensity of seismic events. In deterministic modeling, the hazard is fixed—based on a specific historical or hypothetical earthquake scenario with defined magnitude, location, and rupture characteristics.
- Exposure refers to the assets (buildings, infrastructure, population) located in the hazard zone.
- Vulnerability describes how susceptible those assets are to damage. Hazus uses fragility curves to model vulnerability, estimating the probability of different damage states based on structural characteristics and ground motion parameters.

Importantly, while the hazard in deterministic modeling is fixed, the vulnerability component acts as a proxy for current conditions—meaning it reflects what could happen today if the same ground shaking occurred again. This includes estimates of physical damage, casualties, and economic losses based on today's building inventory and infrastructure.

Hazus supports both deterministic and probabilistic approaches to evaluate earthquake impacts:

- The deterministic approach models the consequences of a specific earthquake scenario. In this analysis, two scenarios were modeled:
  - A magnitude 6.4 earthquake located 13 km SSE of Maria Antonia, Puerto Rico (based on the 2020 event).
  - A magnitude 8.5 earthquake along the Puerto Rico Trench (a hypothetical worst-case scenario).

[300] FEMA, "NEHRP Recommended Seismic Provisions for New Buildings and Other Structures," FEMA P-2082-1, September 2020, https://www.fema.gov/sites/default/files/2020-10/fema_2020-nehrp-provisions_part-1-and-part-2.pdf.

These scenarios allow planners to assess direct impacts and test mitigation strategies, such as retrofitting buildings in high-vulnerability zones or strengthening critical infrastructure.

- The probabilistic approach uses seismic hazard maps and exceedance curves to estimate the likelihood of various levels of ground shaking over time. This method is more suitable for long-term risk planning and prioritizing investments based on average annualized losses. Notably, exceedance curves are not used in deterministic modeling, as the scenario is fixed and not probabilistic in nature.

PLANNING IMPLICATIONS

For mitigation planning:

- Deterministic scenarios help visualize potential damage from specific events, guiding emergency response actions and hardening infrastructure in vulnerable areas.
- Probabilistic models support scenario-based planning by estimating average losses across multiple possible events, which is valuable for cost-benefit analyses and resource allocation.

Central to both approaches is the use of fragility curves, which quantify how different asset types respond to seismic forces. These curves incorporate structural characteristics, design codes, and site conditions to estimate damage probabilities. By integrating fragility curves with exposure data, Hazus enables planners to simulate a range of damage outcomes and develop targeted strategies to reduce risk.

HAZUS MODEL: 6.4 EARTHQUAKE

On January 7, 2020, a magnitude 6.4 earthquake struck southwestern Puerto Rico, causing severe damage in towns such as Guayanilla, Peñuelas, and Ponce. Figure 112 presents the results from a Hazus study, which is a deterministic assessment—meaning it models the impact of a specific earthquake scenario. In this case, a magnitude 6.4 event located 13 km SSE of Maria Antonia, Puerto Rico. The model uses fixed parameters, including the following:

- Magnitude
- Epicenter location
- Depth
- Ground motion attenuation

This approach does not use probabilistic return periods or recurrence intervals. The results reflect the expected losses from this single, defined event—not a range of possible future scenarios.

Figure 112: Hazus-Modeled Building Losses from 2020 Magnitude 6.4 Earthquake in Southwestern Puerto Rico

Using FEMA's Hazus model, the average loss for buildings was calculated to estimate the economic impacts of the earthquake. Hazus evaluates losses from structural and nonstructural damage, content loss, relocation, and business interruption, based on building inventory and ground motion data such as PGA and spectral acceleration (SA).

The total building economic loss refers to the estimated financial impact of earthquake damage on buildings, including the following:

- **Direct Losses:** Costs to repair or replace structural and nonstructural components, contents, and inventory.
- **Indirect Losses:** Business interruption, temporary relocation, rental costs, and wage losses.

The total building-related losses for this magnitude 6.4 earthquake were $1,584.71 million, with the majority (over 90%) attributed to residential occupancies:

- Nonstructural damage: 48%
- Structural damage: 15%
- Content loss: 18%
- Relocation and rental costs: 17%
- Business interruption (wage and capital): 1%

As Figure 113 confirms, areas closest to the epicenter experienced the highest PGA—exceeding 0.5g—which led to the most significant building damage and economic loss. The regions of Guayanilla and Peñuelas, located near the epicenter, show the highest total building economic losses, as illustrated by the dark brown shading, which represents values ranging from $65,911,980 to $136,002,480.

This pattern aligns with Hazus methodology and seismic engineering principles: higher ground acceleration correlates with greater damage, especially in vulnerable structures such as soft-story buildings, which are typically multistory buildings with a weak or open ground floor, making them more susceptible to collapse during strong ground shaking.

The report also confirms that these high-loss regions had substantial building exposure:

- Guayanilla had 1,851 buildings exposed.
- Peñuelas had 2,632 buildings.
- Ponce, with its larger population and building stock, had 22,379 buildings, contributing to significant losses from both structural damage and business interruption.

As seismic waves radiated outward, their intensity diminished, resulting in lower ground acceleration and reduced economic losses in more distant areas. Hazus effectively captured this gradient, reinforcing its value for mitigation planning. By identifying high-risk zones, communities can prioritize retrofits and strengthen resilience against future earthquakes.

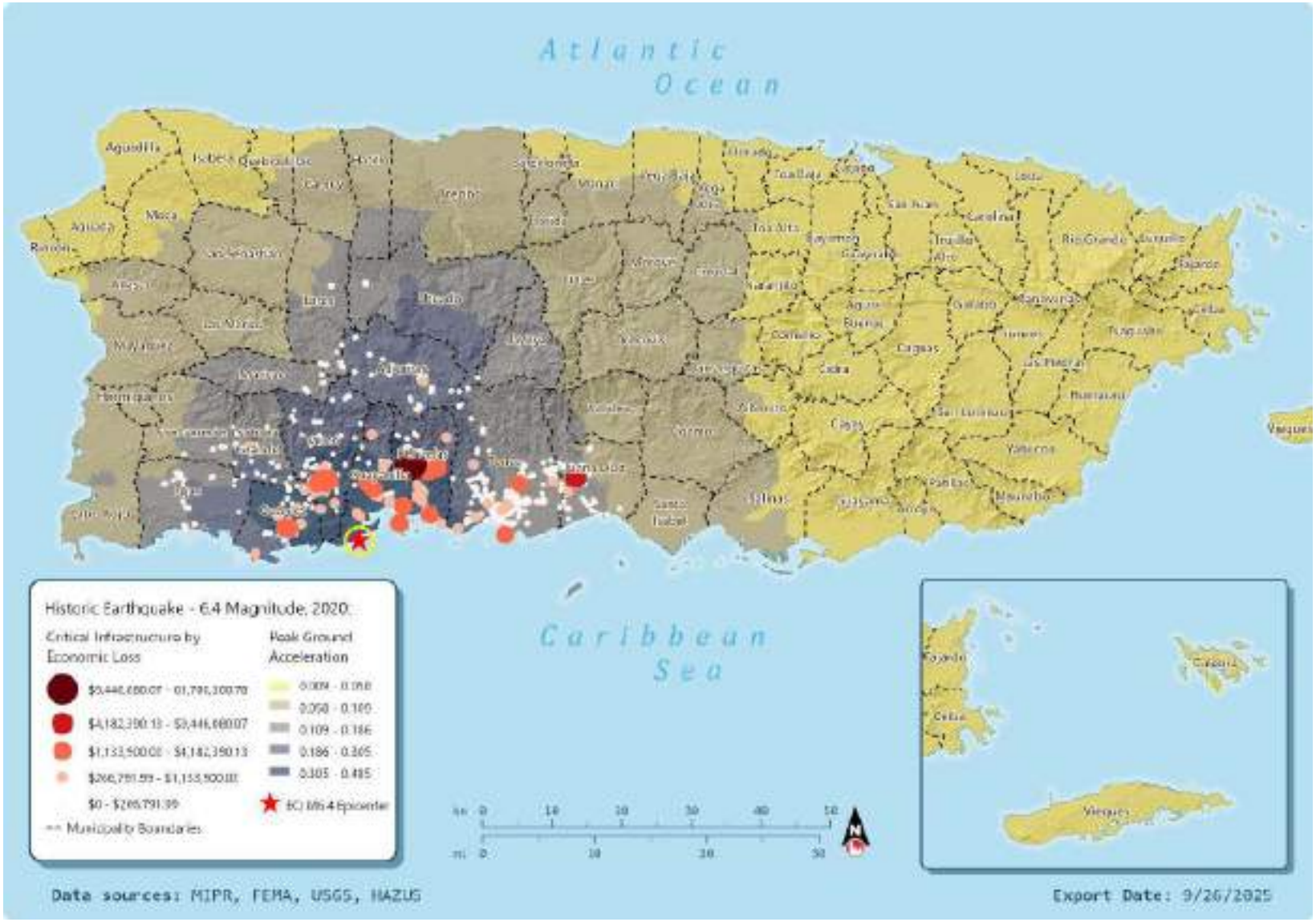


Figure 113: Hazus-Modeled PGA and Critical Infrastructure Losses from the 2020 Magnitude 6.4 Earthquake in Southwestern Puerto Rico

Hazus estimates that $944.96 million in total economic losses were sustained by transportation and utility lifeline systems, broken down as follows:

- Transportation Lifelines:
  - Bridges: $13.86 million
  - Bus facilities: $0.07 million
  - All other components (highways, ports, airports): negligible or no losses
  - **Total: $13.93 million**
- Utility Lifelines:
  - Oil systems facilities: $931.03 million
  - All other systems (electric power, water, wastewater, communications): no significant losses
  - **Total: $931.03 million**

The oil infrastructure sustained the most damage, confirming the vulnerability of high-value assets in regions with strong ground shaking.

The regions with the highest critical infrastructure exposure and economic losses are also those closest to the epicenter, where PGA exceeded 0.5g:

- Guayanilla:
  - 1,851 buildings exposed
  - High building and infrastructure losses
- Peñuelas:
  - 2,632 buildings exposed
  - Significant structural and lifeline damage
- Ponce:
  - 22,379 buildings exposed
  - Largest concentration of infrastructure and building-related losses

This correlation between PGA and exposure confirms the logical outcome: regions with more infrastructure and stronger shaking experienced greater economic losses. This deterministic scenario provides a valuable reference for emergency planning and mitigation. However, a probabilistic approach is ideal for future analyses, as it accounts for the likelihood of various earthquake events, enabling better-informed decisions for long-term resilience and investment.

HAZUS MODEL: 8.5 EARTHQUAKE

To evaluate the potential impacts of a major seismic event in Puerto Rico, we conducted a Hazus-based analysis simulating a worst-case scenario: a magnitude 8.5 earthquake. Although the epicenter and depth

are not explicitly defined, Hazus models the event as a high-magnitude rupture with widespread, island-wide effects. The simulation offers critical insights into anticipated economic losses, particularly concerning building stock and essential infrastructure in densely populated areas.

Figure 114 and Figure 115 visualize the spatial distribution of ground shaking intensity following a worst-case 8.5 earthquake scenario. PGA is a key metric used in these maps, representing the maximum ground acceleration experienced. Higher PGA values correlate with greater structural damage and economic losses. In the magnitude 8.5 scenario, regions with elevated PGA—such as San Juan, Guaynabo, and Loíza—show the highest projected losses.

The simulation revealed significant projected economic losses, especially in municipalities with high concentrations of critical infrastructure. The areas identified as most vulnerable include Moca, Añasco, Barceloneta, Vega Baja, San Juan, Guaynabo, portions of Carolina and Loíza, Juncos, Cayey, Cidra, and Juana Díaz.

The magnitude 8.5 scenario shows major impacts on critical infrastructure, including hospitals, schools, police stations, and emergency operations centers. Municipalities such as Moca, Añasco, Barceloneta, Vega Baja, San Juan, Guaynabo, Carolina, Loíza, Juncos, Cayey, Cidra, and Juana Díaz are identified as highly vulnerable due to their infrastructure concentration.

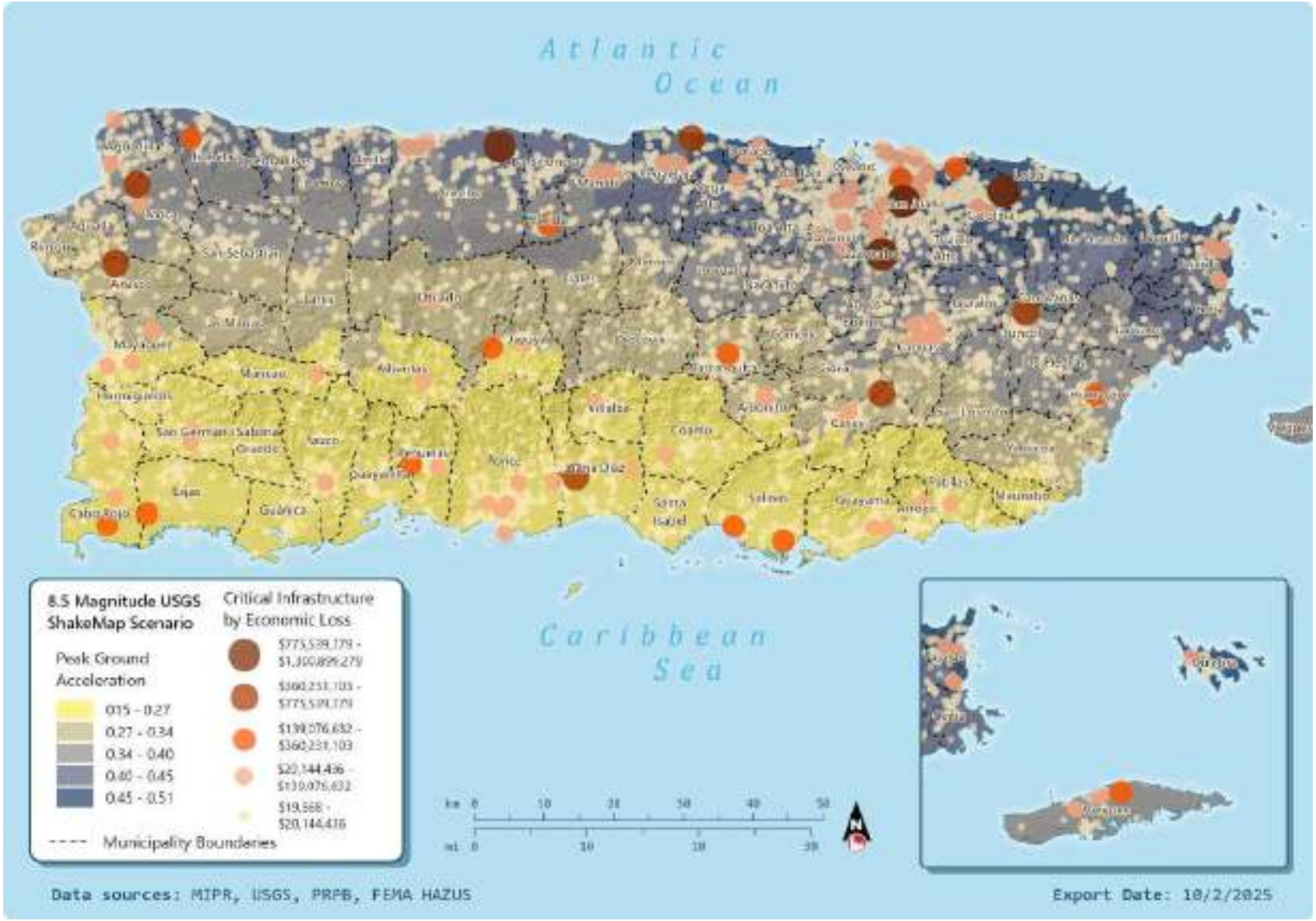


Figure 114: 8.5 Magnitude Probabilistic Earthquake PGA with Critical Infrastructure

In terms of building-related economic losses, the municipalities of Aguadilla and the metropolitan area—including Cataño, Bayamón, San Juan, and Carolina—represent the highest risk. Figure 115 shows that the northern and northeastern regions of Puerto Rico are projected to incur significant financial losses in the event of an earthquake of this magnitude.

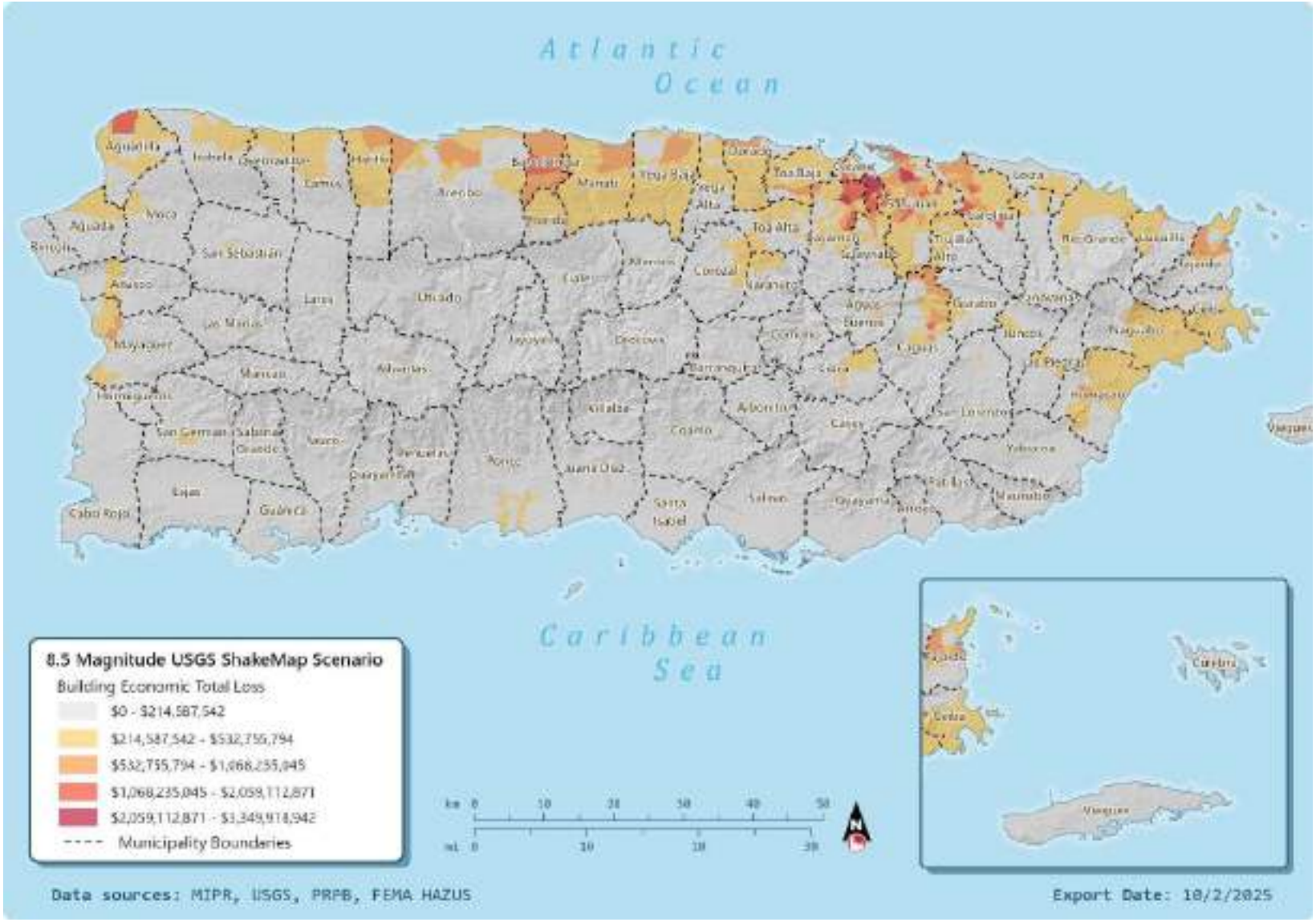


Figure 115: 8.5 Magnitude Probabilistic Earthquake Building Total Loss

Based on the Hazus magnitude 8.5 scenario, Puerto Rico has approximately 1.4 million buildings with a total replacement value of $482 billion. The majority (99%) are residential, accounting for 92% of the total building value. Wood frame construction comprises 23% of the inventory, while unreinforced masonry (URM) buildings show the highest vulnerability, with over 10,000 moderately damaged and 2,600 extensively damaged structures. Single-family homes dominate the exposure, with over 1.25 million units.

Hazus uses a standardized methodology developed by FEMA to estimate losses based on regional inventories and replacement values. The replacement value represents the cost to rebuild or replace damaged structures. Loss calculations are performed using fragility curves, which model the probability of damage states (slight, moderate, extensive, complete) based on ground shaking intensity and building characteristics.

Figure 115 shows a magnitude 8.5 scenario projects total economic losses exceeding $252 billion, with building-related losses accounting for $158 billion. Residential buildings bear over 90% of these losses. The most affected municipalities include Aguadilla, Bayamón, San Juan, Carolina, and Cataño. Losses are categorized into structural, nonstructural, content, and income-related components. Nonstructural losses represent 48% of the total, followed by structural (15%) and content (18%).

Seismic risk maps reveal that Puerto Rico experiences seismic activity comparable to that of the western United States. Notably, the island is divided into two distinct seismic regions, with the west-southwest zone being the most hazardous due to its potential for strong earthquakes and shallow hypocenters. This elevated risk, combined with a dense population and infrastructure that has not recently endured a major seismic event, contributes to a high level of vulnerability and poses a serious threat to public safety across the island.

STATE ASSETS

Based on historical seismic events such as the 1918 and 2020 earthquakes, and current infrastructure vulnerability assessments, the jurisdictions most at risk for damage and loss from future earthquakes in Puerto Rico are concentrated in the island's southwestern region, particularly in municipalities like Guánica, Guayanilla, Yauco, Ponce, and Peñuelas. These areas have repeatedly experienced strong ground shaking and structural damage, and they host critical infrastructure, such as highways, sewer systems, electrical substations, and schools, located in zones of severe seismic acceleration. The concentration of vulnerable assets in these regions, combined with their proximity to active fault lines, underscores their heightened exposure to seismic hazards and the urgent need for targeted mitigation and resilience planning to safeguard public safety and essential services.

LOCAL ASSETS

Future earthquake events in Puerto Rico could result in widespread infrastructure damage, particularly to critical energy assets such as substations, power plants, and transmission lines. This vulnerability is evidenced by past incidents, including the $25,804 in damage sustained by the Palo Seco Substation. Municipalities such as Arecibo and Aguadilla face significant risk, with thousands of structures classified as

"**Very High Risk**" and potential losses estimated in the billions, underscoring the urgent need for accurate damage assessments and resilient infrastructure planning.

As part of efforts to gather data on estimated losses, the Municipality of Toa Baja submitted an information request to LUMA Energy Co. (a private electric utility company that operates and manages the energy transmission and distribution system in Puerto Rico), to verify estimates resulting from natural hazard events. These events impacted generation assets—including various power plants, reservoirs/dams, reserves, and hydroelectric plants—as well as substations, buildings, and other miscellaneous facilities during the period from 2017 to 2022, in support of insurance claims.

This data, provided with support from Puerto Rico Electric Power Authority (PREPA) and LUMA Energy, included power plants, reservoirs, transmission and distribution lines, and several buildings, with a total estimated loss of $67,832,033. It is noted that these figures were updated as of June 7, 2022, and the evaluation and quantification of damage resulting from earthquake events is ongoing and subject to revision. For example, the Palo Seco Substation sustained earthquake-related damages totaling $25,804.

In contrast, the potential earthquake-related losses for the municipality of Arecibo, located in the north of the island, is estimated to be between 5% and 12% of the buildings' replacement value, representing 4,864 structures in the "Very High Risk" category for potential earthquake damage. [301]

The Municipality of Aguadilla estimated that there are 24,000 buildings with a total replacement value (excluding contents) of $3.877 billion. Approximately 100% of the buildings are residential structures. On the other hand, the replacement value of transportation and utility systems is estimated at $346 million and $268 million, respectively. The total value of the utility inventory exceeds $614 million. This inventory includes more than 37 kilometers of roads, 8 bridges, and 5,080 kilometers of pipelines.

COMMUNITY LIFELINES

Earthquake events can significantly disrupt the delivery of critical community lifelines. This was evident during the seismic activity in 2019 and 2020, when earthquakes of magnitude 5.0 and above caused structural damage to essential facilities and infrastructure.

Community lifelines represent the most fundamental services that support the functioning of society. When they are stabilized, they enable all other aspects of a community to operate effectively. These lifelines are vital to public safety and well-being, especially during emergencies, as they provide essential support to individuals and communities in crisis. Without them, communities are significantly more vulnerable to disasters and their cascading impacts.

There are eight key community lifelines, each serving a distinct and critical purpose:

[301] Plan de Mitigacion de Riesgos de Aguadilla, 2024. HMP-ExeSummary-1.pdf

SAFETY AND SECURITY

The Safety and Security lifeline, which includes maintaining public safety, law enforcement, and security operations, provides support for communities during earthquake events by setting up roadblocks, diverting traffic away from the affected area, and providing safe evacuation routes or detour information. Disruption to the Safety and Security lifeline from earthquakes can hinder emergency response efforts to address property and infrastructure failures, injuries, or fatalities.

Future earthquakes in Puerto Rico could significantly disrupt the Safety and Security lifeline by impairing law enforcement operations, delaying emergency evacuations, and limiting access to affected areas. The 2020 earthquakes demonstrated the scale of such disruption, displacing thousands of residents and prompting the Puerto Rico National Guard to establish large tent cities in municipalities like Guánica, Yauco, Guayanilla, Peñuelas, and Ponce (see Figure 116). These shelters, which housed over 3,200 people and provided essential services such as mobile kitchens and showers, underscored the urgent need for coordinated security efforts and rapid deployment of resources to maintain public safety—especially as many individuals remained in cars or open-air shelters due to ongoing aftershocks and limited permanent housing options.

Figure 116: National Guard and U.S. Army Set Up Tent Cities in Southern Puerto Rico[302]

FOOD, HYDRATION, AND SHELTER

The Food, Hydration, and Shelter lifeline provides access to basic needs for those affected by earthquake events. Access to food, water, and shelter can become a challenge if roadways are impacted by earthquakes

[302] Univision Puerto Rico, "Establecen campamentos base en el sur," January 14, 2020, https://www.univision.com/local/puerto-rico-wlii/establecen-campamentos-base-en-el-sur-fotos.

and supply chains are disrupted. Emergency sheltering may become necessary if earthquakes damage power lines, causing prolonged power outages and limiting critical access to electricity.

HEALTH AND MEDICAL

The Health and Medical lifeline, which provides medical care and public health services, could be impacted by earthquakes due to damaged structures that limit access to critical medical care. In addition, earthquake events in the mountainous areas of Puerto Rico could cut off single access roads, limiting emergency response to medical emergencies, and disrupting the distribution of medical supplies.

ENERGY

The Energy lifeline focuses on providing power and fuel to the affected community. Damaged power lines, substations, and pipelines are common during earthquake events. Earthquakes can damage power lines or require emergency power shutoffs to reduce the risk of structural fires, resulting in prolonged power outages. In addition, structural damage to water and wastewater systems can lead to limited access to water needed to power hydroelectric plants.

COMMUNICATIONS

The Communications lifeline provides access to communication tools and services. Earthquakes may impact communication towers located in high susceptibility areas or near fault lines, causing them to collapse, disrupting communications services such as cellular service to telephones, landline telephones, and the internet.

Future seismic events in Puerto Rico could significantly disrupt the Communications lifeline by damaging towers located near fault lines or in high seismic acceleration zones. With 47 antennas situated in areas of "Moderate" seismic risk and one in a "Severe" zone, even partial tower collapse could interrupt cellular, landline, and internet services—hindering emergency coordination and public access to critical information.

TRANSPORTATION

The Transportation lifeline ensures the availability of transportation services for communities during disaster events. Blocked transportation routes can cause supply chain disruptions for food, water, and medical supply deliveries, and disrupt emergency response activities during earthquake events.

Future earthquakes in Puerto Rico could severely impact the transportation lifeline, disrupting access to essential services, and delaying emergency response efforts. Blocked roads and damaged infrastructure may hinder the delivery of food, water, and medical supplies, especially in remote or heavily affected areas. For example, a 5.9-magnitude earthquake on January 11, 2020, caused landslides in Ponce, forcing cars to navigate through debris-covered roads—highlighting the vulnerability of transportation routes during seismic events (see Figure 117).

Figure 117: Cars Navigate Landslide Area After Earthquake Ponce[303]

HAZARDOUS MATERIALS

The Hazardous Materials lifeline includes hazardous materials management. During earthquake events in areas with industrial facilities or near hazardous material storage, spills or leaks can occur, posing environmental and public health risks.

WATER SYSTEMS

The Water Systems lifeline includes freshwater reservoirs, potable water distribution infrastructure, and wastewater treatment plants. Earthquakes can damage underground infrastructure through ground shaking, and structural damage to water and wastewater systems can lead to limited access to water needed to power hydroelectric plants.

Changes in Development

Although Puerto Rico does not currently maintain a database that directly links the age of structures to their seismic vulnerability, aging infrastructure is widely recognized as a key factor in evaluating development risks. Researchers from the University of Puerto Rico at Mayagüez consider structural age among several indicators when assessing seismic exposure. Two pivotal years are often referenced: 1968, when Regulation No. 7 first introduced seismic design requirements, and 1987, when the Puerto Rico Building Code adopted standards for ductility and energy absorption. However, the discovery of multiple active faults since 2000—

[303] Dánica Coto, "Puerto Rico Earthquake Aftermath Deepens as Govt Seeks Help," NBC Boston, January 9, 2020, https://www.nbcboston.com/news/national-international/puerto-rico-earthquake-aftermath-deepens-as-govt-seeks-help/2059832/.

and the expected release of a new seismic hazard map—indicates that even newer buildings may be at risk if their designs did not incorporate the most recent seismic data and hazard models.

Puerto Rico's evolving landscape reflects a dynamic response to both environmental challenges and demographic shifts. In recent years, significant changes in land use, building practices, and population trends have reshaped the island's development priorities. Driven by the lessons learned from Hurricanes Irma and María, as well as ongoing seismic risks, the built environment has undergone substantial regulatory updates to improve resilience and public safety. Simultaneously, demographic data reveals notable shifts in population structure, influencing future growth and redevelopment strategies. Together, these changes underscore the need for adaptive planning and policymaking to ensure sustainable development across Puerto Rico.

LAND USE AND BUILT ENVIRONMENT CHANGES

In response to the heightened awareness of structural vulnerabilities following Hurricanes Irma and María, Puerto Rico has significantly updated its building codes to enhance seismic resilience. The 2011 Puerto Rico Building Code (PRBC) was amended to incorporate provisions from the 2009 International Codes® (I-Codes), and the 2018 Puerto Rico Existing Building Code introduced Appendix A, "Guidelines for the Seismic Retrofit of Existing Buildings." This appendix aims to improve public safety by reducing the risk of injury or death from earthquakes, particularly in buildings with unreinforced masonry bearing walls. The updated code also establishes a collaborative framework for building professionals to refine performance and prescriptive standards.

Puerto Rico is now divided into three seismic design categories—A, B, and C—based on ground acceleration levels, with Category C requiring the most stringent design measures. Engineers must use site-specific ground motion data—including soil type, topography, and proximity to active faults—when designing structures in high-risk areas. Enhanced structural systems, such as steel moment frames and reinforced concrete shear walls, are mandated for Categories B and C, along with compliant joints to mitigate differential movement. All new construction in high-risk zones must undergo special inspections by registered design professionals to ensure compliance with seismic provisions.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Puerto Rico is undergoing a transformative phase of redevelopment aimed at enhancing resilience against seismic hazards. With over $19.8 billion in federal funding allocated for infrastructure reconstruction—including energy systems, schools, and water treatment facilities—the island is integrating seismic risk reduction into its long-term planning.[304] The USGS is leading efforts to update the seismic hazard map for the first time in over 20 years, using advanced airborne geophysical surveys to better identify fault zones

[304] Recovery, Reconstruction, and Resiliency, "Build Puerto Rico – Disaster Recovery Update," https://recovery.pr.gov/documents/COR3-Presentacion-Final-Build-Puerto-Rico-Reconstruction-Summit_20240919T213222.822Z.pdf.

and inform safer building practices.[305] These initiatives, combined with FEMA-supported hazard mitigation projects, position Puerto Rico to rebuild stronger and more seismically resilient communities.

In October 2025, the Puerto Rico Planning Board announced the launch of the review process for the Puerto Rico Land Use Plan. This initiative aims to update the island's planning framework to reflect environmental, demographic, and economic changes that have occurred since the hurricanes of 2017, the earthquakes of 2020, and the COVID-19 pandemic.

POPULATION CHANGES

At the end of June 2025, the annual population estimates by age and sex characteristics for the period 2020–2024 were published. This annual publication is frequently used in the analysis of indicators for specific sub-groups or population cohorts, such as populations within specific age and sex groups. Rates based on population counts in sub-groups across various social and economic phenomena are often updated using these annual demographic estimates, allowing for comparisons that more closely reflect the reality of recent years.

At the Puerto Rico level, for broad age groups (0–17, 18–64, and 65 or older), the annual changes from 2020 to 2024 in percentage terms were as follows (see Figure 118 for percentage change trends):

- A consistent reduction in the population under 18 years old, with changes of at least 3%.
- A reduction from 2020 to 2023 in the potentially active population (ages 18 to 64) ranging from -0.5% to -1.5%, with no substantial change between the last two years (2023–2024).
- A marked and consistent increase in the older adult population (65+), with annual changes of at least 1.7%.[306]

[305] USGS, "2025 Puerto Rico and U.S. Virgin Islands Long-term National Seismic Hazard Model, Earthquake Hazards Program," March 17, 2025, https://www.usgs.gov/programs/earthquake-hazards/science/2025-puerto-rico-and-us-virgin-islands-long-term-national.

[306] U.S. Census Bureau, *Annual Puerto Rico Municipality Resident Population Estimate by Age Groups and Sex (Vintage 2024),* "Population Division Visualización y Cálculo: Instituto de Estadísticas de Puerto Rico," https://censo.estadisticas.pr/node/540.

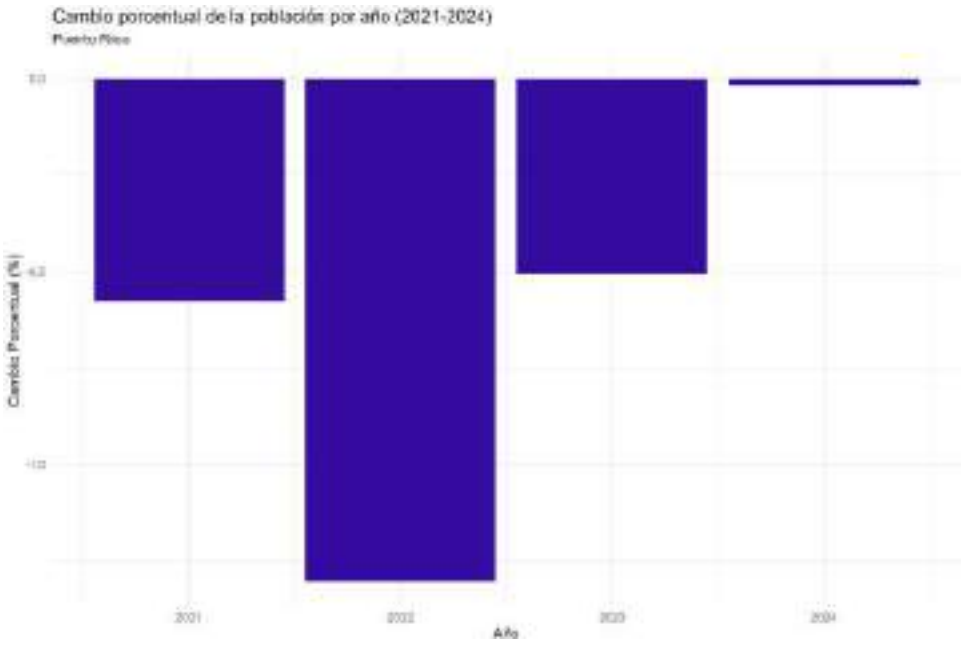


Figure 118: Annual Resident Population Estimates by Age Group and Sex for Puerto Rico Municipalities, 2021–2024[307]

Mitigation Success Stories

PROJECT 4339-0133: PUBLIC BUILDING AUTHORITY – SEISMIC RETROFIT OF EXISTING PUBLIC SCHOOLS ($150 MILLION)

This project aims to enhance the safety of students, teachers, school staff, and the public by reducing seismic risks in public school facilities across Puerto Rico. It focuses on seismically retrofitting up to 55 public schools to address both structural and nonstructural vulnerabilities, ensuring that these critical facilities can better withstand future disasters and continue to function as safe spaces and potential emergency shelters.

[307] U.S. Census Bureau, *Annual Puerto Rico Municipality Resident Population Estimate by Age Groups and Sex (Vintage 2024)*, Population Division Visualización y Cálculo: Instituto de Estadísticas de Puerto Rico, "Gráficas sobre el cambio porcentual por grupos de edad de la población en Municipios y Puerto Rico 2020–2024 State Data Center," https://censo.estadisticas.pr/node/540.

Figure 119: Earthquake-Damaged Middle School in Guánica, Puerto Rico, January 21, 2020

PROJECT 4339-0323: PUERTO RICO DEPARTMENT OF EDUCATION – SCHOOL RETROFIT ($307.3 MILLION)

This initiative evaluates, designs, and retrofits 50 public schools across the island to reduce their exposure to seismic, wind, and flood hazards. Many of these schools face serious structural risks that could endanger thousands of students, teachers, and staff during natural disasters. By upgrading these facilities to meet modern resilience standards, the project aims to significantly lower the risk of injury or loss of life, reduce property damage, and accelerate recovery efforts after future events. These retrofits are a vital investment in both public safety and the continuity of education. They reinforce Puerto Rico's infrastructure and help ensure that schools remain secure and operational when communities need them most.

PROJECT 4339-0011: PUERTO RICO ELECTRIC POWER AUTHORITY (PREPA) – PATILLAS DAM SEISMIC RETROFIT ($558.0 MILLION)

This effort seismically retrofits the Municipality of Patillas Dam to prevent deformation and potential failure caused by earthquakes, which could result in uncontrolled water release and downstream flooding. The rehabilitation aims to restore the reservoir's normal water surface elevations, which are critical for power generation, agricultural irrigation, and supplying water to approximately 100,000 residents in southeastern Puerto Rico. Given the dam's century-old structure, the project faces complex seismic and structural challenges that require extensive data collection and design adjustments to ensure long-term safety and functionality.

SECTION 4.4

EXTREME HEAT

Extreme Heat

EXTREME HEAT DEFINITION

Extreme heat refers to prolonged periods of unusually high temperatures, often accompanied by elevated humidity that prevents natural cooling at night. The Centers for Disease Control and Prevention (CDC) defines extreme heat as conditions when temperatures are at least 10°F above the regional average, persisting for several days or weeks. The National Weather Service (NWS) considers a heat wave to be a period of abnormally hot and humid weather lasting two or more consecutive days.

Extreme heat is one of the most dangerous climate-related hazards in the United States, claiming more lives annually than hurricanes, floods, or tornadoes.[308] In Puerto Rico, heat is no longer an occasional concern but an emerging chronic hazard that compounds vulnerabilities in public health, energy, and infrastructure. FEMA's National Risk Index identifies heat waves as a primary hazard affecting U.S. jurisdictions, including the island.[309] Official records cite only one direct heatstroke death in Puerto Rico between 2015 and 2023. However, experts caution that this severely underestimates the true toll, since many heat-related deaths are coded under cardiovascular or respiratory causes.

Recent analyses show that Puerto Rico endured 161 extreme heat days between May 2024 and May 2025. At the regional scale, the World Meteorological Organization estimates that 36,700 excess deaths occur annually across Latin America and the Caribbean due to heat exposure. Beyond health impacts, extreme heat drives up electricity demand, placing Puerto Rico's already fragile grid under strain and increasing the likelihood of blackouts. It accelerates infrastructure degradation, from asphalt softening to the reduced reliability of water and energy systems. It also imposes significant economic costs: outdoor workers in

[308] CDC. 2022. Extreme Heat Mortality in the United States. Centers for Disease Control and Prevention.
[309] FEMA. 2025. State Mitigation Planning Policy Guide. Federal Emergency Management Agency.

agriculture, construction, and landscaping face reduced productivity; local businesses, open-air markets, and restaurants without sufficient cooling see declines in customer activity; and the tourism sector, one of Puerto Rico's major economic drivers, suffers during prolonged heat waves that diminish visitor comfort. When blackouts caused by peak cooling demand disrupt commerce, healthcare, and essential services, the economic burden compounds. Scaled to Puerto Rico's economy, climate-related productivity and service losses represent nearly 0.8% of GDP, or $800 million annually. Unlike sudden hazards, heat waves cause cumulative harm. Prolonged exposure leads from dehydration and heat exhaustion to heatstroke, a life-threatening condition in which the body can no longer regulate temperature. When heat coincides with Saharan dust intrusions, air quality deteriorates sharply, worsening respiratory stress in a population with an already high asthma prevalence. These compounding effects highlight why extreme heat is increasingly viewed as a multisystem hazard threatening health, lifelines, and resilience.[310]

Location

Puerto Rico lies in the northeastern Caribbean, just north of the equator, giving it a predominantly tropical climate with warm temperatures year-round. Its geographic position amplifies exposure to extreme heat, as consistently high solar radiation and humidity interact with local topography and land use.

Figure 120 illustrates Puerto Rico's location in the tropical belt. This equatorial setting drives consistently warm conditions and shapes how extreme heat events develop across the island. The figure shows the current day's average weather forecast by the NOAA.[311]

[310] Puerto Rico's State of the Climate 2014–2021. https://pubs.usgs.gov/publication/70249920.
[311] Climate Reanalyzer, https://climatereanalyzer.org/wx/todays-weather/?var_id=t2&ortho=1&wt=1.

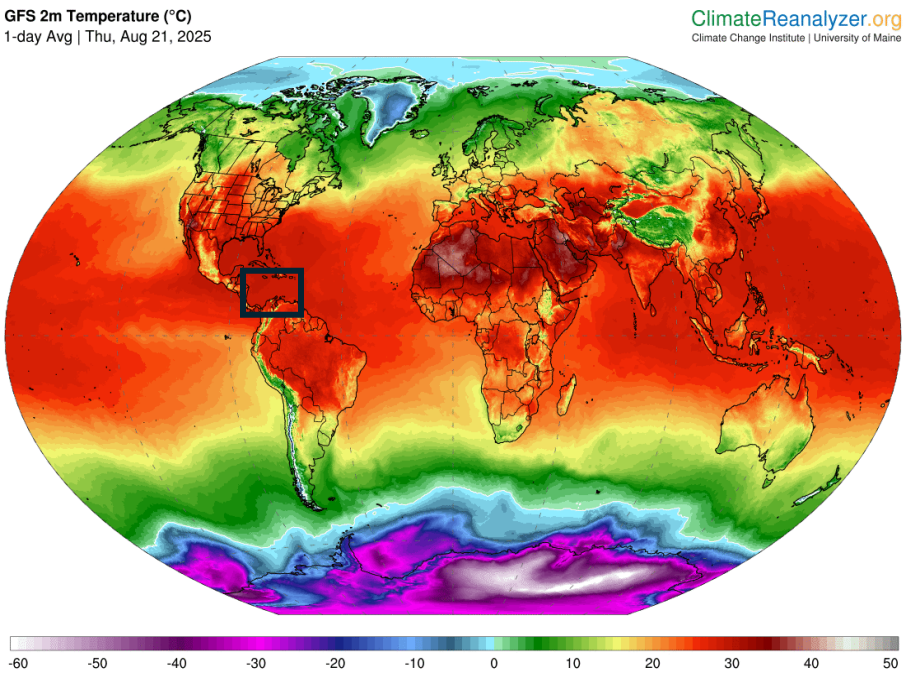


Figure 120: Location of Puerto Rico on the Globe, with the Day's Average Weather for Temperature, Precipitation, Wind, and Other Variables

Observed temperatures vary strongly with elevation. The mean annual temperature in San Juan near sea level is approximately 27°C (80.6°F), while at Cerro Maravilla in the Cordillera Central (≈4,000 ft) it averages near 20°C (68°F). Seasonal variation is modest, with the coolest months in January and February and the warmest in July and August. Over the past 70 years, nighttime minimum temperatures at low elevations have increased by 1.6°C, and by 1.2°C at high elevations, confirming a long-term warming trend that reduces natural nighttime relief.[312] Figure 121 shows the annual average temperature across Puerto Rico which highlights the variation due to elevation.

[312] Puerto Rico's State of the Climate 2014–2021. https://pubs.usgs.gov/publication/70249920.

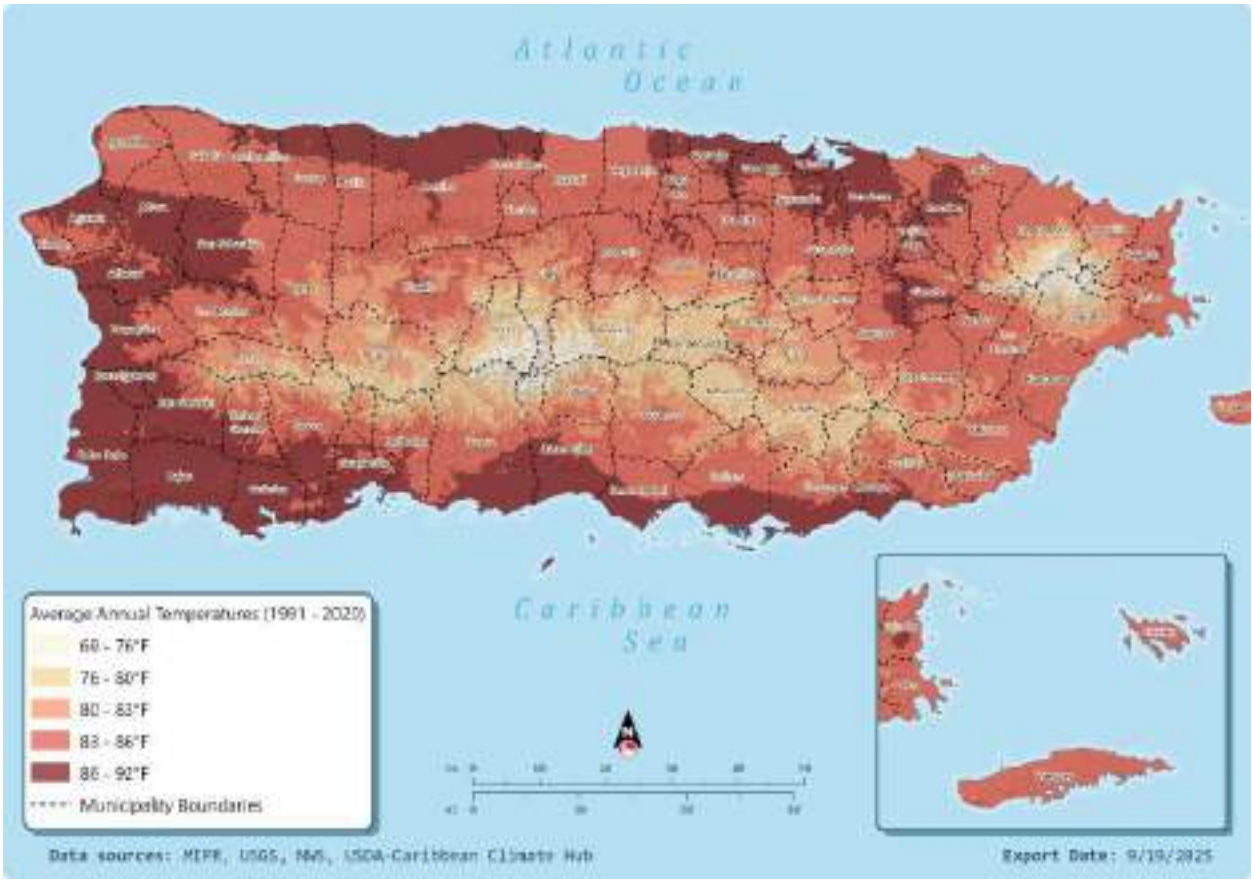


Figure 121: Annual Average Temperature 1991-2020

- **Coastal municipalities** are the most exposed, with higher daytime maximums and dense populations that heighten risk. Urbanized coastal areas, such as San Juan, Bayamón, and Carolina, face the strongest impacts due to the **urban heat island (UHI) effect**, where paved surfaces and limited vegetation trap heat and keep nighttime temperatures high.
- **Mountainous regions** that once offered natural cooling are now experiencing elevated nighttime minimums, reducing opportunities for recovery. This shift is especially concerning vulnerable populations in communities that previously relied on altitude for relief.
- **Southern municipalities**, such as Ponce, Guánica, and Lajas, located in Puerto Rico's drier zones, face compounding risks in which extreme heat interacts with water scarcity and agricultural stress.
- **Outlying islands** like Vieques and Culebra are uniquely vulnerable due to their limited infrastructure and reliance on external energy and water systems, magnifying the impacts of prolonged heat waves.

This geographic distribution underscores that extreme heat is not uniform: low-lying urbanized coasts endure higher daily heat stress, while highland and rural areas face rising nighttime temperatures that extend exposure. These conditions demand locally tailored mitigation strategies that recognize how topography, land use, and infrastructure interact with Puerto Rico's climate.

Previous Occurrences

Extreme Heat is a persistent consideration in Puerto Rico. Temperatures in Puerto Rico can vary significantly due to the island's topography. For example, locations in lower altitude areas have experienced a substantial increase in temperature since the early 20th century. Similarly, temperatures in higher elevations have also risen over the same period.[313] Research indicates that Puerto Rico has experienced temperature changes for more than two decades. One study suggests that temperatures in Puerto Rico rose by 1°F or more between 1950 and 2014.[314] Further studies highlighted record-breaking temperatures in 2012, which were especially significant in San Juan; the analysis indicated that temperatures in urban areas increased significantly faster than in rural areas. According to the CDC, record-breaking temperatures in San Juan have been associated with an increase in mortality rates, particularly in heat-related diseases, such as stroke and cardiovascular diseases.[315] In 2018, the Luis Muñoz Marín meteorological station recorded a week when the minimum temperature stayed at or above 80°F,making it the 30th highest instance of such conditions on record. [316]

Table 39 shows the numbers of days with the Regions of Mayaguez, Ponce, and San Juan above the threshold for 2015–2020.

Table 39: Number of Days with Daily Maximum Temperatures Above the Threshold in Each Region , 2015–2020[317]

	Mayaguez	Ponce	San Juan
2015	31	34	47
2016	36	42	46
2017	42	55	52
2018	11	5	8
2019	46	39	47
2020	53	41	20

[313] Puerto Rico's State of the Climate 2014–2021. San Juan, PR: PRCCC. 13 pp. https://pubs.usgs.gov/publication/70249920.
[314] Méndez-Tejeda, R. Increase in the Number of Hot Days for Decades in Puerto Rico 1950–2014. Environ. Nat. Resour. Res. 2017, 7, 16–26.
[315] CDC Regional Health Effects – U.S. Caribbean, https://www.cdc.gov/climate-health/php/regions/uscaribbean.html.
[316] National Oceanic and Atmospheric Administration (NOAA). (2021). Climate Review for Puerto Rico and the U.S. Virgin Islands. National Weather Service San Juan. https://www.weather.gov/media/sju/climo/monthly_reports/2021/2021.pdf.
[317] Méndez-Lázaro, Pablo A., Claudia Di Napoli, Sona Rivas-Tumanyan, Naydi Pérez-Ríos, Lorena González Sepúlveda, Ernesto Rodríguez, Ernesto Morales et al. "Too hot and too humid in the Caribbean: Impacts of extreme heat events and non-accidental mortality in the tropical island of Puerto Rico (2015-2020)." (2025). 100484.

In 2024, San Juan reached a new record by registering 182 days with temperatures higher than 90°F, including "50 consecutive days with highs at 90 or higher."[318] The previous record dates to 1983, when significantly high temperatures were recorded, with an average of 85.4°F.

Figure 122 shows the maximum temperature recorded across Puerto Rico as recorded by NOAA.[319] [320] Twelve of these locations have exceeded 100°F. Each point represents a station, categorized by its recorded maximum temperatures. Maximum temperatures recorded at stations across Puerto Rico were consolidated into the map below.

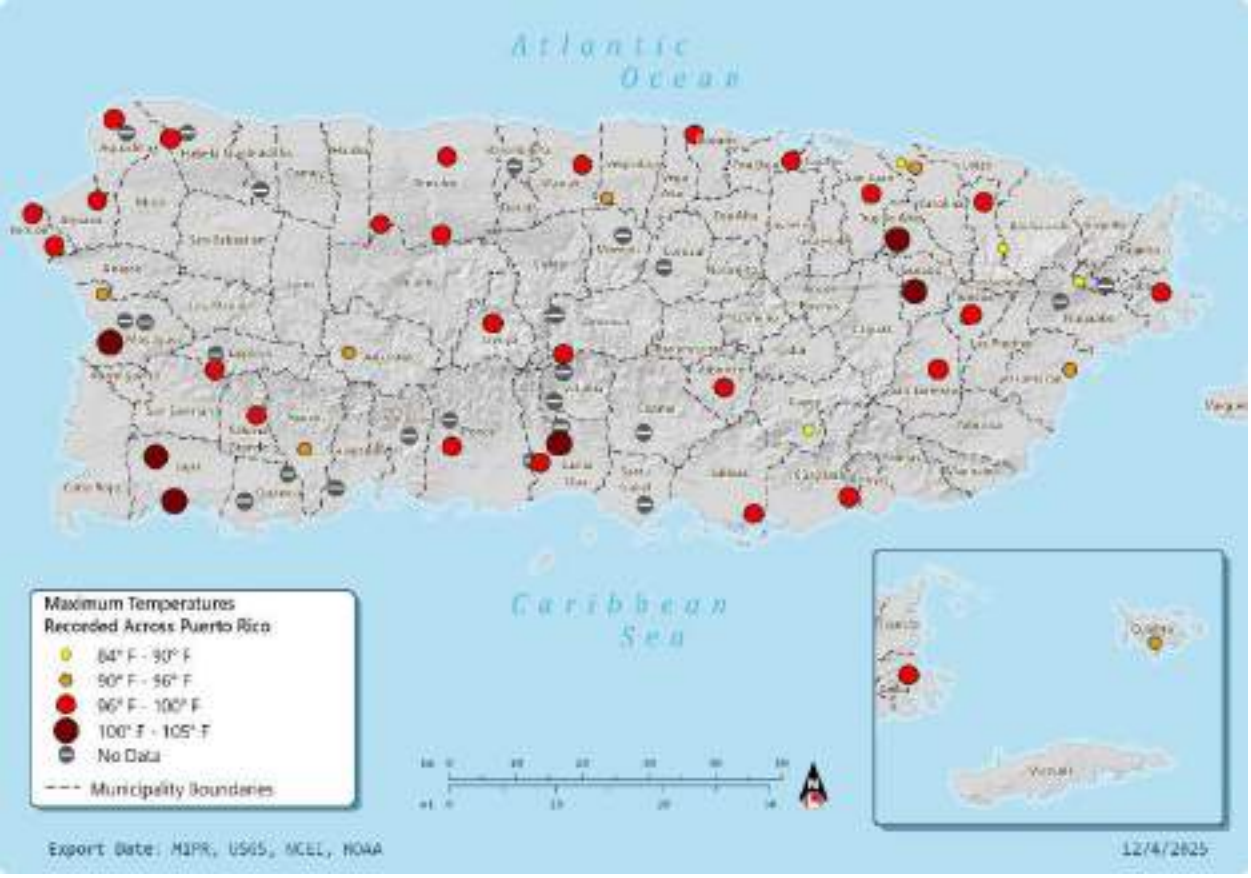


Figure 122: Maximum Temperature Recorded Across Puerto Rico

FEDERAL DISASTER DECLARATIONS

No federal disaster declarations have been issued specifically for Extreme Heat in Puerto Rico. However, Table 40 lists the disaster declarations or emergency proclamations related to energy shortages that have been issued.

[318] NOAA, NWS 2024 a year in review https://storymaps.arcgis.com/stories/7af65122dbe64a44a5976579458ed915.
[319] National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information. Past Weather. https://www.ncei.noaa.gov/access/past-weather/puerto%20rico#.
[320] NOAA Regional Climate Center. (n.d.). SC ACIS2. https://scacis.rcc-acis.org/.

Table 40: Disaster Declarations Involving Energy Sources

Executive Order	Description
DEO 202-25-1	Focuses on the critical shortage of electric generation capacity throughout the island
DEO 202-25-2	Targets the energy grid vulnerability to vegetation encroachment.

PUERTO RICO DISASTER DECLARATIONS

There have been no disaster declarations specifically for Extreme Heat in Puerto Rico.

SIGNIFICANT EVENTS

Extreme weather events in Puerto Rico are increasingly disruptive. Prolonged heat waves put additional stress on the energy grid, leading to multiple power failures, leaving communities without access to cooling systems. This increases the risk of heat-related illnesses in older adults, children, and homeless populations. Beyond the impact on the electrical grid and health, extreme heat has contributed to social disruptions like school closures. Some significant events in Puerto Rico related to extreme heat are as follows:

- In 2012, 2013, and 2014, Puerto Rico experienced various days during the summer season that exceeded previous historical records.[321]
- In 2017, Hurricane Maria caused catastrophic damage to the transmission and distribution of electrical power in Puerto Rico. Without electricity, the population faced increased exposure to extreme heat.
- The 2020 earthquake further damaged the island's two largest power plants, Costa Sur and EcoEléctric.
- Since 2023, over 700 emergency room visits related to heat illnesses have been recorded.[322]
- In September 2023, the Department of Education distributed 21,000 fans to schools, and suspended classes around the island for one day due to a lack of air conditioners in various schools.[323]
    - In 2023, the Puerto Rican Department of Education developed and implemented protocols to activate during extreme heat conditions. In 2023 and 2024, over 350 students required medical assistance because of extreme heat.[324]In the academic year 2023–2024, over 250 students across five jurisdictions sought medical assistance.

[321] U.S. Climate Resilience Toolkit, Climate and Health, http://toolkit.climate.gov/climate-and-health.
[322] NBC News, "Amid more extreme heat, schools in Puerto Rico have limited options," August 21, 2025, https://www.nbcnews.com/news/latino/puerto-rico-extreme-heat-schools-impact-rcna226290, retrieved 8/25/25.
[323] Puerto Rico's public schools clamor for air conditioning to get relief from record-breaking heat, dated 9/8/23. https://financialpost.com/pmn/business-pmn/puerto-ricos-public-schools-clamor-for-air-conditioning-to-get-relief-from-record-breaking-heat, retrieved 8/26/25.
[324] Crisis energética y calor extremo afectan el salón de clase, https://periodismoinvestigativo.com/2025/08/crisis-energetica-calor-extremo-escuelas/.

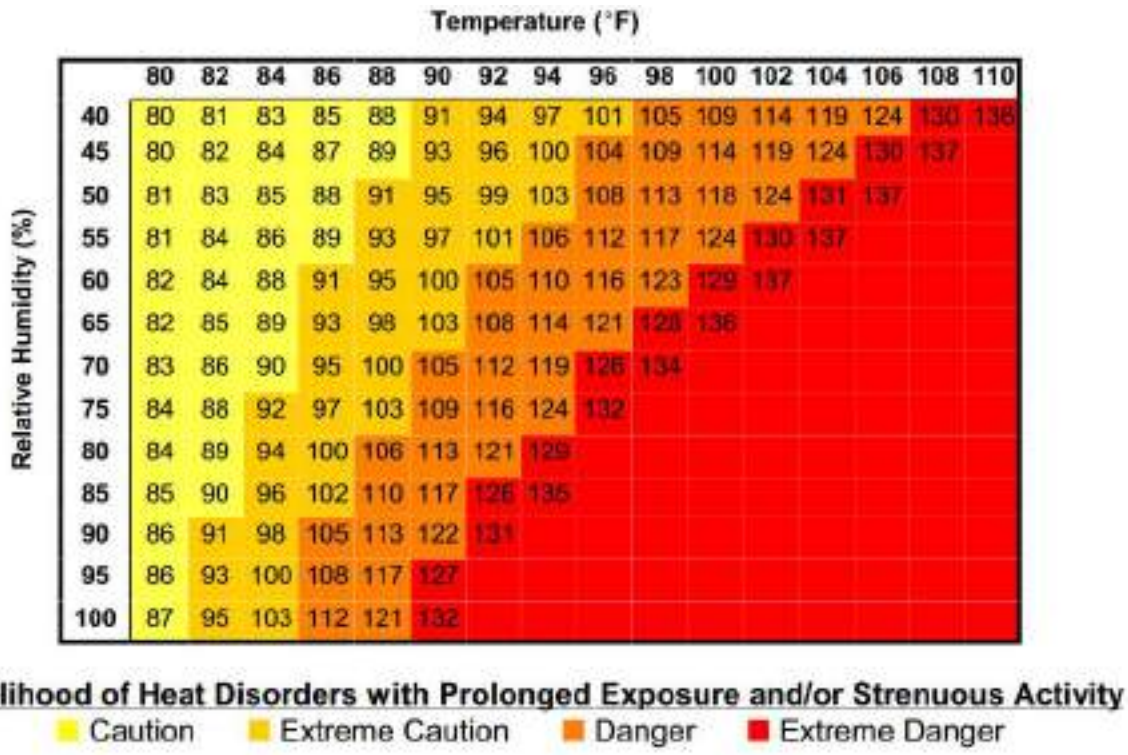
- In mid-2024, NOAA issued a Bleaching Alert Level 2[325] – Widespread bleaching and some mortalities are expected for the coral reef. This alert indicated that the water around Puerto Rico was under severe thermal stress.
- From May 2024 to May 2025, Puerto Rico experienced 161 days categorized as extreme heat.[326]

Potential Severity of Events

The NWS heat index chart (Figure 123) shows how air temperature and relative humidity combine to yield the perceived heat risk in four categories—from "Caution" to "Extreme Danger." Full sun can raise the heat index by up to 15°F.

In Puerto Rico, where relative humidity is consistently high, the heat index often exceeds actual air temperature, pushing conditions into the "Danger" and "Extreme Danger" ranges with temperatures exceeding 105–110°F. This tool is critical for understanding how extreme heat affects the body and for guiding advisories, preparedness actions, and public warnings.

[325] Riesgos de Estrés Térmico Marino en Puerto Rico Año 2 Núm. 4 (Julio 2024) https://www.sampr.org/wp-content/uploads/2024/08/BOLETIN-TECNICO-ES-SAMPR-AGOSTO-2024.pdf.
[326] Giguere, Otto, Tannenbaum, Vahlberg, et al. (2025). Climate Central, Red Cross Red Crescent Climate Centre, World Weather
Attribution. https://www.climatecentral.org/report/climate-change-and-the-escalation-of-global-extreme-heat-2025.



Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

Figure 123: Heat Index Chart from the National Weather Service

The potential severity of the event might have a cascading effect on the whole community, as described Table 41.

Table 41: Cascading Effects of Extreme Heat

Category	Description
Public	Approximately 43.5 % of the population is experiencing poverty, and 489,400 individuals have been identified with one or more disability.[327] Extreme heat can have a significant impact on these communities, as many might not be able to stay inside during extreme heat events. In addition, those with disabilities, the elderly,

[327] Puerto Rico Community Survey 2018-2022, Community Resilience Estimates for Puerto Rico 2022 & County Business Patterns 2022, https://experience.arcgis.com/experience/e354379b03fc479697a20b1cca1485b3/page/Page-1.

Category	Description
	the very young, and those who have medical conditions might be more vulnerable to high heat.
Responders	Increased demand for services can lead to responder burnout while increasing the exposure of first responders to effects from extreme heat, such as dehydration, decline in sleep quality, an increase in aggressive behavior, and a decrease in neurologic function.[328]
Delivery of Services	Vulnerable populations may live in areas with limited access or inadequate infrastructure (e.g., unreliable electricity, lack of access to air conditioning in homes, limited cooling centers), increasing demand for critical services.
Economic Conditions	Extreme heat will likely affect tourism, agriculture, public utilities, and other businesses, as repeated exposure to extreme heat may lower income capacity due to higher service expenditures. Economic losses due to extreme heat are difficult to estimate due to the multiple variables involved. However, recent studies have developed potential economic losses[329] in the next 25 years; the estimates below assume an increase in temperature of at least 2°C. • Agriculture: $13+ million • Manufacturing: $230+ million • Tourism: $4+ million
Environment	Fauna & flora can experience the immediate effects of extreme heat. Coral reef ecosystems, which are susceptible to temperature fluctuations, are experiencing a phenomenon known as coral bleaching, which indicates stress conditions for temperature, light, and nutrients.[330] Coral reefs are responsible for supporting marine biodiversity, including filtering toxins, providing food and habitat for fish nurseries, and acting as barriers against waves and storms. It is estimated that coral reefs contribute over $3 billion to the U.S. economy. This calculation is based on the benefits to fishing, tourism, and coastal protection.[331]
Human health	As Puerto Rico's population continues to age, the demand for healthcare services also will increase. Rising temperatures can increase the likelihood of heat strokes, dehydration, and cardiovascular disease. The augmentation in patient care can overwhelm urgent care and transportation systems. The Health Department's Syndromic Surveillance System uses a combination of indicators to monitor diseases or public health situations. It reported that there have been 183 alerts of diseases related to heat or a lack of electricity from January to September of 2023.[332]

[328] Williams A, McDonogh-Wong L, Spengler JD. The Influence of Extreme Heat on Police and Fire Department Services in 23 U.S. Cities. Geohealth. 2020 Nov 6;4(11):e2020GH000282. doi: 10.1029/2020GH000282. PMID: 33204929; PMCID: PMC7648134.
[329] El Costo de la Inacción, ante el cambio climatico en Puerto Rico, 2024 Cambio Climático (CEACC) de Puerto Rico.
[330] What is Coral Bleaching? National Ocean Service, https://oceanservice.noaa.gov/facts/coral_bleach.html.
[331] Coral reefs, fast fact, NOAA office for coastal management, https://coast.noaa.gov/states/fast-facts/coral-reefs.html.
[332]Historic Heat Affects Puerto Rico's Most Vulnerable, https://periodismoinvestigativo.com/2023/10/historic-heat-affects-puerto-ricos-most-vulnerable/.

Category	Description
Infrastructure	There is a severe high demand on the grid and buildings, particularly building cooling loads. Puerto Rico's energy company has one of the largest customer bases in the U.S. However, due to the damaged infrastructure from previous hurricanes, Puerto Rico provides less power than U.S. mainland utilities.
Agriculture	Damage can include severely reduced crop yields and threats to food security. In addition, livestock can suffer heat stress, lowering production for basic staples, such as milk, eggs, and meat. Warmer conditions may also increase agricultural pests and pathogens.
Tourism	Providers who focus on outdoor activities such as, beach tourism, hiking and festivals may see increased risk of heat illness. Reef degradation may negatively impact destinations that depend on healthy marine environments.

Probability of Future Hazard Events

Extreme heat events are impacting communities all over the world. Data collected and analyzed since the 1950s indicate that temperatures will continue to rise in the upcoming years. Like many warm-weather communities, Puerto Rico routinely experiences excessive heat outlooks, watches, and warnings throughout the island, and it has experienced recurrent periods of extreme heat since 2012. Therefore, there is a **high** likelihood that extreme heat events will continue to impact Puerto Rico.

Projections for the wider Caribbean indicate that annual average temperatures will continue to rise throughout this century, with mid-century increases ranging from 0.9°C to 1.6°C, depending on emission levels, and end-of-century increases reaching between 1.0°C and 3.5°C under high-emission scenarios.[333] Regional climate modeling further suggests that Caribbean islands may warm faster than the surrounding oceans, with the northern Caribbean projected to experience the largest increases.[334] Puerto Rico is expected to warm at an even faster rate than the global average. Downscaled climate models project temperature increases by the end of the century of up to 4.5°C under lower emission pathways and as much as 7°C under high-emission scenarios.[335] Even moderate increases are expected to drastically alter daily conditions, with the number of extremely hot days projected to rise annually by mid-century.[336]

[333] Almarzoui, M., Taylor, M., Stephenson, T., & Campbell, J. (2021). Caribbean climate projections from CMIP6 global models. Journal of Climate, 34.
[334] Campbell, J., Taylor, M., Stephenson, T., & Almarzoui, M. (2021). Regional climate model projections for Caribbean islands under global warming targets. Climate Dynamics, 57.
[335] Hayhoe, K., Stoner, A., Daniel, J., & Wuebbles, D. (2013). Downscaled estimates of future temperature and precipitation. Journal of Geophysical Research: Atmospheres, 118.
[336] Bowden, J. H., Terando, A., Wootten, A., Henareh Khalyani, A., & Hayhoe, K. (2021). Projected changes in extreme heat events for Puerto Rico using downscaled climate models. Climatic Change, 165(3–4), 1–17.

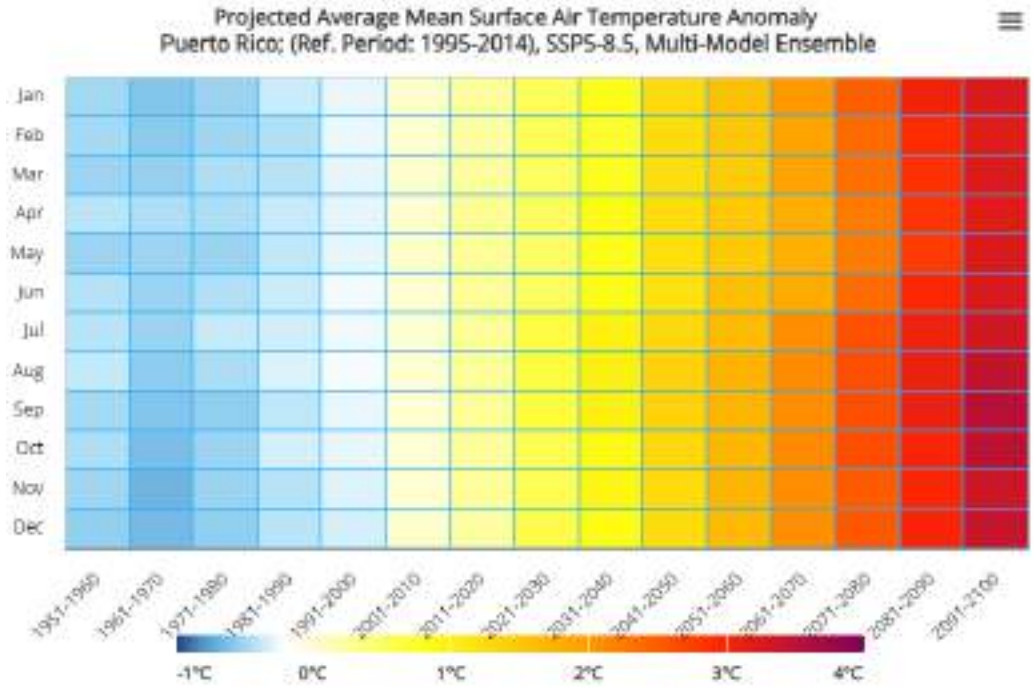


Figure 124: Projected Mean Surface Air Temperature for Puerto Rico, 1951–2100[337]

As air temperature rises, projections by the NOAA models (Figure 125) suggest that, between 2025 and 2040, Puerto Rico may experience an average of 40 days per season with maximum temperatures of over 32.22°C or 90°F. Between 2040 and 2060 this number might double.

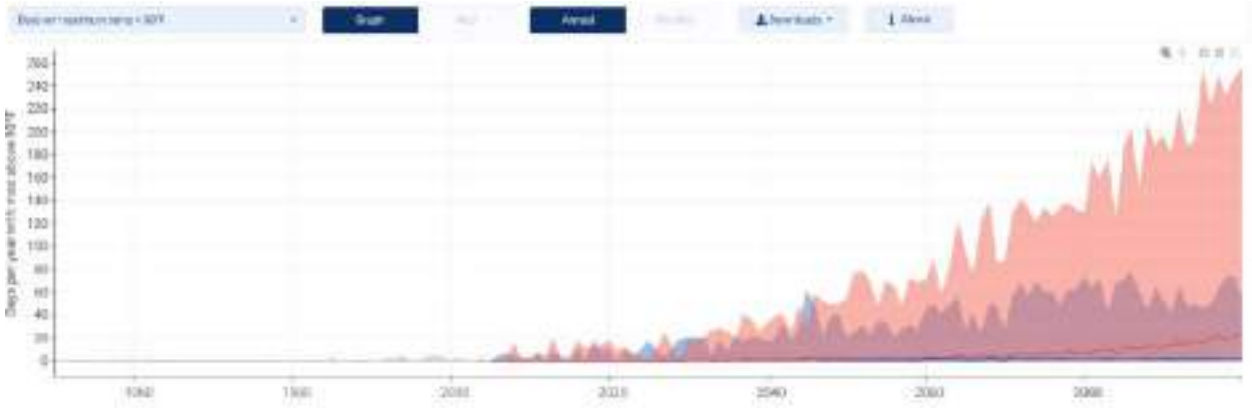


Figure 125: NOAA Climate Projections for Days with Maximum Temperatures over 90°F

Vulnerability Assessment

Situated at the crossroads of tropical latitudes, Puerto Rico is increasingly vulnerable to the intensifying impacts of extreme heat. The rising temperatures observed between 2014 and 2021 confirm a consistent upward trend, showing that extreme heat is no longer an isolated phenomenon but an emerging chronic

[337] *World Bank Group. (2021).* https://climateknowledgeportal.worldbank.org.

hazard.[338] The impacts are unevenly distributed across the island. Coastal zones experience higher daily maximums, mountainous regions that once provided cooler refuges are now facing warmer nighttime temperatures that limit natural relief, and densely urbanized areas like San Juan face amplified risks due to the UHI effect,[339] shown in Figure 126. Together, these conditions mark a shift in Puerto Rico's climate reality, where extreme heat is becoming a persistent stressor with wide-ranging consequences for public health, infrastructure, and community resilience.

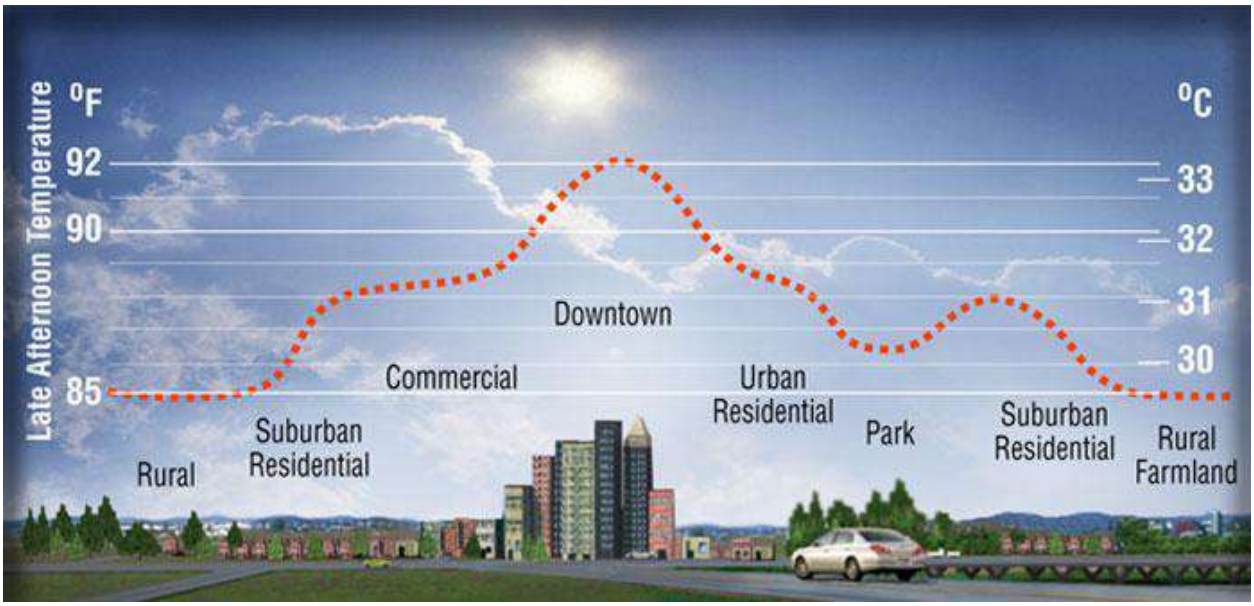


Figure 126: Conceptual Diagram of the Urban Heat Island Effect

In addition to rising temperatures, Puerto Rico's vulnerability to extreme heat is compounded by atmospheric aerosols, particularly Saharan dust intrusions transported across the Atlantic. These dust events are frequent in the Caribbean and contribute to aerosol loading in the atmosphere. Aerosols have a complex role in temperature dynamics: they can reflect solar radiation and create localized cooling, but they also absorb radiation, altering the regional energy balance. When combined with greenhouse gas-driven warming, aerosols can intensify the perception of extreme heat, particularly during prolonged dust episodes. High aerosol concentrations during these heat events also increase public health risks by degrading air quality, compounding the stress of extreme heat on vulnerable populations, including the elderly, young children, individuals with chronic health conditions, outdoor workers, low-income households, and unhoused populations.. This interaction between heat and aerosols further amplifies Puerto Rico's hazard profile, especially in urban and coastal municipalities already facing elevated exposure.

LOCATIONS

Extreme heat affects Puerto Rico unevenly, with risks varying by geography, population density, and infrastructure conditions. The San Juan metropolitan area and surrounding municipalities, such as Bayamón,

[338] Puerto Rico's State of the Climate 2014–2021. https://pubs.usgs.gov/publication/70249920.
[339] Puerto Rico's State of the Climate 2014–2021. San Juan, PR: PRCCC. 506 pp. https://pubs.usgs.gov/publication/70249920.

Carolina, and Guaynabo, are among the most threatened. These densely urbanized communities experience amplified temperatures due to the UHI effect, where impervious surfaces and limited vegetation trap heat during the day and release it slowly at night. As a result, residents face higher exposure to both extreme daytime heat and prolonged nighttime warmth, conditions that increase health risks and strain energy demand[340]. The San Juan metropolitan area provides the clearest example of the UHI effect in Puerto Rico.
.

Coastal municipalities are also highly exposed because of their low elevation, proximity to warm ocean waters, and concentration of critical infrastructure, such as ports, airports, and power plants. In these areas, extreme heat often coincides with other compounding hazards, such as drought, storm surge, and flooding. In contrast, the Cordillera Central—traditionally considered a cooler refuge due to its higher elevation—is no longer immune. Rising nighttime minimum temperatures are reducing natural relief, leaving mountain communities increasingly vulnerable. At the same time, southern and southwestern municipalities, including Ponce, Guánica, and Lajas, already face the island's driest conditions. Here, extreme heat compounds water scarcity and agricultural stress, threatening local livelihoods. The outlying islands of Vieques and Culebra face unique vulnerabilities. Their limited infrastructure and heavy reliance on external lifelines, such as electricity generation and water supply, increase risks during prolonged heat events, especially for schools and healthcare facilities that already operate with constrained resources. These geographic disparities emphasize that extreme heat is not a uniform hazard but a place-based challenge. Urban, coastal, rural, and island communities face distinct exposure pathways, requiring mitigation and adaptation strategies tailored to their specific vulnerabilities.

POPULATIONS

Vulnerable populations face heightened risks during prolonged heat events, as they are more susceptible to heat-related illnesses, dehydration, and even mortality. These risks are further exacerbated in communities with limited access to reliable air conditioning or cooling centers, where residents endure prolonged exposure to extreme temperatures without adequate relief. Elderly individuals and medically fragile populations are particularly at risk, experiencing compounding health impacts when extreme heat coincides with poor air quality, such as during episodes of Saharan dust intrusions, which can intensify respiratory and cardiovascular stress.

STRUCTURES INCLUDING CRITICAL FACILITIES

Many residential structures lack adequate cooling systems, leaving low-income households disproportionately exposed to extreme heat. Critical facilities, such as hospitals, nursing homes, and emergency shelters, also face elevated risks, as increased energy demand during heat events can threaten continuity of care if power outages occur. Similarly, schools and other public facilities without resilient cooling and ventilation systems may experience unsafe indoor conditions during prolonged periods of high temperatures, putting both occupants and essential community services at risk.

[340] U.S. Environmental Protection Agency (EPA). Heat Island Trends. 2023. https://www.epa.gov/heatislands/heat-island-trends.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Puerto Rico's electric grid is highly vulnerable to the surge in air-conditioning demand during extreme heat, significantly increasing the likelihood of blackouts. Power outages under these conditions can disrupt essential community lifelines, including water supply, healthcare services, and communications infrastructure, placing public safety at risk. In addition, transportation networks face reduced reliability, while outdoor workforces experience heightened health risks and decreased productivity during prolonged periods of extreme heat.

PROBLEM STATEMENTS

- Extreme heat disproportionately impacts vulnerable populations across Puerto Rico, including the elderly, young children, individuals with chronic health conditions, outdoor workers, and low-income households with limited access to cooling. Rising nighttime minimum temperatures reduce opportunities for recovery, while urban residents face higher exposure due to the UHI effect.
- Extreme heat places stress on residential, commercial, and institutional structures across Puerto Rico. Buildings without adequate insulation or cooling systems amplify exposure for occupants. Critical facilities, such as hospitals, elder care centers, and schools, are particularly vulnerable to rising energy demand and potential power outages during heat waves.
- Extreme heat directly affects the energy, water, and transportation systems that support community lifelines. Puerto Rico's electric grid, already fragile, is projected to experience a doubling of cooling demand, stressing supply and increasing outage risks. Prolonged outages during extreme heat events would have cascading effects on water supply, communications, and emergency services.

Impact Assessment

Extreme heat in Puerto Rico has been transformed from a seasonal challenge into a pervasive threat, with wide-ranging implications across sectors. During the summer of 2023, approximately 70% of summer days in San Juan and surrounding areas saw a heat index exceeding 100°F, far surpassing historical norms and significantly raising energy demands for cooling around a 25% spike in peak building energy use compared to average years.[341]

Meanwhile, 2024 was officially confirmed as the warmest year on record for the San Juan climate site, setting 131 daily warmest-minimum records and producing 50 consecutive days with highs at or above 90°F, reinforcing the severity of rising thermal stress.[342]

[341] Oppong et al. 2024. Extreme Heat in the Caribbean: Impacts on Well-being and Building Energy Infrastructure The 2023 Summer Case (repository.library.noaa.gov). NOAA/NWS Heat Risk and 2023 conditions.
[342] NOAA & NWS report confirming 2024 as the warmest year on record in San Juan. https://stthomassource.com/content/2025/01/18/2024-named-the-warmest-year-on-record-noaa-and-nws-reports-highlight-extreme-weather-events-across-u-s-v-i-puerto-rico/?utm_source=chatgpt.com.

Looking ahead, the persistence of extreme heat will demand proactive measures that go beyond emergency response. Incorporating cooling strategies into building design, expanding access to shaded public spaces, modernizing the electric grid, and strengthening health surveillance systems are all critical steps to reduce risk. By framing extreme heat as both a public health threat and an infrastructure resilience challenge, Puerto Rico can align its mitigation strategies with federal guidance and build a long-term capacity to protect its most vulnerable communities while safeguarding critical lifelines.

STATE ASSETS

Extreme heat is increasingly reshaping the way Puerto Rico's communities and infrastructure function, including the functionality of state assets and critical infrastructure. Each summer now brings longer and more intense periods of high temperatures that ripple across the island's critical systems. The demand for cooling rises sharply during these heat waves, placing enormous pressure on an electric grid that is already fragile from storm damage and years of underinvestment. Blackouts and service interruptions become more likely during these periods, and when the power goes out, the consequences cascade through hospitals, water pumps, schools, and communications systems, threatening the continuity of essential services.

Schools illustrate the vulnerability of public assets. Many lack adequate cooling or ventilation, forcing teachers and students to endure stifling classroom conditions. In some communities, educators resort to fundraising for fans or relocating classes to shaded outdoor spaces. These measures, however, are no match for prolonged heat, and learning suffers when schools are forced to operate in unsafe temperatures. Many public schools, particularly in rural areas, operate without air-conditioning, forcing teachers and students to adapt with temporary measures, such as fans or outdoor classes, as in Figure 127.

Healthcare facilities also feel the strain. Rising heat leads to more emergency visits for dehydration, heat stress, and respiratory problems, especially when Saharan dust events coincide with high temperatures and degrade air quality. Hospitals must balance the growing demand for care with the challenge of keeping their facilities cool and operational under a power grid that falters under peak demand.

Figure 127: A Fan in a Classroom during a Summer Session[343]

Beyond the walls of public buildings, the built environment itself is under stress. Roads and other infrastructure degrade faster under high heat, while outdoor workers in construction, agriculture, and transportation face unsafe conditions that reduce productivity. Urban areas like San Juan bear the brunt of this burden due to the UHI effect, where concrete and asphalt trap heat and keep nighttime temperatures uncomfortably high. An exact potential dollar loss estimate is difficult to calculate, but it can be assumed there is an economic cost associated with shorter lifespan of transportation systems due to extreme heat.

Water systems also are vulnerable. As heat intensifies, evaporation from reservoirs and storage systems accelerates, reducing available supplies at a time when communities need reliable access to drinking water the most. These pressures highlight the interconnection of assets. When heat affects one system, it inevitably cascades into others, amplifying risks and costs.

Taken together, extreme heat is no longer just an environmental concern but a direct hazard to Puerto Rico's assets. It weakens the resilience of energy, health, education, water, and transportation systems, amplifies existing vulnerabilities, and forces communities to adapt in order to be more resilient.

LOCAL ASSETS

Extreme heat does not affect Puerto Rico evenly. Its impacts vary across municipalities, depending on geography, population density, the condition of infrastructure, and the availability of resources. Coastal metropolitan areas, such as San Juan and Bayamón, face pressures from the UHI effect and population density, while southern and dry-zone municipalities like Ponce, Guánica, and Lajas contend with water scarcity and agricultural stress. Smaller island towns, such as Culebra and Vieques, are uniquely vulnerable

[343] Tatiana Díaz Ramos. "Puerto Rico's schools are unequipped to cope with ever hotter heat waves." Updated August 21, 2025. https://apnews.com/article/puerto-rico-heat-schools-air-conditioning-climate-d11facdb57910ed47a20068a669c43f6.

because of their limited infrastructure and isolation. These local experiences illustrate that extreme heat is not only an environmental challenge but also a hazard with direct consequences for education, health, energy, and community resilience.

COMMUNITY LIFELINES

SAFETY AND SECURITY

Prolonged extreme heat significantly escalates risks to personal safety and public order. The National Weather Service's updated Extreme Heat Warnings help communities respond to "Danger" and "Extreme Danger" heat index levels, enabling timely alerts for vulnerable populations. Puerto Rico's National Integrated Heat Health Information System provides resources to refine protective messaging and heat preparedness for first responders and social services personnel. This guidance supports the development of heat-centered alert protocols and shelters, which are critical for safeguarding residents when storms coincide with heat waves.

FOOD, HYDRATION, AND SHELTER

Heat stress compounds the challenges to food and water delivery systems, particularly where drought or aging infrastructure already strains supply. Over 70% of Puerto Rico's drinking water infrastructure suffered damage or power losses, revealing its fragility during overlapping drought and heat crises. As heat increases, shelter sheltering strategies must incorporate effective cooling and hydration resources to protect displaced populations.

HEALTH AND MEDICAL

Heat places extraordinary burdens on health services. A recent Puerto Rican study found that, despite high vulnerability, older adults often have lower perceptions of heat risk and adopt fewer protective behaviors. Nighttime heat exposure drives much of this risk, which necessitates enhanced early warning, outreach and mental health integration in health surveillance systems—particularly in municipalities with high elderly populations.

ECOSYSTEM

Extreme heat is increasingly destabilizing ecosystems across Puerto Rico's land and marine environments. Rising air and ocean temperatures place stress on species, disrupt ecological processes, and diminish the ability of natural systems to provide critical services that protect and sustain communities. Key impacts include the following:

- **Coral reef degradation** – Elevated sea surface temperatures cause mass coral bleaching and mortality, weakening reef structures that support marine biodiversity (see Figure 128). Puerto Rico's coral reefs are valued at over $1.8 billion, contributing to fisheries, recreation, tourism, and coastal

protection.[344] On average, reefs provide $1.4 million in value per square kilometer.[345] Annually, these ecosystems help protect $490 million in economic activity and $278 million in coastal infrastructure by reducing wave energy by up to 97 percent[346] . Continued heat stress threatens to erode these benefits.

Figure 128: Coral Bleaching

- **Impacts on forests and wildlife** – Puerto Rico's tropical and montane forests are increasingly stressed by rising temperatures and changing climatic conditions, which weaken trees and reduce their capacity to serve as vital carbon sinks. In ecosystems, such as the Luquillo Experimental Forest, shifts in air temperature and cloud cover are altering moisture-dependent habitats, with limited capacity for species to migrate or adapt.[347] Hotter conditions also increase vulnerability to pests, disease, and invasive species, while reducing flowering, fruiting, and natural regeneration—processes essential to sustaining forest health and biodiversity.
- **Wildlife** also is affected (see Table 42). Amphibians, particularly the iconic coquí frog, are highly sensitive to warming conditions. Research has documented reduced body size and altered mating calls linked to thermal stress, signs of adaptation limits in higher-elevation habitats. Insects, which form the base of forest food webs, have also declined dramatically. Studies indicate arthropod

[344] Departamento de Recursos Naturales y Ambientales (DRNA). (2024). *Costo de la Inacción ante el Cambio Climático en Puerto Rico – Resumen Ejecutivo*. https://www.drna.pr.gov/wp-content/uploads/2024/09/Costo-inaccion_Resumen-ejecutivo_09-13-2024.pdf.
[345] Spalding, M., et al. (2017). *Mapping the Global Value and Distribution of Coral Reef Tourism*. *Marine Policy*, 82, 104–113.
[346] Storlazzi, C.D., Reguero, B.G., Cole, A.D., Lowe, E., Shope, J.B., et al. (2019). Rigorously valuing the role of U.S. coral reefs in coastal hazard risk reduction. Nature Sustainability, 2(10), 892–901.
[347] Heartsill-Scalley, T., et al. (2010). Climate and climate variability in the Luquillo Mountains of Puerto Rico. *Ecological Bulletins, 54*, 91–106.

biomass has fallen to 1.6%–10% of historical levels in recent decades, signaling a collapse of insect populations.[348] These cascading changes undermine the survival of birds, bats, and other species that rely on forest resources, signaling that extreme heat is reshaping Puerto Rico's ecosystems in ways that directly compromise both biodiversity and ecological resilience.

Table 42: Heat-Related Impacts on Forests and Wildlife in Puerto Rico

Impact	Details
Forest Health	Increased temperatures weaken tropical and montane forests, reduce growth and regeneration rates, and increase vulnerability to pests, diseases, and invasive species.
Ecological Dynamics	Hotter conditions alter canopy composition, reduce flowering and fruiting, and disrupt natural regeneration cycles, diminishing ecosystem services and carbon storage capacity.
Amphibians	Coquí frogs exhibit reduced body size and altered croaking pitch under higher temperatures, signaling physiological stress and migration to cooler, higher elevations.
Insect Declines	Arthropod biomass in Puerto Rican forests has declined 10–60× compared to historical levels, disrupting food webs and reducing prey availability for birds, bats, and amphibians.

- **Loss of biodiversity and ecological balance** – Heat-driven stress across marine and terrestrial ecosystems contributes to declining species populations, habitat loss, and ecological imbalance. As keystone habitats such as coral reefs and tropical forests deteriorate, the services they provide, such as storm surge protection, water regulation, and biodiversity support, are diminished, reducing both ecological resilience and the ability of Puerto Rico's communities to withstand hazards.

ENERGY

Extreme heat increases electricity demand in Puerto Rico, particularly for cooling, and strains an already fragile grid. According to NOAA's 2024 Heat Study[349], record-breaking nighttime heat events have intensified demand and raised the likelihood of blackouts. Power failures leave residents without cooling during hazardous conditions, compounding risks for vulnerable populations such as older adults, children, and individuals with chronic illnesses. Puerto Rico also consumes nearly 70 times more energy than it produces, relying almost entirely on imported fossil fuels, which makes local electricity costs among the highest under U.S. jurisdiction. These conditions underscore the energy sector's central role in amplifying the health and economic impacts of extreme heat.

[348] Lister, B. C., & García, A. (2018). Climate-driven declines in arthropod abundance restructure a rainforest food web. *Proceedings of the National Academy of Sciences, 115*(44), E10397–E10406. https://doi.org/10.1073/pnas.1722477115
[349] NOAA. (2024). Puerto Rico and U.S. Virgin Islands Annual Climate Summary: Historic Heat Patterns. National Weather Service San Juan. Retrieved from https://www.weather.gov/sju/climate.

COMMUNICATIONS

Extreme heat can impact communication infrastructure directly, such as by causing equipment to overheat, and indirectly through strained power grids resulting in power outages which can disrupt communications. Extreme heat can stress cable and equipment and sustained events can result in equipment damage[350]. Additionally, personal electronic devices such as smartphones may shut down in extreme heat conditions, limiting public communication.

TRANSPORTATION

Extreme heat can accelerate roadway degradation and disrupts transit and emergency response. Maintenance costs can increase due to extreme heat. In addition, high ambient temperatures compromise driver safety and road workers' operations.

HAZARDOUS MATERIALS

High temperatures can destabilize chemical, fuel, and pharmaceutical storage, increasing the risk of accidents at state and municipal facilities. Addressing extreme heat impacts on hazardous materials requires additional storage protocols and early warning systems in high-heat zones, especially for warehouses in urban centers. Personnel responding to hazardous materials incidents also faced increased risk to heat-related illnesses due to the Personal Protective Equipment (PPE) they are required to wear for their personal safety.

WATER SYSTEMS

Water systems in Puerto Rico are highly sensitive to extreme heat. Elevated temperatures accelerate evaporation in reservoirs already reduced by sedimentation and drought, lowering the availability of drinking water when demand is highest. Warmer conditions also degrade water quality, as reduced storage increases contact with contaminated sediments, while heavy rainfall events accelerate erosion and turbidity in reservoirs.

Groundwater resources face similar threats. In 2015, 16% of Puerto Rico's freshwater—equivalent to 107 million gallons per day—came from coastal aquifers, which are increasingly at risk of saltwater intrusion under scenarios of sea level rise.[351] A 1-foot rise in sea level could flood 23.74 km² of aquifer lands,[352] with the greatest impacts projected in Guayanilla (14.8%), Cabo Rojo (13.8%), and Lajas (9.9%).[353] These impacts

[350] U.S. Department of Homeland Security. Implications of Extreme Weather Events on U.S Telecommunications Infrastructure. https://www.dhs.gov/sites/default/files/2024-09/2024aepphasellimpactsofextremeweatherevents.pdf.
[351] Molina-Rivera, W.L., & Irizarry-Ortiz, M.M. (2021). *Estimated Water Withdrawals and Use in Puerto Rico, 2015*. U.S. Geological Survey, Open-File Report 2021–1076. Reston, VA.
[352] NBC News. "Puerto Rico schools cancel classes as they grapple with unceasing, excessive heat," September 8, 2023. https://www.nbcnews.com/news/latino/puerto-rico-schools-cancel-excessive-heat-no-air-conditioning-rcna103923.
[353] Departamento de Recursos Naturales y Ambientales (DRNA). (2024). *Costo de la Inacción ante el Cambio Climático en Puerto Rico – Resumen Ejecutivo*. San Juan, PR.

also extend to agriculture, where irrigation networks already strained by heat could see water supplies reduced, affecting food security and rural economies.[354]

Changes in Development

Puerto Rico's historical development patterns have already shaped its exposure to extreme heat. The expansion of dense urban areas without sufficient vegetation has intensified the UHI effect, producing local temperatures several degrees higher than in surrounding rural zones and reducing natural nighttime cooling. This has increased thermal stress in metropolitan areas such as San Juan, particularly for socially vulnerable populations with limited access to cooling resources.[355]

At the same time, reliance on an aging centralized power grid and underinvestment in resilient public facilities have amplified risks. Schools and healthcare facilities frequently lack adequate cooling or a reliable energy supply, leaving populations directly exposed during extreme heat events. These observed outcomes demonstrate that existing development decisions have already heightened Puerto Rico's sensitivity to heat hazards, regardless of future land use trends.

CHANGES IN LAND USE AND BUILT ENVIRONMENT

Puerto Rico's future vulnerability to extreme heat will also depend on how land use and building practices evolve. Rapid urban expansion in metropolitan and coastal municipalities continues to replace natural landscapes with impervious surfaces, intensifying the UHI effect and limiting natural nighttime cooling. At the same time, much of the island's-built environment consists of aging facilities that lack adequate insulation, shading, or efficient cooling systems, leaving households, schools, and health centers exposed during prolonged heat events.

Recent updates to the Puerto Rico Building Code have sought to address these challenges by introducing standards tailored to tropical climates. The code now requires that residential spaces provide a minimum openable area equivalent to 4% of the floor area for natural ventilation. It also establishes mechanical ventilation rates for certain building types, such as hazardous storage areas, at 1 cubic foot per minute per square foot of floor space.[356] In addition, a newly integrated "Tropical Climate" section promotes cross-ventilation and improved thermal resistance in building envelopes, aiming to reduce reliance on air-conditioning and increase indoor comfort.[357] These measures mark progress, but their effectiveness will depend on widespread enforcement and integration into both public and private development.

[354] U.S. Geological Survey (USGS). (2023). *Water Resources of Puerto Rico*. U.S. Department of the Interior, Washington, DC.
[355] Méndez-Lázaro, P., et al. (2023). Urban heat exposure in Puerto Rico: health and infrastructure challenges. *International Journal of Environmental Research and Public Health, 20*(5), 4123.
[356] International Code Council (ICC). (2018). *Puerto Rico Residential Code: Section 402.2 – Ventilation*. https://codes.iccsafe.org/.
[357] Alvarez-Díaz & Villalón Architects. (2021). *Why the changes in the Puerto Rico Building Codes matter*. https://www.alvarezdiazvillalon.com/.

Coastal land use adds further complexity. As wetlands and vegetated buffers give way to construction, the loss of natural cooling services compounds exposure to extreme heat. As shown in the State Profile, urban expansion along Puerto Rico's northern and southern coasts, particularly in and around San Juan and Cabo Rojo, has sharply reduced natural land cover that previously served as thermal buffers. This contraction of green and wetland areas exacerbates vulnerability to extreme heat and associated hazards. Unless zoning and permitting processes are strengthened to limit development in vulnerable zones and encourage green infrastructure, future land use patterns risk amplifying Puerto Rico's sensitivity to rising temperatures rather than reducing it.

CHANGES IN POPULATION

In recent years, Puerto Rico's demographics have shifted. The island has been undergoing a steady decline in population while seeing a significant rise in older adults. As of 2024, 15% of the population was under the age of 18, 60.4% fell between the ages of 18 and 64, and 24.6% was 65 or older, making it the highest percentage of older adults among U.S jurisdictions, and a significant increase prior decades. .[358] This demographic shift indicates that 39.6% are vulnerable to the effects of heat illnesses and highlights the potential strain on critical infrastructure.

CHANGES IN VULNERABILITY OF STATE ASSETS

State assets, such as schools, have a particular vulnerability to extreme heat, according to a 2023 survey of over 2000 teachers by the Puerto Rico Teachers' Association (AMPR). They noted that their classrooms did not have adequate temperatures conducive to learning. The survey indicated that approximately 83% of classrooms in Puerto Rico have this problem.[359] Furthermore, Puerto Rico still does not have a mandate to include air-conditioning units in every classroom. In 2023, a bill was introduced to add air-conditioning systems, but it was vetoed. In addition to education, school facilities also support sheltering operations. As of 2025, Puerto Rico had 1686 public schools, of which 307 have been assigned to support this function.[360] The lack of cooling systems in public schools may impact the island's ability to open additional shelters.

Extreme heat causes asphalt to soften and crack, impacting roadway maintenance. Roadways in metropolitan areas, such as Roosevelt Roads or the runways at Luis Muñoz Marín International Airport , are more susceptible, due to the UHI effect. Furthermore, as urban areas continue to grow, the added buildings and pavement will help increase the effect of UHI, as shown in Figure 129. The estimated cost in the U.S. for road maintenance and repair due to increasing heat by 2040 is over $20 billion."[361]

[358] U.S. Census. https://www.census.gov/newsroom/press-releases/2025/older-adults-outnumber-children.html.
[359] Fortune, via Associated Press. "Puerto Rican school kids are roasting in the heat with no AC because the governor vetoed a bill mandating it across the island," September 8, 2023. https://fortune.com/2023/09/08/puerto-rico-school-no-air-conditioning-extreme-heat-climate-change/.
[360] Puerto Rico Planning Board.
[361] Extreme Heat Could Cost The U.S. Economy $100 Billion A Year. https://www.forbes.com/sites/jimfoerster/2023/07/18/extreme-heat-has-broad-economic-impacts-beyond-public-safety/?sh=6d323bd3d281.

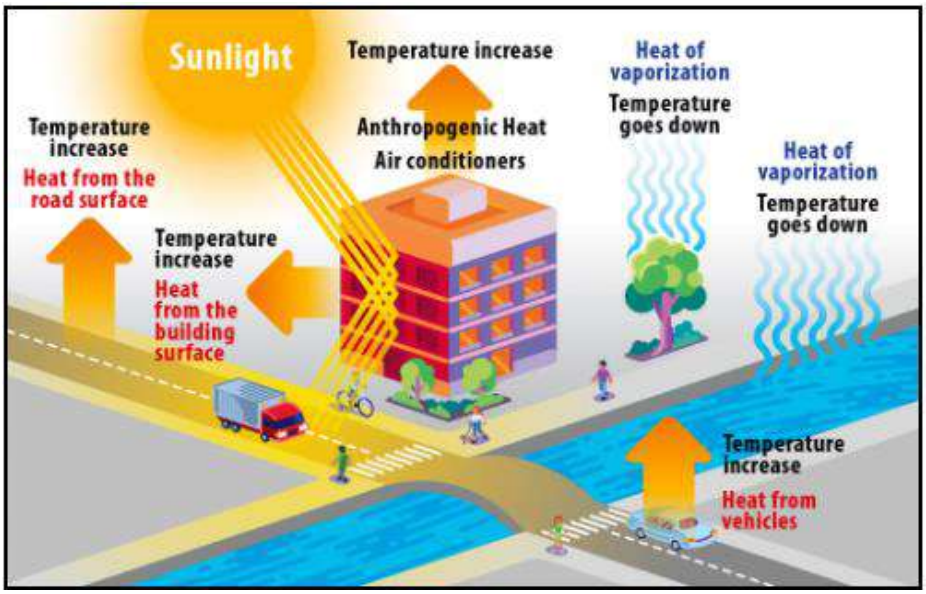


Figure 129: Changes in Temperature from Various Sources[362]

Critical outdoor resources, such as generators, transformers, substations, underground water pipes, communications towers, fiber optic cables, cars, and trucks, also are subject to extreme heat. They face a higher rate of degradation and overheating, increasing the demand for repair or replacement and increasing the cost of maintenance. The cost to the U.S. economy of extreme heat is estimated to be $100 billion annually.[363]

CHANGES IN VULNERABILITY OF LOCAL ASSETS

Local jurisdictions may face the same challenges and costs of maintaining and repairing critical infrastructure as the state assets. Along with these responsibilities, local jurisdictions must consider the increased vulnerability and demand on these critical assets brought on by tourism. In 2023 and 2024, Puerto Rico welcomed over 900,00 visitors, who spent $2.5 billion.[364] Although this revenue is important to support local communities, it also increases the demand for healthcare, building infrastructure, roads, water, electricity, and pavements. Over time, the combination of these resources can amplify the UHI effect, making it difficult for local residents to live and work in their communities.

After Hurricane Maria, it was estimated that the island lost between 20 and 40 million trees,[365] affecting local communities by worsening the heat effects, reducing the natural shade, and increasing UHI.

[362] Florida Local Technical Assistance Program Center. "Urban Heat Island and Pavement Preservation Explained", 2021, https://floridaltap.org/urban-heat-island-and-pavement-preservation-explained/.
[363] Extreme Heat CISA.gov. https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/extreme-weather/extreme-heat.
[364] Instituto de Estadísticas de Puerto Rico, Visitor Profile, Fiscal Year 2023–2024. https://tourism.pr.gov/wp-content/uploads/2025/07/Visitor-Profile-Fiscal-Year-2023-2024.pdf.
[365] Hurricane Maria Study Warns: Climate-Driven Storms May Raze Many Tropical Forests, Columbia Climate School, https://news.climate.columbia.edu/2019/03/25/intensifying-storms-may-mow-down-future-tropical-forests/.

Deforestation can significantly impact the vulnerability of local assets, as the lack of trees contributes to poor air quality, increasing the probability of aggravating symptoms related to heat-related diseases.

Mitigation Success Stories

Extreme heat is a complex and difficult challenge for Puerto Rico. The risks and consequences of extreme heat impact the island's residents daily, predominantly through essential services like health, education, energy, and the economy. Multiple efforts have been made to reduce the impacts of extreme heat, including school policies, environmental conservation, and energy projects.

Due to the record-breaking heat experienced in 2023, Puerto Rico's Department of Education introduced the "Ola de Calor" guidelines, which aim to raise awareness among school staff, students, and their families and reduce the impact of exposure to extreme heat (see Figure 130). The protocols include implementing regular breaks to ensure that staff and students hydrate, guaranteeing that air conditioning units and fans are in working order, and adjusting the uniform code for staff and students. In 2024, the Department of Energy announced the "Programa de Comunidades Resilientes," which allocates up to $365 million toward ensuring a stable energy connection for health clinics and housing in communities with vulnerable populations.[366]

La Cooperative Hidroelétrica de la Montaña (CHM) is a community-run organization that uses hydroelectric plants with solar microgrids to ensure that communities in Adjuntas, Jayuya, Lares, Maricao, and Utado have access to clean energy. The organization aims to reduce the risks and impacts of a lack of energy on the community's health and economy.[367]

[366] United States Department of Energy, Office of Electricity, "Two-Year Progress Update," December 19, 2024, https://www.energy.gov/oe/accomplishments.
[367] Hidroelétrica de la Montaña, Purpose. https://cooperativahidroelectrica.coop/.

Figure 130: Ola de Calor Guidelines[368]

The National Fish and Wildlife Foundation has invested over $5 million to promote programs that support coral reef conservation in Puerto Rico, such as the Protectores de Cuencas , a community-led project to "restore and protect watersheds across Puerto Rico."[369]

The Institute for Socio-Ecological Research (ISER) Caribe, through the Caribbean Reef project, collaborates with various partner organizations throughout the Caribbean. Its goal is to restore over 4 acres of coral reefs in Fajardo, La Parguera, and Rincón. The program also seeks to create public awareness by educating the public and government officials on the importance of coral reefs to the environment and the economic benefits that these areas provide. Figure 131 provides some data on their success.

The Caribbean Community Regenerative Development (CRCD) is a southeast community-based organization that implemented the Arboles contra el Calentón initiative.[370] This initiative collected weather data along 11 routes in the municipalities of Mayagüez, San Germán, Hormigueros, Cabo Rojo, Lajas, and Sabana Grande to determine hot zones and prioritize reforestation efforts in the southeast portion of Puerto Rico.

[368] Departamento de Educación de Puerto Rico. "Ola de Calor Guidelines," https://de.pr.gov/.
[369] Protectores de Cuencas, https://www.protectoresdecuencas.org/.
[370] Science "at the service of communities": first extreme heat monitoring conducted in southwestern Puerto Rico," 2025, https://www.cienciapr.org/en/science-service-communities-first-extreme-heat-monitoring-conducted-southwestern-puerto-rico.

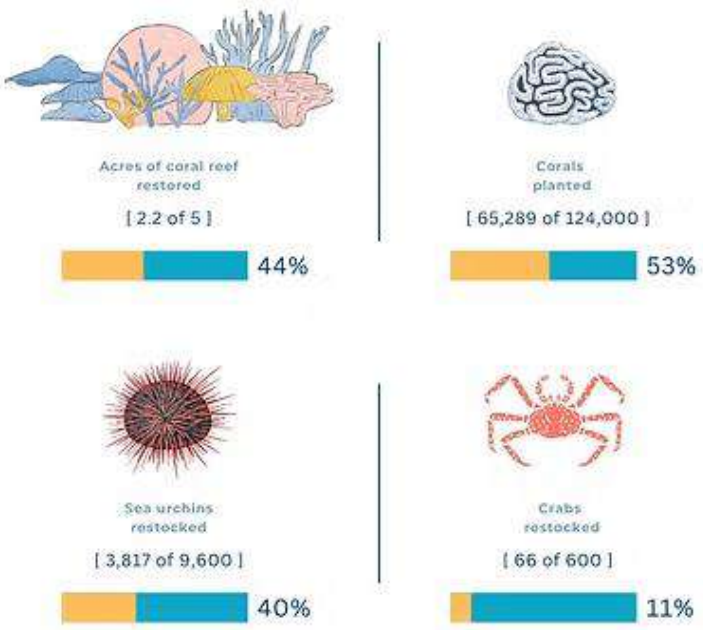


Figure 131: Data on the Restoration of the ISER Caribe Coral Site in Puerto Rico[371]

[371] Institute for Socio-Ecological Research. https://www.isercaribe.org/.

SECTION 4.5

EXTREME WINDS, HURRICANES, AND TROPICAL STORMS

Extreme Winds, Hurricanes, and Tropical Storms

EXTREME WIND DEFINITION

Extreme winds are high velocity winds that result primarily from thunderstorm downdrafts or outflow. These winds can exceed speeds of 50 to 60 miles per hour.[372]

Extreme wind events are often associated with intense meteorological phenomena, including severe thunderstorms, tropical cyclones, and large-scale weather systems.[373] These winds occur when atmospheric conditions produce sustained high wind speeds or sudden gusts that exceed the resistance capacity of natural and built environments.[374] These winds can directly cause structural failures and uproot trees, while also increasing the risk of injury to people.[375]

Types of Extreme Winds

Extreme winds in Puerto Rico are primarily associated with tropical cyclones, which include hurricanes and tropical storms, as well as localized phenomena such as waterspouts, downbursts, and microbursts. These systems originate over the warm waters of the Atlantic and Caribbean basins and represent the most frequent and destructive wind events affecting the island.

[372] NOAA National Severe Storms Laboratory, "Severe Weather 101 – Damaging Winds," https://www.nssl.noaa.gov/education/svrwx101/wind/.
[373] T. Frame, , Harrison et al. "Meteorological risk: extra-tropical cyclones, tropical cyclones and convective storms," Science for Disaster Risk Management, 2017, 246.
[374] S. Cao, "Strong winds and their characteristics," Advanced Structural Wind Engineering, Tokyo: Springer Japan, 2013, pp. 1–25.
[375] National Weather Service, "Beaufort Wind Scale," https://www.weather.gov/mfl/beaufort.

Hurricanes begin as tropical disturbances that develop over ocean regions where sea surface temperatures exceed approximately 26.5 °C (80 °F) [376]. Warm, moist air rises from the surface, creating a zone of low pressure that draws in surrounding air. The Earth's rotation generates the Coriolis effect, causing the air to spin and organize into a cyclonic system. As this system intensifies, it transitions from a tropical depression to a tropical storm once sustained winds reach 39 mph, and finally into a hurricane when winds exceed 74 mph. The storm's circulation strengthens as condensation releases latent heat, driving further convection and lowering central pressure. The most destructive winds occur within the eyewall, where the steep pressure gradient produces sustained winds exceeding 100 mph and gusts that can surpass 150 mph in major hurricanes. The physical processes that drive hurricane development are illustrated in Figure 132, which depicts the vertical structure, circulation patterns, and heat energy exchange that sustain a mature tropical cyclone.

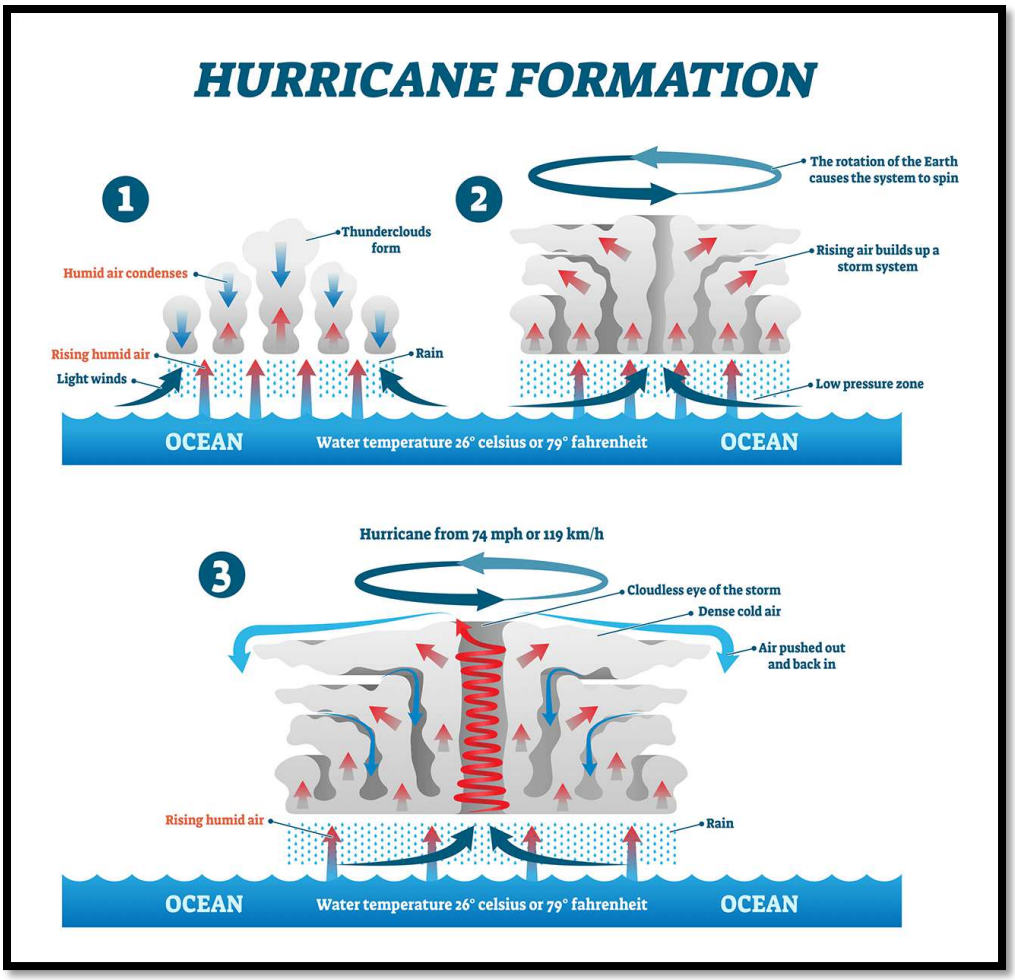


Figure 132: Structure and Formation of a Hurricane[377]

[376] National Aeronautics and Space Administration (NASA). (2022). How Hurricanes Form. Earth Observatory.
[377] Internet Geography. (n.d.). *How do tropical storms form?* Internet Geography. https://www.internetgeography.net/topics/how-do-tropical-storms-form/.

Most hurricanes that affect Puerto Rico originate off the west coast of Africa, near the Cape Verde Islands, where atmospheric disturbances known as African Easterly Waves develop and begin their westward journey across the Atlantic Ocean, carried by the trade winds. As they move over the warm central Atlantic, favorable environmental conditions such as warm sea surface temperatures, high humidity, and low vertical wind shear allow them to intensify into tropical cyclones [378].

Figure 133 illustrates the climatic and atmospheric factors that favor an active Atlantic hurricane season. Warmer ocean temperatures and reduced wind shear across the Main Development Region create an environment conducive to storm development and intensification. A stronger and wetter West African monsoon enhances atmospheric convection and moisture transport, generating a greater number of easterly waves that move westward across the Atlantic. These waves serve as the initial disturbances from which many tropical cyclones form. At the same time, weaker surface trade winds and extended upper-level easterlies promote storm organization and westward propagation [379].

When the Bermuda Azores High, a semi-permanent high-pressure ridge, extends westward, storms are steered directly toward the Caribbean. Conversely, when this system weakens or shifts eastward, storms often curve northward before reaching the island. The greatest risk occurs between August and October, when ocean temperatures and atmospheric moisture are at their seasonal peak.

[378] NOAA Climate Prediction Center (NOAA CPC). (2023). Climate conditions favoring an active Atlantic hurricane season. https://www.cpc.ncep.noaa.gov.
[379] NOAA National Centers for Environmental Information (NCEI). (2024). International Best Track Archive for Climate Stewardship (IBTrACS): Global Tropical Cyclone Track Data. https://www.ncei.noaa.gov/products/international-best-track-archive.

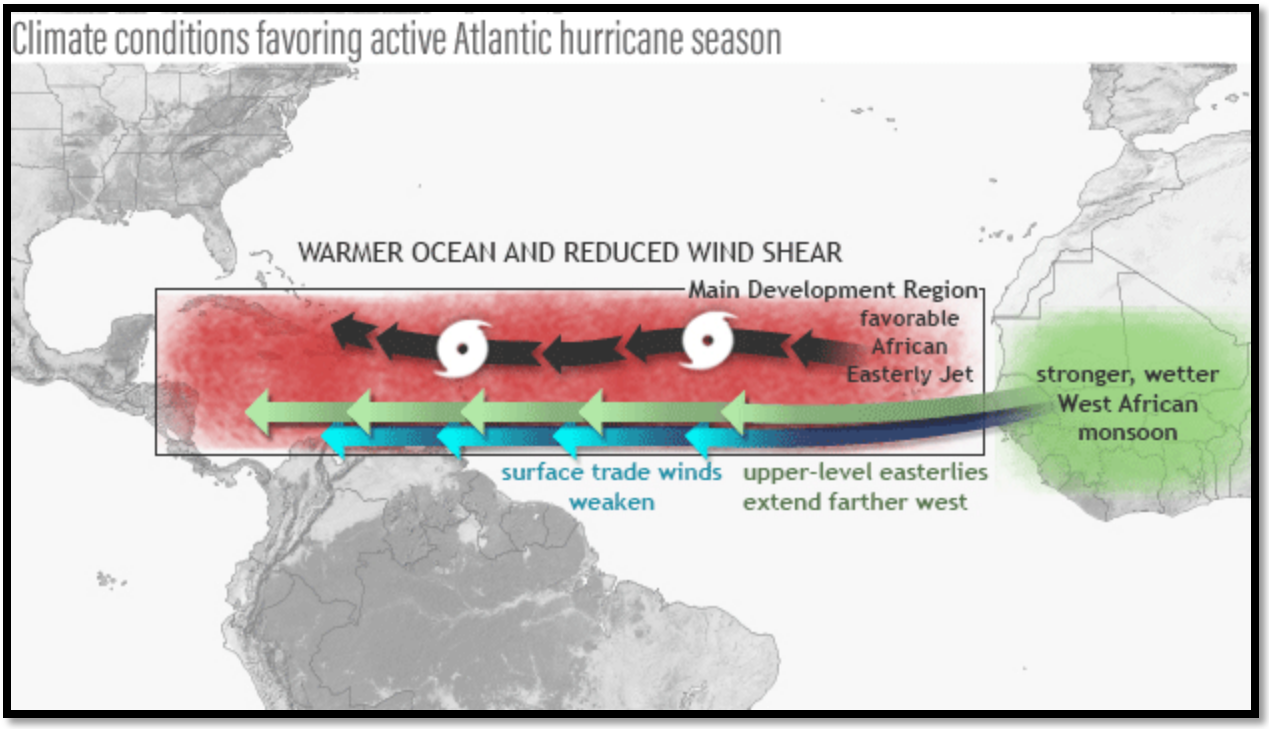


Figure 133: Climate Conditions Favoring an Active Atlantic Hurricane Season[380]

The frequency and intensity of hurricanes affecting Puerto Rico are strongly influenced by the El Niño Southern Oscillation (ENSO). During El Niño phases, warmer Pacific Ocean waters strengthen upper-level westerlies across the Caribbean, increasing wind shear and generally suppressing hurricane formation. In contrast, La Niña phases reduce wind shear and promote enhanced cyclone development, allowing storms to form more easily and travel farther west into the Caribbean.[381]

Puerto Rico is monitored by a non-uniform network of land-based NOAA National Centers for Environmental Information (NCEI) observing stations that provide long-term climatological records; however, wind measurements relevant to extreme wind hazards are primarily obtained from first-order and cooperative stations located at major airports (e.g., Luis Muñoz Marín International Airport), the National Weather Service Weather Forecast Office (WFO) in San Juan, and a limited number of regional stations, rather than being consistently available across all stations island-wide, as illustrated in Figure 134.

[380] *NOAA Climate Prediction Center, 2023.*
[381] NOAA Climate Prediction Center. (2024). El Niño and La Niña: Impacts on the Atlantic Hurricane Season.

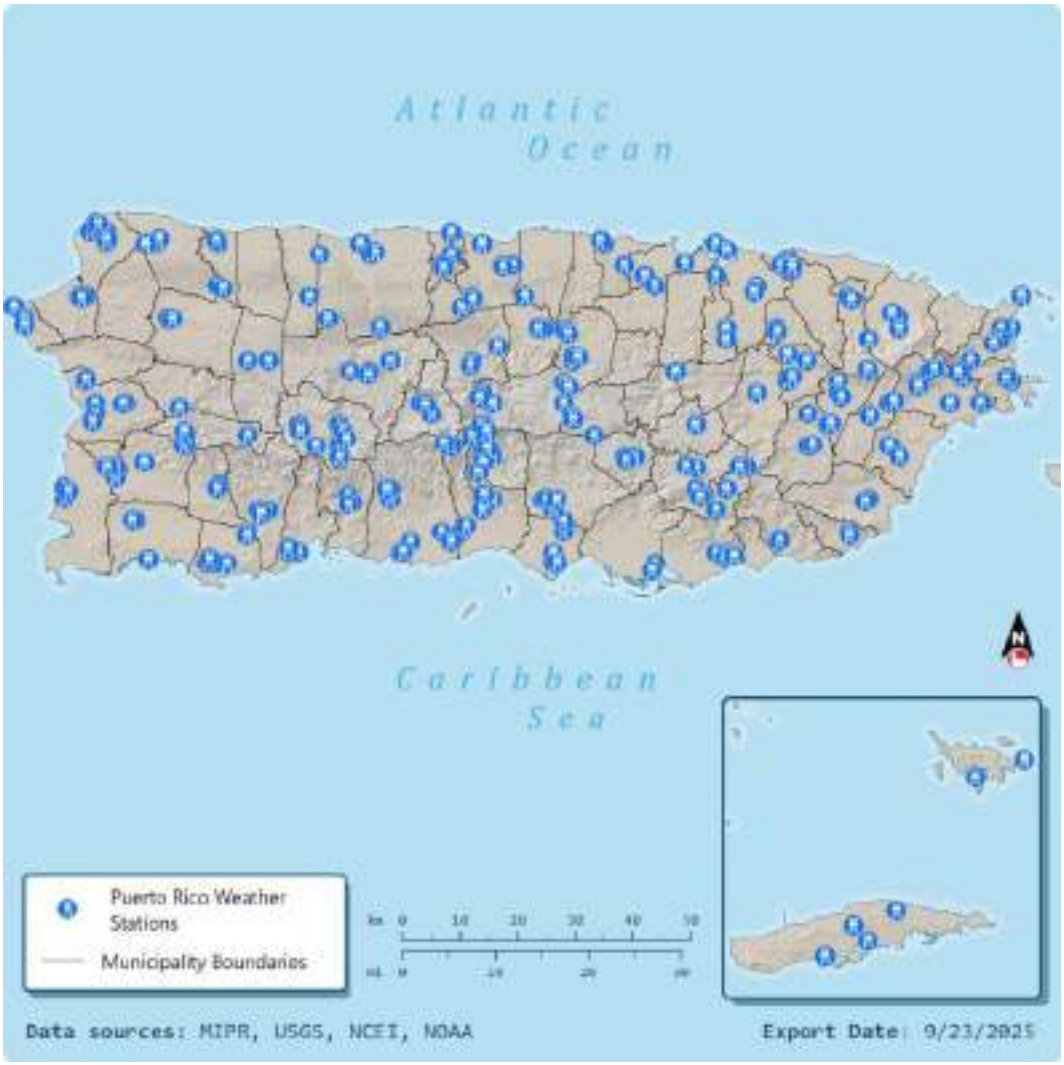


Figure 134: Puerto Rico Weather Stations[382]

Historical evidence from NOAA's Climate Prediction Center shows that many of Puerto Rico's most damaging hurricanes including Hugo (1989), Georges (1998), María (2017), and Fiona (2022) occurred during La Niña or neutral ENSO conditions, when atmospheric circulation favored stronger, westward-moving storms (see Figure 135).

[382] NOAA, "NCEI National Weather Service Stations," https://www.ncei.noaa.gov/access/past-weather/puerto%20rico.

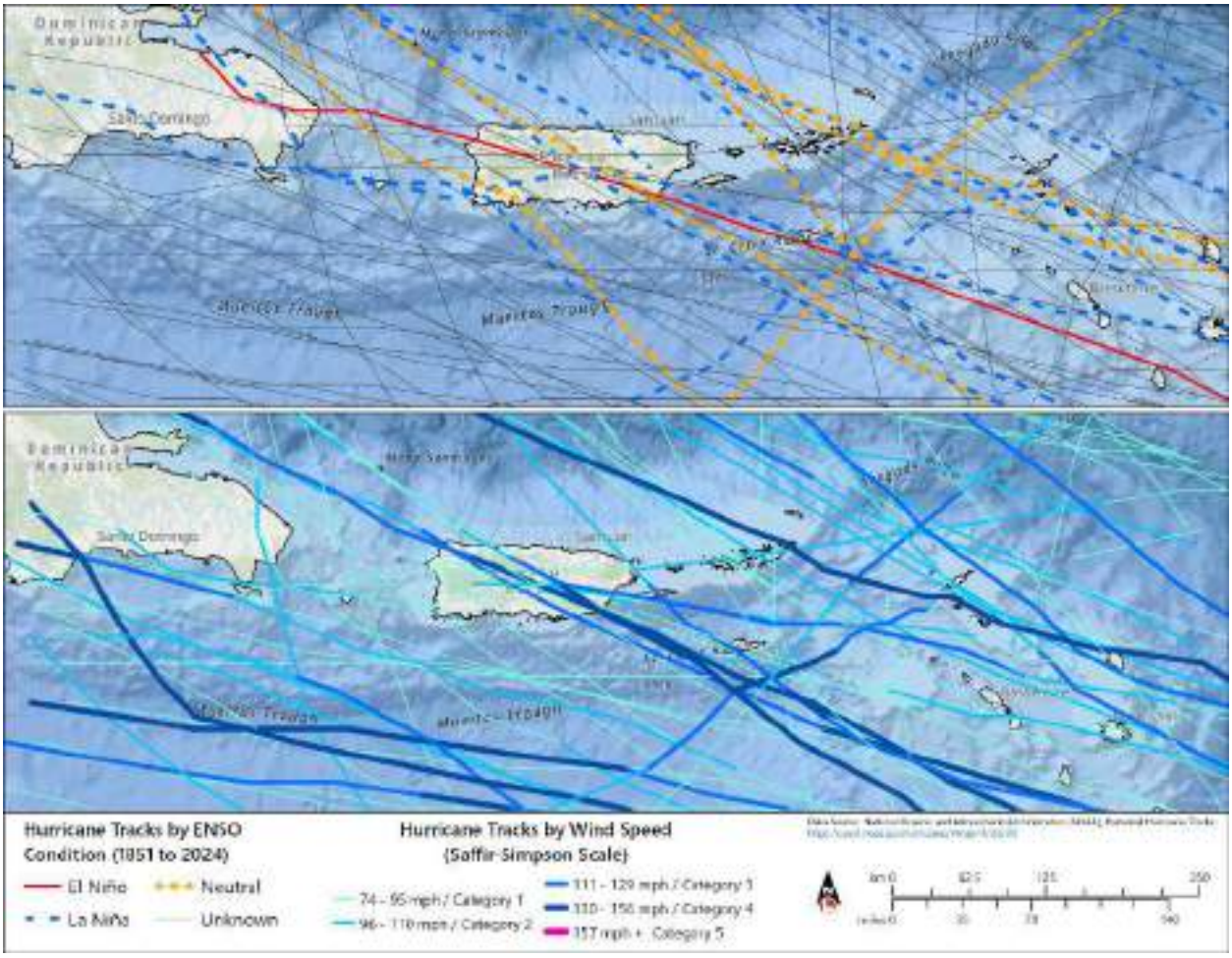


Figure 135: Tracks of Hurricanes over the Past 30 Years under Contrasting ENSO Phases[383]

Beyond tropical cyclones, Puerto Rico occasionally experiences localized wind events such as waterspouts, downbursts, and microbursts. Waterspouts form over near-shore waters under unstable atmospheric conditions and can produce damaging gusts that pose hazards to small vessels and coastal structures. Downbursts and microbursts, on the other hand, are powerful descending air currents generated by severe thunderstorms[384]. When these downdrafts strike the ground, air spreads outward at high velocity, producing concentrated wind bursts that may exceed 100 mph and cause significant localized damage. These events are particularly hazardous in mountainous and valley regions, where terrain effects can amplify wind speeds.

[383] Usar NOAA Hurricane Track: https://coast.noaa.gov/hurricanes/#map=4/32/-80.
[384] National Weather Service (NWS) JetStream. (2023). Thunderstorms, Downbursts, and Microbursts.

Location

Extreme wind events are a threat across all regions of Puerto Rico with their geographic impacts shaped by the island's topography and coastal exposure.[385] The entire island is vulnerable to tropical cyclones and localized wind events, but specific areas consistently demonstrate elevated risk due to past events and location. Coastal regions, particularly those along the eastern and southeastern areas, face the highest exposure to hurricane-force winds.[386] The areas of Yabucoa, Humacao, and Maunabo sustained catastrophic damage from high winds during Hurricane Maria, where the hurricane made landfall with 155 mph sustained winds.[387] Vieques and Culebra suffered extreme structural damage in 1989 during Hurricane Hugo, which struck the island with sustained winds exceeding 140 mph.[388] Other areas often impacted by hurricane-force winds include the northwest coast from Aguadilla to Arecibo, which was hit by Hurricane Georges in 1998 when it traversed the island westward, and the south coast from Guayama to Patillas, which is often affected by southerly wind shifts of passing storms or outer bands.[389]

The Cordillera Central, or Puerto Rico's mountainous region, contributes to dangerous gap winds and wind acceleration over ridges. Adjuntas, Aibonito, Jayuya, Utuado, and Ciales experience frequent wind gusts during tropical cyclone events. During Hurricane Maria, these regions experienced wind gusts of 170 mph to 190 mph with severe damage in higher elevations occurring where terrain channeled or intensified wind flow.[390] These regions are also extremely vulnerable to localized thunderstorm winds, which can funnel down slopes or get trapped in valleys, producing dangerous downbursts.[391] Figure 136 shows areas of high winds from the Interactive Map of Puerto Rico (MIPR) from the Puerto Rico Planning Board (PRPB).[392]

The coastal San Juan metro area and the north-central corridor are densely populated and highly exposed to both thunderstorm winds and tropical cyclone winds. The Luis Muñoz Marín International Airport has documented wind shear and microbursts during convection storm activity.[393] This activity mainly occurs

[385] D. M. Bush et al., "Coastal-zone hazard maps and recommendations: eastern Puerto Rico," *Environmental Geosciences*, 2001 *8*(1), 38–60.
[386] E. R. Boose et al., "Landscape and regional impacts of hurricanes in Puerto Rico," *Ecological Monographs*, 2004 *74*(2), 335–352.
[387] H. J. Cruzado and G. E. Pacheco-Crosetti, "General overview and case studies of damages in Puerto Rico due to Hurricane Maria," *Eighth Congress on Forensic Engineering,* Reston, VA: American Society of Civil Engineers, November 2018, pp. 986–996.
[388] R. W. Rodriguez et al., "Another look at the impact of Hurricane Hugo on the shelf and coastal resources of Puerto Rico, USA," *Journal of Coastal Research*, 1994 278-296.
[389] J. M. Gómez-Fragoso et al., "U.S. Geological Survey response to Hurricane Maria flooding in Puerto Rico and characterization of peak streamflows observed September 20–22, 2017," Scientific Investigations Report 2022-5040, U.S. Geological Survey, 2022; I. C. Colón-Pagán, *Orographic Effects on Rainfall Induced by the Passage of Tropical Cyclones Over a Mountainous Island* (Doctoral dissertation, North Carolina Agricultural and Technical State University), 2010.
[390] R. Pokhrel et al., "Observation and modeling of Hurricane Maria for damage assessment," *Weather and Climate Extremes*, 2021 *33*, 100331.
[391] D. M. Bush et al., "Coastal-zone hazard maps and recommendations: eastern Puerto Rico," *Environmental Geosciences*, 2001 *8*(1), 38–60.
[392] Interactive Map of Puerto Rico, https://jp.pr.gov/mipr-mapa-interactivo-de-puerto-rico/.
[393] M. R., Jury et al. "Mesoscale structure of trade wind convection over Puerto Rico: Composite observations and numerical simulation," *Boundary-Layer Meteorology*, 2009 *132*(2), 289–313.

from June through October. Hurricane Maria brought glass damage, roof failures, and debris hazards to high-rise buildings and critical infrastructure from wind tunneling through the urban corridor.[394]

The western and northern interior valleys are slightly sheltered from extreme wind events, especially areas such as Lares, Las Marias, and San Sebastian.[395] However, these areas did experience widespread wind damage during Hurricanes Georges and Maria due to sustained high winds moving across the island's interior.[396] These areas have forested hills and secondary roads that are highly vulnerable to wind-thrown trees and debris, which frequently complicates emergency access and recovery efforts. The valleys in these areas also amplify wind speed during organized mesoscale convection systems and even pose theoretical risk for derecho-style wind events.

[394] F. F. J. Ortiz, *A bioclimatic approach to the integrated design of transit stations and their immediate surroundings* (Doctoral dissertation, Massachusetts Institute of Technology), 1998.
[395] R. J. Calvesbert, (1974). "The Climate of Puerto Rico and the U.S. Virgin Islands," *Climates of the States: Eastern States, plus Puerto Rico and the US Virgin Islands*, *1*, 453.
[396] E. R. Boose et al., "Landscape and regional impacts of hurricanes in Puerto Rico," *Ecological Monographs*, 2004 *74*(2), 335–352.

Figure 136: High Wind Areas in Puerto Rico [397]

[397] Data for Vieques and Culebra not available.

Previous Occurrences

Extreme wind events in Puerto Rico are a recurring natural hazard with impacts documented throughout the history of the island. The most severe wind damage historically has occurred during tropical cyclones, especially along the island's coastal zones and elevated interior regions where terrain amplifies wind speeds.[398] In 2017, Hurricane Maria brought catastrophic winds across all of Puerto Rico. Sustained wind speeds were near 155 mph, while wind gusts exceeded 200 mph in mountainous areas.[399] Extreme wind events often result in extensive structural damage, infrastructure failure, and cascading impacts such as power outages, communication breakdowns, and transportation disruptions.

FEDERAL DISASTER DECLARATIONS

Table 43 summarizes federal disaster and emergency declarations in Puerto Rico specifically tied to extreme winds (hurricanes and tropical storms). The intensity is based on the Saffir-Simpson Hurricane Wind Scale category at the time of impact in Puerto Rico.

Table 43: Puerto Rico Federal Disaster and Emergency Declarations Specifically Tied to Extreme Winds (Hurricanes and Tropical Storms)

Disaster No.	Storm Name	Intensity
DR-597-PR	Hurricane David / TS Frederic (1979)	Hurricane Category / Tropical Storm
DR-842-PR	Hurricane Hugo (1989)	Hurricane Category 4
DR-1068-PR	Hurricane Marilyn (1995)	Hurricane Category 2
DR-1136-PR	Hurricane Hortense (1996)	Hurricane Category 1
DR-1247-PR	Hurricane Georges (1998)	Hurricane Category 3
DR-1552-PR	Tropical Storm Jeanne (2004)	Tropical Storm
DR-4017-PR	Hurricane Irene (2011)	Hurricane Category 1
DR-4336-PR	Hurricane Irma (2017)	Hurricane Category 5 (at peak, Cat 4 near PR)
DR-4339-PR	Hurricane Maria (2017)	Hurricane Category 4
DR-4671-PR	Hurricane Fiona (2022)	Hurricane Category 1
EM-3610-PR	Tropical Storm Ernesto (2024)	Tropical Storm
DR-4850-PR	Tropical Storm Ernesto (2024)	Tropical Storm

[398] E. R. Boose et al., "Landscape and regional impacts of hurricanes in Puerto Rico," *Ecological Monographs*, 2004 *74*(2), 335–352.
[399] P. J. Vickery et al., "Development of topographic wind speedups and hurricane hazard maps for Puerto Rico," *Journal of Structural Engineering*, 2023 *149*(10), 04023130.

PUERTO RICO DISASTER DECLARATIONS

Puerto Rico Emergency Management and Disaster Administration Act (Act No. 211-1999, as amended), maintains the authority to declare local states of emergency in response to natural hazards, including extreme wind events such as hurricanes and tropical storms. These declarations enable the Commonwealth to activate emergency operations, mobilize the Puerto Rico National Guard, and release local emergency funds when necessary.

However, no independent Puerto Rico disaster declarations have been issued specifically for extreme wind events in recent history. Instead, high-wind emergencies have been managed under broader federal disaster declarations authorized by the President of the United States through FEMA. In practice, local emergency actions—such as activating the Puerto Rico Emergency Management Bureau (PREMB), opening shelters, and coordinating with municipalities—are initiated through executive orders or emergency resolutions issued by the Governor prior to or alongside federal declarations.

This coordination ensures that Puerto Rico's emergency response to hurricanes and tropical storms is aligned with federal protocols while maintaining the Commonwealth's ability to take immediate action when high winds threaten communities.

SIGNIFICANT EVENTS

Even during days without a major hurricane, Puerto Rico can still experience Extreme Winds. The National Centers for Environmental Information (NCEI) Storm Events Database documents significant weather incidents reported across the United States and its territories, including Puerto Rico. For the period May 21, 2021, through April 28, 2025, the NCEI dataset records multiple extreme wind events impacting Puerto Rico, primarily associated with tropical cyclones, thunderstorms, and strong gradient winds.

Table 44: NCEI Data for Extreme Winds[400]

Date	Location	Magnitude (knots)	Injuries	Fatalities	Property Damage	Crop Damage
5/21/2021	Morovis Co.	50	0	0	$5,000	$0
5/22/2021	Morovis Co.	50	0	0	$5,000	$0
5/22/2021	Hatillo Co.	35	0	0	$500	$0
5/28/2021	Trujillo Alto Co.	35	0	0	$1,000	$0
6/9/2021	Naguabo Co.	30	0	0	$500	$0
7/3/2021	Cabo Rojo Co.	26	0	0	$500	$0
7/3/2021	Ponce Co.	35	0	0	$1,000	$0
7/3/2021	San Sebastian Co.	35	0	0	$1,500	$0
9/14/2021	Lares Co.	35	0	0	$1,000	$0

[400] NOAA, Storm Events Database, https://www.ncdc.noaa.gov/stormevents/.

Date	Location	Magnitude (knots)	Injuries	Fatalities	Property Damage	Crop Damage
9/14/2021	Utuado Co.	35	0	0	$1,000	$0
9/14/2021	Utuado Co.	35	0	0	$1,000	$0
9/14/2021	Lares Co.	35	0	0	$1,000	$0
10/1/2021	Vega Alta Co.	35	0	0	$1,000	$0
10/1/2021	Lares Co.	35	0	0	$1,000	$0
10/2/2021	Camuy Co.	35	0	0	$5,000	$0
3/6/2022	San Juan And Vicinity (Zone)	30	0	0	$0	$0
5/25/2022	Orocovis Co.	35	0	0	$0	$1,000
5/26/2022	Villalba Co.	35	0	0	$0	$1,000
5/26/2022	Villalba Co.	40	0	0	$0	$1,000
5/26/2022	San German Co.	35	0	0	$0	$5,000
5/26/2022	San German Co.	35	0	0	$0	$1,000
6/15/2022	Utuado Co.	35	0	0	$1,500	$0
6/15/2022	Aguada Co.	35	0	0	$0	$500
9/17/2022	Ciales Co.	35	0	0	$1,000	$1,000
9/17/2022	Toa Alta Co.	35	0	0	$1,000	$1,000
9/17/2022	San Juan Co.	35	0	0	$1,000	$1,000
9/17/2022	Bayamon Co.	35	0	0	$0	$100
9/18/2022	San Juan Co.	35	0	0	$20,000	$0
9/18/2022	Guaynabo Co.	35	0	0	$0	$5,000
9/18/2022	Yauco Co.	35	0	0	$1,000	$0
9/18/2022	Rincon Co.	35	0	0	$7,500	$0
9/18/2022	Carolina Co.	43	0	0	$20,000	$0
10/17/2022	Barranquitas Co.	40	0	1	$30,000	$0
10/30/2022	Ponce Co.	35	0	0	$2,000	$0
4/28/2023	Naranjito Co.	22	0	0	$1,000	$0
8/1/2023	San Juan Co.	30	0	0	$0	$1,000
8/9/2023	Aguadilla Co.	43	0	0	$6,500	$0
8/9/2023	Aguadilla Co.	43	0	0	$3,500	$0
8/9/2023	Aguadilla Co.	43	0	0	$500	$0

Date	Location	Magnitude (knots)	Injuries	Fatalities	Property Damage	Crop Damage
8/9/2023	Aguadilla Co.	35	0	0	$3,500	$0
8/9/2023	Aguadilla Co.	43	0	0	$20,000	$0
8/16/2023	Mayaguez Co.	35	0	0	$400	$0
8/17/2023	Moca Co.	35	0	0	$500	$0
8/17/2023	Bayamon Co.	35	0	0	$500	$0
8/21/2023	Caguas Co.	35	0	0	$0	$1,000
9/14/2023	Toa Baja Co.	35	0	0	$5,000	$0
9/15/2023	Toa Baja Co.	35	0	0	$1,000	$0
10/27/2023	Guaynabo Co.	26	0	0	$1,500	$0
12/13/2023	Florida Co.	26	0	0	$3,000	$0
2/6/2024	Patillas Co.	44	0	0	$3,000	$0
2/6/2024	Cidra Co.	35	0	0	$2,000	$0
2/6/2024	Hatillo Co.	30	0	0	$5,000	$0
2/6/2024	Caguas Co.	35	0	0	$1,000	$0
2/6/2024	Aibonito Co.	35	0	0	$6,000	$0
2/6/2024	San Juan Co.	35	0	0	$105,000	$0
2/6/2024	Caguas Co.	35	0	0	$8,000	$0
2/6/2024	Arecibo Co.	35	0	0	$1,000	$0
2/6/2024	Cidra Co.	35	0	0	$1,000	$0
2/6/2024	Gurabo Co.	35	0	0	$1,000	$0
2/6/2024	Yabucoa Co.	35	0	0	$1,000	$0
3/21/2024	Santa Isabel Co.	30	0	0	$1,100	$0
5/3/2024	Carolina Co.	30	0	0	$5,000	$0
5/3/2024	Carolina Co.	30	0	0	$1,100	$0
5/3/2024	Canovanas Co.	30	0	0	$20,000	$0
5/6/2024	San German Co.	30	0	0	$1,000	$0
5/8/2024	Vieques Co.	30	0	0	$3,000	$0
5/12/2024	San Juan Co.	40	0	0	$10,000	$0
6/2/2024	Guayama Co.	43	0	0	$100	$0
6/2/2024	Yabucoa Co.	38	0	0	$100	$0

Date	Location	Magnitude (knots)	Injuries	Fatalities	Property Damage	Crop Damage
6/18/2024	Morovis Co.	35	0	0	$0	$1,000
6/19/2024	Catano Co.	35	0	0	$100	$0
6/19/2024	Catano Co.	35	0	0	$300	$0
7/2/2024	Rio Grande Co.	35	0	0	$5,000	$0
7/2/2024	Lajas Co.	35	0	0	$20,000	$0
8/2/2024	Moca Co.	33	0	0	$500	$0
8/14/2024	San Juan And Vicinity (Zone)	40	0	0	$15,000	$0
9/2/2024	Cabo Rojo Co.	35	0	0	$100	$0
9/7/2024	Aguada Co.	35	0	0	$1,000	$0
9/19/2024	Lares Co.	35	0	0	$3,000	$0
9/19/2024	Lares Co.	35	0	0	$1,000	$0
9/25/2024	Las Marias Co.	35	0	0	$10,000	$0
10/29/2024	Lajas Co.	30	0	0	$1,000	$0
10/31/2024	Toa Baja Co.	35	0	0	$15,000	$0
11/10/2024	Maunabo Co.	48	0	0	$1,000	$0
11/11/2024	Ponce Co.	52	0	0	$8,500	$0
3/25/2025	Culebra (Zone)	25	0	0	$1,500	$0
4/1/2025	San Juan And Vicinity (Zone)	25	0	0	$250	$0
4/2/2025	Eastern Interior (Zone)	30	0	0	$15,200	$0
4/2/2025	Eastern Interior (Zone)	30	0	0	$16,200	$0
4/19/2025	Barranquitas Co.	30	0	0	$600	$0
4/19/2025	Ciales Co.	30	0	0	$600	$0
4/19/2025	Bayamon Co.	30	0	0	$600	$0
4/20/2025	Barranquitas Co.	30	0	0	$1,400	$0
4/28/2025	San Juan Co.	30	0	0	$15,000	$0
4/28/2025	Sabana Grande Co.	35	0	0	$2,000	$0

The paths of past wind events recorded in the severe report database by the National Weather Service Storm Prediction Center from 1955 to 2021 are shown in Figure 137. Events with stronger wind speeds are indicated by red colors. High wind events have occurred in many areas, but the map shows a higher number of occurrences in the northern half of the island. In Puerto Rico, many reported wind events reflect indirect or peripheral impacts from passing tropical systems rather than direct hurricane landfall as Figure 137 states.

As previously noted, extreme winds can be very damaging to trees. Figure 138 shows significant forest cover loss from 2000 to 2024. Puerto Rico lost 77.3 kilo-hectare of tree cover from 2001 to 2024, which is 15% of the 2000 total tree cover area.[401] Drivers of deforestation include agriculture, logging, wildfire, settlement and infrastructure, and natural disturbances such as wind events. Significant forest loss, 56.2 hectare, occurred in 2017 primarily due to Hurricanes Maria and Irma.

[401] Global Forest Watch, "Puerto Rico: Forest Change," https://www.globalforestwatch.org/dashboards/country/PRI/?category=forest-change&location=WyJjb3VudHJ5IiwiUFJJIl0%3D.

Figure 137: 2011-2024 Historical Wind Events up to 56 mph[402]

[402] NOAA's National Weather Service Storm Prediction Center, "SVRGIS, https://www.spc.noaa.gov/gis/svrgis/.

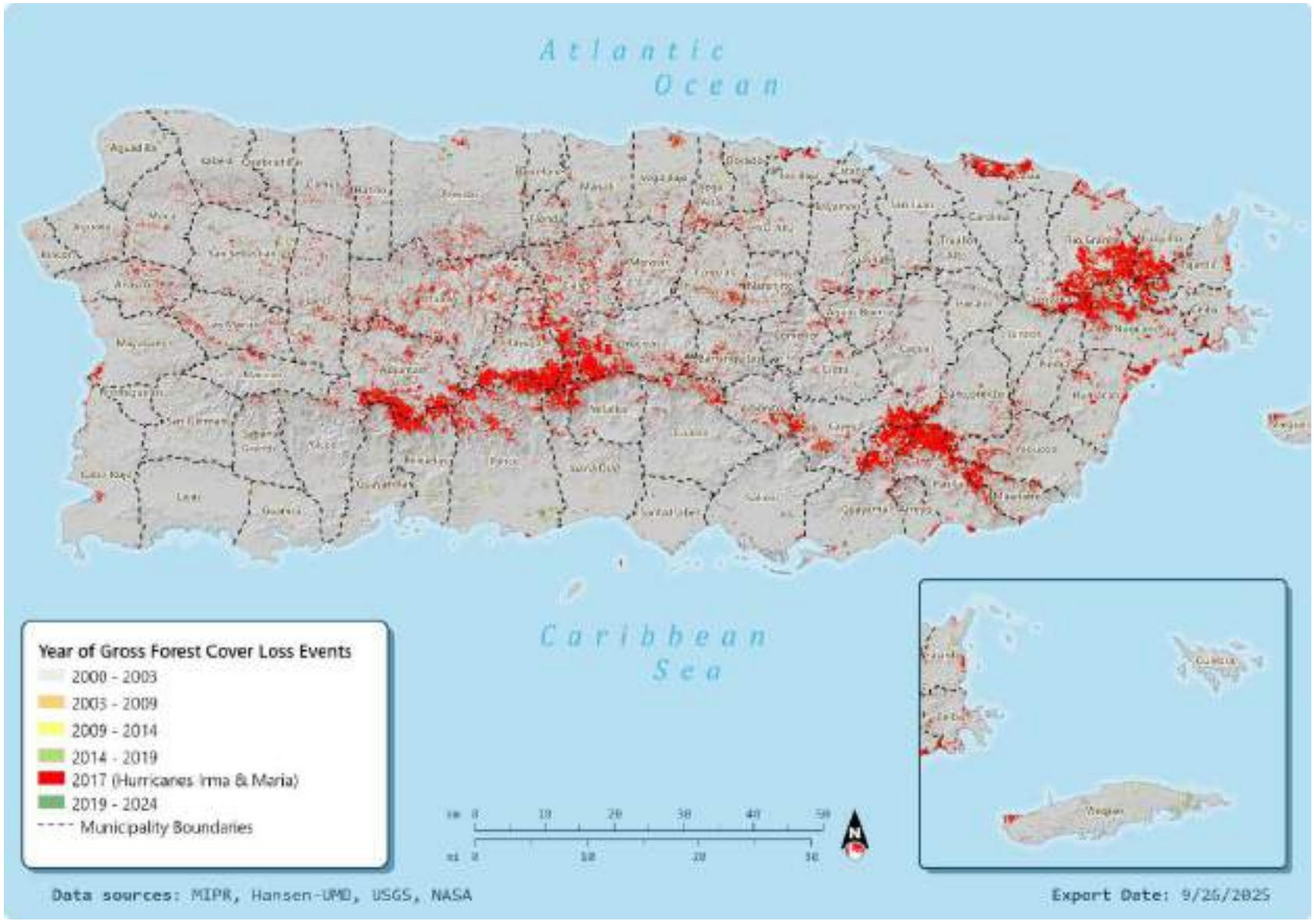


Figure 138: Gross Forest Cover Loss Event by Year

Potential Severity of Event

The wind intensity is commonly measured using the Beaufort Wind Scale. The Beaufort Wind Scale is the standardized empirical measure used to estimate wind speed based on observed conditions. The Beaufort Scale remains widely recognized for classifying wind strength, especially in meteorological reporting and hazard communication.[403] Table 45 displays the Beaufort Wind Scale.

Table 45: Beaufort Wind Scale[404]

Force	Speed (MPH)	Description	Specification
0	0–1	Calm	Sea like a mirror. Calm; smoke rises vertically.
1	1–3	Light Air	Ripples with the appearance of scales are formed, but without foam crests.
2	4–7	Light Breeze	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break.
3	8–12	Gentle Breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses. Leaves and small twigs in constant motion; wind extends light flag.
4	13–18	Moderate Breeze	Small waves, becoming larger; fairly frequent white horses. Raises dust and loose paper; small branches are moved.
5	19–24	Fresh Breeze	Moderate waves, taking a more pronounced long form; many white horses are formed. Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	25–31	Strong Breeze	Large waves begin to form; the white foam crests are more extensive everywhere. Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.
7	32–38	Near Gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind. Whole trees in motion; inconvenience felt when walking against the wind.
8	39–46	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.
9	47–54	Severe Gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility Slight structural damage occurs (chimney-pots and slates removed)

[403] D. Wheeler, and C. Wilkinson, "From calm to storm: the origins of the Beaufort wind scale," *The Mariner's Mirror*, 2004 *90*(2), 187–201.
[404] National Weather Service, "Beaufort Wind Scale," https://www.weather.gov/mfl/beaufort.

Force	Speed (MPH)	Description	Specification
10	55–63	Storm	Very high waves with long overhanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of the wind. On the whole the surface of the sea takes on a white appearance. The tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	64–72	Violent Storm	Exceptionally high waves (small- and medium-size ships might be lost for a time to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.
12	72–83	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.

The Saffir-Simpson Wind Scale is a widely recognized classification system used to measure the intensity of hurricanes utilizing sustained wind speeds.[405] The scale was originally used to estimate potential property damage and flooding associated with tropical cyclones by Herbert Saffir and Robert Simpson.[406] Table 46 displays the Saffir-Simpson Wind Scale.

Table 46: Saffir-Simpson Hurricane Wind Scale[407]

Category	Sustained Winds (MPH)	Types of Damage Due to Hurricane Winds
1	74–95	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96–110	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3	111–129	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be

[405] National Hurricane Center and Central Pacific Hurricane Center, "Saffir-Simpson Hurricane Wind Scale," https://www.nhc.noaa.gov/aboutsshws.php.
[406] H. S. Saffir, "Communicating damage potentials and minimizing hurricane damage," *Hurricane! Coping with Disaster: Progress and Challenges Since Galveston, 1900*, 2003 *55*, 155–164.
[407] National Hurricane Center and Central Pacific Hurricane Center, "Saffir-Simpson Hurricane Wind Scale," https://www.nhc.noaa.gov/aboutsshws.php.

Category	Sustained Winds (MPH)	Types of Damage Due to Hurricane Winds
		snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4	130–156	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5	>156	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Probability of Future Hazard Events

The probability of future extreme wind events in Puerto Rico is informed by a combination of historical records, probabilistic hazard models, and climate assessments. Historical evidence from the NOAA Storm Events Database (NCEI) documents repeated tropical cyclone wind events across the island, with major storms such as Hurricane Maria in 2017 producing sustained winds exceeding 150 mph and causing catastrophic damage to infrastructure and housing. As illustrated in Figure 139, historical hurricane track maps show that Puerto Rico has been repeatedly intersected by tropical cyclones. The International Best Track Archive for Climate Stewardship (IBTrACS) is the most complete global collection of tropical cyclone data available to show the location and intensity of past tropical cyclones.[408] Over the past four decades, Puerto Rico has experienced multiple hurricanes and tropical storms, demonstrating that damaging winds are a recurring feature of the island's hazard profile rather than isolated, rare events.[409]

[408] NOAA NCEI, "International Best Track Archive for Climate Stewardship (IBTrACS)," https://www.ncei.noaa.gov/products/international-best-track-archive.
[409] NOAA NCEI, "Storm Events Database," https://www.ncei.noaa.gov/stormevents.

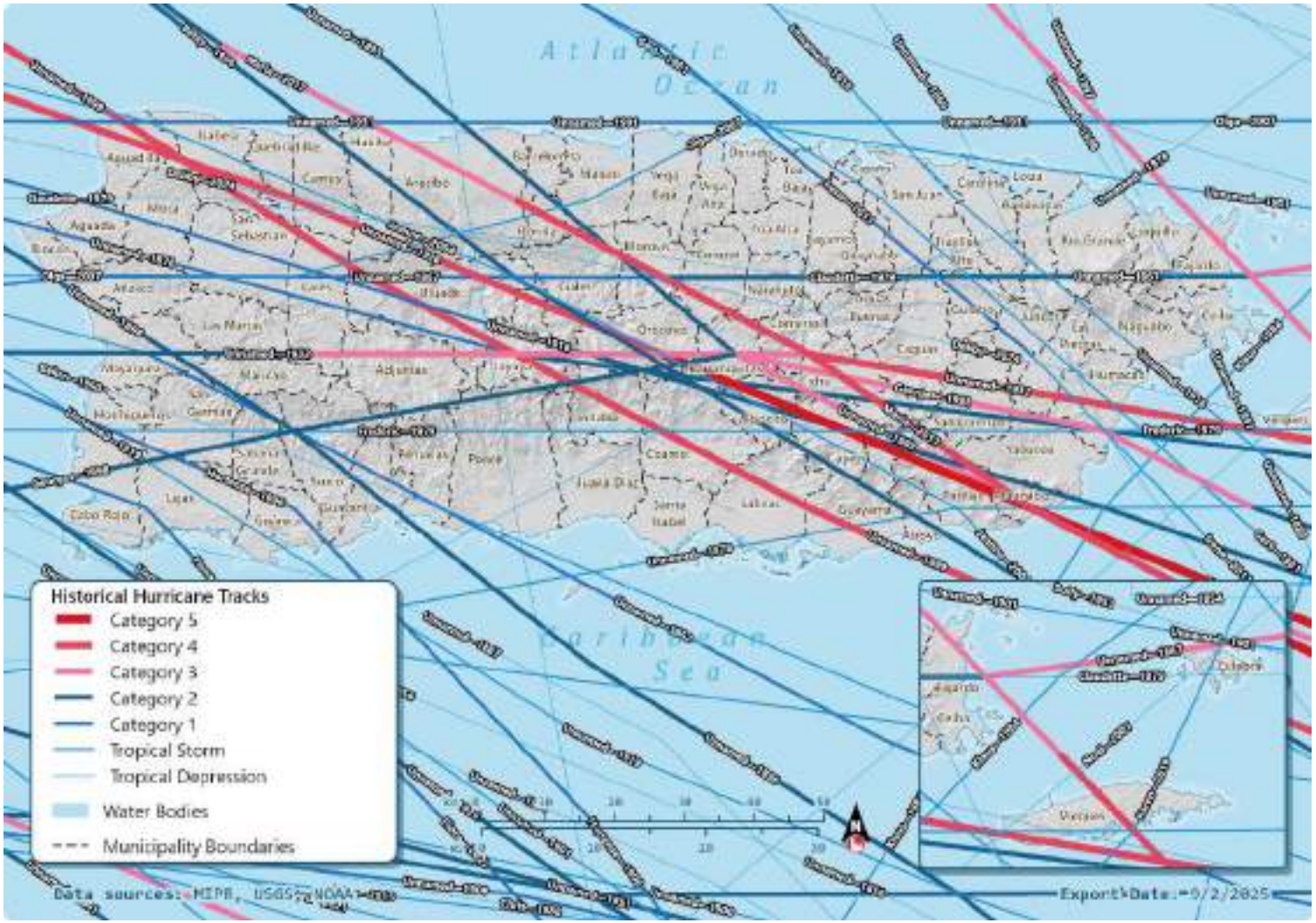


Figure 139: Historical Hurricane Tracks Impacting Puerto Rico[410]

[410] NOAA NCEI, "International Best Track Archive for Climate Stewardship (IBTrACS)," https://services2.arcgis.com/FiaPA4ga0iQKduv3/arcgis/rest/services/IBTrACS_ALL_list_v04r00_lines_1/FeatureServer.

While historical records provide a baseline, they do not fully capture the range of potential future conditions. Probabilistic hazard modeling, such as the methodology incorporated into the ASCE 7 Hazard Tool, simulates thousands of synthetic storm tracks using the NOAA HURDAT2 hurricane database to estimate design wind speeds associated with specific return periods, such as 50-year, 100-year, or 700-year events.[411] These projections confirm that Puerto Rico is consistently exposed to hurricane force winds, with higher recurrence along coastal plains and localized amplification in interior mountain corridors due to terrain effects. Figure 140 highlights how modeled peak gust wind speeds from Hurricane María demonstrate Puerto Rico's exposure to hurricane-force winds, with higher gust speeds along coastal plains and localized wind amplification in mountainous regions driven by terrain effects.

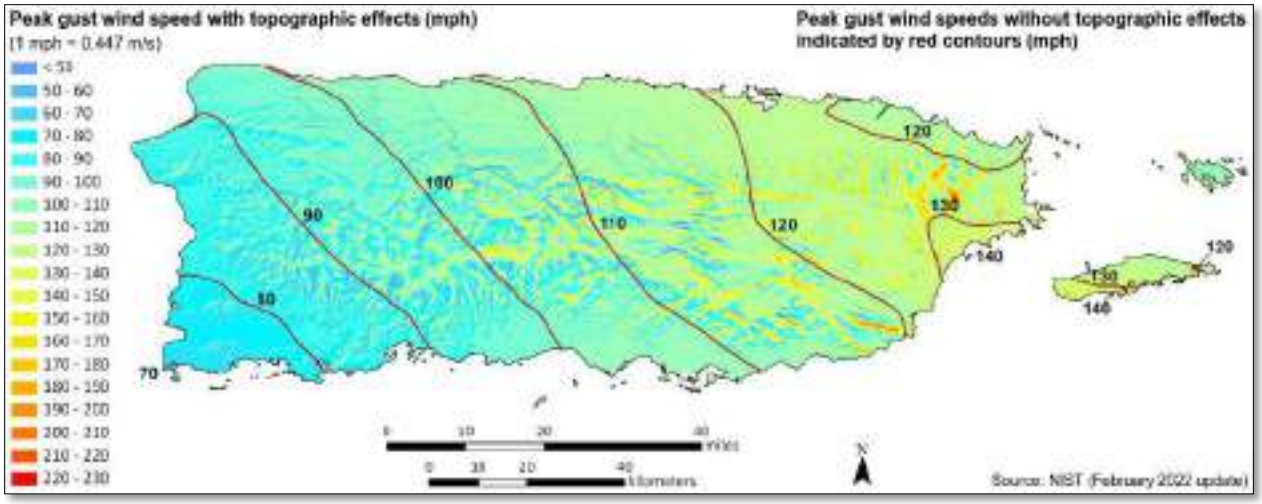


Figure 140: Modeled Peak Gust Wind Speeds from Hurricane Maria, Showing How Terrain Influences Wind Intensity

Climate assessments provide additional context for future risk. The IPCC Sixth Assessment Report (AR6) concludes that while the overall number of tropical cyclones may not increase, the intensity and rapid intensification rates of the strongest storms are projected to rise in a warming climate.[412] As shown in Figure 141, climate model projections indicate an increasing likelihood of more frequent Category 4 and 5 hurricanes in the North Atlantic basin, elevating Puerto Rico's long-term wind risk profile. This trend has particular implications for small island regions, where exposure to intense winds, heavy rainfall, and storm surge is concentrated. NOAA research similarly projects an increase in the frequency of Category 4 and 5 hurricanes in the North Atlantic basin, further elevating the risk profile for Puerto Rico.[413]

[411] American Society of Civil Engineers (ASCE), *Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-16 and 7-22)*, Reston, VA: ASCE.
[412] Intergovernmental Panel on Climate Change (IPCC), *Sixth Assessment Report (AR6), Working Group II: Small Islands*, Geneva: IPCC, 2022.
[413] NOAA Geophysical Fluid Dynamics Laboratory (GFDL), "Global Warming and Hurricanes," https://www.gfdl.noaa.gov/global-warming-and-hurricanes.

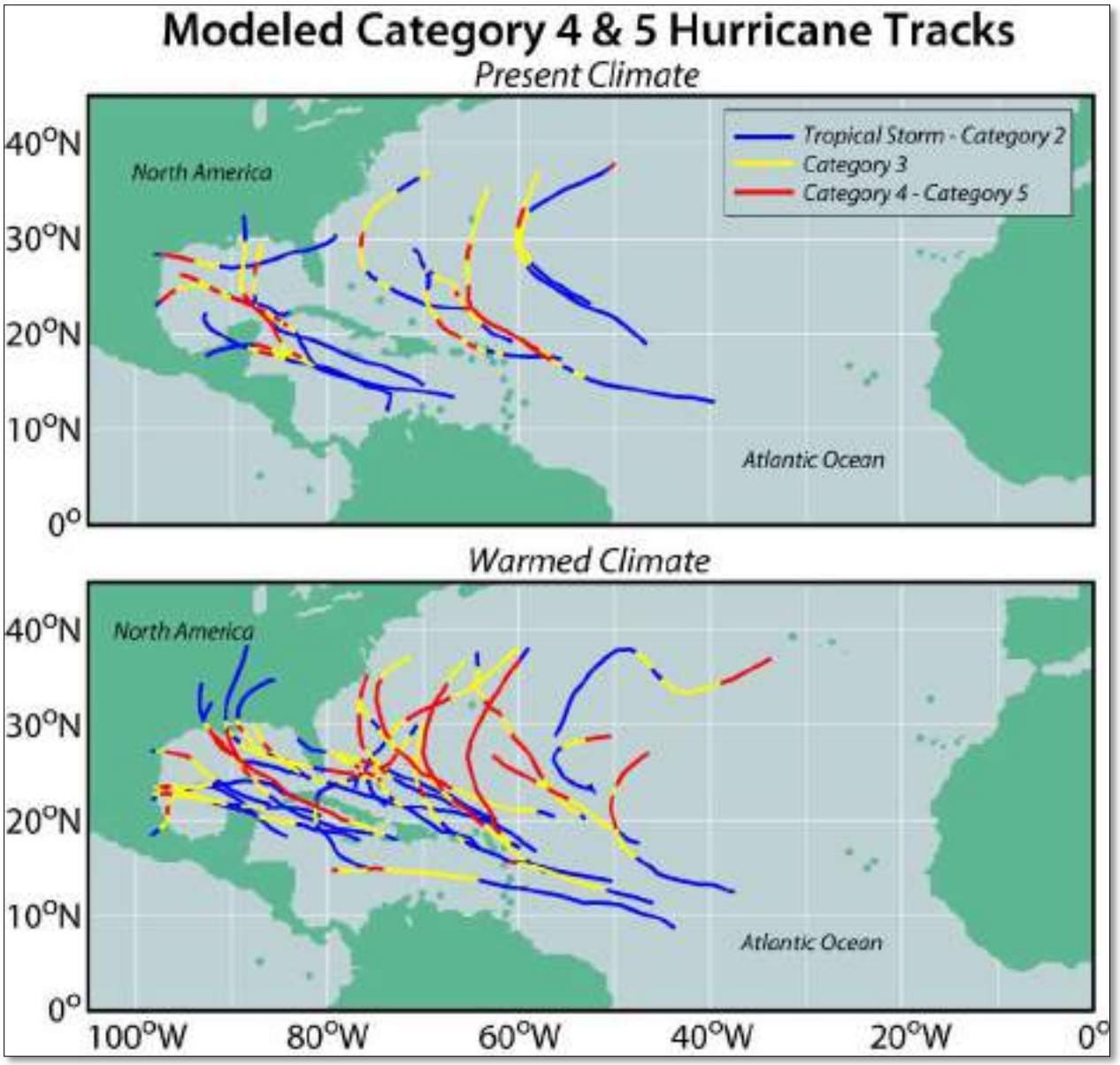


Figure 141: Climate Model Projections Indicate an Increasing Likelihood of More Frequent Category 4 and 5 Hurricanes in the North Atlantic Basin, Elevating Puerto Rico's Long-Term Wind Risk Profile[414]

Taken together, the historical record, modeled projections, and climate outlook indicate that Puerto Rico will continue to face recurring and potentially intensifying exposure to extreme wind events. Based on the frequency of hurricanes making landfall or passing near the island, extreme wind hazards can be expected to occur at least once every five years, which corresponds to a **moderate** probability classification. This assessment recognizes both the established historical recurrence and the emerging influence of climate change on storm intensity, underscoring the need for ongoing investment in wind resilient design and

[414] GFDL (NOAA). "Global Warming and Hurricanes Figures," including projected tracks of Atlantic Category 4–5 hurricanes under climate warming scenarios (Figures 7, 9), https://www.gfdl.noaa.gov/global-warming-and-hurricanes-figures.

hazard mitigation. Table 47 summarizes the scoring for extreme winds in Puerto Rico, including frequency, probability, and the magnitude of observed impacts across social, economic, and environmental dimensions.

Table 47: Extreme Winds Scale, Probability, and Impacts

HIGH			
Category			
Frequency	Not Likely = 50–100 yrs • Likely = 5–10 yrs • Very Likely = annual/seasonal	2	Likely
Probability of Occurrence	Same scale as Frequency, supported by climatology and projections	3	Very Likely
Injuries	Low = none • Medium = minor • High = significant (historical injuries & fatalities)	3	High
Infrastructure/Economy	Low = none • Medium = moderate damages • High = catastrophic losses	3	High
Environment	Low = none • Medium = moderate ecosystem impacts • High = severe ecological disturbance	3	High
Overall Vulnerability	Low = <5 • Medium = 6–10 • High = 11–15	14	High

Vulnerability Assessment

Extreme winds remain one of the most consequential hazards for Puerto Rico, with the capacity to disrupt critical systems and affect the entire island at once. Vulnerability arises not only from the intensity of storms but also from how exposure intersects with the island's terrain, concentrated coastal development, and aging infrastructure.

This assessment views vulnerability as the combination of hazard exposure and adaptive capacity. Examining infrastructure fragility, environmental sensitivity, and social conditions highlights where impacts are likely to be greatest and informs strategies to reduce risks, protect communities, and strengthen resilience against future wind events.

LOCATIONS

Exposure to extreme wind hazards in Puerto Rico varies widely across the island, shaped by settlement patterns, coastal concentration of population, and the amplifying effects of complex terrain. According to the Puerto Rico Coastal Zone Management Program, approximately 2.3 million residents live in the 44 coastal municipalities that comprise the island's designated coastal zone, underscoring how much of Puerto Rico's housing, infrastructure, and economic activity is concentrated near shorelines most frequently

intersected by tropical cyclone tracks.[415] Major metropolitan centers such as San Juan, Ponce, Mayagüez, and Aguadilla represent focal points of risk because of their high density of residential, commercial, and critical facilities.

The island's mountainous interior introduces a different vulnerability profile. Recent engineering studies have produced high-resolution wind modeling on a 100-meter grid across Puerto Rico, demonstrating that ridges and elevated terrain can locally accelerate wind speeds beyond baseline estimates.[416] Similarly, the National Institute of Standards and Technology (NIST), through its Hazard Characterization Project, demonstrated that Puerto Rico's terrain significantly alters peak gust intensities, with amplification observed in exposed mountain corridors.[417] Communities situated in these areas may face disproportionately higher wind loads even when overall storm intensity is moderate.

At the municipal level, vulnerability is uneven. Some smaller coastal towns with aging housing stock and limited enforcement of building codes are especially prone to wind damage and slower recovery, while municipalities with more modern construction and infrastructure benefit from relatively stronger performance under hurricane-force winds. As highlighted by the Columbia University Center for Spatial Research,[418] Puerto Rico's division into 78 municipalities makes it essential to assess risk at the local scale to capture both broad island-wide exposure and localized hotspots of elevated vulnerability.

POPULATIONS

The vulnerability of Puerto Rico's population to extreme winds is shaped by demographic distribution, housing conditions, and social capacity to respond and recover. According to the U.S. Census Bureau, the island's population has declined over the past two decades, yet a large share remains concentrated in coastal municipalities and metropolitan areas such as San Juan, Ponce, and Mayagüez.[419]

A significant proportion of the population lives in older or informally built housing, often lacking wind-resistant construction. Studies after Hurricane Maria documented widespread roof failures, particularly in wood-frame and non-engineered concrete block structures.[420] Communities with high poverty rates face

[415] H. I. Díaz and J. Jacobs, "Puerto Rico Coastal Zone Management Program," University of Puerto Rico / NOAA, 2014, https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/latin-america-and-caribbean/puerto-rico-usvi-bvi/Diaz--Jacobs.--2014.--Puerto-Rico-Coastal-Zone-Management-Program..pdf.
[416] P. Vickery et al., "Development of Topographic Wind Speedups and Hurricane Hazard Maps for Puerto Rico," ResearchGate / ASCE, 2023, https://www.researchgate.net/publication/374332440_Development_of_Topographic_Wind_Speedups_and_Hurricane_Hazard_Maps_for_Puerto_Rico.
[417] National Institute of Standards and Technology (NIST), "NIST reports Progress on Hurricane Maria Study," U.S. Department of Commerce, 2022, https://www.nist.gov/news-events/news/2022/09/nist-reports-progress-hurricane-maria-study.
[418] J. Claramunt et al., "Mapping Municipalities at Risk in Puerto Rico," Columbia University, Center for Spatial Research, 2019, https://puerto-rico-now.c4sr.columbia.edu.
[419] Centers for Disease Control and Prevention (CDC). *Public health preparedness capabilities: National standards for state, local, tribal, and territorial public health.* Atlanta, GA, 2019.
[420] FEMA, *Hurricane María in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance,* FEMA P-2020, 2018.

disproportionate risk, as limited financial resources restrict the ability to retrofit homes, purchase insurance, or relocate away from high hazard areas.

Vulnerable group such as older adults, children, individuals with disabilities, and those with pre-existing health conditions are especially at risk during and after extreme wind events. The Centers for Disease Control and Prevention highlights that such populations are more likely to experience health complications during disaster events, while limited mobility and access to services compound their vulnerability. Language barriers and rural isolation also create additional challenges for effective communication and timely evacuation in some municipalities.[421]

Puerto Rico's population vulnerability reflects both structural exposure in densely settled, wind prone areas and social vulnerability linked to poverty, health, and access to resources. Addressing these risks requires targeted outreach, improved housing resilience, and inclusive planning that accounts for the needs of the most at-risk communities.

Hazus data indicates that Puerto Rico has a total population of 3,285,874 people and over 1,340,000 households.

STRUCTURES INCLUDING CRITICAL FACILITIES

Puerto Rico's built environment exhibits widespread vulnerability to extreme wind hazards, particularly due to the prevalence of older housing stock, informal construction practices, and limited enforcement of building codes prior to recent updates. Post-disaster assessments conducted after Hurricane María (2017) revealed that many residential structures especially those with lightweight roofs, unreinforced masonry walls, or inadequate connections suffered severe failures under sustained winds exceeding 150 mph.[422] The housing sector's fragility is compounded by socio-economic constraints that limit investment in retrofitting or compliance with modern wind resistance standards.

Critical facilities are similarly exposed. Energy infrastructure, including transmission lines and substations, sustained widespread damage during Hurricanes Irma and Maria, leading to prolonged blackouts that lasted months in some communities. Hospitals and health centers were heavily impacted, with many losing power, water, or structural integrity, reducing their capacity to provide essential services at the height of the emergency. Educational facilities also experienced major damage, disrupting learning and creating challenges for their secondary function as emergency shelters.

While modernized facilities constructed under the Puerto Rico Building Code (PRBC, based on IBC/ASCE 7-16) show improved performance, a significant portion of critical infrastructure predates these standards. The Federal Emergency Management Agency (FEMA) and NIST have both emphasized that structures built

[421] C. E. Rodríguez-Díaz, "Maria in Puerto Rico: Natural disaster in a colonial archipelago," *American Journal of Public Health*, 2018, 108(1), 30–32.
[422] FEMA, *Hurricane María in Puerto Rico: Building Performance Observations, Recommendations, and Technical Guidance,* FEMA P-2020, 2018.

without consideration of terrain driven wind amplification in mountainous regions or coastal exposure remain disproportionately at risk.[423]

Overall, structural vulnerability in Puerto Rico reflects the dual challenge of aging and informally built housing on one hand, and critical facilities with limited resilience on the other. Reducing this vulnerability will require investment in retrofitting, stricter enforcement of wind design standards, and system-wide hardening of lifeline infrastructure to withstand future extreme wind events.

Hazus data indicates that there are an estimated 1,405,000 buildings in Puerto Rico with a total replacement value of $482.4 billion. Of these buildings, 99% are residential, and residences account for 92% of the building value. Critical facilities in Puerto Rico include 91 emergency operations centers, 94 fire stations, 309 hospitals, 187 police stations, and 2,021 schools.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Puerto Rico's infrastructure and community lifelines remain highly vulnerable to extreme winds, as demonstrated during Hurricanes Irma (2017), Maria (2017), and Fiona (2022). The electric power grid, which extends across mountainous terrain, is acutely exposed; overhead transmission and distribution lines are repeatedly damaged by high winds and wind-borne debris, while ridges and topographic features locally accelerate wind speeds, amplifying failures. Such disruptions cascade across lifelines, with the collapse of the energy sector disabling water systems, hospitals, and telecommunications.

The telecommunications lifeline also remains fragile: aerial fiber networks, microwave links, and cell towers have shown structural deficiencies during hurricanes, while the U.S. Government Accountability Office (GAO) reported that insufficient fuel logistics for backup generators prolonged communications outages for weeks after Hurricane Maria.[424] This dependency on both physical integrity and energy supply makes telecommunications one of the most sensitive lifelines to extreme wind events.

Water and wastewater facilities are similarly dependent on energy; treatment plants and pump stations lost power, rendering them inoperable and requiring emergency federal assistance. EPA Region 2 assessments found that continuity relied almost entirely on backup generators and protected electrical controls, underscoring their vulnerability to high winds and cascading grid failures.[425]

Transportation systems, including airports, seaports, and roadways, face extreme wind impacts through damage to signage, lighting, and navigational aids, while fallen trees and debris impede emergency response and fuel distribution. Wind related emergency repairs have historically diverted resources from planned capital improvement projects, slowing long-term resilience efforts and underscoring the systemic vulnerability of Puerto Rico's transportation lifelines to hurricane force winds.

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[423] U.S. Government Accountability Office (GAO), *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Strengthen National Preparedness,* GAO-20-100SP, 2020.
[424] GAO, *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges*, U.S. Government Accountability Office, GAO-18-472, 2018.
[425] EPA Region 2. *EPA Hurricane Response Updates for Puerto Rico and the U.S. Virgin Islands*. U.S. Environmental Protection Agency, 2018.

Safety and Security Lifelines, including police stations, emergency operations centers, and community shelters, as well as the Health and Medical Lifeline, are at risk because many critical facilities predate the 2018 Puerto Rico Building Code. Roof systems, fenestration, and rooftop equipment frequently failed under hurricane winds, while limited and undersized standby generation reduced the ability of hospitals and shelters to operate continuously during emergencies.

Although Puerto Rico has adopted modern standards, specifically the 2018 PR Building Code with ASCE 7-16 hurricane wind maps, which require some of the highest design speeds in the United States, large portions of infrastructure and housing stock were constructed before enforcement and thus remain disproportionately exposed.[426] These structural and systemic weaknesses illustrate how extreme winds simultaneously threaten both physical infrastructure and the eight FEMA Community Lifelines — Safety and Security; Food, Hydration, Shelter, and Water Systems; Health and Medical; Energy; Communications; Transportation; Hazardous Materials; and Government Services creating interdependent vulnerabilities in which the failure of one lifeline can propagate across others

Addressing these risks requires integrated hardening of assets, strict enforcement of updated wind codes, retrofitting of legacy infrastructure, and resilient backup power and communications systems to reduce cascading failures and accelerate recovery following major wind events.

PROBLEM STATEMENTS

- Puerto Rico's vulnerability to extreme winds is unevenly distributed. Coastal municipalities concentrate much of the island's population and infrastructure in areas most often impacted by hurricanes, while mountainous terrain amplifies wind speeds along ridges and corridors. At the same time, municipal differences in housing quality, building code enforcement, and recovery capacity create localized hotspots of risk. These spatial disparities highlight the need for location-specific assessments to guide effective mitigation strategies.
- Puerto Rico's population faces uneven vulnerability to extreme winds due to a combination of demographic, social, and structural factors. High concentrations of residents in coastal and metropolitan areas increase exposure to hurricane-force winds, while widespread reliance on older or non-engineered housing elevates the risk of structural failure. Socio-economic challenges, including high poverty rates and limited access to resources, further constrain the ability of many households to prepare for, withstand, and recover from wind-related disasters. Vulnerable groups such as older adults, children, and individuals with health conditions are disproportionately impacted, underscoring the need for tailored strategies that address both physical exposure and social vulnerability.
- Puerto Rico's structures and critical facilities remain highly vulnerable to extreme winds due to the prevalence of aging housing stock, informal construction, and infrastructure built before modern wind-resistance standards. Hurricanes Irma and Maria exposed widespread weaknesses, with roof failures, damaged substations, and hospitals unable to maintain essential services during prolonged outages. Without targeted retrofitting and system-wide hardening, both residential buildings and lifeline

[426] PRBC. *Puerto Rico Building Code 2018*. Puerto Rico Planning Board, incorporating ASCE 7-16 wind provisions, 2018.

facilities will continue to face disproportionate risks, leaving communities exposed to severe disruption when future wind events occur.

- Puerto Rico's infrastructure and community lifelines remain critically vulnerable to extreme wind events. Much of the island's energy, water, communications, transportation, and critical facilities predate modern wind design standards, making them highly susceptible to damage. Interdependencies among lifelines mean that when the power grid fails, cascading disruptions spread across essential services, prolonging outages and recovery. Without systematic retrofitting, resilient backup systems, and stronger enforcement of building codes, Puerto Rico will continue to face severe service interruptions during future hurricanes.

Impact Assessment

Quantitative analysis of potential impacts of extreme wind is based on Hazus probabilistic hurricane scenarios. The Hazus model produces loss estimates from 10-, 20-, 50-, 100-, 200-, 500-, and 1,000-year return intervals. These scenarios model the effects of various severities of wind on structures, critical facilities, and infrastructure and the resulting impacts on the population.

ECONOMIC LOSSES

Building related losses include both direct property damage losses and losses from business interruption, or those associated with the inability to operate a business due to damage sustained during a hurricane. Direct property damage losses are the estimated costs to repair or replace damage caused to buildings and their contents. Business interruption losses include income, wage loss, relocation costs, and temporary living expenses for people displaced from their homes because of the hurricane.

Table 48 and Table 49 show the direct and business interruption losses for each probabilistic return intervals. Table 48 shows the losses based on the direct and indirect loss categories., whereas Table 49 summarizes the losses by occupancy types. In each scenario, residential occupancies account for the highest amount of structural damage. Figure 142 shows the distribution of annualized hurricane losses by census tract.

Table 48: Hazus Economic Losses by Hurricane Return Interval

Return Interval	Building Loss	Contents Loss	Inventory Loss	Income Loss	Relocation Loss	Rental Income Loss	Wage Loss	Total Economic Loss
10-year	$1,019,396,480	$204,959,400	$85,840	$609,000	$33,795,420	$8,201,310	$1,491,990	$1,268,539,440
20-year	$7,682,226,060	$2,212,943,030	$4,783,440	$13,420,040	$466,814.26	$170,204,250	$39,566,130	$10,589,957,200
50-year	$37,583,094,740	$12,996,197,150	$105,550,840	$245,775,610	$2,796,809,280	$1,222,223,610	$370,277,910	$55,319,929,130
100-year	$63,091,547,100	$26,533,425,510	$371,853,150	$890,651,000	$4,988,096,450	$2,492,479,620	$1,090,038,280	$99,458,091,110
200-year	$89,968,242,370	$38,189,244,820	$452,459,360	$1,057,392,060	$7,001,829,770	$3,422,019,460	$1,333,125,64	$141,424,313,480
500-year	$118,866,811,070	$54,175,177,820	$752,710,310	$1,584,000,520	$9,070,298,270	$4,725,115,570	$1,996,209,080	$191,168,322,630
1,000-year	$137,194,699,800	$64,417,834,130	$888,167,410	$1,807,651,490	$10,240,379,300	$5,507,741,950	$2,320,085,730	$222,376,559,820

Table 49: Hazus Hurricane Losses by Building Occupancy Type

Return Interval	Residential	Commercial	Industrial	Other	Total Economic Loss
Exposure Total Building Value	$442,505,864,000	$17,137,311,000	$3,473,491,000	$19,366,219,000	$482,482,885,000
10-year	$1,253,808,700	$4,051,050	$491,820	$10,187,860	$1,268,539,440
20-year	$10,216,550,990	$109,271,990	$14,206,470	$249,927,760	$10,589,957,200
50-year	$50,035,446,460	$2,632,446,470	$436,767,010	$2,215,249,190	$55,319,929,130
100-year	$82,813,912,900	$8,938,974,580	$1,589,275,360	$6,115,928,280	$99,458,091,110
200-year	$120,768,685,640	$10,669,401,410	$1,869,643,530	$8,116,582,910	$141,424,313,480
500-year	$158,935,686,080	$16,690,302,530	$3,085,457,640	$12,456,876,380	$191,168,322,630
1,000-year	$184,056,049,940	$19,507,121,310	$3,595,553,220	$15,217,835,350	$222,376,559,820

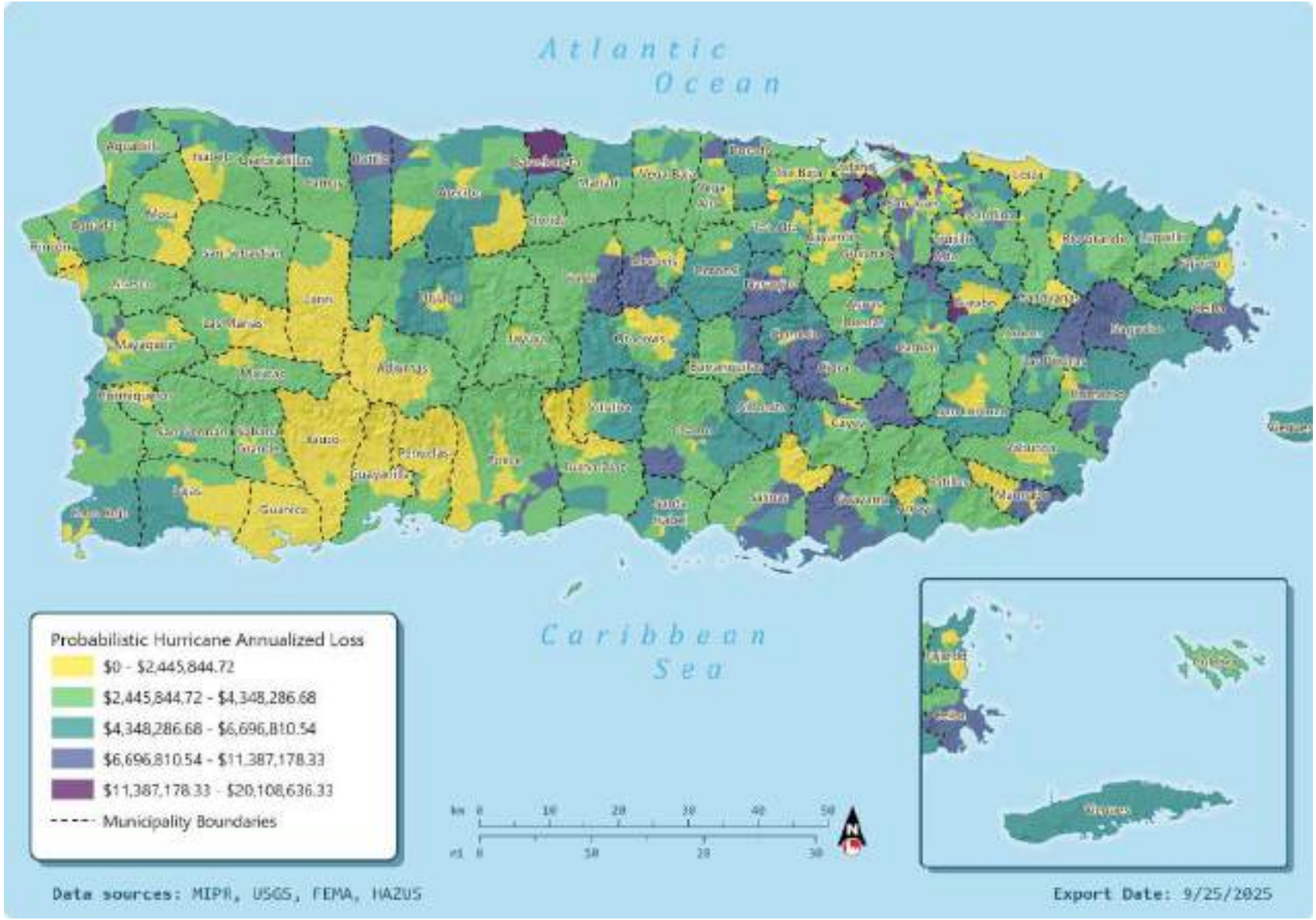


Figure 142: Annualized Loss Estimates for Hurricane

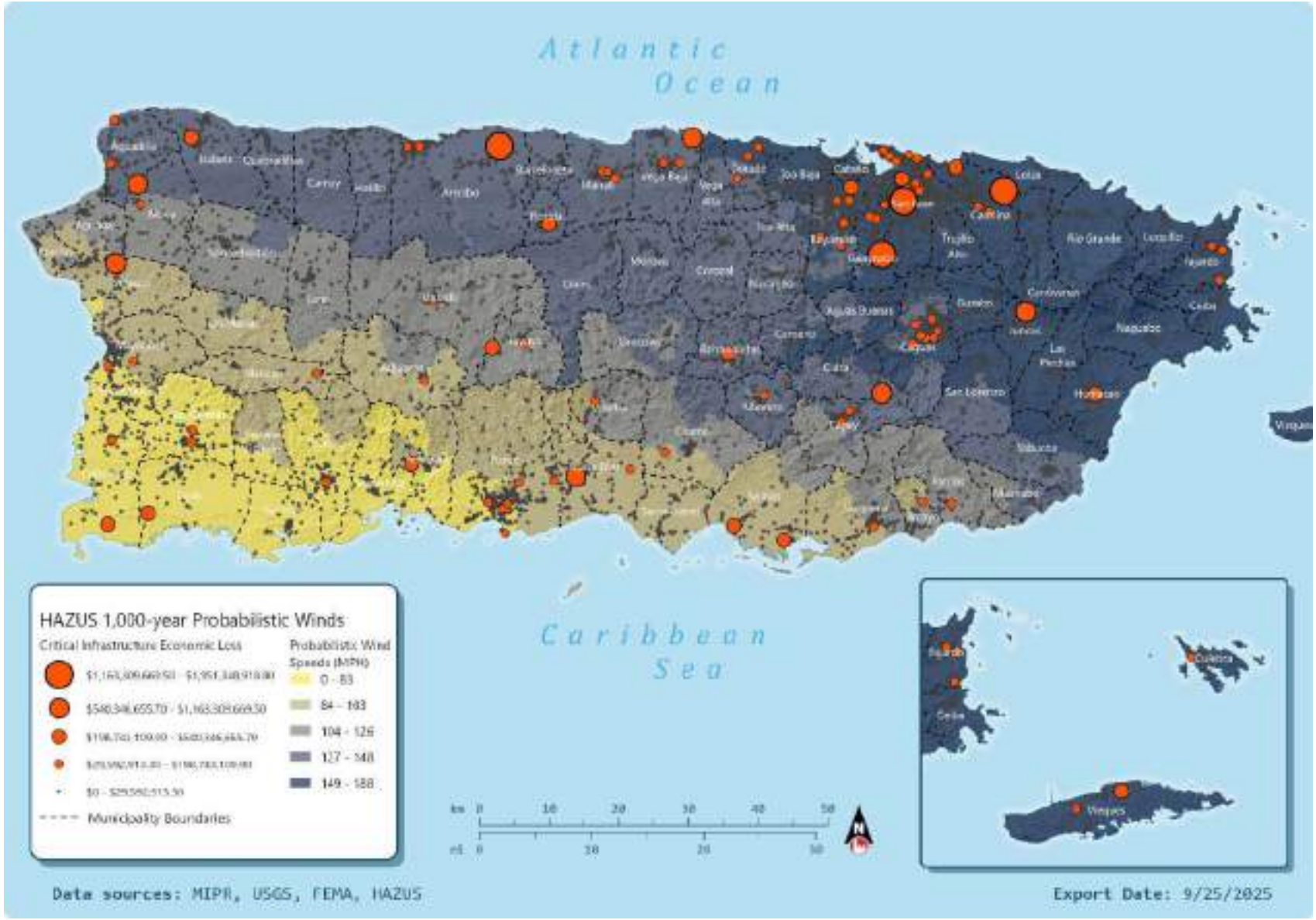


Figure 143: 1,000-Year Return Interval Hurricane: Wind Speeds and Losses to Critical Infrastructure

Hazus estimates the amount of debris that will be generated by the different hurricane scenarios. These are broken into categories according to different types of material and the type of equipment required to handle the debris. It also estimates the number of truckloads required to clear the debris based on an average of 25 tons per truck. Table 50 shows the amount of debris estimated to be generated in each return-interval hurricane scenario.

Table 50: Debris Generated by Hurricane Scenario

Return Interval	Tree Debris	Brick / Wood	Concrete / Steel	Total Debris	Truckloads
10-year	428,593	25,219	8,636	462,448	1,354
20-year	1,246,787	365,530	143,402	1,752,719	20,537
50-year	1,992,707	2,247,018	831,850	5,071,575	123,155
100-year	1,466,248	4,692,475	1,745,205	7,903,928	257,507
200-year	2,516,425	6,996,322	2,873,692	12,386,439	394,801
500-year	2,855,006	10,500,958	4,394,563	17,750,527	595,821
1,000-year	2,976,333	13,248,830	5,710,390	21,935,553	758,369

Based on estimated damage to residential structures, Hazus estimates the number of households that are expected to be displaced from their homes. It also reports a portion of those that are likely to seek temporary public shelter. The estimated sheltering needs for each return-interval scenario are shown in Table 51.

Table 51: Potential Sheltering Needs by Hurricane Scenario

Return Interval	Displaced Households	Persons Requiring Temporary Shelter
10-year	233	627
20-year	7,318	18,988
50-year	57,513	141,170
100-year	140,298	327,860
200-year	210,170	507,237
500-year	310,370	742,018
1,000-year	393,341	937,136

STATE ASSETS

State-owned assets in Puerto Rico, including schools, emergency operations centers, health facilities, government buildings, and critical infrastructure, face significant exposure to extreme wind hazards. Many of these facilities were built prior to the adoption of the 2018 Puerto Rico Building Code, which incorporates ASCE 7-16 hurricane wind provisions, and therefore do not meet current design standards for wind resistance. Local hazard mitigation plans consistently identify government-owned structures as vulnerable, with assessments noting recurring roof failures, damaged fenestration, and loss of mechanical and electrical systems during hurricanes. The cumulative effect of these damages not only disrupts essential public services but also generates substantial repair and replacement costs for state and municipal governments.

Based on the local risk assessments, potential losses to government facilities under major hurricane scenarios are estimated in the hundreds of millions of dollars, with education and health facilities comprising the largest share of exposed assets. For example, municipal plans frequently mention the need to retrofit public schools that serve as emergency shelters, as wind damage to roofing systems and backup power components can compromise both educational continuity and disaster response operations. Similarly, state-level assessments emphasize that critical lifeline facilities such as police stations, firehouses, and water treatment plants are at high risk of operational disruption due to both direct wind impacts and cascading failures from power loss.

The state risk assessment further underscores that extreme wind hazards represent one of the most financially consequential threats to government-owned property and public service continuity. Using FEMA's Hazus modeling and supplemental data, the analysis shows that under a Category 4 hurricane scenario, widespread losses to state owned buildings could exceed billions of dollars when combining direct structural damage, contents losses, and functional downtime. These findings align with municipal estimates that highlight the disproportionate burden on local governments to repair essential facilities, particularly in communities with limited fiscal capacity.

Table 52: Estimated Exposure of State-Owned Assets in Puerto Rico (by Agency)

Asset Category / Agency	Example Facilities / Systems	Reported Capital Assets, Net (Million USD)	Source (Audit Year)
Energy – LUMA	Generation, substations, transmission	7,759	Puerto Rico Electric Power Authority Audited Financial Statements 2021[427]
Water & Wastewater – PRASA (AAA)	Treatment plants, pump stations, pipelines	5,573	Puerto Rico Aqueduct and Sewer Authority Audited Financial Statements 2022[428]

[427] Puerto Rico Electric Power Authority (PREPA), Audited Financial Statements, June 30, 2021, Government of Puerto Rico.

[428] Puerto Rico Electric Power Authority (PREPA), Audited Financial Statements, June 30, 2021, Government of Puerto Rico. Puerto Rico Aqueduct and Sewer Authority (PRASA / AAA), Financial Statements and Required Supplementary Information, June 30, 2022, Government of Puerto Rico.

Asset Category / Agency	Example Facilities / Systems	Reported Capital Assets, Net (Million USD)	Source (Audit Year)
Highways and Transit – PRHTA	Highways, bridges, transit infrastructure	8,332	Puerto Rico Highways and Transportation Authority Audited Financial Statements 2022[429]
Ports – PR Ports Authority	Airports, seaports, ferry terminals	1,257	Puerto Rico Ports Authority Audited Financial Statements 2022[430]
Public Buildings – PBA	Government offices, schools, courthouses	2,911	Puerto Rico Public Building Authority Audited Financial Statement 2022[431]
University of Puerto Rico	Campus facilities, labs, dorms	750	University of Puerto Rico Audited Financial Statements 2022[432]
Medical Services Administration (ASEM)	Centro Médico hospital facilities	72	Medical Services Administration Audited Financial Statements 2022[433]

Total Exposure (across selected agencies): ≈ $26,654 Million

LOCAL ASSETS

Municipal assets across Puerto Rico, including city halls, community centers, local emergency service buildings, parks, and small road networks, are highly exposed to the threat of extreme winds generated by hurricanes and tropical storms. The island's geographic position in the Atlantic hurricane belt places all 78 municipalities within reach of high-intensity tropical cyclones, as demonstrated by Hurricanes Georges (1998), Maria (2017), and Fiona (2022), which produced widespread wind damage and multi-billion-dollar losses.[434] Local facilities are particularly vulnerable because many municipal buildings predate modern building codes and lack adequate roof anchorage, wind-resistant fenestration, or structural reinforcement, leading to disproportionate failures of roofs, glazing, and secondary components under sustained winds exceeding design thresholds.

[429] Puerto Rico Highways and Transportation Authority (PRHTA), "Financial Statements, June 30, 2022," Government of Puerto Rico.
[430] Puerto Rico Ports Authority, "Financial Statements, June 30, 2022," Government of Puerto Rico.
[431] Puerto Rico Public Buildings Authority (PBA), "Basic Financial Statements, June 30, 2022," Government of Puerto Rico.
[432] University of Puerto Rico (UPR), "Basic Financial Statements, June 30, 2022," Government of Puerto Rico.
[433] Medical Services Administration (ASEM), "Audited Financial Statements, June 30, 2022, and 2023," Government of Puerto Rico.
[434] RAND Corporation, "Building Resilience in Puerto Rico: A Study of Strengthening the Island's Municipal Sector," RAND Research Report RR-2604, 2020.

The vulnerability of municipal assets is compounded by incomplete inventories and aging infrastructure. FEMA assessments after Hurricane Maria noted that municipal governments had little to no systematic record of the condition of their public facilities, complicating loss estimation and slowing mitigation planning.[435] This data gap is critical given that local assets often serve dual roles: municipal halls double as emergency coordination centers, community centers serve as shelters, and local schools support continuity of operations. When these assets sustain wind damage, the disruption extends beyond physical loss to the interruption of governance, emergency response, and community lifelines.

Coastal municipalities face an elevated profile because their public assets are often located in low-lying, exposed areas where wind loads accelerate due to unobstructed terrain. Inland municipalities in mountainous regions also experience localized wind amplification along ridgelines and valleys, increasing the likelihood of structural failures in community facilities and rural road networks. Street lighting, signage, and small municipal utilities, typically constructed with lighter materials and lower design thresholds, consistently suffer higher failure rates during windstorms, adding to recovery costs and creating cascading risks through debris hazards.

Finally, municipal capacity to mitigate wind risk is constrained by fiscal limitations and deferred maintenance. Post-Hurricane Maria evaluations highlighted that local governments entered the 2017 hurricane season with limited resources and were unable to implement proactive reinforcement measures. This structural underinvestment has left many municipal assets at sustained high risk of wind damage. Without targeted mitigation such as roof retrofits, installation of hurricane shutters, and stronger anchorage systems municipal facilities will continue to suffer recurrent and costly damage under future storms, perpetuating cycles of service disruption and recovery delays.

COMMUNITY LIFELINES

Community lifelines in Puerto Rico covering safety and security, food, water, shelter, health, energy, communications, transportation, and hazardous materials are highly vulnerable to extreme winds from hurricanes and tropical storms. Wind damage to power lines, hospitals, transportation routes, and communication systems quickly cascade across sectors, amplifying disruption to essential services.

FEMA introduced the Community Lifelines Framework in 2019 to provide a standardized method for identifying and prioritizing the critical services that sustain communities during disasters. Rather than focusing solely on physical infrastructure, the framework emphasizes the functions that must remain operational or be rapidly restored to protect lives, stabilize incidents, and enable recovery. FEMA identifies seven primary lifelines Safety and Security; Food, Hydration, and Shelter; Health and Medical; Energy; Transportation; Hazardous Materials; and Water Systems as the backbone of resilience. When any of these lifelines are disrupted, cascading impacts spread across sectors and increase the vulnerability of populations, especially in areas already facing social and economic challenges.[436]

[435] RAND Corporation, "After Hurricane María: Predisaster Conditions, Postdisaster Experiences, and Recovery in Puerto Rico's Communities," RAND Research Report RR-2606, 2020.
[436] FEMA, "Community Lifelines Implementation Toolkit, Version 2.0," Washington, D.C.: Federal Emergency Management Agency, November 2019.

For Puerto Rico, this framework is particularly relevant given the island's exposure to extreme wind hazards from hurricanes and tropical storms, which have repeatedly demonstrated the interdependence among lifelines. High winds topple transmission lines, damage hospitals and shelters, sever communications, and block transportation routes, resulting in widespread service interruptions that amplify disaster impacts well beyond the initial event. By structuring the risk assessment of community assets around FEMA's lifeline approach, Puerto Rico can ensure that mitigation strategies target the most critical vulnerabilities, enhance continuity of essential services, and strengthen overall resilience to future extreme wind events.

SAFETY AND SECURITY

Extreme winds from hurricanes pose a severe risk to municipal and state facilities that support public safety, including police stations, fire stations, correctional facilities, and emergency operations centers. Roof failures, structural damage, and debris impacts can disrupt law enforcement and emergency response capabilities at the precise moment they are most needed. Loss of access routes due to downed power lines or blocked roads further delays response. The disruption of this lifeline directly undermines the ability to maintain order, provide security, and coordinate disaster response.

FOOD, HYDRATION, AND SHELTER

Food distribution networks, grocery stores, and municipal shelter facilities are highly vulnerable to wind damage and power outages. Hurricane Maria highlighted this when the loss of refrigerated storage, blocked roads, and damaged ports led to widespread shortages of food and bottled water. Shelters, often located in schools or community centers, are prone to roof and window failures under extreme winds, reducing their capacity to house evacuees safely. Ensuring that shelters are wind-resistant and supplied with backup power remains a critical mitigation priority.

HEALTH AND MEDICAL

Hospitals, clinics, and emergency medical services depend heavily on structurally sound facilities and reliable utilities. High winds can damage hospital roofs, destroy medical supply warehouses, and limit access to facilities. Ambulances and mobile units are delayed by debris-clogged roads, while prolonged power outages compromise life-saving equipment and refrigeration for medicines. Hurricane Maria's extensive damage to the health sector in 2017 underscored the cascading risks when medical lifelines fail under extreme winds.

ENERGY

Energy infrastructure is among the most vulnerable to extreme wind hazards in Puerto Rico. Transmission lines and substations are consistently damaged during hurricanes, leading to widespread and prolonged blackouts. High winds topple poles and damage distribution networks, while debris and flooding complicate repair efforts. The collapse of the electrical system after Hurricane Maria demonstrated how dependent all other lifelines are on the stability of this sector.

COMMUNICATIONS

Telecommunications towers, antennas, and fiber optic lines are highly exposed to wind damage. Hurricanes frequently sever communications, as was seen in 2017 when more than 90% of cell towers failed island-wide. The loss of 911 systems, radio networks, and internet connectivity prevents coordination of emergency response, hampers public warnings, and isolates communities. Hardening communication networks is critical to lifeline resilience.

TRANSPORTATION

Airports, seaports, and local road systems face significant disruption during hurricanes. Extreme winds damage runways, port cranes, signage, and bridges, while debris and downed power lines block roads. These impacts slow the delivery of relief supplies and delay evacuation or reentry into affected communities. The closure of Luis Muñoz Marín International Airport after Hurricane Maria illustrates how quickly extreme winds can sever Puerto Rico's link to outside assistance.

HAZARDOUS MATERIALS

Facilities that store fuel, chemicals, or hazardous waste are also at risk of wind damage, which can cause leaks, spills, or fires. High winds can damage storage tanks, pipelines, and containment systems, creating environmental hazards in addition to public safety threats. Municipal landfills and industrial areas near coastal or flood-prone zones face compounded risks when strong winds are combined with storm surge or flooding.

WATER SYSTEMS

Water treatment plants, pumping stations, and distribution lines are exposed to wind-related damage, particularly from falling debris and the loss of power needed to operate pumps. After Hurricane Maria, many municipalities faced weeks without potable water because of collapsed transmission lines and damaged pumping infrastructure. Wind-driven damage to these assets can rapidly cascade into public health crises, emphasizing the need for hardened facilities and redundant power supplies.

Changes in Development

Over recent decades, Puerto Rico's development patterns have evolved in ways that directly affect its vulnerability to extreme wind hazards. Urban expansion, coastal construction growth, and incremental regulatory updates have altered exposure, while demographic decline, informal construction, and aging infrastructure have constrained adaptive capacity. Assessing these shifts is essential to understand how both the state and its municipalities remain exposed to wind related damage during future hurricanes.

LAND USE AND BUILT ENVIRONMENT CHANGES

Although Puerto Rico's overall population growth has slowed, the trend of sprawl and peripheral development continues. Urban land uses cover roughly 16% of the island's surface, much of it expanding

into rural roads and exurban fringes.[437] This dispersed growth increases the footprint of infrastructure networks and places more assets in exposed terrain, where they are harder to service and protect. Coastal development has accelerated, with construction permits in shoreline municipalities increasing by nearly 30% from 2020 to 2021, and coastal towns representing about 65% of permit activity over seven years.[438] These shifts place public and private assets in high-hazard zones, where they face amplified wind loads and compounding risks from storm surge.

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Future growth is likely to concentrate along coastal corridors and in redeveloped urban centers. While Puerto Rico adopted updated building codes in 2018 to improve wind resistance, many existing assets remain locked into more vulnerable forms due to legacy construction.[439] Redevelopment trends will therefore play a critical role in determining whether resilience is improved or vulnerabilities persist. The risk is that without strong enforcement of building standards, redevelopment will reinforce exposure in hazard-prone zones rather than mitigate it.

POPULATION CHANGES

Puerto Rico's population declined by 13.7% between 2000 and 2020,[440] with projections indicating continued contraction and aging. These demographic shifts reduce municipal tax bases and state revenues, limiting funds for retrofits, maintenance, and enforcement of stronger building standards. Out-migration also leaves vacant and deteriorating structures, which may not be maintained to withstand extreme winds. Conversely, some population growth in coastal municipalities has reinforced settlement in high-exposure areas, highlighting uneven vulnerability across the island.

VULNERABILITY OF STATE ASSETS CHANGES

State-owned infrastructure, including hospitals, schools, energy and water facilities, and ports, continues to face high exposure to extreme winds due to deferred maintenance and the legacy of aging assets. Many of these facilities were built decades before the adoption of modern codes, and retrofits have lagged due to fiscal constraints. Although recent efforts have emphasized strengthening power and water systems, vulnerabilities remain, particularly for facilities that serve as critical lifelines during hurricanes.

VULNERABILITY OF LOCAL ASSETS CHANGES

Municipal assets city halls, emergency service buildings, community centers, and small road networks remain highly vulnerable to extreme winds. After Hurricane Maria confirmed that many municipalities lacked comprehensive inventories or structural condition assessments of their facilities, making it difficult to plan targeted retrofits. Informal or unpermitted construction compounds the risk at the local level, as such assets

[437] . ResearchGate. Patterns of Urban Development of Puerto Rico.
[438] Latino Rebels, "Puerto Rico Gave 3,000 Coastal Development Permits in 7 Years," January 28, 2022.
[439] International Code Council (ICC), "Puerto Rico Reconstruction Efforts Underway," 2018.
[440] Financial Oversight and Management Board for Puerto Rico, "A Changing Population: Understanding Puerto Rico's Demographic Trends," 2020.

often fail at much lower wind speeds.[441] As municipalities face fiscal and administrative strain, the capacity to reduce vulnerabilities in their building stock has not kept pace with the increasing hazard profile.

Mitigation Success Stories

In the years since Hurricanes Irma and Maria, and more recently Hurricane Fiona, Puerto Rico has advanced a range of hazard mitigation efforts designed to reduce vulnerability to extreme winds and their cascading impacts. These initiatives demonstrate how coordinated investments, from large scale federal programs to community driven projects, can strengthen resilience across the island. While FEMA mitigation grants have supported wind retrofits of public buildings, modernization of the electric grid, and comprehensive planning through local hazard mitigation plans, nonprofit organizations, and community groups have complemented these efforts by focusing on grassroots resilience. Examples include roof repair brigades, resilience centers, solar microgrids, and community energy cooperatives that provide critical lifelines during extended outages.

Highlighting these success stories not only shows the progress achieved in the last five years, but also provides lessons learned and replicable models for future mitigation. Together, they illustrate that reducing Puerto Rico's vulnerability to extreme winds requires a multi-layered approach integrating federal funding, state and municipal leadership, and the active participation of nonprofits and local communities.

ALL HANDS AND HEARTS ROOF REPAIR & COMMUNITY INFRASTRUCTURE

From January 2018 to March 2022, All Hands and Hearts led recovery efforts in Puerto Rico following Hurricanes Irma and Maria. Focused on the municipalities of Yabucoa and Barranquitas, the nonprofit repaired and reinforced roofs, helping wind resilience to vulnerable homes and rebuilding critical community infrastructure.

RESILIENCE CENTERS / COMMUNITY CLIMATE ADAPTATION

In 2023, a university-community collaboration supported the development of local resilience centers designed to serve as *hubs* during emergencies, including wind-related events. The initiative produced an Emergency Management Toolkit, an emergency mapping system, and established formal outreach networks among participating centers to strengthen community preparedness and response.

CASA PUEBLO / SOLAR & ENERGY RESILIENCE

Since Hurricane Maria, Casa Pueblo in Adjuntas has distributed solar energy solutions to promote resilience and energy independence. Through rooftop and community-scale installations, they've supported households, one nursing home, fire station, community radio station, and local businesses. These systems help maintain power during wind-driven grid outages, ensuring continuity of critical services.

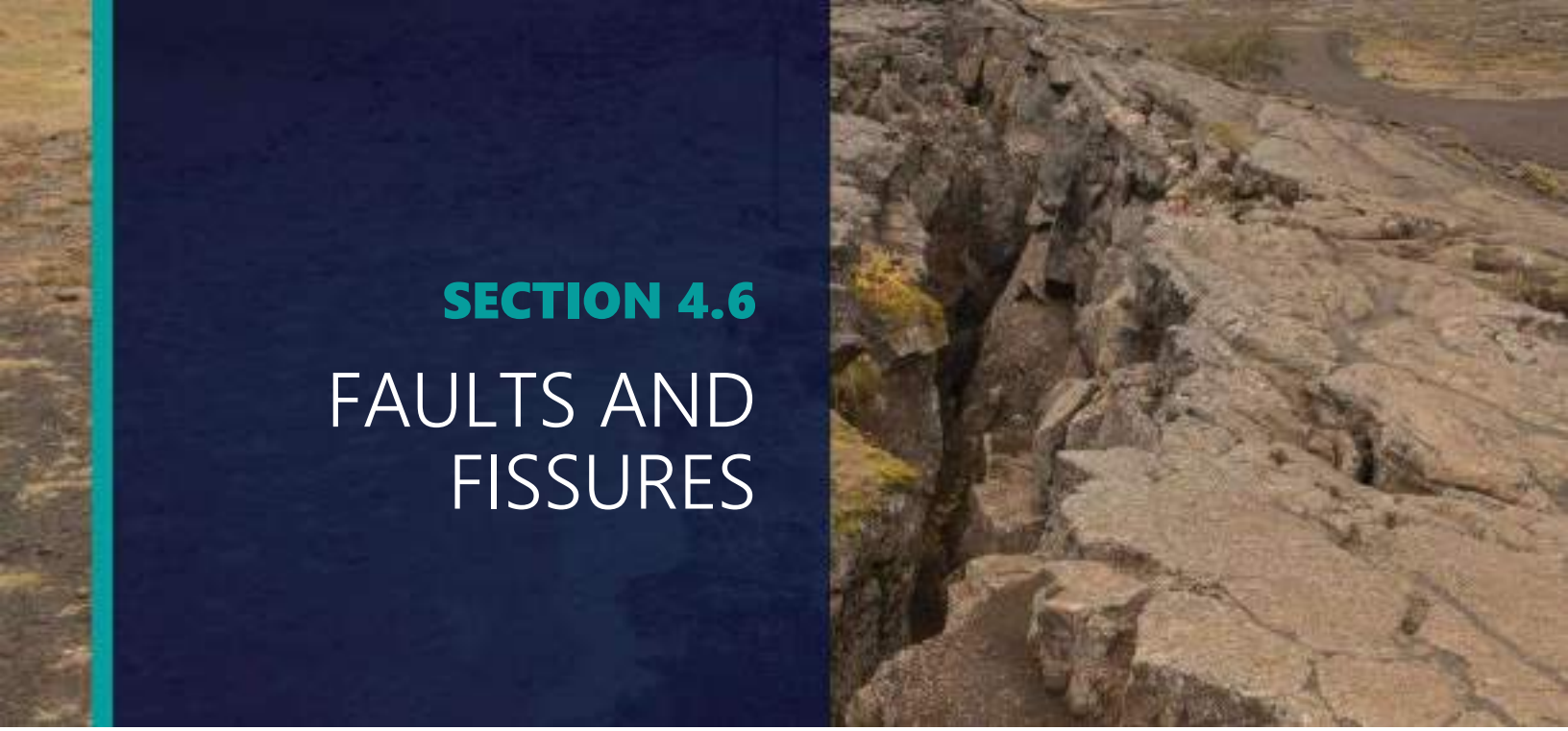
[441] American Bar Association (ABA), "Lack of Proof of Ownership in Puerto Rico Is Crippling Repairs in the Aftermath of Hurricane Maria," 2018.

MENNONITE CENTRAL COMMITTEE (MCC) — SOLAR RELIEF & ENERGY SECURITY

Following Hurricane Maria, MMC partnered with local nonprofit Casa Pueblo to deliver solar energy systems to vulnerable households and communities across Puerto Rico. These off-grid installations provide reliable power during extended outages caused by hurricanes, enhancing resilience against extreme winds and impacts on the centralized electrical grid.

COOPERATIVA HIDROELÉCTRICA DE LA MONTAÑA — COMMUNITY ENERGY COOPERATIVE

Established in 2019, the Cooperativa Hidroeléctrica de la Montaña is a community-led electric cooperative working to restore hydroelectric plants Caonillas and Dos Bocas and deploy microgrids that integrate hydropower and solar energy. Serving municipalities such as Adjuntas, Jayuya, Lares, Maricao, and Utuado, the cooperative aims to provide resilient, locally managed power systems that reduce vulnerability during grid failures caused by extreme wind events.



SECTION 4.6

FAULTS AND FISSURES

Faults and Fissures

FAULTS AND FISSURES DEFINITION

A fault is a fracture or zone of fractures between two blocks of rock, causing displacement over time, resulting in an earthquake.[442]

A fissure is a fracture that can be formed by tectonic processes and hydrologic processes associated with groundwater deposits, opened significantly by cleavage with direction normal to the fracture plane.

The Fault Plane

A fault plane is the fracture surface of a fault. A fault trace or fault line is where the fault can be seen or mapped on the surface. A fault trace is also the line commonly plotted on geologic maps to represent a fault. According to the U.S. Geological Survey (USGS), earth scientists classify faults based on the angle of the fault (the dip in the surface of the earth) and the direction of the slip along the fault line (dip-slip faults) or the motion of the fault. The types of faults are as follows[443]:

- **Normal Fault:** Dip-slip faults are incline fractures where vertical movement of the block above the fault moves downward in relation to the block below (see Figure 144).

[442] U.S. Geological Survey, "What is a Fault and What are the Different Types?" 2025, https://www.usgs.gov/faqs/what-a-fault-and-what-are-different-types.
[443] U.S. Geological Survey, "What is a Fault and What are the Different Types?" 2025, https://www.usgs.gov/faqs/what-a-fault-and-what-are-different-types.

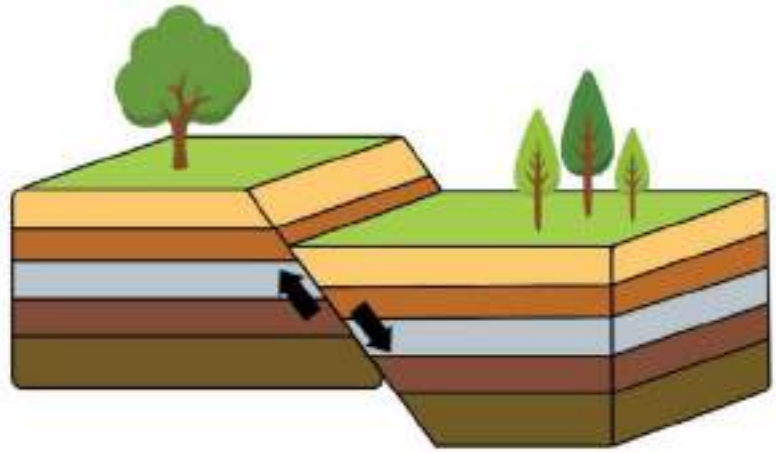


Figure 144: Normal Fault[444]

- **Reverse (Thrust) Fault:** When the rock above the fault moves upward and over the block below, the dip-slip fault is called a reverse fault (see Figure 145). When the dip angle for the reverse fault is shallow, it is described as a **thrust fault** (see Figure 145).

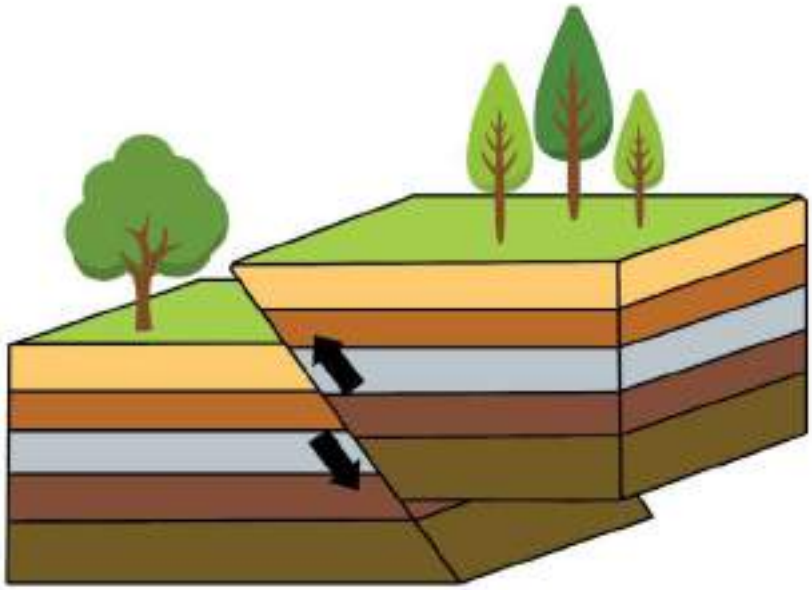


Figure 145: Reverse Fault Illustration[445]

- **Blind Thrust:** This type of thrust fault does not rupture all the way to the surface, and therefore cannot be detected on the ground. It stays buried under the uppermost layers of rock in the earth's crust (see Figure 146).

[444] U.S. Geological Survey, "Normal Fault Illustration," 2025, https://www.usgs.gov/media/images/normal-fault.
[445] U.S. Geological Survey, "Reverse Fault Illustration," 2025, https://www.usgs.gov/media/images/reverse-fault.

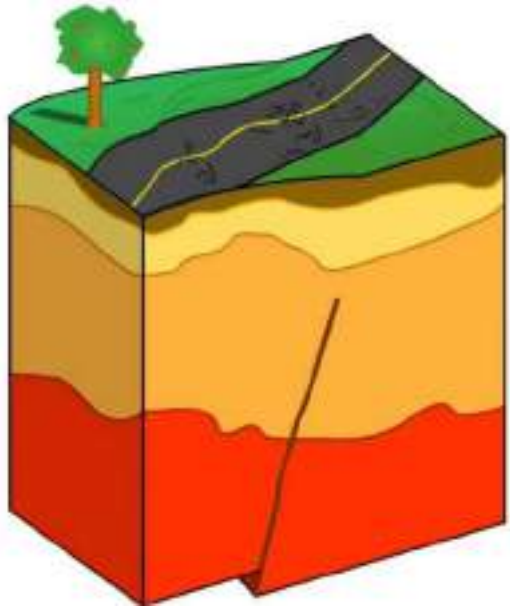


Figure 146: Blind Thrust Fault Illustration[446]

- **Strike-Slip Fault (Transform Fault)**: This type of fault forms when two blocks in the fault slide past one another (see Figure 147).

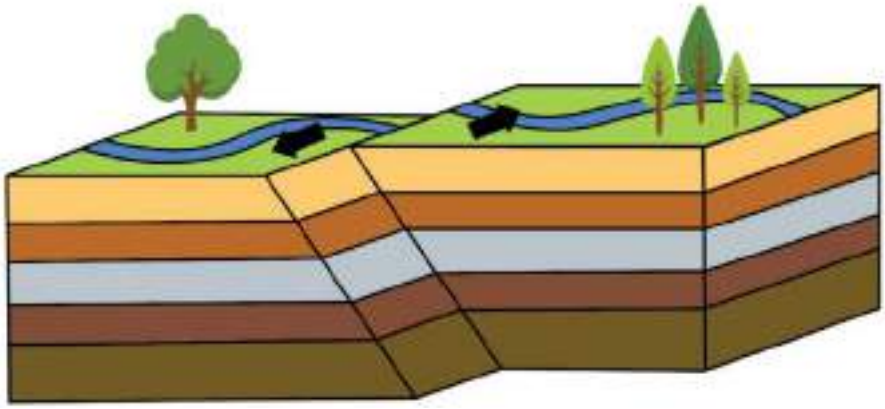


Figure 147: Strike-Slip Fault[447]

- **Left Lateral Strike-Slip Fault:** When displacement of the far block is to the left when viewed from either side, the fault is called a left lateral strike-slip fault.
- **Right Lateral Strike-Slip Fault:** When displacement of the far block is to the right when viewed from either side, the fault is called a right lateral strike-slip fault.

[446] U.S. Geological Survey, "Blind Thrust Fault Illustration," 2025, https://www.usgs.gov/media/videos/blind-thrust-fault.
[447] U.S. Geological Survey, "Strike-Slip Fault Illustration," 2025, https://www.usgs.gov/media/images/transform-fault.

For Puerto Rico's location in the Greater Antilles, the dominant faults are strike-slip faults with dip- or oblique-slip structures at stepovers.[448]

Location

Puerto Rico occupies a highly active tectonic zone where the North American and Caribbean plates interact, producing a complex fault network. Strike-slip faults dominate the region, accommodating most of the lateral plate motion, while normal faults occur in extensional zones such as the Mona Rift, and thrust faults are concentrated in subduction-related areas like the Muertos Trough. This structural diversity is critical for hazard mitigation because each fault type influences earthquake magnitude, rupture behavior, and secondary hazards such as tsunamis and landslides.[449]

The most recognized and potentially hazardous structures include the Puerto Rico Trench, Mona Canyon, Northern Fault Zone Sombrero Seismic Zone, and Mona Passage. These major offshore faults are capable of generating large-magnitude earthquakes, including megathrust events, and pose significant tsunami risk due to their proximity to subduction zones and steep bathymetric slopes. Understanding these fault systems is essential for seismic design standards, land-use planning, and emergency preparedness. Table 53 and Figure 148 summarize the principal fault systems affecting Puerto Rico, their locations, and structural characteristics, providing a foundation for targeted mitigation strategies.[450]

Table 53: Puerto Rico Faults[451]

Fault Name	Relative Location to Island	Absolute Location	Fault Type[1]
Anegada Fault	South-Southeast	(17.91°N, -64.39°W) to (17.72°N, -66.49°W)	Strike-slip
Mona Fault (East)	Northwest	(19.10°N, -67.32°W) to (18.52°N, -67.26°W)	Normal faulting
Mona Fault (West)	Northwest	(18.98°N, -67.50°W) at (18.42°N, -67.64°W)	Normal faulting
Great Northern Fault Zone	Center-East	(18.18°N, -65.72°W) to (18.31°N, -66.30°W)	Strike-slip
Great Southern Fault Zone	Midwest	(18.05°N, -66.51°W) to (18.28°N, -67.09°W)	Strike-slip

[448] R. Styron, J. García-Pelaez, and M. Pagani, "CCAF-DB: the Caribbean and Central American Active Fault Database," *Nat. Hazards Earth Syst. Sci.,* 20, 831–857, https://nhess.copernicus.org/articles/20/831/2020/.
[449] R. Styron, J. García-Pelaez, and M. Pagani, "CCAF-DB: the Caribbean and Central American Active Fault Database," *Nat. Hazards Earth Syst. Sci.,* 20, 831–857, https://nhess.copernicus.org/articles/20/831/2020/.
[450] USGS, "Faults of the Caribbean Region.," 2021, https://www.sciencebase.gov/catalog/item/60a81702d34ea221ce4e5b49.
[451] R. Styron, J. García-Pelaez, and M. Pagani, "CCAF-DB: the Caribbean and Central American Active Fault Database," *Nat. Hazards Earth Syst. Sci.,* 20, 831–857, https://nhess.copernicus.org/articles/20/831/2020/.

Fault Name	Relative Location to Island	Absolute Location	Fault Type[1]
Muertos Trough	South	(17.45°N, -64.16°W) to (17.23°N, -68.30°W)	Thrust/reverse faulting (subduction-related)
Puerto Rico Trench	North	(19.72°N, -63.23°W) to (19.59°N, -68.38°W)	Oblique subduction zone with a large strike-slip component
Northern Fault	Northwest	(18.99°N, -67.48°W) to (19.10°N, -68.35°W)	Strike-slip
Hat Failure (Anegada Passage)	Southeast-Southwest	(18.86°N, -63.69°W) to (17.94°N, -65.42°W)	Transtensional faulting
South Puerto Rico Slope Fault	Offshore south of Puerto Rico, near the Muertos Trough region	Approx 18.0°N, -66.5°W to 17.8°N, -67.3°W	Strike-slip
North Puerto Rico Slope Fault	Offshore north of Puerto Rico, between the island and Puerto Rico Trench	Approx. 18.8°N, -66.0°W to 19.2°N, -66.8°W	Strike-slip
Cordillera-Joyuda Faults	Offshore west of Puerto Rico, near Mona Passage	Approx. 18.2°N, -67.0°W to 18.4°N, -67.4°W	Strike-slip
Yuma Rift	Offshore southwest Puerto Rico, south of Mona Rift	Approx 17.9°N, -67.2°W to 18.0°N, -67.4°W	Normal faulting (extension)

In addition to these large-scale offshore structures, Table 54 illustrates recent geological and geophysical investigations have documented seven onshore faults within Puerto Rico that exhibit evidence of Holocene activity, meaning they have been active within the last 11,700 years. This is a critical finding because Holocene activity strongly suggests these faults remain capable of generating earthquakes in the present tectonic regime.[452]

Unlike the major offshore megathrust systems, which can produce extremely high-magnitude events (M7.5–8.5) but are often located far from population centers, these onshore faults are generally smaller in length and displacement. However, their proximity to urban areas and critical infrastructure significantly elevates their risk profile. Even moderate-magnitude earthquakes (M6–7) originating from these faults can cause

[452] A. M. López et al., "Neotectonic Mapping of Puerto Rico: Evidence for Active Faults and Implications for Seismic Hazard," *Seismica*, 2025, https://seismica.library.mcgill.ca/article/view/1102.

severe localized damage, particularly in regions with vulnerable building stock, aging lifelines, and limited redundancy in transportation and utility networks.[453]

Several of these faults, such as the South Lajas Fault, Salinas Fault, and Punta Montalva Fault, are situated in southwestern Puerto Rico, an area that experienced intense seismic activity during the 2019–2020 earthquake sequence, including the January 7, 2020, M6.4 event. Geological evidence from trenching, ground-penetrating radar, and paleoseismic studies indicates that these faults have produced surface ruptures or deformation features in the recent geologic past. Recurrence intervals range from approximately 3,000 to 4,000 years, underscoring their long-term seismic potential.[454]

Table 54: Active Onshore Faults Identified Through Geological Investigations

Fault Name	Location in Puerto Rico	Fault Type
South Lajas Fault	Southern edge of Lajas Valley (SW Puerto Rico)	Normal with oblique component
Salinas Fault	Southern Puerto Rico near Salinas	Normal (down-to-south), possible lateral
Punta Montalva Fault	Southwestern Puerto Rico (near Parguera coast)	Strike-slip (left-lateral) with vertical
Great Southern Puerto Rico Fault Zone	Southeastern Puerto Rico (near Central Aguirre)	Oblique (strike-slip + normal)
Cerro Goden Fault Zone	Western Puerto Rico (Añasco Valley)	Likely strike-slip with vertical
Parguera Fault	Southwestern coast near La Parguera	Normal (down-to-south)
San Marcos Fault	South-central Puerto Rico (north of Ponce)	Normal (down-to-south)

[453] A. M. López et al., "Neotectonic Mapping of Puerto Rico: Evidence for Active Faults and Implications for Seismic Hazard," *Seismica*, 2025, https://seismica.library.mcgill.ca/article/view/1102.
[454] A. M. López et al., "Neotectonic Mapping of Puerto Rico: Evidence for Active Faults and Implications for Seismic Hazard," *Seismica*, 2025, https://seismica.library.mcgill.ca/article/view/1102.

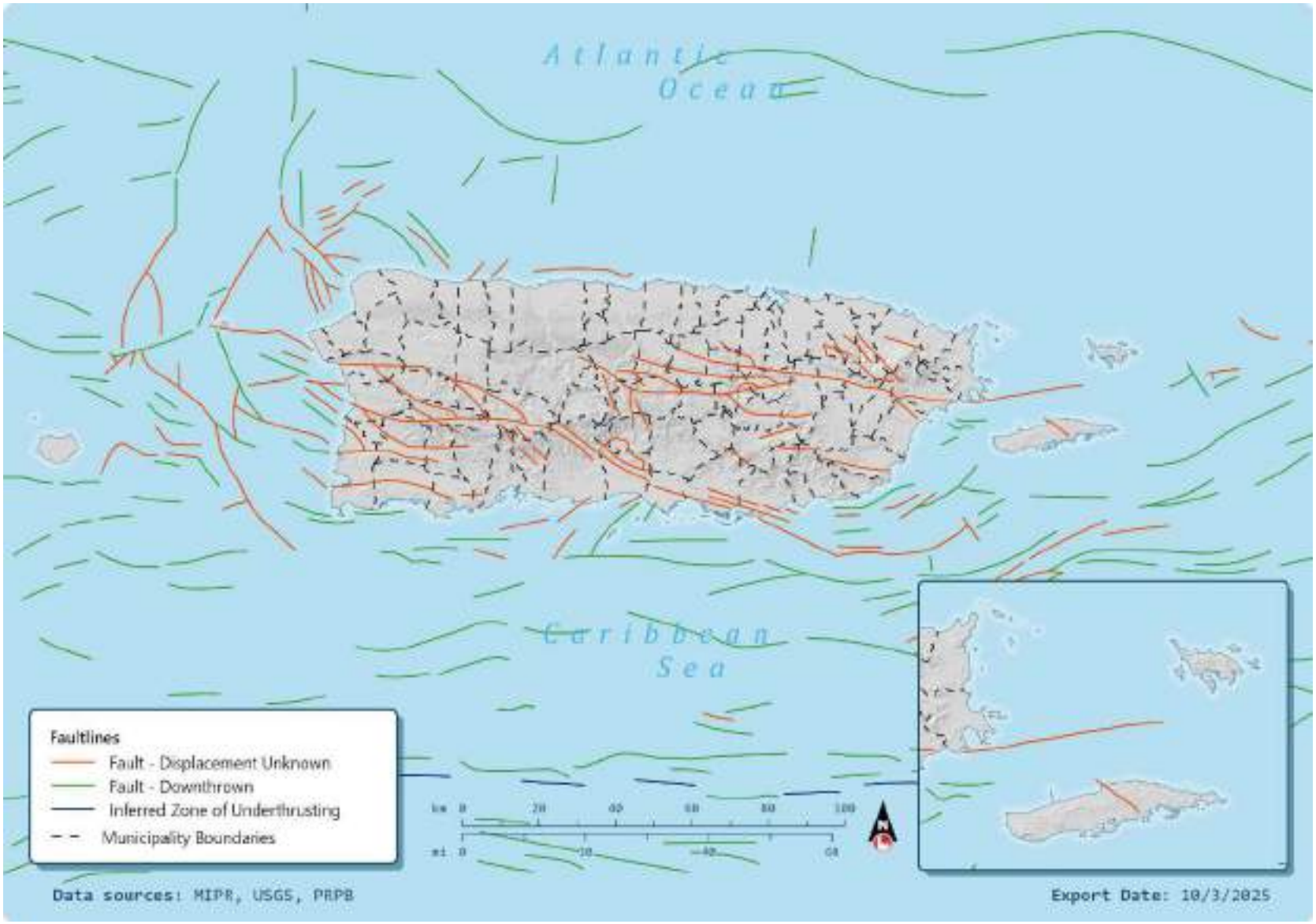


Figure 148: Fault Lines in Puerto Rico

Previous Occurrences

The USGS conducted submerged fault studies in the southern area of Puerto Rico after the January 7, 2020, earthquake event, and revealed the existence of new faults. The studies confirmed a submarine extension of the North Boquerón–Punta Montalva Fault. USGS tentatively identified several additional faults lying 4 and 9 miles offshore, in waters up to about 3,300 feet deep, also within areas identified as the epicenters of some of the 2019–2020 earthquakes.[455]

FEDERAL DISASTER DECLARATIONS

Geological faults are the underlying source of earthquakes; they represent fractures in the earth's crust where stress accumulates until sudden movement releases energy as seismic waves. Because earthquakes are the direct manifestation of fault activity, federal disaster declarations are categorized under earthquake events, not under faults and fissures. This classification reflects the practical reality that disasters are declared based on the impacts of ground shaking damage to infrastructure, displacement of populations, and cascading lifeline failures rather than the mere existence of geological structures. Consequently, there have been no federal disaster declarations for faults or fissures.

PUERTO RICO DISASTER DECLARATIONS

As of September 2025, no disaster declarations have been issued for faults and fissures. However, officials in Puerto Rico issue local disaster declarations for earthquake events rather than for faults or fissures, since earthquakes directly result from fault activity. This approach reflects the practical reality that declarations are based on the impacts of ground shaking, such as structural damage, population displacement, and cascading lifeline failures, rather than the mere presence of geological structures. Consequently, Puerto Rico has not issued any disaster declarations specifically for faults or fissures, as the hazard addressed in emergency management is the earthquake and its consequences, not the fault feature alone.

SIGNIFICANT EVENTS

Faults represent fractures in the earth's crust where stress accumulates until it is suddenly released as seismic waves, producing ground shaking that causes harm. For this reason, the hazard addressed in mitigation planning is earthquakes, not faults or fissures, because the damage to infrastructure, loss of life, and cascading lifeline failures result from the earthquake phenomenon not from the mere existence of a fault.

Puerto Rico's seismic history underscores this distinction. The 1787 earthquake, estimated at magnitude 8.0, originated in the Puerto Rico Trench, a subduction zone north of the island, and caused widespread destruction, including the collapse of churches and damage to San Juan's fortifications. The 1867 earthquake, with a magnitude of 7.3, struck the Anegada Passage between Saint Thomas and Saint Croix, generating a tsunami that impacted Puerto Rico's southern and western coasts. The 1918 San Fermín earthquake, magnitude 7.1–7.2, was linked to the Mona Canyon fault and triggered a tsunami that

[455] U.S. Geological Survey, "Scientist Find Signs of Undersea Faults off SW Puerto Rico," 2025, https://www.usgs.gov/media/images/scientists-find-signs-undersea-faults-sw-puerto-rico.

devastated western Puerto Rico, killing 116 people. More recently, the January 7, 2020, earthquake, magnitude 6.4, occurred near Guayanilla along the South Lajas fault system, damaging homes, schools, and critical infrastructure, and prompting a federal disaster declaration. These events illustrate that while faults define seismic potential, the hazard and the harm is the earthquake itself.

Potential Severity of Event

Fault hazard assessments prioritize magnitude over intensity because magnitude reflects the total energy released at the fault source. Magnitude measures the total energy released at the earthquake source (fault rupture) and is a physical property of the fault system linked to its length, width, slip rate, and rupture characteristics. Intensity, by contrast, describes the effects of shaking at specific locations, which vary by distance, soil conditions, and building vulnerability. Intensity is an impact metric, not a source metric. Thus, when evaluating faults, planners use potential magnitude, as Table 55 confirms, because it reflects the maximum earthquake size a fault can generate, not the variable shaking experienced across communities.[456] As demonstrated in Table 55, Puerto Rico could face devastating consequences as a result of faults and fissures as the potential magnitude of a corresponding earthquake could be up to 8.5 Mw.

Table 55: Potential Magnitudes of Major Faults in Puerto Rico

Fault Name	Relative Location	Absolute Location	Potential Magnitude
Anegada Fault	South-Southeast	(17.91°N, -64.39°W) to (17.72°N, -66.49°W)	7.7
Mona Fault (East)	Northwest	(19.10°N, -67.32°W) to (18.52°N, -67.26°W)	7.5
Mona Fault (West)	Northwest	(18.98°N, -67.50°W) to (18.42°N, -67.64°W)	7.5
Great Northern Fault Zone	Center-east	(18.18°N, -65.72°W) to (18.31°N, -66.30°W)	6.8
Great Southern Fault Zone	Midwest	(18.05°N, -66.51°W) to (18.28°N, -67.09°W)	6.6
Failure of the Dead	South	(17.45°N, -64.16°W) to (17.23°N, -68.30°W)	7.6
Puerto Rico Trench	North	(19.72°N, -63.23°W) to (19.59°N, -68.38°W)	8.5
Northern Fault	Northwest	(18.99°N, -67.48°W) to (19.10°N, -68.35°W)	7.8
Hat Failure	Southeast-southwest	(18.86°N, -63.69°W) to (17.94°N, -65.42°W)	7.7

For reference, the following three faults represent the most significant sources of seismic energy in the region based on their potential magnitude: Puerto Rico Trench, Anegada Fault, and Northern Fault Zone. This discussion focuses exclusively on the physical capacity of these fault systems to generate large

[456] D. G. Masson and K. M. Scanlon, "The Neotectonic Setting of Puerto Rico. *Tectonics, 18*(6), 1124–1139, 1999, https://doi.org/10.1029/1999TC001170.

earthquakes, as determined by their tectonic characteristics and estimated maximum magnitudes. It does not address the variable impacts of ground shaking, infrastructure damage, or cascading lifeline failures, which are analyzed separately in the Earthquake Hazard Profile. By isolating fault potential, this section provides a clear understanding of the underlying geologic severity that shapes Puerto Rico's seismic risk landscape.

PUERTO RICO TRENCH FAULT

The Puerto Rico Trench is the deepest part of the Atlantic Ocean and represents a highly oblique subduction zone where the North American plate is being forced beneath the Caribbean plate. This fault system is capable of generating megathrust earthquakes up to magnitude 7.9, making it the most hazardous structure in the region. Historically, the trench has produced catastrophic events, such as the 1787 earthquake (estimated M8.0) that caused widespread destruction across Puerto Rico, including San Juan's fortifications. The areas most vulnerable to a major rupture here would be northern Puerto Rico, particularly coastal municipalities like San Juan, Arecibo, and Aguadilla, due to proximity to the trench and the risk of tsunamis triggered by submarine landslides. The trench's ability to produce both strong shaking and tsunamis underscores its extreme hazard profile for densely populated northern coastal zones.[457]

ANEGADA FAULT

The Anegada Fault lies southeast of Puerto Rico within the Anegada Passage, a transtensional zone accommodating plate motion between the Caribbean and North American plates. It is primarily a strike-slip fault, but with extensional components that create pull-apart basins. This fault is capable of producing earthquakes up to magnitude 7.7, which, while smaller than the trench's megathrust potential, still represents a severe hazard. Historically, the 1867 earthquake (M_s ~7.3) in this region generated a destructive tsunami that impacted the Virgin Islands and southeastern Puerto Rico. The areas most vulnerable to an Anegada Fault rupture include eastern Puerto Rico, particularly Fajardo and Humacao, as well as offshore islands like Vieques and Culebra. These regions face compounded risks from ground shaking and tsunami inundation due to their coastal exposure and limited evacuation routes.[458]

NORTHERN FAULT ZONE

Northwestern Puerto Rico is exposed to significant seismic hazard from offshore crustal faults located near the plate boundary. These faults accommodate lateral motion and are part of a complex tectonic regime that includes strike-slip and oblique components. While the largest earthquakes in the region are associated with the plate interface (up to M~8.0), crustal faults near the northwest coast are modeled to produce events in the magnitude 6–7 range, which can still cause severe ground shaking in adjacent areas. The primary hazard from these faults is intense shaking rather than tsunami generation, as strike-slip mechanisms generally have limited tsunami potential. Communities in northwestern Puerto Rico are considered

[457] U.S. Geological Survey, "Seafloor Map of Puerto Rico Trench," 2025, https://www.usgs.gov/media/images/seafloor-map-puerto-rico-trench; D. G. Masson, and K. M. Scanlon, "The Neotectonic Setting of Puerto Rico," *Tectonics, 18*(6), 1124–1139, 1999, https://doi.org/10.1029/1999TC001170.

[458] C. S. Mueller et al., *Documentation for 2003 USGS Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Islands* (Open-File Report 03-379), U.S. Geological Survey, 2004, https://pubs.usgs.gov/of/2003/ofr-03-379/OFR-03-379.pdf.

vulnerable due to their proximity to these offshore structures, making seismic design and retrofitting critical for reducing risk.[459]

Probability of Future Hazard Events

The probability of future faults and fissures hazard events remains an ever present threat to Puerto Rico due to its location within a complex plate boundary zone between the North American and Caribbean plates. The island lies on the Puerto Rico–Virgin Islands microplate, which is compressed between these major plates and interacts through subduction, strike-slip, and extensional faulting. This tectonic setting includes the Puerto Rico Trench to the north and the Muertos Trough to the south, creating one of the most seismically active regions in the Western Hemisphere.

However, the overall probability of a notable faults- and fissures-related event is considered low. As outlined in the Earthquake Risk Profile, geological surveys indicate ground motions corresponding to a 10% probability of exceedance in 50 years—an approximate 500-year return period across much of Puerto Rico. These models incorporate historical seismicity, GPS-constrained slip rates, and fault-specific recurrence intervals, confirming that the region can generate high-intensity earthquakes, including megathrust events along the subduction interface and large crustal earthquakes in extensional zones such as the Mona Passage and Anegada Passage. Ongoing geophysical surveys aim to refine fault characterization, which may reveal additional active structures, further emphasizing the island's elevated seismic hazard and the need for robust seismic design standards.[460]

As with the 2021 Puerto Rico State Hazard Mitigation Plan update, there remains the need to further understand and characterize the conditions of faults and fissures located on or around the island. Understanding the state of faults is essential to evaluating and modeling the probability of occurrence of a tsunami and the magnitude of earthquakes that could be generated from the characteristics of the fault. Lesser documented events, including very small earthquakes, may be underrepresented by this analysis of probability as current studies focus on the estimated probability of exceedance of larger events.

Vulnerability Assessment

Communities across Puerto Rico are highly vulnerable to the impacts of a hazard event caused by faults and fissures due to the island's tectonic setting and structural exposure. Most seismic energy is released along deep or offshore fault systems, meaning that ground shaking, not surface rupture, is the primary driver of damage. However, in rare cases, shallow faulting or fissure formation can occur, potentially causing uneven land surfaces and localized ground deformation. These occurrences are uncommon but possible, particularly near active fault zones such as the South Lajas Fault or areas of crustal extension like the Mona

[459] D. G. Masson and K. M. Scanlon, "The Neotectonic Setting of Puerto Rico," *Geological Society of America Bulletin, 103*(1), 144–154, 1991, https://doi.org/10.1130/0016-7606(1991)103<0144:TNSOPR>2.3.CO;2.
[460] C. Mueller et al., "New Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Islands." *Earthquake Spectra,* 26(1), 169-185, 2010, https://earthjay.com/earthquakes/20200107_puerto_rico/mueller_etal_2010_seismic_hazard_maps_puerto_rico_virgin_islands.pdf.

Passage. For this reason, land-use restrictions and geotechnical evaluations in high-risk zones may be warranted to prevent development on unstable ground and to mitigate cascading impacts on infrastructure and lifelines.

Recent geological and geophysical investigations have identified seven onshore faults with Holocene activity, meaning they remain capable of generating earthquakes under the current tectonic regime. Their proximity to urban areas and critical infrastructure significantly elevates exposure and vulnerability. Some examples follow:[461]

- South Lajas Fault, Punta Montalva Fault, and Parguera Fault are concentrated in southwestern Puerto Rico, an area that experienced intense seismic activity during the 2019–2020 earthquake sequence, including the January 7, 2020, magnitude 6.4 event. These municipalities, such as Guánica, Guayanilla, and Yauco contain aging housing stock, limited redundancy in lifelines, and critical facilities like schools and hospitals, making them highly vulnerable to localized damage.
- Salinas Fault and the Great Southern Puerto Rico Fault Zone affect southern and southeastern Puerto Rico, where industrial corridors and transportation networks are concentrated. Damage here could disrupt energy and water systems, compounding recovery challenges.
- Cerro Goden Fault Zone in western Puerto Rico and San Marcos Fault near south-central Puerto Rico pose risks to communities with older infrastructure and limited seismic retrofitting, increasing exposure for lifelines such as highways and power distribution systems.

Even moderate-magnitude earthquakes (M6–7) originating from these faults can cause severe localized damage, particularly in regions with vulnerable building stock, aging lifelines, and limited redundancy in transportation and utility networks. These findings underscore the need for targeted mitigation strategies, such as stricter building codes, retrofitting critical facilities, and land-use planning in fault-adjacent areas to reduce exposure and enhance resilience.

LOCATIONS

Puerto Rico is highly susceptible to seismic activity due to its location within the Puerto Rico–Virgin Islands microplate, which lies between the North American tectonic plate and the northeastern edge of the Caribbean plate. According to the USGS, this microplate is geologically active and capable of generating high-intensity earthquakes, posing a considerable risk to the region.[462]

POPULATIONS

Communities in Puerto Rico located near fault lines and fissures are considered at high risk of impact. These populations face elevated vulnerability to injury and loss of life during earthquake events due to potential structural damage and ground failure.

[461] A. M. López et al., "Neotectonic mapping of Puerto Rico: Evidence for Active Faults and Implications for Seismic Hazard," *Seismica*, 2025, https://seismica.library.mcgill.ca/article/view/1102.
[462] U.S. Geological Survey, "Scientist Find Signs of Undersea Faults off SW Puerto Rico," 2025, https://www.usgs.gov/media/images/scientists-find-signs-undersea-faults-sw-puerto-rico.

STRUCTURES INCLUDING CRITICAL FACILITIES

Since 2000, multiple seismic faults have been discovered within the island, many of them clearly active, which will substantially increase the seismic design loads, especially now that the new Puerto Rico seismic hazard map has been published. Therefore, if engineers have not taken these faults into account in their more recent designs, even new structures could be at a high level of vulnerability.

INFRASTRUCTURE AND COMMUNITY LIFELINES

In Puerto Rico, critical infrastructure vulnerable to seismic faults includes water lines, sanitary, pumping, roads, transmission centers, power generation plant, substations, telecommunication antennas, and shelters and can experience severe maximum acceleration. In addition, state highways are also vulnerable to seismic faults and can experience severe maximum acceleration.

PROBLEM STATEMENTS

- Based on the January 7, 2020, magnitude 6.4 earthquake scenario, the municipalities most affected by the "severe" category of maximum ground acceleration caused by this event were Guanica, Guayanilla, Penuelas, Ponce, Sabana Grande, and Yauco.
- The populations of Guanica, Guayanilla, Penuelas, Ponce, Sabana Grande, and Yauco, with a total population of 32,230, are at risk severe acceleration from faults and fissures.
- Populations living in substandard residential structures are at greater risk of death or injury from events, major property damage, and displacement.
- Populations that have large percentages of people 65 years and older and with disabilities have a greater risk of experiencing injury or death from future events.
- Mitigating vulnerable structures that pose a danger to persons and property may be challenging due to the complexities of implementing new building codes and the high costs of compliance.
- Infrastructure located on fault lines are especially vulnerable to damage in the event of a new fault or fissure event.
- Critical community lifelines located on or near fault lines and fissures are vulnerable to service disruptions, operability failures, and inaccessibility.

Impact Assessment

As outlined in the Earthquake Risk Profile, “impact” refers to the measurable consequences of seismic events, including physical damage, economic losses, casualties, and disruptions to lifelines. FEMA’s Hazus model estimates these impacts by integrating hazard, exposure, and vulnerability data. Two deterministic scenarios were analyzed: a magnitude 6.4 earthquake based on the January 2020 event and a hypothetical magnitude 8.5 rupture along the Puerto Rico Trench. The 6.4 scenario resulted in building-related losses of approximately $1.58 billion, with over 90% attributed to residential structures, and additional $945 million

in lifeline damages, primarily oil infrastructure. Municipalities closest to the epicenter, such as Guayanilla, Peñuelas, and Ponce, experienced the highest losses due to peak ground accelerations exceeding 0.5g, underscoring the correlation between shaking intensity and structural vulnerability.

In contrast, the 8.5 scenario projects catastrophic, islandwide impacts, with total economic losses exceeding $252 billion and building-related losses accounting for $158 billion. Residential structures dominate exposure, and unreinforced masonry buildings show the highest fragility, with thousands expected to sustain moderate to extensive damage. Critical infrastructure, including hospitals, schools, and emergency facilities, faces severe disruption, particularly in high-density municipalities such as San Juan, Bayamón, Carolina, and Aguadilla. These findings highlight the urgent need for seismic retrofitting, updated building codes, and targeted mitigation strategies to reduce vulnerability in areas of concentrated population and infrastructure.

COMMUNITY LIFELINES

Faults and fissures events can significantly disrupt the delivery of critical community lifelines. This was evident during the seismic activity in 2019 and 2020, when earthquakes of magnitude 5.0 and above caused structural damage to essential facilities and infrastructure.

Community lifelines represent the most fundamental services that support the functioning of society. When stabilized, they enable all other aspects of a community to operate effectively. These lifelines are vital to public safety and well-being, especially during emergencies, as they provide essential support to individuals and communities in crisis. Without them, communities become far more vulnerable to disasters and their cascading impacts.

There are eight key community lifelines, each serving a distinct and critical purpose:

SAFETY AND SECURITY

The Safety and Security Lifeline, which includes maintaining public safety, law enforcement, and security operations, provides support for communities during faults and fissures event to set up roadblocks, divert traffic away from the event, and provide safe evacuation routes or detour information. Safety and Security Lifeline disruption from faults and fissures can hinder emergency response efforts to respond to property and infrastructure failures, injuries, or fatalities.

FOOD, HYDRATION, AND SHELTER

The Food, Hydration, and Shelter Lifeline provides access to basic needs for those affected by the faults and fissures event. Access to food, water, and shelter can become a challenge if roadways are impacted by faults and fissures and supply chains are disrupted. Emergency sheltering may become necessary in the event of faults and fissures damaging powerlines that may cause prolonged power outages and limit critical access to electricity.

HEALTH AND MEDICAL

The Health and Medical Lifeline, which provides medical care and public health services, could be impacted by faults and fissures from damaged structures that limit access to critical medical care. Also, faults and fissures events in the mountainous areas of Puerto Rico could cut off single access roads that limit emergency response to medical emergencies and disrupt the distribution of medical supplies.

ENERGY

The Energy Lifeline focuses on providing power and fuel to the affected community. Damaged power lines, substations and pipelines are common during faults and fissures events. Faults and fissures can damage powerlines or require emergency power shut offs to reduce the risk of structural fires and may result in prolonged power outages. In addition, structural damage to water and wastewater systems can lead to limited access to water needed to power hydropower plants.

COMMUNICATIONS

The Communications Lifeline provides access to communication tools and services. Faults and fissures may impact communication towers located in high susceptibility areas or fault lines that cause them to collapse, disrupting communications services such as cellular service to telephones, landline telephones, and the internet. With 47 antennas situated in areas of Puerto Rico designated as moderate seismic risk and 1 in a severe zone, even partial tower collapse could interrupt cellular, landline, and internet services, hindering emergency coordination and public access to critical information.

TRANSPORTATION

The Transportation Lifeline ensures the availability of transportation services for communities during disaster events. Blocked transportation routes can cause supply chain disruptions for food, water, and medical supply deliveries and disrupt emergency response activities during faults and fissures events. Future faults and fissures in Puerto Rico could severely impact the Transportation Lifeline, disrupting access to essential services and delaying emergency response efforts. Blocked roads and damaged infrastructure may hinder the delivery of food, water, and medical supplies, especially in remote or heavily affected areas.

HAZARDOUS MATERIALS

The Hazardous Materials Lifeline includes addressing hazardous materials management. In areas with industrial facilities or near hazardous material storage, faults and fissures events can lead to spills or leaks, posing environmental and public health risks.

WATER SYSTEMS

The Water Systems Lifeline includes freshwater reservoirs, potable water distribution infrastructure, and wastewater treatment plants. Faults and fissures can damage underground infrastructure from ground shaking, and structural damage to water and wastewater systems can lead to limited access to water needed to power hydraulic power plants.

Changes in Development

Recent development trends in Puerto Rico reflect a growing emphasis on seismic resilience, driven by lessons learned from the 2019–2020 earthquake sequence and updated hazard data. Building codes have been strengthened to incorporate modern seismic provisions, including requirements for ductility, energy absorption, and site-specific ground motion analysis. The 2018 Puerto Rico Existing Building Code introduced guidelines for retrofitting unreinforced masonry structures, which remain highly vulnerable to ground shaking. These updates aim to reduce structural failure risks in areas near active fault zones and improve the performance of critical facilities such as schools, hospitals, and emergency shelters.

In addition to regulatory changes, Puerto Rico is undergoing significant redevelopment supported by federal funding for infrastructure reconstruction, including energy systems, water treatment facilities, and transportation networks. These investments prioritize seismic risk reduction and integrate updated hazard maps to guide safer land-use planning. However, aging infrastructure and phased adoption of new codes present ongoing challenges, leaving some assets exposed to fault-related hazards. Future growth strategies emphasize adaptive planning and targeted retrofitting to ensure that development aligns with the island's elevated seismic risk and mitigates cascading impacts on lifelines.

Mitigation Success Stories

2025 PUERTO RICO–U.S. VIRGIN ISLANDS NATIONAL SEISMIC HAZARD MODEL UPDATE

Researchers from the USGS and collaborating institutions developed comprehensive geologic input databases for the upcoming 2025 update of the National Seismic Hazard Model for Puerto Rico and the U.S. Virgin Islands. This update focuses on improving characterization of active crustal faults to refine seismic hazard estimates.[463]

Key Enhancements:

- Expansion of fault data: The model now includes 35 fault sections (up from 3 in the 2003 model), 6 fault-zone polygons, and 51 earthquake geology sites, significantly improving spatial coverage of active structures.
- Integration of paleoseismic trench data: Trench observations were incorporated to estimate slip rates and recurrence intervals for faults lacking published data. Slip-rate bins were assigned based on landscape expression and trench evidence.
- Revision of major zones: Structural interpretations of the Mona and Anegada extensional zones were updated to reflect new geophysical and geological findings.

[463] J. T. Jobe et al., "Geologic Input Databases for the 2025 Puerto Rico–U.S. Virgin Islands National Seismic Hazard Model Update: Crustal Faults Component," *Seismological Research Letters, 96*(2A), 1018–1044, 2025, https://doi.org/10.1785/0220230222.

- Inclusion criteria: Faults ≥7 km in length with clear evidence of Quaternary activity and peer-reviewed documentation were included.

Purpose and Impact: This project enhances understanding of active crustal faults capable of generating damaging earthquakes. By refining fault geometry, slip rates, and recurrence intervals, the updated model provides a more accurate basis for the following:

- Land-use planning near fault zones
- Seismic design standards for critical infrastructure
- Emergency preparedness and mitigation strategies

SECTION 4.7

FLOODING

Flooding

FLOODING DEFINITION

Flooding is defined as the overflowing of water onto normally dry land. It is often triggered by heavy rainfall, rapid snowmelt, coastal storm surges, or the failure of infrastructure.[464]

Flooding is classified as one of the following: inland or riverine flooding, pluvial or surface water flooding, coastal flooding, and storm surge.[465]

- *Inland or riverine flooding* occurs when rivers, streams, or lakes rise beyond their banks and overflow into adjacent land. It is usually caused by heavy rainfall, melting snow, downstream effects, or dam failures. Heavy rainfall is the most common cause of riverine flooding, as the soil cannot absorb the precipitation quickly, resulting in a rapid increase in the water level.
- *Pluvial flooding* includes surface water flooding and flash flooding. Surface water flooding occurs when heavy rainfall overwhelms drainage systems or fails to absorb into the ground, causing water to accumulate or flow across the surface. Urban or densely populated areas are at higher risk, as buildings and pavements limit the ground's ability to absorb water. Flash flooding is intense and fast-moving. It occurs within a limited period, no longer than six hours after heavy rain, wildfire, or a structural failure,

[464] NOAA National Severe Storms Laboratory. *Severe Weather 101 – Floods,* https://www.nssl.noaa.gov/education/svrwx101/floods/.
[465] NOAA National Severe Storms Laboratory. Flood by type, https://www.nssl.noaa.gov/education/svrwx101/floods/types/.

such as a dam breach. Due to its high velocity and potential to move debris, flash flooding is among the most dangerous types of flooding.[466]

- *Coastal flooding* typically occurs in low-lying areas along the coast and is triggered by heavy rain and higher-than-normal high tide.
- *Storm surge* occurs when a storm-induced surge in water levels exceeds the expected astronomical tide.[467]

The following factors contribute to or trigger floods: topography, precipitation, severe weather patterns (such as low-pressure events), tropical depressions, tropical storms, and hurricanes. Puerto Rico's steep mountainous terrain, combined with frequent and intense rainfall, creates a landscape highly susceptible to flooding.[468]

Rainfall on sharp elevation gradients rapidly transforms into surface runoff, especially when soils are already near saturation and unable to absorb additional water. This runoff funnels swiftly into river channels, which often breach their banks downstream, particularly in low-lying coastal plains.[469]

Tropical cyclones and storms intensify the problem by delivering heavy precipitation over short periods, overwhelming both natural and engineered drainage systems and triggering flash floods. Additionally, the spatial and temporal variability of rainfall plays a crucial role: localized high-intensity storms accelerate runoff, while prolonged rainfall events saturate soils and diminish infiltration capacity. Even moderate rain spread over several days can set the stage for severe flooding.[470]

Location

Puerto Rico's location, geography, topography, and hydrology create flooding challenges across the island. The island is exposed to tropical storms and hurricanes that can cause heavy rainfall, storm surge, and coastal inundation. Puerto Rico has over 1,000 bodies of water; 50 are classified as significant rivers.[471] Cordillera Central and other mountain ranges have steep slopes that may create flash floods and landslides. Toa Baja, Loíza, Humacao, parts of San Juan, and other municipalities are built on floodplains, wetlands, and reclaimed coastal land.[472] Rapid urbanization in many jurisdictions, such as San Juan, Bayamon, and Carolina,

[466] United Nations Office for Disaster Risk Reduction, Terminology on Disaster Risk Reduction https://www.undrr.org/understanding-disaster-risk/terminology/hips/mh0606.
[467] NOAA, What is storm surge https://www.nhc.noaa.gov/surge/.
[468] Hernández Ayala, J. J., Keellings, D., Waylen, P. R., & Matyas, C. J. (2017). Extreme Floods and Their Relationship with Tropical Cyclones in Puerto Rico. *Hydrological Sciences Journal*, *62*(13), 2103–2119, https://doi.org/10.1080/02626667.2017.1368521.
[469] USGS Programs in Puerto Rico. https://pubs.usgs.gov/fs/FS-051-96/?.
[470] Archer, L., Neal, J., Bates, P., Vosper, E., Carroll, D., Sosa, J., and Mitchell, D.: Current and future rainfall-driven flood risk from hurricanes in Puerto Rico under 1.5 and 2 °C climate change, Nat. Hazards Earth Syst. Sci., 24, 375–396, 2024, https://doi.org/10.5194/nhess-24-375-2024.
[471] American Whitewater, Puerto Rico Navigability Report, 2021, https://www.americanwhitewater.org/engage/our-work/river-access/navigability-toolkit/.

[472] Estuario, Flood Zone Map, https://estuario.org/flood-zones/.

has increased urban flooding. Additional information regarding the island's topography and location is provided in the State Profile section.

Figure 149 shows the mean annual rainfall map for 1991–2020, The map illustrates the spatial distribution of precipitation across Puerto Rico and highlights distinct variations between coastal plains and mountainous interiors. The map shows higher rainfall totals concentrated in the island's mountain regions. By averaging data over three decades, the map provides a clear depiction of long-term rainfall patterns.[473]

Figure 150 shows the river network map of Puerto Rico and illustrates the island's hydrological features through a detailed watershed delineation process. The map offers a detailed representation of Puerto Rico's hydrological network, highlighting the island's rivers, tributaries, and watershed boundaries. This demonstrates the critical role these bodies of water play in shaping flood vulnerability across jurisdictions.[474]

[473] National Weather Service, Rainfall Monthly Maps, https://www.weather.gov/sju/climo_rainfall_monthly_maps.
[474] Huner, F, Flood Risk Assessment and Mapping for Puerto Rico Using September Climate Data and Multi-Criteria Analysis, https://drive.google.com/file/d/1k3waxwBj66N1LPSlVfQkJrx0vlNEuNQe/view?usp=share_link.

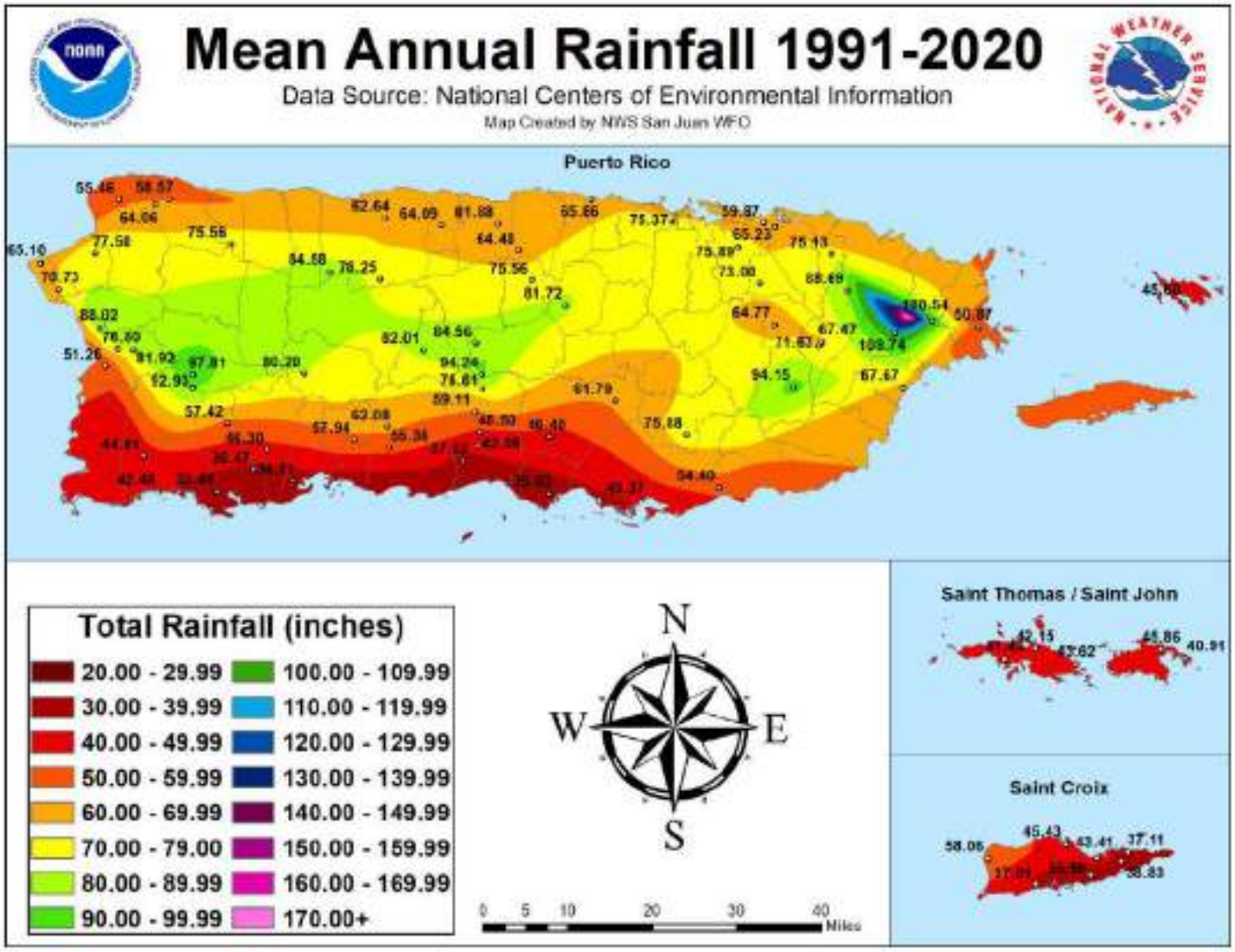


Figure 149: Mean Annual Rain for Puerto Rico 1991–2020

Figure 150: Largest River Network Map of Puerto Rico

Previous Occurrences

Puerto Rico's geographic and climatic conditions make it persistently vulnerable to flooding. The island's mountainous interior, aging drainage infrastructure, and exposure to tropical weather systems, combined with the compounding effects of ongoing recovery from previous disasters create conditions where flooding events occur frequently and across diverse terrain, affecting both coastal lowlands and inland river valleys.

Between 2020 and 2025, this vulnerability was repeatedly confirmed at the federal level. Puerto Rico received multiple major disaster declarations tied to severe storms, flooding, landslides, and mudslides, including declarations in 2022 (DR-4671-PR, Hurricane Fiona) and 2024 (DR-4805-PR, covering the April–May 2024 flooding event affecting 13 municipalities), as well as an emergency declaration in August 2024 for Tropical Storm Ernesto (EM-3610-PR). According to NOAA's National Centers for Environmental Information (NCEI) Storm Events Database, flood events recorded in Puerto Rico during this period resulted in property damage across the majority of reporting days, reflecting the regularity and geographic breadth of the hazard.[475]

The NCEI database reports that between 2020 and 2025, there were 113 days with events of coastal flood, flash flood, or flood, resulting in $14,349,000 in property damage and $1,900 in crop damage. Table 56 provides an overview of these flood events over a five-year period.

Table 56: Overview of Flood Events in Puerto Rico Between January 1, 2020, and August 31, 2025

Description	Total Numbers
Number of County/Zone Areas Affected:	71
Number of Days with Event:	113
Number of Days with Event and Death:	6
Number of Days with Event and Death or Injury:	6
Number of Days with Event and Property Damage:	35
Number of Days with Event and Crop Damage	1

FEDERAL DECLARATIONS

The federal disaster declaration, shown in Table 57, offers a chronological overview of major flooding events in Puerto Rico that warranted federal aid for flooding since the last plan update. Each entry includes the declaration number, event date, and the affected municipalities. The table highlights the persistent

[475] NOAA National Centers for Environmental Information (NCEI). Storm Events Database. Retrieved from https://www.ncei.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Coastal+Flood&eventType=%28C%29+Flash+Flood&eventType=%28Z%29+Flood&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2020&endDate_mm=08&endDate_dd=31&endDate_yyyy=2025&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=99%2CPUERTO+RICO.

vulnerability of both coastal and mountainous regions, with certain areas appearing repeatedly due to their ongoing exposure to flood hazards.[476]

Table 57: Federal Declarations Due to Flooding Incidents

Disaster Number	Declaration Date	Incident Period	Description	Locations
DR-4850-PR	11/27/24	8/13/24–8/16/24	Tropical Storm Ernesto • Emergency Work (Categories A-B): Dollars Obligated $4,413,154.30 • Permanent Work (Categories C-G): Dollars Obligated $7,128,919.53	Aguas Buenas, Aibonito, Añasco, Barranquitas, Canóvanas, Ceiba, Coamo, Comerío, Corozal, Hormigueros, Jayuya, Las Marías, Loíza, Manatí, Maricao, Maunabo, Mayagüez, Naguabo, Orocovis, San Lorenzo, San Sebastián, Santa Isabel, Vega Alta, Vieques, Villalba, and Yabucoa.
EM-3610-PR	8/13/24	8/13/24–8/16/24	Tropical Storm Ernesto Emergency protective measures (Category B), limited to direct federal assistance, under the PA	All 78 municipalities
DR-4805-PR	7/23/24	4/29/24–5/10/24	Puerto Rico Severe Storms, Flooding, Landslides, and Mudslides Hazard Mitigation Grants	Adjuntas, Guánica, Lajas, Las Marías, Luquillo, Maricao, Naranjito, Orocovis, Sábana Grande, San Sebastián, Toa Alta, Utuado, and Yauco Municipalities for Public Assistance
DR-4649-PR	3/29/22	2/4/22–3/29/22	Puerto Rico Severe Storm, Flooding, and Landslides (DR-4649-PR) Individual Assistance	Cata, Dorado, Toa Baja, Vega Alta, and Vega Baja

PUERTO RICO DISASTER DECLARATIONS

The Puerto Rico declarations are shown in Table 58, which illustrates the State of Emergency Orders issued for flooding incidents. Each row captures the specific municipalities affected. By compiling these orders, the table demonstrates the frequency and severity of flood emergencies across the island.[477] Additionally, since

[476] FEMA Disasters and Other Declarations, https://www.fema.gov/disaster/declarations?field_dv2_declaration_date_value%5Bmin%5D=2015&field_dv2_declaration_date_value%5Bmax%5D=2025&field_dv2_declaration_type_value=DR&field_dv2_incident_type_target_id_selective=49112&field_dv2_state_territory_tribal_value%5B%5D=PR.

[477] Puerto Rico, Documentos Administrativos, Ordenes Executivas, https://www.estado.pr.gov/ordenes-ejecutivas.

the publication of the 2021 Puerto Rico State Hazard Mitigation Plan, the Government of Puerto Rico has issued seven State of Emergency declarations.

Table 58: State of Emergency Executive Order Issued in Puerto Rico Due to Flooding Events

Executive Order	Date	Description	Locations
EO 2025-22	5/1/25	Declared a State of Emergency due to heavy rainfall that has caused rivers to overflow and landslides.	Aguas Buenas, Corozal, Naranjito and Orocovis.
EO 2024-09	5/8/25	Declared a State of Emergency due to a weather pattern that brought significant rain.	Adjuntas, Arecibo, Camuy, Ciales, Corozal, Guayanilla, Lares, Manati, Maricao, Mayaguez, Naranjito, Ponte, Río Grande, Sabana Grande, Toa Alta, Toa Baja, Utuado, and Yauco.
EO 2023-032	10/29/23	On 10/27/23, Puerto Rico experienced the passage of a low-pressure system that prompted several flash flood warnings.	San Juan, Guaynabo, and Loiza
EO 2023-011	5/8/23	A State of Emergency was issued due to flash floods caused by torrential rains.	Naranjito
EO 2023-008	4/11/23	A State of Emergency was issued due to flash floods caused by torrential rains.	San Lorenzo, Gurabo, Loiza, Guayama, Río Grande, Arroyo, Juncos, Las Piedras, Caguas, Canovanas, Carolina, Trujillo Alto, Patillas, Maunabo and Yabucoa.
EO 2022-052	10/31/22	A State of Emergency was issued due to flash floods caused by torrential rains.	Maricao, Orocovis, Humacao, Naguabo, Patillas, San German, Hormigueros, Adjuntas, Ponce, Ciales, Yabucoa, Salinas, Aguada, Guayama, Maunabo, Utuado, Mayaguez, Aibonito, Jayuya, and Las Marias
EO 2022-008	2/8/22	A State of Emergency was issued due to flash floods caused by torrential rains.	San Juan, Guaynabo, Catano, Dorado, Toa Baja, Toa Alta, Vega Baja, Vega Alta, Naranjito, Aguas Buenas, Patillas, Humacao, Bayamon, Naguabo, and Trujillo Alto.
EO 2020-070	9/18/20	A State of Emergency was issued due to flash floods caused by torrential rains.	Arecibo

Figure 151 highlights the jurisdictions in Puerto Rico that are most vulnerable to inundation, clearly illustrating the geographic distribution of declared flood disasters. Adjuntas, Utuado, Villalba, Orocovis, and other jurisdictions exhibit susceptibility due to steep mountain slopes that feed fast-moving rivers, which may overflow after heavy rainfall.

Figure 151: Flood Disaster Declarations by Municipality

REPETITIVE LOSS AND SEVERE REPETITIVE LOSS STRUCTURES

The National Flood Insurance Program has paid out an estimated over $55 billion in NFIP claims paid in Puerto Rico[478]. Structures located in flood-prone areas that have incurred repeated flood losses and filed multiple NFIP claims may be designated as Repetitive Loss (RL) or Severe Repetitive Loss (SRL). According to the NFIP,

- **Repetitive Loss** (RL): Two or more flood insurance claims of $1,000 or more within any 10-year period since 1978.
- **Severe Repetitive Loss** (SRL): Four or more claims of $5,000 or more, or at least two claims that cumulatively exceed the structure's value.[479]

According to the Puerto Rico Planning Board and NFIP data, as of 2025 Puerto Rico has a total of 1,919 and 215 SRL properties. Puerto Rico has experienced 13,956 total repetitive loss claims amounting to approximately $140.4 million in net payments. Table 59 shows the distribution by structure type. 37 properties have been mitigated.

Table 59: Structure Type by Losses and Total Net Payments

Structure Type	Number of Losses	Total Net Payment
Commercial	1,090	$19,900,965
Multi family	310	$2,144,517
Non-Business/Non Residential	167	$12,492,722
Other	6,980	$70,227,240
Other Residential	62	$690,334
Single Family	5,334	$34,203,053
Small Business (Non-Residential)	13	$783,748
Grand Total	**13,956**	**$140,442,579**

The majority of financial impact is concentrated in Single-Family and Other categories, which together represent over 74% of total payments. Mitigation strategies aimed at these property types may be more effective in reducing NFIP payouts due to flood damage.

Flood-related repetitive loss claims in Puerto Rico are not evenly distributed across the island. Certain municipalities experience significantly higher concentrations of losses and insurance payouts, reflecting

[478] FloodSmart.gov. *Historical NFIP Claims Information and Trends.* https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=all&maxy=all&county=&gtype=tstate.
[479] Federal Emergency Management Agency (FEMA). *OpenFEMA Dataset: NFIP Multiple Loss Properties - v1.* https://www.fema.gov/openfema-data-page/nfip-multiple-loss-properties-v1.

their vulnerability to coastal, riverine, and urban flooding. Table 60 summarizes the number of repetitive loss claims and associated NFIP payments for buildings and contents by municipality.

Table 60: Repetitive Loss Summary by Municipality

Municipality	Number of Losses	Net Building Payment	Net Contents Payment	Total Net Payment
ADJUNTAS	2	$5,257	$3,725	$8,981
AGUADA	11	$109,838	$119,969	$229,807
ANASCO	2	—	$10,000	$10,000
ARECIBO	343	$2,607,328	$2,707,368	$5,314,687
BAYAMON	149	$273,455	$807,753	$1,081,206
CAMUY	2	$6,969	$15,603	$22,572
CAROLINA	95	$714,589	$340,488	$1,055,074
FAJARDO	186	$341,885	$581,116	$923,000
GUANICA	6	$9,948	$20,387	$30,336
GUAYAMA	46	$371,125	$208,047	$579,171
GUAYANILLA	52	$216,124	$584,202	$800,325
GUAYNABO	76	$487,033	$667,996	$1,155,032
HUMACAO	102	$338,953	$297,267	$636,218
LAJAS	4	$19,237	—	$19,237
LAS PIEDRAS	5	$3,936	$20,241	$24,177
LOIZA	69	$199,196	$146,027	$345,223
MANATI	14	$44,458	$20,659	$65,117
MAUNABO	10	$17,603	$11,832	$29,435
PATILLAS	28	$217,061	105,248	$322,307
PONCE	95	$257,924	$444,190	$702,114
TOA BAJA	464	$2,313,395	$4,577,235	$6,890,630
Unknown	5,188	$19,369,105	$29,868,193	$49,237,254
YAUCO	29	$96,219	$643,187	$739,405
Other	6,978	$28,020,616	$42,200,655	$70,221,271
Grand Total	13,956	$56,041,254	$84,401,388	$140,442,579

Flood-related repetitive loss claims in Puerto Rico are concentrated in a few municipalities, with significant disparities in both the number of claims and total net payments. According to PRPB and NFIP data, the

highest loss concentrations are in Toa Baja, with 464 losses totaling approximately $6.89 million, reflecting its high exposure to coastal and riverine flooding. Arecibo follows with 343 losses and $5.31 million in payments. Bayamón and Guaynabo also report substantial losses, exceeding $1 million each.

On the other hand, moderate municipalities are: Carolina, Ponce, Humacao, and Fajardo each report between $600,000 and $1 million in total payments, indicating recurring flood impacts in urban and coastal areas. Lower Loss Municipalities are those smaller municipalities such as Adjuntas, Anasco, Lajas, Camuy, and Maunabo show minimal repetitive loss activity, with payments under $30,000.

Data also contains unclassified/Other: Meaning that a large portion of claims ($49.2 million) is categorized as Unknown, and $70.2 million as Other, suggesting incomplete location data or aggregated claims across multiple jurisdictions.

Overall, Puerto Rico recorded 13,956 repetitive loss claims totaling $140.4 million in net payments, with $56 million for building damage and $84.4 million for contents. This distribution highlights the concentration of repetitive flood losses in coastal and urban municipalities, particularly in the northern and eastern regions.

SIGNIFICANT EVENTS

The Flood of September 6, 1960, was started by the passage of Hurricane Donna, which caused historical discharges on the Río Humacao, Río Turabo, and Río Valenciano. Reported damage amounted to $7 million, equivalent to more than $76 million in 2025.

The floods of October 5–10, 1970, were triggered by a slow-moving tropical depression that cased several days of consecutive rainfall, with the highest total being 41 inches near Jayuya. Most of the devastation was in the San Juan area. Approximately 18 lives were lost, more than 600 homes were destroyed, and more than 10,000 people were displaced. Damages approximate $65 million, equivalent to $502 million in 2025.[480]

[480] NOAA, Floods of October 5-10, 1970, https://www.weather.gov/safety/flood-states-pr.

Figure 152: Guamani River near Guayama in Southeast Puerto Rico, Hurricane Hortense. Photo: Israel Matos

The floods of October 6–7, 1985, began with a stationary tropical depression that dropped "22 inches of rainfall within 24 hours over the interior hills of the south-central coast."[481] This incident had severe hydrologic consequences as the Río Grande de Manatí experienced a level noted once in 100 years. Furthermore, the rain triggered a landslide in the Mameyes neighborhood in Ponce, costing over 150 lives, and destroying more than 100 homes. Property damages were estimated at over $125 million, equivalent to $375 million in 2025.[482] (The economic loss amount has been adjusted for inflation, ensuring it reflects today's dollar value for a more accurate comparison with current financial impacts).

The floods of January 5 and 6, 1992, occurred when a cold front released more than 20 inches of rain in less than 24 hours. The floods severely impacted the jurisdictions of Cayey, Comerío, Toa Baja, Dorado, and the town of Patillas. The damages surpassed 150 million, 167 individuals received medical care, 23 lives were lost, and 550 residents were displaced.[483]

Hurricane Hortense, September 9 and 10, 1996, dropped up to 24 inches of cumulative rainfall across the eastern interior of Puerto Rico, triggering a devastating flood event. The Río Grande de Loíza, which runs through the densely populated region of the island, received over 24 inches of rainfall, leading to additional flooding in Trujillo Alto, Carolina, and Loiza.[484]

In late September 2017, Hurricane Maria struck Puerto Rico as a Category 4 storm, unleashing one of the most catastrophic flooding events in the island's history. Between September 20 and 22, torrential rains

[481] NOAA, In Puerto Rico, 1985, https://repository.library.noaa.gov/view/noaa/7115/noaa_7115_DS1.pdf.
[482] USGS, The flood of May 17-18 and October 6-7, 1985, https://pubs.usgs.gov/of/1987/0123/report.pdf.
[483] U.S. Geological Survey, Torres-Sierra, Heriberto, The Floods of January 5-6, 1992, https://pubs.usgs.gov/of/1995/0374/report.pdf.
[484] National Weather Service, Hurricane Hortense, September 9-10, 1996, https://www.weather.gov/safety/flood-states-pr#.

blanketed the region, with some areas recording nearly 38 inches of rainfall in just a few days. This deluge was not the result of gradual climate variability but rather the direct consequence of a single, intense hurricane system.[485]

The storm's rainfall rapidly transformed rivers into raging torrents. The U.S. Geological Survey documented peak streamflows at 73 monitoring sites, and 28 of these set all-time records. At Río Grande de Loíza near Caguas, flows surged to 83,000 cubic feet per second, while Carraízo Dam reached an astonishing 223,000 cfs. Many rivers exceeded their 100-year flood thresholds, and some surpassed 500-year recurrence intervals, signaling the extraordinary nature of this event.[486]

Unlike floods driven by long-term climate trends, Maria's flooding was sudden and violent. It was an acute, hurricane-oriented disaster marked by flash floods in mountainous terrain and widespread inundation in low-lying areas. Bridges collapsed, roads washed away, and critical infrastructure was crippled. The devastation underscored how a single tropical cyclone can overwhelm hydrologic systems in ways that differ fundamentally from the slower, seasonal shifts associated with climate variability.

On September 18, 2022, Hurricane Fiona slammed into southwestern Puerto Rico as a Category 1 storm, unleashing a deluge that would devastate the island. Torrential rain fell relentlessly, with some areas receiving two to three feet of water in just hours. Rivers surged at alarming speeds—one rose more than 15 feet in three hours, climbing an inch every 12 seconds. This extraordinary rainfall overwhelmed waterways, triggering flash floods, sweeping away bridges, and carving mudslides into the mountainous terrain. By evening, entire communities were cut off, roads vanished under torrents, and the island faced one of its most catastrophic flooding events in recent history.[487]

In early May 2025, Puerto Rico experienced severe flooding caused by persistent heavy rains that lasted for two weeks. The intense downpours triggered flash flood warnings across the island, submerging streets, isolating families, and causing landslides. On May 3, a tree fell onto a car in Toa Baja during a landslide, killing a 44-year-old man and injuring a woman. This marked the second fatality linked to the flooding, following a man swept away while driving through floodwaters earlier that week. Multiple municipalities declared states of emergency as damages mounted Vega Alta estimated $7 million in losses, while Cidra reported $3 million in infrastructure damage. The rains also disrupted water services in several towns, including Ceiba and Caguas, where landslides damaged pipelines and filtration plants. Authorities continued

[485] Gómez-Fragoso, J.M., Smith, M., & Santiago, M. (2022). *U.S. Geological Survey response to Hurricane Maria flooding in Puerto Rico and characterization of peak streamflows observed September 20–22, 2017* (Scientific Investigations Report 2022–5040, ver. 1.1, July 2022). U.S. Geological Survey. https://pubs.usgs.gov/publication/sir20225040.
[486] Gómez-Fragoso, J.M., Smith, M., & Santiago, M. (2022). *U.S. Geological Survey response to Hurricane Maria flooding in Puerto Rico and characterization of peak streamflows observed September 20–22, 2017* (Scientific Investigations Report 2022–5040, ver. 1.1, July 2022). U.S. Geological Survey. https://pubs.usgs.gov/publication/sir20225040.
[487] Finch, A. (2022, September 19). *Hurricane Fiona devastates Puerto Rico with heavy rain, flooding and mudslides*. AccuWeather. Retrieved from https://www.accuweather.com/en/hurricane/hurricane-fiona-devastates-puerto-rico-with-heavy-rain-flooding-and-mudslides/1249326.

emergency aid and repairs as forecasts predicted more rain, leaving communities in precarious conditions.[488]

The National Flood Insurance Program (NFIP) significant flood events data provides a detailed historical record of major flood losses across Puerto Rico. Table 61 highlights the insurance claims and payments issued in Puerto Rico between 1987 and 1995.[489]

Table 61: NFIP Significant Event Data

Date of Loss	Number of Paid Losses	Total Net Payment
April 11, 1987	556	$3,791,566.72
December 13, 1981	891	$3,472,554.79
December 7, 1987	196	$718,051.11
January 5, 1992	390	$3,510,942.13
May 18, 1985	501	$2,363,035.84
May 12, 1986	802	$2,156,437.87
November 26, 1987	226	$683,150.87
November 3, 1992	123	$1,967,427.84
September 12, 1982	201	$608,358.40
September 6, 1995	16	$135,249.23

[488] McCarthy, J. (2025, May 5). Heavy rains continue to pound Puerto Rico, flooding streets and causing 2nd death. *Virgin Islands Free Press*. Retrieved from https://vifreepress.com/2025/05/heavy-rains-continue-to-pound-puerto-rico-flooding-streets-and-causing-2nd-death/.

[489] National Flood Insurance Significant Flood Event Data, https://agents.floodsmart.gov/sites/default/files/media/document/2025-07/nfip_significant-flood-events_20220630.xlsx.

Table 62 provides a summary of recent storm events in Puerto Rico that resulted in flooding, property damage, and fatalities. These events, occurring in April, September, and November, align with Puerto Rico's bimodal rainfall pattern, which features two distinct wet seasons: an early season from April to July and a late season from August to November. This seasonal distribution underscores the island's vulnerability to heavy rainfall and flash flooding during these periods, reinforcing the need for targeted mitigation strategies in flood-prone municipalities.

Table 62: NCEI Storm Events Database[490]

Date of Loss	Number of Deaths	Region	Total Property damage ($)	Flood Caused
April 28, 2025	1	San Juan	$25,000	Heavy Rain
September 25, 2025	1	YAUCO	$16.500	Heavy Rain
November 16, 2024	1	YABUCOA	$60,000	Heavy Rain
November 10, 2022	1	Juncos	$5000	Heavy Rain

Potential Severity of Event

Puerto Rico is particularly susceptible to flooding, with streams playing a major role in amplifying flood risks amid frequent extreme weather events. According to a 2004 study, waterways in Puerto Rico represent over half of the peak unit discharge events documented in the U.S.[491] In addition, Puerto Rico regularly endures severe weather events that deliver intense rainfall; this secures Puerto Rico's position among the leading regions in the North Atlantic for both cumulative precipitation and peak daily rain intensities associated with individual tropical storms over the past three decades. Hurricanes like Irma, Maria, and Fiona underscore Puerto Rico's vulnerability to extreme weather. They unleash widespread flooding that severely impacts both coastal and benthic ecosystems. Intense rainfall and elevated river discharge lead to extensive environmental degradation, including erosion, habitat disruption, and contamination across marine and shoreline areas.[492]

Figure 153 outlines the western and central regions of Puerto Rico, which exhibit elevated flood risk, a pattern influenced by the island's topography. In higher-altitude zones, orographic precipitation—rainfall enhanced by mountainous terrain—is common. While these elevated areas may experience lower absolute

[490] National Centers for Environmental Information. Storm Events Database. https://www.ncei.noaa.gov/stormevents/.
[491] O'Connor, J. E., & Costa, J. E. (2004), Spatial distribution of the largest rainfall-runoff floods from basins between 2.6 and 26,000 km2 in the United States and Puerto Rico. Water Resources Research, 40(W01103), https://doi.org/10.1029/2003WR002247.
[492] Hernández, W. J., Ortiz-Rosa, S., Armstrong, R. A., Geiger, E. F., Eakin, C. M., & Warner, R. A., (2020), Quantifying the effects of Hurricanes Irma and Maria on coastal water quality in Puerto Rico using moderate resolution satellite sensors, Remote Sensing, 12(6), 964. https://doi.org/10.3390/rs12060964.

flood risk due to steep slopes and elevation, they still face greater flood vulnerability compared to adjacent lower-lying regions, owing to rapid runoff and limited absorption capacity.[493]

Figure 153: Puerto Rico Flood Risk as of September 2024

Storm surge is a sudden rise in water level and wave action often associated with hurricanes and severe storms. It is primarily caused by strong onshore winds. Storm surge can travel up rivers, canals and other low elevation areas that extend many miles inland from the immediate coastline in some areas.[494] Storm Surge Risk Maps identify areas that may be vulnerable to coastal flooding due to storm surge.

Figure 154 illustrates areas vulnerable to coastal flooding caused by storm surge during hurricanes. Zones are categorized by hurricane intensity using the Saffir-Simpson scale (Categories 1–5), with each color representing the maximum potential inundation depth and inland reach for that category. Category 1 zones indicate flooding in low-lying coastal areas, while Category 5 zones show catastrophic surge that can extend far inland, inundating critical infrastructure and evacuation routes.

Storm surge projections are derived from NOAA's SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model, which simulates thousands of hypothetical storms varying in size, speed, track, and tide level. The model outputs Maximum Envelope of Water (MEOW) and Maximum of MEOWs (MOM) scenarios to identify worst-case surge conditions for each hurricane category. These results are combined with high-resolution elevation data to produce the inundation zones shown on this map.

[493] Huner, F, Flood Risk Assessment and Mapping for Puerto Rico Using September Climate Data and Multi-Criteria Analysis, https://drive.google.com/file/d/1k3waxwBj66N1LPSlVfQkJrx0vlNEuNQe/view?usp=share_link.
[494] NOAA, National Weather Service. National Hurricane Center, Storm Surge Overview, https://www.nhc.noaa.gov/surge/.

Northern Puerto Rico, including the San Juan metropolitan area, appears most impacted by storm surge risk due to its low-lying coastal terrain and high population density.

Figure 154: Storm Surge Inundation Zones for Puerto Rico

It is also important to consider the influence of sea level rise on flooding, as rising sea levels can substantially amplify the severity of flooding in Puerto Rico, particularly in coastal municipalities. As the baseline sea level climbs, storm surge, wave overtopping, and high-tide inundation reach farther inland and with greater depth, meaning that even moderate storms or high tides may inundate areas that were once considered safe. For example, USGS projections for the San Juan National Historic Site estimate increased probabilities and depths of inundation under multiple sea-level rise scenarios, with certain areas becoming "likely" to flood that currently are not vulnerable under existing sea levels.[495]

The NOAA Office for Coastal Management provides data to visualize impacts from coastal flooding and sea level rise up to 10 feet above mean higher high water (MHHW). Sea level rise maps literature-supported levels of rise on top of mean higher high water levels, incorporates local or regional tidal variations, and evaluates elevation data for hydrological connectivity. This data illustrates the scale of potential flooding but does not account for erosion, subsidence or future construction.[496]

[495] USGS Projected sea-level rise and high tide flooding at San Juan Historic site, https://www.usgs.gov/publications/projected-sea-level-rise-and-high-tide-flooding-san-juan-national-historic-site-puerto.
[496] NOAA, Office for Coastal Management, Sea Level Rise Viewer. https://coast.noaa.gov/digitalcoast/tools/slr.html.

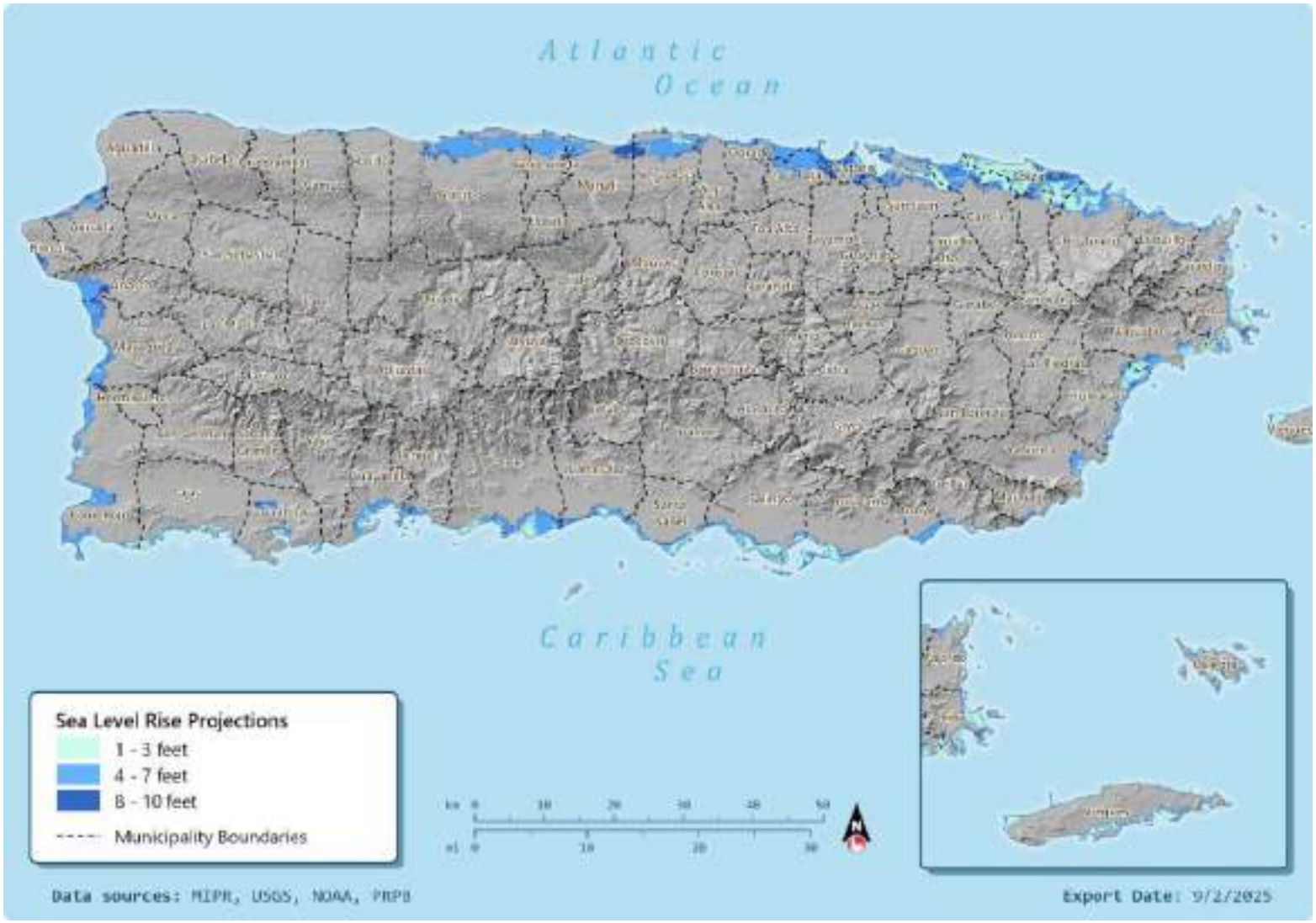


Figure 155: Sea Level Rise Projections[497]

[497] NOAA, Office for Coastal Management, Sea Level Rise Viewer, https://coast.noaa.gov/slrdata/Depth_Rasters/PR/index.html.

Probability of Future Hazard Events

Based on location and significant events, there is a **high** probability flooding events will continue to impact Puerto Rico. The island is already experiencing substantial floods. A 2024 study conducted in the aftermath of Hurricane Maria found that approximately 8% of the population is exposed to flood incidents caused by severe weather events such as hurricanes. It further indicates that the likelihood of these events will continue to rise as temperature fluctuations increase.[498]

According to NOAA's 2022 study, sea levels along the U.S. coastline are projected to rise by an average of 10 to 12 inches over the next 30 years. This rise is equivalent to the total increase observed over the previous century (1920–2020), although the rate and impact of sea level rise vary by region due to differences in land elevation and ocean dynamics. By 2050, coastal communities are expected to face more frequent minor flooding, defined as water levels reaching approximately 2 feet (0.6 meters) above average high tide. These events can disrupt daily life through stormwater backups and road closures. Moderate flooding, with water levels around 3 feet (0.9 meters) above high tide, poses greater risks, often resulting in damage to homes, businesses, and infrastructure.[499]

FEMA's Flood Insurance Rate Map (FIRM), shown in Figure 156, indicates the areas at risk of flooding across Puerto Rico. FIRMs are tools used to guide decision-makers in assessing flood risk and planning infrastructure. They classify flood zones based on statistical return periods, primarily the 1% annual chance (100-year) flood and the 0.2% annual chance (500-year) flood. The difference between these events lies in their expected magnitude and rarity. A 0.2% event is more extreme and less frequent than a 1% event, as it includes more severe rainfall scenarios over a longer statistical timeframe. These maps help determine appropriate design standards. For example, a hospital might be designed for a 1,000-year flood, while a residential building may be adequately protected against a 500-year flood.

The Advisory Base Flood Elevation (ABFE) maps provide more detailed elevation data for the 1% flood scenario, supporting floodplain management and building regulations. The ABFE shown in Figure 157, which provides an in-depth representation of the 1% annual chance flood using base flood elevations. These measurements reflect statistical averages only; it is possible for two or more floods with a 1% yearly chance to occur within a short time.[500]

[498] Archer, L., Neal, J., Bates, P., Vosper, E., Carroll, D., Sosa, J., and Mitchell, D.: Current and future rainfall-driven flood risk from hurricanes in Puerto Rico under 1.5 and 2 °C climate change, Nat. Hazards Earth Syst. Sci., 24, 375–396, 2024, https://doi.org/10.5194/nhess-24-375-2024.
[499] NOAA, Tides & Currents, 2022 Sea Level Rise Technical Report, U.S. Sea Level Change, https://earth.gov/sealevel/us/resources/2022-sea-level-rise-technical-report/.
[500] USGS, The 100-Year Flood, https://www.usgs.gov/water-science-school/science/100-year-flood.

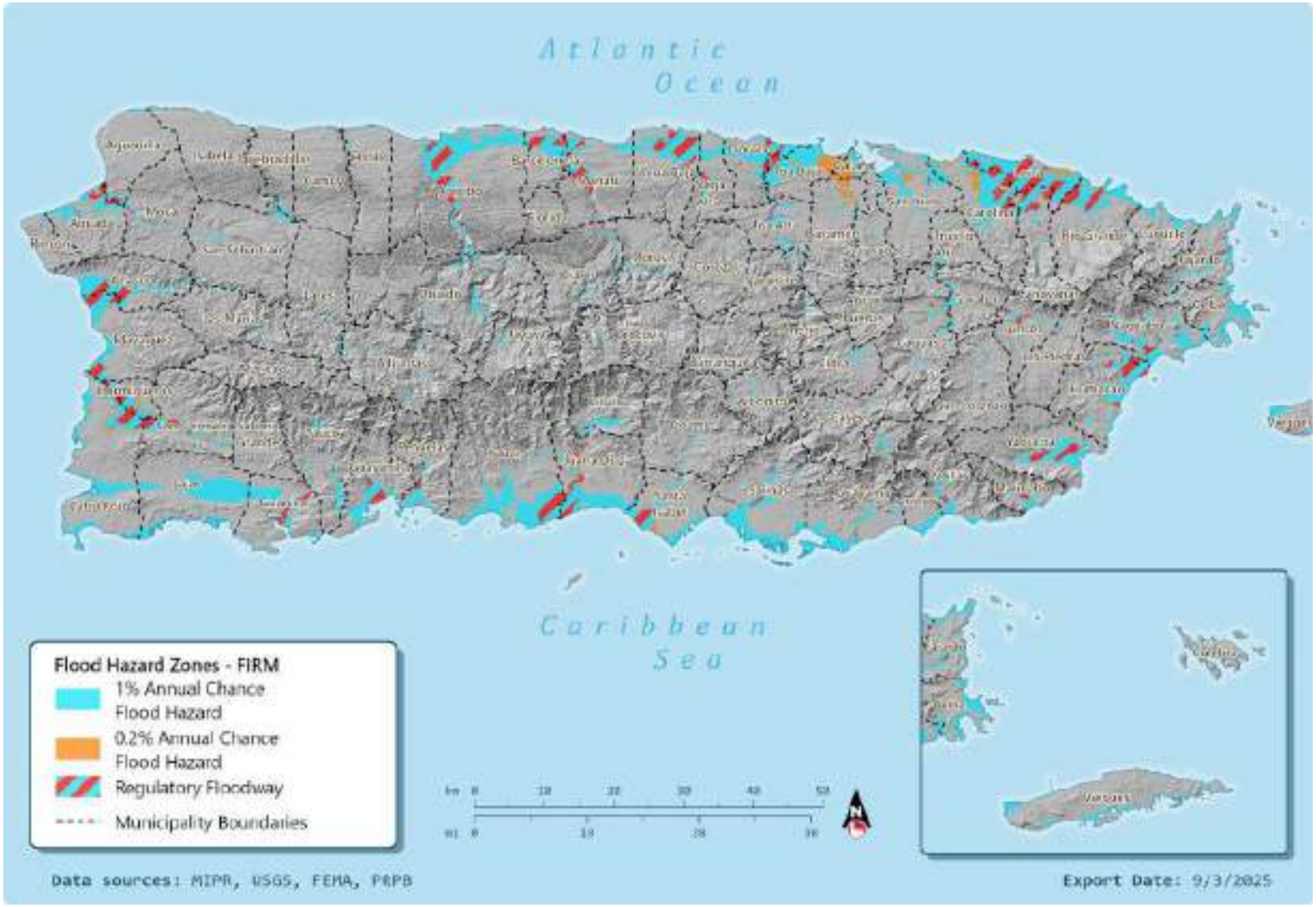


Figure 156: Flood Insurance Rate Map (FIRM)

Figure 157: Advisory Base Flood Elevation (ABFE) Map

Vulnerability Assessment

Flooding represents one of the most recurring hazards affecting Puerto Rico. Puerto Rico's vulnerability to flooding encompasses physical, environmental, social, and economic consequences that increase the potential for loss across all sectors. The assessment below provides a high-level overview of the island's vulnerabilities.

Flooding is one of the most widespread and costly hazards worldwide. It is estimated that the annual cost to the globe is $368 billion, and by 2050, riverine flooding may cause more than $400 billion in annual losses.[501]. Repetitive loss properties are tracked under the National Flood Insurance Program (NFIP). These are buildings that have received two or more NFIP claim payments exceeding $1,000 within any ten-year span. While designated as repetitive loss, such properties may or may not currently hold active NFIP insurance coverage. Between 2020 and 2024, the NFIP paid 79 claims totaling over $2.5 million, as illustrated in Table 63. [502]

Table 63: NFIP Claims by Municipality 2020–2024

Name	Total Paid Claims	Total Claim Dollars Paid
Aguada	2	$55,418.18
Arecibo	27	$1,104,147.87
Bayamón	3	$133,582.16
Carolina	3	$12,697.56
Coamo	1	$30,894.27
Guánica	2	$20,951.98
Guayama	2	$61,466.02
Guayanilla	1	$21,500.00
Guaynabo	5	$153,596.05
Loiza	1	$25,790.28
Patillas	1	$99,086.05
Toa Baja	24	$811,683.28
Yauco	1	$13,312.45
Total		$2,544,126.15

[501]United Nations Office for Disaster Risk reduction, Global Assessment Report on Disaster Risk Reduction. 2025 https://www.undrr.org/gar/gar2025/hazard-exploration/floods#:~:text=Currently%2C%20the%20annual%20average%20losses,439%20billion%20in%20annual%20losses.

[502] Historical NFIP Claims Information and Trends for Puerto Rico, https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=2020&maxy=2024&county=&gtype=tstate.

A significant portion of the island's older adult population resides in flood-prone, low-lying areas such as Toa Baja, Arecibo, Humacao, and Loíza. Repeated exposure to flooding has tested their recovery capacity, while vulnerable groups—including the elderly, disabled, and homeless—often have limited evacuation options, which places additional strain on shelter systems. Although Puerto Rico maintains approximately 307 shelters, the number equipped to handle special needs cases requiring advanced medical or physical assistance remains unclear.[503] Emergency responders face heightened risks during flood events, including injuries and exposure to biological and chemical hazards from contaminated water, sewage, and debris. Beyond physical dangers, mental health challenges are significant. Following Hurricane Maria, over 40% of healthcare workers who assisted survivors reported symptoms of post-traumatic stress disorder and anxiety.

Flooding also disrupts governance and public services. Local governments may suspend non-essential operations, while damaged roads and bridges hinder access to critical services. Economic repercussions are substantial: businesses may close, tax revenues decline, and jurisdictions incur costs to restore infrastructure. After the May 1, 2025, floods, municipalities anticipated needing $100,000 in recovery funds.[504]

Environmental degradation is another consequence. Riverine and coastal flooding erodes shorelines, damages coral reefs and mangroves, and contaminates wetlands with debris and sewage. These conditions elevate public health risks, including disease outbreaks, mold exposure, and psychological trauma. Standing water facilitates the spread of leptospirosis and mosquito-borne illnesses, including dengue, chikungunya, and Zika. In the wake of Hurricane Maria, more than 25 deaths were attributed to bacterial infections from contaminated water.

Floodwater also threatens critical infrastructure, disrupting electricity, potable water systems, waste management, and medical supply chains. Agriculture is particularly vulnerable: in 2022, Ponce and Arecibo led the island in farm revenue, with 1,500 farms generating over $300 million in sales.[505] Yet, annual flood-related losses are estimated at $1.9 million for Arecibo and $1.8 million for Ponce,[506] which highlights the economic vulnerability of key agricultural regions. Table 64 gives a summary of the community lifelines that are located within potential sea level rise areas and their total replacement cost. Figure 158 shows the locations of critical facilities or infrastructure that fall within potential sea level rise areas.

Tourism, a vital economic sector, is also at risk. In 2023 and 2024, Puerto Rico welcomed over 900,000 visitors, who spent a total of $2.5 billion, with the majority staying in San Juan, Carolina, Bayamón, and

[503] Puerto Rico Planning Viewer, https://fema.maps.arcgis.com/apps/webappviewer/index.html?id=6d961e268f6f41ffa1f1e13e48dd8b1d.
[504] Newsday, Officials in Puerto Rico Expand State Emergency after weeks of heavy rain, https://www.newsday.com/news/nation/puerto-rico-heavy-rains-emergency-killed-g78211.
[505] Census-of-Ag-22_HL_PuertoRico.pdf, https://www.nass.usda.gov/Publications/Highlights/2024/Census-of-Ag-22_HL_PuertoRico.pdf.
[506] CNN, Deaths from bacterial disease in Puerto Rico spiked after Maria, https://www.cnn.com/2018/07/03/health/sutter-leptospirosis-outbreak-puerto-rico-invs/index.html.

Ponce. Flooding in historic districts (such as Old San Juan), beach erosion, and infrastructure damage could deter future arrivals and impact the island's tourism revenue.[507]

Table 64: Community Lifelines Exposed to Flooding

Community Lifeline	Count of Facilities	Total Replacement Cost
Communications	56	$86,542,565.62
Energy	14	$25,894,863.90
Food, Shelter, Hydration	4	$2,156,607.75
Hazardous Materials	40	$45,013,094.88
Health and Medical	2	$8,372,666.58
Safety and Security	64	$93,929,439.96
Transportation	31	$200,119,399.24
Water Systems	217	$7,604,190.00
Total	**428**	**$469,632,827.92**

[507] Instituto de Estadísticas de Puerto Rico, Visitor Profile, Fiscal Year 2023–2024, https://tourism.pr.gov/wp-content/uploads/2025/07/Visitor-Profile-Fiscal-Year-2023-2024.pdf.

Figure 158: Critical Infrastructure with Sea Level Rise Projection

LOCATIONS

Caguas, located south of San Juan, ranks high on the Community Exposure Index. Its elevated Threat Index score is primarily influenced by its proximity to six rivers—Río Grande de Loíza, Río Turabo, Río Caguitas, Río Cañaboncito, Río Bairoa, and Río Cañas—a factor that increases the area's susceptibility to flooding. In the southwestern region of Puerto Rico, near Ponce and Mayagüez, the Threat Index is shaped by factors such as low-lying terrain and impermeable surfaces. Contributions like flood-prone zones and storm surge risks further elevate the threat levels. While both cities are densely populated, Mayagüez stands out for having a higher concentration of socially vulnerable communities compared to Ponce.[508]

POPULATIONS

Puerto Rico continues to face some of the highest poverty levels in the United States, which significantly affects the daily lives and the ability to recover from disasters such as flooding. According to the U.S. Census Bureau, nearly 40% of Puerto Ricans live below the federal poverty line.[509] Households in rural and coastal areas with limited income have faced more financial hardship following a disaster. Furthermore, many low-income households reside in flood-prone areas and have inadequate infrastructure protection. This increases the exposure of vulnerable populations to waterborne diseases.

STRUCTURES INCLUDING CRITICAL FACILITIES

Flooding events pose a direct threat to Puerto Rico's water system infrastructure. Aging pipelines, outdated treatment facilities, and structural instability already plague the system, and flood conditions accelerate failures by overwhelming drainage capacity, contaminating water sources, and damaging exposed components. These vulnerabilities are compounded by rapid urban development, which places additional strain on already fragile systems. The growing demands of the tourism industry further intensify pressure on water resources, often outpacing the system's capacity to deliver safe, reliable service. Together, these factors threaten public health, environmental sustainability, and the island's ability to recover from flood events.

Power generation and distribution infrastructure in Puerto Rico is concentrated around the coast,[510] and this leaves plants and substations highly vulnerable to multiple hazards, including flooding. Energy disruptions can ripple into water, health, and communication lifelines, prolonging the response and recovery process.

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[508] Dobson, J.G., Johnson, I.P., Rhodes, K.A., Lussier, B.C., and Byler, K.A. (2020) Puerto Rico Coastal Resilience Assessment. UNC Asheville National Environmental Modeling and Analysis Center, Asheville, NC. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/sites/default/files/2020-08/puerto-rico-coastal-resilience-assessment.pdf.
"Puerto Rico Coastal Resilience Assessment," https://www.nfwf.org/sites/default/files/2020-08/puerto-rico-coastal-resilience-assessment.pdf.

[509] U.S. Census, Quick Facts: Puerto Rico, https://www.census.gov/quickfacts/PR.

[510] Grid Modernization for Puerto Rico, COR 3, https://recovery.pr.gov/es/documents/Grid%20Modernization%20Plan_20191213%20(2).pdf.

PROBLEM STATEMENTS

- The jurisdictions located in the coastal and mountainous areas of the island are most vulnerable to flooding events. Low-pressure weather systems, hurricanes, the annual rainy season, and other weather patterns often impact these jurisdictions.
- In Puerto Rico, approximately 10%[511] of the population faces flood exposure from hurricane rainfall events occurring as frequently as every five years. This persistent vulnerability undermines community resilience, strains emergency response systems, and increases the risk of long-term displacement, health crises, and economic disruption.
- Puerto Rico's deteriorating water infrastructure—burdened by aging systems, structural vulnerabilities, rapid urban expansion, and rising tourism demands—poses a critical threat to public health, environmental sustainability, and long-term resilience.
- Puerto Rico's energy lifeline is dangerously exposed, with power generation and distribution clustered along the coast. The entire grid stands vulnerable to hurricanes, flooding, and climate-driven disasters.

Impact Assessment

FEMA's framework, impact refers to the measurable consequences of a hazard event on people, property, infrastructure, and the economy. For flooding, this includes physical damage to buildings and contents, disruption of essential services, and economic losses such as income reduction, relocation costs, and wage impacts. Quantifying these impacts is critical for prioritizing mitigation strategies and allocating resources effectively. Hazus, FEMA's standardized loss estimation tool, plays a central role in this process by modeling flood scenarios, such as the 100-year FIRM and 500-year ABFE and calculating potential losses for buildings, contents, and business interruption. These outputs provide planners and decision-makers with data-driven insights to guide resilient design, emergency planning, and long-term recovery efforts.

HAZUS FLOOD SCENARIOS

ECONOMIC LOSSES

Building related losses include both direct property damage losses and losses from business interruption, or those associated with the inability to operate a business due to damage sustained during flooding. Direct property damage losses are the estimated costs to repair or replace damage caused to buildings and their contents. Business interruption losses include income, wage loss, relocation costs, and temporary living expenses for people displaced from their homes because of flooding.

Building related losses refers to the number and type of assets located within designated floodplain areas, specifically those identified in FEMA's Flood Insurance Rate Maps (FIRMs) and Advisory Base Flood Elevation

[511] Archer, L., Neal, J., Bates, P., Vosper, E., Carroll, D., Sosa, J., and Mitchell, D., Current and Future Rainfall-Driven Flood Risk from Hurricanes in Puerto Rico under 1.5 and 2 °C Climate Change, *Nat. Hazards Earth Syst. Sci.*, 24, 375–396, 2024, https://doi.org/10.5194/nhess-24-375-2024.

(ABFE) maps. Understanding exposure is a critical precursor to assessing vulnerability, which evaluates each asset's capacity to resist flood damage based on its location, elevation, and structural integrity.

FIRM maps are probabilistic tools developed through hydrologic and hydraulic modeling. They depict areas subject to flooding based on statistical return periods—most commonly the 1% annual chance (100-year) and 0.2% annual chance (500-year) flood events. These maps are widely used for infrastructure design, land use planning, and cost-benefit mitigation strategies.

In contrast, ABFE maps are deterministic and scenario-based. They represent a single, conservative flood scenario, typically the 1% annual chance flood, and are designed to support emergency response, disaster recovery, and resilient rebuilding efforts. ABFE maps incorporate more detailed elevation data and are often used in post-disaster contexts to guide reconstruction in high-risk areas. ABFE maps are particularly useful when existing FIRMs are outdated or insufficient for guiding reconstruction.

A 100-year return period flood has a 1% chance of occurring in any given year, while a 500-year return period flood has a 0.2% chance. Although less frequent, the 500-year flood scenario is more intense and covers a broader area, which explains why the replacement value of assets exposed in the 500-year floodplain is greater than in the 100-year floodplain in both FIRM and ABFE.

Table 65 provides a consolidated view of the total replacement value of assets exposed under four flood scenarios: FIRM 100-year, FIRM 500-year, ABFE 100-year, and ABFE 500-year. It breaks down exposure by asset type: residential, commercial, industrial, government, education, religion, and agriculture, and shows that residential assets overwhelmingly dominate exposure across all scenarios, consistently accounting for more than 85% of the total replacement value. Commercial assets follow as the second most exposed category, while other asset types (industrial, government, education, etc.) represent much smaller proportions. This pattern persists regardless of whether the scenario is probabilistic (FIRM) or deterministic (ABFE) and whether it reflects a 100-year or 500-year return period flood event. As anticipated from the ABFE methodology, the estimated replacement values for both 100-year and 500-year return period scenarios are substantially higher than those derived from FIRM maps. This difference confirms that ABFE applies a more conservative, deterministic approach, prioritizing elevated safety margins and minimizing uncertainty in post-disaster reconstruction planning.

Table 65: Hazus Flood Scenario Loss Estimates by Building Occupancy Type (Thousands)

Flood Scenario	Residential	Commercial	Industrial	Other	Total Economic Loss
100-year FIRM	$78,321,570	$5,366,489	$777,707	$3,627,297	$88,093,063
100-year ABFE	$261,258,269	$30,711,927	$3,259,191	$17,573,854	$301,031,144
500-year FIRM	$369,642,673	$5,366,489	$5,820,062	$26,301,135	$432,475,797
500-year ABFE	$284,608,597	$21,343,593	$4,489,392	$21,374,955	$331,816,537

Figure 159 illustrates the percentage distribution of Puerto Rico's total asset exposure value across different flood scenarios. The chart compares exposure under FEMA's Flood Insurance Rate Maps (FIRM) and Advisory Base Flood Elevation (ABFE) maps for both 100-year and 500-year return periods. This visual highlights how residential assets dominate exposure consistently exceeding 85%, while commercial and other asset types represent smaller shares.

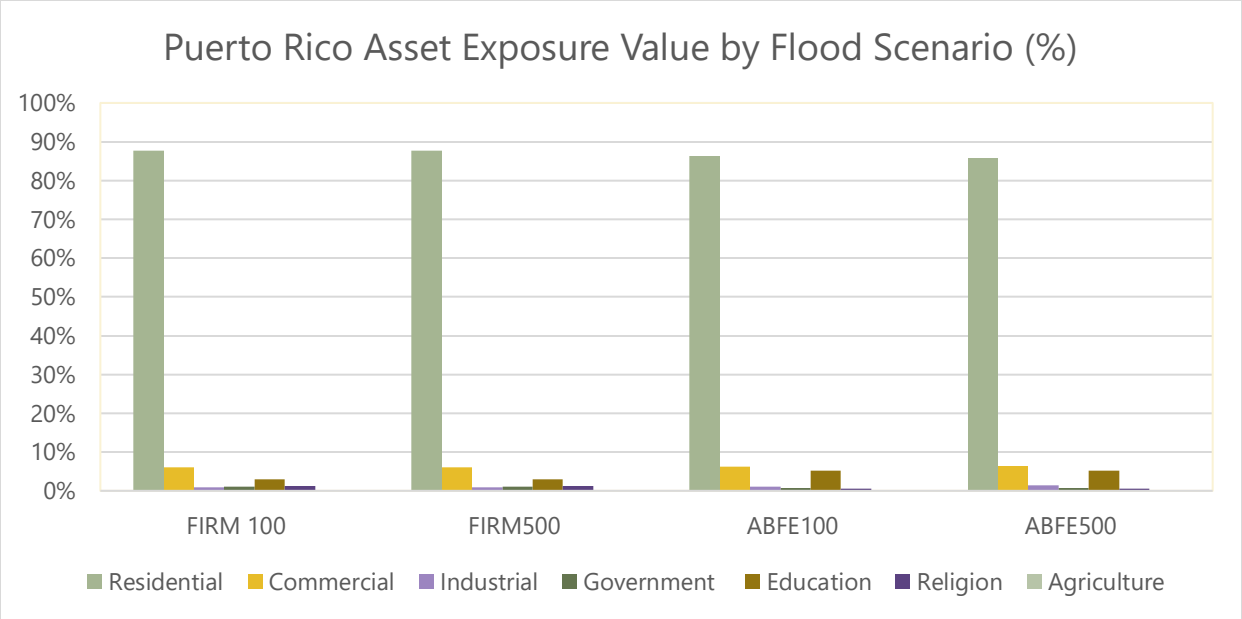

Figure 159: Puerto Rico Asset Exposure Value by Flood Scenario in Relative Terms

Figures 16 to 23 provide a detailed breakdown of asset exposure and replacement value across Puerto Rico's municipalities. These figures highlight municipalities with substantial asset inventories; municipalities not shown have minimal representation due to limited inventory. However, it is important to note that the full inventory, including all 76 municipalities was modeled in Hazus. This comprehensive modeling is reflected in Table 66, which presents the total replacement value of assets located within the 100-year and 500-year floodplains for both FIRM and ABFE scenarios.

- Tables 11 to 14 show the percentage of asset types (residential, commercial, industrial, government, education, etc.) located within the FIRM and ABFE floodplains. These figures reveal that residential assets dominate, consistently exceeding 85% in all municipalities. Commercial assets follow, with higher concentrations in urban hubs like San Juan, reflecting its role as the island's economic center.
- Figures 17,19,21 and 23 illustrate the replacement value of exposed assets in millions of dollars for both the 100-year and 500-year flood scenarios. As expected, San Juan has the highest replacement value due to its dense population and infrastructure footprint, making it the most asset-rich municipality in Puerto Rico.

These figures underscore the importance of integrating exposure data into flood mitigation planning. By identifying which assets are at risk and understanding their structural and economic significance, planners can prioritize interventions that enhance resilience and reduce long-term losses.

Table 66: Percentage of Asset Types within 100 year ABFE

Municipality	% Commercial	%Residential	%Industrial	% Government	% Education	% Agriculture	% Religion
Adjuntas	0.15%	99.58%	0.09%	0.03%	0.15%	0.00%	0.00%
Aguada	0.09%	99.75%	0.04%	0.00%	0.12%	0.00%	0.00%
Aguadilla	0.11%	99.59%	0.04%	0.04%	0.18%	0.00%	0.04%
Aguas Buenas	0.08%	99.67%	0.00%	0.08%	0.17%	0.00%	0.00%
Aibonito	0.41%	99.45%	0.00%	0.03%	0.09%	0.00%	0.02%
Arecibo	0.73%	99.04%	0.08%	0.03%	0.10%	0.01%	0.01%
Arroyo	0.27%	99.56%	0.00%	0.05%	0.10%	0.00%	0.02%
Barceloneta	0.36%	99.51%	0.02%	0.02%	0.08%	0.00%	0.02%
Barranquitas	0.03%	99.72%	0.00%	0.03%	0.22%	0.00%	0.00%
Bayamón	1.00%	98.73%	0.13%	0.03%	0.12%	0.00%	0.01%
Cabo Rojo	0.56%	99.30%	0.01%	0.02%	0.09%	0.00%	0.01%
Caguas	0.10%	99.74%	0.01%	0.05%	0.10%	0.00%	0.01%
Camuy	0.61%	99.18%	0.00%	0.10%	0.10%	0.00%	0.00%
Canóvanas	0.24%	99.63%	0.01%	0.02%	0.09%	0.00%	0.01%
Carolina	0.35%	99.47%	0.06%	0.02%	0.09%	0.01%	0.00%
Cataño	0.72%	98.97%	0.10%	0.05%	0.14%	0.00%	0.01%
Cayey	0.06%	99.72%	0.00%	0.04%	0.18%	0.00%	0.00%
Ceiba	0.05%	99.77%	0.02%	0.05%	0.11%	0.00%	0.00%
Cidra	0.00%	99.89%	0.00%	0.02%	0.09%	0.00%	0.00%
Coamo	0.22%	99.64%	0.00%	0.00%	0.13%	0.00%	0.00%
Comerío	0.21%	99.55%	0.00%	0.10%	0.14%	0.00%	0.00%

Municipality	% Commercial	%Residential	%Industrial	% Government	% Education	% Agriculture	% Religion
Corozal	0.26%	99.52%	0.00%	0.07%	0.15%	0.00%	0.00%
Culebra	0.16%	99.52%	0.00%	0.24%	0.08%	0.00%	0.00%
Dorado	0.12%	99.78%	0.01%	0.03%	0.06%	0.00%	0.00%
Fajardo	0.31%	99.52%	0.07%	0.05%	0.05%	0.00%	0.00%
Guánica	0.41%	99.27%	0.10%	0.07%	0.15%	0.00%	0.00%
Guayama	0.10%	99.73%	0.03%	0.00%	0.14%	0.00%	0.00%
Guayanilla	0.19%	99.59%	0.05%	0.05%	0.12%	0.00%	0.00%
Guaynabo	0.69%	98.82%	0.32%	0.08%	0.07%	0.00%	0.01%
Gurabo	0.05%	99.80%	0.02%	0.02%	0.10%	0.00%	0.00%
Hatillo	0.15%	99.47%	0.00%	0.15%	0.23%	0.00%	0.00%
Hormigueros	0.22%	99.50%	0.00%	0.11%	0.17%	0.00%	0.00%
Humacao	0.23%	99.64%	0.01%	0.01%	0.11%	0.00%	0.00%
Isabela	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	0.27%	99.45%	0.03%	0.03%	0.20%	0.00%	0.00%
Juana Díaz	0.05%	99.87%	0.01%	0.00%	0.07%	0.00%	0.00%
Juncos	0.20%	99.58%	0.00%	0.04%	0.18%	0.00%	0.00%
Lajas	0.00%	99.92%	0.00%	0.04%	0.04%	0.00%	0.00%
Lares	0.07%	99.64%	0.00%	0.14%	0.14%	0.00%	0.00%
Las Marías	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	0.00%	99.95%	0.00%	0.00%	0.05%	0.00%	0.00%
Loíza	0.09%	99.72%	0.02%	0.04%	0.11%	0.00%	0.02%
Luquillo	0.33%	99.56%	0.00%	0.00%	0.11%	0.00%	0.00%

Municipality	% Commercial	%Residential	%Industrial	% Government	% Education	% Agriculture	% Religion
Manatí	0.00%	99.91%	0.00%	0.05%	0.05%	0.00%	0.00%
Maricao	0.00%	99.76%	0.00%	0.24%	0.00%	0.00%	0.00%
Maunabo	0.16%	99.62%	0.00%	0.10%	0.13%	0.00%	0.00%
Mayagüez	0.71%	99.03%	0.08%	0.02%	0.15%	0.00%	0.01%
Moca	0.00%	99.95%	0.00%	0.00%	0.05%	0.00%	0.00%
Morovis	0.00%	99.75%	0.00%	0.00%	0.25%	0.00%	0.00%
Naguabo	0.12%	99.79%	0.01%	0.01%	0.06%	0.00%	0.01%
Naranjito	0.92%	98.62%	0.00%	0.15%	0.26%	0.00%	0.05%
Orocovis	0.19%	99.19%	0.06%	0.19%	0.37%	0.00%	0.00%
Patillas	0.02%	99.82%	0.00%	0.07%	0.04%	0.04%	0.00%
Peñuelas	0.05%	99.69%	0.07%	0.05%	0.14%	0.00%	0.00%
Ponce	0.81%	98.89%	0.10%	0.01%	0.17%	0.00%	0.02%
Quebradillas	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rincón	0.00%	99.91%	0.00%	0.00%	0.09%	0.00%	0.00%
Río Grande	0.17%	99.75%	0.01%	0.01%	0.05%	0.00%	0.00%
Sabana Grande	0.15%	99.58%	0.09%	0.03%	0.15%	0.00%	0.00%
Salinas	0.26%	99.51%	0.07%	0.03%	0.12%	0.00%	0.02%
San Germán	0.20%	99.61%	0.04%	0.04%	0.12%	0.00%	0.00%
San Juan	2.88%	96.03%	0.63%	0.08%	0.20%	0.05%	0.13%
San Lorenzo	0.08%	99.81%	0.01%	0.03%	0.08%	0.00%	0.00%
San Sebastían	0.03%	99.82%	0.00%	0.03%	0.12%	0.00%	0.00%
Santa Isabela	0.00%	99.85%	0.00%	0.05%	0.10%	0.00%	0.00%

Municipality	% Commercial	%Residential	%Industrial	% Government	% Education	% Agriculture	% Religion
Toa Baja	0.25%	99.60%	0.05%	0.02%	0.07%	0.00%	0.01%
Trujillo Alto	0.14%	99.63%	0.08%	0.04%	0.12%	0.00%	0.00%
Utuado	0.25%	99.52%	0.03%	0.03%	0.17%	0.00%	0.00%
Vega Alta	0.00%	99.95%	0.00%	0.02%	0.03%	0.00%	0.00%
Vega Baja	0.23%	99.63%	0.02%	0.02%	0.09%	0.00%	0.00%
Vieques	0.10%	99.80%	0.00%	0.05%	0.05%	0.00%	0.00%
Villalba	0.16%	99.32%	0.00%	0.10%	0.42%	0.00%	0.00%
Yabucoa	0.29%	99.39%	0.08%	0.04%	0.19%	0.00%	0.02%
Yauco	0.40%	99.30%	0.04%	0.04%	0.21%	0.00%	0.00%
Grand Total	**0.45%**	**99.31%**	**0.08%**	**0.03%**	**0.12%**	**0.00%**	**0.01%**

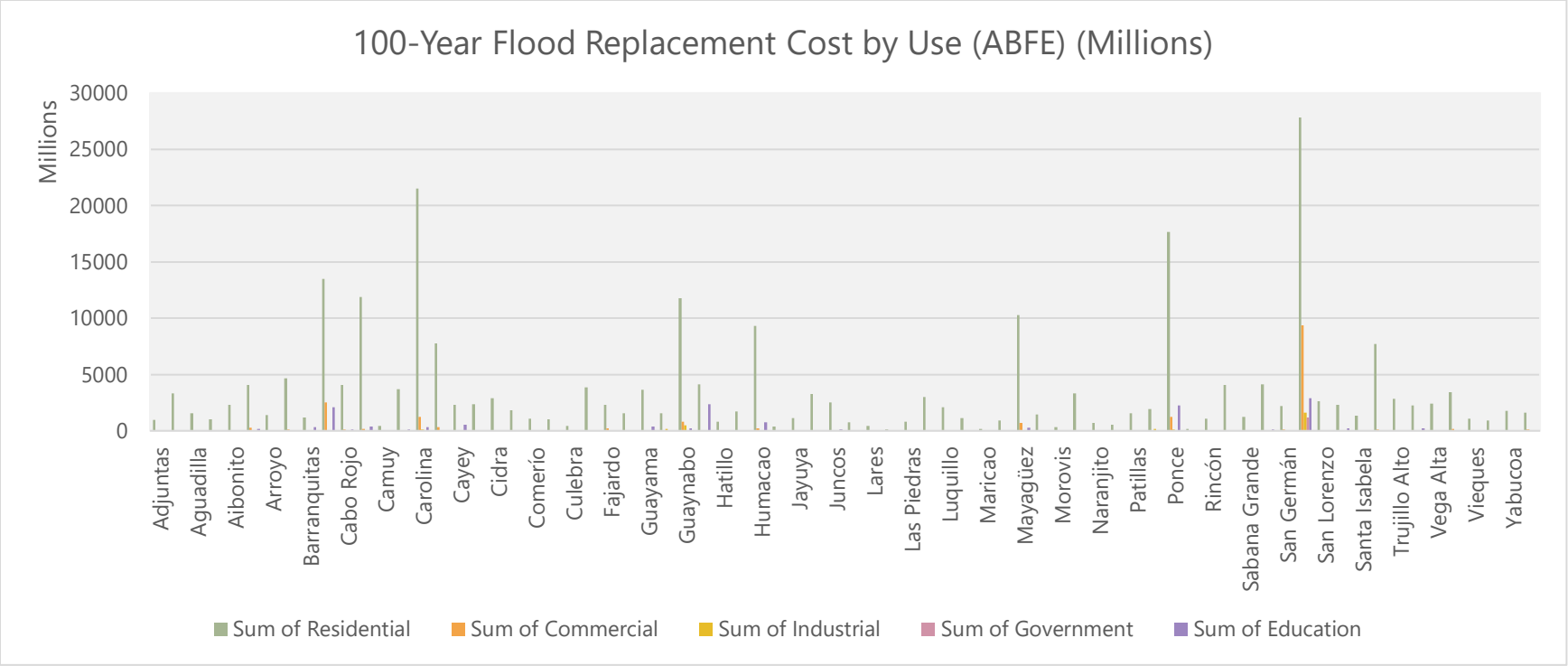

Figure 160: Municipal Asset Replacement Value by Type within 100-year ABFE Floodplain Areas

Table 67: Percentage of Asset Types within 100- year FIRM Floodplains

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education
Adjuntas	99.84%	0.00%	0.00%	0.00%	0.00%	0.16%
Aguada	99.83%	0.03%	0.06%	0.00%	0.00%	0.08%
Aguadilla	99.43%	0.17%	0.00%	0.00%	0.06%	0.28%
Aguas Buenas	99.81%	0.00%	0.00%	0.00%	0.00%	0.19%
Aibonito	99.89%	0.07%	0.00%	0.00%	0.00%	0.04%
Añasco	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arecibo	99.05%	0.76%	0.15%	0.04%	0.00%	0.00%
Arroyo	99.68%	0.32%	0.00%	0.00%	0.00%	0.00%
Barceloneta	99.90%	0.00%	0.00%	0.00%	0.00%	0.10%
Barranquitas	98.90%	0.22%	0.00%	0.00%	0.00%	0.66%
Bayamón	99.69%	0.10%	0.00%	0.00%	0.00%	0.21%
Cabo Rojo	99.91%	0.00%	0.02%	0.00%	0.00%	0.07%
Caguas	99.87%	0.00%	0.00%	0.00%	0.00%	0.10%
Camuy	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Canóvanas	99.91%	0.00%	0.00%	0.00%	0.00%	0.09%
Carolina	98.83%	0.83%	0.18%	0.00%	0.00%	0.10%
Cataño	98.47%	1.08%	0.17%	0.00%	0.02%	0.19%
Cayey	99.34%	0.17%	0.00%	0.00%	0.00%	0.39%
Ceiba	99.89%	0.00%	0.00%	0.00%	0.00%	0.11%
Ciales	99.74%	0.00%	0.00%	0.00%	0.00%	0.26%
Cidra	99.88%	0.00%	0.00%	0.00%	0.00%	0.08%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education
Coamo	99.93%	0.00%	0.00%	0.00%	0.00%	0.07%
Comerío	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	99.45%	0.18%	0.00%	0.00%	0.00%	0.09%
Dorado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fajardo	99.73%	0.13%	0.13%	0.00%	0.00%	0.00%
Guánica	99.26%	0.43%	0.18%	0.00%	0.00%	0.06%
Guayama	99.83%	0.00%	0.05%	0.00%	0.00%	0.12%
Guayanilla	99.88%	0.00%	0.12%	0.00%	0.00%	0.00%
Guaynabo	98.95%	0.71%	0.09%	0.00%	0.03%	0.14%
Gurabo	99.87%	0.00%	0.00%	0.00%	0.00%	0.13%
Hatillo	99.75%	0.12%	0.00%	0.00%	0.00%	0.12%
Hormigueros	99.82%	0.00%	0.00%	0.00%	0.00%	0.18%
Humacao	99.93%	0.02%	0.00%	0.00%	0.00%	0.06%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	99.83%	0.00%	0.00%	0.00%	0.00%	0.00%
Juana Díaz	99.94%	0.00%	0.00%	0.00%	0.00%	0.06%
Juncos	99.86%	0.00%	0.00%	0.00%	0.00%	0.14%
Lajas	99.90%	0.00%	0.00%	0.00%	0.00%	0.05%
Lares	99.36%	0.13%	0.00%	0.00%	0.00%	0.26%
Las Marías	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loíza	99.63%	0.12%	0.02%	0.00%	0.04%	0.12%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education
Luquillo	99.72%	0.20%	0.00%	0.00%	0.00%	0.08%
Manatí	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maricao	99.68%	0.00%	0.00%	0.00%	0.00%	0.00%
Maunabo	99.78%	0.00%	0.00%	0.00%	0.00%	0.11%
Mayagüez	98.53%	1.19%	0.17%	0.00%	0.00%	0.10%
Moca	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Morovis	99.84%	0.00%	0.00%	0.00%	0.00%	0.16%
Naguabo	99.87%	0.02%	0.02%	0.00%	0.00%	0.10%
Naranjito	99.87%	0.00%	0.00%	0.00%	0.00%	0.13%
Orocovis	99.17%	0.00%	0.00%	0.00%	0.00%	0.83%
Patillas	99.96%	0.00%	0.00%	0.00%	0.00%	0.04%
Peñuelas	98.95%	0.35%	0.35%	0.00%	0.00%	0.35%
Ponce	99.19%	0.51%	0.08%	0.00%	0.05%	0.15%
Quebradillas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rincón	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Río Grande	99.79%	0.17%	0.00%	0.00%	0.00%	0.04%
Sabana Grande	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	99.84%	0.00%	0.03%	0.00%	0.00%	0.11%
San Germán	99.76%	0.12%	0.00%	0.00%	0.00%	0.12%
San Juan	96.42%	2.61%	0.43%	0.02%	0.14%	0.19%
San Lorenzo	99.83%	0.00%	0.00%	0.00%	0.00%	0.08%
San Sebastían	99.91%	0.00%	0.00%	0.00%	0.00%	0.09%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education
Santa Isabel	99.79%	0.00%	0.00%	0.00%	0.00%	0.16%
Toa Alta	99.92%	0.03%	0.00%	0.00%	0.00%	0.05%
Toa Baja	99.59%	0.14%	0.14%	0.00%	0.00%	0.07%
Trujillo Alto	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Utuado	99.85%	0.00%	0.00%	0.00%	0.00%	0.15%
Vega Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Baja	99.89%	0.00%	0.00%	0.00%	0.00%	0.11%
Vieques	99.68%	0.24%	0.00%	0.00%	0.00%	0.00%
Villalba	99.42%	0.00%	0.00%	0.00%	0.00%	0.58%
Yabucoa	99.93%	0.00%	0.00%	0.00%	0.00%	0.07%
Yauco	99.78%	0.07%	0.00%	0.00%	0.00%	0.15%
Grand Total	**99.43%**	**0.35%**	**0.06%**	**0.00%**	**0.01%**	**0.11%**

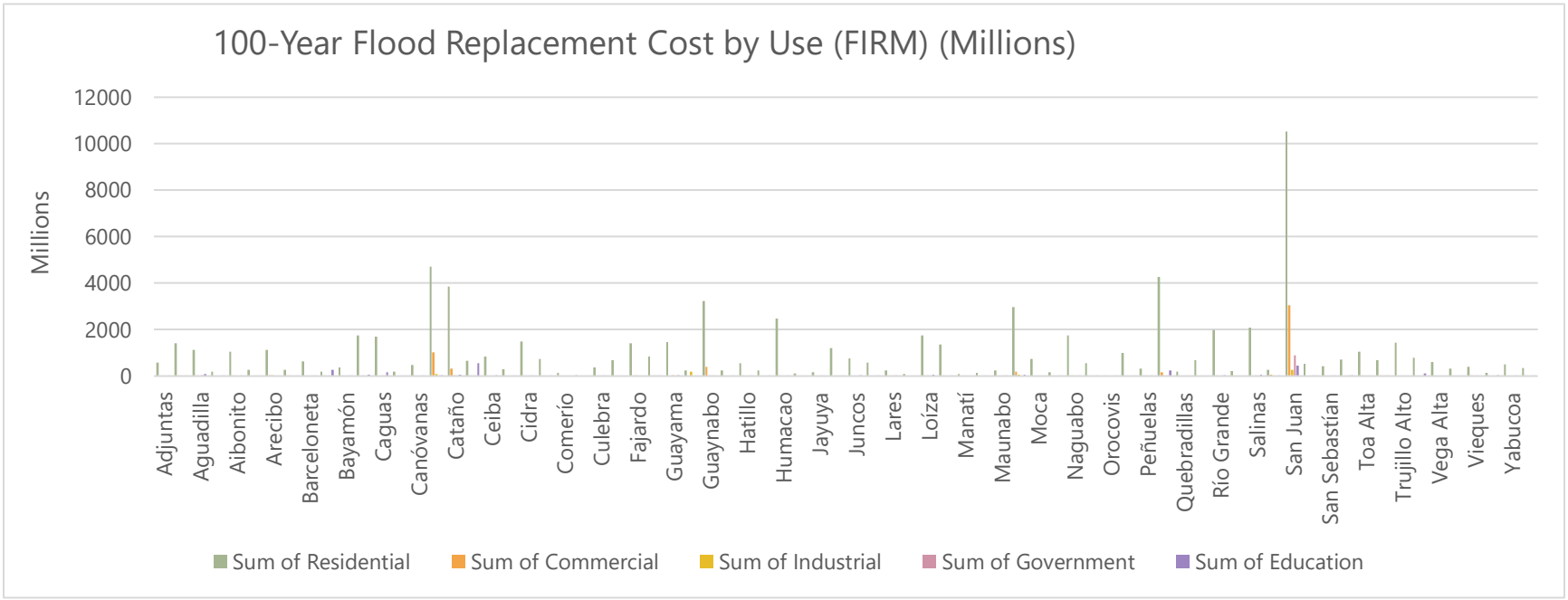

Figure 161: Municipal Asset Replacement Value by Type within 100-year FIRM Floodplain Areas

Table 68: Percentage of Asset Types within 500- year ABFE Floodplains

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education	% Government
Adjuntas	99.58%	0.17%	0.09%	0.00%	0.00%	0.11%	0.06%
Aguada	99.77%	0.12%	0.02%	0.00%	0.00%	0.09%	0.00%
Aguadilla	99.82%	0.04%	0.01%	0.00%	0.01%	0.10%	0.01%
Aguas Buenas	99.70%	0.06%	0.00%	0.00%	0.00%	0.18%	0.06%
Aibonito	99.65%	0.22%	0.01%	0.00%	0.01%	0.09%	0.03%
Añasco	99.66%	0.18%	0.00%	0.00%	0.00%	0.12%	0.03%
Arecibo	99.27%	0.54%	0.05%	0.01%	0.01%	0.10%	0.02%
Arroyo	99.64%	0.18%	0.00%	0.00%	0.01%	0.14%	0.03%
Barceloneta	99.69%	0.19%	0.01%	0.00%	0.01%	0.07%	0.03%
Barranquitas	99.59%	0.11%	0.00%	0.00%	0.00%	0.26%	0.04%
Bayamón	98.94%	0.75%	0.12%	0.00%	0.01%	0.16%	0.02%
Cabo Rojo	99.56%	0.28%	0.02%	0.00%	0.00%	0.11%	0.03%
Caguas	99.71%	0.11%	0.01%	0.00%	0.01%	0.13%	0.04%
Camuy	99.30%	0.47%	0.00%	0.00%	0.00%	0.12%	0.12%
Canóvanas	99.79%	0.11%	0.01%	0.00%	0.01%	0.05%	0.02%
Carolina	99.51%	0.30%	0.05%	0.01%	0.00%	0.12%	0.01%
Cataño	98.90%	0.76%	0.10%	0.00%	0.01%	0.18%	0.05%
Cayey	99.70%	0.10%	0.00%	0.00%	0.00%	0.19%	0.01%
Ceiba	99.76%	0.11%	0.02%	0.00%	0.00%	0.08%	0.02%
Ciales	98.56%	0.91%	0.15%	0.00%	0.00%	0.24%	0.14%
Cidra	99.95%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education	% Government
Coamo	99.65%	0.25%	0.01%	0.00%	0.00%	0.09%	0.00%
Comerío	99.69%	0.17%	0.00%	0.00%	0.00%	0.06%	0.08%
Corozal	99.43%	0.32%	0.00%	0.00%	0.00%	0.19%	0.06%
Culebra	99.53%	0.16%	0.00%	0.00%	0.00%	0.08%	0.24%
Dorado	99.83%	0.06%	0.01%	0.00%	0.00%	0.08%	0.02%
Fajardo	99.60%	0.24%	0.09%	0.00%	0.00%	0.04%	0.02%
Guánica	99.45%	0.31%	0.05%	0.00%	0.00%	0.15%	0.04%
Guayama	99.77%	0.09%	0.02%	0.00%	0.00%	0.13%	0.00%
Guayanilla	99.64%	0.16%	0.04%	0.00%	0.00%	0.12%	0.04%
Guaynabo	99.20%	0.49%	0.14%	0.00%	0.01%	0.10%	0.06%
Gurabo	99.85%	0.04%	0.02%	0.00%	0.00%	0.07%	0.01%
Hatillo	99.56%	0.16%	0.00%	0.00%	0.00%	0.14%	0.14%
Hormigueros	99.67%	0.11%	0.00%	0.00%	0.00%	0.14%	0.08%
Humacao	99.68%	0.20%	0.00%	0.00%	0.00%	0.11%	0.00%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	99.50%	0.30%	0.03%	0.00%	0.00%	0.16%	0.01%
Juana Díaz	99.85%	0.07%	0.02%	0.00%	0.00%	0.05%	0.01%
Juncos	99.75%	0.13%	0.00%	0.00%	0.00%	0.10%	0.01%
Lajas	99.88%	0.00%	0.00%	0.00%	0.00%	0.07%	0.05%
Lares	99.21%	0.41%	0.00%	0.00%	0.00%	0.21%	0.17%
Las Marías	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Las Piedras	99.96%	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education	% Government
Loíza	99.81%	0.07%	0.01%	0.00%	0.01%	0.08%	0.02%
Luquillo	99.49%	0.38%	0.00%	0.00%	0.00%	0.10%	0.03%
Manatí	99.91%	0.00%	0.00%	0.00%	0.00%	0.07%	0.02%
Maricao	99.51%	0.00%	0.00%	0.00%	0.00%	0.12%	0.37%
Maunabo	99.65%	0.13%	0.00%	0.00%	0.00%	0.14%	0.08%
Mayagüez	98.92%	0.76%	0.11%	0.00%	0.01%	0.18%	0.01%
Moca	99.93%	0.01%	0.00%	0.00%	0.00%	0.06%	0.00%
Morovis	99.86%	0.00%	0.00%	0.00%	0.00%	0.14%	0.00%
Naguabo	99.80%	0.09%	0.02%	0.00%	0.01%	0.06%	0.01%
Naranjito	99.15%	0.63%	0.00%	0.00%	0.03%	0.11%	0.08%
Orocovis	99.46%	0.16%	0.05%	0.00%	0.00%	0.24%	0.08%
Patillas	99.73%	0.13%	0.04%	0.02%	0.00%	0.06%	0.03%
Peñuelas	99.80%	0.03%	0.04%	0.00%	0.00%	0.11%	0.03%
Ponce	99.23%	0.55%	0.05%	0.00%	0.01%	0.14%	0.01%
Quebradillas	99.90%	0.00%	0.00%	0.00%	0.00%	0.10%	0.00%
Rincón	99.86%	0.00%	0.00%	0.00%	0.00%	0.10%	0.03%
Río Grande	99.79%	0.15%	0.01%	0.00%	0.00%	0.05%	0.01%
Sabana Grande	99.56%	0.21%	0.10%	0.00%	0.00%	0.10%	0.03%
Salinas	99.57%	0.21%	0.06%	0.00%	0.01%	0.13%	0.02%
San Germán	99.60%	0.19%	0.02%	0.00%	0.00%	0.15%	0.04%
San Juan	95.80%	3.12%	0.66%	0.05%	0.12%	0.18%	0.07%
San Lorenzo	99.89%	0.05%	0.01%	0.00%	0.00%	0.05%	0.01%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Religion	% Education	% Government
San Sebastían	99.85%	0.03%	0.00%	0.00%	0.00%	0.09%	0.02%
Santa Isabel	99.77%	0.05%	0.01%	0.00%	0.00%	0.13%	0.04%
Toa Alta	99.66%	0.19%	0.01%	0.00%	0.00%	0.10%	0.03%
Toa Baja	99.41%	0.38%	0.09%	0.00%	0.00%	0.08%	0.03%
Trujillo Alto	99.71%	0.07%	0.11%	0.00%	0.00%	0.07%	0.04%
Utuado	99.65%	0.18%	0.02%	0.00%	0.00%	0.13%	0.02%
Vega Alta	99.96%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%
Vega Baja	99.52%	0.33%	0.02%	0.00%	0.00%	0.11%	0.01%
Vieques	99.74%	0.14%	0.00%	0.01%	0.00%	0.08%	0.03%
Villalba	99.41%	0.17%	0.00%	0.00%	0.00%	0.34%	0.08%
Yabucoa	99.45%	0.25%	0.08%	0.00%	0.02%	0.15%	0.05%
Yauco	99.54%	0.23%	0.03%	0.00%	0.00%	0.17%	0.02%
Grand Total	**99.40%**	**0.38%**	**0.07%**	**0.00%**	**0.01%**	**0.11%**	**0.03%**

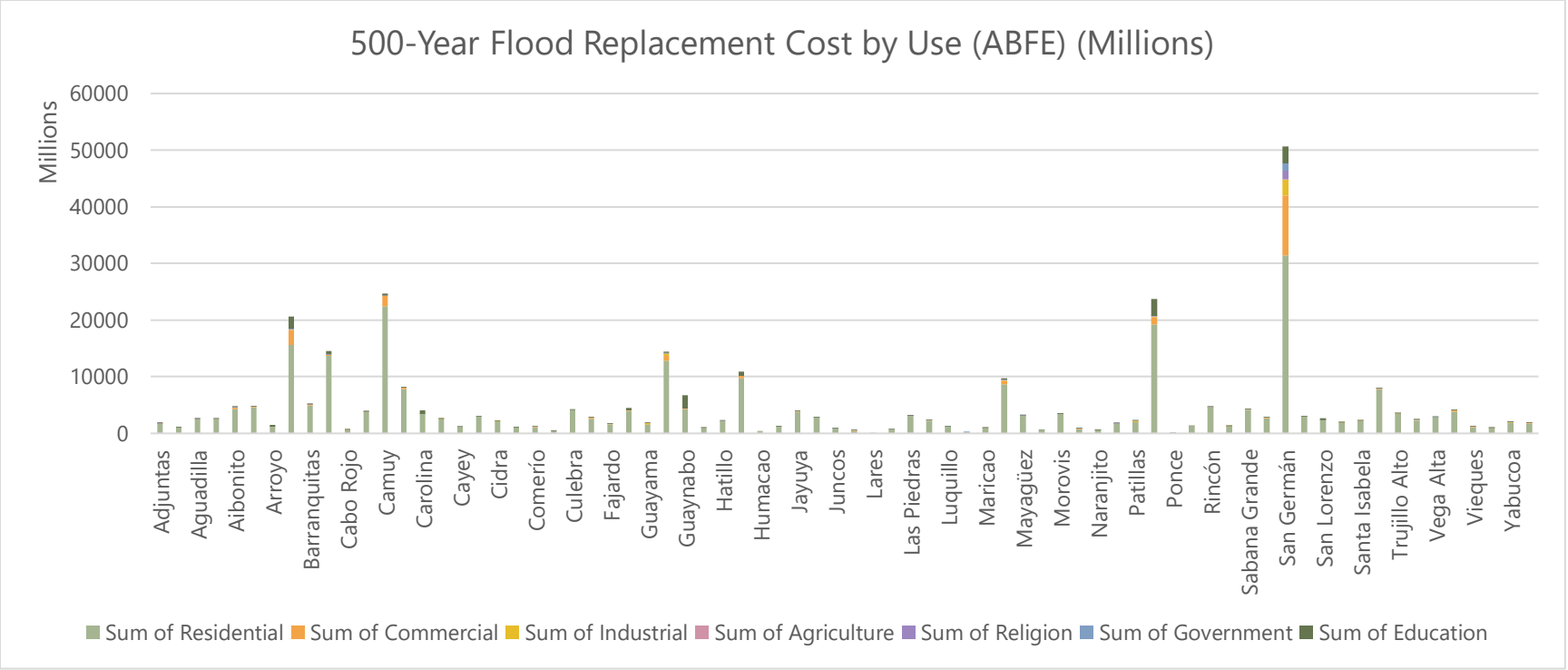

Figure 162: Municipal Asset replacement value by Type within 500-year ABFE Floodplain Areas

Table 69: Percentage of Asset Types within 500- year FIRM Floodplains

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Government	% Education	% Religion
Adjuntas	99.03%	0.00%	0.00%	0.00%	0.00%	0.97%	0.00%
Aguada	97.66%	0.67%	0.55%	0.00%	0.00%	1.11%	0.00%
Aguadilla	91.51%	0.16%	0.00%	0.00%	1.33%	5.40%	1.60%
Aguas Buenas	99.89%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%
Aibonito	98.24%	0.15%	0.00%	0.00%	0.00%	1.62%	0.00%
Añasco	99.71%	0.00%	0.00%	0.00%	0.00%	0.29%	0.00%
Arecibo	92.41%	5.51%	1.71%	0.34%	0.00%	0.03%	0.00%
Arroyo	96.32%	3.68%	0.00%	0.00%	0.00%	0.00%	0.00%
Barceloneta	99.05%	0.00%	0.00%	0.00%	0.00%	0.95%	0.00%
Barranquitas	44.83%	1.89%	0.00%	0.00%	0.65%	52.63%	0.00%
Bayamón	80.80%	18.06%	0.00%	0.00%	0.00%	1.14%	0.00%
Cabo Rojo	96.40%	0.00%	0.14%	0.00%	0.73%	2.73%	0.00%
Caguas	93.43%	0.00%	0.00%	0.00%	0.26%	6.32%	0.00%
Camuy	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Canóvanas	99.30%	0.00%	0.00%	0.00%	0.00%	0.70%	0.00%
Carolina	81.84%	15.49%	2.02%	0.00%	0.00%	0.65%	0.00%
Cataño	84.11%	12.60%	0.81%	0.00%	0.72%	1.70%	0.06%
Cayey	64.92%	0.84%	0.00%	0.00%	0.22%	34.03%	0.00%
Ceiba	98.08%	0.00%	0.00%	0.00%	0.00%	1.92%	0.00%
Ciales	95.48%	2.62%	0.46%	0.00%	0.21%	1.23%	0.00%
Cidra	99.34%	0.00%	0.00%	0.00%	0.25%	0.41%	0.00%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Government	% Education	% Religion
Coamo	98.17%	0.00%	0.00%	0.00%	0.00%	1.83%	0.00%
Comerío	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corozal	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Culebra	97.40%	1.14%	0.00%	0.00%	1.23%	0.23%	0.00%
Dorado	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fajardo	99.12%	0.43%	0.45%	0.00%	0.00%	0.00%	0.00%
Guánica	98.72%	0.57%	0.25%	0.00%	0.14%	0.33%	0.00%
Guayama	94.21%	0.00%	1.55%	0.00%	0.00%	4.24%	0.00%
Guayanilla	77.32%	0.00%	22.68%	0.00%	0.00%	0.00%	0.00%
Guaynabo	80.76%	18.74%	0.04%	0.00%	0.08%	0.24%	0.14%
Gurabo	99.41%	0.00%	0.00%	0.00%	0.00%	0.59%	0.00%
Hatillo	99.06%	0.73%	0.00%	0.00%	0.00%	0.22%	0.00%
Hormigueros	99.07%	0.00%	0.00%	0.00%	0.00%	0.93%	0.00%
Humacao	99.56%	0.02%	0.00%	0.00%	0.00%	0.42%	0.00%
Isabela	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Jayuya	98.45%	0.00%	0.00%	0.00%	1.55%	0.00%	0.00%
Juana Díaz	99.95%	0.00%	0.00%	0.00%	0.00%	0.05%	0.00%
Juncos	97.48%	0.00%	0.00%	0.00%	0.00%	2.52%	0.00%
Lajas	97.32%	0.00%	0.00%	0.00%	2.09%	0.58%	0.00%
Lares	80.63%	4.66%	0.00%	0.00%	1.87%	12.83%	0.00%
Las Marías	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Loíza	95.63%	0.72%	0.01%	0.00%	0.18%	3.22%	0.26%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Government	% Education	% Religion
Luquillo	98.84%	0.54%	0.00%	0.00%	0.07%	0.55%	0.00%
Manatí	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maricao	89.59%	0.00%	0.00%	0.00%	3.62%	6.79%	0.00%
Maunabo	97.37%	0.00%	0.00%	0.00%	0.41%	2.22%	0.00%
Mayagüez	89.70%	6.90%	1.64%	0.00%	0.00%	1.77%	0.00%
Moca	99.94%	0.00%	0.00%	0.00%	0.00%	0.06%	0.00%
Morovis	99.75%	0.00%	0.00%	0.00%	0.00%	0.25%	0.00%
Naguabo	99.59%	0.07%	0.02%	0.00%	0.00%	0.33%	0.00%
Naranjito	98.06%	0.00%	0.00%	0.00%	0.00%	1.94%	0.00%
Orocovis	98.25%	0.00%	0.00%	0.00%	0.00%	1.75%	0.00%
Patillas	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peñuelas	66.58%	0.02%	33.25%	0.00%	0.00%	0.15%	0.00%
Ponce	90.25%	3.13%	0.29%	0.00%	0.16%	5.79%	0.39%
Quebradillas	98.62%	0.00%	0.00%	0.00%	0.00%	1.38%	0.00%
Rincón	99.70%	0.00%	0.00%	0.00%	0.17%	0.13%	0.00%
Río Grande	98.07%	0.44%	0.00%	0.00%	0.00%	1.49%	0.00%
Sabana Grande	99.54%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%
Salinas	97.46%	0.00%	0.02%	0.00%	0.05%	2.46%	0.00%
San Germán	86.19%	10.78%	0.00%	0.00%	0.00%	3.03%	0.00%
San Juan	65.22%	17.29%	1.69%	0.30%	6.58%	3.48%	5.43%
San Lorenzo	97.25%	0.10%	0.00%	0.00%	0.25%	2.41%	0.00%
San Sebastían	99.52%	0.00%	0.00%	0.00%	0.00%	0.48%	0.00%

Municipality	% Residential	% Commercial	% Industrial	% Agriculture	% Government	% Education	% Religion
Santa Isabel	92.46%	0.00%	0.00%	0.00%	0.52%	7.01%	0.00%
Toa Alta	99.72%	0.01%	0.00%	0.00%	0.00%	0.27%	0.00%
Toa Baja	96.03%	0.17%	3.66%	0.00%	0.14%	0.00%	0.00%
Trujillo Alto	99.09%	0.00%	0.00%	0.00%	0.26%	0.65%	0.00%
Utuado	83.54%	0.00%	0.00%	0.00%	0.00%	16.46%	0.00%
Vega Alta	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Vega Baja	99.67%	0.00%	0.00%	0.00%	0.00%	0.33%	0.00%
Vieques	82.69%	1.14%	0.00%	0.00%	0.48%	15.70%	0.00%
Villalba	87.72%	0.00%	0.00%	0.00%	0.00%	12.28%	0.00%
Yabucoa	99.77%	0.00%	0.00%	0.00%	0.00%	0.23%	0.00%
Yauco	97.03%	0.33%	0.00%	0.00%	0.00%	2.64%	0.00%
Grand Total	**88.25%**	**5.47%**	**0.85%**	**0.05%**	**1.18%**	**3.30%**	**0.91%**

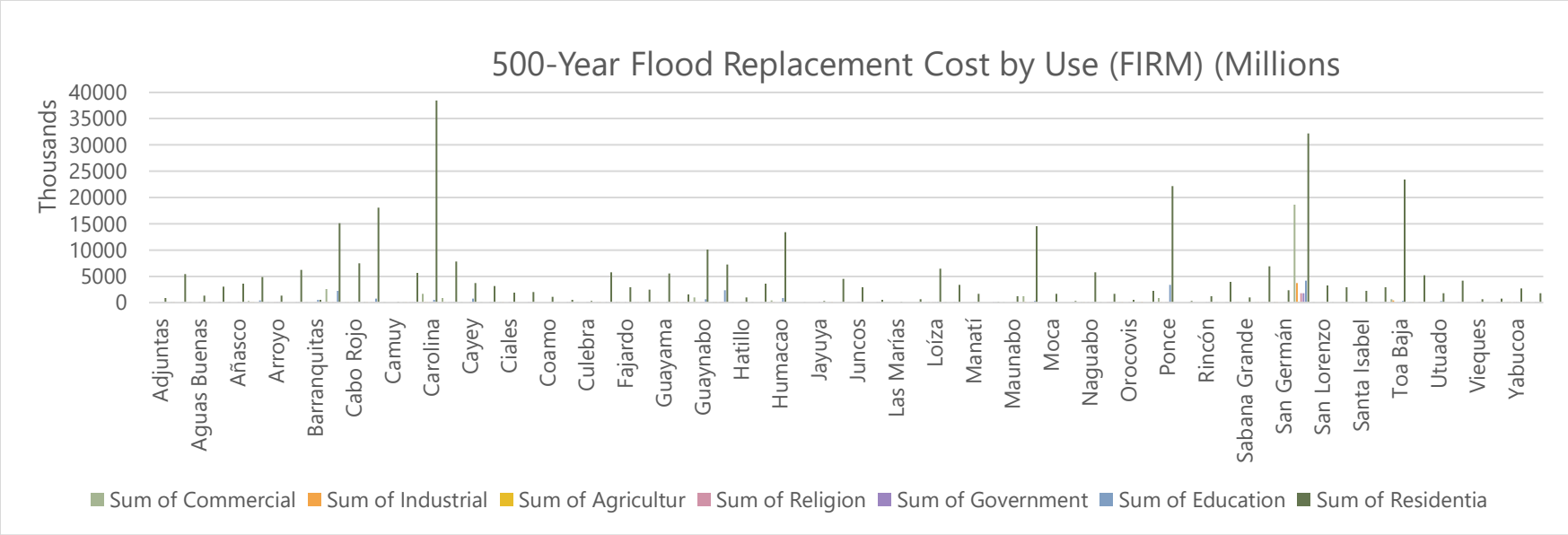

Figure 163: Municipal Asset Replacement Value by Type within 500-year FIRM Floodplain Areas

INFRASTRUCTURE AND COMMUNITY LIFELINES

Figure 164 shows the exposure of FEMA community lifelines to flooding. Among these lifelines, Hazardous Materials infrastructure has the highest replacement value at risk. This is likely because Puerto Rico has numerous industrial zones, chemical storage facilities, and fuel depots located in low-lying coastal areas and floodplains. These sites often contain specialized equipment, containment systems, and safety installations that are expensive to replace. Additionally, their proximity to ports and transportation corridors—areas highly susceptible to storm surge and riverine flooding—further amplifies exposure. The concentration of high-value hazardous material facilities in vulnerable zones explains why this lifeline dominates replacement cost estimates compared to others like energy or transportation.

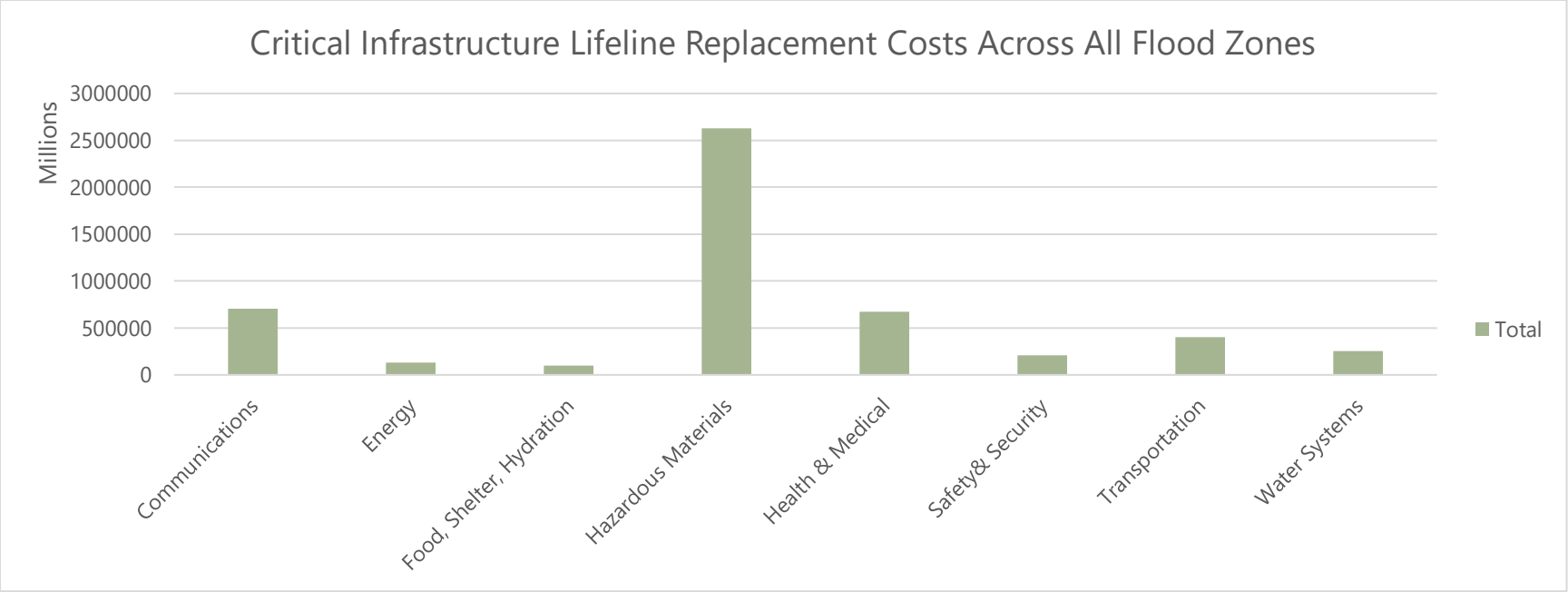

Figure 164: Estimated Replacement Costs for Critical Infrastructure Lifelines in Flood-Prone Zones

Table 70 summarizes the estimated economic losses for Puerto Rico under two modeled flood scenarios: FIRM 100-year and ABFE 500-year. These estimates were generated using FEMA's Hazus methodology, which accounts for direct building damage and business interruption losses (including income, relocation, rental, and wage impacts). The values represent millions of dollars and provide a comparative view of potential flood impacts under probabilistic (FIRM) and deterministic (ABFE) approaches.

Table 70: Hazus Flood Scenario Economic Loss Estimates (Millions)

Flood Scenario	Building Loss	Contents Loss	Inventory Loss	Income Loss	Relocation Loss	Rental Income Loss	Wage Loss	Total Economic Loss
100-year FIRM	$47,204	$32,071	$807	$7,889	$21,114	$13,179	$49,044	$171,311
500-year FIRM	$47,204	$32,071	$807	$7,889	$21,114	$13,179	$49,044	$171,311
100-year ABFE	$734,318	$529,375	$13,679	$120,436	$220,569	$134,674	$389,611	$2,142,662
500-year ABFE	$2,253,235	$1,436,593	$30,394,	$230,417	$388,280	$246,433	$791,822	$5,377,176

Figure 165 to Figure 168 illustrate the estimated replacement value of critical infrastructure assets located within flood-prone areas under four modeled scenarios: FEMA's Flood Insurance Rate Maps (FIRM) and Advisory Base Flood Elevation (ABFE) maps for both the 100-year and 500-year return periods. These maps provide a comparative view of exposure across probabilistic (FIRM) and deterministic (ABFE) approaches, highlighting how replacement costs escalate significantly under ABFE scenarios due to their conservative assumptions.

Figure 165: Estimated Critical Infrastructure Replacement Value in Puerto Rico's 100-Year Floodplain (FIRM Scenario)

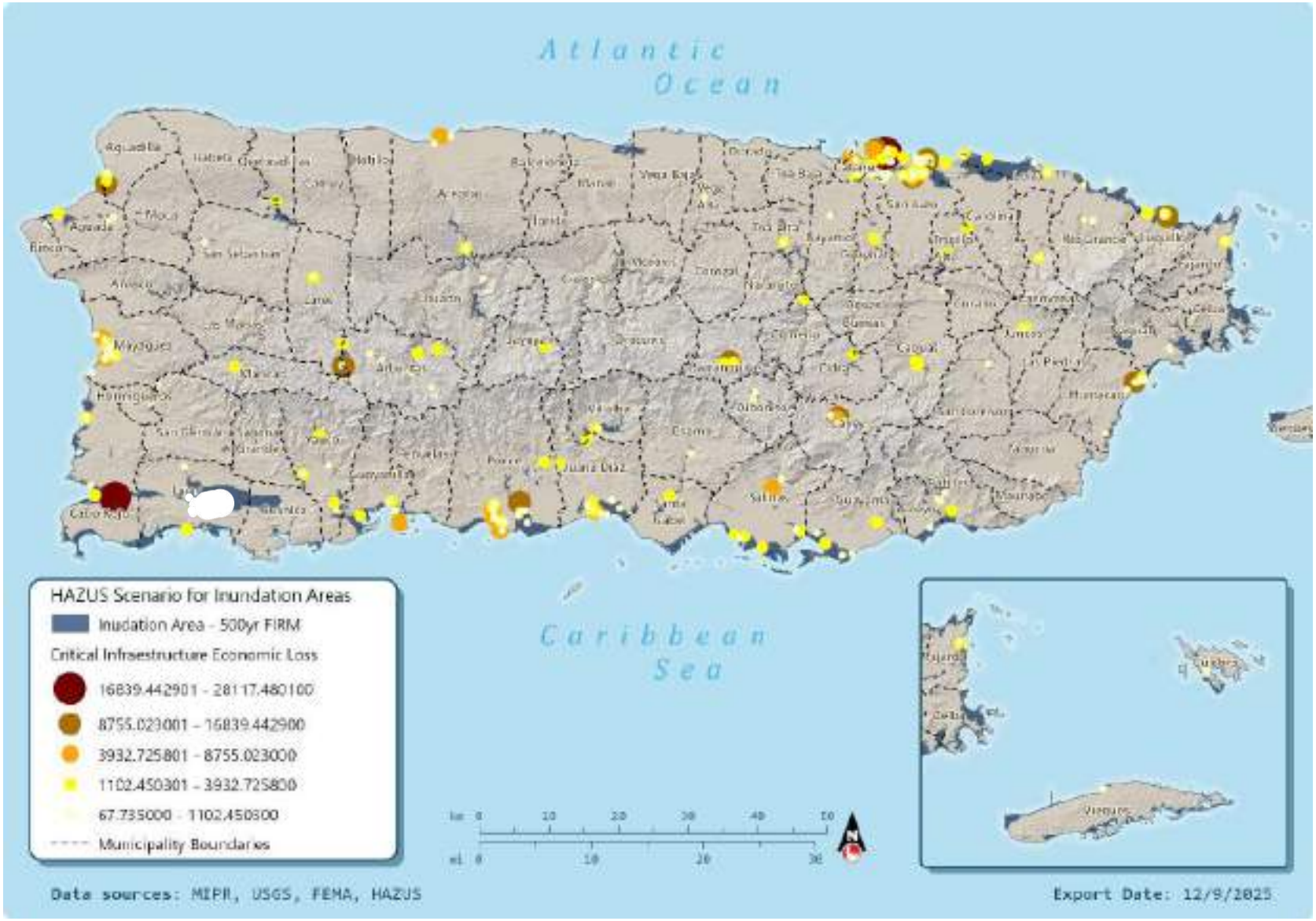

Figure 166: Estimated Critical Infrastructure Replacement Value in Puerto Rico's 500-Year Floodplain (FIRM Scenario)

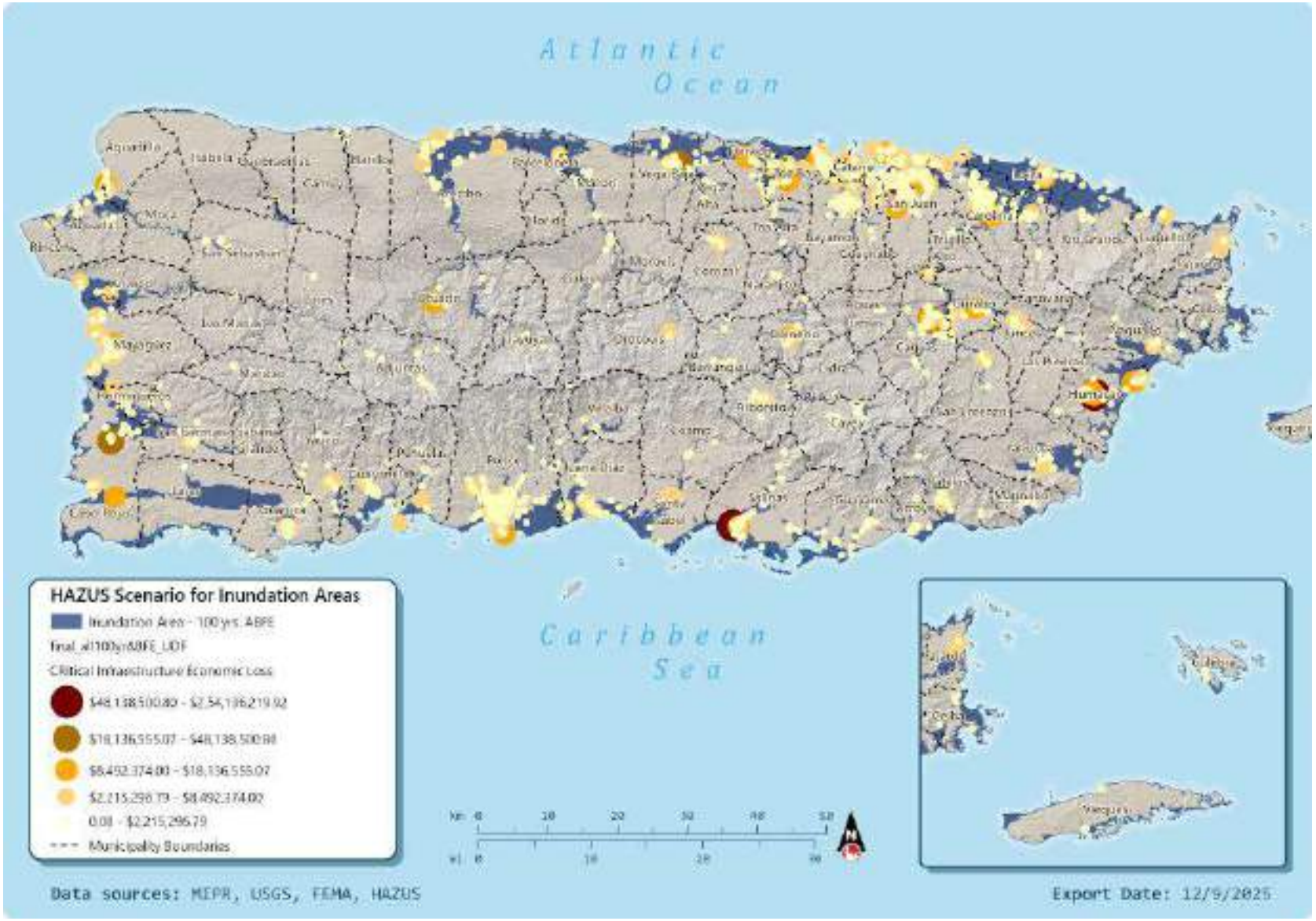

Figure 167: Estimated Critical Infrastructure Replacement Value in Puerto Rico's 100-Year Floodplain (ABFE Scenario)

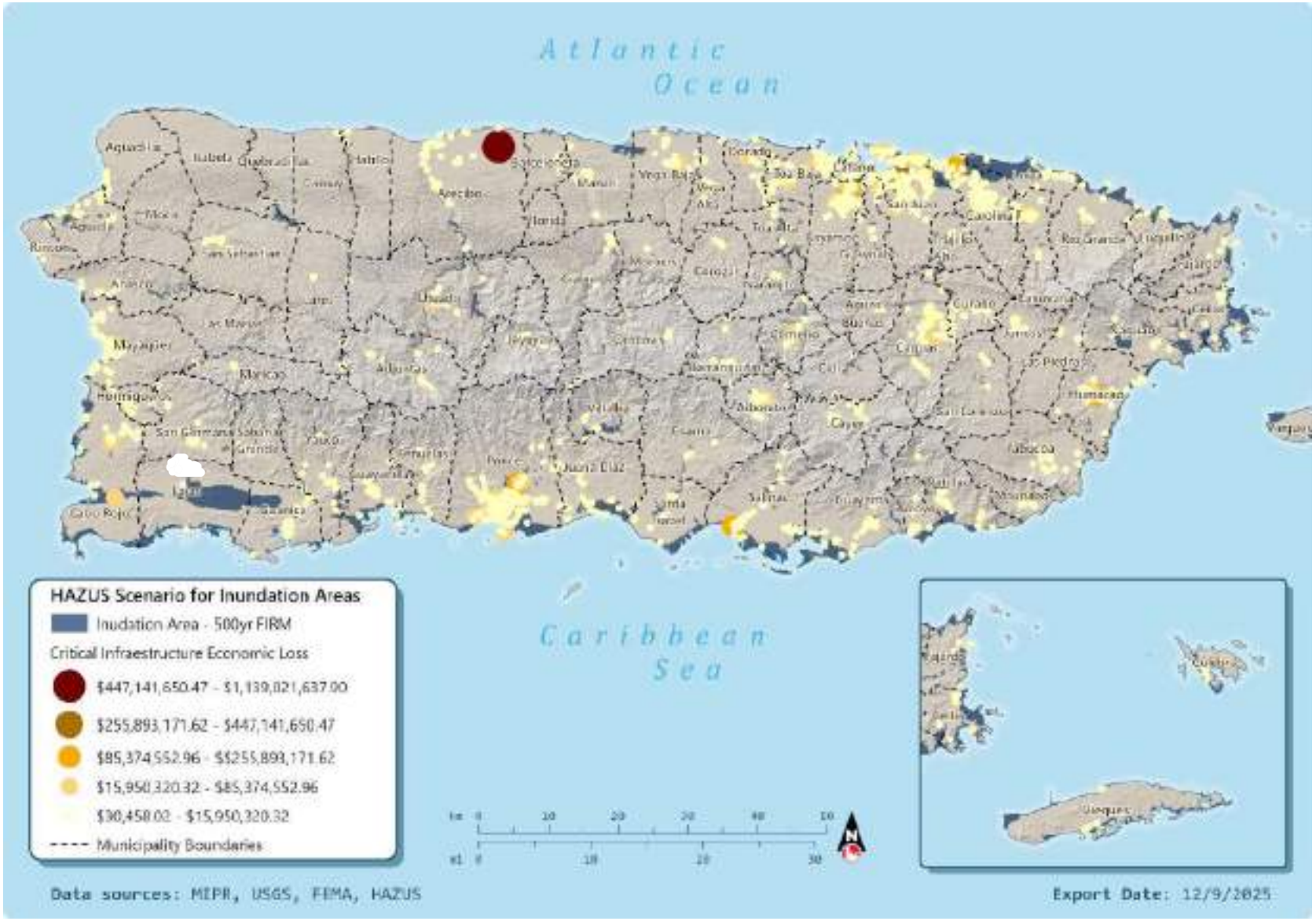

Figure 168: Estimated Critical Infrastructure Replacement Value in Puerto Rico's 500-Year Floodplain (ABFE Scenario)

Based on estimated damage to residential structures, Hazus estimates the number of households that are expected to be displaced from their homes. It also reports a portion of those that are likely to seek temporary public shelter. The estimated sheltering needs for each return-interval scenario are shown in Table 71.

Table 71: Shelter Needs for Hazus Flooding Scenarios

Flood Scenario	Displaced Households	Persons Requiring Temporary Shelter
100-year FIRM	28,086	30,247
100-year ABFE	156,334	130,138
500-year FIRM	28,086	30,274
500-year ABFE	195,078	154,851

STATE ASSETS

State assets like hospitals, ports, the energy grid, schools, water systems, and government buildings are highly vulnerable to flooding, and the ability to strengthen or rebuild these assets may be obstructed by growing logistical expenditures, supply and demand costs, labor issues, construction and environmental impact studies, and limited time to spend grant funds..

The flood damage assessment across various occupancy types demonstrates a clear trend of increasing vulnerability as flood severity intensifies and under the more conservative ABFE (Advisory Base Flood Elevation) assumptions. Under the ABFE 500-year flood scenario, the most severe and conservative condition, certain occupancy categories exhibit particularly high average damage percentages.

Government-related assets, such as General Services (GOV1) and Emergency Response facilities (GOV2), show average damages nearing 89% and 88%, respectively. Educational institutions also face significant risks, with colleges and universities (EDU2) experiencing average damages around 87%, and grade schools (EDU1) around 82%. Healthcare infrastructure is similarly vulnerable: hospitals (COM6) and medical offices/clinics (COM7) show substantial damage levels, averaging 82% and 80%, respectively.

Regions with the highest concentration of assets exposed to the FIRM 500-year and ABFE 500-year flood scenarios include:

- **San Juan:** Hosting a large number of critical assets across all occupancy types, including major hospitals, educational institutions, government facilities, and communication infrastructure. San Juan consistently shows high replacement costs and damage percentages under both FIRM 500 and ABFE 500 scenarios, reflecting its dense urban infrastructure and flood risk.
- **Bayamón:** Another key urban area with significant government, healthcare, and educational assets vulnerable to severe flood events. Bayamón's emergency response facilities and medical centers are notably exposed under the ABFE 500-year scenario.

- **Toa Baja:** This municipality contains numerous state assets, including emergency response stations and educational facilities, with high damage percentages under ABFE 500 conditions, indicating critical flood vulnerability.
- **Cataño and Carolina:** Both municipalities have substantial government and healthcare assets at risk, with emergency response and general services facilities showing high damage levels in the ABFE 500-year scenario.
- **Loíza and Salinas:** These regions also have a notable presence of vulnerable state assets, particularly in healthcare and government sectors, with damage percentages approaching or exceeding 80% under ABFE 500 conditions.
- **Humacao and Guayama:** These areas contain important healthcare and industrial assets exposed to significant flood damage under the most severe scenarios.

These findings underscore the critical exposure of essential state assets, particularly in education, healthcare, and government sectors, to extreme flood hazards in these regions. They highlight the importance of incorporating conservative elevation assumptions into hazard mitigation planning to better capture potential risks and prioritize resilience efforts in the most vulnerable municipalities. Table 72 shows state assets by occupancy type and percentage of damage due to flooding.

Table 72: Average Flood Damage Percentages by Occupancy Type and Flood Scenario

Occupancy Type / Average of (%) Damage	FIRM 100	FIRM 500	ABFE 100	ABFE 500
IND2 – Light Industrial	30%	33%	38%	67%
IND3 – Food/Drugs/Chemicals	30%	33%	37%	69%
IND4 – Metals/Minerals Processing	29%	28%	32%	59%
IND5 – High Technology	31%	30%	41%	68%
IND6 – Construction	49%	48%	53%	79%
EDU1 – Grade Schools	27%	32%	32%	82%
EDU2 – Colleges/Universities	37%	37%	35%	87%
GOV1 – General Services	39%	41%	38%	89%
GOV2 – Emergency Response	28%	30%	36%	88%
COM4 – Professional/Technical Services	23%	25%	39%	68%
COM6 – Hospital	67%	53%	13%	82%
COM7 – Medical Office/Clinic	36%	39%	37%	80%

To provide a clearer understanding of how flood severity and elevation assumptions affect critical infrastructure, the following section presents detailed examples of damage estimates for two essential state assets under multiple flood scenarios.

FIRM 100-Year Flood Scenario

Under the baseline FIRM 100-year flood event, Instituto Loaiza Cordero incurs approximately 40.5% damage to its replacement cost. This level of impact highlights the susceptibility of educational infrastructure even during moderate flood conditions. Similarly, Doctors Center Hospital San Fernando De suffers damage exceeding 81.5%, reaffirming the critical exposure of healthcare facilities. These examples illustrate the substantial risk faced by essential state assets in education and healthcare sectors under this scenario.

FIRM 500-Year Flood Scenario

In the more severe FIRM 500-year flood scenario, Instituto Loaiza Cordero's damage rises to about 50.6%, reflecting the amplified risk as flood severity increases. Doctors Center Hospital San Fernando De maintains high vulnerability, with damage levels around 81.6%. This scenario demonstrates the escalating potential losses to critical infrastructure as flood return periods lengthen, emphasizing the need for robust mitigation strategies.

ABFE 100-Year Flood Scenario

When applying Advisory Base Flood Elevation (ABFE) assumptions to the 100-year scenario, Instituto Loaiza Cordero sustains damage of approximately 40.5%, consistent with the FIRM 100-year scenario but influenced by conservative elevation adjustments. Doctors Center Hospital San Fernando De experiences damage exceeding 81.5%, underscoring the importance of incorporating advisory flood elevations into hazard mitigation planning for a more comprehensive risk assessment.

ABFE 500-Year Flood Scenario

Under the most conservative and severe condition—the ABFE 500-year flood scenario—Instituto Loaiza Cordero's damage surpasses 50.6%, indicating heightened vulnerability under extreme flood conditions. Doctors Center Hospital San Fernando De faces damage near 82%, highlighting the critical need for healthcare infrastructure resilience. This scenario represents the highest replacement cost exposure, reinforcing the necessity of detailed flood hazard assessments and elevation adjustments to safeguard essential community assets

These results underscore the sensitivity of damage estimates to both flood severity and elevation assumptions. The ABFE 500-year scenario poses the greatest financial risk, with total estimated replacement costs for state assets increasing from approximately $4.8 billion under the FIRM 100-year scenario to over $6.3 billion under the ABFE 500-year scenario. This substantial increase reflects the amplified risk and potential losses as flood events become more severe and conservative floodplain boundaries are applied.

Overall, the data emphasize the importance of integrating detailed flood hazard scenarios and elevation adjustments into hazard mitigation planning. Doing so ensures a more accurate risk profile for essential community assets, particularly in education and healthcare sectors, while supporting informed decision-making for resilience and preparedness

TOTAL REPLACEMENT COST

To complement the damage percentage analysis presented in Table 72, Table 73 summarizes the total estimated replacement costs for critical state assets under different flood scenarios. These estimates are derived using Hazus methodologies and FEMA flood modeling assumptions, providing a comprehensive view of financial exposure as flood severity and elevation assumptions change.

Table 73: Critical Infrastructure State Assets Replacement Cost

Flood Scenario	Total Replacement Cost
100-year FIRM	$4,831,198,784
100-year ABFE	$5,074,041,745
500-year FIRM	$5,530,269,712
500-year ABFE	$6,337,486,492

LOCAL ASSETS

At the municipal level, flooding can cause catastrophic damage to a community. For example, the May 2025 flood caused widespread damage and disrupted essential services. In Vega Alta, preliminary estimated flood damages exceeded $6.5 million. In Ceiba, a landslide collapsed a key pipeline, cutting off drinking water and forcing emergency water deliveries by truck. Cidra, in the central region, reported more than $3 million in damage to roads and drainage systems. In Aguas Buenas, heavy rains flooded streets, opened a sinkhole, and displaced over 25 families. A ruptured water pipe in Caguas halted operations at the town's central filtration plant, jeopardizing access to clean water.[512]

As local governments continue to experience flooding incidents, their residents must confront the economic challenges associated with rebuilding their communities. Seeking additional funds to rebuild local assets can be overwhelming and requires resources unavailable to impacted communities. For example, due to a strenuous application process and various approval processes, many local jurisdictions could not receive grants from the revolving funds to recover advances, leaving over $700 million in unused funds.[513]

[512] Spectrum News, Heavy rains continue to pound Puerto Rico, flooding streets and causing 2nd death, https://ny1.com/nyc/all-boroughs/news/2025/05/04/puerto-rico-heavy-rains-flooding-deaths.
[513] Municipalities in Puerto Rico Miss Out on $750 Million Reconstruction Fund, https://periodismoinvestigativo.com/2025/07/municipalities-left-out-million-dollar-recovery/.

COMMUNITY LIFELINES

The following sections describe how each of the community lifelines is affected by flooding. The effects of flooding on a community extend beyond immediate physical damage; they leave a ripple effect that may devastate a community.

SAFETY AND SECURITY

Floods endanger lives via water hazards, flash flooding, and structural collapse. Flood-prone areas often require mass evacuation and sheltering operations. These conditions may limit first responders' ability to provide immediate life-saving services, as roads may be blocked or damaged due to poor road conditions.

FOOD, HYDRATION, AND SHELTER

Flooding incidents threaten a community's food, hydration, and shelter resources. Food, water, and shelter resources are disrupted when transportation networks fail. Moreover, floods directly impact crop production, as soil degradation can occur from recurring exposure. In addition to sand, silt, clay, and other mineral matter, soil needs larvae, earthworms, and nutrients to support plant development. Flooding alters the biological composition of these habitats, which makes it difficult for these organisms to survive and, in turn, weakens food production.[514]

Furthermore, floods significantly undermine the functionality, safety, and accessibility of emergency shelters. Facilities situated in low-lying areas or near riverbanks are especially vulnerable to inundation, which can damage infrastructure, render sleeping quarters unusable, and destroy critical supplies such as bedding, food, and medical equipment. During Hurricane Maria, many shelters suffered structural damage or lost access to power and essential services, and this created hazardous conditions for evacuees. Flooding often necessitates the relocation of displaced individuals, leading to overcrowding in alternate shelters and complicating logistics. Blocked or damaged roads further hinder safe access for both evacuees and supply delivery teams, exacerbating the crisis response.[515]

HEALTH AND MEDICAL

A single flood can shatter public health systems, unleashing disease, injury, and long-term crises that outlast the waters. Standing water increases the risk of gastrointestinal illnesses, wound infection, and respiratory diseases from mold exposures in flooded homes.[516]

[514] More Floods Mean Worse Soil, https://www.project-syndicate.org/commentary/flooding-can-damage-soil-microbiome-by-esther-ngumbi-2023-10#:~:text=Compared%20to%20the%20visible%20devastation,biomass%20and%20soil%2Dfungi%20content.
[515] NIST shares preliminary findings from hurricane maria\ https://www.nist.gov/news-events/news/2025/07/nist-shares-preliminary-findings-hurricane-maria-investigation.
[516] CDC, Safety Guidelines: Floodwater, https://www.cdc.gov/floods/safety/floodwater-after-a-disaster-or-emergency-safety.html?CDC_AAref_Val=https://www.cdc.gov/disasters/floods/floodsafety.html.

ENERGY

The energy infrastructure is fragile, and stress from a flooding incident can cause severe damage to the grid. During floods, substations, switchyards, transformers, and underground cables may be inundated or shorted, forcing shutdowns of transmission and distribution circuits and triggering island-wide outages. Flooding or storm-driven rainfall has repeatedly isolated segments of the network, delaying repair crews and limiting access to damaged sites. When energy is lost, critical infrastructure, such as hospitals, water treatment plants, and communications hubs, loses functionality or must shift to backup generators, many of which are themselves vulnerable if fuel delivery is compromised by flooded roads or bridges[517].

After Hurricane Maria, nearly 100% of customers lost power as the flood-damaged grid collapsed under the combined force of wind and water. In response to frequent blackouts and extended outages, in January 2025, the government created an Energy Czar position. The role centralizes oversight of the island's generation, transmission, and distribution of energy, aiming to accelerate system repairs and support system modernization.[518]

COMMUNICATIONS

Flooding damages underground cables, cellular towers, and communication hubs, cutting off critical information across all levels and stakeholders. Loss of communication impairs coordination of resources among responders, prevents residents from receiving public information, and slows the request for assistance.

TRANSPORTATION

Roads, bridges, and ports are among the most heavily impacted assets during floods. Washed-out bridges in Puerto Rico's interior and inundated highways in coastal and urban areas can disrupt first responders, residents, and tourists' services and significantly reduce Puerto Rico's supply chain capacity.

HAZARDOUS MATERIALS

Flooding can unleash hazardous materials by submerging chemical storage sites, industrial zones, and fuel tanks. In Puerto Rico, industrial areas located in flood-prone zones are at heightened risk of toxic spills, which can contaminate waterways and endanger ecosystems and public health. Improper disposal of hazardous waste further amplifies exposure during severe storms.

[517] U.S. Department of Energy, Energy Resilience Solutions for the Puerto Rico Grid, final Report, https://www.energy.gov/oe/articles/energy-resilience-solutions-puerto-rico-grid-report-june-2018
[518] Puerto Rico's new governor appoints energy czar to tackle power crisis, https://subscriber.politicopro.com/article/eenews/2025/01/10/puerto-ricos-new-governor-appoints-energy-czar-to-tackle-power-crisis-00197344.

WATER SYSTEMS

Flooding poses a severe threat to Puerto Rico's water system. Heavy rainfall and storm surge can overwhelm water treatment plants, contaminate resources with pollutants, and cause interruption of services, creating a public health emergency.

Changes in Development

Flooding from hurricanes and low-pressure systems has repeatedly revealed the fragility of Puerto Rico's population and critical infrastructure. Decades of rapid construction, urban sprawl over former agricultural lands, and widespread development in flood-prone areas have directly increased the island's exposure to flood hazards. Impervious surfaces from urban development reduce natural water absorption, accelerating stormwater runoff and increasing flood intensity in downstream areas. These land use changes have further intensified the island's susceptibility to flood-related disasters and complicate efforts to manage and mitigate flood risk effectively.[519]

LAND USE AND BUILT ENVIRONMENT CHANGES

Coastal dune systems in Puerto Rico currently represent a highly vulnerable landscape facing multiple conservation threats. Key stressors include unauthorized sand extraction, uncontrolled pedestrian activity, damage to native vegetation caused by invasive green iguanas, and the illegal operation of all-terrain vehicles. Additionally, public awareness of dunes' ecological and protective value remains limited. The absence of structured sand relocation programs has led to significant annual losses of beach sand. Although legal frameworks exist to safeguard these environments, enforcement remains inconsistent and insufficient to address the scale of degradation.[520]

POPULATION AND URBANIZATION TRENDS

According to the U.S. Census Bureau, Puerto Rico's population has declined from approximately 3.8 million in 2000 to an estimated 3.1 million in 2024, with projections indicating a continued decline to around 2.5 million by 2050.[521]. However, this trend masks significant intra-island variation. San Juan, Bayamón, Guaynabo, and other urban centers are experiencing redevelopment and densification, while some western and coastal municipalities are seeing modest growth due to tourism and infrastructure investments.[522]

[519] The Guardian. "Why new construction projects are making Puerto Rico's climate disasters worse." November 19, 2022. https://www.theguardian.com/world/2022/nov/19/puerto-rico-climate-crisis-new-construction.
[520] Dobson, J.G., Johnson, I.P., Rhodes, K.A., Lussier, B.C., and Byler, K.A. (2020) Puerto Rico Coastal Resilience Assessment. UNC Asheville National Environmental Modeling and Analysis Center, Asheville, NC. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/sites/default/files/2020-08/puerto-rico-coastal-resilience-assessment.pdf.
[521] Population Estimates and Projections for Puerto Rico, https://www.census.gov/data/academy/webinars/2024/population-estimates-and-projections-for-puerto-rico.html.
[522] Puerto Rico Population Change 2000 to 2028, https://www.arcgis.com/home/item.html?id=6249005a6de04ce7a31e39696f1133b8.

The Puerto Rico Planning Board (PRPB) has identified areas of concentrated development pressure, particularly in low-lying coastal zones and riverine floodplains, where land availability and economic incentives drive construction despite known flood risks. [523]These areas may face increased flood risk due to:

- Urban infill and densification in flood-prone zones, especially near estuaries, rivers, and low-lying coastal areas[524]
- Expansion of residential and commercial development into previously undeveloped floodplains, particularly in municipalities with limited developable land
- Increased impervious surfaces, which reduce natural infiltration and exacerbate stormwater runoff and flash flooding.[525]

REDEVELOPMENT AND INFRASTRUCTURE INVESTMENT

Post-disaster recovery efforts following Hurricanes Irma and María have catalyzed widespread redevelopment. Billions of dollars in federal funding from HUD CDBG-DR/MIT, FEMA Hazard Mitigation Grant Program (HMGP), and infrastructure modernization programs are being used to rebuild housing, schools, hospitals, and transportation systems. However, many of these projects are located within or adjacent to Special Flood Hazard Areas (SFHAs), which increases the importance of integrating flood resilience into design and siting decisions. Key trends are:

- Reconstruction of housing and critical facilities in areas affected by Hurricanes María and Fiona, some of which remain within SFHAs
- Modernization of transportation and energy infrastructure, including roadways, bridges, and substations, which may intersect with flood-prone zones
- Revitalization of urban centers and coastal tourism zones, which may increase exposure to coastal and riverine flooding if not guided by resilient land use planning

FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) program has provided updated flood hazard data, including advisory base flood elevations (ABFEs), Limit of Moderate Wave Action (LiMWA) zones, and coastal erosion projections, which are critical for guiding resilient redevelopment.[526] These products highlight areas where future development should be limited or require enhanced mitigation measures.

[523] Puerto Rico Fiscal Oversight and Management Board. (n.d.), A changing population: Understanding Puerto Rico's demographic trends, https://oversightboard.pr.gov/a-changing-population-understanding-puerto-ricos-demographic-trends.
[524] FEMA Carolina's Environmental Assessment 2023, https://www.fema.gov/sites/default/files/documents/fema_pr-carolina-downtown-ea-appendices_02212023.pdf.
[525] Natural and Nature-Based Solutions Job Aid for Stormwater Management in Puerto Rico, https://www.fema.gov/sites/default/files/documents/fema_4339-guide-nnbs-job-aids-stormwater-puerto-rico.pdf; Final Puerto Rico Section 309 Assessment & Strategy, https://www.drna.pr.gov/wp-content/uploads/2022/11/PR_309_ASSESSMENT_STRATEGY_2023.pdf.
[526] Data and Online Products: Puerto Rico, https://gis-r2-fema.hub.arcgis.com/pages/puerto-rico.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Understanding projected future growth and redevelopment patterns is critical for assessing how flood risk may evolve across Puerto Rico. Puerto Rico's shifting land use policies—marked by declining agricultural activity and expanding urban sprawl across the island—have heightened vulnerability to flooding in fragile regions, undermining efforts toward disaster resilience and environmental protection.

As population shifts, infrastructure grows, and land use changes, new vulnerabilities may emerge in areas previously considered low risk. This section outlines anticipated trends in population growth, urban expansion, and redevelopment that may influence flood exposure.

IMPLICATIONS FOR FLOOD RISK

Future growth and redevelopment across Puerto Rico have the potential to significantly influence flood risk, particularly in areas where land use pressures and infrastructure limitations intersect with known hazard zones. As developable land becomes increasingly scarce, developers and property owners are building more frequently in floodplains, often guided by zoning regulations that are outdated and fail to account for current or projected flood hazards.[527]

Puerto Rico's Planning Regulation No. 13, revised in 2021, acknowledges the need to update floodplain management practices to reflect evolving development pressures and flood risks. The regulation was revised to align with FEMA's National Flood Insurance Program (NFIP) and includes provisions for controlling construction in flood-prone zones. This revision was necessary because previous regulations did not adequately address modern development patterns and hazard data.

In fact, FEMA's Advisory Flood Risk Mapping Report for Puerto Rico, developed after Hurricanes Irma and María, highlights that redevelopment and reconstruction efforts have occurred within 1% and 0.2% annual chance floodplains, often without sufficient elevation or floodproofing.[528] The Planning Board has publicly stated that over 200,000 homes are in flood-prone areas, based on FEMA flood maps.[529] Urban expansion contributes to the proliferation of impervious surfaces, such as roads, parking lots, and rooftops, which reduce natural infiltration and increase surface runoff during heavy rainfall events. This can overwhelm existing stormwater systems and exacerbate localized flooding, especially in densely populated municipalities. In many cases, redevelopment is occurring in areas already known to be vulnerable to flooding, yet without adequate elevation, drainage improvements, or floodproofing measures. This not only increases the exposure of physical assets but also places additional strain on emergency response and recovery systems.

Moreover, these patterns of growth often disproportionately affect vulnerable populations, including elderly residents, low-income households, and communities with limited access to resilient infrastructure. Without

[527] Reglamento de inundaciones-Feb 2021 -English RM-JP Rev-3.29.21-Final RM.docx, https://www.scribd.com/document/838800861/22966-Reglamento-de-inundaciones-Feb-2021-English-RM-JP-Rev-3-29-21-Final-RM-cert.
[528] Flood Risk Analysis and Mapping, https://portaldeinundacion.jp.pr.gov/mapasInteractivos.html.
[529] P.R. Planning Board says 200K homes in flood-prone areas - News is My Business, https://newsismybusiness.com/planning-flood-prone/.

deliberate planning, redevelopment may inadvertently concentrate risk in areas least equipped to manage it.

To mitigate these emerging threats, future development must be guided by updated floodplain maps, resilient zoning ordinances, and the integration of nature-based solutions. Effective coordination among planning agencies, municipal governments, and infrastructure authorities will be critical to ensuring that redevelopment efforts reduce, rather than exacerbate, long-term flood vulnerability.

POPULATION CHANGES

Puerto Rico has experienced a significant shift in population. As of 2024, 15% of the population is under 18, 60.4% falls between 18 and 64, and 24.6% is 65 or older. A significant portion of the population lives and works in flood-prone coastal zones, and as the likelihood of flooding incidents increases, these densely populated areas may experience significant exposure to displacement and structural damage. Additionally, economic and social inequities in lower-income areas prompt residents to build structures informally in flood-prone areas, increasing the potential exposure to damage and limited resources.[530]

VULNERABILITY OF STATE ASSETS CHANGES

Due to the aging infrastructure, flooding is increasingly reshaping life in Puerto Rico, transforming how communities function and exposing the fragility of infrastructure under mounting environmental, economic, and social pressures.

VULNERABILITY OF LOCAL ASSETS CHANGES

Flooding is expected to significantly increase the vulnerability of Puerto Rico's local infrastructure and communities, particularly those located in low-lying areas, river valleys, and coastal zones. With rising rainfall intensity and climbing sea levels, essential facilities—including schools, health clinics, community centers, and water systems—will face more frequent disruptions and physical damage. Transportation networks, such as roads and bridges that link rural and urban areas, are likely to suffer from increased washouts and erosion, which can cut off access during emergencies and slow recovery efforts.

Residential neighborhoods, particularly those located in floodplains or near poorly maintained drainage systems, will be at heightened risk of property damage, displacement, and prolonged economic hardship. These recurring impacts will place significant pressure on municipal budgets, impede the upkeep of vital services, and weaken local adaptive capacity. As a result, communities will become increasingly reliant on state and federal support—not only for immediate disaster response but also for long-term resilience planning.

[530] Garcia, Ivis and Nicolas Hernandez, "'They're just trying to survive:' the relationship between social vulnerability, informal housing and environmental risk in Loiza, Puerto Rico, USA," Volume 2, World Development Sustainability, ScienceDirect, June 2023, https://www.sciencedirect.com/science/article/pii/S2772655X23000216.

Mitigation Success Stories

Over the past decade, Puerto Rico has endured many catastrophic challenges from hurricanes, pandemics, and extreme rainfall. As a result, it has taken several steps toward reducing risks through mitigation efforts. In recent years, projects funded by the federal government, local investment, and community-based initiatives have had a long-term impact on lessening the effects of flooding. The following stories demonstrate the progress made by Puerto Rico and the achievements made despite challenging topography, aging infrastructure, and limited resources.

- The Arecibo Seawalls project consists of building two sections of a concrete seawall, approximately 4000 linear feet along Avenida Atlántico, and another 1700 linear feet near Barrio Obrero. The project will enhance the community's protection of lives, property, and critical infrastructure. The estimated cost of the project is $36 million.[531]
- The Puerto Rico Department of Education (PRDE) – School Retrofit project is designed to reduce the schools' vulnerability to hazards applicable to the island. Many schools in Puerto Rico are at risk of structural failure. This project will strengthen Puerto Rico's capacity to offer safe classrooms and increase the availability of shelter resources in the event of a flood or hurricane.[532] The estimated cost of the project is $307 million.
- The Department of Natural Resources has allocated approximately $15 million to improve flood control and critical infrastructure across the island. This includes funding for lift stations in Ocean Park and the Villa Palmera community, which recently experienced flood events.[533]
- Casa Pueblo – Ajuntas is a community-driven organization that focuses on the restoration of the watershed and reforestation. The organization plants trees in the impacted hillside to restore forest cover and reduce the impact of runoff and soil erosion.
- Mangrove forest in Pozuelo seeks to restore the mangrove ecosystem. The undertaking covers more than 600 acres and is part of the $3 million project carried out in collaboration with NOAA, Puerto Rico Department of Natural and Environmental Resources, The Ocean Foundation, Jobos Bay National Estuarine Research Reserve, National Fish and Wildlife Foundation, and BoriCorps.[534]

[531] The San Juan Daily Star, "Arecibo receives $36.3 Million for breakwaters to stanch coast erosion," September 4, 2025, https://www.sanjuandailystar.com/post/arecibo-receives-36-3-million-for-breakwaters-to-stanch-coastal-erosion.
[532] Puerto Rico Department of Education, "Road to New Schools: Public Policy Plan for Reconstruction of School Buildings in Puerto Rico," March 2022, https://de.pr.gov/wp-content/uploads/2022/09/prde-schools-infrastructure-plan-draft.pdf.
[533] Governor discusses $15.2M funding for critical flood control infrastructure improvements, https://espaciosabiertos.org/report-your-budget-and-your-priorities-the-oversight-board-and-fiscal-unilateralism/.
[534] Record-Breaking Effort to Restore Puerto Rico's Hurricane-Damaged Mangroves, https://coast.noaa.gov/states/stories/mangrove-restoration.html.

SECTION 4.8

HEAVY RAIN

Heavy Rain

HEAVY RAIN DEFINITION

A rainfall rate of 0.30 inches or more per hour is considered heavy rain, according to the American Meteorological Society. Rainfall rates of 1 inch per hour or higher are considered extreme and can lead to flash flooding, especially if the ground is already saturated.[535]

Puerto Rico experiences high precipitation events due to its tropical location, as Figure 169 illustrates. The monthly average annual precipitation reflects the typical amount of rainfall received in each month, averaged over a 30-year period (1991–2020). Areas with higher precipitation are typically located in the central mountainous and eastern coastal regions, where orographic effects and trade winds contribute to increased rainfall.

Regions with notably higher precipitation are:

- Adjuntas: Receives over 12 inches in September and 10 inches in August
- Maricao: Peaks at 14.18 inches in September and 12.16 inches in August
- Humacao: Records 12.24 inches in October and 12.17 inches in August
- San Sebastián: Has the highest monthly average, reaching 13.22 inches in May and 11.76 inches in October. This region's location in the northwestern interior of Puerto Rico, near the Cordillera Central Mountain range, contributes to its high rainfall through orographic lift.

[535] Dolce, C. (2025, April 1). *What is heavy rain? Here's how much rain can fall in one hour*. Weather.com. https://weather.com/storms/severe/news/2025-03-20-heavy-rainfall-rate-records.

- Paraíso (near Río Grande): Located on the northeastern coast of Puerto Rico, this area peaks at 12.75 inches in October and 12.72 inches in May, with high rainfall influenced by coastal exposure and orographic effects.

Hurricane Fiona, which struck Puerto Rico on September 18, 2022, serves as a stark example of how extreme rainfall can trigger cascading hazards across the island. Fiona made landfall as a Category 1 hurricane, but its torrential rain—which exceeded 30 inches in some areas—caused catastrophic flooding, landslides, and infrastructure failures. One of the most severely affected regions was Utuado, located in the central mountainous interior. The town had previously (after Hurricane Maria in 2017) installed a temporary bridge, but Fiona's intense rainfall swept that bridge away, cutting off access and highlighting the vulnerability of recovery infrastructure. Additionally, Ponce, on the southern coast, recorded over 31 inches of rain in just 72 hours, rivaling the rainfall totals of Hurricane Maria.[536,537]

[536] Finch, A. (2022, September 19). *Rainfall from deadly Hurricane Fiona tops 30 inches in Puerto Rico*. AccuWeather. https://www.accuweather.com/en/hurricane/hurricane-fiona-devastates-puerto-rico-with-heavy-rain-flooding-and-mudslides/1249326.

[537] AECOM. (2025). *Puerto Rico Island-wide Probable Maximum Precipitation Study*. Retrieved October 10, 2025, from https://www.aecom.com.

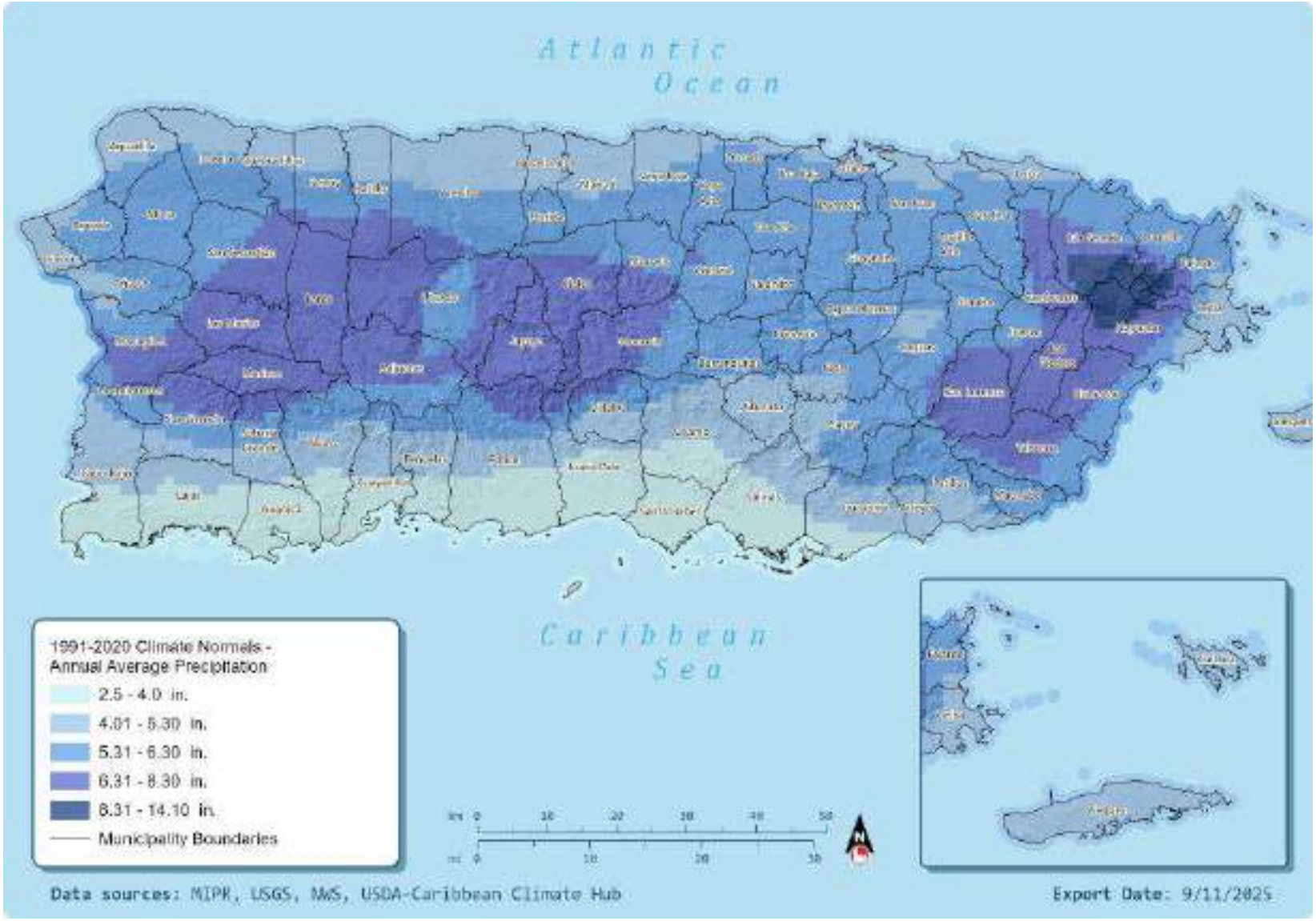

Figure 169: Monthly Annual Average Precipitation in Puerto Rico

Location

Puerto Rico's topography—mountainous interiors (Cordillera Central), coastal plains, and varied elevations—plays a crucial role in shaping its climate and weather:

- Orographic lifting causes moist air to rise over mountains, cooling and condensing to produce heavy rainfall, especially in the Luquillo Mountains and central highlands.[538]
- Trade winds from the east interact with terrain, creating microclimates and influencing precipitation patterns.

Figure 170 shows normal precipitation across Puerto Rico based on data collected over a 30-year period. Numbers on the map indicate the average annual precipitation in inches. As seen in Figure 170, rainfall varies significantly by region, with some areas receiving substantially more precipitation than others.

To provide a more comprehensive view, see both the 1991–2020 (see Figure 169) and 1981–2010 precipitation maps. These reflect the best available data at the time of this plan update. Including both maps from agencies like NOAA and USGS helps diversify the sources and illustrate different rainfall metrics, which is useful for identifying regions in Puerto Rico that are more prone to heavy precipitation and potential flood risks. As seen, rainfall varies significantly by region:

- Mountainous areas, especially in the central and eastern parts (e.g., the Luquillo Mountains), receive the highest rainfall, often exceeding 100 inches annually.
- Coastal and southern regions tend to be drier, with some areas receiving less than 40 inches per year.

Heavy rainfall in Puerto Rico is often linked to:

- Hurricanes and Tropical Storms: These are the most frequent and intense sources of precipitation. Hurricane Maria (2017) caused catastrophic rainfall and flooding.[539]
- La Niña Phenomenon: La Niña events are associated with above-average rainfall in Puerto Rico, especially during the wet season. ENSO (El Niño–Southern Oscillation) phases significantly influence precipitation patterns.
- Warmer Sea Surface Temperatures: These temperatures are projected to increase the intensity of tropical cyclones and associated rainfall.

[538] Van Beusekom, A. E., & González, G. (2022). Near-surface atmospheric behavior over complex tropical topography in Puerto Rico dominated by seasonal patterns despite frequent environmental changes. *Earth Interactions, 26*(1), 151–167. https://doi.org/10.1175/EI-D-21-0020.1.

[539] U.S. Geological Survey. (2022, June 22). *Puerto Rico Natural Hazards: Hurricanes | Peligros naturales de Puerto Rico: Huracanes*. U.S. Department of the Interior. https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-natural-hazards-hurricanes-peligros-naturales-de.

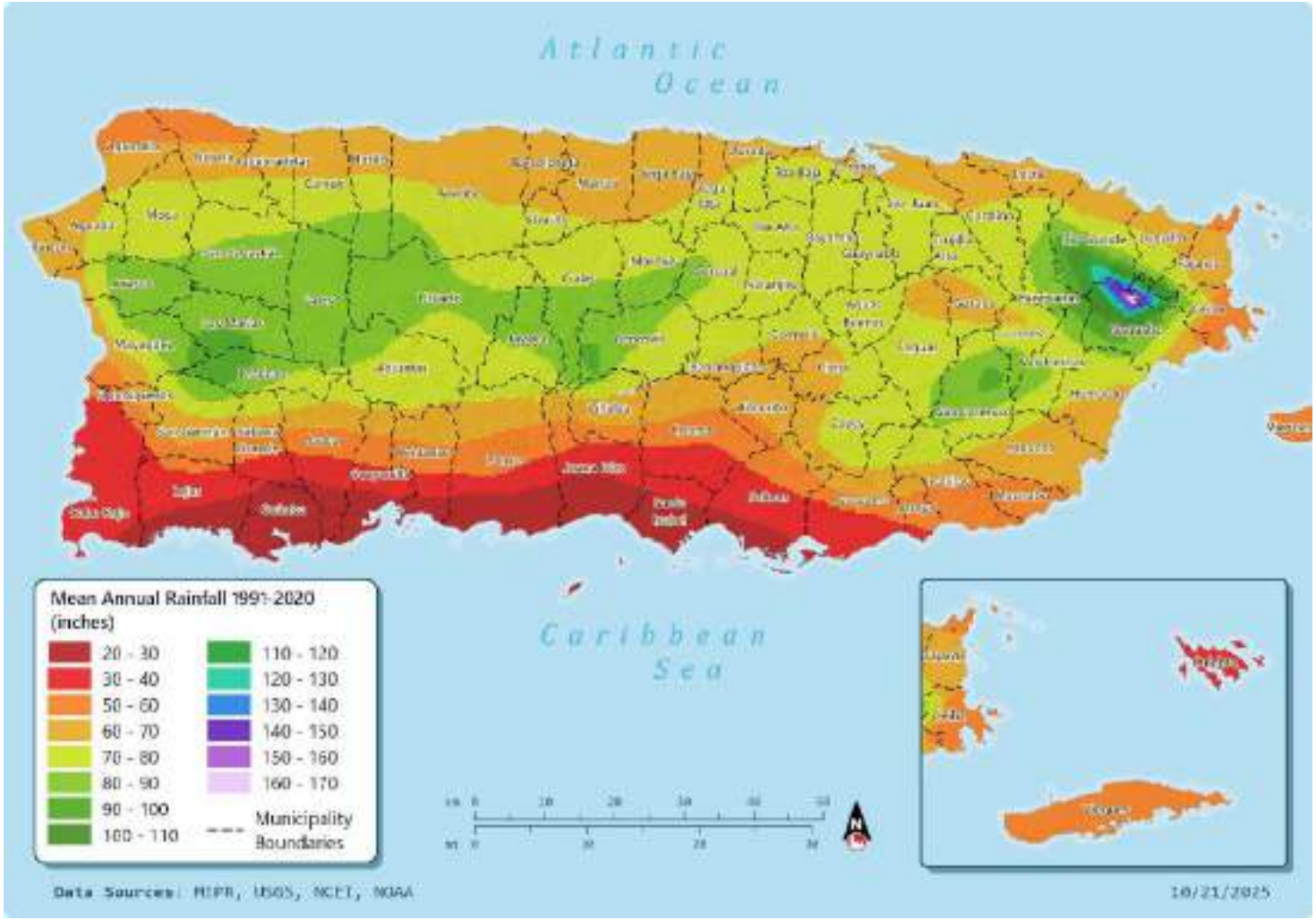

Figure 170: Distribution Maps of Normal Precipitation Across Puerto Rico over a 30-Year Period (1981–2010)[540]

[540] Caribbean-Florida Water Science Center. (2016, November 26). *30-year normal precipitation distribution maps for Puerto Rico*. U.S. Geological Survey. https://www.usgs.gov/media/images/30-year-normal-precipitation-distribution-maps-puerto-rico.

Previous Occurrences

Heavy rain events in Puerto Rico are often linked to broader climatic phenomena, such as hurricanes and La Niña, which significantly increase the risk of flooding and landslides. Hurricanes like Maria (2017), Georges (1998), and Hortense (1996) brought extreme rainfall—sometimes exceeding 250 mm in just 48 hours—leading to widespread landslide activity and infrastructure damage. These events are particularly dangerous when soils are already saturated, a condition that amplifies slope instability. Additionally, La Niña phases tend to enhance Atlantic hurricane activity, indirectly contributing to more frequent and intense rainfall events in the region. Scientific studies and hazard assessments have confirmed that these climatic drivers are key contributors to Puerto Rico's vulnerability to hydrometeorological disasters.[541]

Hurricane Fiona brought catastrophic rainfall to Puerto Rico, with totals exceeding 30 inches in some areas, such as Ponce and La Plaza. The deluge caused widespread flash flooding, submerging homes, vehicles, and even airport runways. The storm's impact was devastating, leading to at least four confirmed fatalities across the Caribbean and leaving over 1.3 million residents without power and more than 778,000 without drinking water. Infrastructure failures, including the collapse of a bridge installed after Hurricane Maria, highlighted the island's vulnerability. The blackout and water service disruptions compounded the crisis, with emergency services stretched thin and many residents stranded in their homes.

Economically, the storm's toll is estimated at around $10 billion, nearly 10% of Puerto Rico's annual GDP, according to AccuWeather. This level of damage is comparable to a severe recession, underscoring the long-term implications for recovery. Many families were severely affected, especially in the southern and mountainous regions, where flooding and landslides were most intense. The lingering trauma from Hurricane Maria, which struck five years earlier, resurfaced for many residents, as Fiona exposed the fragility of the island's infrastructure and emergency preparedness. Despite some restoration efforts, the scale of destruction has left communities grappling with uncertainty and loss.[542]

FEDERAL DISASTER DECLARATIONS

Table 74 presents selected disaster declarations from the past five years that identify "severe storm" which is likely to include heavy rain as one of the hazards.

In the context of federal disaster declarations, a severe storm generally refers to a weather event characterized by intense atmospheric disturbances such as high winds, hail, heavy rainfall, and sometimes tornadoes. These storms can result in significant damage to infrastructure, property, and natural systems, and they are often associated with secondary hazards, such as flooding and landslides.

[541] U.S. Geological Survey. (2022). *Puerto Rico Natural Hazards: Hurricanes*. https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-hazards-hurricane-impacts.
[542] Finch, Allison. "Rainfall from deadly Hurricane Fiona tops 30 inches in Puerto Rico." AccuWeather. September 20, 2022. https://www.accuweather.com/en/hurricane/hurricane-fiona-devastates-puerto-rico-with-heavy-rain-flooding-and-mudslides/1249326.

Table 74: Disaster Declarations from the Past Five Years

Disaster Name	Declaration ID	Incident Period	Declared On	Description
Puerto Rico Severe Storms, Flooding, Landslides, and Mudslides	DR-4805-PR	April 29 – May 10, 2024	July 23, 2024	A multi-hazard event involving severe storms that triggered widespread flooding, landslides, and mudslides across Puerto Rico
Puerto Rico Severe Storm, Flooding, and Landslides	DR-4649-PR	February 4–6, 2022	March 29, 2022	A short duration but intense storm system that caused widespread flooding and landslides in multiple regions of Puerto Rico
Puerto Rico Severe Storm and Flooding	DR-4571-PR	September 13, 2020	November 5, 2020	A severe weather event that led to widespread flooding, prompting a major disaster declaration

PUERTO RICO DISASTER DECLARATIONS

At the state level in Puerto Rico, emergency declarations can be directly linked to heavy rainfall, especially when it leads to cascading hazards like flooding, landslides, and infrastructure damage. For instance, in May 2025, the Puerto Rican government declared a state of emergency in multiple municipalities after two weeks of persistent rain caused fatalities, widespread flooding, and landslides. The event also resulted in over $10 million in damages.[543]

More recently, in May 2025, Governor Pedro Pierluisi declared a state of emergency in response to two weeks of persistent and intense rainfall across Puerto Rico. This prolonged rain event triggered widespread flooding and landslides, which were the primary hazards responsible for the resulting damage. At least two fatalities were reported: one man was swept away while attempting to drive through floodwaters, and another was killed when a tree fell on his car during a landslide in Toa Baja. Several municipalities, including San Juan, Vega Alta, and Cidra, declared local emergencies. Vega Alta reported approximately $7 million in flood-related damages, while Cidra estimated $3 million in losses and began drawing from the governor's emergency reserve funds. The event underscores how sustained rainfall can lead to cascading hazards that overwhelm infrastructure and prompt both local and territorial emergency declarations. It also highlights the growing urgency of integrating rainfall-induced hazards, such as flooding and landslides, into comprehensive mitigation planning, especially as climate-related events become more frequent, intense, and disruptive.[544]

[543] Associated Press. (2024, May 10). *Puerto Rico declares state of emergency after heavy flooding, landslides*. MaxM News. https://apnews.com/article/puerto-rico-rains-flooding-ab489797310e46864c2a894c1d523485.
[544] Associated Press. (2025, May 4). *Heavy rains continue to pound Puerto Rico, flooding streets and causing 2nd death*. Spectrum News. https://spectrumlocalnews.com/us/snplus/news/2025/05/04/puerto-rico-heavy-rains-flooding-deaths.

SIGNIFICANT EVENTS

Puerto Rico's early warning systems rely on 24-hour maximum precipitation and multi-day accumulation metrics to assess hazard risk. According to the USGS Landslide Monitoring Network and research from the University of Puerto Rico–Mayagüez, rainfall threshold activations in Puerto Rico (2021–2023) have been documented.

Traditionally, rainfall intensity and storm duration have been used as thresholds for landslide initiation in Puerto Rico, as noted by Figueroa-Colón (2025). However, after Hurricane Maria, it was observed that incorporating soil saturation into the analysis could result in lower rainfall thresholds for landslide occurrence.[545]

Based on this premise, Figueroa-Colón used data from eight soil moisture monitoring stations across Puerto Rico's mountainous regions to identify multiple instances where rainfall and antecedent soil saturation exceeded landslide-triggering thresholds. The study's findings, illustrated in Figure 171, confirm the correlation between hydrometeorological conditions and landslide susceptibility.

[545] Figueroa Colón, T. (2025). *Landslide forecasting for Puerto Rico: Establishing hydro-meteorological thresholds for rainfall-induced mass wasting* (Master's thesis, University of Puerto Rico, Mayagüez Campus). https://www.researchgate.net/.

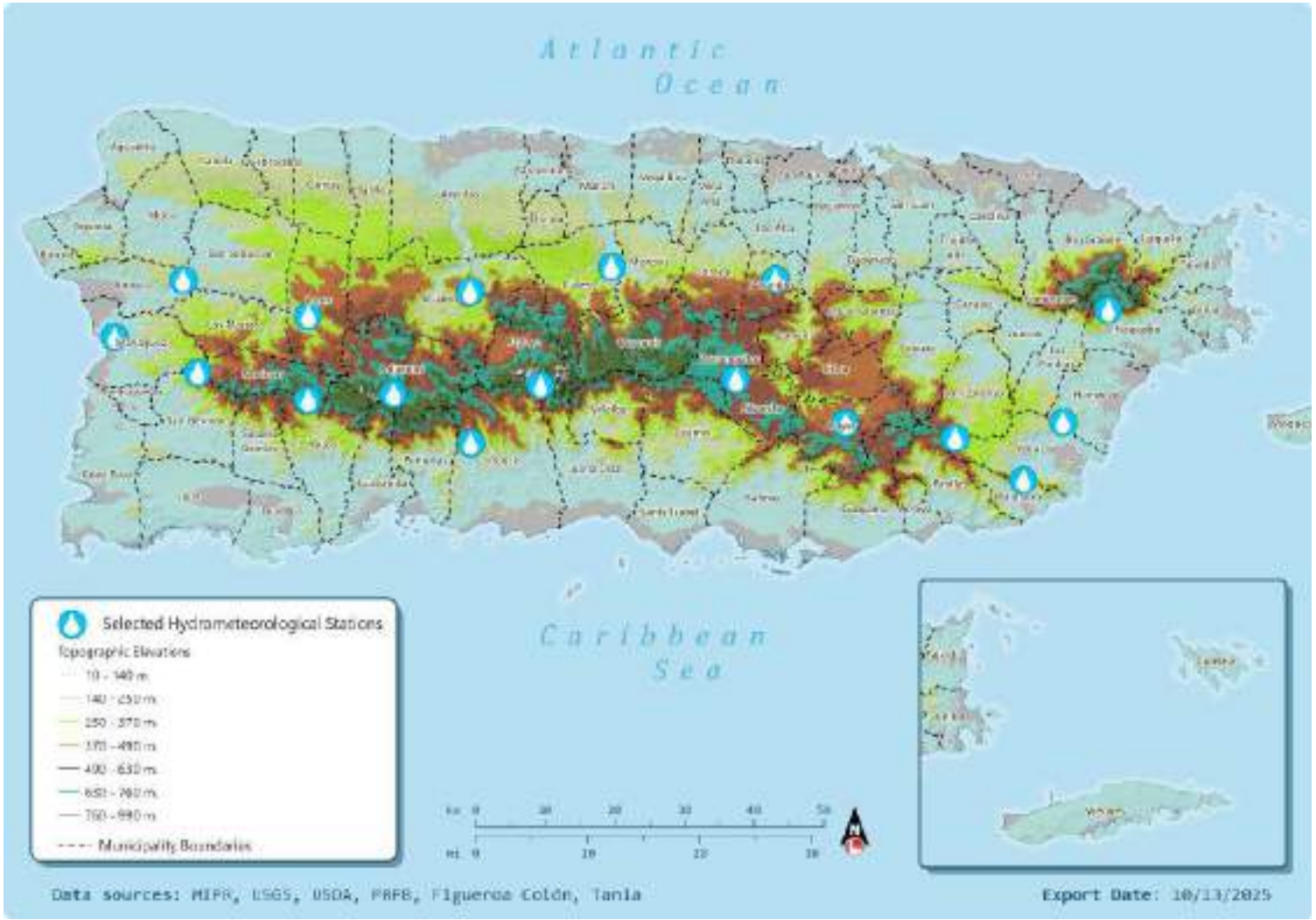

Figure 171: Topography Map and the Locations of the Mentioned Stations[546]

[546] Figueroa-Colón, T. (2025). *Landslide forecasting for Puerto Rico: Establishing hydro-meteorological thresholds for rainfall-induced mass wasting* (Master's thesis, University of Puerto Rico, Mayagüez Campus). ResearchGate. https://www.researchgate.net/publication/389273488.

Other significant precipitation events are associated with 18 major storm events, including 14 tropical systems and 4 general/easterly wave storms. These storms were selected based on their historical rainfall intensity and spatial coverage and were used to model plausible worst-case scenarios for hazard planning.[547]

- Hurricane Maria (September 2017) produced rainfall intensities with recurrence intervals exceeding 250 years in some areas. Rainfall depths were far above the 100-year 24-hour threshold (e.g., >36.91 inches), contributing to widespread flooding and over 70,000 landslides.
- The January 1992 "Three Kings Day" Storm was a rare and powerful frontal system that stalled over Puerto Rico, unleashing prolonged and intense rainfall, particularly over the central highlands. Because of its duration, spatial coverage, and intensity, the storm serves as a benchmark or controlling storm: that is, its characteristics are used to define the upper limits of rainfall that could theoretically occur in Puerto Rico. In PMP modeling, such storms are critical for estimating the maximum possible rainfall that could impact dam safety, flood risk, and infrastructure planning.[548] As Figure 172 shows, the storm produced extremely intense and prolonged rainfall, especially over the central mountainous interior. For example, Toro Negro Forest recorded 20.3 inches in 24 hours, and Cayey station recorded 19.6 inches, breaking previous records.

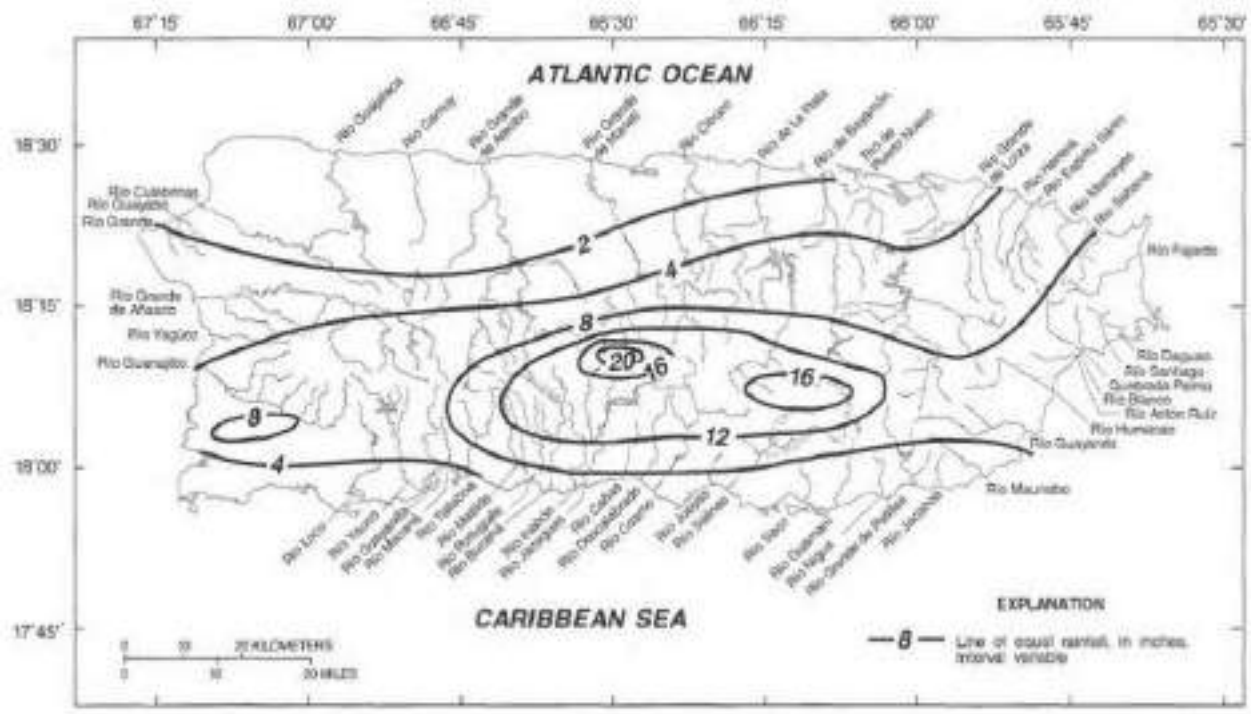

Figure 172: Cumulative Rainfall over Puerto Rico during January 5 and 6, 1992

[547] Applied Weather Associates. (2021). *Probable Maximum Precipitation Study for Puerto Rico: Final Report*. Prepared for the Puerto Rico Electric Power Authority in partnership with the U.S. Bureau of Reclamation under subcontract to AECOM. https://www.appliedweatherassociates.com.

[548] Torres-Sierra, H. (1996). Flood of January 5–6, 1992, in Puerto Rico (Open-File Report 95-374). U.S. Geological Survey. https://pubs.usgs.gov/of/1995/0374/report.pdf.

- The Dos Bocas Storm (September 1975), when transposed to the Patillas Dam basin, resulted in a 27% increase in rainfall due to terrain and moisture maximization, indicating high hazard potential.
- General storms and tropical easterly waves frequently produced rainfall exceeding 62 mm in 24 hours, with antecedent soil saturation greater than 85%, thereby meeting landslide-triggering thresholds.

Using Depth-Area-Duration (DAD) analysis and Geographic Transposition Factors (GTF) researchers quantified how these storms would behave if they occurred in different parts of the island. The maximum PMP depths were found in the Cordillera Central and El Yunque/Sierra de Luquillo regions, where topography enhances rainfall.[549]

Potential Severity of Event

The Probable Maximum Precipitation (PMP) Study for Puerto Rico was completed in 2021 by Applied Weather Associates (AWA), in partnership with the Puerto Rico Electric Power Authority (PREPA) and the U.S. Bureau of Reclamation. The study used a storm-based approach to identify the maximum PMP depths across the island. It integrated historical extreme rainfall events, sea surface temperature maximization, and terrain effects to model the most intense precipitation scenarios.

The worst-case scenario is defined by:[550]

- A tropical storm–type PMP event occurring over a 100-square-mile area for 72 hours can exceed 50 inches of rainfall in the most vulnerable regions, such as El Yunque National Forest, Sierra de Luquillo, and the Cordillera Central.
- Hurricane Maria (2017) was used as a benchmark, with rainfall depths transposed and maximized to simulate even more extreme conditions. The study applied a Total Adjustment Factor (TAF) of up to 1.27, meaning rainfall could be 27% higher than observed if maximum moisture and terrain effects align.
- The "critically stacked" temporal pattern was used to simulate rainfall accumulation, embedding shorter-duration PMP depths within longer ones (e.g., 1-hour within 6-hour, within 24-hour, etc.), creating a runoff-maximizing scenario for dam safety and flood modeling.

The maximum rainfall depths that could occur across Puerto Rico is under a tropical storm scenario, covering a large area (100 square miles) over a prolonged duration (72 hours). The study highlights regions like El Yunque, Sierra de Luquillo, and the Cordillera Central, where topography amplifies rainfall through orographic lifting. These depths represent the upper bound of physically possible precipitation, used for designing infrastructure to withstand extreme events.

[549] Applied Weather Associates. (2021). *Probable Maximum Precipitation Study for Puerto Rico: Final Report*. Prepared for the Puerto Rico Electric Power Authority in partnership with the U.S. Bureau of Reclamation under subcontract to AECOM. https://www.appliedweatherassociates.com/wp-content/uploads/2023/09/probable_maximum_precipitation_study_for_puerto_rico-final_report.pdf.

[550] Applied Weather Associates. (2021). *Probable Maximum Precipitation Study for Puerto Rico: Final Report*. Prepared for the Puerto Rico Electric Power Authority in partnership with the U.S. Bureau of Reclamation under subcontract to AECOM. https://www.appliedweatherassociates.com.

The consequences of such extreme precipitation, if it were to occur, would likely include:

- Catastrophic flooding across multiple watersheds, especially in small, fast-response basins.
- Widespread landslides, particularly in steep, clay-rich terrains, similar to the over 70,000 landslides triggered by Hurricane Maria.
- Infrastructure failure, including dam overtopping, road collapses, and overwhelmed drainage systems.
- Disruption of emergency services, isolation of communities, and potential loss of life.

The study emphasizes that while this scenario is theoretically possible, it represents a design-level event used for planning and engineering safety—not a forecast. It is intended to ensure that critical infrastructure can withstand the most extreme meteorological conditions that could physically occur.

Probability of Future Hazard Events

Rainfall Thresholds for Hazard Classification in Puerto Rico include:[551]

- **Low Rainfall:** <25 mm in 24 hours. Generally, not hazardous unless soils are already saturated or terrain is highly unstable. These conditions may contribute to gradual accumulation of moisture, but rarely trigger immediate hazards.
- **Normal Rainfall:** 25–62 mm in 24 hours. Reflects typical wet-season conditions. This range may lead to increased soil saturation, especially in clay-rich areas, and can create conditions conducive to future hazard events if followed by additional rainfall.
- **Heavy Rainfall:** >62 mm in 24 hours. This is a critical threshold for triggering landslides in clayey soils, particularly when antecedent soil saturation exceeds 85%. This threshold was validated through statistical modeling using landslide reports and soil moisture data from multiple monitoring stations across Puerto Rico.
- **Extreme Rainfall:** >85 mm in 24 hours or >150 mm over several days. These levels are associated with flash floods, debris flows, and widespread landslides, especially in mountainous regions such as Cayey, Adjuntas, and Barranquitas, where steep slopes and vulnerable soils increase hazard potential.

These assessments and thresholds focus solely on the hazard component, meaning they estimate the maximum physically possible precipitation under extreme conditions. They do not include exposure data—such as population, infrastructure, or economic assets—and therefore do not quantify risk. A true risk assessment requires integrating hazard data with vulnerability and asset inventories to evaluate potential losses or impacts. In contrast, the PMP approach concentrates on hazard intensity and likelihood, which is essential for designing resilient infrastructure but is insufficient for comprehensive emergency planning or socioeconomic impact analysis.

[551] Figueroa Colón, T. (2025). *Landslide forecasting for Puerto Rico: Establishing hydro-meteorological thresholds for rainfall-induced mass wasting* (Master's thesis, University of Puerto Rico, Mayagüez Campus). ResearchGate. https://www.researchgate.net/publication/389273488_landslide_forecasting_for_puerto_rico_establishing_hydro-meteorological_thresholds_for_rainfall-induced_mass_wasting.

Table 75 presents 72-hour Probable Maximum Precipitation (PMP) values for a 100 square mile basin across various regions in Puerto Rico.[552] These values are derived from the Applied Weather Associates (AWA) study using the Storm Precipitation Analysis System (SPAS), which simulates thousands of synthetic storms through storm transposition, maximization, and historical data analysis. The classification presented is based on spatially distributed PMP values (e.g., Table 75) and represents the modeled worst-case rainfall scenario in terms of precipitation depth. It is important to note that this classification reflects only the areas where the modeled scenario indicates higher rainfall accumulation and does not imply any specific intensity or direct correlation to potential damage. As heavy rainfall alone does not constitute a hazard, this classification is intended to inform further hazard modeling (e.g., landslides, flooding) rather than serve as a direct hazard indicator.

Table 75: Mean Annual Rainfall and 72-Hour Probable Maximum Precipitation (PMP)

Region / Municipality	Mean Annual Rainfall (in/year)	72-Hour PMP (inches)	Rainfall Classification (Based on PMP)
El Yunque / Sierra de Luquillo	120	49.9	Very high
Cordillera Central (e.g., Adjuntas)	100	48.5	Very high
Southeast (e.g., Patillas Dam)	80	48	Very high
San Juan Metro Area	55	47.2	High
Arecibo Region	60	46.7	Moderate
Southwest Coast (e.g., Cabo Rojo)	35	46.8	Moderate
Northwest (e.g., Aguadilla)	45	22	Low

Vulnerability Assessment

Torrential rainfall poses a multifaceted hazard to Puerto Rico, particularly in the context of extreme weather events such as hurricanes and frontal systems. The central and eastern highlands of Puerto Rico—notably the Cordillera Central and Sierra de Luquillo—are among the regions most vulnerable to extreme rainfall. These regions consistently exhibit the highest Probable Maximum Precipitation (PMP) depths due to

[552] Applied Weather Associates. (2021). *Probable Maximum Precipitation Study for Puerto Rico: Final Report*. Prepared for the Puerto Rico Electric Power Authority in partnership with the U.S. Bureau of Reclamation under subcontract to AECOM. https://www.appliedweatherassociates.com.

orographic enhancement, a process in which moist air is lifted over mountainous terrain, leading to intensified precipitation.[553]

Figure 173 -Number of Buildings in Regions Exceeding 100 mm Mean Annual Rainfall highlights the concentration of structures in areas where precipitation levels are consistently high. These regions include the mountainous interiors of Puerto Rico, such as the Cordillera Central and Sierra de Luquillo, which experience some of the highest rainfall totals on the island. The presence of thousands of buildings in these zones indicates significant exposure to conditions that frequently trigger secondary hazards.

High rainfall in steep terrain increases the likelihood of landslides, while rapid runoff overwhelms drainage systems, leading to flash flooding. This exposure is compounded in municipalities with documented flood declarations and high landslide densities following events like Hurricane Maria. Urban areas such as San Juan and Humacao also appear prominently in the chart, reflecting vulnerability to pluvial flooding caused by inadequate stormwater infrastructure.

The data presented in this Figure 173 underscores the need for targeted mitigation strategies. Regions with high building counts in extreme rainfall zones represent areas where infrastructure resilience, land-use planning, and emergency preparedness must be prioritized.

[553] Applied Weather Associates. (2021). *Probable Maximum Precipitation Study for Puerto Rico: Final Report*. Prepared for the Puerto Rico Electric Power Authority in partnership with the U.S. Bureau of Reclamation under subcontract to AECOM. https://www.appliedweatherassociates.com.

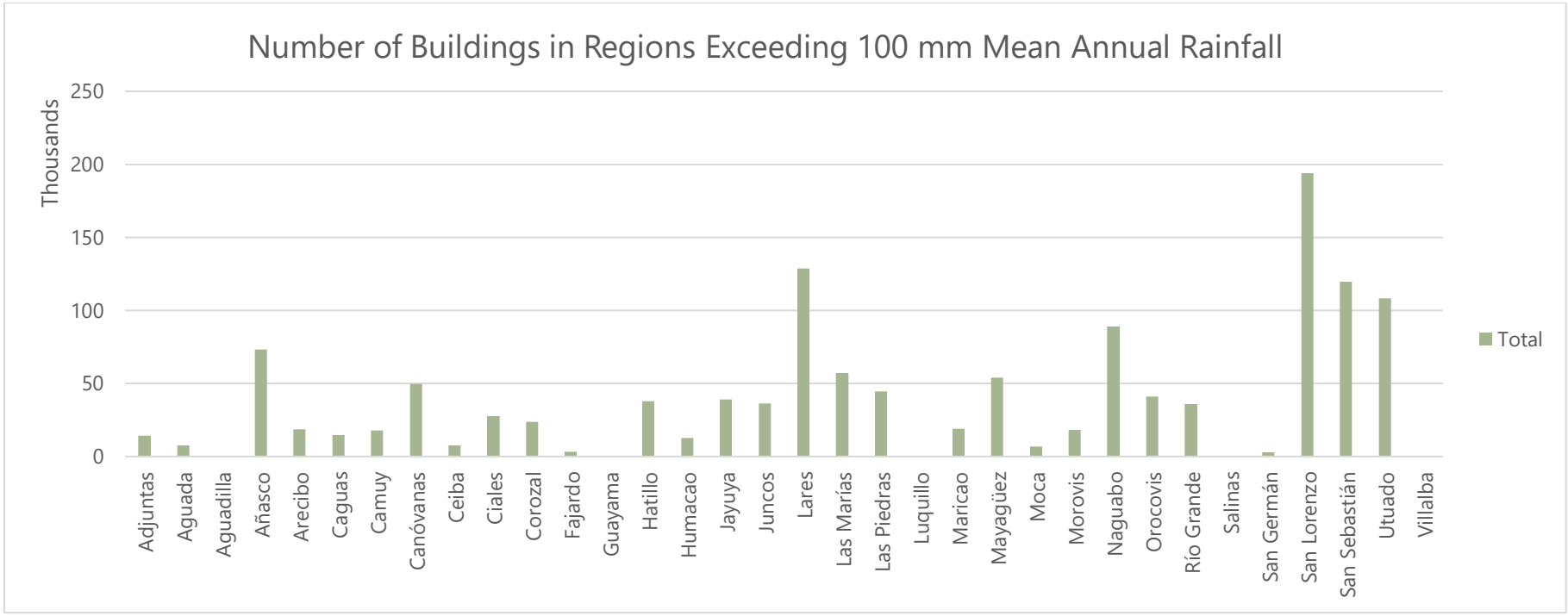

Figure 173: Number of Buildings Exposed in Regions Exceeding 100 mm Mean Annual Rainfall

LOCATION

Regions most vulnerable to heavy rainfall in Puerto Rico are those where high precipitation levels intersect with steep topography and limited drainage infrastructure, increasing susceptibility to both landslides and flooding. Based on secondary data cited throughout this document, the Cordillera Central and Sierra de Luquillo stand out as priority concern areas due to their orographic enhancement, which intensifies rainfall and contributes to landslide risk. These mountainous zones consistently record the highest annual precipitation and Probable Maximum Precipitation (PMP) depths. Additionally, municipalities such as San Sebastián and Humacao, while not as elevated, experience high monthly rainfall averages and are prone to urban flooding due to inadequate drainage systems and coastal exposure. The spatial overlap of these precipitation metrics with historical flood declarations and landslide occurrences confirms that these regions are particularly vulnerable to hazards triggered by rainfall.

LANDSLIDE SUSCEPTIBILITY IN MOUNTAINOUS REGIONS

Regions exposed to torrential rainfall are more vulnerable to landslides, especially during prolonged or intense events. The Landslide Profile includes susceptibility mapping and historical inventories to support this analysis. Figure 174 confirms that areas with elevated precipitation exposure are also more susceptible to landslides, as previously demonstrated in Figure 172 and Figure 173.

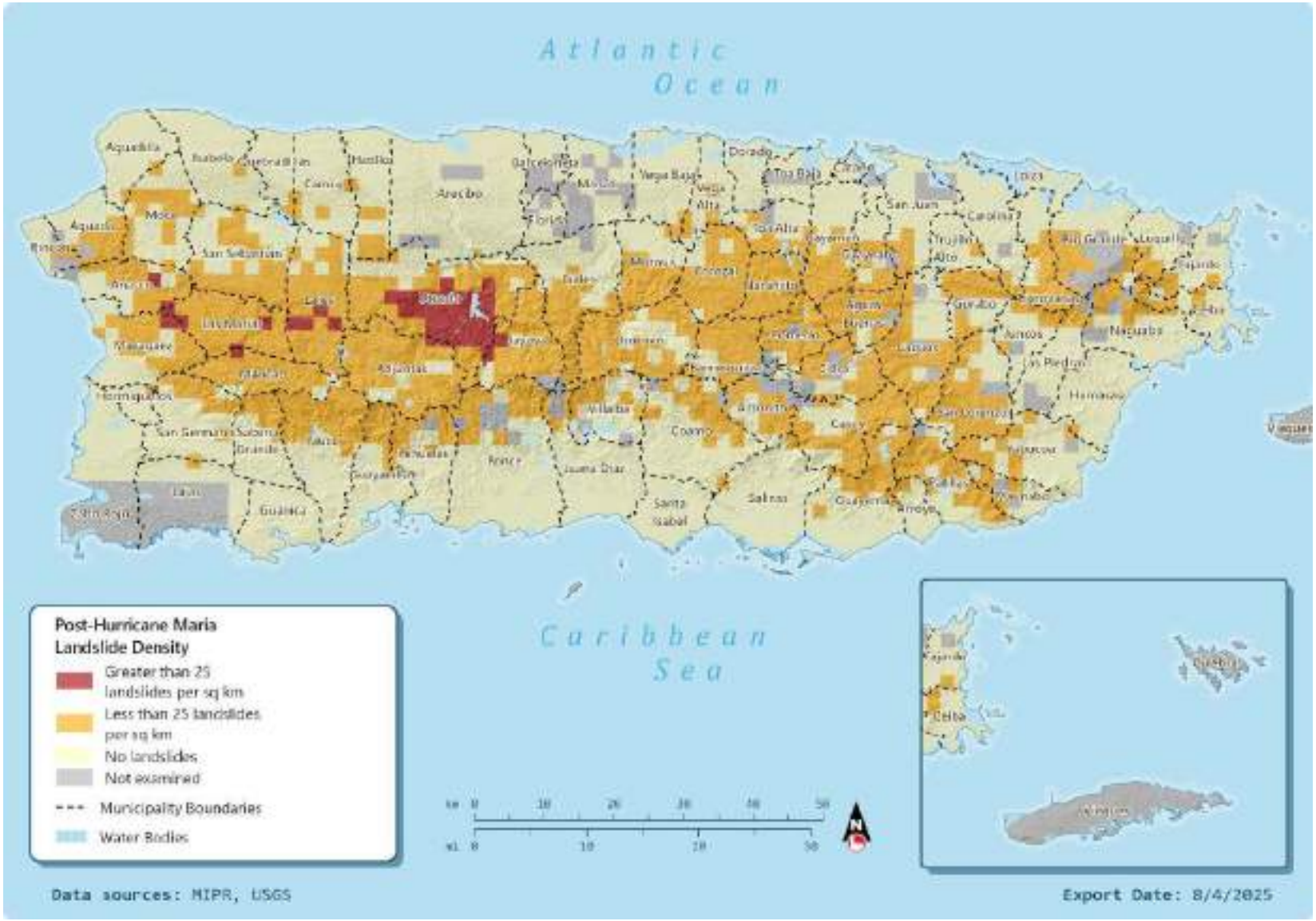

Figure 174: Post-Hurricane Maria Landslide Density

FLOOD VULNERABILITY IN PUERTO RICO

Precipitation plays a central role in flooding by contributing to excessive surface runoff, overwhelming natural and built drainage systems, and elevating river levels beyond their capacity. When rainfall intensity or duration exceeds the ability of the landscape or infrastructure to absorb or redirect water, flooding becomes likely, especially in areas with insufficient drainage capacity or aging floodplain management systems.

PLUVIAL FLOODING IN URBAN AREAS

In urban settings, torrential rainfall can lead to pluvial flooding, which occurs when rain overwhelms drainage systems. This type of flooding differs from riverine flooding and is especially problematic in cities like San Juan, Bayamón, and Ponce. Urban areas with limited stormwater infrastructure are highly vulnerable to pluvial flooding, particularly during high-intensity rainfall events.

Figure 175 illustrates the number of flood-related disaster declarations across Puerto Rico's municipalities, based on data from FEMA. Municipalities are shaded according to declaration frequency, with darker tones indicating higher counts (ranging from 0 to 15). The spatial distribution of flood declarations aligns closely with regions known for high precipitation, particularly in the central and eastern highlands such as the Cordillera Central and Sierra de Luquillo. These areas are also characterized by steep terrain and insufficient infrastructure capacity, which heightens their vulnerability to flooding.

This correlation reinforces the understanding that torrential rainfall, when combined with topographic and infrastructural constraints, significantly contributes to flood risk. The map supports the broader hazard assessment by visually confirming that flood-prone municipalities often coincide with zones of elevated precipitation and limited drainage capacity, making them key targets for mitigation planning.

Puerto Rico's vulnerability to torrential rainfall is shaped by a complex interplay of exposure, terrain susceptibility, and infrastructure capacity:

- Mountainous regions are exposed to extreme rainfall and are highly susceptible to landslides
- Flood-prone zones are defined by a combination of topography and hydrology
- Urban areas face pluvial flooding risks due to insufficient drainage infrastructure

Figure 175: Flood Declaration Count

POPULATION

The regions most vulnerable to heavy rainfall in Puerto Rico—namely the Cordillera Central, Sierra de Luquillo, San Sebastián, and Humacao—are home to substantial populations that heighten the potential impact of rainfall-induced hazards.

According to the 2020 U.S. Census and updated estimates through 2025, municipalities within the Cordillera Central such as Adjuntas (18,373), Barranquitas (30,032), and Utuado (27,395) collectively represent tens of thousands of residents living in steep, landslide-prone terrain. The Sierra de Luquillo region, encompassing Luquillo (17,314), Río Grande (44,162), and Naguabo (21,023), is characterized by high precipitation and dense forest cover, with populations exposed to both flooding and slope instability. San Sebastián, located near the Cordillera Central, has a population of approximately 41,809 and experiences some of the highest monthly rainfall averages on the island. Humacao, a coastal municipality with 49,409 residents, is particularly vulnerable to urban flooding due to poor drainage and its exposure to tropical systems. These population figures underscore the importance of targeted mitigation strategies in high-risk zones, where the intersection of topography, precipitation, and infrastructure limitations poses significant threats to public safety and community resilience.[554]

STRUCTURES INCLUDING CRITICAL FACILITIES

Structures, including critical facilities, are generally more vulnerable to high-impact hazards such as flooding and landslides, rather than to rainfall alone. While isolated cases of roof damage due to poor maintenance and water accumulation can occur, heavy rain by itself—when not accompanied by wind or terrain instability—rarely compromises the structural integrity of well-built facilities. Hospitals, for example, are primarily affected during severe storm events or hurricanes, which combine heavy rainfall with strong winds and flying debris. However, due to their essential role in emergency response and public health, hospitals and other critical infrastructure are typically constructed under stricter building codes and engineering standards. These standards enhance their resilience, making them more capable of withstanding the effects of precipitation compared to residential structures, which may lack adequate protective measures.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Torrential rainfall, while not a hazard, often acts as a critical trigger for other hazards such as flooding, flash floods, landslides, and infrastructure failures. In alignment with FEMA's Community Lifelines framework, this profile recognizes that such rainfall events can disrupt essential services and systems. However, because the impacts of torrential rainfall are primarily realized through secondary hazards like flooding and landslides, the detailed analysis of consequences and vulnerabilities is deferred to the respective hazard, where these dynamics are further explored. For example, transportation systems—including roads, bridges, and culverts—are highly susceptible to damage from slope failures and floodwaters, often isolating communities and delaying emergency response. Similarly, critical facilities such as hospitals and emergency shelters may face operational risks if access routes are compromised or if backup systems fail due to prolonged rainfall

[554] Census Reporter. Luquillo Municipio, PR. https://censusreporter.org/profiles/05000US72089-luquillo-municipio-pr/.

and strain on infrastructure. These vulnerabilities highlight the importance of integrating rainfall-induced hazard considerations into infrastructure planning and emergency preparedness efforts.

Impact Assessment

Rainfall is a key trigger for other hazards such as landslides and flooding. Therefore, impacts—such as economic losses, fatalities, and injuries—are typically attributed to these secondary hazards rather than to rainfall alone. As such, this section defers the discussion of impacts to hazard-specific profiles, such as those for landslides and flooding.

Table 76 presents a qualitative analysis of regions in Puerto Rico that are most likely to experience impacts related to heavy rainfall. These regions—such as El Yunque, the Cordillera Central, San Sebastián, and Humacao—are characterized by high precipitation exposure, which aligns closely with areas historically prone to flooding and landslides. This alignment confirms that heavy rain is not merely a meteorological event but a critical triggering condition for cascading hazards.

By examining precipitation metrics (e.g., annual rainfall and Probable Maximum Precipitation), landslide susceptibility (e.g., terrain steepness and soil saturation), and flood vulnerability (e.g., drainage limitations and declaration frequency), the table illustrates how heavy rain contributes to compound risks. The regions listed are not only exposed to intense rainfall but also possess physical and infrastructural characteristics that amplify hazard impacts. Therefore, this table serves as a foundational tool for identifying priority areas in hazard mitigation planning, emphasizing the need for integrated strategies that address both direct and indirect consequences of extreme precipitation.

Table 76: Priority Regions for Rainfall-Induced Hazard Mitigation

Region / Municipality	Precipitation Exposure	Landslide Susceptibility	Flooding Vulnerability	Probability of Experiencing Impacts Due to Heavy Rainfall
El Yunque / Sierra de Luquillo	Very High (120 in./year, PMP 49.9 in.)	High (Orographic lift, steep terrain)	High (Frequent flood declarations)	High
Cordillera Central (e.g., Adjuntas)	Very High (100 in./year, PMP 48.5 in.)	High (Slope–relief threshold exceeded)	High (Flood–prone terrain)	High
San Sebastián	High (13.22 in./month in May)	High (Located near Cordillera Central)	Medium (Less urbanized but still flood–prone)	Medium
Humacao	High (12.24 in./month in October)	Medium (Coastal, less steep terrain)	High (Urban flooding risk)	Medium

STATE ASSETS

State assets, as mentioned in other profiles, are clearly identified based on the various impacts they may experience under different hazard types and intensity levels. Key assets prone to heavy rain impacts in Puerto Rico are:

- Road and transportation networks
  - Landslides: Mountainous regions like Utuado, Adjuntas, and Lares are prone to slope failures.
  - Flooding: Urban areas such as San Juan and Bayamón experience flash flooding due to inadequate drainage.
  - Washed-out bridges and culverts disrupt access to critical services and emergency response.
- Critical facilities
  - Hospitals, emergency shelters, and power substations located in flood zones face operational risks.
  - Backup systems may be compromised if access roads are blocked or if fuel delivery is disrupted.

LOCAL ASSETS

Local assets, as mentioned in other profiles, are clearly identified based on the various impacts they may experience under different hazard types and intensity levels. Key local assets prone to heavy rain impacts in Puerto Rico are:

- Sewage and stormwater infrastructure
  - Aging or undersized systems often lead to overflow during intense rainfall.
  - Combined sewer systems in some areas may discharge untreated water during storms.
  - Coastal and low-lying communities are especially vulnerable to contamination and public health risks.
- Residential areas
  - Informal housing in floodplains or steep slopes is highly susceptible to damage.
  - Repetitive loss properties often lack adequate mitigation measures.

COMMUNITY LIFELINES

Torrential rainfall, while not a hazard in itself, often acts as a critical trigger for other hazards such as flooding, flash floods, landslides, and infrastructure failures. In alignment with FEMA's Community Lifelines framework, this profile recognizes that such rainfall events can significantly disrupt essential services and systems. However, because the impacts of torrential rainfall are primarily realized through these secondary hazards, the detailed analysis of consequences and vulnerabilities is deferred to the respective hazard profiles (e.g., flooding, landslides), where these dynamics are examined in greater detail.

SAFETY AND SECURITY

Torrential rainfall can compromise safety and security infrastructure—such as emergency services and law enforcement facilities—due to flooding, landslides, and road washouts that delay response times and access.

FOOD, HYDRATION, AND SHELTER

Critical facilities that provide food, water, and shelter are often disrupted during torrential rain events, primarily due to access limitations, supply chain interruptions, and structural damage caused by flooding and landslides.

HEALTH AND MEDICAL

Health and medical services are vulnerable to torrential rainfall impacts, as flooding and debris flows can damage hospitals, clinics, and emergency transport routes, delaying care and endangering lives.

ENERGY

Torrential rains can lead to power outages and infrastructure failures in the energy sector, especially when flooding, erosion, or landslides damage power lines, substations, or fuel supply routes.

COMMUNICATIONS

Communication networks, including cellular towers and fiber-optic lines, are at risk of disruption during torrential rainfall due to water intrusion, landslides, and infrastructure collapse.

TRANSPORTATION

Torrential rainfall often causes severe damage to transportation systems—such as roads, bridges, and airports—through flooding, flash floods, and slope failures, resulting in the isolation of communities and delays in emergency response efforts.

HAZARDOUS MATERIALS

Heavy rainfall can lead to the release or spread of hazardous materials when storage facilities or transport routes are compromised by flooding, erosion, or landslides.

WATER SYSTEMS

Water infrastructure, including treatment plants and distribution networks, is highly susceptible to damage during torrential rain events due to inundation, sedimentation, and contamination from overland flow and landslides.

Changes in Development

Urban development can either increase or reduce the resilience of community lifelines infrastructure, with land use playing a critical role. In particular, areas where heavy precipitation coincides with high landslide susceptibility may be restricted or flagged for further engineering analysis and more robust design requirements, especially for infrastructure such as aqueducts, dams, and other water management systems.

Transportation infrastructure (e.g., roads and highways) accounts for about 20% of the study areas and contributes heavily to runoff, heat island effects, and ecosystem fragmentation. Missed opportunities for transit-oriented development (TOD) with integrated green infrastructure have limited sustainable urban growth.

LAND USE AND BUILT ENVIRONMENT CHANGES

Urbanization in Puerto Rico has led to the widespread replacement of pervious surfaces (like soils and vegetation) with impervious surfaces (such as concrete, asphalt, and rooftops). This transformation disrupts the natural hydrological cycle by:[555]

- Increasing stormwater runoff
- Reducing infiltration
- Exacerbating flooding risks
- Diminishing ecosystem services like water filtration and climate regulation

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Redevelopment patterns across Puerto Rico have heightened vulnerability to heavy rainfall impacts by concentrating on commercial and transportation infrastructure, such as large-scale parking lots and shopping centers. These projects typically favor impervious surfaces and lack integrated green infrastructure, which accelerates stormwater runoff and reduces natural infiltration, amplifying flood risks and drainage challenges. Key observations are:

- A lack of transit-oriented development (TOD) near transit hubs limits the use of compact, mixed-use design strategies that reduce impervious surface area.
- Puerto Rico's urban areas, especially Bayamón and Ponce, are undergoing rapid land conversion from pervious (natural) surfaces to impervious (developed) ones.
- Over a five-year period, 60 hectares of green space in Bayamón were converted into paved surfaces, indicating a strong trend toward car-centric, single-use development.[556]

[555] Burgos-López, C. (2025) Understanding Urban Surfaces: Nature-Based Solutions (NbS) for Stormwater Management. Journal of Water Resource and Protection, 17, 307-321. https://doi.org/10.4236/jwarp.2025.175015.
[556] Burgos-López, C. (2025) Understanding Urban Surfaces: Nature-Based Solutions (NbS) for Stormwater Management. Journal of Water Resource and Protection, 17, 307-321. https://doi.org/10.4236/jwarp.2025.175015.

POPULATION CHANGES

Continued urban growth and redevelopment—especially in the absence of integrated green infrastructure—will exacerbate runoff issues, because the transformation of land for single-use replaces natural infiltration zones with impervious surfaces.

VULNERABILITY OF STATE ASSETS CHANGES

Urbanization and the expansion of impervious surfaces in Puerto Rico have significantly increased stormwater runoff, complicating efforts to manage water flow during heavy rain events. This has elevated the vulnerability of state assets—particularly national transportation infrastructure such as highways—to hazards like flash floods, flooding, and landslides. The growing risk is largely due to infrastructure upgrades lagging behind the pace of urban development and water management demands. As impervious surfaces expand, natural infiltration decreases, placing additional strain on drainage systems and increasing exposure to hydrometeorological hazards.[557]

Recent studies confirm that Puerto Rico's water management infrastructure has not kept pace with increasing demand, particularly in urban areas. The RAND Corporation highlights that legacy challenges in infrastructure and maintenance—such as outdated systems and financial stress—have exacerbated vulnerabilities, especially in the aftermath of hurricanes Irma and Maria. The ASCE Infrastructure Report Card for Puerto Rico also notes a significant investment gap and poor infrastructure grades, with roads and bridges receiving especially low marks despite their importance for stormwater management.[558]

Moreover, precipitation trends in Puerto Rico have not shown dramatic increases over the past three decades. A 2025 study analyzing data from 114 stations across 19 watersheds found that average precipitation has slightly decreased, while river discharge and reservoir levels have increased due to factors such as sedimentation and poor maintenance—not increased rainfall. ENSO-related variability (El Niño and La Niña) continues to influence seasonal patterns, but these fluctuations remain within expected parameters and do not suggest a long-term intensification of precipitation hazards.[559]

VULNERABILITY OF LOCAL ASSETS CHANGES

Flooding and poor drainage systems have a direct impact on the following critical infrastructure and community assets:

[557] Burgos-López, C. (2025) Understanding Urban Surfaces: Nature-Based Solutions (NbS) for Stormwater Management. Journal of Water Resource and Protection, 17, 307-321. https://doi.org/10.4236/jwarp.2025.175015.
[558] Preston, B. L., Miro, M. E., Brenner, P., Gilmore, C. K., Raffensperger, J. F., Madrigano, J., Ntazinda, A., Blackhurst, M., & Catt, D. (2020). *Beyond recovery: Transforming Puerto Rico's water sector in the wake of Hurricanes Irma and María* (RR-2608). RAND Corporation. https://www.rand.org/pubs/research_reports/RR2608.html.
[559] Trossi-Torres, G., Muñoz-Barreto, J., Feliciano-Cruz, L. I., & Lakhankar, T. (2025). *Impacts of precipitation trends on reservoirs and rivers in Puerto Rico from 1990 to 2022*. Sustainability, 17(17), 7801. https://doi.org/10.3390/su17177801.

WATER AND WASTEWATER SYSTEMS

- Facilities operated by the Puerto Rico Aqueduct and Sewer Authority (PRASA) have faced cost overruns and delays due to flood damage and insufficient sewage capacity.
- Lago Loíza/Carraízo Dam, which supplies potable water to over 750,000 people in San Juan, experienced uncontrolled releases during Hurricane Hortense as a result of excessive runoff.

ELECTRIC POWER INFRASTRUCTURE

- San Juan Power Plant and other grid components were severely impacted by flooding, leading to prolonged outages and increased vulnerability during storms.
- Casa Pueblo and other community-based energy hubs have emerged in response to grid failures. Transportation and Roads.[560]

TRANSPORTATION AND ROADS

Bridges and highways, especially in mountainous and coastal regions, are in poor condition. Over 11.7% of bridges are structurally deficient, and flooding often halts transportation.

PUBLIC SCHOOLS AND HEALTH FACILITIES[561]

- Schools in flood-prone areas like Añasco were exposed to damaging flood depths during Hurricane Maria.[562]
- Health services were disrupted due to power outages and lack of access, affecting vulnerable populations.

COASTAL INFRASTRUCTURE

Puerto Rico's eastern and central mountainous regions receive the most rainfall, contributing to runoff and flooding in adjacent low-lying areas. The San Juan metro area, western floodplains, and southern slopes are particularly vulnerable. Local assets such as water treatment plants, power stations, bridges, schools, and hospitals are frequently impacted due to insufficient sewage capacity and aging infrastructure, underscoring the need for resilient planning and investment.

[560]Jacobo, J. (2024, September 19). *Puerto Rico's infrastructure still recovering from Hurricane María 7 years after the Category 4 storm devastated the island*. ABC News. https://abcnews.go.com/US/puerto-ricos-infrastructure-recovering-hurricane-maria-7-years/story?id=113672746.

[561] American Society of Civil Engineers. (2019). *2019 Puerto Rico Infrastructure Report Card*. ASCE. https://infrastructurereportcard.org/state-item/puerto-rico/.

[562]Harmsen Truckenbrod, E. M. (n.d.). *Flood impacts on critical infrastructure in a coastal floodplain in Western Puerto Rico during Hurricane María*. University of Puerto Rico Researcher Portal. https://researchers.upr.edu/vivo/display/n1058.

Mitigation Success Stories

FEMA FLOOD CONTROL PROJECTS IN PUERTO RICO

In response to increasing flood risks and the impacts of changing conditions, the Federal Emergency Management Agency (FEMA) has awarded $15 million to support flood control projects across several municipalities in Puerto Rico. This funding is part of a broader investment exceeding $122 million across 35 projects, aimed at enhancing stormwater infrastructure and reducing urban runoff.[563]

The initiative includes the installation of reinforced concrete pipelines, corrugated metal pipes, and expanded stormwater drainage systems. Municipalities such as Barceloneta, Patillas, Villalba, Coamo, and San Germán are among the beneficiaries, working in partnership with FEMA to implement nature-based and engineered solutions that improve resilience and protect communities from future flooding events.

CITY REVITALIZATION PROGRAM

The City Revitalization Program (CRP) is a major recovery and redevelopment initiative led by the Puerto Rico Department of Housing, funded through $1.298 billion in CDBG-DR allocations. Designed to restore and enhance urban centers impacted by Hurricanes Irma and Maria, the program prioritizes resilient infrastructure, including stormwater management, green infrastructure, and natural resource recovery.[564]

Through projects like bioswales, rain gardens, and permeable pavements, CRP aims to reduce urban runoff, improve water quality, and mitigate flood risks. These efforts are part of a broader strategy to promote sustainable urban development, enhance climate resilience, and support environmental justice across all of Puerto Rico's 78 municipalities.

The CRP includes several initiatives directly addressing stormwater management, runoff reduction, and water infrastructure resilience:

- Green Infrastructure and "RE-Green"
  - Integration of green best practices in infrastructure projects.
  - Projects designed to have restorative and protective effects on natural infrastructure.

    Examples:
    - Rain gardens
    - Permeable pavements
    - Bioswales

[563] Stormwater Solutions. (2023, September 26). *FEMA awards $15M for flood control projects in Puerto Rico*. https://www.stormwater.com/stormwater-management/flood-control/press-release/53078735/fema-awards-15m-for-flood-control-projects-in-puerto-rico.

[564] Puerto Rico Department of Housing. (2024). *City Revitalization Program - CDBG-DR/MIT Recovery Funds*. Recuperación PR. https://www.recuperacion.pr.gov/en/city-revitalization/.

    - Tree planting and reforestation
- Waste Repurposing and Reduction
    - Strategies to reduce solid waste and prevent pollution in waterways.
    - Supports cleaner urban environments and healthier runoff systems.
- Public Infrastructure Improvements
    - Upgrades to stormwater drainage systems.
    - Rehabilitation of water lines and sewer systems in urban corridors.

SECTION 4.9

INVASIVE SPECIES

Invasive Species

INVASIVE SPECIES DEFINITION

An invasive species is defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health."[565] To further clarify, "an alien species is any species, including its seeds, eggs, spores, or other biological matter capable of propagating that species, that is not native to that ecosystem."[566]

Invasive species in Puerto Rico pose a substantial ecological threat, impacting local biodiversity, agriculture, and the overall health of various ecosystems. The issue encompasses a wide range of plants, animals, insects, and pathogens—including viruses, bacteria, fungi, and parasites—that have been introduced, intentionally or unintentionally, into the island's diverse environments. These invasives often outcompete native species for resources, disrupt food webs, and contribute to the decline of endemic flora and fauna, which are particularly vulnerable to their specialized adaptations.

Puerto Rico is home to a diverse range of alien flora, comprising 1,032 species across 117 families and 581 genera. A noteworthy aspect of this biodiversity is that 55 of the 117 families include at least one invasive species, which accounts for 32.3% of the island's total flora.[567]

[565] National Invasive Species Information Center, "Executive Order 13112-Invasive Species,"https://www.invasivespeciesinfo.gov/executive-order-13112#details--section-1-definitions.
[566] National Invasive Species Information Center, "Executive Order 13112-Invasive Species,"https://www.invasivespeciesinfo.gov/executive-order-13112#details--section-1-definitions.
[567] Springer Nature Link, "Naturalization and Invasion of Alien Plants in Puerto Rico and the Virgin Islands," https://link.springer.com/article/10.1007/s10530-014-0712-3.

In terms of invasion classification, a total of 392 species (38%) are categorized as casual, which means they can thrive and reproduce occasionally outside of cultivation but do not establish self-sustaining populations and require continual introduction to persist. Additionally, 463 species (44.9%) are considered naturalized; these plants maintain self-replacing populations for at least a decade without human intervention and can grow independently. The remaining 177 species (17.2%) are identified as invasive, which refers to naturalized species that produce a significant number of reproductive offspring, often at considerable distances from their parent plants, thereby having the potential to spread widely. Seventy-one percent of the invasive species in Puerto Rico have long residence times, having been introduced between 1875 and 1925.[568]

The majority of invasive species in Puerto Rico consist of herbs, grasses, and trees. Specifically, herbs and grasses account for 52% of all invasive species, while trees and shrubs represent approximately 28.2% of the invasive plant population.[569]

The most common invasive species in Puerto Rico include:

- **Reptiles:** Green Iguana, Reticulated Python, Invasive Boa Constrictor, Spectacled Caiman, and the Cane Toad
- **Plants:** Kudzu Vine, bamboo, and the African tulip tree
- **Marine Species:** Red Lionfish, Whitespotted Clarias, invasive coral (Xenia umbellata), armored catfish
- **Mammals:** Small Indian mongoose, rats and mice, feral pigs
- **Invertebrates:** Yellow fever mosquito (Aedes aegypti), Africanized honeybee, Harrisia cactus mealybug

Invasive species, such as the green iguana and the red lionfish, pose substantial threats to Puerto Rico's ecosystem. The green iguana, introduced to the island approximately 20 years ago, has no natural predators, resulting in a dramatic increase in its population. This increase has caused substantial deforestation and damage to nature preserves. For example, at Las Cabezas de San Juan Nature Preserve in Fajardo, researchers had identified around 1,000 iguana nests in 2015. Female iguanas reach sexual maturity at approximately 16 months and can lay up to 60 eggs, highlighting their rapid reproductive capacity. While they primarily consume vegetation, iguanas also eat insects and small rodents, resulting in the destruction of crops and a decline in native species.[570]

The red lionfish, originally from the Indian Ocean, further complicates the ecological balance in Puerto Rico. It is highly venomous, and many local species do not recognize it as a predator, making them vulnerable to its predation. The lionfish's appetite for larger quantities of important local fish, such as red snapper and

[568] Springer Nature Link, "Naturalization and Invasion of Alien Plants in Puerto Rico and the Virgin Islands," https://link.springer.com/article/10.1007/s10530-014-0712-3.
[569] Springer Nature Link, "Naturalization and Invasion of Alien Plants in Puerto Rico and the Virgin Islands," https://link.springer.com/article/10.1007/s10530-014-0712-3.
[570] USDA, "Invasive Species Educational Program," n.d., https://www.fs.usda.gov/managing-land/invasive-species.

grouper, threatens marine biodiversity. Additionally, its presence could impact tourism, as its toxicity poses risks to both local ecosystems and recreational activities in the surrounding waters.[571]

The **Cane Toad** (Rhinella marina) was deliberately introduced into Puerto Rico in the 1920s with the intention of managing agricultural pests, particularly in sugarcane fields. However, this decision led to unintended ecological consequences. The cane toad possesses highly toxic skin that contains bufotenin and other harmful compounds, which can be lethal to native predators. Species such as the coqui frog, along with various reptiles and mammals, lack the evolutionary adaptations to resist these toxins, resulting in substantial population declines among native species.[572]

The **reticulated python** (Malayopython reticulatus) is recognized as one of the largest snake species globally, not only in length, often reaching 10 to 20 feet, but also in mass, with adult specimens weighing between 100 and 300 pounds. It thrives in diverse ecosystems, including humid forests, grasslands, and even urban areas, demonstrating remarkable adaptability to varying environments.

As an apex predator, the reticulated python plays a pivotal role in maintaining ecological balance by regulating prey populations. This regulation is crucial for supporting the health of ecosystems in which it resides. The reticulated python primarily preys on a variety of small mammals such as rats, rabbits, birds, and, on occasion, larger mammals. Interestingly, due to its adaptable feeding habits, this species can often be found in proximity to human settlements, where it capitalizes on the abundance of food such as rodents, domestic pets, and small livestock.

Since 2012, isolated observations of M. reticulatus have been reported in Puerto Rico, including possible human-mediated transport or accidental introduction. In 2019, multiple reports emerged from Puerto Rico documenting the presence of reticulated pythons along the José de Diego Expressway (Puerto Rico Highway 22) near Arecibo. Additionally, reticulated pythons have been observed in the western and southern regions of the island, including one particularly notable specimen measuring over 18 feet in length, which highlights the potential ecological implications of this species' presence in non-native areass.[573]

In recent years, three species of large invasive constrictor snakes have been spreading across Puerto Rico. Boa constrictors, originally native to South and Central America, are now commonly found on the west side of the island. Additionally, the ball python, another invasive constrictor, is also beginning to spread

The problem of invasive snakes, particularly boa constrictors, is particularly evident in the wildlife refuge of Cabo Rojo, which is considered one of the most important stopover sites for migratory species and shorebirds in the eastern Caribbean. These birds play a critical role in the complex and ancient island

[571] USDA, "Invasive Species Educational Program," https://www.fs.usda.gov/managing-land/invasive-species.
[572] Oregan State University, "Invaders of Paradise: Overview of Invasive Species Challenges Faced in Puerto Rico," https://agsci.oregonstate.edu/sites/agscid7/files/academics/world-agriculture/2024pr-mitchell_spencer_invasive-species-pr-poster.pdf.
[573] Elden, J. M., Picone, J., Buontempo, M., Burgess, K., & Conley, D. (2024). Account of a Non-native Malayopython reticulatus in Puerto Rico. Bulletin of the Chicago Herpetological Society 59(9):125-127. 59(9), 125–127. https://www.researchgate.net/publication/384292780_Account_of_a_Non-native_Malayopython_reticulatus_in_Puerto_Rico_Bulletin_of_the_Chicago_Herpetological_Society_599125-127.

ecosystems, helping to control insect populations and other small animals they consume, and dispersing nutrients throughout the island through their feces.

Invasive snakes, including boas, pose a significant threat not only within Cabo Rojo but also across the entire island. They disrupt the natural balance of the ecosystem by preying on native species. This predation can lead to declines in local bird populations, which are already vulnerable due to habitat loss and other environmental pressures. Additionally, the presence of invasive boas can result in a decrease in biodiversity, as local fauna struggle to compete with these non-native predators.

Currently, the situation in Puerto Rico is not so extreme, but the risks remain. While invasive constrictors are already widespread in some areas, they are only just beginning to expand across Puerto Rico, according to scientists. This indicates that local experts and environmental officials still have an opportunity to mitigate the potential damage these snakes could cause. If allowed to proliferate unchecked, these invasive species could further threaten the region's delicate ecosystems.[574]

The spectacled caiman (Caiman crocodilus) was introduced to Puerto Rico over 50 years ago, with the Tortuguero Lagoon National Wildlife Refuge (TLNR) as its epicenter. It has since established itself as an apex predator in the region. While there are concerns about the potential impact of this naturalized predator on Puerto Rico's native fauna, little is known about the caiman's diet.

The spectacled caiman, also known as the common caiman, is a medium-sized crocodilian that is considered an opportunistic omni-carnivorous species. Its diet includes a wide variety of invertebrates, fish, amphibians, reptiles, birds, and even mammals in larger specimens. In the 1960s, it was introduced to Puerto Rico primarily due to the legal caiman pet trade. The combination of both deliberate and accidental releases from pet owners is likely responsible for its introduction into the natural environment.

In 1985, following an increasing number of sightings within the TLNR and surrounding areas, the Department of Natural and Environmental Resources (DNER) implemented a management plan aimed at eradicating the species from the island. Since then, the frequency of caiman sightings and encounters has surged well beyond the TLNR, raising concerns among authorities and residents in the San Juan Bay Estuary regarding the presence of the caiman.[575]

Xenia umbellata is a species of coral native to the Red Sea, known for its resilience to higher temperatures compared to native coral species. This tolerance enables it to thrive in warmer waters, where it can grow over and smother native corals, resulting in significant ecological consequences.

Atmospheric change poses a profound threat to coral reefs worldwide, causing elevated water temperatures, increased acidity, and greater exposure to ultraviolet rays. These stressors can weaken native

[574] Vox, "Massive Invasive Snakes are on the Loose and Spreading in Puerto Rico," May 21, 2024, https://www.vox.com/24144224/invasive-species-snakes-puerto-rico.
[575] USDA, "Diet of the Non-Native Spectacled Caiman (Caiman crocodilus) in Puerto Rico," March 18, 2016, https://data.fs.usda.gov/research/pubs/iitf/ja_iitf_2016_Bontemps001.pdf.

corals, making them more susceptible to competition from invasive species like Xenia umbellata, which is less affected by these environmental changes.

The invasion of Xenia umbellata disrupts the delicate balance of relationships within the reef ecosystem. Many species of reef fish rely on specific types of coral not only for shelter but also for food. The takeover by invasive corals can lead to a decline in fish populations, which can further impact other marine species that depend on fish for sustenance.

Moreover, the ramifications of invasive corals extend beyond ecological disruption. Healthy coral reefs play a crucial role in coastal protection by absorbing wave energy and buffering shorelines from storm impacts. When invasive species dominate and healthy reefs decline, the coastal areas become more vulnerable to erosion and the effects of natural disasters, compromising both environmental integrity and human safety. Puerto Rico has declared an emergency due to the invasive coral and is implementing an emergency response strategy.[576]

The **Sharptooth walking catfish** (Clarias catfish, Clarias gariepinus) is native to parts of the Middle East, Asia, and Africa, but it has emerged as one of the world's most invasive freshwater species, causing substantial threats to ecosystems, such as those in Puerto Rico. Its invasiveness contributes to a range of ecological and economic concerns for local environments and communities.[577]

One of the primary ways that Clarias catfish disrupt ecosystems is through their competition with native fish species for resources. Clarias catfish are known to consume a wide variety of prey, including smaller fish, crustaceans, and even amphibians. This aggressive invader can outcompete local fauna for food and habitat, potentially leading to declines in native fish populations and altering the ecological balance. The physical presence of Clarias catfish in freshwater systems can also lead to habitat degradation. Their burrowing and nesting habits can disrupt sediment structures, increasing turbidity and altering water quality. This has adverse effects on aquatic plants that depend on clear water for photosynthesis and growth. Such disruptions can affect the entire aquatic food web, as the loss of native species can have cascading effects on predators and other organisms that rely on them.

The species' ability to invade is partly due to its unique adaptations, such as the capability to breathe atmospheric oxygen, which allows it to survive in hypoxic or poor water quality conditions. Additionally, Clarias catfish can disperse over moist land to colonize new water systems. In 2018, two specimens purported to be Sharptooth walking catfish were collected in Canal de Patillas, in the Guayama municipality of southeastern Puerto Rico, with several more specimens identified the following year.

To assess the extent of the invasion, environmental DNA (eDNA) surveillance was utilized as a rapid and efficient tool. Water samples were collected from 66 sites across a variety of habitats in the area where the fish had first been reported. The sDNA-metabarcoding analysis revealed Clarias eDNA at 40 of 63 sites

[576] Puerto Rico 51st, "Invasive Coral Hits Puerto Rico," May 20, 2024, https://www.pr51st.com/invasive-coral-hits-puerto-rico/#:~:text=Invasive%20Coral%20Hits%20Puerto%20Rico%20%7C%20Puerto%20Rico%2051st.
[577] USGS, "Environmental DNA Reveals Invasion of Puerto Rican Waterways by Non-Native Clarias Catfish," https://www.usgs.gov/publications/environmental-dna-reveals-invasion-puerto-rican-waterways-non-native-clarias-catfish.

sampled, indicating a more extensive distribution than previously documented. Interestingly, molecular analysis suggested that the Whitespotted Clarias (C. Fuscus) is the likely invader, with original specimens misidentified as C. Gariepinus due to reliance on morphological characteristics rather than genetic features.[578]

The **armored catfish**, native to the freshwater systems of Central and South America, poses substantial ecological threats when introduced to new environments, such as Puerto Rico. It was likely introduced in the 1990s through the release of aquarium specimens. The species has established itself in at least eight rivers and two reservoirs.

The impacts of this invasive fish are concerning. Its burrowing behavior contributes to shoreline erosion and disrupts sediment, harming local ecosystems. The species' rapid reproduction enables it to thrive, outcompeting native fish species, and has detrimental effects on reservoir fish. Furthermore, at least 20 endangered brown pelicans have died from choking on this fish, highlighting its dangerous presence in the food chain. The availability of the fish aquarium trade, along with habitat modifications, has facilitated its invasion, posing ongoing ecological challenges in Puerto Rico.[579]

Mongooses are invasive species in Puerto Rico, significantly contributing to the decline and extinction of several local species, including various birds, reptiles, and amphibians. The mongooses (Herpestes auripunctatus) are originally native to India and were introduced to the Caribbean and Pacific islands during the 19th century and into the early 20th century, specifically as a biological control measure to manage rat populations, another invasive species that poses a threat to sugarcane plantations

Despite the initial intention of using mongooses to control rats, these small, agile predators quickly adapted and expanded their diet to include native wildlife. They have been particularly detrimental to local island species, preying extensively on ground-nesting birds, which are vulnerable to habitat loss and environmental changes. Additionally, mongooses pose a substantial threat to marine turtle populations, especially the eggs and hatchlings of these threatened species.

In response to the ecological havoc caused by mongooses, local and federal agencies have made numerous attempts to remove or at least reduce their populations from the islands. However, these efforts have frequently been unsuccessful. One of the main challenges is the rapid reproductive rate of mongooses, which allows their populations to rebound quickly even after culling. Although they are classified as

[578] USGS, "Environmental DNA Reveals Invasion of Puerto Rican Waterways by Non-Native Clarias Catfish," https://www.usgs.gov/publications/environmental-dna-reveals-invasion-puerto-rican-waterways-non-native-clarias-catfish.

[579] Bunkley-Williams, L., Williams, E. H., Lilystrom, C. G., Corujo-Flores, I., & Churchill, T. N. (1994). The South American Sailfin Armored Catfish, Liposarcus multiradiatus (Hancock), a New Exotic Established in Puerto Rican Fresh Waters. Caribbean Journal of Science, 30. https://www.researchgate.net/publication/264869992_The_South_American_Sailfin_Armored_Catfish_Liposarcus_multiradiatus_Hancock_a_New_Exotic_Established_in_Puerto_Rican_Fresh_Waters.

omnivorous and consume a variety of foods, mongooses tend to predominantly hunt local species, resulting in substantial impacts on the island's biodiversity.[580]

Invasive rodents, especially the Black Rat (Rattus rattus) and the Norway Rat (Rattus norvegicus), pose threats to Puerto Rico's ecosystems and agriculture. Since their introduction in the 1500s, these species have displaced native rodents, leading to the extinction of all native rodent species on the island. In the Caribbean National Forest, home to many native and endangered species like the Puerto Rican Parrot (Amazona vittata), these invasive rats prey on birds, snails, arthropods, and various plants.

Rodents have a negative impact on agricultural resources and disrupt ecosystems, as they consume plants and harm native wildlife populations. Their rapid reproduction and ability to thrive in diverse habitats mean that few areas in Puerto Rico, both urban and natural, are free from their presence. This invasion has critical implications for biodiversity conservation and sustainable agriculture in Puerto Rico today.[581]

Puerto Rico is facing a significant challenge with **feral potbellied pigs**, which are descendants of pigs brought by European explorers and wild boars introduced for hunting. The U.S. Department of Agriculture estimates that thousands of these pigs are now on the island, causing damage to gardens and crops, polluting water sources, and spreading waste throughout communities. As a result, Puerto Rico has declared a public health disaster.

The crisis began around 2015 when some families acquired pigs as pets, unaware that they could grow over 250 pounds and reproduce rapidly. The situation worsened after Hurricane Maria, as many pigs escaped or were released by their owners.

The ongoing presence of these pigs is impacting Puerto Rico's tourism income and public health, potentially increasing costs beyond environmental damage. The pigs carry diseases and parasites, making them unsafe to eat, and they have no natural predators. While a federal task force removed 500 pigs from San Juan in 2019, the population continues to rise, leading to current efforts focused on trapping and euthanizing the animals.[582]

Tropical kudzu (Pueraria phaseoloides) is an invasive vine that poses significant ecological challenges in Puerto Rico. Initially introduced for erosion control and forage, tropical kudzu has rapidly spread across various ecosystems, outcompeting native plant species for sunlight, space, and nutrients. Its aggressive growth can smother trees and shrubs, disrupting local habitats and diminishing biodiversity.

[580] Silvis Lab, "Where and How Well are Mongooses Doing in Puerto Rico?" January 20, 2016, https://silvis.forest.wisc.edu/research/where-and-how-well-are-mongooses-doing-in-puerto-rico/#:~:text=She%20wants%20to%20know%20where,source%20of%20food%20of%20mongooses.&text=Ultimately%2C%20Diana%20will%20have%20a,and%20resilience%20after%20species%20introductions.
[581] University of Nebraska Lincoln, "Invasive Rats (Rattus sp.) but not Always Mice (Mus musculus), are Ubiquitous at All elevations and Habitats within the Caribbean National Forest, Puerto Rico," 2018, https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=3101&context=icwdm_usdanwrc.
[582] PR51st, "Feral Pigs in Puerto Rico," January 4, 2021, https://www.pr51st.com/feral-pigs-in-puerto-rico/.

This vine can grow up to a foot per day under optimal conditions, leading to dense cover that alters the landscape and negatively affects wildlife that depend on native flora. The sheer biomass of kudzu can also impact agricultural productivity, as it invades crop fields and gardens, making it a concern for local farmers.

Efforts to manage tropical kudzu involve monitoring its spread, raising public awareness about its ecological impact, and implementing control measures such as mechanical removal and the use of herbicides.[583]

In the 1930s and 1940s, several Asian **bamboo** species, including Bambusa vulgaris, B. longispiculata, B. tulda, B. tuldoides, and Dendrocalamus strictus, were introduced to the Caribbean National Forest in Puerto Rico with the intent of stabilizing slopes. While they served their initial purpose, these species have since naturalized, leading to significant ecological impacts on the island.

The invasive nature of these bamboos has resulted in them spreading around waterways and riparian areas, where they outcompete native vegetation, disrupt local ecosystems, and alter natural water flow patterns. The ongoing invasion of these bamboo species continues to threaten biodiversity in Puerto Rico, making it increasingly challenging for native plants and animals to thrive.[584]

The **African tulip tree** (Spathodea campanulata), native to tropical Africa, is highly valued by horticulturists for its rapid growth, striking red flowers, and the ability to provide shade. However, these features contribute to its status as a powerful invasive species, particularly in Puerto Rico, where it has become the most abundant tree species, taking over abandoned farmland and moist secondary rainforests.

The tree excels in degrading land and wildlife habitats, propagating rapidly both by seeds and runners, with a high germination success rate. Its vigorous growth allows it to outcompete native species, leading to the abandonment of farmland as farmers struggle to control the spread of the tulip trees. This has resulted in the replacement of complex native habitats with less diverse, invasive-dominated forests, which support fewer rare species.

Presently, the tulip tree poses significant ecological challenges in Puerto Rico. Its dominance in the landscape disrupts local ecosystems, and controlling its growth requires potent herbicides, as biological control methods are still under research. Overall, while the tulip tree can regenerate abandoned farmlands into forest, its aggressive nature makes it a detrimental force to Puerto Rico's native biodiversity and agricultural land.[585]

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[583] Feedipedia, "Tropical Kudzu (Pueraria phaseoloides)," https://www.feedipedia.org/node/257#:~:text=Because%20of%20its%20vigorous%20fast,shrubs%20(CABI%2C%202013).

[584] ScienceDirect, "Rapid Bamboo Invasion (Expansion) and its Effects on Biodiversity and Soil Processes," https://www.sciencedirect.com/science/article/pii/S2351989419304111#:~:text=In%20the%201930s%20and%201940s,et%20al.%2C%202000).

[585] Novel Ecology, "Double-Edged Sward: The Tulip Tree Forests of Puerto Rico," June 28, 2021, https://novelecology.com/2021/06/28/double-edged-sward-the-tulip-tree-forests-of-puerto-rico/#:~:text=African%20tulip%20trees%20are%20swallowing,tree%20releases%20thousands%20every%20year.

The **Aedes aegypti mosquito** (yellow fever mosquito) is the primary vector responsible for the transmission of several serious infectious diseases, including Dengue, Chikungunya, and Zika. Dengue has been an endemic health issue in Puerto Rico for decades.

Chikungunya has also had a significant impact, causing illness and loss of work capacity, along with long-lasting effects for many Puerto Ricans. The Zika epidemic, particularly due to its serious consequences such as microcephaly, Guillain-Barré Syndrome, and potential long-term neurological disorders, has highlighted the urgent need to eliminate Aedes aegypti, the source of transmission.

Furthermore, diseases transmitted by Aedes aegypti have resulted in severe economic repercussions for Puerto Rico, with total losses amounting to hundreds of millions of dollars due to healthcare costs and the cancellation of tourism and sporting events.[586]

Africanized bees were introduced to Puerto Rico in 1994, marking the first recorded instance of these bees on an oceanic island. They are recognized as an invasive species due to their well-documented negative effects on human health and their competition for resources with native organisms, particularly concerning nesting sites. These bees pose a notable risk to public safety, as their aggressive behavior can lead to more frequent and severe sting incidents, which can be life-threatening for individuals with allergies.

Africanized honeybees are hybrids of the African race (Apis mellifera scutellata) and various European races. In continental America, several tropical adaptations have been preserved, including heightened defensive behavior, resistance to mites, and a smaller size compared to other subspecies. Despite their adaptability, they also exhibit significant genetic and morphological differences from both their original subspecies and the invading populations. Currently, the presence of Africanized honeybees continues to impact beekeeping practices on the island, as local apiarists must implement new management strategies to ensure safety and maintain the health of their hives.[587]

The Harrisia Cactus mealybug (Hypogeococcus pungens) was initially believed to be a polyphagous species originating from South America. It has been reported as a pest that devastates native cacti in Puerto Rico, posing a substantial threat to cactus diversity in the Caribbean and North America. Currently, the impacts on H. pungens in Puerto Rico are severe, as it has contributed to the decline of several native cactus species, disrupting local ecosystems and the species that depend on them. The infested cacti often exhibit signs of distress, including reduced growth and increased susceptibility to disease, ultimately leading to die-offs in some populations.

However, there is still uncertainty regarding the pest's identity and the source population from South America. Recent studies have indicated substantial genetic differentiation among local populations, suggesting H. pungens may actually comprise a species complex. Findings indicate that H. pungens includes

[586] Puerto Rico Science, Technology & Research Trust, "Findings from the Technical Workshop to Create a Safe, Effective and Integrated Strategy for the control and Elimination of Aedes Aegypti from Puerto Rico," 2016, https://prsciencetrust.org/wp-content/uploads/2016/08/FINDINGS-FROM-PUERTO-RICO-VECTOR-CONTROL-WORKSHOP.pdf.
[587] National Institute of Health, "Gentle Africanized Bees on an Oceanic Island," November 2012, https://pmc.ncbi.nlm.nih.gov/articles/PMC3492899/.

at least five distinct species, each strongly associated with specific host plants. Furthermore, it has been established that the cactus pest in Puerto Rico derives from southeastern Brazilian mealybugs.[588]

Location

In Puerto Rico, invasive plants, pests, and animals are commonly found in various locations, particularly where human activity has altered the environment. Moist, secondary rainforests, such as El Yunque National Forest, Carite State Forest, Toro Negro State Forest, and Rio Abajo State Forest, are significantly impacted by invasive plant species, including the African Tulip Tree.[589]

Agricultural regions, including the central areas around Cidra and Utuado, face challenges from invasive pests, such as the green iguana and the Diaprepes root weevil, which can devastate crops. Additionally, feral hogs (Vietnamese pot-bellied pig) are a notable concern, as they damage agricultural lands while competing with native wildlife for resources.[590] These species can have substantial economic impacts on local farming and crop yields.

Urban and suburban areas, particularly around San Juan and other densely populated regions, also deal with the effects of invasive species. Green iguanas are common in these environments as well as in most regions of Puerto Rico, posing a threat to local bird populations, especially those that nest on the ground. The introduction and proliferation of these species are often linked to habitat disturbances due to urbanization and the horticultural trade. Additionally, feral pigs, black rats, and reticulated pythons are common in these areas. The European green crab was most recently found in June 2025, when traps were set in False Bay. Eight green crabs were found, which were the first invasive European green crabs found in San Juan County since 2016.[591]

Coastal zones, including Luquillo Beach and Isla de Vieques, are also vulnerable to invasive species. The Cane Toad, brought to the island for pest control, has spread to these areas, contributing to the decline of native wildlife. Moreover, forested regions like El Yunque National Forest have reported the presence of invasive species such as spikemoss and certain bamboos (Bambusa and Dendrocalamus strictus), which alter the forest structure and limit the growth of native plants.[592]

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[588] National Institute of Health, "Species Complex Diversification by Host Plant Use in an Herbivorous Insect: The Source of Puerto Rican Cactus Mealybug Pest and Implications for Biological Control," August 20, 2020, https://pmc.ncbi.nlm.nih.gov/articles/PMC7548167/.
[589] Novel Ecology, "Double-Edged Sward: The Tulip Tree Forests of Puerto Rico," June 28, 2021, https://novelecology.com/2021/06/28/double-edged-sward-the-tulip-tree-forests-of-puerto-rico/#:~:text=African%20tulip%20trees%20are%20swallowing,tree%20releases%20thousands%20every%20year.
[590] ABC News, "Feral Pigs Flummox Puerto Rico, Invading Communities and Reproducing Rapidly," December 24, 2020, https://www.nbcnews.com/news/latino/feral-pigs-flummox-puerto-rico-invading-communities-reproducing-rapidly-n1252338.
[591] Friends of the San Juans, "Protect Sam Juan Shoreline from Invasive European Green Crab," August 8, 2025, https://sanjuans.org/protect-san-juan-shorelines-from-invasive-european-green-crab/#:~:text=The%20European%20Green%20Crab%20is,to%20grow%20our%20impact%20quickly.
[592] Frontiers, "Invasive Species in Puerto Rico: The View of El Yunque," March 7, 2021, https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2021.640121/full#T1.

Lastly, areas experiencing habitat disturbance, such as those around Ponce and Bayamón, provide favorable conditions for invasive species to establish themselves. Deforestation and urban development disrupt native ecosystems, allowing invasive organisms to thrive without natural predators. These various locations highlight the widespread nature of invasive species in Puerto Rico and the urgent need for management efforts to protect the island's unique biodiversity and ecosystems.

Table 77, Table 78, and Table 79 show invasive species located within the El Yunque National Forest but not specific to the EYNF.

Table 77: Invasive Plants in El Yunque National Forest[593]

Common Name	Species	Habitats Invaded	Impacts
Christmas tree bush or coral plant	Ardisia elliptica	Roadsides, disturbed areas along trails. Common by the El Toro trail, from sea level to 600+ m. Rapidly spreading along RD-186.	Aggressive invader displacing and smothering native vegetation.
Bamboo	Bambusa spp. (B. vulgaris, B. longispiculata, B. tulda, and B. tuldoides)	Disturbed areas, roadsides, and riparian areas	Native vegetation, native stream macroinvertebrate communities
Cobra or rattlesnake plant	Calathea lutea	Roadsides, disturbed areas. Rapidly spreading along RD Dash 191 and Portal Dash Sabana Road.	Native vegetation
Elephant grass	Cenchrus purpureaus	Roadsides, abandoned agricultural fields, lowlands, forest margins, and disturbed areas.	Native vegetation Forming dense stands
Job's tears	Coix lacryma-jobi	Riparian areas	Native riparian vegetation
Giant bamboo	Dendrocalamus strictus	Disturbed areas, roadsides, and riparian areas	Native vegetation, native stream macroinvertebrate communities
Purple yam	Dioscorea alata	Disturbed areas, forest margins, and	Native vegetation

[593] Frontiers, "Invasive Species in Puerto Rico: The View of El Yunque," March 7, 2021, https://www.frontiersin.org/journals/ecology-and-evolution/articles/10.3389/fevo.2021.640121/full#T1.

Common Name	Species	Habitats Invaded	Impacts
		secondary forests at lower and middle elevations	
Pothos/ Devil's ivy	Epepremnum pinnatum	Disturbed areas, roadsides, secondary forests, climbing on the trunks of trees and getting into the canopy	Native vegetation Smothering native epiphytes
Ginger lily/white ginger	Hedychium coroanium	Edges of shaded secondary forest and disturbed areas along trails	Native vegetation Forming dense stands
Busy Lizzie/Balsam	Impatiens walleriana	Shaded secondary forest and roadsides	Native vegetation
Morning glory	Ipomoea spp. (I. batatas, I. carnea, I. nil, I, Ochracea, I. purpurea, I. quamoclit, and I. tricolor	Roadsides, waste places, thickets and secondary forests, forest margins, and riparian areas	Locally abundant, especially after hurricanes. Spreading and smothering native vegetation
Narrow-leafed redtop or mowgrass	Melinis minutiflora	Roadsides	Native vegetation
Bamboo fern	Nephrolepsis brownii	Disturbed areas, roadsides, landslides	Native vegetation
Tiger orchid	Oeceoclades maculata	Penetrated mature forest but is most abundant in areas with moderate levels of past disturbance.	Native vegetation
Tanglehead	Paspalum fascicultatum	Roadsides, abandoned agricultural fields, lowlands, forest margins, and disturbed areas.	Native vegetation Forming dense stands
Tropical kudzu	Pueraria phaseoloides	Disturbed areas, roadsides, forest margins, secondary forests	Spreading rapidly, forming dense colonies that engulf native vegetation
Umbrella tree	Schefflera actinophylla	Disturbed areas, secondary forests, and	Native vegetation

Common Name	Species	Habitats Invaded	Impacts
		lowlands. Also, invading primary forests	
Blue spikemoss	Selaginella willdenowii	Roadsides. Very abundant along RD-186	Spreading and smothering native vegetation
Ground orchid	Spathoglottis plicata	Roadsides, landslides, and disturbed areas	Native vegetation, fungi
African tulip tree	Spathodea campanulate	Lowlands, secondary forests	Native vegetation
Creeping oxeye or Singapore daisy	Sphagneticola trilobata	Roadsides, waste areas, and landslides	Native vegetation
Arrowhead plant or Neo-Mexicanus	Sygnonium podophyllum	Disturbed areas, roadsides, and secondary forests	Form dense colonies that engulf native vegetation
Rose apple	Syzygium jambos	Riparian areas, secondary forests, and lowlands	Native vegetation
Black-eyed Susan vine and fragrant trout lily	Thunbergia alata and T. fragrans	Roadsides, waste places, secondary forests, forest margins, and riparian areas	Spreading rapidly, forming dense colonies that engulf native vegetation and shade out native vegetation in the understory
Mahu or Blue Mahoe	Talipariti tiliaceum	Roadsides, disturbed areas along trails, dense thickets near El Toro Trail	Native vegetation. Forming dense stands.
Moses-in-the-cradle	Tradescantia spanthacea	Disturbed areas and roads along the wilderness boundary	Native vegetation

Table 78: Invasive Terrestrial Vertebrates in El Yunque National Forest[594]

Common Name	Species	Habitats invaded	Impacts	Impacts
House cat	Felis catus	All	Birds, reptiles, and invertebrates	Birds, reptiles, and invertebrates
Mongoose	Herpestes auropunctatus	All	Birds, reptiles, and invertebrates	Birds, reptiles, and invertebrates
Black rat	Rattus	All	Native vegetation, birds, reptiles, and invertebrates	Native vegetation, birds, reptiles, and invertebrates
House mouse	Mus musculus	Roadsides and grassy areas	Native vegetation, invertebrates	Native vegetation, invertebrates
Cane toad	Rhinella marina	Roadsides	Reptiles and invertebrates	Reptiles and invertebrates
Green iguana	Iguana	Roadsides	Native vegetation	Native vegetation

Table 79: Invasive Terrestrial Invertebrates in El Yunque National Forest[595]

Common Name	Species	Habitats invaded	Impacts
Amazonian earthworm	Pontoscolex corethrurus	All	Invertebrate soil communities, soil dynamics, and native vegetation
Earthworm	Ocnerodrilus occidentalis	All except the Palo Colorado Forest type	Invertebrate soil communities, soil dynamics, and native vegetation
Africanized honeybee	Apis mellifera hybrid	All	Native parrots and other cavity-nesting birds, and humans
Yellow fever mosquito	Aedes aegypti	All	humans

The map in Figure 176 is based on species data from the Island Conservation's Threatened Island Biodiversity Database provided by the U.S. Fish and Wildlife Service. It represents the importance of island

[594] Frontiers, "Top Invasive Animal Species in El Yunque National Forest (EYNF), Puerto Rico," https://www.frontiersin.org/files/Articles/640121/fevo-09-640121-HTML/image_m/fevo-09-640121-t002.jpg.
[595] Frontiers, "Top Invasive Animal Species in El Yunque National Forest (EYNF), Puerto Rico," https://www.frontiersin.org/files/Articles/640121/fevo-09-640121-HTML/image_m/fevo-09-640121-t002.jpg.

habitat for federally listed and other imperiled species based on the presence of imperiled and invasive animals. As noted in the details accompanying this data, islands provide important habitats and tend to be ecologically unique hotspots for species diversity. Their relative isolation from disturbance and mainland predators can provide protection but can also increase their vulnerability to invasive species. The critical habitats identified in Figure 176 refer to areas with specific physical or biological features that are essential to conserving threatened or endangered species and require special management.[596]

Figure 176: Imperiled species

Previous Occurrences

Identifying specific previous occurrences of invasive species in Puerto Rico presents a challenge due to the island's long history and varied timelines of their introduction. Many invasive species have been present for decades, if not longer, which complicates the ability to pinpoint their initial arrival and subsequent spread. This prolonged coexistence with native species can obscure the ecological impacts and make it difficult to assess the extent of their influence on local ecosystems. Furthermore, the interactions between these

[596] U.S. Fish and Wildlife Service, Caribbean Island Habitat (Southeast Blueprint Indicator), August 25, 2025, https://gis-fws.opendata.arcgis.com/maps/fws::caribbean-island-habitat-southeast-blueprint-indicator-2023/about.

invasive species and the existing flora and fauna have evolved over time, making it harder to distinguish between natural occurrences and those driven by invasive species.

FEDERAL DISASTER DECLARATIONS

There have been no federal disaster declarations in Puerto Rico related to invasive species.

PUERTO RICO DISASTER DECLARATIONS

There have been no disaster declarations in Puerto Rico due to invasive species; however, public health emergencies have been declared, which are discussed below.

SIGNIFICANT EVENTS

In March 2024, Puerto Rico faced a rising public health crisis as the number of dengue cases surged dramatically, attributed to the yellow fever mosquito, Aedes aegypti.[597] As the spring season unfolded, the Health Department reported 549 cases from January through March alone. In contrast, the entire previous year had recorded 1,293 cases, highlighting a troubling escalation in the island's mosquito-borne diseases.[598]

This was not the first time Puerto Rico had faced a health emergency. Just a few years prior, in January 2021, a similar declaration was made due to the alarming presence of feral pigs. Efforts to control the population included a federal task force that, in July 2019, successfully rounded up and removed 500 pigs from the capital, San Juan. Yet, despite these efforts, the feral pig population continued to burgeon across the island, raising concern about ecological balance and public health.[599]

Furthermore, a public health emergency for Zika was first declared on August 12, 2016. This declaration was renewed multiple times, reflecting the persistent threat to pregnant women and their newborns.[600] By the end of 2016, the Puerto Rico Department of Health had documented 10,690 laboratory-confirmed cases of Zika, with 1,035 of those linked to pregnant women.[601]

SIGNIFICANT INTRODUCTION OF INVASIVE SPECIES

Invasive species pose a significant threat to ecosystems worldwide, and Puerto Rico is no exception. The island's unique biodiversity has been challenged by several species that have been introduced, either

[597] CNN, "Puerto Rico Declares Public Health Emergency as Dengue Cases Surge," March 28, 2024, https://www.cnn.com/2024/03/28/health/dengue-fever-puerto-rico-emergency.
[598] NPR, "Here's what to Know about Dengue, as Puerto Rico declares a Public Health Emergency," March 27, 2024, https://www.npr.org/2024/03/27/1241210938/dengue-puerto-rico-public-health-emergency-facts-disease.
[599] PR51st, "Feral Pigs in Puerto Rico," January 4, 2021, https://www.pr51st.com/feral-pigs-in-puerto-rico/.
[600] Administration for Strategic Preparedness & Response, "Renewal of Determination that a Public Health Emergency Exists," April 28, 2017, https://aspr.hhs.gov/legal/PHE/Pages/zika-renewal-28April2017.aspx.
[601] American Hospital Association, "HHS Declares Public Health Emergency in Puerto Rico in Response to Zika," August 15, 2016, https://www.aha.org/news/headline/2016-08-15-hhs-declares-public-health-emergency-puerto-rico-response-zika.

intentionally or inadvertently, over the years. This section will explore some of the most notable invasive species in Puerto Rico.

- The introduction of the feral Spanish pig: There are no pig species native to Puerto Rico. However, when the Spaniards introduced pigs to the island in the early 1500s, it sparked an ongoing swine invasion that persists to this day. This event is significant for Puerto Rico because it has led to economic and environmental challenges that impact residents' daily lives. Many Puerto Ricans consider the introduction of these pigs a "disaster."

  Currently, the Vietnamese pot-bellied pig poses a major concern, with thousands of feral hogs roaming the island. They create noise disturbances, damage gardens, and knock over trash cans, resulting in significant nuisance for residents. Moreover, these feral hogs harm food production and contribute to a decline in overall hygiene on the island. The situation has created challenges for agriculture, tourism, and public health, making it a pressing issue for the community.[602]

- The introduction of the mongoose to Puerto Rico marks a significant turning point in the island's ecological history. Originally introduced as a solution to the rat infestation devastating the sugarcane plantations, the mongoose quickly became an unintended contributor to ecological imbalance. Rather than controlling the rat population, these small carnivores have led to the decline and even extinction of several native plant and bird species.

  The mongoose's predatory nature poses a grave threat to Puerto Rico's unique wildlife. While they do eat rats, their varied diet includes local birds, amphibians, and reptiles, which has allowed the rat population to thrive despite the presence of mongooses. This has created a cycle of ecological disruption, where the very solution intended to protect agricultural interests has, in fact, exacerbated the problem.

  Furthermore, mongooses are implicated in approximately 70% of rabies infections on the island, which poses a public health concern to all residents. Their introduction highlights the complexities and unintended consequences of introducing non-native species into an ecosystem. Overall, the mongoose's presence is a stark reminder of the importance of cautious ecological management and the lasting impacts of human intervention in natural systems.[603]

- The introduction of Caimans and Green Iguanas to Puerto Rico during the pet trade in the 1960s and 1970s has turned into a significant ecological event that poses serious risks to the island's biodiversity and agriculture. Today, the Green Iguana has become particularly notorious as an invasive species, with current estimates indicating a population of around 10 million on the island. This overwhelming population has led to extensive damage to local crops and has created hazardous conditions on roads and runways.

[602] NBC News, "Feral pigs flummox Puerto Rico, invading communities and reproducing rapidly," 2020, https://www.nbcnews.com/news/latino/feral-pigs-flummox-puerto-rico-invading-communities-reproducing-rapidly-n1252338.

[603] SILVIS Lab, Where and how well are mongooses doing in Puerto Rico?, 2016, https://silvis.forest.wisc.edu/research/where-and-how-well-are-mongooses-doing-in-puerto-rico/#:~:text=Mongooses%20are%20an%20invasive%20species%20in%20Puerto%20Rico%2C,and%20connectivity%20of%20mongoose%20populations%20and%20their%20diet.

Similarly, the Spectacled Caiman has established itself as an apex predator in Puerto Rico, often inhabiting urban areas and near schools, posing a safety concern for residents. The presence of these invasive species has disrupted local ecosystems and threatened native wildlife, making their control a pressing issue for conservationists and authorities.[604]

To combat their proliferation, both species are regularly hunted for population control. The Green Iguana is often hunted not only to manage its numbers but also for its meat, which is considered a traditional local dish. Despite these efforts, hunting alone has proven insufficient to completely eradicate these species from the island, highlighting the ongoing challenges Puerto Rico faces in mitigating the impacts of invasive species on its environment and agricultural systems. This situation underscores the need for more comprehensive strategies to address the ecological imbalances caused by these introductions and to protect the island's rich biodiversity.[605]

- Over the past two decades, invasive snakes have increasingly infiltrated urban areas, with a notable surge beginning in 2013. In December 2024, the Puerto Rican government took a decisive stand, calling for aggressive action to combat this urgent issue. The introduction of Boa Constrictors to the island can be traced back to 2012, likely linked to the exotic pet trade, which led to the release of these massive snakes into the wild.

  Puerto Rico's unique environment serves as an ideal habitat for Boa Constrictors, characterized by its warm climate, dense forests, and lack of natural predators. These snakes can grow to 75 pounds and reach lengths of 30 feet, largely due to their access to abundant prey, including the numerous cats and birds that populate the island. Initially estimated at 150 Boa Constrictors in Cabo Rojo in 2012, the population density in wildlife refuges has increased to approximately five snakes per acre.

  The significant escalation of Boa Constrictor numbers poses serious risks not only to local pets and livestock but also threatens the ecological balance of the region. The potential spread of disease to native snake species further compounds the urgency of this crisis. As the invasive population continues to grow, the call for coordinated management efforts becomes critical to safeguard both biodiversity and the interests of local communities. Addressing this phenomenon is essential for preserving Puerto Rico's unique wildlife and ensuring the safety of its residents.[606]

- The invasive Lionfish, first observed along the Atlantic Coast and in the Caribbean since 2001, has seen a staggering increase in its population over the last 10 to 15 years, with a notable surge in 2021. These strikingly beautiful yet perilous creatures pose a significant threat to marine ecosystems and local economies. A sting from a Lionfish can result in a painful puncture wound, which can deter tourists and snorkeling enthusiasts from exploring the vibrant reefs of Puerto Rico. The fear of potential Lionfish

[604] NBC News, "Caimans surround Puerto Rico town, so locals fight back with lassoes – and marinade," December 8, 2012, https://www.nbcnews.com/news/world/caimans-surround-puerto-rico-town-so-locals-fight-back-lassoes-flna1C7505588.
[605] NeoBiota, "Experimental Evidence of Negative Agricultural Impacts and Effectiveness of Mitigation Strategies of Invasive Green Iguanas (Iguana igualna) in Puerto Rico," October 28, 2024, https://neobiota.pensoft.net/article/114925/.
[606] Wide Open Spaces, "Puerto Rico Are Battling Giant Invasive Snakes: 'We Have a Serious Problem,'" 2024, https://www.wideopenspaces.com/puerto-rico-are-battling-giant-invasive-snakes-we-have-a-serious-problem/.

stings hampers tourism, a critical component of the local economy, and limits access to the natural beauty of these underwater habitats.

Lionfish are voracious predators, consuming a wide range of native species, which leads to a detrimental impact on local fish populations and the overall health of coral reef ecosystems. Their arrival in Puerto Rico is primarily attributed to human activity, particularly through the aquarium trade, where they were initially kept as exotic pets. Once released into the wild, their capacity to flourish was further exacerbated by their aggressive feeding habits, the absence of natural predators, and the abundance of food available in these marine environments.

The exponential growth of the Lionfish population is alarming, as they possess toxic spines that render most potential predators helpless. This invasion not only threatens biodiversity but also poses serious challenges for local fishermen, who are actively working to control their numbers, viewing Lionfish both as a pest and a potential food source for human consumption. However, despite these efforts, overall population control remains minimal.

This situation is significant not only because it disrupts the delicate balance of marine ecosystems but also because it highlights the broader implications of human actions on wildlife. The Lionfish invasion serves as a crucial reminder of the need for responsible pet ownership and the potential consequences of introducing non-native species into fragile ecosystems. Addressing this issue is crucial for the preservation of marine biodiversity and the sustainability of local economies in areas like Puerto Rico, which rely heavily on tourism and fishing.[607]

- Xenia umbellata is an invasive soft coral species that was first observed in October 2023, marking a concerning addition to marine ecosystems. Shortly after, in March 2024, Latissimia ningalooensis, a species originally native to Australia, was also identified in the waters of Puerto Rico. Genetic testing of these two species has revealed their native habitats, indicating that their simultaneous presence in Puerto Rico is likely due to similar introduction pathways, such as shipping, rafting on floating debris, or possibly the aquarium trade.

  The significance of these events cannot be overstated. Both species pose a serious threat to local reef ecosystems by rapidly outcompeting native flora and fauna, leading to overgrown reef habitats that can displace indigenous species. This disruption not only compromises biodiversity but can also weaken the overall health of the marine environment, affecting fish populations and the livelihoods of local communities dependent on fishing and tourism. The potential for L. ningalooensis to spread quickly and extensively raises concerns for conservationists, as its proliferation could significantly alter the structure and function of reefs. As invasive species often lack natural predators in their new environments, the management and mitigation of such invasions are critical to preserving the delicate balance of Puerto Rico's marine ecosystems. The introduction of these corals underscores the urgent need for increased monitoring and proactive measures to protect native species and habitats from further degradation.[608]

[607] PR Day Trips, "Lionfish in Puerto Rico," February 3, 2021, https://www.puertoricodaytrips.com/lionfish-puerto-rico/.
[608] Reef Resilience Network, "First record of a second invasive soft coral species, Latissimia ningalooensis, in southern Puerto Rico," June 20, 2025, https://reefresilience.org/article-summaries/first-record-of-a-second-invasive-soft-coral-species-latissimia-ningalooensis-in-southern-puerto-rico/.

- The presence of the Boa Constrictor and the Reticulated Python continues to escalate as a major concern for the state of Puerto Rico. The Reticulated Python, recognized as the world's longest snake and native to South and Southeast Asia, has increasingly been spotted in urban areas, including schools. This alarming trend has prompted lawmakers to take decisive action by allowing "unlimited hunting" of these species, which have been classified as harmful and dangerous.

  The potential threat to human safety, particularly for vulnerable populations such as children, is a primary concern. Reports of Reticulated Pythons preying on humans underscore the urgency for intervention in managing these invasive species. Additionally, the environmental balance in Puerto Rico is at risk, as these snakes can disrupt local ecosystems and impact native wildlife. As the island grapples with this dual challenge of safeguarding its residents and preserving its natural heritage, the ongoing battle against these invasive snakes is critical for public safety and ecological stability.[609]

Potential Severity of Event

DISEASE SEVERITY SCALE: PLANTS/AGRICULTURE

The Disease Severity Scale (DSI) is a critical tool for assessing the impact of various pathogens and environmental factors on crop health and productivity. By systematically categorizing the severity of disease symptoms, this scale enables farmers, agronomists, and researchers to make informed decisions regarding pest management, disease control strategies, and overall crop management practices. The DSI serves as a quantitative measure of disease impact, reflecting factors such as the proportion of affected plants and the severity of symptoms observed in the field.

This scale typically ranges from 0 to 5 or 0 to 10, where lower scores indicate minimal damage and higher scores reflect increasingly severe levels of damage. For instance, a rating of 0 signifies no visible symptoms, while a score of 4 or 5 suggests severe damage characterized by significant leaf drop, stunted growth, and potential plant death. Understanding where a particular plant falls on this scale can help in assessing the overall health and resilience of native species affected by this invasive pest.

As an example, the Brazilian mealybug feeds by extracting sap from native plants, resulting in various symptoms that can be effectively evaluated using the DSI. Moderate infestations may result in yellowing leaves and reduced vigor, while high-density populations can cause extensive damage, including the growth of sooty mold from honeydew secretions, further inhibiting photosynthesis. As the severity of infestation increases, plants become more susceptible to secondary infections and environmental stressors, which can elevate their severity ratings. The DSI helps in determining not only the immediate impact on individual plants but also the potential for broader ecological consequences.

Employing the DSI also enables researchers and land managers to prioritize control measures effectively. By evaluating the extent of damage across different species, targeted strategies can be initiated to manage mealybug populations. For example, if a sensitive native cactus is rated at 4, it signals an urgent need for

[609] Vox, "Massive Invasive Snakes are on the Loose and Spreading in Puerto Rico," May 21, 2024, https://www.vox.com/24144224/invasive-species-snakes-puerto-rico.

intervention to mitigate further damage and support recovery efforts. This prioritization is crucial, as it enables the efficient allocation of resources to combat the invasive threat before it leads to a significant loss of biodiversity.

The current severity of native cacti infested with the H. Pungens mealybug is currently unknown; however, it is estimated that some plots in the Guánica dry forest have seen the death of up to 80% of native cacti.[610]

Table 80: Plant Disease Severity Scale[611]

Disease Score	Lesion Area %	Disease Reaction
0	0	Highly Resistant (HR)
1	1-10	Resistant (R)
3	11-30	Moderately Resistant (MR)
5	31-50	Moderately Susceptible (MS)
7	51-75	Susceptible (S)
9	76-100	Highly Susceptible (HS)

THE ENVIRONMENTAL IMPACT CLASSIFICATION FOR ALIEN TAXA (EICAT)

The EICAT serves as a standardized framework for assessing the ecological impacts of alien species, which are organisms introduced to areas outside their natural ranges. This includes various taxa across different kingdoms, such as invasive mammals, reptiles, amphibians, birds, insects, and plants. By categorizing these species into five distinct impact levels, the EICAT provides a clear understanding of the potential harm an alien species may pose to native ecosystems. Each category reflects a different magnitude of impact, allowing researchers and conservationists to prioritize their efforts based on the severity of the threat. The five impact levels and their definitions are described in Table 81.[612]

[610] Entomology PR, "Harrisia cactus mealybug: Biological Control Gone Wrong," January 17, 2023, https://entomologylabpr.blogspot.com/2013/01/harrisia-cactus-mealybug-biological.html#:~:text=SOME%20OF%20THE%20COLUMNAR%20CACTI,options%20for%20combating%20the%20mealybug.

[611] Khan, M., et al. (2015). Assessment of Yield Losses Caused by Bacterial Blight of Rice in Upper Dir, Khyber Pakhtunkhwa Province. ResearchGate, 2015(32), 74–78. https://www.researchgate.net/publication/308597732_assessment_of_yield_lossess_caused_by_bacterial_blight_of_rice_in_upper_dir_khyber_pakhtunkhwa_province_pakistan.

[612] IUCN Library System, "IUCN EICAT Categories and Criteria," 2020, https://portals.iucn.org/library/sites/library/files/documents/2020-026-En.pdf.

Table 81: Impact Categories for Alien Species[613]

Magnitude of Impact	Taxon Description
Massive (MV)	A taxon is considered to have massive impacts when it causes naturally irreversible community changes through local sub-population, or global extinction (or presumed extinction) of at least one native taxon.
Major (MR)	A taxon is considered to have Major impacts when it causes community changes through the local or sub-population extinction (or presumed extinction) of at least one native taxon, which would be naturally reversible if the alien taxon were no longer present. Its impacts do not lead to naturally irreversible local population, sub-population, or global taxon extinctions.
Moderate (MO)	A taxon is considered to have Moderate impacts when it causes declines in the population size of at least one native taxon but has not been observed to lead to the local extinction of a native taxon.
Minor (MN)	A taxon is considered to have Minor impacts when it causes reductions in the performance of individuals in the native biota, but no declines in native population sizes, and has no impact that would cause it to be classified in a higher impact category.
Minimal Concern (MC)	A taxon is considered to have impacts of Minimal Concern when it causes negligible levels of impacts, but no reduction in the performance of individuals in the native biota. Note that all alien taxa have impacts on the recipient environment at some level, for example, by altering species diversity or community similarity (e.g., biotic homogenization). For this reason, there is no category equating to "no impact".

Additionally, only taxa for which changes in the individual performance of natives have been studied but not detected are assigned an MC category. Taxa that have been evaluated under the EICAT process, for which impacts have not been addressed in any study, should not be classified in this category, but rather classified as follows in Table 82.

Table 82: Data Deficient Impact Categories[614]

Classification	Description
Data Deficient (DD)	A taxon is categorized as Data Deficient when the best available evidence indicates that it has (or had) individuals existing in a wild state in a region beyond the boundary of its native geographic range, but either there is inadequate information to classify the taxon with respect to its impact, or insufficient time has elapsed since introduction for impacts to have become apparent. It is expected that all introduced taxa will have some level of impact because, by definition, an alien taxon in a new

[613] IUCN Library System, "IUCN EICAT Categories and Criteria," 2020, https://portals.iucn.org/library/sites/library/files/documents/2020-026-En.pdf.
[614] IUCN Library System, "IUCN EICAT Categories and Criteria," 2020, https://portals.iucn.org/library/sites/library/files/documents/2020-026-En.pdf.

Classification	Description
	environment has a non-zero impact. However, listing a taxon as Data Deficient recognizes that current information is insufficient to assess that level of impact.
No Alien Populations (NA)	A taxon is categorized as having No Alien Populations when there is no reliable evidence that it has (or had) individuals existing in a wild state in a region beyond the boundary of its native geographic range. In this case, absence of evidence is assumed to be evidence of absence, as it is impossible to prove that a taxon has no alien individuals anywhere in the world. Taxa with individuals kept in captivity or cultivation in an area to which it is not native would be classified here. A taxon could currently have no individuals existing in a wild state in a region beyond the boundary of its native geographic range because it has died out in, or has been eradicated from, such an area. In these cases, there should be evidence relating to impact that causes it to be classified in one of the impact categories (MC, MN, MO, MR, MV), or alternatively, no evidence of impact, which would cause it to be classified as DD.
Not Evaluated (NE)	A taxon is categorized as Not Evaluated when it has not yet been evaluated against the EICAT impact categories.

The importance of EICAT extends beyond classification; it plays a significant role in management and conservation planning. By providing a systematic way to evaluate and categorize the influence of invasive species, EICAT helps guide policymakers and conservationists in prioritizing which species require immediate intervention. Higher-impact categories indicate a need for urgent management actions, while lower-impact species may be subject to ongoing monitoring to assess potential changes over time.

In addition, EICAT supports ecosystem monitoring efforts by enabling the identification and assessment of new alien species introductions, as more data becomes available. Classifications can be updated, leading to a deeper understanding of ecological dynamics in response to invasive species. Furthermore, EICAT's standardized terminology facilitates effective communication among scientists, policymakers, and the public, ensuring that the potential risks associated with invasive species are clearly articulated. This heightened awareness can lead to improved resources and support for invasive species management initiatives, ultimately contributing to the protection of native biodiversity.

Estimating the extent of invasive species in Puerto Rico reveals significant challenges to the island's native ecosystems. The difficulty in tracking and measuring the extent of invasions, combined with limited resources for conservation efforts, complicates the effective management and mitigation of their impact. In terms of plants, it is estimated that 50% of the floral species are non-native and are a major concern (MR).

When it comes to mammals, invasive species such as the black rat and mongoose comprise roughly 20-30% of the total mammalian population in Puerto Rico and pose a moderate concern (MO). These mammals pose a serious threat to native birds, particularly those that nest on the ground. Their predatory behaviors and competition for resources have contributed massively to the decline of several native species.

Invasive reptiles, including the well-known green iguana, account for about 10-15% of the island's reptile population and are a minor concern (MN). While they can add diversity to the ecosystem, their competition

with native reptiles presents challenges and potential imbalances, which can sometimes lead to declines in native species populations.

Lastly, invasive insects comprise a significant portion of the insect community, estimated at approximately 30-40%, posing a major concern (MR). The prevalence of insects can disrupt ecological interactions, further complicating efforts to preserve Puerto Rico's ecosystems.

Probability of Future Hazard Events

The probability that future invasive species will establish themselves in Puerto Rico is **high**, influenced by several interconnected factors. One of the primary drivers is human activity, including agricultural practices, horticulture, and increased global trade. As these activities expand, the likelihood of inadvertently introducing non-native species into the ecosystem rises. Each new introduction carries the potential for a species to establish and create ecological imbalances.

Habitat disturbance also significantly contributes to the establishment of invasive species. Urban development, deforestation, and changes in land use disrupt natural ecosystems, creating opportunities for invasive species to thrive. Disturbed habitats often lack the resilience of intact ecosystems, making them more susceptible to colonization by species that can exploit these changes. Consequently, as Puerto Rico continues to face land-use changes, the risk of invasions increases.

Atmospheric changes play a critical role in shaping the future of invasive species on the island. Altered weather patterns and shifts in temperature and precipitation can create more favorable conditions for certain non-native species. As weather patterns continue to change, it may allow some invasive species to expand their ranges or become established in areas where they could not previously survive. This dynamic creates another layer of complexity regarding the potential for future invasions.

Additionally, the lack of natural predators in new environments allows many invasive species to thrive unchecked. In Puerto Rico, many non-native species can outcompete native plants and animals for resources, contributing to the decline of native species, which are often poorly equipped to deal with such competition. Given the island's unique biodiversity, the introduction of even a few invasive species can have far-reaching consequences.

Lastly, the agricultural sector plays a vital role in the introduction of non-native species. Non-native plants used for crops or ornamental purposes can escape into the wild, leading to their establishment in local ecosystems. Therefore, the combination of human activity, ecological vulnerability, habitat disturbance, and atmospheric changes creates a conducive environment for the establishment of future invasive species.

Vulnerability Assessment

Puerto Rico faces substantial challenges from invasive species that threaten its unique ecosystems and agricultural sectors. The island's warm climate and varied habitats create an inviting environment for various non-native organisms, which can outcompete, prey upon, or bring diseases to native species. This vulnerability assessment aims to identify the specific invasive species impacting Puerto Rico and their

potential effects on their locations, local ecosystems, population, structures, critical facilities, infrastructure, and community lifelines. By understanding the intricacies of these invasions, Puerto Rico can develop effective management strategies to mitigate their impact, protect native biodiversity, and promote ecological resilience.

LOCATIONS

Puerto Rico is under extreme threat from various invasive species across multiple taxonomic groups, including mammals, insects, marine animals, reptiles, and plants. The unique ecosystems and biodiversity of the island are at risk, necessitating a comprehensive assessment to understand the impacts and guide management efforts.

Invasive mammals, including the mongoose and various rat species, pose a serious threat to Puerto Rican wildlife. The mongoose preys on native birds and reptiles, leading to a decline in their populations, while rats damage crops and disrupt ecosystems. Municipalities like Caguas and Ponce, which are heavily agricultural, are particularly affected, significantly impacting agricultural productivity and straining local economies as farmers struggle to protect their livelihoods.

Invasive insects also greatly impact local ecosystems. The Africanized honeybee poses a significant threat due to its aggressive nature, which can lead to injuries in humans and livestock, thereby disrupting the ecological balance in affected areas. Municipalities such as Bayamón and San Juan are facing the challenges presented by these bees, including potential harm to local beekeeping industries and public safety concerns.

Additionally, the H. pungens mealybug has emerged as a major pest, particularly affecting agricultural output. The invasive species damages native cacti and a variety of crops, leading to reduced yields and increased food insecurity in the region. As these invasive insects proliferate, they can fundamentally change local agricultural practices and threaten the livelihoods of farmers.

Marine ecosystems are not spared, with the lionfish becoming a notable predator of native fish species, drastically altering the marine food web. Coastal municipalities, such as Fajardo and Isla Verde, face challenges from invasive species, along with the influx of Caribbean sargassum, which can suffocate local fish habitats and negatively impact coastal ecosystems. This poses challenges not only to diversity but also to local fisheries and the tourism industry that relies on these vibrant ocean resources.

Reptiles, such as the green iguana, can also disrupt local environments. As herbivores, they consume native plants, competing with local species for limited resources. Areas like Luquillo and Rincón are particularly impacted as their presence can reduce agricultural yields, placing additional pressure on farmers who must contend with the economic repercussions of these invasive reptiles.

Invasive plants like the African tulip tree and various bamboo species displace native vegetation, leading to habitat alteration in municipalities such as Guayama and Vieques. This competition diminishes biodiversity and threatens local agricultural sectors by reducing crop yields and altering land use patterns. Such ecological and economic pressures necessitate urgent attention and action to protect Puerto Rico's natural heritage.

To mitigate the impacts of invasive species, several strategies should be considered. Monitoring and early detection programs can help identify and address invasive species before they become entrenched. Public awareness campaigns are crucial for educating local communities about the importance of protecting native biodiversity. Effective management strategies, including removal and prevention measures, can significantly reduce invasive species populations. Finally, fostering collaboration between governmental and non-governmental organizations will support ongoing research into the ecological impacts of these species.

POPULATIONS

The elderly are among the most vulnerable groups in Puerto Rico, particularly regarding health and mobility. Many older adults have chronic health conditions that can be exacerbated by the presence of invasive species, such as mosquitoes that carry diseases like dengue fever. Additionally, they may have limited access to healthcare services and resources necessary for prevention and treatment. The impact of invasive species on local ecosystems can further affect their access to traditional food sources and medicinal plants that are vital for their health and well-being.

Children are another vulnerable demographic, as their developing immune systems make them particularly susceptible to diseases spread by invasive species. The presence of invasive pests can lead to increased exposure to environmental toxins or allergens, which can affect children's health. Moreover, disruptions to local ecosystems, such as the decline of native flora, can impact educational opportunities related to nature and cultural heritage, which are integral to children's development and understanding of their environment.

Among agricultural communities, smallholder farmers represent a population at high risk due to the presence of invasive species. Often relying on traditional farming methods, they may lack the resources and knowledge needed to combat invasive pests effectively. As their crops face threats from non-native species, the potential for economic hardship increases, impacting their families and communities. The reliance on monoculture practices makes their farms particularly vulnerable to widespread crop failures.

Residents of coastal areas, including fishermen and tourism workers, face similar risks. Invasive marine species can disrupt essential ecosystems, such as coral reefs and mangroves, which are critical for both biodiversity and local economies. Many coastal community members depend on these ecosystems for their livelihoods, so economic stability can be directly threatened by the spread of invasive species.

Indigenous populations in Puerto Rico also face unique challenges related to invasive species. Their cultural practices and food systems often rely on native plants that are threatened by non-native organisms. This not only poses risks to their health by disrupting access to traditional food sources but can also undermine their cultural identity and heritage, increasing their vulnerability in multiple dimensions.

Within urban areas, certain groups, particularly low-income residents and those with limited access to healthcare, face heightened risks from invasive species. The concentration of people in cities can lead to public health concerns, particularly with the rise of disease vectors such as mosquitoes. The lack of green spaces can exacerbate these issues, limiting residents' opportunities for outdoor activities and increasing their exposure to health risks.

People with disabilities are particularly vulnerable to the effects of invasive species, as their mobility and access to resources may be limited. This can make it difficult for them to seek healthcare, maintain their homes, and protect themselves from disease vectors. Additionally, the deterioration of local ecosystems can hinder their access to public spaces and community activities, further isolating them.

Those experiencing homelessness face significant risks due to invasive species, as they often lack stable shelter and access to basic health services. Increased exposure to disease vectors can lead to further health complications, and the presence of invasive plants can limit the availability of safe spaces. Addressing the needs of homeless populations is essential for ensuring their safety and well-being in the face of these environmental challenges.

STRUCTURES INCLUDING CRITICAL FACILITIES

Invasive species, such as the green iguana and kudzu vine, have become a threat to homes, businesses, and critical facilities across the island. Their establishment can disrupt essential services and contribute to infrastructure damage. One primary concern is the potential damage to residential and commercial buildings. Invasive plants, like kudzu vine, can rapidly grow and infiltrate structures, compromising their integrity, especially in humid environments. Additionally, burrowing rodents can destabilize the soil around foundations, risking severe structural failures. Such damage not only endangers the safety of homes and businesses but also incurs hefty repair costs and service interruptions that can impact daily operations.

Critical facilities, such as hospitals, schools, and water treatment plants, are also susceptible to the influence of invasive species. For instance, aquatic invasive plants can alter the natural ecology of water sources, potentially leading to contamination of drinking water. This contamination poses serious public health risks, making it vital for water treatment facilities to actively monitor changes in water quality attributable to non-native organisms.[615]

Transportation networks leading to and from critical facilities can be obstructed by invasive plant species, which can block roadways and railways. This poses safety hazards for commuters and delays emergency response times, undermining public safety and preparedness in times of crisis. Additionally, increased maintenance costs resulting from invasive encroachments can impact the operational efficiency of businesses, further complicating the effects of these species.[616]

The health risks associated with invasive species extend beyond physical damage; they can also pose a threat to residents and workers. For example, the Africanized Honeybee can pose dangers to individuals in outdoor workplaces near critical facilities. They will often build nests in wall voids, and their tendency to swarm can lead to new colonies forming, posing safety risks from potential stings.

[615] Currents, "The Growing Impact of Invasive Species on Water Quality," June 23, 2023, https://www.idexxcurrents.com/en/latest/the-growing-impact-of-invasive-species-on-water-quality/#:~:text=Invasive%20species%20disturb%20and%20degrade,Mackinaw%20River%20Watershed%20in%20Michigan.

[616] U.S. Department of Transportation, "Invasive Species Impacts on Transportation Infrastructure," November 2021, https://www.environment.fhwa.dot.gov/env_topics/documents/Invasive_Species_Impacts_on_Transportation_Infrastructure_November_2021.pdf.

The loss of biodiversity resulting from these invasive species can exacerbate ecological imbalances, raising vulnerabilities for homes and businesses, as well as critical infrastructure. As native species decline, the ecosystem becomes more susceptible to threats like atmospheric pattern changes and natural disasters, further endangering stability.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Invasive species can severely impact critical infrastructure within Puerto Rico. For example, the overgrowth of invasive plants can obstruct road transportation and access, leading to difficulties in logistics and emergency response. The presence of species like the mongoose presents additional risks to motorists, contributing to vehicle accidents. Waterways are also affected; invasive plants can hinder water flow, resulting in flooding that can damage infrastructure. Utilities are also at risk, with species such as the green iguana causing outages by climbing utility poles and damaging essential equipment. Additionally, pests like termites threaten the structural integrity of buildings, leading to increased maintenance costs and safety hazards.

The threats posed by invasive species extend to vital community lifelines such as food security, public health, and emergency response systems. Agricultural production is vulnerable to significant risks from pests and diseases introduced by invasive species, which jeopardize local food supplies and impact economic stability. Public health is also at risk, particularly from vectors like the Aedes aegypti mosquito, which can transmit diseases such as dengue and Zika. This increases the demand for healthcare services, particularly during outbreaks. Moreover, disruptions to transportation and communication infrastructure caused by invasive species can impede emergency response efforts, especially during natural disasters such as hurricanes, thereby complicating relief and recovery operations.

PROBLEM STATEMENTS

- Invasive species in Puerto Rico are threatening local ecosystems and agricultural productivity, with specific municipalities bearing the brunt of this crisis. In Caguas and Ponce, invasive mammals like mongooses and rats harm native wildlife and disrupt farming.
- Municipalities such as Bayamón and San Juan face challenges from aggressive invasive insects such as the Africanized honeybee, impacting public safety and local industries.
- Coastal areas like Fajardo and Isla Verde are experiencing significant ecological disturbance from lionfish and Caribbean sargassum, adversely affecting fisheries and tourism.
- Vulnerable populations in Puerto Rico face heightened risks due to socio-economic challenges, limited access to healthcare, and the impacts of many invasive species on local ecosystems and food security.
- Invasive species, such as the green iguana and kudzu vine, threaten the integrity of residential and commercial structures, including critical facilities like hospitals and water treatment plants. These species can compromise building stability, disrupt essential services, and lead to costly repairs. Additionally, their rapid proliferation can obstruct transportation networks, affecting emergency response times and public safety. The contamination of natural resources and the associated public

health risks further underscore the urgent need for proactive management and monitoring strategies to mitigate these impacts.

- Invasive species threaten Puerto Rico's infrastructure and critical community lifelines, compromising transportation, utilities, and public health systems. The obstruction of roadways by invasive plants and the risk of accidents caused by species like the mongoose hinder logistics and emergency response efforts.
- Pests that damage agricultural production and introduce diseases amplify food insecurity and health risks, especially during natural disasters.

Impact Assessment

Various aspects of the ecosystem, economy, and public health can be impacted by invasive species in Puerto Rico.

STATE ASSETS

The critical infrastructures potentially affected by invasive species in Puerto Rico include dams, water treatment facilities, aqueducts, drinking water wells, and agricultural and livestock operations.

At the state level, the rich biodiversity of Puerto Rico, encompassing tropical forests, coral reefs, and wetlands, is under siege from invaders like the Red Lionfish and the Africanized Honeybee. The Africanized Honeybee, known for its aggressive behavior, can disrupt local apiculture and threaten public safety, while species like the Green Iguana and the Reticulated Python impact native wildlife through predation and competition for resources. These species often outcompete native flora and fauna, leading to a decline in species diversity and disrupting the natural balance of ecosystems.

Agriculture is a crucial sector of the Puerto Rican economy, but it is facing significant challenges due to invasive pests, such as the Harrisia cactus mealybug and other harmful insects that damage crops. Feral pigs also cause problems by rooting through agricultural land, damaging crops, and contributing to soil erosion. These issues not only threaten food security but also impact the economic stability that depends on agricultural exports.

Invasive plants like Kudzu Vine and the African Tulip Tree are further complicating the situation. Kudzu Vine can rapidly choke out native vegetation, while the African Tulip Tree competes with local flora and alters ecosystems. These invasives disrupt forest ecosystems and watersheds, impacting water quality and availability, as well as adversely affecting state-managed natural resources dependent on healthy ecosystems.

LOCAL ASSETS

At the local level, various municipalities experience unique challenges due to invasive species. In San Juan, urban landscapes suffer from invasive plants that impede efforts to beautify parks and public spaces. Ponce,

known for its agricultural output, faces significant threats from invasive pests and diseases that impact sugarcane and coffee plantations, leading to economic losses and reduced job opportunities. Arecibo, with its coastal ecosystems, grapples with invaders that disrupt local fishing activities and degrade coral reefs, affecting both biodiversity and the fishing economy.

In Caguas, the presence of invasive insects threatens home gardens and municipally managed green spaces, leading to increased maintenance costs for the municipality and impacting local food supplies. Mayagüez faces pressure on its agricultural economy due to invasive plant species competing with traditional crops, ultimately affecting the livelihoods of local farmers. Similarly, Arroyo's local water bodies are troubled by invasive aquatic plants, which disrupt fishing and recreational activities and hinder community engagement in nature-based activities.

COMMUNITY LIFELINES

FEMA Community Lifelines are essential frameworks for assessing and responding to the needs of communities during and after disasters. In Puerto Rico, all FEMA lifelines, encompassing safety and security, food, hydration, and shelter, health and medical, energy, communication, transportation, and hazardous materials, face additional challenges due to invasive species. These non-native organisms disrupt ecosystems, threaten public health, and damage infrastructure, ultimately straining the vital services that communities rely on.

SAFETY AND SECURITY

In Puerto Rico, invasive species have a significant impact on the community's lifeline of safety and security. They increase human-wildlife interactions, straining law enforcement resources. Fire services face heightened risks from more frequent and intense wildfires, largely due to the presence of flammable invasive plants. Search and rescue operations are hindered as thick vegetation obstructs access, slowing response times.

FOOD, HYDRATION, AND SHELTER

Food, hydration, and shelter can be impacted by invasive species that compete with native plants and agricultural crops. For instance, invasive insects like the Brown Marmorated Stink Bug can devastate key crops, leading to diminished food availability and economic strains for local farmers. This loss threatens community stability, especially during crises. Moreover, pathogens like those causing Citrus Greening Disease can jeopardize the citrus industry, further compromising food security.

Invasive species in Puerto Rico can significantly affect hydration and access to clean drinking water through various ecological mechanisms. One major issue is the disruption of water quality caused by invasive plants. These species can establish dense root systems that alter filtration processes in wetlands, leading to increased sedimentation and nutrient runoff, which compromise water safety.

Invasive species can change watershed dynamics by impacting soil composition and vegetation cover. This may hinder the soil's ability to retain moisture, resulting in excessive water loss or flooding, which directly affects freshwater availability for drinking and agriculture. The decline in biodiversity due to invasive species

further exacerbates these issues, as it compromises ecosystem resilience and natural water purification, potentially introducing pathogens into water sources.

Invasive plant species can outcompete and displace native flora, which are vital for providing essential resources such as wood for construction and materials for building shelters. These native plants not only support local ecosystems but also contribute to biodiversity, soil stability, and habitat for wildlife. The loss of native vegetation due to invasive species can lead to a decline in these critical materials, negatively impacting both the environment and human communities that rely on them for sustainable living and shelter construction. With fewer native plants, communities struggle to secure safe living environments.

HEALTH AND MEDICAL

Invasive species can introduce new pathogens that threaten local populations. For instance, amphibian declines due to Chytrid Fungus can disrupt ecosystems and contribute to the loss of species that play roles in maintaining healthy environments. Additionally, as invasive species alter the landscape, they may force communities to adapt to new health risks, including potential increases in insect-borne diseases carried by species that thrive in disturbed environments. The introduction of harmful non-native species may overwhelm healthcare systems as new health challenges emerge, necessitating additional resources and targeted public health initiatives.

ENERGY

Invasive plants, such as the African Tulip Tree, alter landscapes and create fire hazards, increasing the risk of wildfires, which can threaten energy infrastructure. Energy production facilities that rely on natural resources can be affected by invasive species that compromise local ecosystems, potentially leading to energy shortages during critical periods.

COMMUNICATIONS

Communications lifelines in Puerto Rico can be significantly impacted by habitat alterations caused by invasive species. The presence of invasive plants can obstruct communication infrastructure, such as transmission towers and lines, making it challenging for emergency services to communicate effectively during crises. This interference can hinder the ability to distribute critical information, coordinate response efforts, and connect communities with the help they need.[617]

TRANSPORTATION

Invasive species can disrupt transportation routes and infrastructure. Dense thickets of invasive plants can obstruct roads or waterways, complicating emergency response efforts and increasing the risk of accidents. In waterways, species such as water hyacinth and zebra mussels can hinder shipping and flood control,

[617] Commercial Weed Control, "Brush Mowing on Transmission Towers," https://www.commercialweedcontrol.com/services/brush-mowing-on-transmitter-towers/#:~:text=Firstly%2C%20overgrown%20vegetation%20can%20obstruct%20the%20clear,causing%20mechanical%20damage%20and%20compromising%20structural%20integrity.

resulting in delays and increased operational costs. Additionally, increasing animal crossings can heighten the risk of vehicle collisions.

HAZARDOUS MATERIALS

Certain invasive species, such as Japanese knotweed and common reed, have been documented to accumulate heavy metals, including lead, cadmium, and arsenic, from contaminated soils. These plants can absorb toxic substances through their roots and then transfer them to other organisms when they are consumed by herbivores or decompose, contaminating the soil. Bioaccumulation poses a significant risk, as these heavy metals can enter the food chain, affecting not only plant health but also the safety of livestock and wildlife, and potentially impacting human health through the consumption of contaminated food products. This bioaccumulation complicates the management of contaminated sites, as the presence of these invasive species can hinder remediation efforts. Additionally, the proliferation of invasives can make it more difficult to monitor and manage hazardous materials effectively.

WATER SYSTEMS

Invasive species can alter water quality by introducing new nutrient cycles and changing the chemical composition of aquatic environments. For instance, certain invasive plants may increase nutrient levels, which can lead to algal blooms that deplete oxygen and harm fish and other aquatic life. Additionally, invasive plants can disrupt hydrology by obstructing rivers and streams, changing sedimentation patterns, or even leading to flooding. This can affect water availability for communities that rely on these systems for drinking water, agriculture, and recreational activities. Furthermore, invasive fish species may outcompete native species for food and habitat, leading to declines in native populations and disrupting local ecosystems and fisheries. Moreover, invasive organisms can damage infrastructure, such as water treatment facilities and pipes. For instance, zebra mussels, an invasive mollusk, can clog water intake systems, resulting in increased maintenance costs and potential disruptions to the water supply.

Changes in Development

In recent years, Puerto Rico has witnessed significant changes in its development landscape, driven by a combination of urbanization, agricultural expansion, and infrastructure projects. These shifts, while aimed at fostering economic growth and improving living conditions, have critical impacts on the island’s ecological integrity. Understanding how these developmental changes affect Puerto Rico's vulnerability to invasive species, including invasive plants, mammals, reptiles, invertebrates, and marine animals, is essential for effective management and conservation strategies.

This section examines the multifaceted ways in which development changes have influenced Puerto Rico's susceptibility to invasive species, highlighting both the challenges and potential solutions in managing these ecological threats.

LAND USE AND BUILT ENVIRONMENT CHANGES

Invasive species in Puerto Rico have heightened the vulnerability of land use and built environments, creating challenges. The loss of biodiversity due to invasive species outcompeting native plants disrupts local ecosystem services like pest control and pollination, diminishing environmental resilience.

Moreover, invasive plants often lead to increased soil erosion, which threatens agricultural lands and infrastructure, particularly after heavy rains or storms. This erosion complicates recovery efforts following natural disasters such as hurricanes.

Invasive species can also alter fire regimes, raising the risk of wildfires that endanger communities and habitats. Economically, managing invasive species requires resources that could otherwise be allocated to support recovery initiatives. Additionally, some invasive species increase health risks by boosting populations of disease vectors like mosquitoes, further impacting public safety. Overall, the spread of invasive species in Puerto Rico significantly **increases vulnerability** and necessitates urgent management strategies to protect the island's recovery and resilience.

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

The projected future and growth of invasive species is concerning, as current trends indicate an increase in their prevalence due to ongoing development pressures. Urbanization, infrastructure expansion, and agricultural practices create disturbances in native ecosystems, making them more susceptible to invasive species. Invasive species are particularly adept at exploiting disturbed environments. With native competitors weakened or eradicated, these non-native organisms often flourish, outcompeting indigenous species for resources like nutrients. This phenomenon can lead to a significant decrease in biodiversity, compromising the integrity of ecosystems that are already under stress. Puerto Rico's rapid development, characterized by construction, land conversion for agriculture, and urban area expansion, is likely to exacerbate the spread of these invasive species.

Several factors further compound this issue. Habitat fragmentation, often a byproduct of urban development, divides ecosystems into smaller, isolated patches. This not only makes it easier for invasive species to establish themselves in these fragmented habitats but also disrupts the movement of native species, hindering their ability to adapt or relocate in response to environmental changes.

Atmospheric change presents another layer of complexity, as shifting weather patterns, rising temperatures, and an increased frequency of extreme weather events create new niches for invasive species to exploit. Some invasive species are remarkably resilient to changing conditions, enabling them to thrive where native species may struggle to survive. Additionally, globalization facilitates the movement of organisms across borders, with many invasive species introduced intentionally or accidentally through trade and travel.

The socio-economic implications of invasive species proliferation are also noteworthy. A decline in native biodiversity can impact agriculture, tourism, and local industries that depend on healthy ecosystems. Managed ecosystems can suffer from reduced agricultural yields due to competition with invasive species. At the same time, areas that rely on ecotourism may see a decline in visitor interest as natural landscapes become dominated by non-native species.

POPULATION CHANGES

As the human population in Puerto Rico declines, the dynamics of urban areas and natural habitats are shifting significantly. Reduced urban development often leads to the abandonment of previously inhabited land, which can result in the gradual recovery of natural habitats. However, this change may also create conditions favorable for invasive species to thrive, as these species are often resilient in disturbed environments. Although there may be less competition from human activities, invasive species can still outcompete native flora and fauna that face their own challenges due to habitat loss and degradation. This scenario poses a risk to biodiversity and could disrupt ecosystems, leading to long-term ecological consequences.

Furthermore, a declining population reduces the demand for resources like food, water, and land. When agricultural areas are abandoned or reduced in intensity, non-native species that were previously cultivated may spread uncontrolled if they escape into the wild, further challenging native ecosystems. The shift from intensive farming to less cultivated land can exacerbate the risk of invasion, as fewer management practices are in place to control non-native plants.

Additionally, population decline can have mixed effects on atmospheric changes and pollution. As industrial activities diminish and urban areas contract, the environmental stress on ecosystems may lessen. However, changes in land use can still impact climate conditions, with altered rainfall patterns and rising temperatures potentially benefiting invasive species that are more adaptable. This ecological imbalance emphasizes the importance of addressing invasive species management, even as population numbers dwindle.

On the positive side, a smaller population can foster increased awareness of environmental issues among residents who remain engaged with their communities. This environment can pave the way for stronger advocacy and management efforts against invasive species. Community involvement in conservation initiatives can enhance practices related to native gardening and responsible landscaping, thereby reducing the chances of introducing new invasive species. Nevertheless, it is vital that these efforts are guided by sound knowledge; otherwise, the growing interest in gardening may inadvertently lead to the introduction of non-native plants that could become invasive.

The interplay between population declines and invasive species in Puerto Rico presents both challenges and opportunities. Striking a balance between ecological health and the changing needs of the community requires concerted efforts focused on sustainable development. By understanding and addressing these dynamics, it is possible to protect Puerto Rico's unique biodiversity while adapting to demographic changes in a responsible manner.

VULNERABILITY OF STATE ASSETS CHANGES

Over the past five years, Puerto Rico has continued to face the challenges posed by invasive species, particularly in the aftermath of natural disasters like Hurricane Maria. The hurricane significantly impacted local ecosystems, and recovery efforts have highlighted the ongoing threat of invasive species to biodiversity and economic stability.

One notable change has been the increased awareness and response to the impact of invasive species on agriculture, fisheries, and the environment. Efforts have emerged to manage invasive mammals, such as rats and mongooses, which continue to threaten local wildlife and crops. For example, educational initiatives have aimed to inform farmers about best practices for pest management, helping to mitigate the damage caused by these invasive species.

In marine environments, lionfish populations have been a persistent issue. However, recent years have seen increased community actions, including spearfishing tournaments and awareness campaigns, to control their numbers and educate the public about their threat to native fish populations and local fisheries.

There has also been a rising concern about invasive plants leading to soil degradation and erosion, particularly in areas affected by severe weather. Recovery projects have aimed to restore native vegetation, which helps stabilize soils and enhance resilience against further erosion.

VULNERABILITY OF LOCAL ASSETS CHANGES

Invasive species continue to increase the vulnerability of local assets in Puerto Rico by disrupting ecosystems and reducing biodiversity. However, in the past five years, there has been heightened awareness and increased efforts to address these challenges. While species like the African snail and guava fruit fly still outcompete native flora and fauna, leading to weakened resilience against diseases and environmental stressors, local initiatives have begun to mitigate these impacts.

Efforts in biological control and community engagement to manage invasive populations have shown preliminary success, although the threats remain significant. The introduction of additional pests and diseases continues to pose risks to local crops. Specifically, the brown tree snake persists in its role of drastically reducing native bird populations, which are crucial for ecological functions such as seed dispersal and pest control, exacerbating agricultural instability.

Moreover, invasive plants continue to disrupt habitats and alter water flow, heightening flooding risks to infrastructure. Yet, recent conservation programs have focused more on restoring native ecosystems and improving urban planning to limit the spread of invasive species. This shift in strategy aims to create more resilient habitats and enhance conservation efforts, though the battle against invasive species remains ongoing.

Mitigation Success Stories

Over the past five years, there has been heightened awareness, along with various strategies, aimed at addressing the issue of invasive species. Government agencies, non-profit organizations, and local communities have come together to implement management plans that focus on both the prevention and control of invasive species. Educational campaigns have been launched to inform the public about the impact of these species, while research initiatives have sought to better understand their dynamics and effects on native flora and fauna. Furthermore, collaborations with international organizations have brought additional resources and expertise to the island. As Puerto Rico continues to navigate the complexities of

invasive species, these collective efforts reflect a commitment to preserving the island's unique environment.

PUERTO RICO DEPARTMENT OF NATURAL AND ENVIRONMENTAL RESOURCES (DNER)

Since 2004, the Puerto Rico Department of Natural and Environmental Resources (DNER) has demonstrated a steadfast commitment to safeguarding Puerto Rico's marine ecosystem through a comprehensive approach aimed at mitigating the impacts of lionfish. These invasive species pose a significant threat to local biodiversity. The strategy encompasses regulations, community engagement, education, and research, which together have led to substantial progress in controlling lionfish populations within the region.

The initiative commenced with the prohibition of lionfish importation, a crucial step in preventing the further proliferation of this invasive species. The regulatory measure has laid a strong foundation for subsequent proactive interventions. A dedicated response team was tasked with monitoring and removing lionfish from public beaches and bridge supports in the San Juan area. Recognizing the importance of community involvement, the DNER mobilized volunteer groups across the northern coast, Vieques, and Desecheo, while also collaborating with commercial fishers and ornamental collectors on the western coast to enhance outreach.

Education and training have been central to the initiative. By partnering with non-governmental organizations such as Scuba Dogs, the Vieques Conservation and Historic Trust, and Eco Tono, they have empowered individuals through training on effective collection methods. These partnerships have fostered a committed community of responders prepared to address lionfish infestations. Additionally, local high schools are incentivizing student participation in the collection process by offering community service credits, thereby aligning educational objectives with environmental stewardship.

To promote the consumption of lionfish, the DNER has organized lionfish derbies and encouraged local chefs to incorporate this invasive species into their culinary offerings. The media outreach has successfully generated significant attention, culminating in the establishment of restaurants that have begun offering lionfish, with additional establishments expressing interest. In collaboration with the University of Puerto Rico, the DNER is developing a comprehensive marketing plan designed to raise awareness further and stimulate demand for lionfish.

The collaborative efforts extend to research, where DNER actively supports studies conducted by DNER, REEF, and Simon Fraser University. The findings from these research initiatives not only inform practices but also educate the public about the ecological impacts of lionfish and their exotic spines. As public awareness campaigns evolve, the DNER has transitioned from initial public alarm to a more informed discourse surrounding lionfish management.

The results of the collaborative endeavors are evident. The DNER has established several areas under effective control through consistent removal initiatives, and the DNER is witnessing the emergence of an increasing number of trained responders ready to address this issue. Support from local media has been

instrumental in disseminating vital information, ensuring that lionfish awareness remains at the forefront of public consciousness.

The DNER's ongoing strategy to combat the lionfish invasion exemplifies the efficacy of regulation, community collaboration, and education in environmental mitigation. By fostering cooperation among various stakeholders, from government agencies to local volunteers, the DNER is making significant strides in protecting Puerto Rico's marine ecosystem, thereby paving the way for a more sustainable and resilient future.[618]

ISLAND CONSERVATION PROJECT

Desecheo Island, once a thriving sanctuary for seabirds, has encountered significant challenges due to the presence of invasive species that threaten to undermine the rich avian heritage. In 2007, Island Conservation collaborated with the U.S. Fish and Wildlife Service and dedicated local partners to restore the natural ecological balance of Desecheo Island. The initiative to remove invasive mammals was deemed successful in 2017, thereby facilitating the return of seabirds and the restoration of essential nutrient flows that connect terrestrial and marine environments.

Rather than passively awaiting the return of the birds, the team implemented innovative social attraction techniques to encourage their recognition. By utilizing decoys, mirrors, and sound systems that emitted avian calls, they effectively simulated a vibrant colony of seabirds on Desecheo, which attracted the birds.

Initial sightings of Audubon's Shearwaters, a cavity-nesting species that favors roosting beneath dense vegetation, were sporadically captured by motion-sensing cameras. However, in 2023, biosecurity inspectors discovered a solitary white egg delicately situated at the base of a social attraction speaker. This egg, together with feathers subsequently identified by the Smithsonian Feather Identification Laboratory as belonging to an Audubon's Shearwater, marked a historic milestone, as this near-threatened species was documented nesting on Desecheo Island for the first time.

This significant development transcends mere scientific achievement; it serves as a compelling testament to the efficacy of collaboration, innovation, and an unwavering commitment to conservation. It illustrates the transformation of a previously imbalanced island into a sanctuary where seabirds can once again flourish.

Nesting seabirds are pivotal in transferring critical nutrients from marine to terrestrial environments, thereby enhancing soil quality and local nearshore ecosystems. This process results in considerable improvements in fish biomass and marine health. With recent evidence affirming the effectiveness of conservation efforts in the holistic restoration of ecosystems, Island Conservation remains committed to collaborating with the

[618] ICIR, "Lionfish Response in Puerto Rico," 2019, https://www.icriforum.org/wp-content/uploads/2019/12/Puerto%20Rico.pdf.

U.S. Fish and Wildlife Service and local partners to expedite ecological recovery and facilitate the return of absent species.[619]

[619] Island Conservation, "Restoring Desecheo: Social Attraction Success for the Audubon's Shearwater," July 3, 2024, https://www.islandconservation.org/restoring-desecheo-social-attraction-success-for-the-audubons-shearwater/#:~:text=EER%20has%20a%20proven%20track,and%20the%20U.S.%20Virgin%20Islands.

SECTION 4.10

LANDSLIDES

Landslides

LANDSLIDE DEFINITION

The United States Geological Survey (USGS) defines landslide as the movement of a mass of rock, debris, or earth down a slope.[620] The landslide term "mass wasting" refers to the downslope movement of soil and rock under the pull of gravity.

There are multiple causes for landslides, initiating downslope movement under the pull of gravity, that exceed the strength of the earth materials that compose the slope. Factors such as rainfall, changes in water level, river or coastal erosion, changes in groundwater, earthquakes, volcanic activity, disturbance by human activities, or any combination of these can cause landslides. In addition, submarine landslides—which are underwater landslides—can result from earthquake shaking and can cause tsunamis that damage coastal areas.[621] Figure 177 illustrates the parts of an earthflow landslide, which is a type of mass wasting in which water-saturated, fine-grained materials slowly flow downslope under the influence of gravity.

[620] USGS, 2025, "What Is a Landslide and What Causes One?," https://www.usgs.gov/faqs/what-a-landslide-and-what-causes-one.
[621] USGS, 2025, "What Is a Landslide and What Causes One?," https://www.usgs.gov/faqs/what-a-landslide-and-what-causes-one.

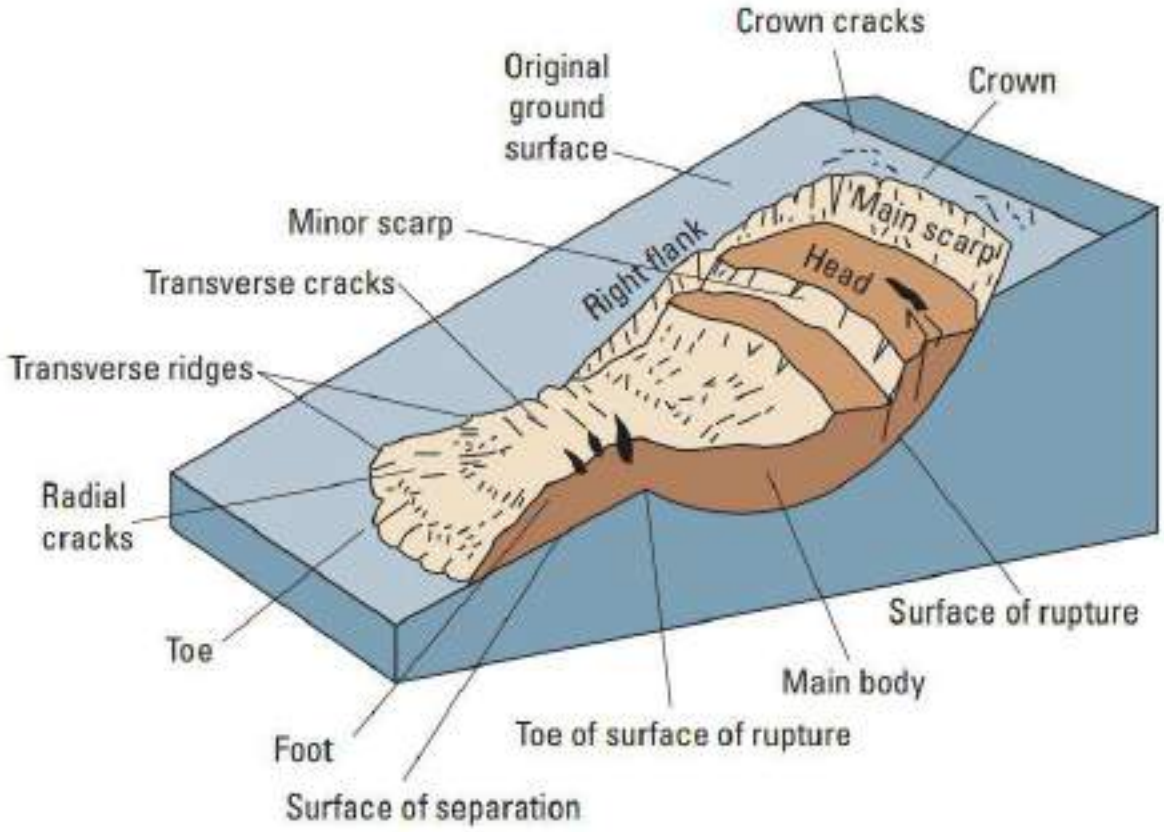

Figure 177: Parts of an Earthflow Landslide[622]

Landslide Types

Landslides are classified based on the type of material and the movement of that material. Landslide material can include rock, soil, debris, or any combination of these. Figure 178 illustrates the six landslide classifications.

[622] USGS, 2025, "The Landslide Handbook: A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.

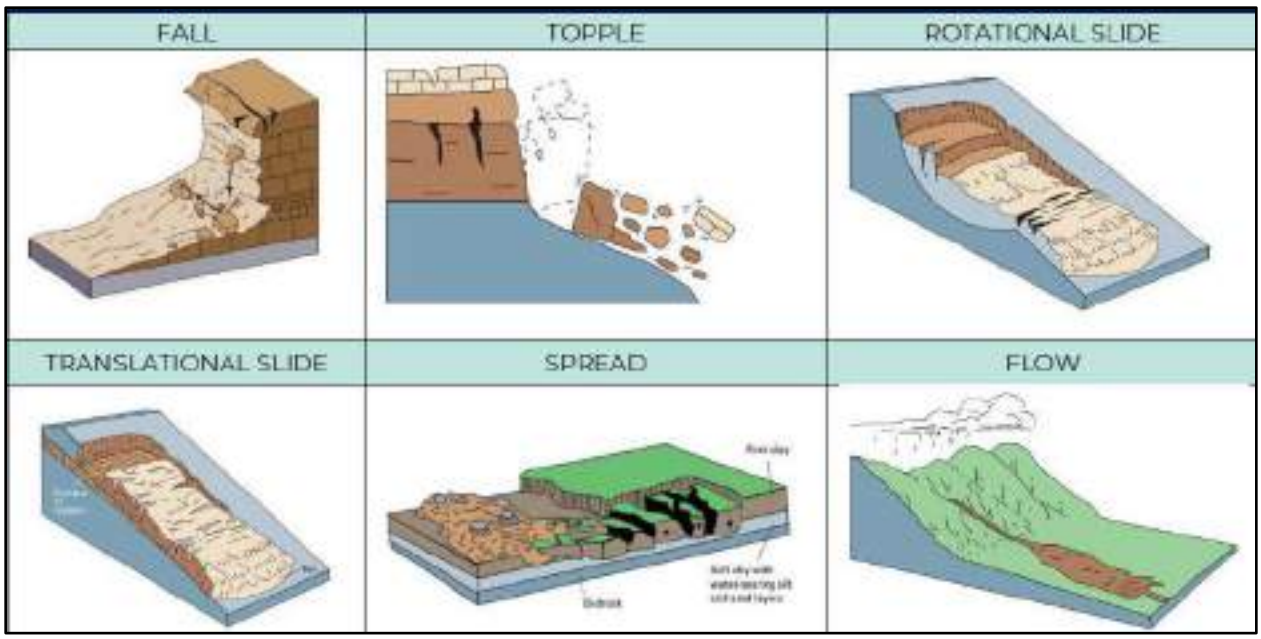

Figure 178: Types of Landslides[623]

- **Falls:** A fall occurs when rock, soil, or both, detach abruptly from steep slopes or cliffs. Falls can be triggered by the undercutting of the slope by natural processes such as streams and rivers, or by human activities such as excavation during road building or maintenance, and by earthquake shaking or other intense vibration.[624]
- **Topples:** A topple occurs when the weight of materials (rock, debris, or earthen materials) upslope displaces the mass of soil or rock around a point located below the center of gravity. Topples can be triggered by gravity, water occurring in cracks within the mass, vibration, undercutting, differential weathering, excavation, or stream erosion.[625]
- **Rotational Slides:** This type of slide occurs when a mass of material ruptures from the area of local failure, as it curves upward in a spoon-shaped form. The movement occurs about a rotational axis, parallel to the slope's contour. Rotational slides can be triggered by intense or sustained rainfall, which saturates the slopes and increases groundwater within the mass. River flooding can also erode the base of slopes, triggering a rotational slide. Earthquake shaking may also trigger this type of slide.[626]
- **Translational Slide:** This type of slide occurs when the mass moves downward and outward in a flat, lengthy extension from the surface of rupture, particularly at steep inclines. Translational slides can also be triggered by intense or sustained rainfall, as slopes are saturated from rainfall and groundwater

[623] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.
[624] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.
[625] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.
[626] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.

increases within the mass. River flooding can cause erosion at the base of slopes, triggering a translational slide. In addition, inundation of water from local irrigation systems, leakage from pipes, undercutting, or earthquake shaking can all trigger translational slides.[627]

- **Spreads:** A lateral spread occurs on very gentle slopes or flat terrain, as an extension of the stronger upper layer of rock or soil moves above an underlying softer, weaker layer. Lateral spreads are often triggered by ground overloading on unstable slopes, liquefaction of the lower weak layer by earthquake shaking, liquefaction caused by erosion at the base of a riverbank or slope, or saturation from rainfall or groundwater changes.[628]
- **Flows:** Debris flows, often inaccurately referred to as mudslides, are actually a type of mass movement in which loose soil, rock, or organic materials combined with water into a type of slurry that moves rapidly downslope. Occasionally, rotational or translational slides can evolve into debris flows if water is combined with the landmass, causing increased velocity. Dry flows can sometimes occur in cohesionless sand (sand flows). Debris flows are often triggered by intense surface-water flow, due to heavy precipitation that erodes and mobilizes loose soil or rock, as part of other types of landslides that occur on steep slopes and consist of a large proportion of silt- and sand-sized material. The extremely rapid nature of debris flows, which often occur without warning, makes this type of landslide more deadly.[629]

Location

Intense rainfall associated with tropical storms and hurricanes is the primary trigger of landslides in Puerto Rico. Prolonged or high-intensity precipitation increases soil moisture and pore-water pressure, reducing shear strength and promoting shallow slope failures, particularly in the mountainous interior of the island.

Local geology, steep slopes, disturbed land cover, and human modifications such as road construction further amplify landslide susceptibility. The municipalities summarized in Table 83 represent examples of jurisdictions that contain mapped areas classified as High or Very High susceptibility in the USGS rainfall-induced landslide susceptibility assessment.

[627] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.
[628] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.
[629] USGS, "The Landslide Handbook, A Guide to Understanding Landslides, Section 1: Basic Information About Landslides," 2025, https://pubs.usgs.gov/circ/1325/pdf/Sections/Section1.pdf.

Table 83: Municipalities in Puerto Rico with High and Very High Susceptibility to Rainfall-Induced Landslides[630]

Municipality	Susceptibility Category	Primary Triggers and Contributing Factors
Barranquitas	Very High to Extremely High	Steep slopes (Cordillera Central), intense rainfall, road cuts, concave/convex curvature, high-susceptibility soils (e.g., Lirios/Los Guineos)
Orocovis and Jayuya	High to Very High	Steep interior slopes, high rainfall/soil moisture during María, nearby intrusive terrane with low-cohesion residuum, roadway disturbance, and concave curvature
Utuado	Very High to Extremely High	High rainfall and soil moisture, steep terrain, Cretaceous intrusive rocks (Utuado pluton), very high-SI soils (e.g., Pellejas clay loam)
Ceiba	High to Very High	High mean annual precipitation, steep cut/fill slopes, development and roadway disturbance, concave topography
Bayamón	High	Steep mogote flanks, urban development, road proximity, localized slope and curvature effects
Guayanilla	High	Road cuts along PR-2, engineered slopes, local steepening despite lower regional rainfall

Puerto Rico is frequently affected by extreme precipitation associated with cyclonic systems, including hurricanes and tropical storms, which commonly trigger rainfall-induced landslides across the island. Areas with moderate to extremely high landslide susceptibility are particularly vulnerable during these events. The mountainous region of central Puerto Rico exhibits the highest density of historical landslides, as shown in Figure 179. While prior landslide occurrence is widespread across the island (Figure 180), Hurricane Maria produced an exceptional concentration of slope failures. Figure 180 illustrates the spatial density of landslide sites triggered by Hurricane Maria, highlighting the central and eastern mountainous regions as areas of particularly intense landslide activity.

[630] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

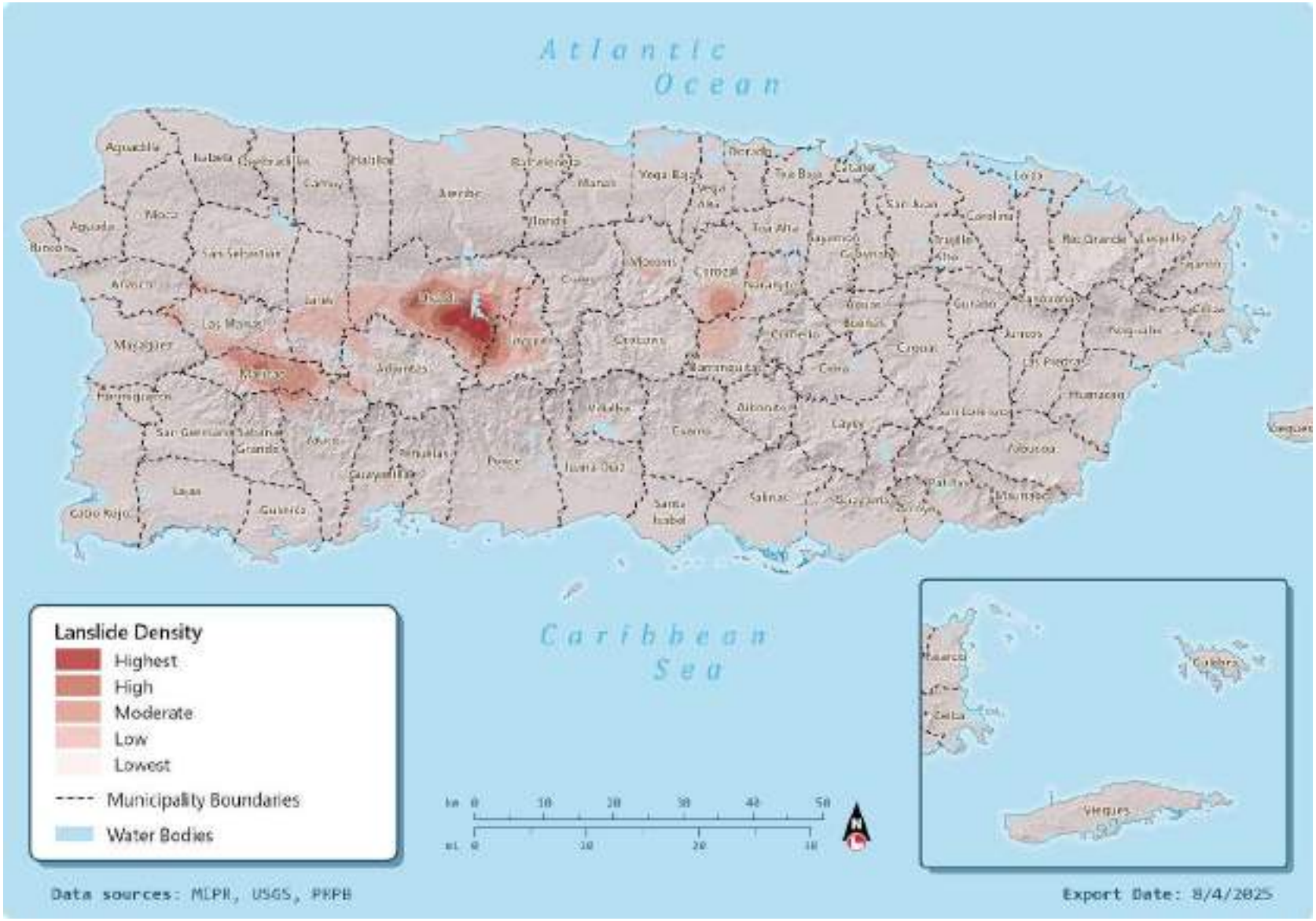

Figure 179: Landslide Density Map for Puerto Rico

The 2019 United States Geological Survey Puerto Rico Landslide study "Map of Slope-Failure Locations in Puerto Rico After Hurricane María," conducted after Hurricane Maria in 2017, includes assessments of the slope and curvature of the land surface, mean annual precipitation, proximity to roads, land cover, and soil moisture, and identified several locations across the island where the potential for landslides or high landslide density exists.[631] Figure 180 below shows Puerto Ric landslide density map and legend, with color coding to indicate levels of density from highest to lowest landslide density for each municipality. Based on the mapping, the municipalities of Utuado and Maricao have the highest landslide density.

The study identified landslide susceptibility in 72 of the 78 municipalities of Puerto Rico after Hurricane Maria, mapping a total of 71,431 landslides from that event. No landslides were documented on the islands of Culebra or Vieques. The municipalities of Maricao, Utuado, Jayuya, and Corozal experienced more than 100 landslides per square kilometer. Utuado had eight landslides recorded from this event. The Río Grande de Arecibo and Río Grande de Añasco watersheds, each with over 30 landslides per square kilometer, had drainage basins with the highest density of landslides. The Río Grande de Arecibo basin had six out of the seven sub-basins with more than 50 landslides per square kilometer.[632]

[631] USGS, ScienceBase Catalog, "Map of Slope-Failure Locations in Puerto Rico After Hurricane María," 2019, https://www.sciencebase.gov/catalog/item/5d4c8b26e4b01d82ce8dfeb0.
[632] USGS, ScienceBase Catalog, "Map of Slope-Failure Locations in Puerto Rico After Hurricane María," 2019, https://www.sciencebase.gov/catalog/item/5d4c8b26e4b01d82ce8dfeb0.

Figure 180: Post–Hurricane Maria Landslide Density Map of Puerto Rico

Previous Occurrences

Landslides are a natural phenomenon in Puerto Rico, having occurred periodically since the island was inhabited. Historically, landslides in Puerto Rico have most often occurred along the steep slopes of the central mountainous region during heavy rain events. In 2017, Hurricane Maria triggered more than 70,000 landslides across the island, with particular intensity in and around the mountainous municipalities of Utuado, Maricao, and Corozal.

FEDERAL DISASTER DECLARATIONS

Table 84 provides a list of federal disaster declarations for Puerto Rico related to landslide events. Figure 181 and Figure 182 are map illustrations showing federal disaster declarations and a legend to identify designated areas for public assistance or individual assistance disaster grant eligibility. Both public assistance and individual assistance have been approved for this hazard since the last plan update.

Table 84: Federal Disaster Declarations for Puerto Rico Involving Landslides (2015–2025)[633]

Disaster Number	Declaration Date	Description	Locations
DR-4805-PR Severe Storms, Flooding, Landslides, Mudslides	7/23/2024	From April 29 to May 10, 2024, Puerto Rico was impacted by severe storms, flooding, landslides, and mudslides, leading to a major disaster declaration for severe storms. Public Assistance (Categories A–G) was approved for all municipalities in designated areas. The Hazard Mitigation Grant Program was available island-wide (see Figure 181).	Municipalities of Adjuntas, Guánica, Lajas, Las Marías, Luquillo, Maricao, Naranjito, Orocovis, Sábana Grande, San Sebastián, Toa Alta, Utuado, and Yauco
DR-4649-PR Severe Storms, Flooding, Landslides	3/29/2022	From February 4 to February 6, the northern coast of Puerto Rico was struck by a severe storm that led to flooding and landslides. Individual Assistance was approved for all municipalities in designated areas. The Hazard Mitigation Grant Program was available island-wide (see Figure 182).	Municipalities of Cataño, Dorado, Toa Baja, Vega Alta, and Vega Baja

[633] Federal Emergency Management Agency (FEMA), 2025, "Federal Disaster Declarations Puerto Rico Mudslide/Landslide 2015-2025." https://www.fema.gov/disaster/declarations?field_dv2_declaration_date_value%5Bmin%5D=2015&field_dv2_declaration_date_value%5Bmax%5D=2025&field_dv2_declaration_type_value=DR&field_dv2_incident_type_target_id_selective=49126&field_dv2_state_territory_tribal_value%5B%5D=PR.

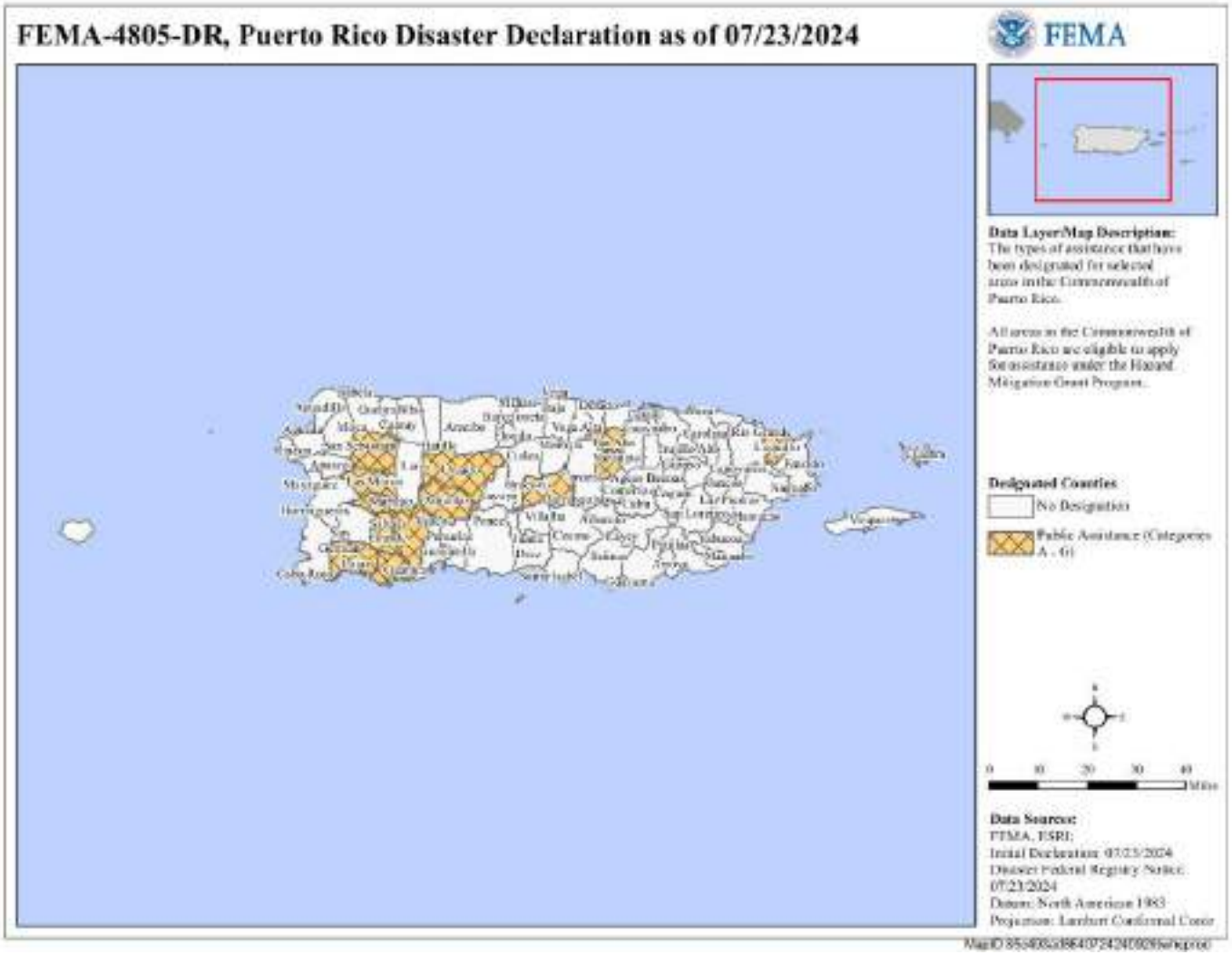

Figure 181: Map of FEMA Disaster Declaration 4805 for Puerto Rico Public Assistance Designation[634]

[634] FEMA, "Designated Areas: Disaster 4805," 2025, https://www.fema.gov/disaster/4805/designated-areas.

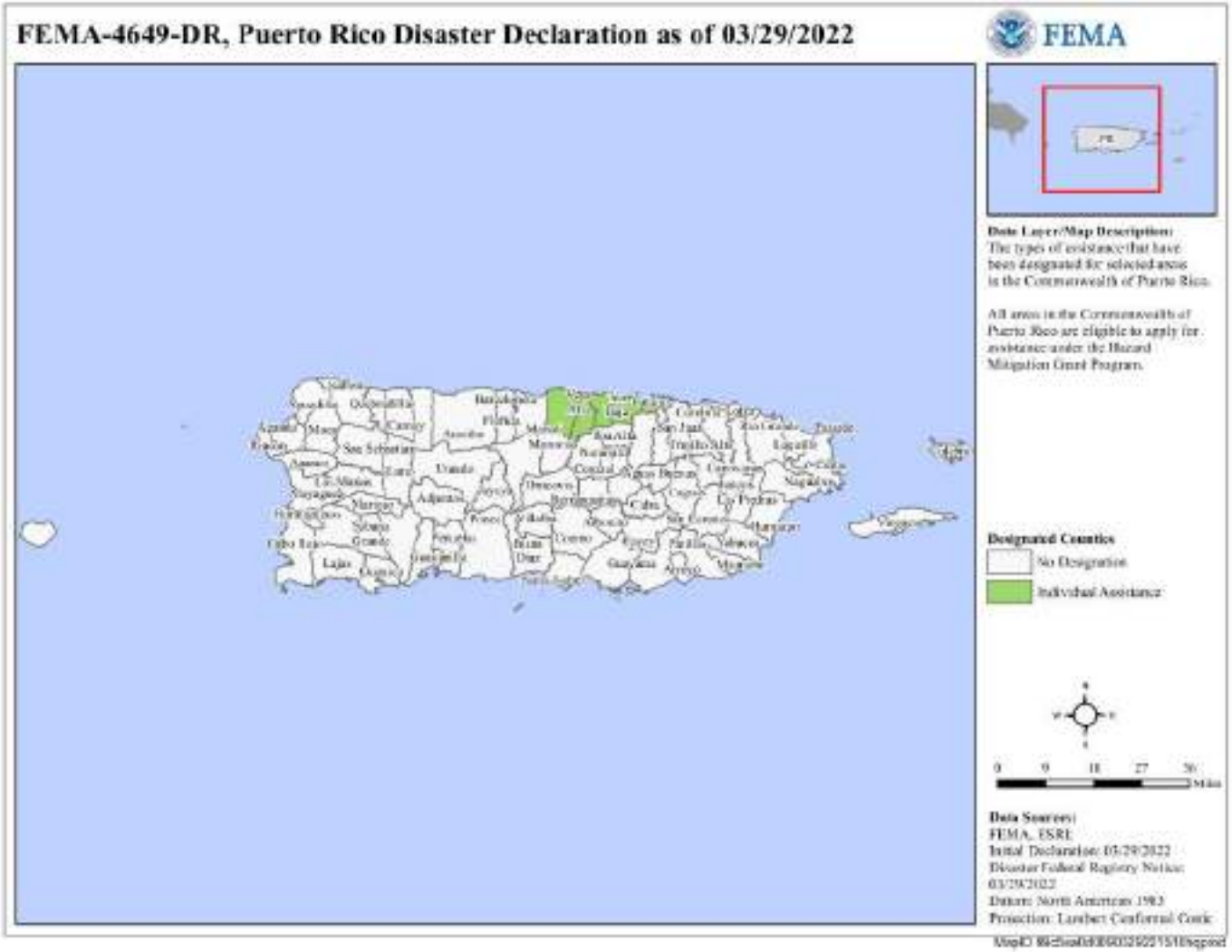

Figure 182: Map of FEMA Disaster Declaration 4649 for Puerto Rico Individual Assistance Designation[635]

[635] FEMA, "Designated Areas: Disaster 4649," 2025, https://www.fema.gov/disaster/4649/designated-areas.

PUERTO RICO DISASTER DECLARATIONS

Since the last plan update, Puerto Rico has declared a State of Emergency following tropical storms in 2022, 2024, and 2025, including the secondary hazards of landslides and mudslides. Table 85 provides a list of State of Emergency declarations for tropical storms in Puerto Rico since the last plan update.

Table 85: Puerto Rico Landslide Disaster Declarations[636]

Disaster Number	Declaration Date	Description	Locations
OE-2025-022	4/19/2025	Executive Order by the Governor declaring a State of Emergency in the municipalities significantly affected by flash floods caused by torrential rains. Rainfall caused landslides, sudden rises in water bodies, and significant water accumulation in urban and rural areas. Resulting damage was substantial and affected homes, roads, critical infrastructure, and essential services.	Municipalities of Aguas Buenas, Corozal, Naranjito, and Orocovis
OE-2025-004[637]	1/2/2025	Declaration of emergency due to critical road infrastructure conditions and landslides on highways. Measures implemented to protect public safety and transportation.	All of Puerto Rico
OE-2024-021[638]	8/12/2024	State of Emergency declared due to Tropical Storm Ernesto, which brought heavy rainfall, flash flooding, and landslides.	All of Puerto Rico
OE-2022-045[639]	9/17/2022	State of Emergency declared in preparation for Tropical Storm Fiona. Rainfall of 5–10 inches caused flash flooding and mudslides.	All of Puerto Rico

SIGNIFICANT EVENTS

Documentation of landslides in Puerto Rico dates back to the late 19th and early 20th centuries; however, access to specific details about these events is limited. The 1985 landslide at Barrio Mameyes, which killed nearly 200 people in a neighborhood of Ponce, marked a major turning point in documenting landslides in Puerto Rico. Since then, more detailed data on landslides and their impacts on Puerto Rico have become

[636] Puerto Rico Department of State, "Executive Orders," 2025, https://www.estado.pr.gov/ordenes-ejecutivas.
[637] Puerto Rico Department of State, "Executive Orders 2025-004," 2025, https://www.estado.pr.gov/ordenes-ejecutivas?year=2025.
[638] Puerto Rico Department of State, "Executive Orders 2024-021," 2025, https://www.estado.pr.gov/ordenes-ejecutivas?year=2024.
[639] Puerto Rico Department of State, "Executive Orders 2025-045," 2025, https://www.estado.pr.gov/ordenes-ejecutivas?year=2022.

available.[640] Table 86 contains reports from the National Centers for Environmental Information, which maintains a storm events database on significant natural hazards. However, since landslides are a geological hazard, the database does not provide specific event details for landslides as a primary hazard, but rather as a secondary hazard associated with tropical storms.

Table 86: National Centers for Environmental Information Data on Landslides[641]

Date	Location	Description	Total Event Damages
11/16/2024	Ceiba	Stations over southeast Puerto Rico (the most affected) reported rainfall of 3–6 inches over that weekend. Several flooding, flash flooding, and landslide events were reported. A local emergency manager reported landslides near a property in Quebrada Seca Calle El Sol Solar 219 in Ceiba. The terrain gave way, and a bridge was damaged.	$75,000 in property damage
11/1/2024	Maunabo	A series of cold fronts and a polar trough increased moisture and instability across the region at the end of October and start of November. Above-normal moisture, saturated soils, and high river levels increased the risk of flooding. A Flash Flood Watch went into effect on November 1. Debris flow, sinkholes, flooding, and flash flooding were reported in southeastern and north-central Puerto Rico. Landslides damaged a house and cars along PR-759 km 3.9.	$33,000 in property damage
9/9/2024	Jayuya	An upper-level trough lingered in the region, promoting unsettled weather conditions. A tropical wave brought additional moisture. Widespread showers and thunderstorms produced 1–3 inches of rain daily, with maximum amounts up to 5 inches. This led to several reports of mudslides, lightning, and flooding. A sinkhole restricted traffic on PR-140.	$10,000 in property damage

[640] K. Stephen Hughes and Alesandra C. Morales-Vélez, "Landslide Science in Puerto Rico: Past, Present, and Future," *Revista Internacional de Desastres Naturales, Accidentes e Infraestructura Civil.* 19–20, no. 1 (2020): 175–186, https://www.scipedia.com/wd/images/8/85/Draft_Colucci_652630551_7451_F_RIDNAIC_Landslide_Science_in_Puerto_Rico_Past%2C_Present_and_Future_K._Hughes_and_A._Morales.pdf.

[641] National Centers for Environmental Information, "Storm Events Database," 2025, https://www.ncei.noaa.gov/stormevents/.

Date	Location	Description	Total Event Damages
5/6/2024	Hacienda El Patrimonio, Morovis	Saturated soils from previous rainfall, combined with a lingering storm, caused major flooding and landslides. A landslide made PR-155 near Hacienda El Patrimonio impassable.	$10,000 in property damage
5/6/2024	Camino Los Aguirres, Barranquitas	Saturated soils from previous rainfall events, combined with a lingering storm, caused major flooding and landslides. A landslide affected Camino Los Aguirres near PR-143, including a washed-out bridge.	$50,000 in property damage
11/5/2022	Monumento El Jíbaro, Salinas	A significant influx of moisture, combined with heavy rainfalls in the previous months, caused flooding and mudslides. A mudslide on PR-52 at Monumento El Jíbaro closed the highway for over a week.	$3,000,000 in property damage
10/27/2022	Yabucoa	Heavy rains triggered debris flows, which created a hole on PR-3.	$20,000 in property damage.
10/26/2022	Barrio Limones, Adjuntas	Heavy rain triggered debris flows, which led to a bridge collapse on PR-920 in Barrio Limones.	$50,000 in property damage

RECENT SIGNIFICANT EVENTS

- **September 18, 2022:** Tropical Storm Fiona inundated Puerto Rico with over 25 inches of rain, resulting in more than 1,000 landslides, primarily in the island's central mountainous region.[642] These landslides caused significant damage to roads, cut off several municipalities, and destroyed numerous structures.[643]
- **January 6–7, 2020:** A magnitude 6.4 earthquake occurred near Barrio Indios, Guayanilla, Puerto Rico, on January 7, 2020. This event was the culmination of a series of earthquakes that struck Puerto Rico in early January 2020. Over 800 landslides were documented as a result. The largest mass movements occurred on natural slopes, with rockfalls in road cuts causing widespread transportation disruptions and structural damage (see Figure 183).[644]

[642] Alesandra Morales, Stephen Hughes, et al., "Geotechnical Impacts of Hurricane Fiona in Puerto Rico," Geotechnical Extreme Event Reconnaissance (GEER) Association Report No. GEER 81, March 8, 2023, https://geerassociation.org/components/com_geer_reports/geerfiles/GEER_HurricaneFiona_report.pdf.
[643] Richard J. Pasch, Brad J. Reinhart, and Laura Alaka, "Tropical Cyclone Report Hurricane Fiona," 2023, https://www.nhc.noaa.gov/data/tcr/AL072022_Fiona.pdf.
[644] Kate E. Allstadt, Eric M. Thompson, et al., "Ground Failure Triggered by the 7 January 2020 M 6.4 Puerto Rico Earthquake," *Seismological Research Letters* 93, no. 2A (2022): 594–608, https://pubs.geoscienceworld.org/ssa/srl/article-abstract/93/2A/594/611684/Ground-Failure-Triggered-by-the-7-January-2020-M-6?redirectedFrom=fulltext.

Figure 183: Landslide in Ponce, Puerto Rico, Triggered by the 2020 Earthquake[645]

- **September 20, 2017:** Hurricane Maria, a Category 4 hurricane brought heavy rains, with some estimates of maximum rainfall as high as 56 inches. This level of precipitation, combined with the rainfall from Hurricane Irma two weeks prior, led to over 70,000 landslides across the island.[646] These landslides blocked roads, isolating communities and killed at least three people (see Figure 184 through Figure 186).[647]

[645] USGS, "Landslide Triggered by M6.4 Earthquake in Puerto Rico," January 16, 2020, https://www.usgs.gov/media/images/landslide-triggered-m64-earthquake-puerto-rico.
[646] Erin Bessette-Kirton, Corina Cerovski-Darriau, et al., "Landslides Triggered by Hurricane Maria: Assessment of an Extreme Event in Puerto Rico," *GSA Today* 29, no. 6 (2019): 4–10, https://rock.geosociety.org/gsatoday/science/G383A/GSATG383A.pdf.
[647] J. West, L. A. Rodríguez-Cruz, et al., "Steep Risks: Assessing Social Vulnerability to Landslides in Rural Puerto Rico," 2023, Natural Hazards Center Public Health Report Series 34, University of Colorado Boulder, https://hazards.colorado.edu/public-health-disaster-research/steep-risks.

Figure 184: Landslide Along PR-4131 in Lares, Puerto Rico, 2017[648]

Figure 185: Landslides After Hurricane Maria in Utuado, Puerto Rico, 2017[649]

[648] K. Stephen Hughes and William H. Schulz, "Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico," U.S. Department of the Interior and USGS, Open File Report 2020-1022 (2020), https://pubs.usgs.gov/of/2020/1022/ofr20201022_pamphlet.pdf.

[649] USGS, "A Helicopter Flight Reveals Landslides' Damage in Utuado Municipality," 2017, https://www.usgs.gov/media/images/a-helicopter-flight-reveals-landslides-damage-utuado-municipality.

- **September 18, 1989:** Hurricane Hugo, a category 4 hurricane, came with high winds and torrential rain, totaling 15 inches. The inundation of rain saturated the soil and triggered more than 400 landslides, with some as large as 4,500 square meters.[650]
- **– October 5–7, 1985:** Severe storms dropped 22 inches of rainfall in a 24-hour period island-wide. Flooding affected mostly rural areas in southern Puerto Rico but caused significant loss of life and widespread property damage. Landslides near Ponce, the collapse of a bridge at Río Coamo, and the destruction of homes near Ponce resulted in about 170 fatalities and an estimated $125 million in damages in Mameyes, a neighborhood of Ponce. Flooding was also severe at Barceloneta on the north coast.[651] Subsequent research found that improper septic collection and water distribution operations likely contributed to the slide movement (see Figure 186).[652]

Figure 186: Landslide in Barrio Mameyes, 1985[653]

[650] Matthew C. Larsen and Angel J. Torres-Sanchez, "Landslides Triggered by Hurricane Hugo in Eastern Puerto Rico, September 1989," *Caribbean Journal of Science* 28, no. 3-4 (1992): 113–125, https://pubs.usgs.gov/publication/70171323.
[651] Ferdinand Quinones and K. G. Johnson, "The Floods of May 17–18, 1985 and October 6–7, 1985 in Puerto Rico," USGS Open-File Report 87-123, https://www.usgs.gov/publications/floods-may-17-18-1985-and-october-6-7-1985-puerto-rico.
[652] Jocelyn West, Lindsay Davis, et al., "Principles for Collaborative Risk Communication: Reducing Landslide Losses in Puerto Rico," *Journal of Emergency Management* 19, no. 8 (2022): 41–61,https://hazards.colorado.edu/uploads/documents/principles-of-collaborative-risk-communication-puertorico-west-et-al-2021.pdf.
[653] USGS, "Catastrophic Landslide," 1985, https://www.usgs.gov/media/images/catastrophic-landslide-0.

Potential Severity of Event

Landslides occur when the stability of a slope changes and, as it loses equilibrium, the result is mass wasting. The degree of steepness, soil moisture, soil thickness, the angle at which rock debris lies, and the presence of vegetation combine to produce a slope that will tend to maintain stability until something changes. The landslide susceptibility variable is used as a scale to determine the most likely areas where a landslide could occur and threaten people's lives and property. Landslide susceptibility levels are categorized as low, moderate, high, and highest, as shown in Figure 187.

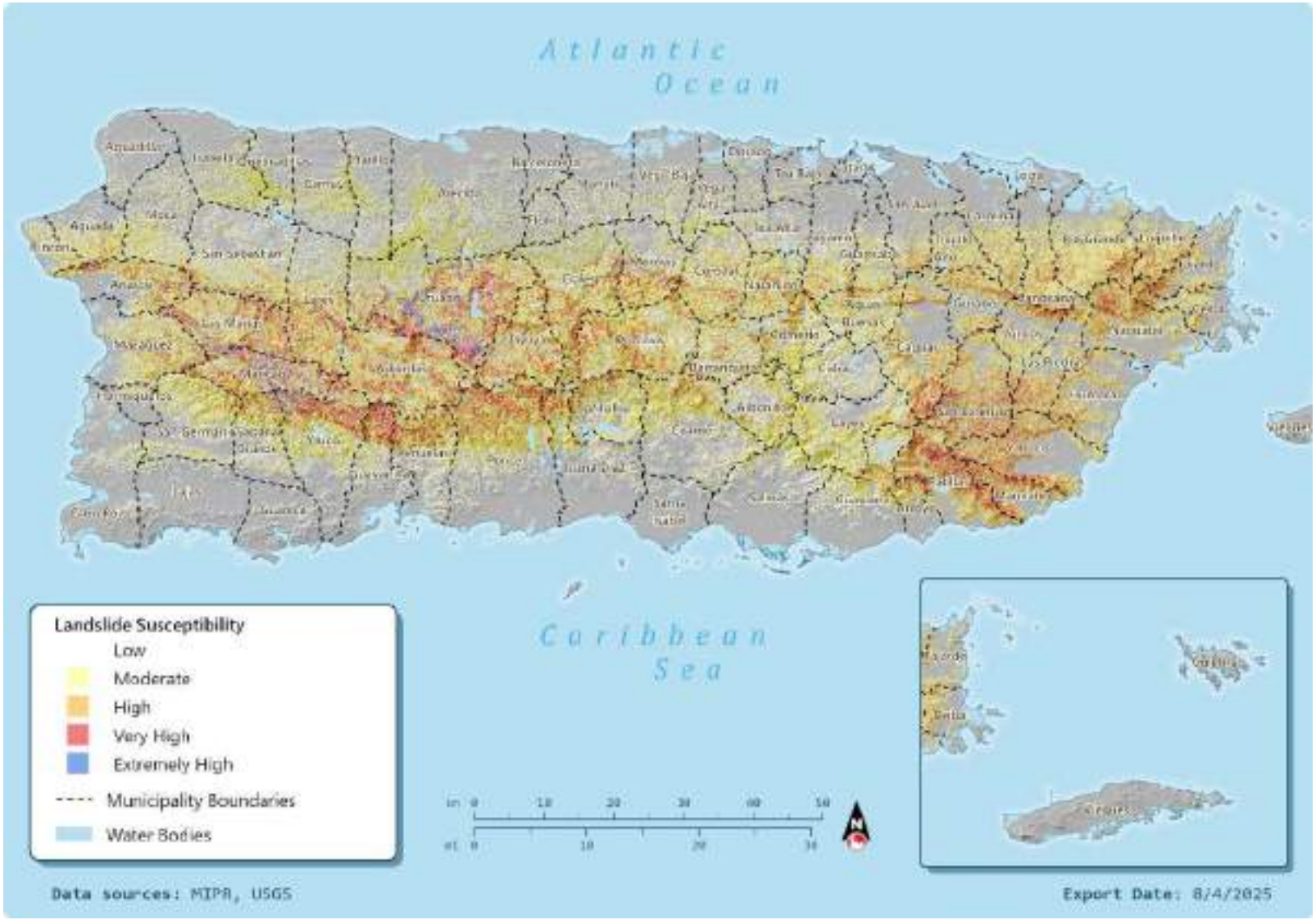

Figure 187: Puerto Rico Landslide Susceptibility Map

Most of Puerto Rico's landmass is classified as moderate susceptibility. Puerto Rico's primarily topographic disequilibrium, rapid bedrock weathering, high-frequency intense rainfall events, and intensive agricultural and urbanization practices during the past centuries have contributed to island-wide high landslide susceptibility (refer to Figure 187).[654]

Each landslide may have a different level of severity depending on the assets impacted. Landslides can destroy structures, impact foundations, block or destroy roads, break pipes and damage other infrastructure, as well as cause deaths and injuries.

Probability of Future Hazard Events

Landslides are a **highly likely** and recurring hazard in Puerto Rico due to the combined influence of steep mountainous topography, landslide susceptible soils and geologic units, and frequent periods of intense precipitation. Unlike hazards defined by discrete events, landslides in Puerto Rico are time-oriented and climate-dependent, occurring most often during periods when rainfall intensity and duration exceed the stability thresholds of slopes in the island's interior and along steep river valleys.[655] Despite steep slopes, the Puerto Rico karst zone generally has low susceptibility to rainfall-triggered landslides.

ROLE OF PRECIPITATION AND CLIMATE VARIABILITY

The most frequent trigger of landslides in Puerto Rico is intense rainfall, particularly when heavy precipitation coincides with steep slopes and deeply weathered soils in mountainous terrain. The U.S. Geological Survey (USGS) confirms that high-intensity rainfall associated with tropical atmospheric systems is the dominant landslide-provoking mechanism island-wide, responsible for widespread slope failures during and shortly after major rain events.[656]

Puerto Rico's climate exhibits bi-modal variability, with a primary rainy season from May through November and a distinct peak during the Atlantic hurricane season. While hurricanes and tropical storms are often associated with landslide disasters, it is important to note that wind impacts do not exacerbate landslides directly; rather, it is the large volumes of rainfall, prolonged saturation, and elevated soil moisture conditions generated by these systems that initiate slope failures.

USGS landslide susceptibility modeling following Hurricane María demonstrated that rainfall and soil moisture, not storm category or wind strength, were the primary controls on landslide occurrence. More

[654] K. Stephen Hughes and William H. Schulz, "Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico," U.S. Department of the Interior and USGS, Open File Report 2020–1022 (2020): 91 pp., 1 plate, scale 1:150,000, https://doi.org/10.3133/ofr20201022.

[655] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

[656] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

than 70,000 landslides were triggered by Hurricane María, validating the strong relationship between extreme precipitation, mountainous terrain, and widespread slope failure.[657]

INFLUENCE OF TOPOGRAPHY AND SLOPE

Puerto Rico's rugged interior topography, particularly within the Cordillera Central and other mountainous regions, significantly increases the probability of future landslide events. USGS susceptibility analyses show that landslide likelihood increases sharply on slopes greater than approximately 25 degrees, with the highest susceptibility occurring on slopes between 30 and 45 degrees, which are common throughout the central mountainous zone.

Because steep slopes are a permanent physical characteristic of the island, areas with high or very high landslide susceptibility can be expected to experience recurrent slope failures whenever triggering precipitation thresholds are met. As a result, landslides are anticipated to remain a frequent secondary hazard associated with hurricanes, tropical storms, and other extreme rainfall events.[658]

RIVER EROSION, CHANNEL INCISION, AND LOCALIZED RISK

The USGS identifies fluvial incision and proximity to river channels as important factors influencing landslide susceptibility. River erosion contributes to slope instability by undercutting hillsides, steepening valley walls, and promoting long-term topographic disequilibrium in adjacent slopes.

While river erosion is not always explicitly isolated as a primary variable at the state-wide scale, the analysis confirms that areas within short distances of river channels, particularly in mountainous watersheds, exhibit elevated landslide susceptibility due to the combined effects of slope, soil moisture, and channel downcutting.

Because this document is a State Hazard Mitigation Plan, detailed riverbank and channel-specific landslide processes are best addressed at the local planning level, where higher-resolution data and site-specific conditions can be evaluated. However, mitigation actions, such as slope stabilization, drainage improvements, and setbacks, should be prioritized in areas experiencing significant river or coastal erosion, especially where erosion coincides with steep terrain and developed areas.[659]

Figure 188 presents the island-wide inventory of slope failures mapped after Hurricane María, with 71,431 individual landslides identified from high-resolution post-event imagery. Because María was an extreme

[657] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.
[658] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.
[659] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

rainfall event that triggered 70,000+ failures across Puerto Rico, the figure is visually dominated by hurricane-induced landslides, especially in the mountainous interior.

Importantly, the spatial pattern of these María landslides aligns with the USGS rainfall-induced landslide susceptibility model, which is built from the factors described above, slope (heavily weighted), curvature, proximity to roads and streams, geologic terrane, mean annual precipitation, land cover, soil class, and event soil moisture. This agreement provides empirical validation of the model's factor selection and methodology for Puerto Rico under extreme rainfall conditions.

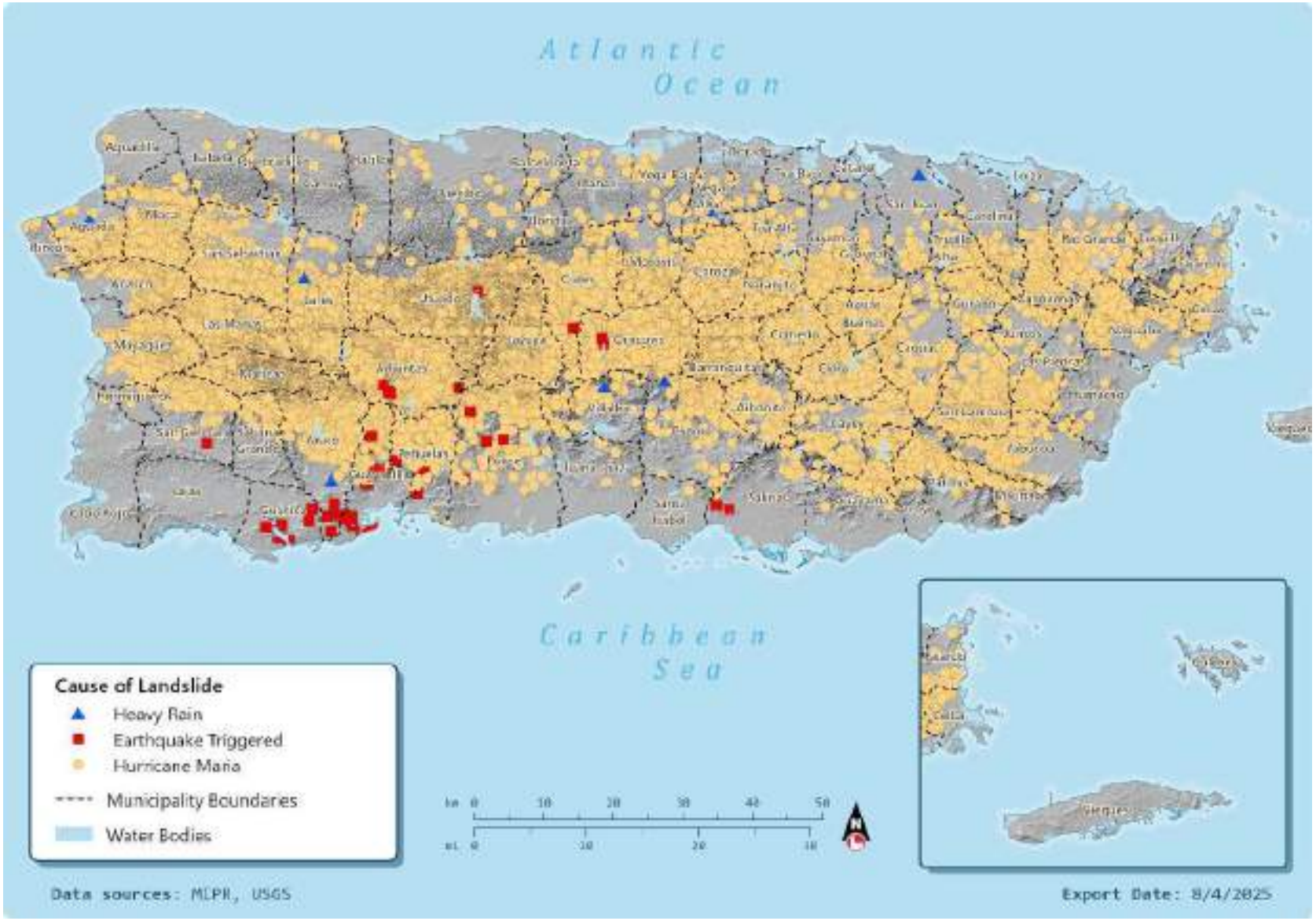

Figure 188: Cause of Landslides Map for Puerto Rico

Human activity is expected to continue contributing to future conditions that increase the probability of high and very high landslide susceptibility across Puerto Rico, particularly in the island's mountainous interior. Centuries of agricultural modification, expansion of road networks, hillside excavation, and unplanned or informal development have altered slope geometry, drainage patterns, soil stability, and vegetation cover, often in areas that were already naturally susceptible to rainfall-induced slope failure (see Figure 189).

As documented by USGS analyses, proximity to roads, disturbed land cover, and anthropogenic topographic perturbations are statistically associated with increased landslide occurrence, underscoring the role of human-altered landscapes in exacerbating risk. However, the scope of this State Hazard Mitigation Plan does not extend to identifying or evaluating individual informal settlements across the entire island or analyzing their effects on specific, localized landslide sites. That level of site-specific assessment, integrating detailed slope modifications, informal construction practices, localized drainage alterations, and community-level exposure is more appropriately conducted through local hazard mitigation plans and engineering studies. While this plan focuses on statewide patterns and drivers of landslide susceptibility, it recognizes that mitigation actions, including addressing informal settlements through improved land-use planning, drainage management, slope stabilization, and risk-informed relocation, where necessary, are critical to reducing landslide exacerbation in many jurisdictions throughout Puerto Rico.[660]

[660] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

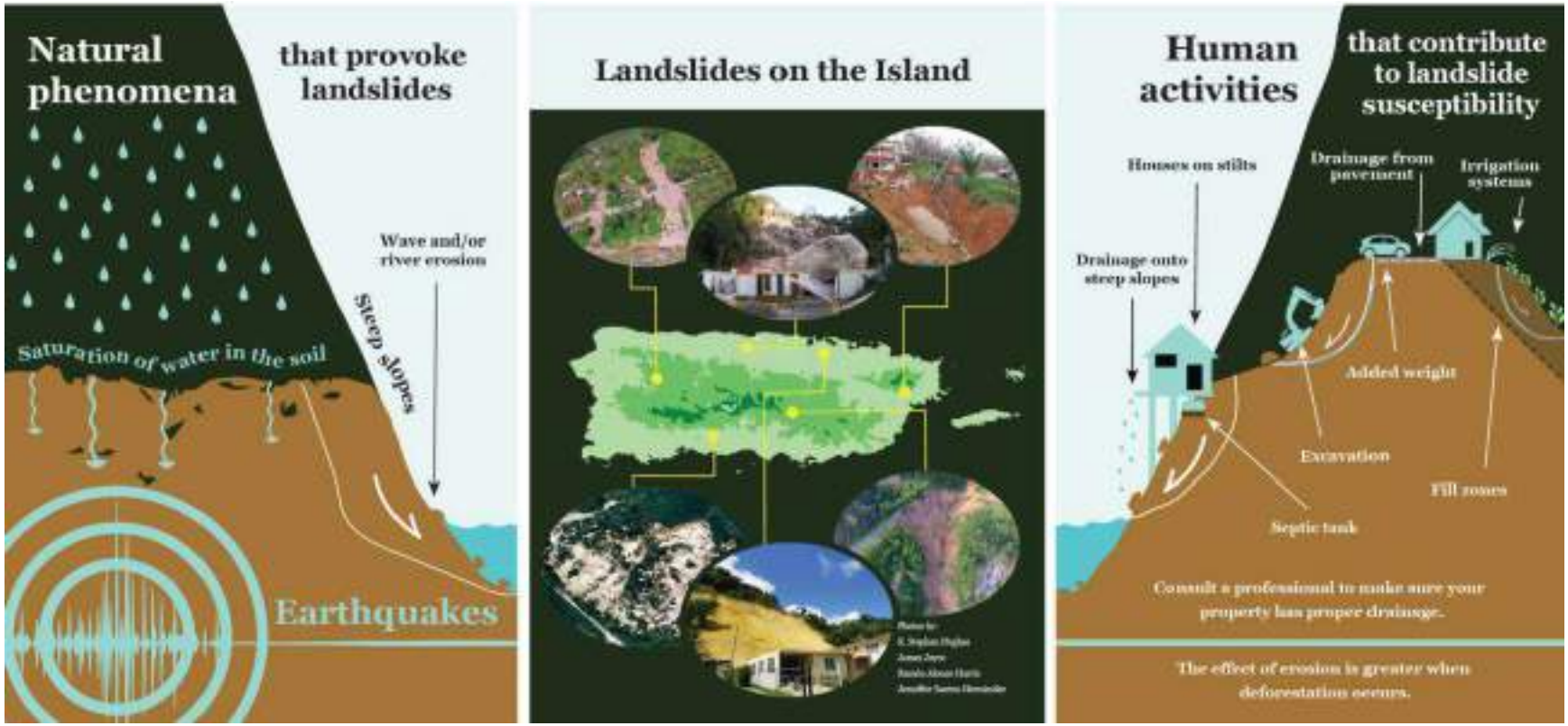

Figure 189: Factors Contributing to Landslide Susceptibility Under Future Conditions in Puerto Rico[661]

[661] USGS, "Puerto Rico Natural Hazards: Landslides," 2022, https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-natural-hazards-landslides-peligros-naturales-de.

Vulnerability Assessment

Puerto Rico's vulnerability to landslides has increased over the centuries, as agricultural and urban modifications to its landscape have made hillsides on the tropical island extremely unstable. Tropical atmospheric systems that trigger rain-induced landslides on the island's rugged mountainous areas make millions of residents vulnerable to such events.[662] In addition, Puerto Rico lies at the seismically active interface of the North American and Caribbean tectonic plates. Seismic shaking from frequent earthquakes can also trigger widespread slope failure.

EXPOSURE

The Puerto Rico Landslide Susceptibility Map highlights areas categorized as low, moderate, high, and highest susceptibility to landslides. When comparing this map to the following figures (Figure 190 on Replacement Value by Building Type Use (Millions) and Figure 191 on Landslide Exposure Analysis by Use Type (%)), it becomes clear that exposure is concentrated in zones of high and highest susceptibility, primarily in the mountainous interior. Residential structures represent the largest share of replacement value, indicating that homes in these areas are the most vulnerable. Critical facilities and commercial buildings also appear in high-susceptibility zones, but their overall replacement value is lower compared to residential assets.

This pattern is particularly significant when viewed alongside recent U.S. Census population trends. Between 2020 and 2024, municipalities with the highest landslide susceptibility experienced population declines, including Utuado (–4.0%), Adjuntas (–2.3%), and Maricao (–5.7%). Despite these declines, exposure remains elevated because the built environment, especially residential housing, road networks, and utilities, has not decreased at the same rate as the population. In some areas, it has even expanded due to post-disaster reconstruction and infrastructure investment.

Together, these findings emphasize that population decline alone does not equate to reduced landslide risk. Instead, landslides continue to pose a significant threat to housing stability and essential services, particularly in highly susceptible mountainous municipalities. These conditions highlight the need for targeted mitigation strategies that prioritize residential areas, critical infrastructure, and community lifelines in high-risk zones, while integrating landslide susceptibility mapping and demographic trends into land-use planning, redevelopment, and infrastructure design decisions.

[662] K. Stephen Hughes and William H. Schulz, "Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico," U.S. Department of the Interior and USGS Open File Report 2020–1022 (2020), 91 pp., 1 plate, scale 1:150,000, https://doi.org/10.3133/ofr20201022.

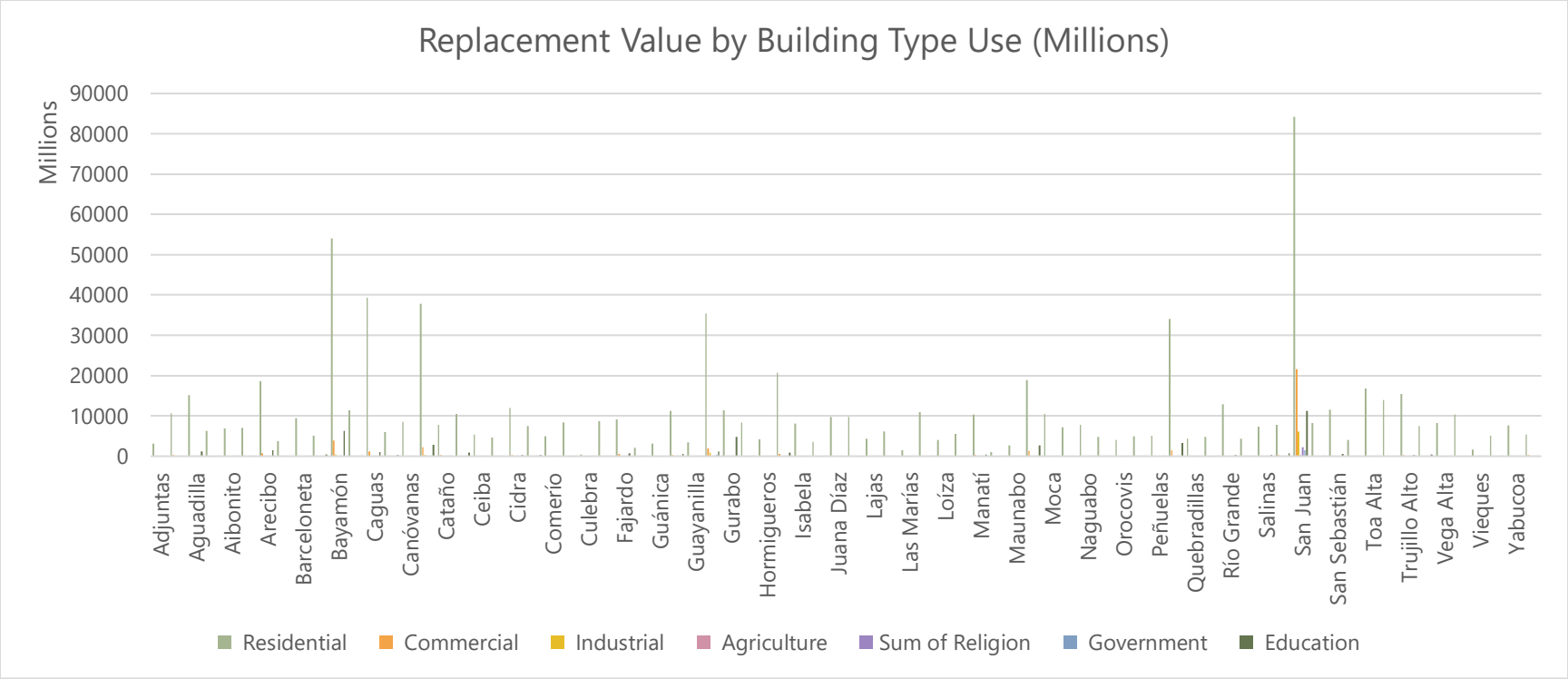

Figure 190: Replacement Value by Building Type Use (Millions)

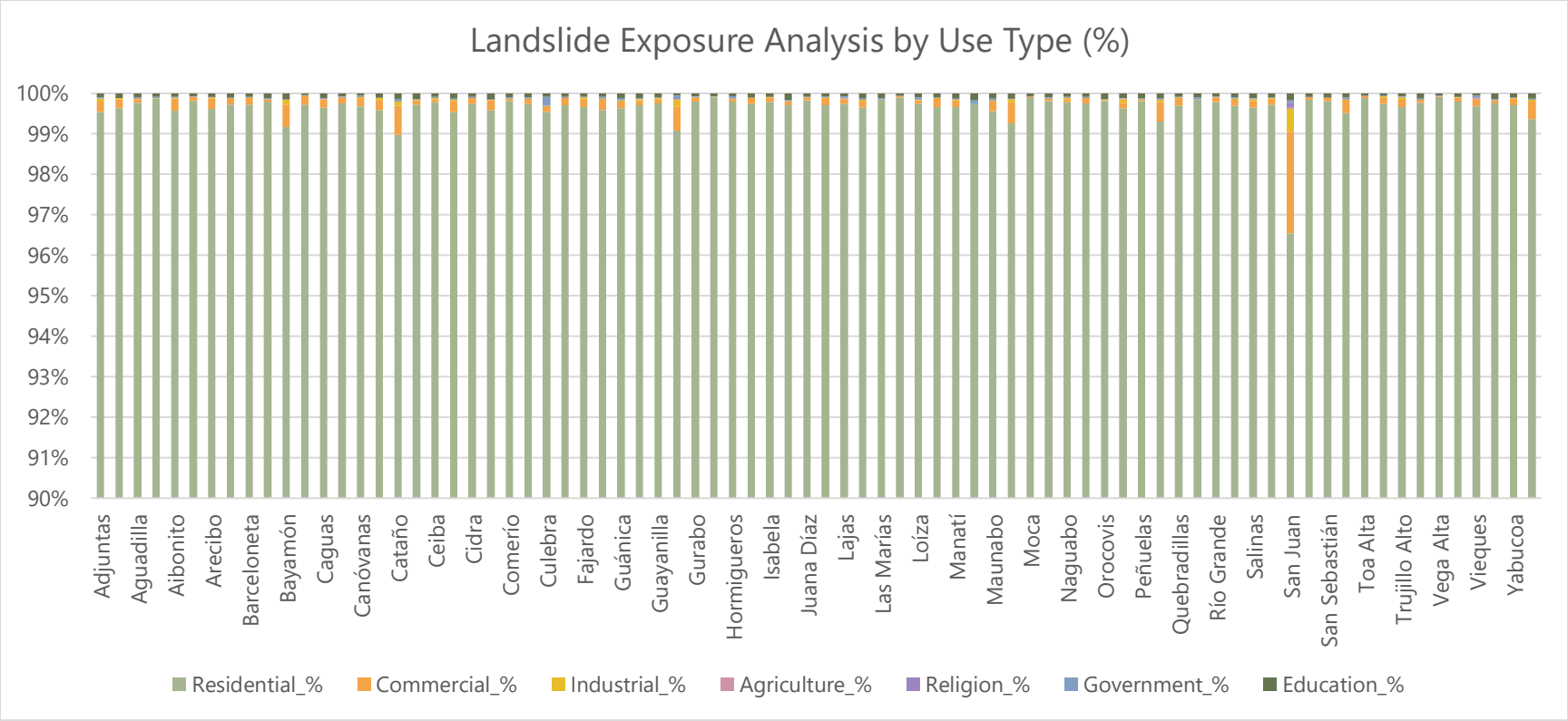

Figure 191: Landslide Exposure Analysis by Use Type (%)

LOCATIONS

The municipalities of Utuado, Adjuntas, Maricao, Jayuya, Las Marías (located in the island's mountainous central zone), and Ponce have the large majority (60% or more) of their landmass classified as extremely susceptible to landslides. According to the USGS study, more than 70,000 landslides were identified after Hurricane Maria, with the highest concentrations found in the mountainous areas of the island.[663]

Table 87 summarizes the areas that were most affected by landslides during Hurricane Maria. While Maria was an extreme event, the patterns it revealed are useful at the planning level to prioritize where mitigation actions such as retaining walls, slope stabilization, and nature-based solutions should be accelerated.[664] The study mapped landslide density across Puerto Rico using post-storm imagery. It found landslides in at least 59 of 78 municipalities, with five clusters of very high landslide density (HLD) across the north-central and northwestern Cordillera Central.

Table 87: Areas Most Affected by Landslides during Hurricane María

Municipality	What the Study Found	Why It Matters for Planning
Naranjito (municipality)	Approximately 45% of the municipality classified as High Landslide Density (HLD) following Maria	Indicates widespread slope instability and infrastructure exposure; prioritize corridor-scale slope stabilization, road cut support, and drainage improvements
Utuado (municipality)	Approximately 38% of the municipality classified as HLD	Focus on stabilization of hillslopes adjacent to communities and transportation routes
North-Central & Northwestern Cordillera Central (regional clusters)	Five HLD clusters north of the Cordillera Central divide	Target ridge-to-valley interventions (reforestation, bioengineering, drainage management) and hardening of critical lifelines crossing these belts

POPULATIONS

Falling material, such as rocks and boulders, can bounce or roll great distances and damage structures or kill people. Damage to secondary and tertiary roads from particularly high rockfalls can cause deaths in vehicles hit by rocks and can block highways. Fast-moving debris flows can catch whole communities off guard with little to no warning of the impending event.

[663] K. Stephen Hughes and William H. Schulz, "Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico," U.S. Department of the Interior and USGS Open File Report 2020–1022 (2020), 91 pp., 1 plate, scale 1:150,000, https://doi.org/10.3133/ofr20201022.

[664] Bessette-Kirton, E.K., Cerovski-Darriau, C., Schulz, W.H., Coe, J.A., Kean, J.W., Godt, J.W., Thomas, M.A., & Hughes, K.S. (2019). "Landslides Triggered by Hurricane Maria: Assessment of an Extreme Event in Puerto Rico." *GSA Today*, 29(6), 4–10. DOI: 10.1130/GSATG383A.1.

STRUCTURES INCLUDING CRITICAL FACILITIES

Debris flows can have a deadly effect due to their, high-speed movement, which can incorporate large boulders and other pieces of debris. Debris flows are known to move large objects such as houses in their downslope flow or fill structures with rapidly accumulating sediment and organic matter. They can affect water quality with large deposits of silt and debris.

Falls can damage property beneath the fall line of large rocks. Structures located on the moving mass of a slide or lateral spread can be severely damaged as the mass tilts and deforms. The large volume of material that is displaced is difficult to permanently stabilize, or it may dam nearby rivers, causing flooding.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Landslide types—such as rotational and translational slides, or lateral spreads—can damage structures and roads, causing major disruptions to community lifelines. Structures located on the moving mass of a slide can be severely damaged as the mass tilts and deforms. Infrastructure damage and structural failures are common outcomes of all landslide types.

Figure 192 illustrates the financial exposure of essential facilities located in areas of high and highest landslide susceptibility. Similar to the previous figures, the data emphasizes that critical infrastructure—such as transportation routes, energy systems, water facilities, and emergency services—represents a substantial replacement value concentrated in Puerto Rico's mountainous interior. These assets are vital for maintaining community lifelines, and their vulnerability to landslides means that damage could lead to cascading impacts on safety, health, and economic stability. The high replacement costs underscore the importance of prioritizing mitigation measures for these facilities to reduce disruption and protect public services during future landslide events.

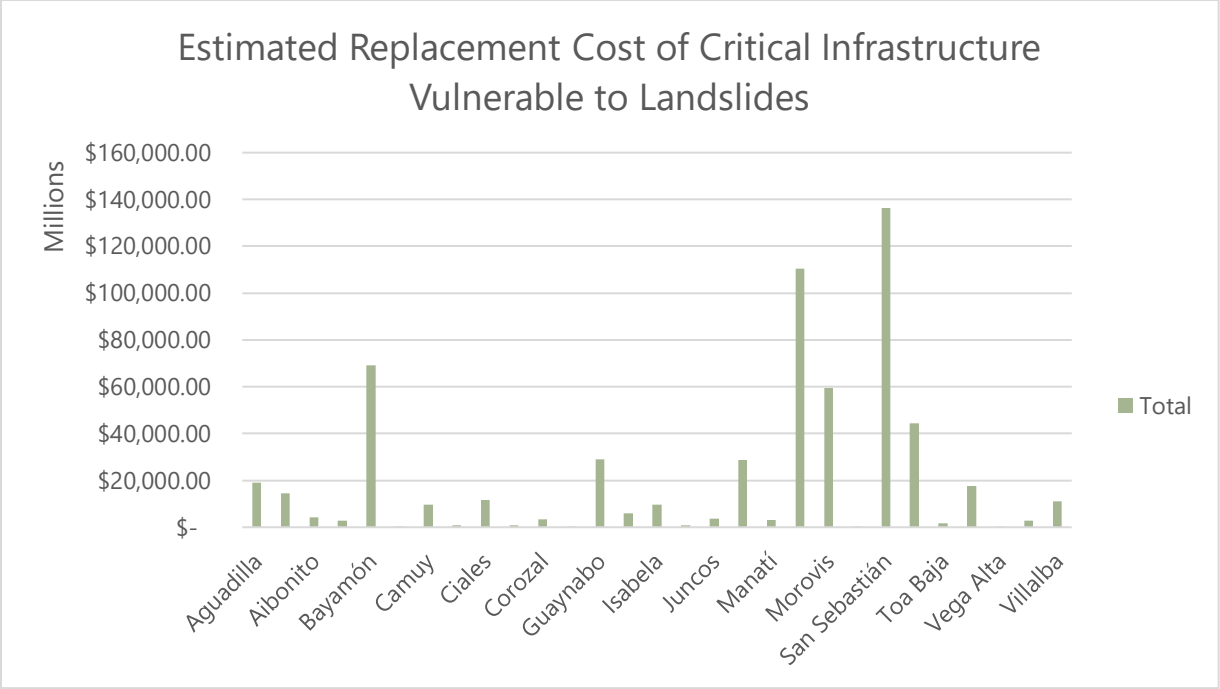

Figure 192: Replacement Cost of Critical Infrastructure Vulnerable to Landslides

PROBLEM STATEMENT

- The municipalities and state assets located in the mountainous areas of the island are most vulnerable to landslide events and are often impacted by rain-induced landslides as a secondary hazard associated with hurricanes and tropical storms.
- All landslide types increase vulnerability to all populations in landslide-susceptible areas of the island, as they often cause road closures, cutting off access to needed resources, damage structures and infrastructure, and put lives in danger.
- Puerto Rico's critical facilities located in landslide-susceptible areas are vulnerable during hurricane events, such as Hurricane Maria in 2017 and Hurricane Fiona in 2022, due to extreme precipitation rates from rainfall that weaken landmasses and lead to sediment accumulation in freshwater reservoirs, which reduces available water supplies. In addition, recent earthquake events of magnitude 5 or greater in 2019 and 2020 damaged several poorly built or aged structures on the southwestern part of the island, and caused ground shaking that loosened the landmass, increasing the vulnerability of roads and structures to landslides.
- Puerto Rico's secondary and tertiary roads in mountainous areas are highly susceptible to landslides, particularly where single-access roads exist. Also, exposed freshwater reservoirs, potable water systems, and wastewater systems may be vulnerable to damage, contamination, or service disruptions due to their location.
- Electrical grid lines that extend into the mountainous areas are among the infrastructure most at risk from landslides.

Impact Assessment

STATE ASSETS

Three hundred forty-nine critical facilities valued at over $600 million were identified within areas of high and highest landslide susceptibility. Figure 196 shows the distribution of these vulnerable state assets by municipality. Table 88 summarizes these exposure values by community lifeline categories. Safety and Security facilities are those for which the highest number are located within high landslide susceptibility. Damage to these facilities from a landslide could seriously impede the response to community safety and security needs immediately following a landslide. Ninety hazardous materials facilities are also vulnerable, and damage to these facilities from a landslide may expose nearby residents to additional danger and health impacts from a release of hazardous materials (see Figure 196).

Table 88: Replacement Value of Assets Vulnerable to Landslide by Community Lifelines

Community Lifeline	Facility Count	Replacement Value
Communications	55	$37,299,558.20
Energy	10	$10,915,229.40
Food, Shelter, Hydration	30	$41,595,056.20
Hazardous Materials	90	$97,116,793.20
Health and Medial	18	$86,778,446.50
Safety and Security	115	$283,696,746.20
Transportation	8	$26,905,161.20
Water Systems	23	$17,036,605.00
Total	**349**	**$601,343,595.90**

LOCAL ASSETS

For many municipalities, there are no standard models to estimate losses in structures and their contents that could result from landslides and other mass movements. As an alternative, the USGS landslide susceptibility categories (*low, moderate, high, very high*) were used based on the best available information. However, there is still insufficient data to calculate monetary losses from building damage. Still, historical data and local hazard mitigation plans indicate that many municipalities have local assets in moderate- to high-risk zones, including local fire stations, educational institutions, electrical substations,

Transportation routes are also routinely affected by landslides. Several major roads across Puerto Rico remain affected by landslides, rendering some towns inaccessible and posing serious risks to public safety. For example, PR-52 is the only highway that connects southern Puerto Rico to San Juan. The collapse of the mountain located in front of the Monumento al Jíbaro Puertorriqueño occurred after an episode of intense rainfall on November 5, 2022. At the time of the landslide, improvements were being made to that section of the road. Since then, the Puerto Rico Highways and Transportation Authority (ACT) and its contracted

company have undertaken mitigation work to ensure the continuity of vehicular traffic, which later led to the launch of the official rehabilitation project. To resolve the issue, three terraces must be built, each with its corresponding protective mesh. The first terrace, located at the top, was completed 2023 and the second was constructed throughout 2024. As of now, the work remains unfinished (see Figure 193).

Figure 193: Landslide Between Salinas and Cayey, November 5, 2022[665]

Another local example occurred in the Municipality of Comerío, a section of PR-167, specifically at kilometer 4.9 in the Doña Elena neighborhood, was temporarily closed on May 22, 2025, due to a landslide involving soil and large rocks. The incident occurred on the roadway heading from Comerío to Bayamón and resulted in a massive rock falling onto a pickup truck (see Figure 194). Fortunately, no injuries were reported.[666] However, displacement costs can be occurred and public safety is at risk when communities are not accessible due to landslides.

[665] Michelle Estrada Torres, "Landslide Between Salinas and Cayey: Repair Will Take 10-15 More Months," *La Perla Del Sur*, December 24, 2024, https://www.periodicolaperla.com/actualidad/derrumbe-entre-salinas-y-cayey-reparacion-tomara-de-10-a-15-meses-mas/.

[666] "Highway 167 Closed in the Direction of Comerío to Bayamón Due to Landslide," NotiCel, May 22, 2025, https://www.noticel.com/gobierno/ahora/20250522/cierran-carretera-167-en-direccion-de-comerio-a-bayamon-por-deslizamiento-de-terreno/.

Figure 194: Landslide Between Comerío and Bayamón, May 22, 2025[667]

PR-179, at kilometer 9.3 in Guayama, was temporarily closed on Thursday, June 19, 2025, after a landslide occurred from a nearby mountainside onto the roadway (see Figure 195). As a safety measure, both directions of the roadway were closed due to landslides repeatedly occurring every 5 to 15 minutes, including fairly large falling rocks. Transportation route closure can also result in economic losses. People traveling to and from local communities may not be able to go to work or may experience long delays or detours. Closures for significant periods of time could have larger impacts on local assets.

[667] "Highway 167 Closed in the Direction of Comerío to Bayamón Due to Landslide," NotiCel, May 22, 2025, https://www.noticel.com/gobierno/ahora/20250522/cierran-carretera-167-en-direccion-de-comerio-a-bayamon-por-deslizamiento-de-terreno/.

Figure 195: Landslide on Road Leading to the Carite Community in Guayama, June 19, 2025[668]

COMMUNITY LIFELINES

The 2017 and 2022 hurricane seasons demonstrated the vulnerability of critical infrastructure including community lifelines in Puerto Rico to natural hazards, including landslides. In addition, the 2019 and 2020 seismic activity presented challenges to municipalities that experienced structural damage to critical facilities and infrastructure from earthquakes measuring magnitude 5 and higher.

The map below shows the location of critical infrastructure, grouped by FEMA Community Lifeline, that fall within the high and highest landslide susceptibility areas (see Figure 196). A total of 349 facilities are within areas susceptible to landslide, primary across the north perimeter of the mountainous interior of the island.

[668] "PR-179 Highway in Guayama Closed Due to Landslides," *Primera Hora*, June 19, 2025, https://www.primerahora.com/noticias/puerto-rico/notas/cierran-carretera-pr-179-en-guayama-por-deslizamientos/.

Figure 196: Critical Infrastructure in Landslide Susceptible Areas

SAFETY AND SECURITY

The Safety and Security lifeline—which includes maintaining public safety, law enforcement, and security operations—provides support for communities during a landslide event by setting up roadblocks, diverting traffic away from the affected area, and providing safe evacuation routes or detour information. Disruption of the Safety and Security lifeline due to landslides can hinder emergency response efforts to address property and infrastructure failures, injuries, or fatalities.

FOOD, HYDRATION, AND SHELTER

The Food, Hydration, and Shelter lifeline provides access to basic needs for those affected by a landslide event. Access to food, water, and shelter can become a challenge if single-access roadways in the mountainous areas of Puerto Rico are impacted by landslides and supply chains are disrupted. Additionally, emergency sheltering may be required if landslides damage power lines, causing prolonged power outages and limiting critical access to electricity.

HEALTH AND MEDICAL

The Health and Medical lifeline, which provides medical care and public health services, could be impacted by landslides through damage to structures that limit access to critical medical care. Also, landslide events in mountainous areas of Puerto Rico could cut off single-access roads, limiting emergency response to medical emergencies and disrupting the distribution of medical supplies.

ENERGY

The Energy lifeline focuses on providing power and fuel to the affected community. Damaged power lines, substations, and pipelines are common during landslide events. In Puerto Rico, landslides can damage power lines, cause prolonged power outages, or contaminate freshwater reservoirs with debris flows of sand and silt, disrupting electricity and water services in the community.

COMMUNICATIONS

The Communications lifeline provides access to communication tools and services. Landslides may impact communication towers located on rotational or translational slides and spreads in the mountainous areas of Puerto Rico, or those positioned within the path of downhill debris flows, which may be knocked out by falling rock and toppled during landslide movement.

TRANSPORTATION

The Transportation lifeline ensures the availability of transportation services for communities during disaster events. Blocked transportation routes can cause supply chain disruptions for food, water, and medical supply deliveries, and disrupt emergency response activities during a landslide event. This is a particular concern in communities with a single access or evacuation route. Without transportation, communities can face increased vulnerability to other hazard types as well.

USGS analyses demonstrate that landslide susceptibility in Puerto Rico increases markedly within 100 meters of road corridors, reflecting the combined effects of excavation, slope undercutting, unmanaged runoff, and vegetation removal. These patterns are most pronounced in the Cordillera Central and other rugged interior regions, where development pressure intersects directly with highly landslide-prone terrain.

HAZARDOUS MATERIALS

The Hazardous Materials lifeline includes the management of hazardous materials. During a landslide event in areas of Puerto Rico with industrial facilities or near hazardous material storage, landslides can lead to spills or leaks into surface or groundwater, posing environmental and public health risks.

WATER SYSTEMS

The Water Systems lifeline includes freshwater reservoirs, potable water distribution infrastructure, and wastewater treatment plants. Landslides can send falling rock, or sand and silt from debris flows, into water systems and contaminate the water supply, or damage underground infrastructure from landmass movement, such as rotational slides and lateral spreads.

Changes in Development

Since the last plan update, several major natural hazard events, including Hurricane Irma, have underscored the vulnerability of Puerto Rico's population and critical infrastructure to landslides as a significant secondary hazard. Extreme precipitation associated with tropical cyclones and seismic ground shaking have repeatedly triggered widespread slope failures, particularly within the island's mountainous interior. These events have demonstrated that landslides pose a recurring threat not only to life safety but also to transportation networks, housing, utilities, and emergency access.

At the same time, long-term human modification of the landscape has compounded this natural susceptibility. Decades of agricultural terracing, hillside excavation, road construction, and the conversion of former agricultural and forest lands to residential and mixed uses have altered slope geometry, drainage patterns, vegetation cover, and soil strength across large portions of the island. The U.S. Geological Survey landslide susceptibility assessment for Puerto Rico highlights that anthropogenic topographic perturbations, especially road cuts, fills, and unmanaged drainage, are strongly associated with increased landslide occurrence. More than half of Puerto Rico's land area lies within approximately 75 meters of a roadway, and landslide susceptibility increases markedly within roughly 100 meters of roads, reflecting the destabilizing effects of construction and maintenance activities on steep terrain.[669]

Landcover analyses indicate that a growing share of Puerto Rico's development has expanded beyond coastal plains into the foothills and mountainous interior, including the Cordillera Central. Nearly half of urban and developed land occurs in hilly and mountainous regions, reflecting continued upslope expansion where flat land is limited. Subsequent landslide-susceptibility studies identify these interior areas,

[669] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

particularly municipalities such as Utuado, Jayuya, Orocovis, and Maricao, as highly prone to rainfall-triggered slope failures due to steep terrain, dissected landforms, and constrained settlement patterns.[670] [671]

Landslide susceptibility is highest in the Cordillera Central and adjacent mountainous regions, where steep slopes, deeply weathered soils, high annual rainfall, and dense transportation networks intersect. USGS frequency-ratio analyses indicate that susceptibility increases sharply on slopes exceeding approximately 25 degrees and is particularly elevated in disturbed land covers, including abandoned or active coffee-growing areas that are interlaced with informal roads and trails.[672]

While Puerto Rico's total population declined between 2020 and 2025, and many interior municipalities experienced net population losses, available evidence indicates that the spatial footprint of development in landslide-susceptible terrain has not contracted proportionally. Development in Puerto Rico is closely tied to road access and that low-density construction persists into hilly and mountainous areas once access is established. Subsequent disaster recovery efforts have largely focused on rebuilding and upgrading housing, transportation, and utility infrastructure in these same locations, reinforcing long-standing patterns of exposure to slope instability even as demographic pressure has eased.[673]

As a result, even where fewer residents may be physically present, buildings, transportation corridors, water and power lines, and other lifelines remain in place and are often irreplaceable or essential for regional connectivity. Landslides affecting these systems can isolate communities, delay emergency response, and generate cascading impacts well beyond the immediate failure area. In several mountainous municipalities, urbanized areas and infrastructure now extend farther upslope than in previous decades, increasing both the likelihood and potential consequences of slope failures during intense or prolonged rainfall events.

In summary, while demographic decline may modestly reduce life-safety exposure in some interior areas, continued construction, reconstruction, and infrastructure investment in unstable slopes mean that structural and functional exposure remains high. Effective mitigation will therefore require not only public awareness and emergency planning, but also stronger integration of landslide susceptibility data, land-cover analysis, and slope thresholds into land-use planning, reconstruction, and infrastructure design decisions, particularly in Puerto Rico's mountainous interior.

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[670] Bessette-Kirton, Erin, Corina Cerovski-Darriau, Kate E. Allstadt, William H. Schulz, Eric M. Thompson, Randall W. Jibson, and others. 2019. "Landslides Triggered by Hurricane Maria: Assessment of an Extreme Event in Puerto Rico." *GSA Today* 29 (6): 4–10. https://doi.org/10.1130/GSATG383A.1.

[671] Sebastián Martinuzzi, William A. Gould, Olga M. Ramos González, Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data, Landscape and Urban Planning, Volume 79, Issues 3–4, 2007, Pages 288-297, ISSN 0169-2046, https://doi.org/10.1016/j.landurbplan.2006.02.014 (https://www.sciencedirect.com/science/article/pii/S0169204606000478).

[672] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

[673] Sebastián Martinuzzi, William A. Gould, Olga M. Ramos González, Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data, Landscape and Urban Planning, Volume 79, Issues 3–4, 2007, Pages 288-297, ISSN 0169-2046, https://doi.org/10.1016/j.landurbplan.2006.02.014 (https://www.sciencedirect.com/science/article/pii/S0169204606000478).

LAND USE AND BUILT ENVIRONMENT CHANGES

Recent land use policies—such as those enacted by the Puerto Rico Joint Permit Regulations of 2019, 2020, and 2022—modified agricultural zoning laws to encourage more sustainable and eco-friendly development practices by adding other nonagricultural land uses to land zoned for agricultural use, such as residential (one- to two-family dwelling and second floor), commercial (cannabis, manufacturing, and agro-lodge), industrial (renewable energy projects), tourism (bed and breakfast, short-term supplementary accommodation, agrotourism, and ecotourism).[674] These new agricultural land use policies could increase vulnerability to landslide risk for populations, structures and infrastructure built to accommodate these new agro-resource economies.

In the study, Susceptibility Index (SI) values were calculated for 66 unique land cover classes to quantify how different land uses and vegetation types influence the likelihood of rainfall-triggered landslides. The results show strong variability among land cover types, highlighting the important role of land use and human disturbance in slope instability.[675]

The highest SI values are associated with montane wet evergreen abandoned or active coffee plantations and related montane shrubland and woodland classes, which cluster mainly in the rugged western interior and central mountainous regions of Puerto Rico. These areas experienced elevated susceptibility because historic and ongoing agricultural practices, particularly coffee cultivation, have altered natural hillslopes through terracing, vegetation modification, and the construction of dense networks of unpaved farm roads that concentrate runoff and weaken slope stability. In contrast, urban areas, wetlands, beaches, water bodies, and arid or low-relief land cover types generally show strongly negative SI values, reflecting low landslide occurrence due to flatter terrain, engineered surfaces, or saturated low-energy environments. Forested land covers display mixed behavior: some secondary and montane forests show moderate to high SI where they coincide with steep slopes and high rainfall, while mature or lowland forests tend to be neutral to negatively correlated. Overall, the analysis demonstrates that land cover acts as a proxy for both geomorphic setting and land-use history, with the highest susceptibility concentrated in steep, wet, and human-modified mountainous landscapes, as documented in the open USGS study.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Land use policies in Puerto Rico have evolved over time to address issues such as urban sprawl, natural resource protection, and disaster resilience. The trend toward a decline in traditional agricultural land use and an increase in urban sprawl in over 40% of the island continues to increase vulnerability to landslides in susceptible areas of Puerto Rico.

[674] Junta de Planificación de Puerto Rico, "Reglamento conjunto para la expedición de permisos relacionados al desarrollo," 2022, https://docs.pr.gov/files/DDEC/OGPe/Reglamentos/RC-2023-E.pdf.
[675] K. Stephen Hughes and William H. Schulz, *Map Depicting Susceptibility to Landslides Triggered by Intense Rainfall, Puerto Rico*, Open-File Report 2020–1022 (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/ofr20201022.

POPULATION CHANGES

Over the last five years, areas that experienced the most landslides following Hurricane Maria experienced population decline, including municipalities such as Utuado (-4%), Jayuya (-2.3%), Maricao (-5.7%), Las Marias (-2.3%)[676]. Other areas which have High susceptibility to landslides have also experienced population decline, but at a slower rate, including municipalities such as Lares (-1.3%), San Sebastián (-0.9%), and Morovis (-0.7%). Other municipalities such as Moca, which also has a High susceptibility to landslides, have experienced a small population increase of 0.2%. Increased populations in high-risk areas can indicate an increased risk to landslide events however, building practices can mitigate this risk.

Mitigation Success Stories

PUERTO RICO LANDSLIDE MONITORING NETWORK

Puerto Rico has collaborated with several sectors of the community to identify landslide risk and develop mitigation projects to reduce that risk. In 2022, the Puerto Rico Landslide Hazard Mitigation Office at the University of Puerto Rico Mayagüez initiated the Puerto Rico Landslide Monitoring Network.[677] The effort was established to monitor landslides in vulnerable communities, since Hurricane Maria and Hurricane Fiona resulted in an unprecedented number of landslides across Puerto Rico.

During Hurricane Fiona, the team at the Puerto Rico Landslide Hazard Mitigation Office informed a local community leader of the hazardous conditions in one neighborhood on the east side of the island, located in this high-risk area. The information was used to activate an evacuation just before a massive landslide buried a roadway and one home.[678]

The network currently consists of 18 monitoring stations strategically located in areas of high to very high landslide potential with each station serving as an analog for the conditions in its surrounding area (see Figure 197). Data are visually monitored by a graphical screen that provides near real-time updates on an island map. By monitoring these conditions, the Puerto Rico Landslide Hazard Mitigation Office is better able to detect the triggers of landslides, giving communities the warning they need to act before disaster strikes.[679]

[676] U.S. Census Bureau, "Puerto Rico Municipios Population Totals: 2020–2024," https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-puerto-rico-municipios.html.
[677] In collaboration with the USGS Landslide Hazards Program, the Puerto Rico Science Trust, the National Oceanic and Atmospheric Administration (NOAA) Caribbean Climate Adaptation Network (CCAN), and the University of Puerto Rico Department of Geology.
[678] USGS, "Puerto Rico Landslide Monitoring Network," 2025, https://www.usgs.gov/programs/landslide-hazards/science/puerto-rico-landslide-monitoring-network.
[679] USGS, "Puerto Rico Landslide Monitoring Network," 2025, https://www.usgs.gov/programs/landslide-hazards/science/puerto-rico-landslide-monitoring-network.

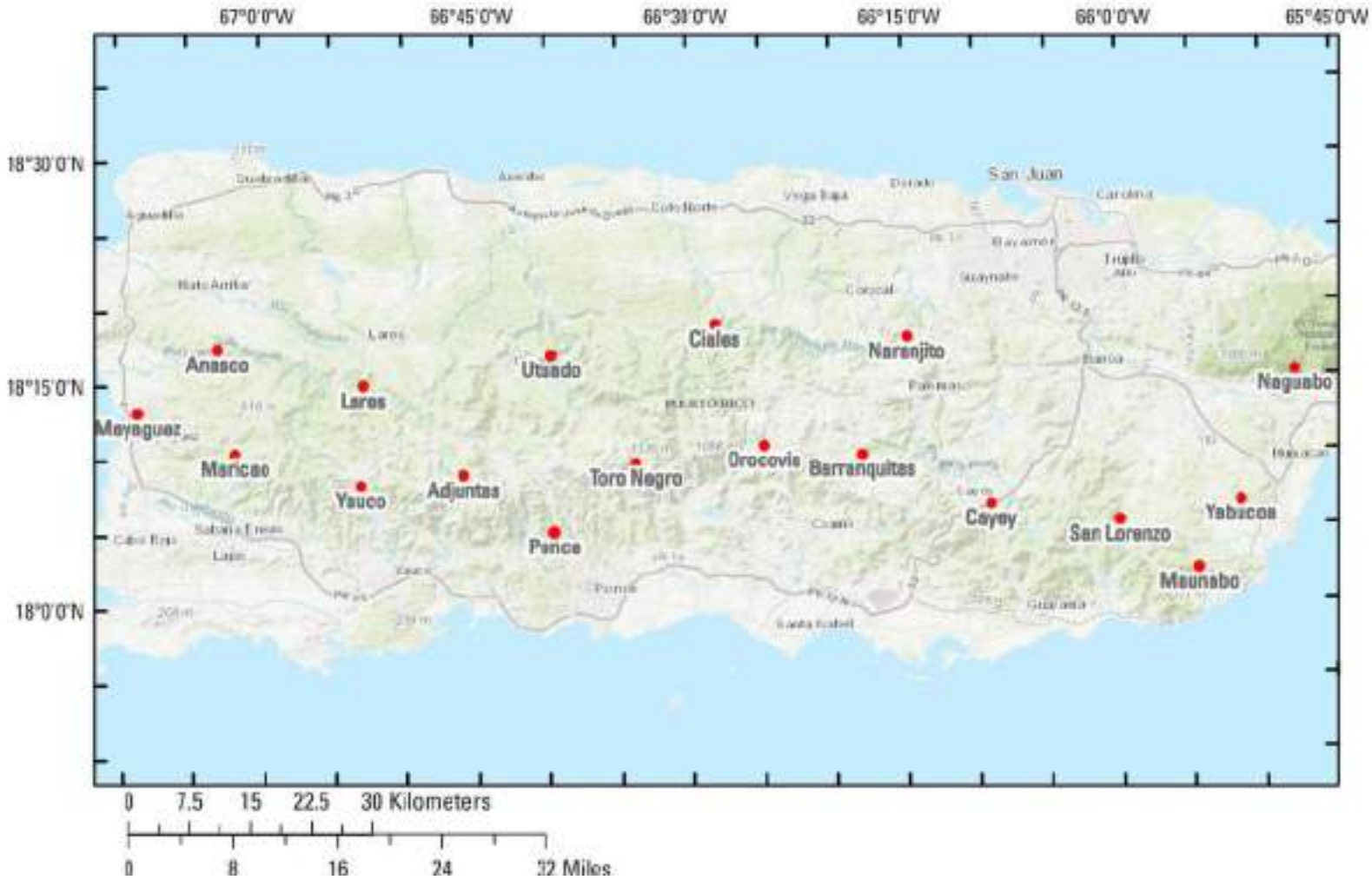

Figure 197: Puerto Rico Landslide Monitoring Network Monitoring Stations[680]

[680] USGS, "Puerto Rico Landslide Monitoring Network," January 30, 2023, https://www.usgs.gov/programs/landslide-hazards/science/puerto-rico-landslide-monitoring-network.

AIBONITO, PUERTO RICO

Barrio Cuyón in Aibonito has experienced recurring landslides along PR-162 at kilometer 2.7 since at least the 1970s. In September 2023, torrential rains triggered multiple landslide events at this location, prompting the closure of PR-162 for public safety. This disruption forced residents to take lengthy detours, significantly impacting daily travel. This stretch of state road had previously shown signs of instability after Hurricane Fiona and other tropical cyclones had placed stress on the infrastructure, increasing the potential for landslides in the area.[681]

[681] Sylvia Verónica Camacho, "Overwhelmed Residents of Aibonito Affected by Landslides on the Road," WAPA.TV, March 7, 2024, https://wapa.tv/noticias/locales/agobiados-vecinos-de-aibonito-afectados-por-derrumbes-en-carretera/article_a51b3ee6-dc07-11ee-8dfb-0f6d32e2c032.html.

SECTION 4.11
LIGHTNING

Lightning

LIGHTNING DEFINITION

Lightning is a high-energy atmospheric discharge resulting from the buildup of electrical charges between cloud layers, the air, or the Earth's surface. When the electrostatic potential between oppositely charged regions exceeds the dielectric strength of the surrounding air, the insulating barrier fails—triggering a rapid release of energy in the form of a lightning strike.[682]

While most lightning stays within a thunderstorm cloud, there are other types of lightning that may pose hazards to those on the ground as well:[683]

- **Intra-cloud lightning**, the most common form, occurs within a single cloud and typically manifests as bright flickers illuminating the cloud's interior.
- **Inter-cloud lightning** spans between separate clouds when the charge differential between neighboring storm cells becomes sufficient to overcome the insulating properties of the air.
- **Cloud-to-ground lightning** poses the greatest threat to life and infrastructure, delivering high-voltage current directly to the Earth's surface.

Each of these discharge types plays a role in neutralizing accumulated charges and contributes to the overall energy balance of the thunderstorm system. When lightning strikes, the electrical current can exceed 30,000 amperes, heating the surrounding air to temperatures nearing 50,000°F (27,760°C)—almost five times hotter than the surface of the Sun. This rapid heating occurs within microseconds, forming a plasma channel and

[682] National Severe Storms Laboratory, "Lightning Basics," National Oceanic and Atmospheric Administration, https://www.nssl.noaa.gov/education/svrwx101/lightning/.
[683] National Severe Storms Laboratory, "Types of Lightning," National Oceanic and Atmospheric Administration, https://www.nssl.noaa.gov/education/svrwx101/lightning/types/.

causing explosive expansion of air. The resulting energy can ignite wildfires, fuse sand into fulgurites, and inflict severe or fatal injuries on humans through direct or indirect strikes.[684]

Thunderstorms are defined by their convective nature and the presence of lightning and thunder. While cloud-to-ground strikes are the most visible, the majority of lightning activity occurs within or between clouds, often unseen from the ground. This makes lightning a hidden hazard, especially for aviation and outdoor activities. The National Weather Service emphasizes that "if you can hear thunder, you are close enough to be struck by lightning," underscoring the need for caution even in the absence of visible strikes.[685]

Thunder itself is the acoustic result of lightning's extreme thermal impact. As the superheated air expands explosively and then contracts, it generates pressure waves that we perceive as thunder. The rumbling quality arises from the irregular lightning channel and the way sound waves reflect off terrain, cloud structures, and atmospheric layers. Public safety campaigns often use thunder's travel speed—approximately 1 mile per 5 seconds—to estimate storm proximity. Guidelines such as the "30–30 Rule" (seek shelter if thunder occurs within 30 seconds of a lightning flash) are critical for reducing lightning-related injuries.[686]

Location

Puerto Rico's tropical location places it squarely in the trajectory of warm, moisture-laden air masses. These airflows interact with prevailing trade winds and Atlantic-origin weather systems, producing a highly volatile atmospheric environment conducive to frequent and intense convective activity. This dynamic setting significantly elevates the potential for severe weather phenomena, including thunderstorms, tropical cyclones, and flash flooding events across the island.[687]

The island's topography significantly contributes to lightning occurrence and exposure. Puerto Rico is characterized by a central mountain chain, the Cordillera Central, which runs east–west through much of the island. This mountain range, with peaks exceeding 4,000 feet, acts as a natural lifting mechanism for moist air. When warm, humid air is forced upward by the mountains, it cools and condenses, producing strong updrafts that intensify thunderstorm development. These convective storms are often accompanied by frequent lightning.[688]

Additionally, coastal sea breezes converge with mountain-driven winds, increasing the likelihood of afternoon and evening thunderstorms. The surrounding warm ocean waters provide a nearly continuous

[684] National Oceanic and Atmospheric Administration, Weather glossary: L, https://www.noaa.gov/jetstream/appendix/weather-glossary-l.
[685] National Oceanic and Atmospheric Administration, NWS Lightning Safety, https://www.weather.gov/safety/lightning-safety.
[686] National Oceanic and Atmospheric Administration, Lightning Safety Outreach, "NOAA Lightning Science and Safety."
[687] Vassiliki Kotroni and Kostas Lagouvardos, "Lightning occurrence in relation with elevation, terrain slope, and vegetation cover in the Mediterranean," *Journal of Geophysical Research Atmospheres*, November 2008, 113(D21), DOI: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2008JD010605.
[688] Puerto Rico Tour Base, "Understanding Puerto Rico's Weather," January 11, 2024, https://puertoricotourbase.com/travel-tips/understanding-puerto-ricos-weather.

source of heat and moisture, fueling the atmospheric instability required for lightning activity. As a result, Puerto Rico experiences one of the higher lightning densities in the Caribbean, making lightning a recurring natural hazard with risks to public safety, infrastructure, and lifelines such as power distribution and communications.[689] For additional information on Puerto Rico's location, refer to the State Profile section.

Previous Occurrences

In 2021, Puerto Rico documented a total of 171,005 lightning occurrences, encompassing both intra-cloud and cloud-to-ground events. This translates to a spatial lightning density of approximately 19.12 events per square kilometer, indicating a high-frequency lightning environment.[690] In a broader Caribbean/Central America analysis, Puerto Rico is noted among territories with nontrivial lightning densities—its frequency (1.45 events in a referenced metric) was contrasted against others in that region.[691]

Figure 198 shows that Puerto Rico experiences elevated total lightning density relative to the Northeast Caribbean, with the island's interior and mountainous municipalities typically showing the highest densities. This spatial pattern reflects orographic enhancement of convection and frequent convergence of sea-breeze and upslope flows over the Cordillera Central, which act to concentrate convective storms and lightning over high elevation areas.

[689] G. Sola et al., "Recurrent Lightning Spots: Where Lightning Strikes More Than Twice," *Journal of Geophysical Research: Atmospheres*, Volume 129, Issue 5, https://agupubs.onlinelibrary.wiley.com/journal/21698996.
[690] Vaisala, "2021 Global Lightning Statistics," https://www.vaisala.com/sites/default/files/documents/WEA-MET-2021-Global-Lightning-Statistics-B212467EN-A.pdf.
[691] Caribbean Meteorological Organization, "Lightning fatalities and injuries in Caribbean, Central and Americas" [Presentation], CMO Symposium, 2021.

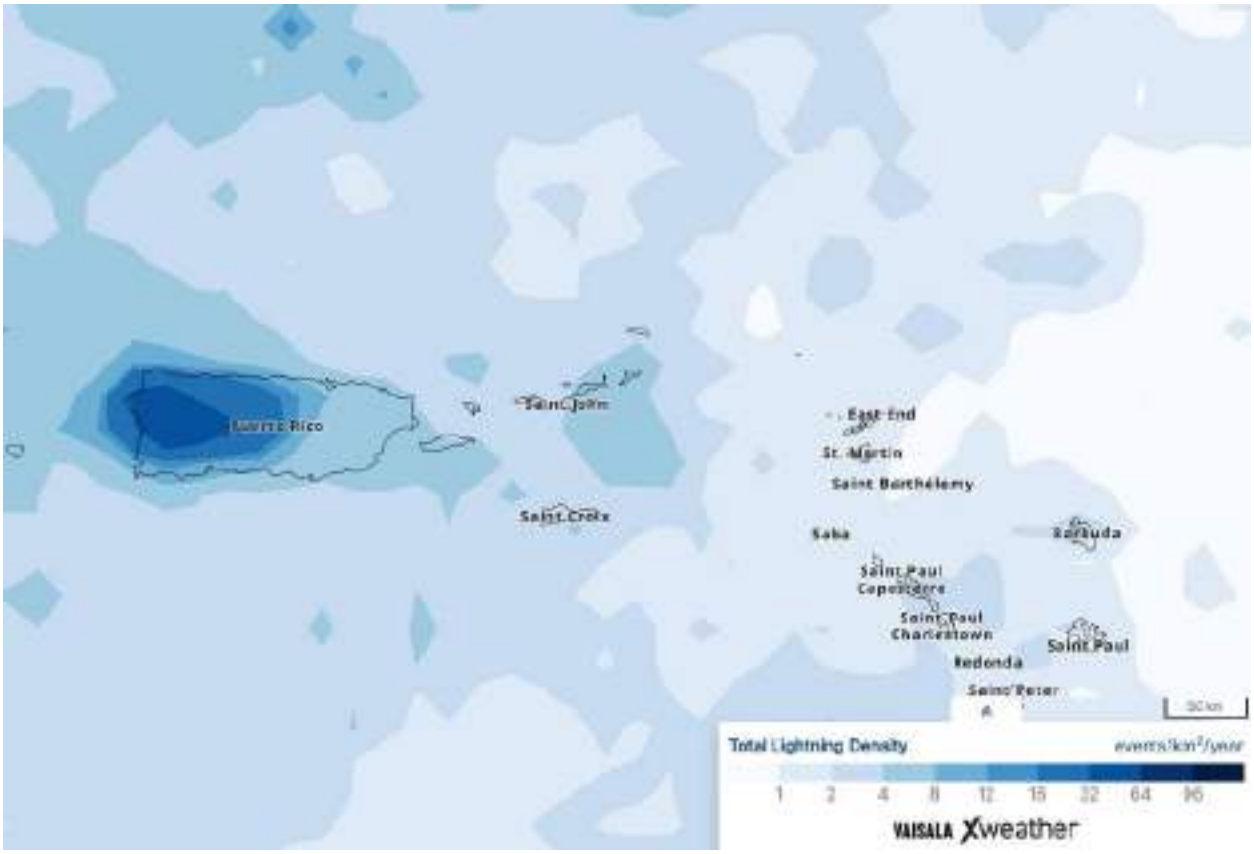

Figure 198: Average Annual Lightning Density (events/km²/year) for Puerto Rico (Vaisala Gridded Density Product) from 2016 to 2024

Locations of reported historic lightning strikes is displayed in Figure 199 as recorded by NOAA-NCEI during 2016 to 2024.

Figure 199: Historic Lightning Incidents in Puerto Rico from 2000-2025

FEDERAL DISASTER DECLARATIONS

There have been no federal declarations for lightning in Puerto Rico.

PUERTO RICO DISASTER DECLARATIONS

There have been no state of emergency declarations for lightning in Puerto Rico.

SIGNIFICANT EVENTS

Lightning poses significant risks to infrastructure, public safety, and continuity of operations. Understanding the mechanics of lightning and its significant event is essential for hazard mitigation planning, response coordination, and public warning systems.

Among its many datasets, National Centers for Environmental Information (NCEI) maintains comprehensive records of lightning activity, which are critical for understanding the frequency, distribution, and impacts of this natural hazard. These data are derived from advanced detection networks such as the National Lightning Detection Network (NLDN) and the Earth Networks Total Lightning Network (ENTLN), as well as from satellite-based instruments like the Geostationary Lightning Mapper (GLM) onboard the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) – R series satellites.

Table 89 summarizes the NCEI Storm Event Database for lightning strike incident records available for Puerto Rico between January 1, 2012, and August 31, 2025. Table 90 provides detailed information from both the NCEI and NWS Year in Review on the location, date, the cause of the lightning and the resulting damage of lightning strike incidents for Puerto Rico between January 1, 2012, and December 26, 2025.[692,693] Both of these tables are actively updated on the NCEI website as new findings and documentation are recorded and are up to date as of December 26, 2025. According to the National Weather Service 2025 Year in Review, there were 14 documented incidents throughout Puerto Rico in 2025, with one fatality in Lago Toa Vaca, Villalba.

Table 89: Summary Count of NCEI Severe Storm Database Lightning Strike Incident Records Available for Puerto Rico Between January 1, 2012, and December 26, 2025[692]

Summary Information	Count
Number of County/Zone areas affected	27
Number of Days with Event	32
Number of Days with Event and Death	4
Number of Days with Event and Death or Injury	8

[692] National Centers for Environmental Information, Storm events database: Lightning events in Puerto Rico, https://www.ncei.noaa.gov/stormevents/listevents.jsp?eventType=%28C%29+Lightning&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2012&endDate_mm=08&endDate_dd=31&endDate_yyyy=2025&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=99%2CPUERTO+RICO.

Summary Information	Count
Number of Days with Event and Property Damage	24
Number of Days with Event and Crop Damage	1
Number of Event Types Reported	1

Table 90: NCEI Storm Event Database and 2025 NWS Year in Review Lightning Strike Incident Events from January 1, 2012 to December 26, 2025[692,693]

Date	Location	Description	Damages
10/18/2025	Naranjito	Lightning damaged a pine tree near an auto parts store.	Branches and trunk of pine tree at auto parts store visibly impacted.
10/11/2025	Vega Baja	A pine tree was struck near a spotter's home.	Localized damage reported near spotter's home.
10/10/2025	Bayamon	A lightning strike damaged power lines and a power pole on Calle 59.	Power lines and pole damaged on Calle 59.
10/5/2025	Carolina	Lightning hit a tree, scattering debris over homes and onto PR-26, damaging vehicles and affecting individuals	Tree debris over homes and on PR-26, damaged multiple vehicles.
10/5/2025	Carolina	Man struck by lightning while exiting vehicle.	53-year-old man struck, reported in stable condition.
9/22/2025	Utuado	A deep tropical moisture surge contributed to the generation of showers and thunderstorms. As rain accumulated, soil became saturated, and flooding and landslides were registered. Also, wind and lightning damage was also observed within the thunderstorms.	A police officer was struck by lightning at the Policia de Puerto Rico: Comandancia Regional de Utuado. The officer was standing outside the building, sheltering under an umbrella, when he was struck by lightning.
9/12/2025	Orocovis	Persistent shower activity was observed as a tropical wave moves across the local area. This moisture, along with a weak steering flow, resulted in the development of strong	A member of the public posted an image on social media of a fallen power pole struck by lightning during thunderstorm activity in Bo. Saltos, Sector La Charca in Orocovis.

[693] National Oceanic and Atmospheric Administration, "2025: Year in Review," https://www.weather.gov/media/sju/climo/monthly_reports/2025/Annual.pdf.

Date	Location	Description	Damages
		thunderstorms across the interior of Puerto Rico.	
8/30/2025	Villaba	A tropical wave moving south of the islands, moisture, local effects, excessive diurnal heating, and sea breeze variations, promoted the formation of showers and thunderstorms over the islands during the last two days of the month. Flooding was reported in Yauco and Carolina, while a fatal lightning strike was reported in Toa Vaca Lake, Villalba.	The 911 Call Center reported that at approximately 3:20 PM AST, a lightning strike impacted two individuals in a boat near the fishing club by the dam at Lago Toa Vaca. One individual was reported conscious with burns to the hands but breathing. The second individual, a 48 year old male, was thrown into the water by the impact; his body was found at around 8 PM ast.
8/23/2025	Isabela	Lightning struck during a baseball game.	No injuries reported.
8/16/2025	Aguada	Major Hurricane Erin moved northeast and north of Puerto Rico and the U.S. Virgin Islands. Erin's Outer Bands and then Feeder Bands still affected the islands, producing strong thunderstorms, gusty winds, and heavy rains across the islands. Several reports of wind gust damage, along with reports of high surf, flooding and debris flow were received between August 16 to 18.	Broadcast media through social media reported a lightning strike that impacted a residence in the Bo. Lagunas sector of Aguada. Residents reported a loud explosion-like sound and a bright flash that woke people from sleep. Minor structural damage to a wall was observed. No injuries were reported. Lightning strike occurred within outer bands associated with Hurricane Erin.
8/2/2025	Aibonito	A tropical wave, southeasterly flow and abundant tropical moisture over the islands promoted t-storm formation. A lightning strike impacted electrical lines in Aibonito, causing a utility pole to fall and result in a power outage.	A NWS employee and emergency managers, reported a lightning strike that impacted electrical lines near KM 3.0 of PR-725 in the Los Pinos sector of Barrio Llanos. The incident caused a utility pole to fall and scattered debris in the area, resulting in a power outage.
7/27/2025	San Juan	A tropical wave moving over the region on July 27th triggered frequent bands of passing showers over the Anegada Passage, Caribbean, and Atlantic waters during the early morning hours. As the day progressed,	Social media post reported a damaged building roof edge at the Condado Real Condominium in Kings Court Street & McLeary Avenue.

Date	Location	Description	Damages
		scattered showers and thunderstorms developed over the eastern half of Puerto Rico. Some of these thunderstorms impacted northeastern Puerto Rico and produced wind gusts of up to 40 mph and frequent cloud to ground lightning. 3 people were injured by a lightning strike in Fajardo while the side of a roof was damaged by a lightning strike in San Juan.	
7/27/2025	Fajardo	A tropical wave moving over the region on July 27th triggered frequent bands of passing showers over the Anegada Passage, Caribbean, and Atlantic waters during the early morning hours. As the day progressed, scattered showers and thunderstorms developed over the eastern half of Puerto Rico. Some of these thunderstorms impacted northeastern Puerto Rico and produced wind gusts of up to 40 mph and frequent cloud to ground lightning. 3 people were injured by a lightning strike in Fajardo while the side of a roof was damaged by a lightning strike in San Juan.	The 911 Call Center and Emergency Managers reported that 2 female minors and 1 female adult were injured by a lightning strike at the Balneario Seven Seas, Fajardo, near PR-987 (Cabezas St.). The female minors were reported as stable, conscious and breathing at the time of the report. One of the minors age was not reported but the other one was reported as being 16 years old. The female adult was 21 years old.
5/20/2025	Arecibo	A strong upper-level trough brought an unsettled weather pattern, heightening the risk of excessive rainfall across the islands from May 17th to the 20th.	An emergency manager reported a lightning strike incident involving a 17-year-old female in Bo, Santa Rosa sector La 15. The individual was stable and conscious at the regional hospital in Arecibo.
5/4/2025	Caguas	Unstable and wet weather conditions were anticipated in early May due to a combination of abundant tropical moisture and a series of upper-level troughs moving over the region.	Broadcast media reported via social media that lightning struck a house in Sector Borinquen. Pieces of the roof came off, and the electricity in the residence was interrupted.

Date	Location	Description	Damages
9/21/2024	Morovis	The proximity of an upper level trough, along with an area of enhanced moisture, very light winds and strong heating resulted in explosive convection developing over Puerto Rico. The thunderstorms produced very heavy rainfall, lightning, gusty winds, and even hail. Flooding and landslides were reported in several areas in Puerto Rico. Water surges along rivers were common, with some rivers even reaching flood stage.	A lightning strike hit a house in Calle Reina of Sector La Linea in Morovis, damaging part of the roof.
9/20/2024	Lajas	The proximity of an upper level trough, along with an area of enhanced moisture, very light winds and strong heating resulted in explosive convection developing over Puerto Rico. The thunderstorms produced very heavy rainfall, lightning, gusty winds, and even hail. Flooding and landslides were reported in several areas in Puerto Rico. Water surges along rivers were common, with some rivers even reaching flood stage.	A lightning strike hit the roof of a residence along PR-117, between km 9.8 and 10.4, in Barrio La Plata, Lajas.
9/13/2024	Cabo Rojo	Another tropical wave moved into the region by the middle of September. With previously saturated soils and additional showers and thunderstorms, mudslides, gusty winds, and flooding was reported in Puerto Rico. This event brought rainfall accumulations of 1 to 2 inches per day, especially in the interior and west, and portions of eastern Puerto Rico, including the San Juan metro area.	A post in social media showed a lightning striking a palm tree at Balneario de Boqueron in Cabo Rojo.
9/9/2024	Cabo Rojo	An upper level trough lingered in the region, promoting unsettled weather conditions. Additionally, a tropical wave approached,	A lightning stroke a wall at Galeria 100 Shopping Center in Cabo

Date	Location	Description	Damages
		bringing plenty of moisture in the region. Widespread showers and thunderstorms were observed across Puerto Rico, with rainfall accumulations of 1 to 3 inches each day, and maximum amounts up to 5 inches. This led to several reports of mudslides, lightning, and flooding	Rojo. The pictures indicated a small hole was left on the wall.
9/7/2024	Cabo Rojo	Unsettled weather conditions prevailed across Puerto Rico through the first week of September as a retrograding upper level trough lingered in the region. The instability of the trough, diurnal heating, and low level moisture combined to generate widespread showers and thunderstorms across the region. Each day, accumulations ranged from 2 to 3 inches, with maximum amounts up to 5 inches in some areas. This led to several reports of mudslides, lightning, and gusty winds.	Lightning struck the outside wall of a house in Urbanización Mirador del Sol in Cabo Rojo. Damage was visible from outside the house, with paint and some cement surrounding the areas (entry and exit points were visible and showed damage) stripped away. Small debris was visible in the garden and driveway.
9/7/2024	San Juan	Unsettled weather conditions prevailed across Puerto Rico through the first week of September as a retrograding upper level trough lingered in the region. The instability of the trough, diurnal heating, and low level moisture combined to generate widespread showers and thunderstorms across the region. Each day, accumulations ranged from 2 to 3 inches, with maximum amounts up to 5 inches in some areas. This led to several reports of mudslides, lightning, and gusty winds.	Lightning struck the roof of a house in Residencial Fray Bartolome de las Casas in Santurce. Damage to the roof was visible from inside the house, with paint surrounding the area stripped away and small debris visible on the living room. The house was left without electrical power. Paramedics visited the scene, but everyone was ok.
6/20/2024	Arecibo	Series of troughs enhanced afternoon convection during the week. Flooding, thunderstorm wind and hail reports were	Lightning struck the roof of a residence in Barrio Santana, Arecibo. The news report says that a 60-year-old woman was

Date	Location	Description	Damages
		received at some point during the week. Activity caused a landslide in Bayamon. Lightning struck the roof of a residence, causing injuries and damaged appliances, furniture, and the roof of the house.	injured by debris from the roof and that her phone exploded.
5/27/2024	Isabela	Afternoon convection on May 27 over northwestern Puerto Rico produced cloud-to-ground lightning over Isabela, injuring three individuals.	A social media post indicated that a lightning strike affected 3 minors in Montones Beach in Isabela.
10/17/2023	Morovis	On October 17, a mid-level high pressure was weakening as an upper-level low was approaching the area, and a surface trough was also helping to promote afternoon showers and thunderstorms. Lightning from one of these thunderstorms caused a fire in Morovis that mainly affected vegetation.	Social media post from reporter showed a fire affecting mainly vegetation that started with a lightning strike.
10/4/2023	Culebra	Outer bands from Tropical Storm Philippe, which passed northeast of the islands, resulted in heavy rain, river rises, lightning strikes and flooding across various sectors of the islands. Up to 5 to 10 inches of rain fell over mainly eastern Puerto Rico from Oct 1 through October 5.	Emergency managers indicated that the power station at Culebra was struck by lightning, causing a fire and a resulting power outage across the island.
9/10/2022	San Juan	As Hurricane Earl lifted well north of the islands, moisture was pulled from the Caribbean into the islands, bringing a continued active weather period.	A social media post showed that lightning struck a light post, which caught fire. This was around road PR-199, close to Paseos Veterinary Center.
9/4/2022	Salinas	A lightning strike killed two people on a jet ski near Cayo Matias, just off the coastal waters of Salinas. Hurricane Earl was moving about 100 miles north-northeast of the islands at the time.	Lightning struck a jet ski in Cayo Matias, just south of Salinas. There were two fatalities and a third person was taken to a hospital. A marine weather statement due to thunderstorms was in effect for nearby waters.

Date	Location	Description	Damages
7/10/2022	Toa Baja	An induced surface trough and a tropical wave approached the islands. At the same time, an upper level trough dug from the northeast, providing instability aloft. The combination resulted in periods of heavy rain and gusty winds, with multiple flooding reports received.	A lightning strike hit a tree, causing it to fall over powerlines and resulting in several areas without power service. The tree also hit two cars. Highway PR-863 was closed in Pajaros, Toa Baja, around Farmacia Plaza and at the intersection of Road PR-819.
7/2/2022	Las Piedras	An active tropical wave moved across the area. This wave brought periods of heavy rainfall, along with strong gusty winds, resulting in multiple flood reports.	Social media and press members reported lightning striking a house in Las Piedras.
6/15/2022	Hatillo	The combination of an upper level trough and above normal moisture resulted in a very active afternoon along the municipalities of the interior, north and west of Puerto Rico. The wind gusts associated with the thunderstorm activity caused some trees to fall down on the roads.	Lightning struck a residence, causing damage to the roof.
9/8/2021	Coamo	Light steering flow and sufficient low-level moisture combined with strong daytime heating and local effects to generate heavy showers and thunderstorms across most of interior Puerto Rico.	Lightning struck City Hall, damaging a part of the building facade.
9/28/2020	San Sebastian	A tropical wave combined with an upper-level trough, resulting in enhanced thunderstorm activity across interior and western Puerto Rico.	Lightning struck a wooden house in sector Guacio, completely destroying it.
9/29/2019	Carolina	Showers and thunderstorms developed across Puerto Rico and the U.S. Virgin Islands, due to a tropical wave moving across the area.	Lightning struck a house at Calle Portugal in Vistamar sector, causing a fire at the house.
9/12/2019	Villalba	Local and diurnal effects in combination with sufficient moisture led to the development of showers and thunderstorms	A lightning struck a man, who was injured and taken to a nearby hospital, where his condition was stable.

Date	Location	Description	Damages
		across portions of interior, southern, and western Puerto Rico.	
9/5/2017	Juana Diaz	A flash flood watch was in effect due to the proximity of Hurricane Irma. Showers, thunderstorms, very strong winds were expected.	A 63-year-old fisherman died by a lightning strike. The man anchored his boat on the beach in Barrio Capitanejo at Juana Diaz, when a lightning struck on the water.
10/22/2016	Orocovis	Strong thunderstorms developed across the western interior section of Puerto Rico. These thunderstorms were accompanied by strong gusty winds and excessive cloud to ground lightning.	Lightning struck the power source line to a home located in Barrio Mata Cana sector el Hobo, road PR-568 km 7.8 Some minor structural damage occurred. Electrical power was affected.
6/20/2016	Lajas	A tropical wave moved across the area.	Lajas Emergency Management Agency reported a house hit by a lightning strike at Barrio Cuesta Blanca carr. 116, km 15.3. No fatalities were reported, as the house was empty.
5/8/2016	Aguadilla	Upper level trough combined with daytime heating and local effects to produce scattered showers with isolated thunderstorms over the north central, western interior, and west sections of Puerto Rico.	Excessive lightning strikes were observed across Aguadilla municipality.
5/8/2016	Barceloneta	Upper level trough combined with daytime heating and local effects to produce scattered showers with isolated thunderstorms over the north central, western interior, and west sections of Puerto Rico.	Excessive lightning reported in Barceloneta and surrounding municipalities.
5/8/2016	Mayagüez	Upper level trough combined with daytime heating and local effects to produce scattered showers with isolated thunderstorms over the north central, western interior, and west sections of Puerto Rico.	Excessive lightning reported over Mayaguez and vicinity.
7/18/2013	Hatillo	A very strong tropical wave moved over Puerto Rico on July 18, 2013. It brought deep topical	Lightning struck a balcony and knocked down a power line in Barrio Pajuil.

Date	Location	Description	Damages
		moisture from the Intertropical Convergence Zone through the area. These features, in combination with a southeast wind flow and local effects produced torrential rainfall, mainly along the north coast of Puerto Rico. Streamers from El Yunque National Forest developed in the afternoon on July 18, 2013, and were moving very slowly toward the northwest, which affected the San Juan Metropolitan area. The streamers redeveloped over the same area and brought with them torrential rainfall that led to serious flooding across the San Juan Metro Area, with total rainfall accumulation exceeding 9 inches over San Juan. Rainfall totals between 3 and 5 inches were also reported across the North Central section of Puerto Rico. Several reports of flooding were received from the municipalities of San Juan, Carolina, Bayamón, and Guaynabo with hundreds of residences and roads affected by the waters. Overall losses were estimated over $1 million across the San Juan Metropolitan area.	
7/18/2013	Ponce	A very strong tropical wave moved over Puerto Rico on July 18, 2013. It brought deep topical moisture from the Intertropical Convergence Zone through the area. These features, in combination with a southeast wind flow and local effects produced torrential rainfall, mainly along the north coast of Puerto Rico. Streamers from El Yunque National Forest developed in the afternoon on July 18, 2013, and were moving	Lightning broke a post in Barrio Clausell, Road 19 in the municipality of Ponce.

Date	Location	Description	Damages
		very slowly toward the northwest, which affected the San Juan Metropolitan area. The streamers redeveloped over the same area and brought with them torrential rainfall that led to serious flooding across the San Juan Metro Area, with total rainfall accumulation exceeding 9 inches over San Juan. Rainfall totals between 3 and 5 inches were also reported across the North Central section of Puerto Rico. Several reports of flooding were received from the municipalities of San Juan, Carolina, Bayamón, and Guaynabo with hundreds of residences and roads affected by the waters. Overall losses were estimated over $1 million across the San Juan Metropolitan area.	
7/18/2012	Rincon	The combination of a tropical wave and a mid-level perturbation and their associated moisture, decent upper level ventilation, and an upper level trough produced scattered showers with isolated strong thunderstorms over the northwest section of Puerto Rico.	A 14-year-old boy was stuck by lightning at Sandy Beach. He was transported to the hospital in stable condition.

There have been 28 lightning event days in Puerto Rico from 2020 to 2025. These events have led to a total of 11 injuries and 3 deaths in that time period. Most events occurred in the late afternoon, predominantly in the peak hurricane season month of September. There has been an estimated $86,200 in property damage and $1,300 in crop damage related to lightning.[694] The following events highlight the unprecedented nature of lightning occurrences, including fatalities.

[694] National Centers for Environmental Information, Storm Events Database, "Lightning Events-Puerto Rico (2020-2025)," 2026, https://www.ncei.noaa.gov/stormevents/listevents.jsp?eventType=%28C%29+Lightning&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=2020&endDate_mm=12&endDate_dd=31&endDate_yyyy=2025&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=99%2CPUERTO+RICO.

- **September 5, 2022 – Jet Ski Lightning Fatality, Salinas:** Two individuals were killed and another injured when lightning struck while they were jet skiing off the southern coast of Puerto Rico near Salinas. This tragic event highlights the risk of recreational activities in exposed coastal waters during thunderstorms.[695]
- **May 2024 – Lightning Strike Injures Children, Isabela:** Three children were struck by lightning while on a beach in Isabela; one suffered critical injuries. This underscores the dangers lightning poses to groups gathered in open spaces near the shoreline.[696]
- **August 30, 2025:** Two individuals struck by lightning in Lago Toa Vaca, Villalba. One sustained burns, the second was a confirmed fatality.
- **2006–2024 – Documented Fatalities and Injuries:** According to the U.S. Lightning Safety Council, Puerto Rico has recorded 5 lightning-related fatalities between 2006 and 2024, reflecting the persistent risk across the island.

Potential Severity of Event

Puerto Rico's climate is tropical, experiencing rainfall during the months of May through November and cold fronts in December to April that can bring rainstorms. These weather patterns can develop the conditions for convection, meaning heat and moisture are lifted into the atmosphere and cumulonimbus clouds are formed, leading to thunderstorms. This formation can also happen during tropical storms.[697] Furthermore, the NCEI Storm Events Database since 2012 showcases the majority of the lightning incidents (83.7%) occurred within the June 1 to November 30 Atlantic Hurricane Season. Of these events, 48.4% occurred in the month of September, which is the peak of hurricane season.[698]

Lightning frequency is likely to increase in the future given the environmental conditions that raise global temperatures, leading to a more unstable atmosphere where lightning occurs.[699] Lightning is measured via the Lightning Activity level (LAL) scale. As demonstrated in Table 91, this a numerical scale used to describe the frequency and type of lightning activity in a specific area over a given period. It ranges from 0 to 6, with each level representing an increasing threat of lightning.[700]

[695] Sistek, Scott, "2 killed by lightning strike while jet skiing in Puerto Rico," Fox Weather, September 6, 2022, https://www.foxweather.com/extreme-weather/2-killed-by-lightning-strike-while-jet-skiing-in-puerto-rico.
[696] Associated Press, "3 children hospitalized in Puerto Rico after lightning strikes beach," May 27, 2024, https://apnews.com/article/eef5c440c271c656a2e2f9ca2c9bfe52.
[697] Royal Meteorological Society, "What are Convective Storms," https://www.rmets.org/metmatters/what-are-convective-storms.
[698] NOAA NCEI, "Storm Events Database," 2025, https://www.ncei.noaa.gov/stormevents/listevents.jsp?eventType=%28C%29+Lightning&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=9999&endDate_mm=12&endDate_dd=31&endDate_yyyy=9999&county=ALL&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=99%2CPUERTO+RICO.
[699] Anhuci, Bea, "Lightning in a warming world," WUFT, December 23, 2025, https://www.wuft.org/environment/2025-12-23/lightning-in-a-warming-world.
[700] Lightning Activity Level scale, National Weather Service, https://www.weather.gov/media/rnk/fire/LAL.pdf.

Table 91: Lightning Activity Level scale

Level	Activity
LAL 1	No thunderstorms.
LAL 2	isolated thunderstorms. Light rain will occasionally reach the ground. Lightning is very infrequent, 1 to 5 cloud-to-ground strikes in a 5-minute period.
LAL 3	Widely scattered thunderstorms. Light to moderate rain will reach the ground. Lightning is infrequent, 6 to 10 cloud-to-ground strikes in a 5-minute period.
LAL 4	Scattered thunderstorms. Moderate rain is commonly produced. Lightning is frequent, 11 to 15 cloud-to-ground strikes in a 5-minute period
LAL 5	Numerous thunderstorms. Rainfall is moderate to heavy. Lightning is frequent and intense, greater than 15 cloud-to-ground strikes in a 5-minute period.
LAL 6	Dry lightning (same as LAL 3 but without the rain). This type of lightning has the potential for extreme fire activity and is normally highlighted in fire weather forecasts with Red Flag Warning

Due to the island's climate conditions and with the influence of heat, humidity, and ocean temperatures, Puerto Rico can experience lightning strikes falling in many of the categories described in the LAL; however, based on recent lightning data, it was determined that Puerto Rico does not rank amongst the most lightning-prone areas in the world.[701]

Probability of Future Hazard Events

Puerto Rico has a **high** likelihood of continuing to experience lightning events, based on available lightning climatology datasets (e.g., NASA LIS/OTD). The expected number of lightning flashes over a facility footprint can be estimated by multiplying the regional flash density (flashes/km^2/year) by the facility's area.[702] Puerto Rico exhibits moderately high lightning flash densities relative to global averages, confirming persistent exposure to electrified convection. The Vaisala's interactive maps indicate that while surrounding Caribbean open ocean regions average under 0.1 flashes/km^2/yr, Puerto Rico experiences a higher nationwide average between 0.4 and 1.5 events/km^2/yr.[703]

Furthermore, in a NASA Astrophysics Data System and American Geophysical Union (AGU) meteorological study, researchers located intense lightning hotspots 36 kilometers west of the Arecibo Observatory. Remarkably, positive lightning flashes comprised 35% of these total discharges. This concentration vastly

[701] Vaisala Xweather, "The Annual Lightning Report," https://indd.adobe.com/view/97f5506f-f312-493b-a9d2-d6f3bd06408a.
[702] National Lightning Safety Institute, "Lightning safety: A guide for the public," http://diliev.com/Home/applications/Library/Lightnings/lightningsafety5/www.lightningsafety.com/nlsi_lhm/prbshort.html.
[703] Holle, Ron, "Lightning Density Map for Every Country in the World," Vaisala, April 20, 2021, https://www.vaisala.com/en/blog/2021-04/lightning-density-maps-every-country-world.

exceeds the 10% global baseline, proving that exceptionally powerful, highly electrified cloud matrices consistently form over Puerto Rico's interior mountains.[704]

As part of temporal and seasonal patterns, lightning activity peaks during afternoon and evening hours, especially in the wet season, increasing the daily conditional probability of thunderstorms. Furthermore, trade winds and tropical waves frequently trigger multi-day thunderstorm sequences, particularly during the wet season. This clustering effect compounds risk, leading to saturated soils, elevated flash flood potential, and increased landslide susceptibility. Additionally, research suggest that fluctuations in future temperature and moisture conditions will continue to intensify thunderstorm rainfall rates, reducing recurrence intervals and increasing the likelihood of damaging outcomes.[705]

Vulnerability Assessment

A vulnerability assessment is a critical tool for identifying how hazards like lightning translate into tangible risks for communities, infrastructure, and essential services. In Puerto Rico, the frequent occurrence of thunderstorms and lightning—intensified by the island's tropical climate, mountainous terrain, and evolving development patterns—creates a complex and uneven landscape of exposure. Understanding these disparities is key to designing effective mitigation strategies and enhancing resilience across the island.

[704] Salazar, S, et al., "First Survey of Lightning Effect in the Lower Ionosphere Over Arecibo, Puerto Rico," American Geophysical Union, Fall Meeting 2019, Abstract #AE31B-31111; 2019AGUFMAE31B3111S, December 2019, https://ui.adsabs.harvard.edu/abs/2019AGUFMAE31B3111S/abstract.
[705] Votaw, Gary S., et al., "An Historic Rainfall at San Juan Puerto Rico," https://www.weather.gov/media/sju/hydrology/RecordRainfall_July18_2013.pdf?utm.

LOCATIONS

Puerto Rico's location within the tropical belt creates a highly favorable environment for electrified convection, particularly during afternoon hours. The interaction of land-sea breezes, complex terrain, and moisture-rich air masses contributes to frequent lightning development. Additionally, the island's steep terrain, including the Cordillera Central, Sierra de Cayey, and Sierra de Luquillo, interacts dynamically with moist trade-wind air and diurnal sea-breeze circulations to create ideal conditions for deep, electrified convection.[706]

POPULATIONS

Municipalities across Puerto Rico face varying degrees of vulnerability to lightning-related disruptions, shaped by population size, terrain, and infrastructure distribution. In areas with modest populations, a single severe lightning-induced outage or equipment failure can impact a significant portion of residents, quickly overwhelming local backup capacity. Rural and mountainous municipalities such as Adjuntas, Jayuya, and Orocovis are particularly at risk due to dispersed populations and challenging terrain, which can delay service restoration and heighten danger for individuals reliant on electricity or medical care.

STRUCTURES INCLUDING CRITICAL FACILITIES

Lightning is a multifaceted hazard with cascading impacts across residential, public, and critical infrastructure. It can ignite fires and destroy electronic systems in homes, schools, and community buildings, undermining their safety and functionality. More critically, lightning-induced disruptions at hospitals, water treatment facilities, fuel depots, power substations, and communication hubs can interrupt essential services, delay emergency response, and compromise public health and safety. These interlinked failures pose serious challenges to community resilience and recovery during severe weather events.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Lightning in Puerto Rico poses a widespread threat that extends beyond the island's fragile power grid, impacting the essential buildings and systems that support daily life and emergency response. Residential homes, small businesses, schools, hospitals, water treatment facilities, hazardous material depots, and communication hubs are all highly susceptible to both direct lightning strikes and indirect electrical surges. These events can spark fires, destroy sensitive equipment, and interrupt the operation of critical services.

When lifeline infrastructure, such as hospitals, water systems, and communication centers, is compromised, the consequences ripple through communities. Interruptions to medical care, clean water access, hazardous material containment, and emergency communications can quickly escalate into public safety crises. At the household and business level, repeated lightning-related damage leads to financial hardship, service instability, and increased safety risks, particularly in areas with limited resources or backup capacity.

[706] N. Hosannah, et al., "Impacts of Local Convective Processes on Rain on the Caribbean Island of Puerto Rico," *Journal of Geophysical Research: Atmospheres* 124, no. 12 (2019): 6009-6026, https://doi.org/10.1029/2018JD029825.

PROBLEM STATEMENTS

- Lightning poses a persistent and hazardous threat across Puerto Rico, with elevated risk concentrated in municipalities situated near high-elevation terrain in the Tropical Rainforest Climate of the state. Intensity is elevated particularly in the interior mountainous municipalities along the Cordillera Central and in the northeastern highlands, such as Río Grande. These regions experience intensified thunderstorm activity driven by orographic lift and the interaction of sea breezes with mountainous topography. As a result, lightning flash densities in these interior and upland zones consistently exceed those observed in coastal or lowland areas.
- Lightning is a frequent and damaging hazard across Puerto Rico, with particularly elevated intensity in interior mountainous municipalities along the Cordillera Central and in the northeastern highlands, such as Río Grande. These regions experience weather conditions that create highly electrified thunderstorms, resulting in elevated lightning strike density compared to coastal and lowland areas. This geographic concentration of lightning activity increases the vulnerability of the residents in those areas.
- Lightning presents a widespread and escalating threat to Puerto Rico's structures, including those identified as critical facilities, as both direct strikes and indirect electrical surges can ignite fires, destroy sensitive equipment, and disrupt essential services.
- Puerto Rico's critical infrastructure faces heightened vulnerability to lightning strikes, driven by the island's tropical climate and rugged terrain. Frequent strikes disrupt essential services, damage key facilities, and create direct threats to public safety, underscoring the need for resilient systems and protective measures across lifeline sectors.

Impact Assessment

Evaluating the impacts of lightning in Puerto Rico is critical for understanding how this hazard destabilizes communities, compromises infrastructure, and burdens public services. Lightning strikes—and the electrical surges they trigger—affect more than just the island's power grid; they also threaten the core facilities that support daily life and emergency response, including residences, businesses, schools, hospitals, water systems, and communication networks. The resulting damage spans from physical destruction and equipment failure to widespread service interruptions that jeopardize public safety, health, and economic resilience.

The following two charts illustrate how different building types in Puerto Rico are exposed to lightning hazards and the economic implications of that exposure. Figure 200, the Lightning Building Exposure by Type Use (%) chart shows that residential structures overwhelmingly dominate exposure, accounting for nearly all building use percentages across municipalities. This reflects the island's development pattern, where homes are widely distributed even in mountainous areas prone to convective storm, making them highly susceptible to lightning strikes. Other categories such as commercial, education, government, and industrial uses represent only fractional percentages, indicating that while these sectors occupy less physical space, their exposure still matters for critical services and operations.

Figure 201, the Lightning Building Replacement Value by Type Use (Millions) chart shifts focus to economic vulnerability. Here, residential buildings again represent the largest share of replacement value, underscoring the financial risk posed by widespread housing exposure. However, commercial and educational facilities also contribute significantly to total value, particularly in urban centers like San Juan and Ponce, where dense infrastructure and lifeline services amplify potential losses. Industrial and government facilities, though fewer in number, carry high stakes because damage to these assets can disrupt essential operations, emergency response, and economic activity. Together, these charts highlight that while residential exposure drives overall risk, the concentration of high-value assets in critical sectors magnifies the consequences of lightning-related disruptions.

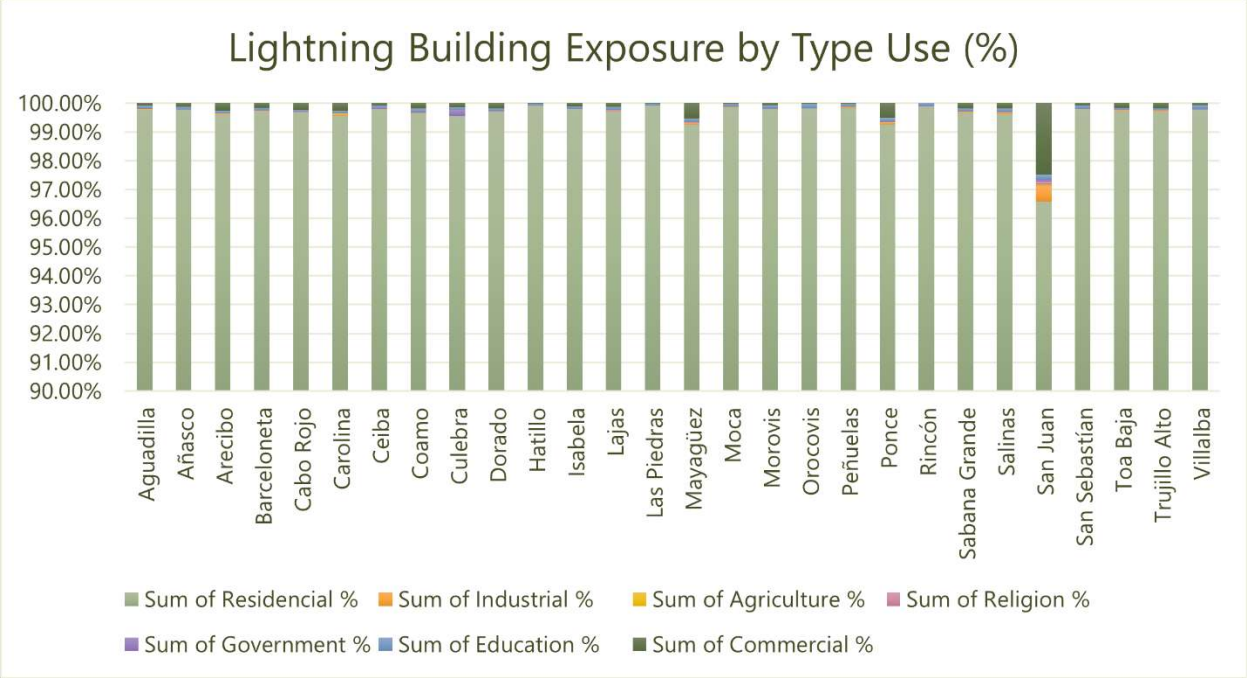

Figure 200: Distribution of Building Exposure to Lightning by Use Type (%)

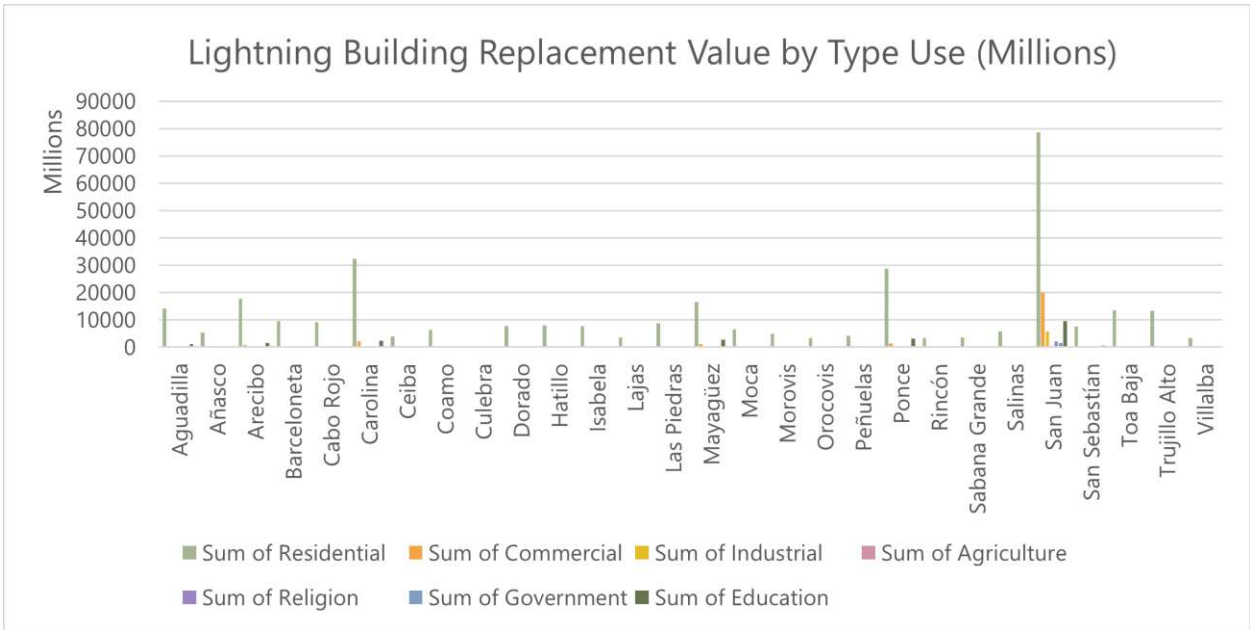

Figure 201: Estimated Replacement Value of Buildings by Use Type (in Millions)

In addition to socioeconomic factors, lightning impacts might have a significant effect on the environment; for example, topical forests are struck by lightning an estimated 35 to 67 million times annually, and recent observations suggest that these events are becoming more frequent. This increase may be linked to shifts in atmospheric conditions that promote stronger storm development. As lightning activity intensifies, it poses growing risks to forest ecosystems, including tree damage, changes in species composition, and a higher likelihood of fire in drier regions.[707]

El Yunque National Forest is the only tropical forest in the U.S national forest system. Located in the Luquillo Mountains, the forest encompasses 28,000 acres, is home to rich vegetation and biodiversity, and has steep slopes rising over 3,280 feet over sea level.[708] Figure 202 illustrates the site and elevation of each peak within El Yunque.[709] A lightning strike could impact the tallest tress by immediately killing them or causing a slow death.[710] Additional information on the island's forest can be found on State Profile section.

[707] Gora, Evan M., et al., "In the tropics, woody vines make lightning more deadly for forests," Cary Institute of Ecosystem Studies, EurekAlert! March 27, 2023, https://www.eurekalert.org/news-releases/984083.
[708] USDA Forest Services, U.S Department of Agriculture, "Natural Resources," https://www.fs.usda.gov/r08/elyunque/natural-resources.
[709] USDA, "El Yunque National Forest Atlas," https://www.fs.usda.gov/research/treesearch/56095.
[710] Mahon, Elise, "Lightning strikes shape tropical forests," University of Wisconsin–Madison, https://news.wisc.edu/lightning-strikes-shape-tropical-forests/.

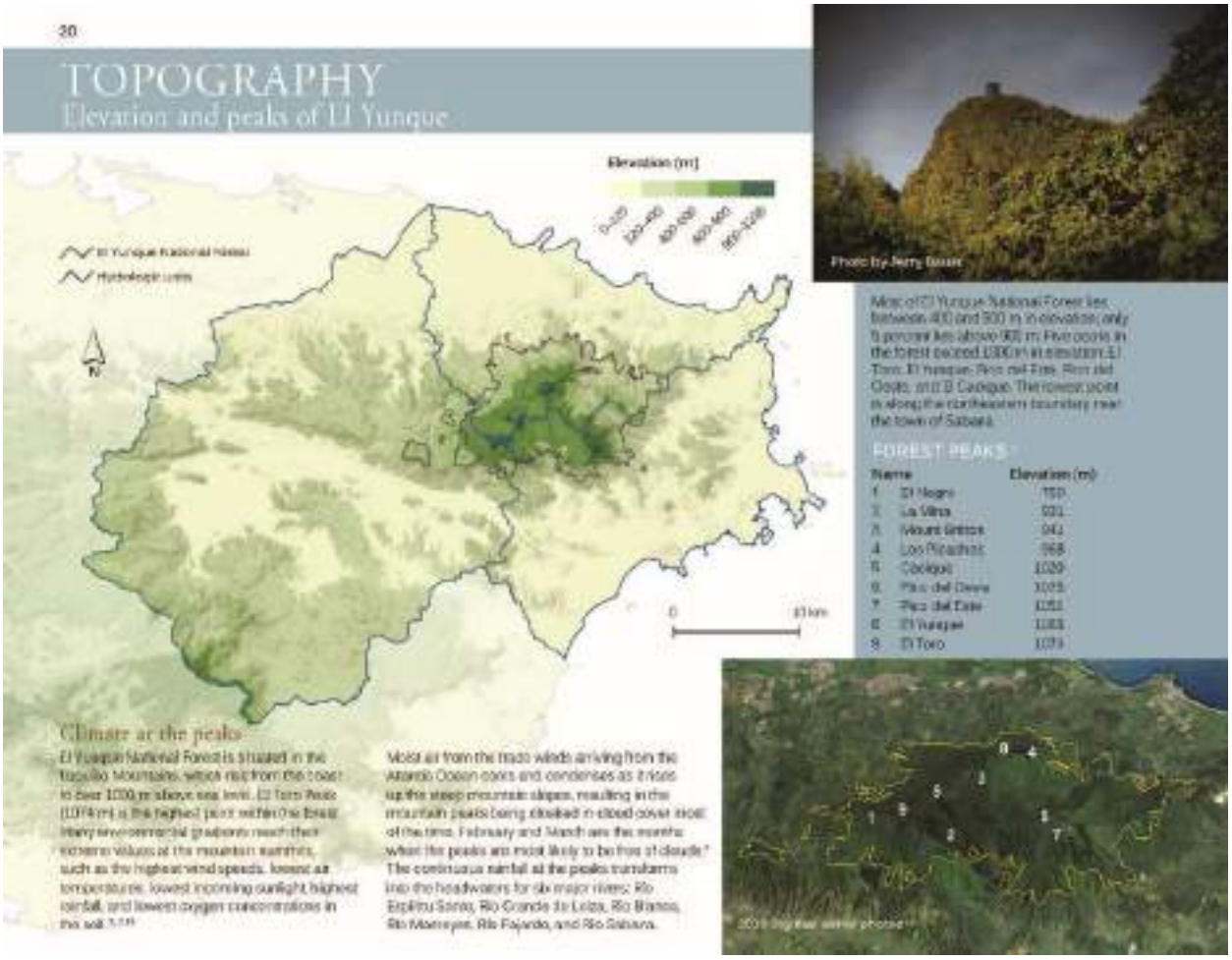

Figure 202: El Yunque Topography

STATE ASSETS

Schools, government buildings, and community centers frequently function as critical shelters during disasters, making their operational reliability essential. However, lightning-induced power surges can compromise these facilities by damaging electronic equipment, disrupting communication systems, and interrupting essential services—undermining their effectiveness as lifeline infrastructure.

Facilities lacking well-maintained lightning protection systems face heightened risks, including roof fires and failures in HVAC and security systems. These vulnerabilities can delay emergency response, reduce shelter capacity, and jeopardize public safety during severe weather events. An exact dollar value is hard to calculate, but in general, all state assets are at risk from lightning strikes and may be damaged or destroyed by a lightning-caused fire.

LOCAL ASSETS

Lightning strikes can inflict serious structural damage by igniting fires, puncturing roofs and walls, and compromising electrical wiring. Homes constructed from older wood or concrete materials, especially those lacking modern grounding systems, are particularly vulnerable to these impacts.

In rural and mountainous municipalities such as Adjuntas, Jayuya, and Utuado, many residences do not have surge protection or professionally installed grounding.[711] This leaves households exposed to recurring electrical fires, equipment failures, and costly damage during thunderstorm events. For example, in Adjuntas and adjacent jurisdictions, residents have a difficult time installing roof solar panels due to the limited availability of resources and rising costs.[712] Furthermore, many of residents in these areas are dependent on medical equipment, and lack of modern wiring could place additional responsibilities on local assets, such fire and medical departments.[713]

COMMUNITY LIFELINES

Across Puerto Rico, lightning is a frequent convective hazard that contributes to public safety risk (fatalities/injuries), ignition of wildland and structure fires, and electrical system disruptions that cascade to critical lifelines (healthcare, water, communications, fuel). Because Puerto Rico's electricity system and some critical facilities remain vulnerable after years of storm damage and system fragility, lightning-caused outages and ancillary impacts can produce outsized consequences.

SAFETY AND SECURITY

When power, communications, water pumping systems, or emergency services fail during thunderstorms, vulnerable populations, such as the elderly, low income individuals and families, and those with chronic illness, face amplified risk. A study on Puerto Rico notes how infrastructure disruptions impede household capabilities—like access to water, food storage, healthcare, and cooling/heating operations.[714]

FOOD, HYDRATION, AND SHELTER

Interior municipalities in Puerto Rico often face compounded vulnerabilities due to socioeconomic and infrastructural limitations. Many of these areas have lower median incomes and depend heavily on subsistence or small-scale agriculture, leaving limited financial flexibility for backup power systems or infrastructure hardening.

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[711] Cooperativa Hidroeléctrica de la Montaña, https://cooperativahidroelectrica.coop/.
[712] Lily Carey, "Energy Instability in Rural Puerto Rico: Building Power Structures From the Ground Up," LatinoNewsNetwork, July 17, 2025, https://latinonewsnetwork.com/environment/energy-instability-in-rural-puerto-rico-building-power-structures-from-the-ground-up/.
[713] Eliván Martínez Mercado, "Health Department Refuses to Create the List of Patients Vulnerable During Blackouts," *Centro de Periodismo Investigativo*, https://periodismoinvestigativo.com/2024/08/electricity-dependent-list-blackouts/.
[714] Susan Spierre Clark, et al., "Impact of Infrastructure Disruptions on Puerto Rican Household Capabilities, Health, and Well-Being," https://hazards.colorado.edu/public-health-disaster-research/impact-of-infrastructure-disruptions-on-puerto-rican-household-capabilities-health-and-well-being.

Institutional capacity is frequently constrained—smaller municipal budgets and limited technical staffing can hinder the implementation of lightning protection measures, surge arrestors, and resilient infrastructure upgrades. At the household level, rural residents may have lower insurance coverage and reduced ability to absorb repair costs following lightning-related damage, increasing long-term recovery challenges.

HEALTH AND MEDICAL

Direct lightning strikes, though infrequent, pose elevated risks to individuals engaged in outdoor activities—particularly farmers in mountainous regions (that experience the rare occurrence of "Dry Lightning"), utility crews, hikers, and residents of rural households. These groups face greater exposure due to prolonged time spent in open or elevated environments.

Beyond direct impacts, lightning-induced power outages can disrupt critical systems, including medical devices, ventilators, refrigeration for temperature-sensitive medications, and hospital operations. Such interruptions carry serious consequences for vulnerable populations, especially older adults, individuals with disabilities, and those reliant on life-support equipment. Extended outages in these contexts can rapidly escalate into life-threatening situations.

ENERGY

Lightning strikes contribute to grid destabilization, transformer failure, and cascading outages, making power interruptions more frequent in high-strike zones. In municipalities with limited redundancy and weaker grid resilience, outages last longer and recovery is slower.

COMMUNICATIONS

Telecommunications infrastructure—including cell towers, microwave links, and head-end facilities—consists of tall, exposed structures with extensive conductive pathways. These systems are highly vulnerable to both direct and nearby lightning strikes, which can induce damaging electrical surges. Without adequate bonding and surge protection, such surges can disable critical components like radios, baseband units, rectifiers, and routers; disrupt microwave transmission links; and propagate through both overhead and underground networks.[715]

Thunderstorms further compound this risk by triggering commercial power outages, forcing sites to rely on limited-duration backup systems. In Puerto Rico, communications reliability is tightly interwoven with the electrical grid. Past grid failures have led to widespread service disruptions across telecom nodes, cable head-ends, data centers, and tower sites, while also interfering with water system telemetry. Lightning-induced faults and breaker trips can act as catalysts for these cascading failures, underscoring the need for robust surge protection and resilient power strategies.[716]

[715] Raycap, "Cellular Site Surge Protection Systems," https://www.raycap.com/cellular-site-surge-protection-systems/.
[716] Associated Press, "Crews restore power to nearly all customers after island-wide blackout hit Puerto Rico," April 18, 2025, https://apnews.com/article/puerto-rico-blackout-power-outage-luma-9c5ee88c846d0fd81ce0510ea8a55a50.

TRANSPORTATION

Populations in mountainous municipalities often live in widely dispersed, remote barrios far from municipal centers. Lack of access to emergency services and road/bridge damage during lightning incidents can isolate communities and delay restoration of services.

HAZARDOUS MATERIALS

Lightning poses a serious hazard to fuel terminals and industrial facilities, particularly those storing flammable or toxic substances. Direct strikes can ignite vapor clouds or above-ground storage tanks, while nearby strikes often induce electrical surges that compromise control systems and pump motors, potentially leading to hazardous material release.[717]

Facilities regulated under the Environmental Protection Agency's Risk Management Program frequently handle chemicals such as chlorine and ammonia, chemicals with which any loss of containment carries significant public health risks. Infrastructure elements like tanks, spheres, rail spurs, and loading racks in coastal municipalities are especially vulnerable, with some located near elevated terrain where step and touch potentials during lightning events are more severe.

Aging bonding and grounding systems, along with inadequate floating roof shunts and seals, increase the likelihood of rim fires following a strike. Additionally, programmable logic controllers and SCADA systems are highly susceptible to surge damage. If emergency shutdowns or pressure relief mechanisms malfunction during such events, the risk of uncontrolled releases escalates.

WATER SYSTEMS

Water treatment facilities, well fields, and pump/lift stations rely heavily on uninterrupted electric power to maintain operations. Lightning strikes can trigger electrical surges and grid trips, disabling high-service pumps, and SCADA systems, which in turn can lead to pressure loss and boil-water advisories. In Puerto Rico, such grid disturbances have repeatedly cascaded into widespread water service outages, highlighting the critical interdependence between power and water infrastructure.

Smaller systems and those outside the Puerto Rico Aqueduct and Sewer Authority network are particularly vulnerable. With limited redundancy and fewer resources, these systems face heightened risk—where a single outage or equipment failure can halt water treatment and distribution entirely.

Changes in Development

Since the last plan was updated, there have been major natural hazard events such as hurricanes and severe thunderstorms that have revealed significant vulnerability of the island's population and critical infrastructure to lightning strikes associated with these hazard events. Commercial and residential expansion in more urban and tourist areas like San Juan, Ponce, and Aguadilla[718] have placed more

[717] EPA, Risk Management Program (RMP) Rule, "List of Regulated Substances under the Risk Management Program," https://www.epa.gov/rmp/list-regulated-substances-under-risk-management-program.
[718] Welcome to Puerto Rico, "Puerto Rico Top 10 Cites," https://welcome.topuertorico.org/topcities.shtml.

infrastructure within zones where convective activity and strike density increases the risk of direct strikes, electrical surges, equipment failure, and cascading service disruptions.

LAND USE AND BUILT ENVIRONMENT CHANGES

Land use and development patterns in Puerto Rico significantly influence the island's vulnerability to lightning hazards. The placement and construction of homes, businesses, and critical infrastructure directly shape exposure to high-risk zones and determine the resilience of structures against electrical surges and storm-related disruptions. In 2018, Puerto Rico implemented new building codes to address electrical instability, surge protection, and grounding.[719] These changes are focused on improving the island's resiliency to hazardous events. Additionally in 2019, 2020, and 2022, Puerto Rico passed regulations to encourage renewable energy projects to reduce the vulnerability of its population.[720]

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Puerto Rico's evolving energy landscape and demographic trends are reshaping its exposure to lightning-related hazards. As distributed solar and battery systems expand—particularly in remote or vulnerable areas—new microgrids offer the potential to reduce reliance on the centralized power grid and shield communities from lightning-induced outages.

POPULATION CHANGES

In certain regions, slow development in Puerto Rico's mountainous interior has led to a decline in population exposure to lightning-prone zones. However, this trend has also left behind aging housing and infrastructure that often lack modern grounding, surge protection, and resilient power systems, heightening vulnerability for those who remain.

Meanwhile, ongoing urban expansion in coastal and peri-urban areas such as San Juan, Cayey, and Río Grande has concentrated residents, businesses, and critical facilities in zones heavily dependent on reliable electricity and communications. As a result, lightning-related disruptions in these densely populated areas can have amplified consequences, affecting lifeline services and community resilience.[721]

VULNERABILITY OF STATE ASSETS CHANGES

Land use policies in Puerto Rico have gradually adapted to confront challenges like urban expansion and environmental conservation. Regulatory changes between 2019 and 2022 have tried to lessen the impact of land development and building construction.[722]

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[719] Juan Nieves, "Puerto Rico's new building code are creating a more resilient island," Consulting-Specifying Engineer, https://www.csemag.com/puerto-ricos-new-building-codes-are-creating-a-more-resilient-island/.
[720] Junta de Planificación de Puerto Rico, "Reglamento conjunto para la expedición de permisos relacionados al desarrollo," 2022, https://docs.pr.gov/files/DDEC/OGPe/Reglamentos/RC-2023-E.pdf.
[721] Financial Oversight and Management Board for Puerto Rico, "A Changing Population: Understanding Puerto Rico's Demographic Trends," https://oversightboard.pr.gov/a-changing-population-understanding-puerto-ricos-demographic-trends/.
[722] "What Is the Joint Regulation 2022?" Citizens of the Karst, December 22, 2022,

VULNERABILITY OF LOCAL ASSETS CHANGES

Puerto Rico has recently strengthened its building codes and regulations to improve infrastructure resilience, including protections against lightning hazards.[723] However, gaps in enforcement and limited retrofitting efforts mean that many older buildings remain exposed. While newer construction is more likely to feature enhanced grounding, metallic continuity, modern electrical systems, and surge protection, legacy structures, especially in interior municipalities, often lack these safeguards.

As development expands into less densely populated, hilly, and forest-adjacent areas, more buildings are being constructed in zones with elevated lightning strike probability due to increased convective uplift, such as ridges and slopes. Meanwhile, the continued presence of aging, informally built housing stock in mountainous regions leaves many homes without proper grounding or resilient power infrastructure. Even with updated codes, these improvements may not apply retroactively, leaving a significant portion of the local assets vulnerable to lightning-related damage and service disruptions.

Mitigation Success Stories

Lightning is a persistent and often overlooked threat in Puerto Rico, with the power to damage homes, disable vital infrastructure, and interrupt essential services like electricity, water, and communications. Despite the severity of these risks, many communities and institutions across the island, and in similar regions, have shown that strategic mitigation efforts can significantly reduce vulnerability and safeguard lives and property.

PROGRAMA ACCESO SOLAR (SOLAR ACCESS PROGRAM)

Launched in February 2024 by the U.S. Department of Energy under the Puerto Rico Energy Resilience Fund, the Programa Acceso Solar is designed to improve energy security for low-income homeowners in Puerto Rico. The initiative provides subsidized rooftop solar systems paired with battery storage at zero upfront cost for eligible participants. The program also includes an educational component: teaching homeowners how to use and maintain the systems against dust, vegetation, and other obstructions that could cause a lightning strike.[724]

LET'S SHARE THE SUN FOUNDATION

The Let's Share the Sun Foundation is a nonprofit organization working to expand energy access in rural Puerto Rico by funding solar panel installations for underserved communities. In partnership with Casa Pueblo, an environmental justice group based in Adjuntas, the foundation focuses on helping residents, especially those who rely on electricity to power critical medical equipment, install rooftop solar systems.

https://cdk-pr.org/en/2022/12/22/what-is-the-joint-regulation-2022/.

[723] Alvarez-Diaz & Villalin, "Why the Changes in the Puerto Rico Building Codes Matter," https://www.alvarezdiazvillalon.com/blog/why-the-changes-in-the-puerto-rico-building-codes-matter.

[724] Gobierno de Puerto Rico, "¡Cuida tus placas solares y asegura la energía de tu hogar!" https://recuperacion.pr.gov/placas-solares/.

This initiative not only promotes energy independence and resilience but also prioritizes the health and safety of vulnerable populations living in remote areas.[725]

[725] Let's Share the Sun Foundation, https://www.letssharethesun.org/.

SECTION 4.12

LIQUEFACTION

Liquefaction

DEFINITION

According to the USGS, liquefaction occurs when loosely packed, waterlogged sediments at or near the surface lose their strength in response to strong ground shaking. Liquefaction beneath buildings and other structures can cause major damage during earthquakes.726

Strong earthquake shaking can cause water-saturated, unconsolidated soil to behave like a dense fluid rather than a solid. This process, known as *liquefaction*, occurs when loosely packed, water-logged sediment loses strength during intense ground motion. Under normal conditions, soil particles carry the load, but in saturated soils, water fills the pore spaces and helps support that load. During seismic vibrations, the soil structure is disrupted, excess pore pressure builds, and the soil's effective stress drops nearly to zero. When this happens, the soil temporarily behaves like a liquid and can no longer support structures, often resulting in severe ground deformation and damage. These processes are illustrated in Figure 203 and Figure 204.[727,728]

[726] USGS, "What is Liquefaction?" https://www.usgs.gov/faqs/what-liquefaction.
[727] USGS, "What is Liquefaction?" https://www.usgs.gov/faqs/what-liquefaction.
[728] TechnoStruct Academy, Understanding Soil Liquefaction: Causes and Effect, May 6, 2024, https://www.technostructacademy.com/blog/understanding-soil-liquefaction-causes-and-effects/.

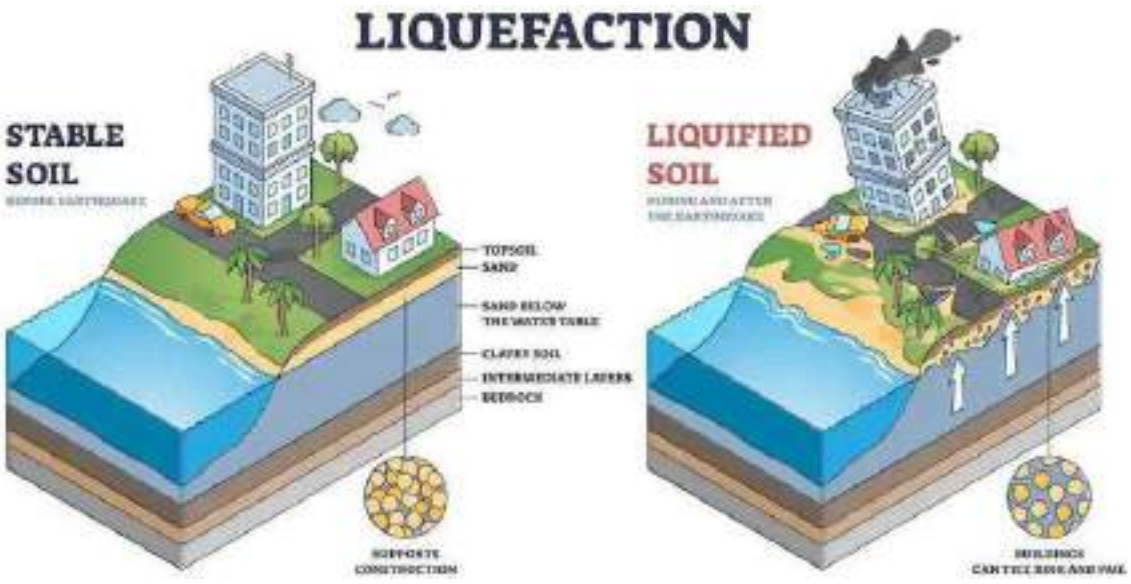


Figure 203: Example of Liquefaction[729]

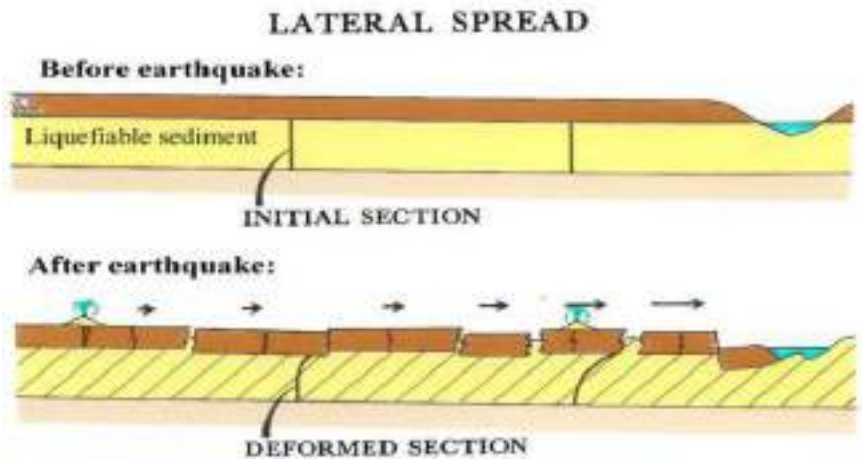


Figure 204: Ground Deformation[730]

Soil liquefaction can have devastating consequences, including the destabilization of buildings, bridges, and underground infrastructure, such as water and drainage systems, leading to sinking or collapse and posing serious risks to human life.[731] In addition, it can trigger secondary hazards, such as landslides and tsunamis,

[729] TechnoStruct Academy, Understanding Soil Liquefaction: Causes and Effect, May 6, 2024. https://www.technostructacademy.com/blog/understanding-soil-liquefaction-causes-and-effects/.
[730] Menard Innovation, "What is Soil Liquefaction? Causes, Effects and Mitigation," August 29, 2024, https://www.menard-asia.com/2024/08/29/soil-liquefaction/#:~:text=Soil%20liquefaction%20occurs%20when%20saturated,major%20concern%20in%20seismic%20zones.
[731] TechnoStruct Academy, Understanding Soil Liquefaction: Causes and Effect, May 6, 2024. https://www.technostructacademy.com/blog/understanding-soil-liquefaction-causes-and-effects/.

especially in coastal areas, where erosion-induced failures may lead to sudden, large-scale ground movements.

There are two main types of failure from soil liquefaction: **flow liquefaction**, and **cyclic liquefaction**. **Flow liquefaction** can cause rapid, large-scale ground failure, which can cause landslides or flow slides (especially where slopes and embankments are involved). It occurs in loose, cohesionless soils—most commonly sand and silts, and entails a sudden loss of soil shear strength due to static loading. As the most severe type of liquefaction, it can produce a complete and unexpected collapse of structures above ground.[732] On the other hand, when pore water pressure builds up progressively due to a pattern of cyclic loading, **cyclic liquefaction** can occur, resulting in the accumulation of large shear strains. The characteristic effect of this type of liquefaction is a temporary reduction in effective stress, which can lead to the soil losing its strength entirely (although in many cases, the loss of soil strength is only partial).[733]

Location

USGS conducted an inventory of liquefaction-related phenomena in Puerto Rico after the *moment magnitude* (M) 6.4 earthquake of January 7, 2020. As liquefaction is primarily a subsurface process, it should be noted that surface expression might not extend over the entire area where liquefaction occurs at depth. The inventory defined a "liquefaction area" type to indicate places where manifestations of liquefaction (fissures, sand ejecta, sand boils, settlement) were pervasive, but there was no obvious lateral displacement. In addition, the inventory identified locations where "lateral spreading" or lateral displacements, often toward bodies of water and likely related to liquefaction, were observed. Figure 205 is a map of Puerto Rico's susceptibility to liquefaction.

[732] Lees, Andrew, "Soil Liquefaction: Causes, Effects, and Solutions," https://www.tensarinternational.com/resources/articles/soil-liquefaction.
[733] Lees, Andrew, "Soil Liquefaction: Causes, Effects, and Solutions," https://www.tensarinternational.com/resources/articles/soil-liquefaction.

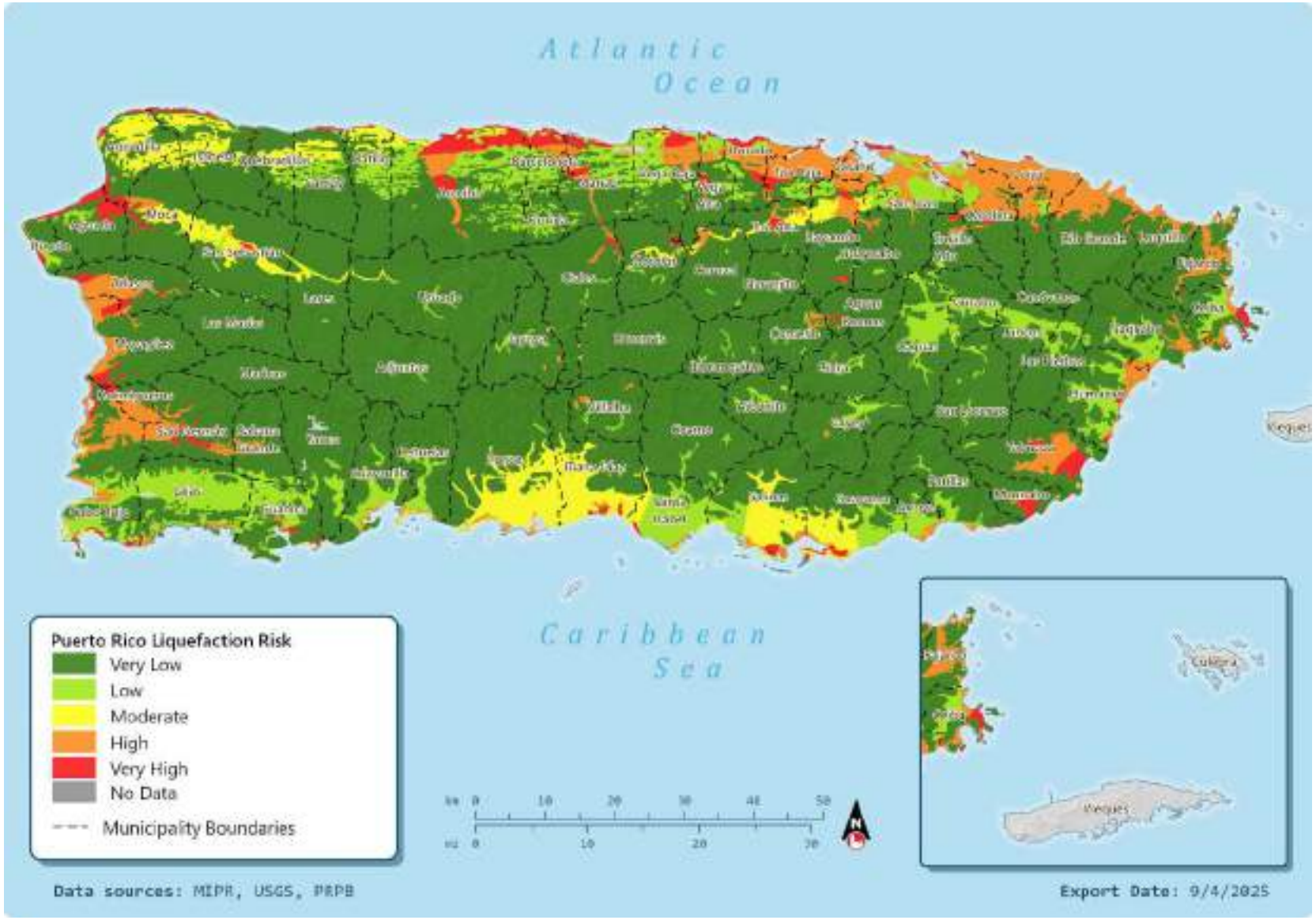


Figure 205: Puerto Rico Liquefaction Susceptibility Map

The areas of highest liquefaction hazard occur along the low-lying coastal plain, where beach, river, and swamp sediments interfinger to form relatively thick sequences of loose, fine-grained cohesionless deposits. The Río Bayamón and Río La Plata valleys both contain highly susceptible deposits.[734] The areas underlain by Quaternary silica sands, blanket deposits, colluvium, valley fill, and alluvial fan deposits have low to moderate susceptibility to liquefaction. Most of the areas to the south of the coastal plain lie in **Moderate, Low, or Very Low** hazard zones.

TYPES OF SOIL IN PUERTO RICO

Puerto Rico has 11 of the 12 soil types recognized by the USDA's Soil Classification System.[735] This system helps scientists and farmers understand how different soils behave, what crops grow best in them, and how to manage them sustainably. Even though Puerto Rico is a small island, it has a wide variety of soils thanks to its diverse climate, landscapes, plants and animals, and geological history. Soil names are based on the municipalities or geographic areas where they were first identified by the Soil Conservation Service (now the Natural Resources Conservation Service). Soils with similar profiles form a series, which are further divided into phases based on texture, slope, and other characteristics (see Figure 206).[736]

[734] USGS, "Liquefaction susceptibility of the Bayamón and Juan quadrangles, Puerto Rico," January 2008.
[735] Climate, Organisms, Relief, Parent Material, and Time, Jenny, 1941.
[736] "Los Suelos Principales en Puerto Rico," por Ferdinand Quiñones and Sylvana Palacios, Inventario de Recursos de Agua de Puerto Rico, 2004, https://www.recursosaguapuertorico.com/Los_Suelos_Principales_en_Puerto_Rico.pdf.

Figure 206: Puerto Rico's Soil Orders

Previous Occurrences

More than 90 liquefaction features found along rivers in northwestern and north-central Puerto Rico provide a record of large earthquakes during the past 5,400 years. The liquefaction features, including sand dikes, sand blows, and sand sills, are attributed to the historical earthquakes of 1918, 1787, and 1670 and two paleo earthquakes, circa 1201–410 B.C. and 1304–1508 A.D.[737]

Several features were formed during the M 7.3 earthquake in 1918 and the 1670 event, which might have reached M 7 and was likely centered in the Añasco River Valley. Evidence of liquefaction along the Río Culebrinas—and possibly along parts of the Río Grande de Añasco—suggests that an M ≥6.5 earthquake occurred between 1300 and 1508 A.D.

In 2005, the Geological Society of America published a special paper focusing on the Río Culebrinas, Río Grande de Añasco, and Río Guanajibo. The study identified and analyzed numerous liquefaction features, examined organic samples associated with these features, and conducted liquefaction potential assessments using previously collected geotechnical data from the three rivers. The primary objective was to enhance the understanding of the age and magnitude distribution of liquefaction features along Puerto Rico's western, northern, and eastern coasts.[738]

The 1918 earthquake and related tsunami had their greatest impact on the western coast of Puerto Rico, killing at least 114 persons and causing $4 million in damage.[739] This earthquake also induced liquefaction near Aguadilla and in the Río Grande de Añasco valley. Sand boils and fountains of sand up to 10–12 feet high were observed, especially in cane fields in western Puerto Rico. Extensive liquefaction features were found along Río Culebrinas, Río Grande de Añasco, and Río Guanajibo.

Following the M 6.4 earthquake that struck southwestern Puerto Rico on January 7, 2020, severe liquefaction was documented across southern coastal regions, particularly near Ponce. Field investigations conducted by the USGS and collaborators identified extensive ground failure features, including sand boils, ground fissures, and lateral spreading. These phenomena caused significant damage to homes along creeks, prompting evacuations due to ground settlement and instability. The earthquake also triggered over 300 landslides and caused widespread infrastructure damage, underscoring the vulnerability of the region's geotechnical conditions to seismic activity.[740] Figure 207 shows the effects of liquefaction.

[737] Tuttle, Martitia P., Kathleen Dyer-Williams, Eugene S. Schweig, Carol S. Prentice, Juan Carlos Moya, and Kathleen B. Tucker. "Liquefaction induced by historic and prehistoric earthquakes in western Puerto Rico." (2005).
[738] Tuttle, Martitia P., Kathleen Dyer-Williams, Eugene S. Schweig, Carol S. Prentice, Juan Carlos Moya, and Kathleen B. Tucker. "Liquefaction induced by historic and prehistoric earthquakes in western Puerto Rico." (2005).
[739] Reid and Taber, 1919.
[740] United States Geological Survey, "Inventory of liquefaction features triggered by the 7 January 2020 M6.4 Puerto Rico earthquake," September 21, 2021, https://www.usgs.gov/data/inventory-liquefaction-features-triggered-7-january-2020-m64-puerto-rico-earthquake.

Figure 207: 2020 Earthquakes Aftermath

FEDERAL DISASTER DECLARATIONS

As for summer of 2025, no federal disaster declaration has been issued for liquefaction. This geotechnical phenomenon has consistently emerged as a damaging consequence of major natural disasters, particularly earthquakes and hurricanes. In Puerto Rico, liquefaction was notably documented during the 2020 earthquake sequence, especially the M 6.4 event on January 7, which triggered ground failure in southern coastal areas, such as Ponce.[741]

Historical earthquakes, such as the 1918 San Fermín event, and paleo liquefaction features along rivers in western Puerto Rico further illustrate its recurring presence. Hurricane-related liquefaction also has been observed, particularly during Hurricane Maria in 2017 and Hurricane Fiona in 2022. Maria triggered over 71,000 landslides across the island, many of which occurred in saturated soil prone to liquefaction.[742] Fiona brought over 25 inches of rain to some areas, causing widespread flooding, landslides, and erosion that compromised infrastructure and soil stability. These cases demonstrate that, while liquefaction might not be the primary cause of federal declarations, its destructive impact is deeply intertwined with the effects of larger disasters, warranting its inclusion in hazard assessments and mitigation strategies.[743]

[741] USGS, "Field observations of ground failure triggered by the 2020 Puerto Rico earthquake sequence," August 6, 2020. https://www.usgs.gov/data/field-observations-ground-failure-triggered-2020-puerto-rico-earthquake-sequence.
[742] USGS. Field observations of landslides and related materials following Hurricane Maria, Puerto Rico, October 25, 2023. https://www.usgs.gov/data/field-observations-landslides-and-related-materials-following-hurricane-maria-puerto-rico.
[743] GEER Association, "Geotechnical Impacts of Hurricane Fiona in Puerto Rico," March 8, 2023. https://geerassociation.org/components/com_geer_reports/geerfiles/GEER_HurricaneFiona_report.pdf.

DISASTER DECLARATIONS

EXECUTIVE ORDER NO. OE-2020-01

On January 7, 2020, the former Governor of Puerto Rico, Hon. Wanda Vázquez Garced, signed Executive Order OE-2020-001, officially declaring a state of emergency throughout Puerto Rico in response to seismic activity, including an M 6.4 earthquake near the Municipality of Guayanilla. The declaration enabled government agencies to activate emergency procurement procedures and coordinate immediate response efforts to safeguard lives, infrastructure, and public services amid ongoing aftershocks and widespread damage.[744]

In response to the state of emergency declaration, Puerto Rico's Financial Oversight and Management Board (FOMB) authorized the use of Emergency Reserve funds from fiscal years 2019 and 2020, totaling $260 million, as needed by the Government of Puerto Rico for earthquake-related expenses.[745]

SIGNIFICANT EVENTS

CAYO AURORA GUÁNICA, PUERTO RICO (GILLIGAN ISLAND), 2020

After the 2020 earthquakes in southern Puerto Rico, Gilligan's Island suffered irreversible subsidence due to seismic activity, causing parts of the island to become permanently submerged underwater. Figure 208 shows water washing over an area that used to sit on sand before a 2020 earthquake lowered the ground level by 7–9 inches. Scientists attribute this rise in water level on the island to processes such as sand liquefaction and fault displacement, which drastically reduced the island's area and caused damage to infrastructure. As a result, the nature reserve remains closed to the public while the impact and recovery of the area are assessed (see Figure 209).

[744] Government of Puerto Rico, Executive Order No. OE-2020-01, https://www.lexjuris.com/ordenes/OE-2020-001.pdf.
[745] Financial Oversight and Management Board for Puerto Rico, "Statement," January 7, 2020, https://drive.google.com/file/d/1FWhHxEDMLMZcffJfwU1uHIQcJk1AtVt2/view. Note that FY2019 Emergency Reserve of $130M was fully utilized to cover costs associated with Dorian Storm and the January earthquakes. FY2020 Reserve balance as of May 8, 2020, was approximately $46.8M.

Figure 208: Gazebo in Gilligan's Island That Used to Sit on Sand[746]

Figure 209: Warning Signs on Gilligan Island, Guánica Puerto Rico

Potential Severity of Event

Puerto Rico is encircled by active seismic faults that have historically triggered powerful earthquakes, causing widespread damage. One of the most destructive secondary effects of these seismic events is liquefaction. The characteristics of soil play a crucial role in determining how vulnerable surface materials are to liquefaction.[747] Ground deformation manifestations, such as lateral spreading, sand boils, and settlement, are key indicators of severity. For planning purposes, severity can be categorized into five levels: very low, low, moderate, high, and very high. Areas classified as very high severity are expected to experience

[746] NotiCentro WapaTV, "Dramático hundimiento de la isla de Guilligan en Guánica," February 18, 2020, https://wapa.tv/noticias/locales/dram-tico-hundimiento-de-la-isla-de-guilligan-en-gu-nica/video_1b1070a3-6fa1-5163-b7e3-9dac25ab39ab.html.

[747] American Geophysical Union Fall Meeting 2021, held in New Orleans, LA, 13–17 December 2021, id. NS25C-0440.

widespread ground deformation and infrastructure failure, while low severity areas may show little to no surface evidence of liquefaction.

The severity of liquefaction events in Puerto Rico is determined by the extent of ground failure and the resulting damage to infrastructure during strong seismic shaking. In Puerto Rico, the highest severity zones are concentrated in coastal plains and river valleys, particularly in municipalities like San Juan, Bayamón, Toa Baja, Carolina, and Ponce, where young alluvial and swamp deposits with shallow groundwater increase susceptibility.[748] Although historical liquefaction events are rare, modeling and borehole data suggest that a repeat of a 1918 or 2020-type earthquake could result in severe consequences in these high-risk areas.

Probability of Future Hazard Events

Soil liquefaction can lead to significant and widespread disruptions to both infrastructure and the natural environment. Its main consequences include structural failure, ground instability, and serious environmental and economic impacts.[749] A thorough understanding of these effects is essential for engineers and urban planners to develop resilient systems and effectively reduce the risks associated with liquefaction. There are four general causes of soul liquefaction:[750]

- **Seismic activity**
  - Earthquakes are the leading cause of liquefaction. Ground shaking rearranges soil particles, reduces effective stress, and destabilizes saturated soils.
- **Saturation of soil**
  - Liquefaction requires the soil to be saturated or nearly saturated. High groundwater levels and poor drainage increase vulnerability.
- **Soil composition and properties**
  - Loose, granular soils, such as sand, are most susceptible.
  - Particle size, shape, and gradation influence soil behavior under stress.

[748] Bachhuber, J. L., et al., "Liquefaction susceptibility of the Bayamón and San Juan quadrangles, Puerto Rico" (Final Technical Report, USGS Award 03HQGR0107), U.S. Geological Survey, 2008, https://www.researchgate.net/profile/James-Hengesh/publication/302897494_Liquefaction_susceptibility_of_the_Bayamon_and_San_Juan_Quadrangles_Puerto_Rico/links/5732bf4408ae9f741b23616b/Liquefaction-susceptibility-of-the-Bayamon-and-San-Juan-Quadrangles-Puerto-Rico.pdf.

[749] Menard Innovation. "What is Soil Liquefaction? Causes, Effects and Mitigation," August 29, 2024, https://www.menard-asia.com/2024/08/29/soil-liquefaction/#:~:text=Soil%20liquefaction%20occurs%20when%20saturated,major%20concern%20in%20seismic%20zones.

[750] Menard Innovation. "What is Soil Liquefaction? Causes, Effects and Mitigation," August 29, 2024, https://www.menard-asia.com/2024/08/29/soil-liquefaction/#:~:text=Soil%20liquefaction%20occurs%20when%20saturated,major%20concern%20in%20seismic%20zones.

  - Cohesive soils (e.g., clay) are generally less prone to liquefaction.
- **Human activities and construction impacts**
  - Excavation, pile driving, and land development can disturb the soil structure.
  - Changes in drainage and groundwater levels due to construction can elevate the liquefaction risk.

Puerto Rico faces **high** probability of experiencing liquefaction in the future, especially in coastal and low-lying regions with soft, saturated soils. Although earthquake frequency and intensity are not expected to change significantly, the island's position along active tectonic plate boundaries ensures that seismic activity remains a constant threat. When strong shaking occurs in areas already saturated by increasingly frequent and intense rainfall, the likelihood of liquefaction rises sharply. This combination can lead to severe infrastructure damage, service disruptions, and heightened risk in densely populated communities

Vulnerability Assessment

Puerto Rico is **highly vulnerable to future liquefaction** events due to its geological and hydrological conditions, particularly in low-lying coastal areas and river valleys where loose, water-saturated soils are common. These soils, combined with the island's ongoing seismic activity, create conditions in which strong ground shaking can trigger liquefaction and cause significant ground instability. Infrastructure in these zones—including roads, bridges, utilities, and buildings—faces elevated risk if built on susceptible soils. Historical evidence, including impacts from the 2020 earthquake sequence, highlights these weaknesses and underscores the need for targeted mitigation measures and land-use planning to reduce future risk.

LOCATIONS

Puerto Rico is highly susceptible to seismic activity due to its location on the Puerto Rico–Virgin Islands microplate, which lies between the North American tectonic plate and the northeastern edge of the Caribbean plate. According to the USGS, this microplate is geologically active and capable of generating high-intensity earthquakes, posing a considerable risk to the region.

POPULATIONS

Populations in Puerto Rico's coastal and low-lying regions—where loose, water-saturated soils are common—face an elevated risk of damage and loss during seismic events due to liquefaction. These conditions greatly increase the likelihood of ground failure, putting affected communities at higher risk of injury and loss of life during a major earthquake.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Puerto Rico's critical infrastructure and community lifeline systems may be uniquely vulnerable to seismic hazards based on the topography and geography of the island, lacking the ability to access neighboring jurisdictional support for life-sustaining critical operations during hazard events.

PROBLEM STATEMENTS

- Critical infrastructure in liquefaction-prone zones—including roads, bridges, utilities, and emergency facilities—is at a heightened risk of damage during earthquakes. This vulnerability threatens the continuity of essential services and emergency response capabilities, especially in densely populated coastal communities.
- Populations residing in Puerto Rico's coastal and low-lying regions face elevated risks of injury and loss of life due to the potential for soil liquefaction during seismic events. Loose, water-saturated soils in these areas amplify ground shaking and may compromise structural stability, increasing the likelihood of building collapse and infrastructure failure.
- Many homes and buildings in Puerto Rico were built before modern earthquake safety standards were in place. If they have not been updated to meet the 2018 International Residential Code (IRC) or the 2018 International Building Code (IBC), they are more likely to suffer major damage in a strong earthquake and liquefaction event.
- A liquefaction event in Puerto Rico could severely disrupt critical infrastructure and community lifeline systems, such as transportation, water, power, and emergency services, particularly in areas where saturated and unstable soils increase the risk of ground failure, structural collapse, and prolonged service outages during a major earthquake.

Impact Assessment

Table 92 provides a detailed breakdown of the financial exposure of Puerto Rico's eight primary community lifelines, including communications, energy, transportation, water systems, and health services located in areas susceptible to liquefaction. The analysis includes state and local critical facilities. The combined estimated replacement cost exceeds $5.2 billion, underscoring the scale of potential losses if a major seismic event triggers widespread ground failure. This analysis highlights that liquefaction risk extends beyond residential structures to systems critical for emergency response and long-term recovery, making targeted mitigation and resilience planning imperative.

Table 92: Estimated Replacement Costs for Community Lifelines in Puerto Rico

Lifeline	Replacement Cost (Thousands)
Communications	$ 296,336,569
Energy	$ 74,781,782
Food, Shelter, Hydration	$ 204,602,605
Hazardous Materials	$ 2,773,057,617
Health and Medical	$ 686,479,085
Safety and Security	$ 917,123,745

Lifeline	Replacement Cost (Thousands)
Transportation	$ 195,564,813
Water Systems	$ 89,093,538
Grand Total	**$ 5,237,039,755**

Complementing Table 92, Figure 210 illustrates the proportional distribution of these replacement costs across lifeline sectors. This visualization emphasizes which sectors carry the greatest financial exposure, with hazardous materials and safety/security accounting for the largest shares. Furthermore, key infrastructure with higher percentages indicate sectors with greater vulnerability or more extensive damage potential, highlighting where investment, mitigation, and resilience planning may be prioritized. Thus by showing relative percentages, Figure 210 complements the absolute values in Table 94, providing a clearer understanding of sector-specific vulnerabilities and guiding prioritization for risk reduction strategies.

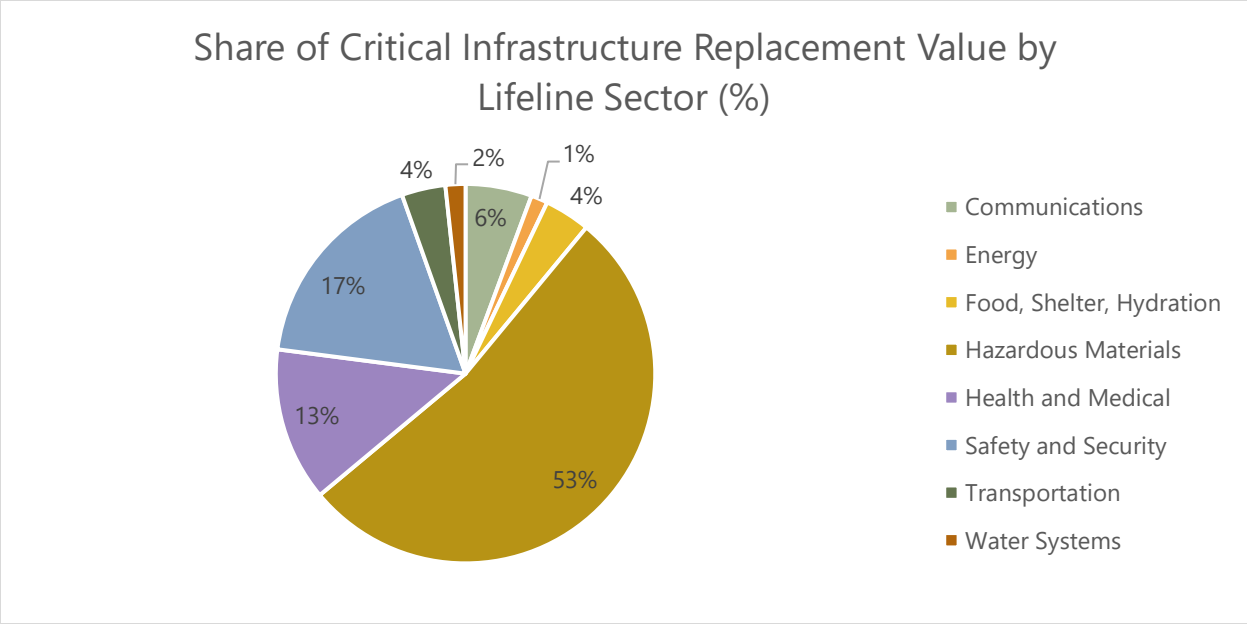


Figure 210: Share of Critical Infrastructure Replacement Value by Lifeline Sector

Building on the Puerto Rico Liquefaction Susceptibility Map (Figure 205), Figure 211, Figure 212, and Figure 213 illustrate the distribution of replacement value by building use type across zones classified as Moderate, High, and Very High liquefaction susceptibility. The map reveals that the most severe hazard bands concentrate along the island's low-lying coastal plains and major river valleys, particularly the Río Bayamón and Río La Plata corridors, where thick, loose, water-saturated sediments dominate. These geologic conditions explain why the Very High susceptibility chart shows the greatest concentration of exposure: dense clusters of urban development, port-adjacent facilities, and estuarine areas in municipalities such as San Juan, Bayamón, Toa Baja, Mayagüez, and Carolina. Here, young alluvial and swamp deposits combined with shallow groundwater amplify risk, placing both large residential stocks and significant nonresidential assets, commercial, industrial, and public facilities at stake. These same corridors also host critical lifeline infrastructure (energy, transportation, water, and communications), which further elevates potential losses.

By contrast, the High susceptibility chart reflects the next ring of development beyond these coastal cores and river mouths. These areas include extensive residential neighborhoods interspersed with schools, municipal facilities, and distributed utilities, maintaining substantial exposure even at slightly lower development density. Finally, the Moderate susceptibility chart corresponds to valley fill and alluvial fan deposits and tracts south of the coastal plain. Here, exposure is more dispersed across suburban and rural settings, producing a broader geographic footprint but lower concentrations of high-value assets per square mile.

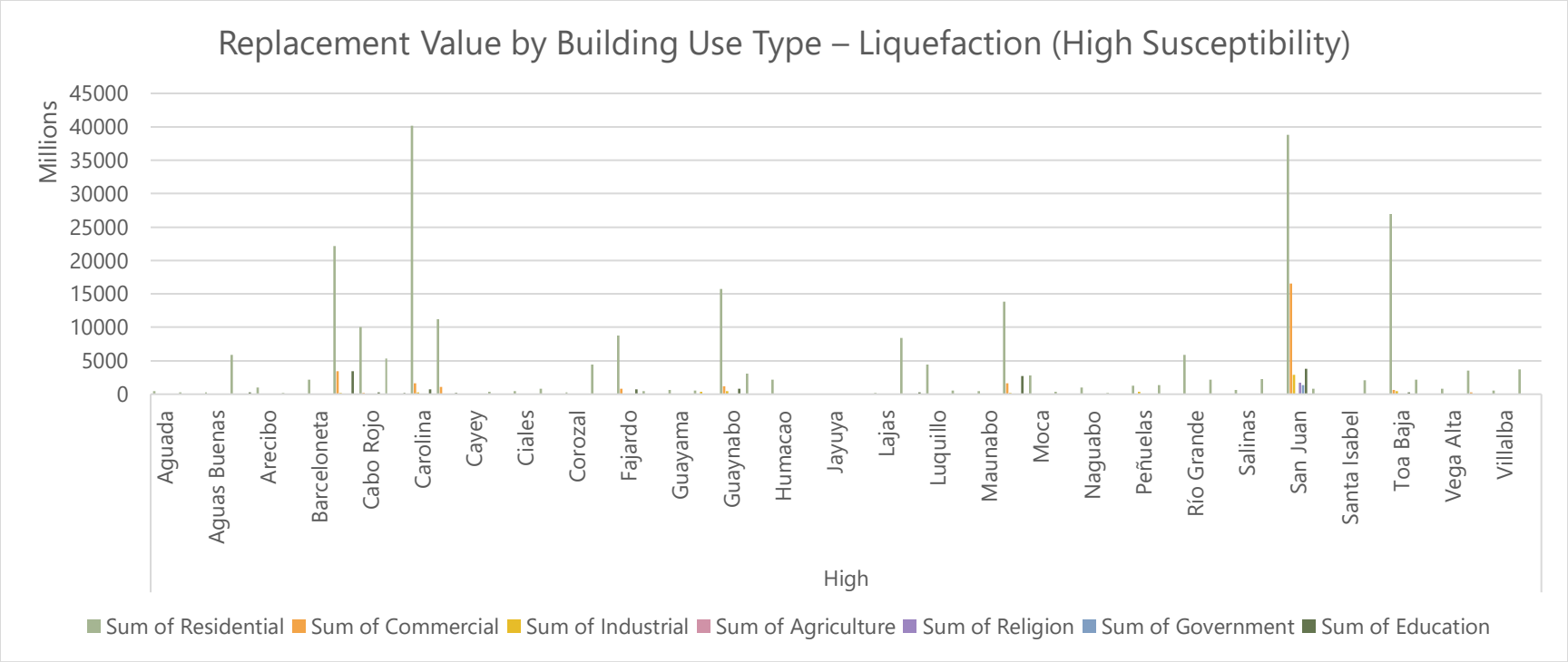


Figure 211: Distribution of Building Replacement Value in High Liquefaction Susceptibility Zones

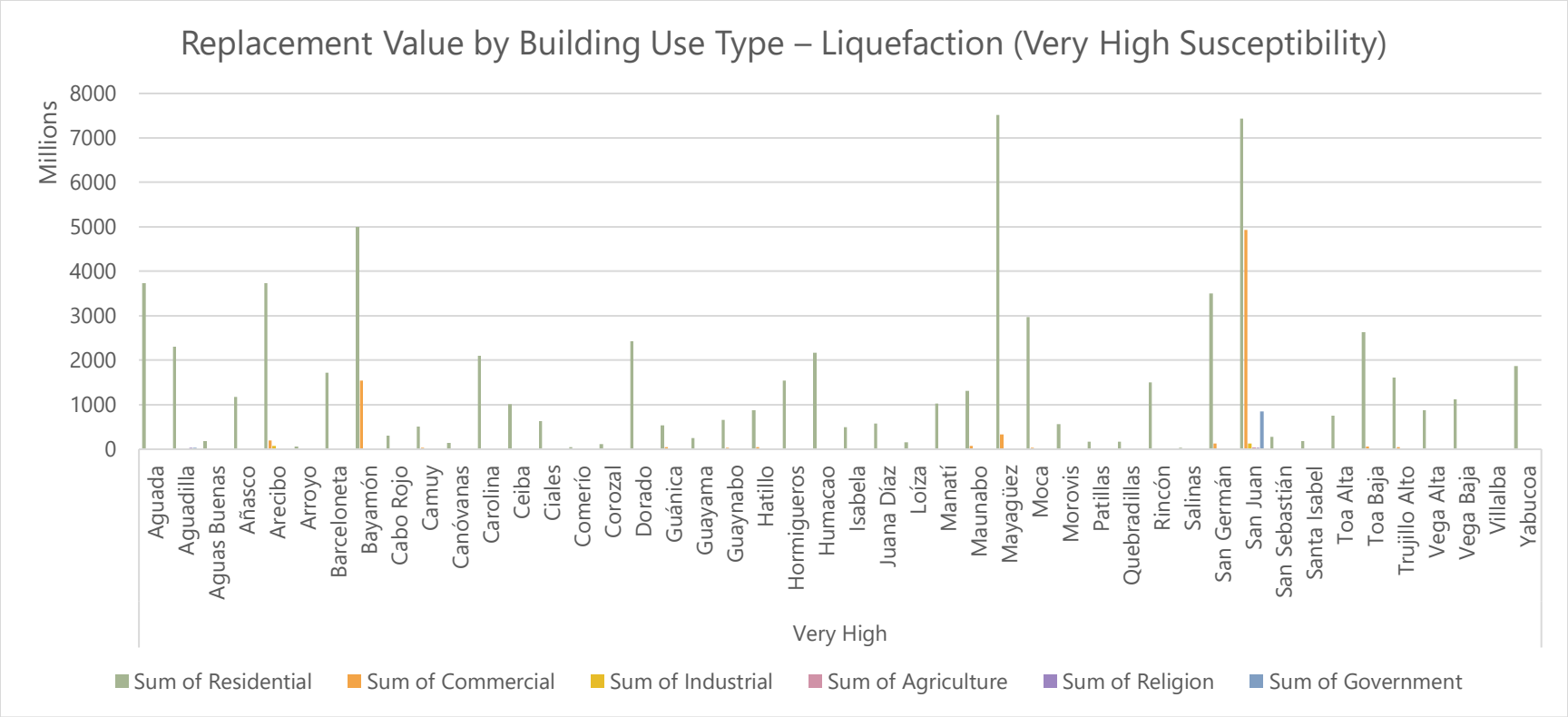


Figure 212: Distribution of Building Replacement Value in Very High Liquefaction Susceptibility Zones

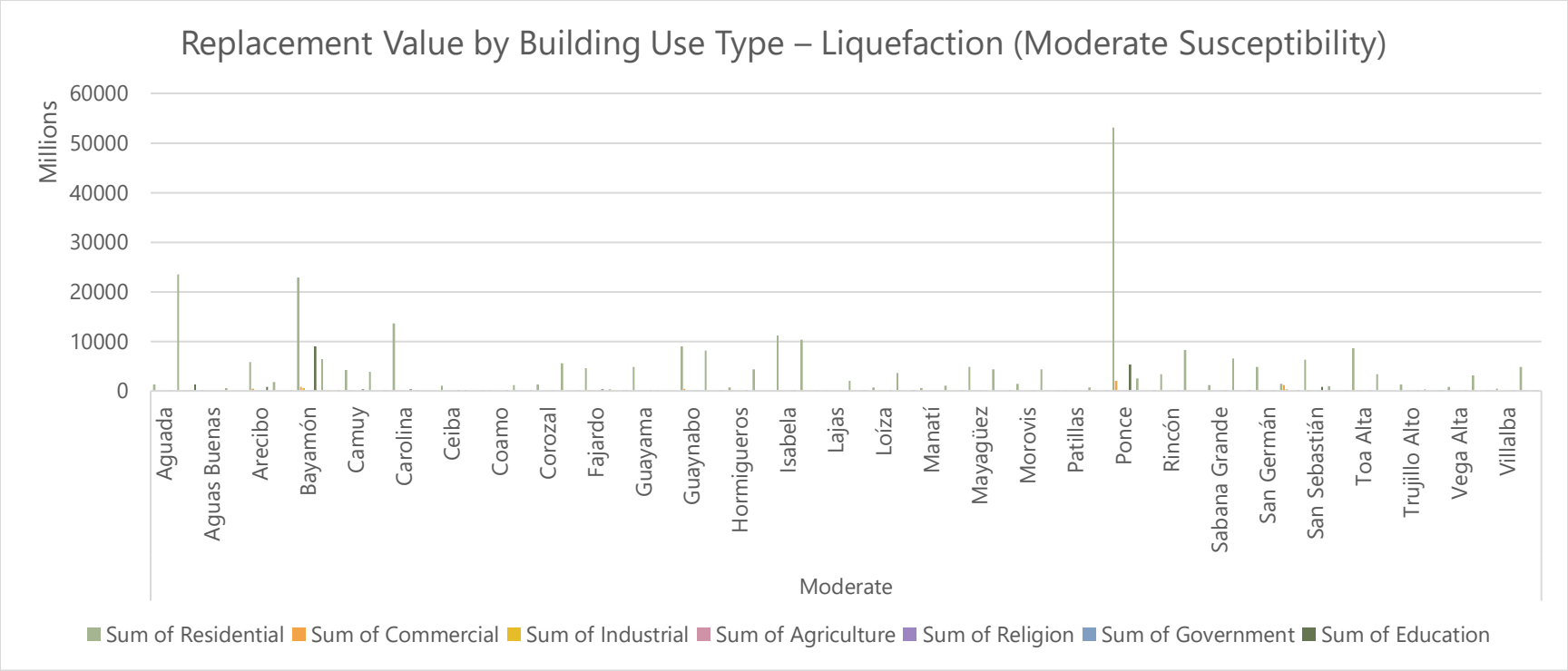


Figure 213: Distribution of Building Replacement Value in Moderate Liquefaction Susceptibility Zones

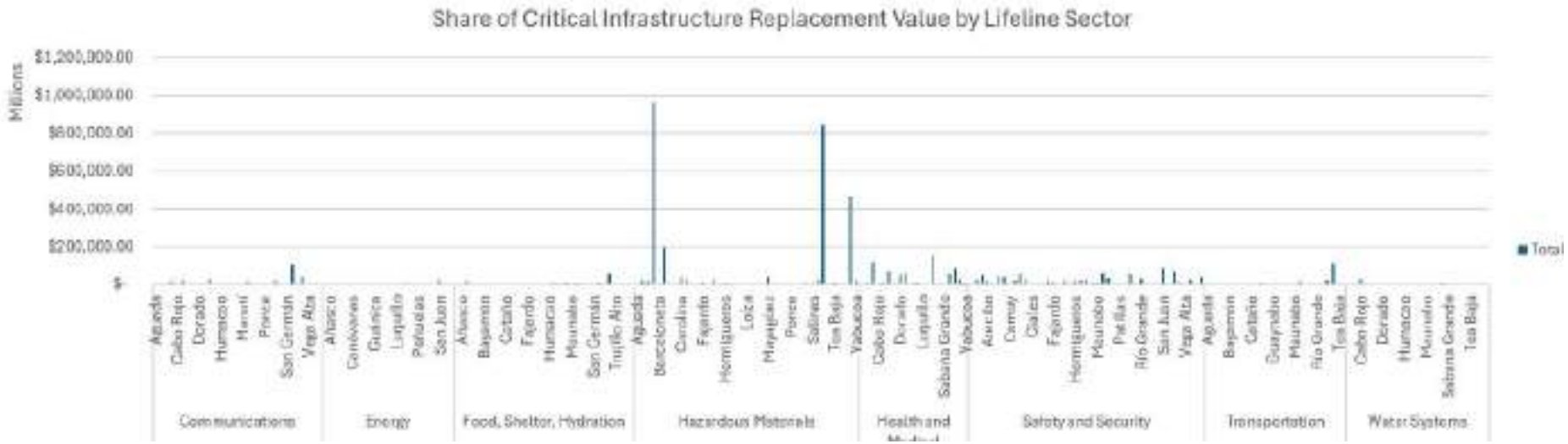


Figure 214: Share of Critical Infrastructure Replacement Value by Lifeline Sector

As part of the 2021 Puerto Rico State Hazard Mitigation Plan, earthquake risk was assessed using two GIS layers: Seismic Acceleration and Liquefaction. The analysis was based on the January 7, 2020, M 6.4 earthquake in Guayanilla. Using ArcGIS Pro, the 10 municipalities most exposed to seismic acceleration were identified based on the frequency of "Severe" and "Very Strong" categories in census tracts and the affected population. For liquefaction risk, the 10 most exposed municipalities were selected using total affected population data, as census tract frequencies did not align with actual population impact in the "Very High" liquefaction category. Those municipalities are as follows:

- Aguada
- Aguadilla
- Arecibo
- Bayamón
- Dorado
- Mayagüez
- San Germán
- San Juan
- Toa Baja
- Vega Baja

Furthermore, Table 93 illustrates the total population is susceptible to high or very high risk for liquefaction.

Table 93: Population with the Highest Liquefaction Susceptibility by Municipalities

Municipality	Population at Risk for High Liquefaction	Population at Risk for Very High Liquefaction	Grand Total
San Juan	70,365	9,090	79,455
Carolina	74,599	1,938	76,537
Toa Baja	47,497	3,544	51,041
Bayamón	29,079	3,909	32,988
Mayagüez	25,674	4,109	29,783
Cataño	22,696		22,696
Loíza	21,106	161	21,267
Fajardo	16,500	-	16,500
Cabo Rojo	13,863	189	14,052
Añasco	11,882	2,035	13,917
Dorado	6,666	4,233	10,899
Guaynabo	9,480	758	10,238
Río Grande	8,572		8,572
San Germán	3,443	4,979	8,422
Canóvanas	7,446	624	8,070
Vega Baja	6,000	2,067	8,067
Yabucoa	6,440	1,373	7,813
Arecibo	969	6,259	7,228
Hormigueros	4,579	2,061	6,640

Municipality	Population at Risk for High Liquefaction	Population at Risk for Very High Liquefaction	Grand Total
Moca	4,920	1,061	5,981
Barceloneta	3,346	1,954	5,300
Trujillo Alto	2,567	2,367	4,934
Sabana Grande	4,917		4,917
Aguada	15	4,733	4,748
Humacao	3,920	434	4,354
Luquillo	3,854		3,854
Toa Alta	2,762	711	3,473
Aguadilla	382	2,932	3,314
Maunabo	427	2,389	2,816
Rincón		1,949	1,949
Manatí	387	1,407	1,794
Vega Alta	790	881	1,671
Juana Díaz	23	1,617	1,640
Ciales	546	986	1,532
Guánica	179	1,161	1,340
Naguabo	1,182		1,182
Comerío	1,062	-	1,062
Corozal	923	16	939
Ponce	919	-	919
Isabela	-	741	741
Villalba	684	-	684
Salinas	650	-	650
San Sebastián	316	321	637
Morovis	129	454	583
Camuy		530	530
Hatillo		503	503
Patillas	234	258	492
Guayanilla	426		426
Arroyo	348	8	356

Municipality	Population at Risk for High Liquefaction	Population at Risk for Very High Liquefaction	Grand Total
Guayama	212	121	333
Aguas Buenas	68	213	281
Lajas	279		279
Cayey	179		179
Santa Isabel	25	40	65
Peñuelas	58		58
Jayuya	38		38
Ceiba	32	-	32
Quebradillas	13	-	13
Lares	-	-	-
Grand Total	**423,655**	**75,129**	**498,784**

STATE ASSETS

State assets may be vulnerable to damage if located in areas of high liquefaction susceptibility. When soil liquefies, the ground can settle unevenly, causing buildings to sink or tilt. The load-bearing capacity of soils may be reduced, leading to the failure of foundations for heavy structures. As a result, buildings can experience cracking walls, floors, and foundations, and possible structural failure. Liquefaction can also damage underground utilities such as water, gas, and sewage lines. Table 94 summarizes critical facilities potentially vulnerable to liquefaction and their total replacement value. For example, Food, Shelter, Hydration, Health and Medical, and Water Systems analyses, to name a few, were considered as part of the all critical facilities analysis shown in Figure 214 and further illustrated in Figure 215, which showcases the locations of these assets overlaid on areas susceptible to liquefaction.

Table 94: State Critical Facilities Vulnerable to Liquefaction

Community Lifeline	Count of Facilities	Total Replacement Cost
Communications	5	$5,700,466.51
Energy	1	$131,658.48
Hazardous Materials	1	$6,005,439.01
Safety and Security	1	$251,489.81
Transportation	1	$3,672,129.07
Total	**9**	**$15,761,182.89**

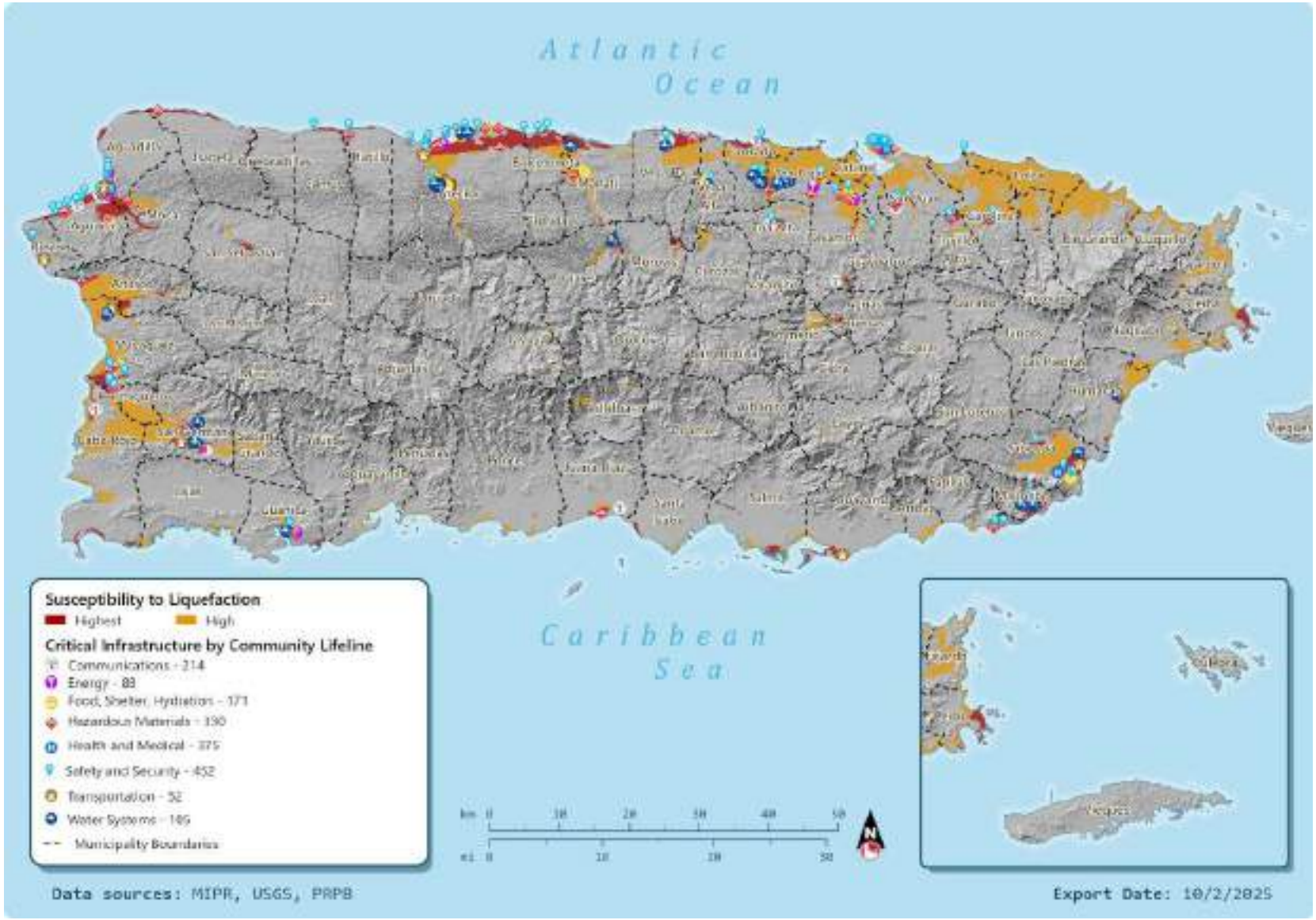


Figure 215: Critical Infrastructure with Soil Subsidence

LOCAL ASSETS

Puerto Rico's seismic vulnerability is increasingly shaped by the exposure of both state and local assets to earthquake-induced liquefaction. As urban development expands into geologically sensitive zones, the risk to critical infrastructure, residential communities, and public services intensifies. Coastal and river-adjacent municipalities, such as Arecibo, Mayagüez, Aguada, San Germán, Dorado, and San Juan, exhibit significant concentrations of assets in areas classified as high or very high liquefaction risk.

These vulnerabilities are not static; they are affected by population density (see Table 93) changes in land use, and infrastructure investment can alter the landscape of risk. For example, Mayagüez has over 16,000 structures in high-risk zones, while Aguada has more than 10,000 residents in areas with very high susceptibility. In San Juan, the historic district of Old San Juan faces the highest nonresidential losses, highlighting the threat to cultural and economic assets.

If a major seismic event were to occur, the consequences could be severe: widespread structural damage, displacement of residents, disruption of emergency services, and long-term economic losses. The estimated damage—ranging from $1.7 million in San Germán to $9.3 million in San Juan—underscores the urgent need for targeted mitigation strategies, updated land use planning, and resilient infrastructure design. Understanding and addressing these shifting vulnerabilities is essential to reduce future impacts, protect lives, and safeguard Puerto Rico's built environment.

For example, the Municipality of Cataño faces significant vulnerability to seismic hazards, with 100% of its population and residential structures exposed to risks associated with ground acceleration, liquefaction, and mass movement. This level of exposure presents a serious threat to human life, primarily due to the structural characteristics of existing buildings. Estimated structural losses could reach approximately $1.6 billion, with an additional $55 million in economic losses from service disruptions and reduced productivity. Industrial and commercial zones also are at risk, with projected structural damage totaling $28 million. Furthermore, the municipality contains roughly 3,000 meters of fuel transportation pipeline running along PR-165 to the Palo Seco power plant, representing a critical infrastructure asset that could be severely impacted in the event of a seismic event.

COMMUNITY LIFELINES

As stated in the earthquake profile, earthquake and liquefaction events pose a serious threat to the continuity of essential community lifelines. This was clearly demonstrated during the seismic events of 2019 and 2020, when earthquakes exceeding M 5.0 caused structural damage to critical infrastructure and key service facilities. There are eight primary community lifelines, each serving a distinct and indispensable role in maintaining public safety and resilience, which could be impacted by liquefaction.

SAFETY AND SECURITY

The Safety and Security Lifeline is essential before, during and after liquefaction events. This lifeline supports efforts, such as establishing roadblocks, redirecting traffic away from unstable zones, and facilitating safe evacuation routes. Beyond immediate response, it helps secure hazardous areas and maintain order during

recovery. When disrupted, due to damaged infrastructure or overwhelmed services, both emergency aid and long-term recovery can be delayed, increasing risks to affected communities.

FOOD, HYDRATION, AND SHELTER

A liquefaction event can severely disrupt access to food, clean water, and safe shelter, especially when roadways become impassable and supply chains are interrupted. In areas where liquefaction damages power lines and utility infrastructure, prolonged outages may limit access to electricity, further complicating food storage, water purification, and shelter operations. Ensuring the continuity of the food, hydration, and shelter lifeline is critical to reducing human suffering and maintaining stability during and after a liquefaction event.

HEALTH AND MEDICAL

The Health and Medical Lifeline, which ensures access to medical care and public health services, can be severely disrupted in the aftermath of a liquefaction event. Structural damage to hospitals, clinics, and emergency facilities may limit access to critical care, especially in regions where liquefaction compromises building integrity. In mountainous areas of Puerto Rico, where single access roads connect remote communities, ground failure caused by liquefaction can isolate these areas, obstructing the delivery of essential services such as medical supplies, food, and gas. These disruptions can significantly hinder the ability to treat injuries, manage public health needs, and maintain continuity of care during a crisis.

ENERGY

In Puerto Rico, the Energy Lifeline is especially vulnerable to the effects of liquefaction, a hazard that can occur during strong earthquakes due to the island's coastal and alluvial soils. Liquefaction can cause the ground to lose strength and behave like a liquid, damaging critical infrastructure, such as power lines, substations, and fuel pipelines. These disruptions can lead to widespread and prolonged power outages, especially in densely populated and low-lying areas.

COMMUNICATIONS

In Puerto Rico, the Communications Lifeline is at risk during liquefaction events. Ground failure can damage communications towers and underground cables, leading to widespread outages in cellular, landline, and internet services. These disruptions affect not only emergency response capabilities but also public access to critical information and services. Long-term impacts may include delayed recovery operations, reduced coordination among agencies, and prolonged isolation of affected communities. Strengthening infrastructure resilience is essential to ensure continuity of communications before, during, and after such events.

TRANSPORTATION

The Transportation Lifeline is essential for ensuring mobility and access to critical services, particularly during and after disaster events. In liquefaction scenarios, ground failure can severely damage roads, bridges, and ports, key infrastructure for transporting supplies, especially in island settings like Puerto Rico.

Blocked or collapsed routes can delay the delivery of food, water, and medical aid, disrupt evacuation efforts, and disrupt long-term recovery operations. Hazardous Materials.

The Hazardous Materials Lifeline includes addressing hazardous materials management. In Puerto Rico, liquefaction during an earthquake can compromise facilities that store or handle hazardous materials, especially in industrial zones and near ports. Ground instability may cause tanks, pipelines, or containment systems to rupture, leading to spills or leaks. These incidents pose serious environmental and public health risks, particularly in densely populated or ecologically sensitive areas.

WATER SYSTEMS

The Water Systems Lifeline includes freshwater reservoirs, potable water distribution infrastructure, and wastewater treatment plants. Ground failure can damage underground pipes, tanks, and treatment facilities, disrupting water distribution and sanitation services.

Changes in Development

Since the last plan update, major natural hazard events, such as hurricanes and earthquakes, have increased the vulnerability of the island's population and critical infrastructure due to liquefaction risks associated with these events (i.e., saturation of soil).

LAND USE AND BUILT ENVIRONMENT CHANGES

Although the Earthquake Profile includes references and background on seismic vulnerabilities, it is important to recognize that liquefaction is a secondary hazard triggered mostly by earthquakes. Thus, the same structural vulnerabilities and code updates apply. In Puerto Rico, while no formal database directly links building age to seismic risk, the Rapid Visual Screening method identifies age as a key factor. Structures built before 1968, when seismic design was first introduced, and 1987, when ductility and energy absorption were added to the code, are particularly vulnerable. However, even newer buildings may be at risk due to the discovery of active faults and evolving seismic hazard maps.

In response to both natural disasters and shifting demographics, Puerto Rico has updated its land use policies and building codes to increase resilience. The 2011 Puerto Rico Building Code, incorporating the 2009 I-Codes, and the 2018 Existing Building Code with seismic retrofit guidelines, aims to reduce structural failures during earthquakes and, by extension, liquefaction-related damage. These codes require site-specific assessments that include soil type and proximity to faults, both of which are critical factors in liquefaction susceptibility. Enhanced structural systems and mandatory inspections in high-risk zones further support this resilience.

In short, while these regulatory changes were designed with seismic safety in mind, they are equally critical for mitigating liquefaction impacts, given the close relationship between the two hazards.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

As Puerto Rico continues to plan for future growth and redevelopment, especially in response to population shifts and post-disaster recovery in the past several years, it is essential to consider the risks posed by liquefaction in land use and infrastructure planning. Many of the island's coastal and low-lying areas, where redevelopment is likely to occur, such as San Juan, Ponce, and Aguadilla, are also the most susceptible to liquefaction during earthquakes. As new housing, commercial developments, and critical infrastructure are built, integrating updated seismic hazard data, soil assessments, and resilient design standards will be crucial to reducing long-term vulnerability.

POPULATION CHANGES

As Puerto Rico experiences ongoing population shifts, including urban migration, coastal development, and population decline in rural areas, it is critical to consider how these trends intersect with liquefaction risk. Many of the areas seeing new or intensified development also are among the most susceptible to liquefaction during earthquakes due to loose, water-saturated soils. At the same time, depopulated inland regions may receive less investment in infrastructure upgrades, leaving older, vulnerable systems in place. These demographic changes highlight the need for targeted planning and risk-informed redevelopment that account for both seismic and liquefaction hazards to protect communities and ensure long-term resilience.

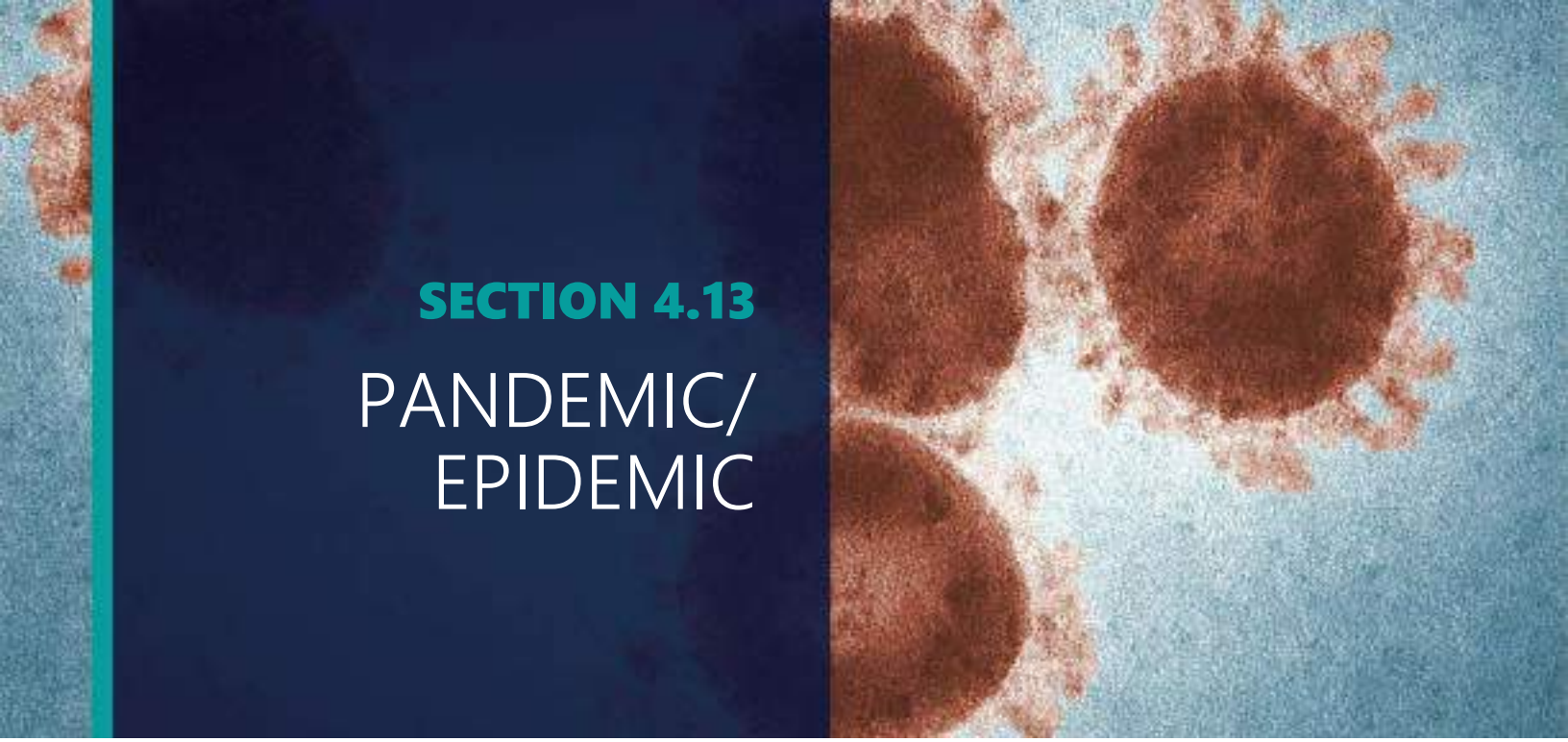
Mitigation Success Stories

MUNICIPALITY OF ARECIBO – OPERATIONAL CONTINUITY

On May 6, 2019, Arecibo's Municipal Emergency Management Office and other agencies were relocated to a shared site strategically selected to reduce exposure to natural hazards, such as extreme winds, flooding, earthquakes, liquefaction, and landslides. The aim was to enhance operational continuity and public safety by placing critical services in a more secure and accessible location. As a result of this proactive relocation, no additional mitigation work was deemed necessary for these risks, since the new site already meets the criteria for reduced vulnerability and improved resilience.

MUNICIPALITY OF ARECIBO – BARRIO ISLOTE

A new project aims to enable an alternate access route in Barrio Islote, where only one long, flood-prone road serves as both entrance and exit. This situation poses a serious risk to residents, especially during heavy rain or emergency events, as it can leave entire communities and urbanizations, such as Costas del Atlántico, isolated or with only one evacuation option. The proposed solution involves rehabilitating the old train route, which is an existing road, to serve as a safer and more reliable alternative. This initiative is critical for improving emergency response and community resilience, with an estimated investment of $7,114,500.



SECTION 4.13

PANDEMIC/ EPIDEMIC

Pandemic/Epidemic

PANDEMIC/EPIDEMIC DEFINITION

The World Health Organization (WHO) defines pandemics, epidemics, and endemic diseases based on a disease's rate of spread. Thus, the difference between an epidemic and a pandemic is not in the severity of the disease, but the degree to which it has spread.[751]

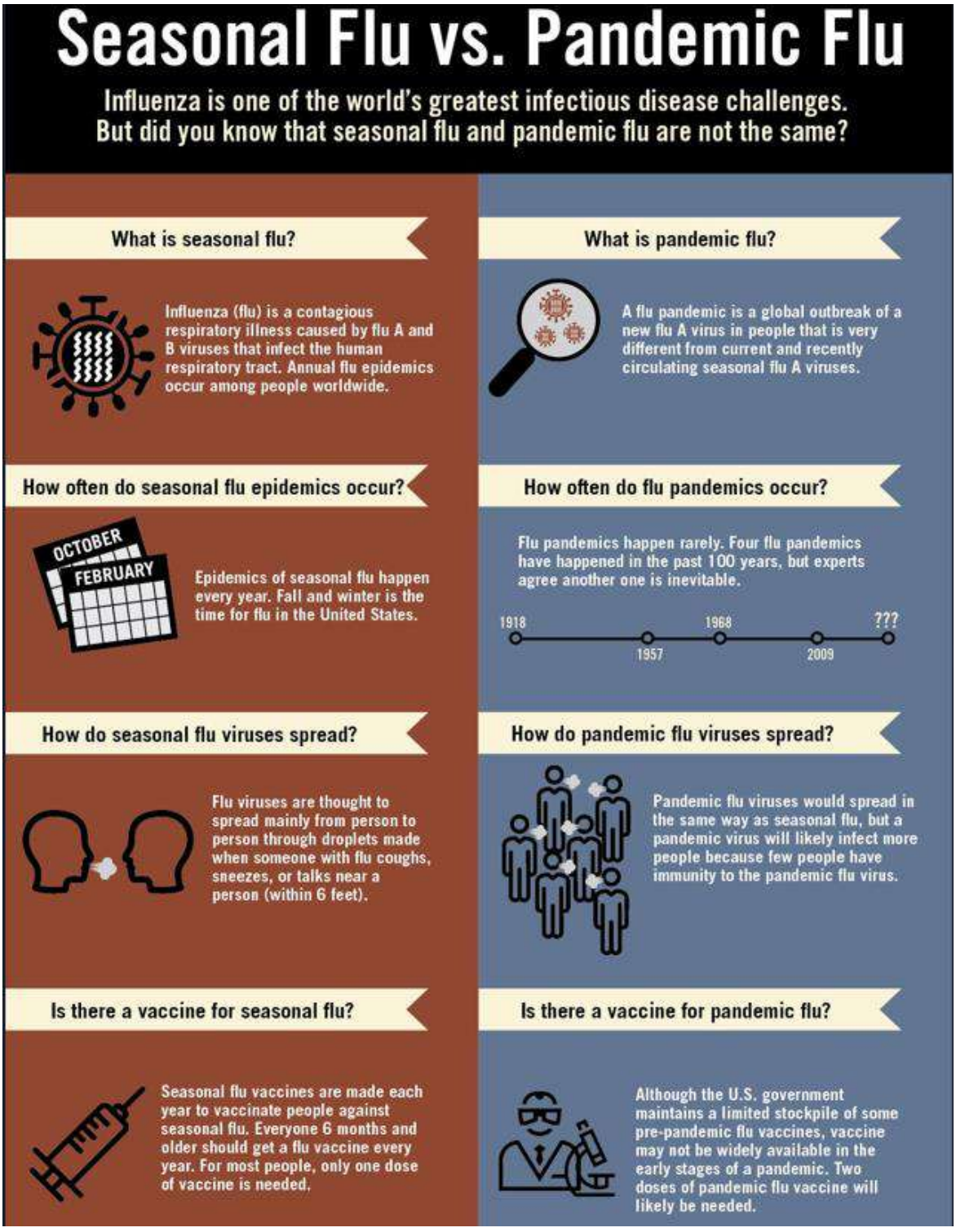
Pandemic Influenza

Pandemic influenza is a global outbreak of a new influenza A virus that is very different from current and recently circulating human seasonal influenza A viruses. New or novel influenza A viruses can emerge to cause a pandemic infecting people easily and spread from person to person in an efficient and sustained way.[752]

As new viruses evolve, immunity against the new pandemic virus is low for most humans, and there may not be vaccines widely available to reduce the spread. Many people will become sick, depending on the characteristics of the virus and depending on the levels of immunity. And as with seasonal flu, the health conditions and age of people being affected can impact susceptibility levels.[753] The Puerto Rico Department of Health is currently conducting epidemiological surveillance on COVID-19 and the data collected was

[751] Columbia University Mailman School of Public Health, "Epidemic, Endemic, Pandemic: What Are the Differences?" February 19, 2021, https://www.publichealth.columbia.edu/news/epidemic-endemic-pandemic-what-are-differences.
[752] Centers for Disease Control and Prevention, "Pandemic Flu," 2025, https://www.cdc.gov/pandemic-flu/basics/index.html.
[753] Centers for Disease Control and Prevention, "Pandemic Flu," 2025, https://www.cdc.gov/pandemic-flu/basics/index.html.

used for this hazard profile assessment. Figure 216 below provides an explanation of the differences between seasonal flu and pandemic flu.[754]



[754] Columbia University Mailman School of Public Health, "Epidemic, Endemic, Pandemic: What Are the Differences?" February 19, 2021, https://www.publichealth.columbia.edu/news/epidemic-endemic-pandemic-what-are-differences.

Figure 216: Centers for Disease Control, "Seasonal Flu vs. Pandemic Flu"[755]

Epidemic Disease

Epidemics are an unexpected increase in the number of disease cases in a specific geographical area. Examples of epidemics are yellow fever, smallpox, measles, and polio. Not all epidemics are necessarily contagious. West Nile fever and the rapid increase in obesity rates are also considered epidemics. "Epidemic" can refer to a disease or other specific health-related behavior (e.g., smoking) with rates that are clearly above the expected occurrence in a community or region.

The Puerto Rico Department of Health is currently conducting epidemiological surveillance on the following diseases: dengue, Zika virus, chikungunya, and mpox (formerly called monkeypox), and the data collected was used for this hazard profile assessment.

- The Zika virus is most commonly spread to people by the bite of an infected *Aedes* species mosquito. It can also be spread through sex from a person who is infected with Zika virus to their sexual partner(s). Zika virus can be passed from a pregnant woman to her fetus. Infection during pregnancy can cause certain birth defects. Many people infected with Zika will not have symptoms or will only have mild symptoms. The most common symptoms are fever, rash, headache, joint and muscle pain, and red eyes. Zika virus typically occurs in tropical and subtropical areas of Africa, the Americas, Southern Asia, and

[755] Centers for Disease Control and Prevention, "Seasonal Flu vs. Pandemic Flu Infographic," 2025, https://www.cdc.gov/pandemic-flu/basics/index.html.

Western Pacific. There is currently no vaccine to prevent or medicine to treat Zika.[756] Other forms of transmission were also confirmed, such as blood transfusions.[757]

- Chikungunya virus is spread to people by the bite of an infected mosquito. Outbreaks have occurred in Africa, the Americas, Asia, Europe, and islands in the Indian and Pacific Oceans. There is a risk the virus can spread to unaffected areas by infected travelers. The most common symptoms of chikungunya are fever and joint pain. Other symptoms can include headache, muscle pain, joint swelling, or rash. There are currently no medicines to treat chikungunya. The best way to prevent chikungunya is to protect against mosquito bites.[758]
- Mpox is an infectious disease that can cause a painful rash, enlarged lymph nodes, fever, headache, muscle ache, back pain, and low energy. Most people fully recover, but some get very sick.[759]

Location

A pandemic cuts across international boundaries, unlike regional epidemics. This wide geographical reach is how pandemics lead to large-scale social disruption, economic loss, and general hardship. A declared epidemic can progress into a pandemic. An epidemic is large but contained in its spread. A pandemic is international and out of control.[760]

Figure 217 below illustrates the cumulative total of COVID-19 case reported to WHO as of August 17, 2025. The legend provides the WHO Regions represented by different colors for each region.[761]

[756] Centers for Disease Control and Prevention, "About Zika," January 30, 2025, https://www.cdc.gov/zika/about/index.html.
[757] Government of Puerto Rico, Department of State, "Executive Order 2019-003," 2025, https://docs.pr.gov/files/Estado/OrdenesEjecutivas/2016/OE-2016-003.pdf.
[758] Centers for Disease Control and Prevention, "About Chikungunya," May 15, 2024, https://www.cdc.gov/chikungunya/about/index.html.
[759] World Health Organization, "Mpox," August 26, 2024, https://www.who.int/news-room/fact-sheets/detail/mpox.
[760] Columbia University Mailman School of Public Health, "Epidemic, Endemic, Pandemic: What Are the Differences?" February 19, 2021, https://www.publichealth.columbia.edu/news/epidemic-endemic-pandemic-what-are-differences.
[761] World Health Organization, "WHO Covid 19 Dashboard," 2025, https://data.who.int/dashboards/covid19/cases?n=c.

COVID-19 WORLDWIDE

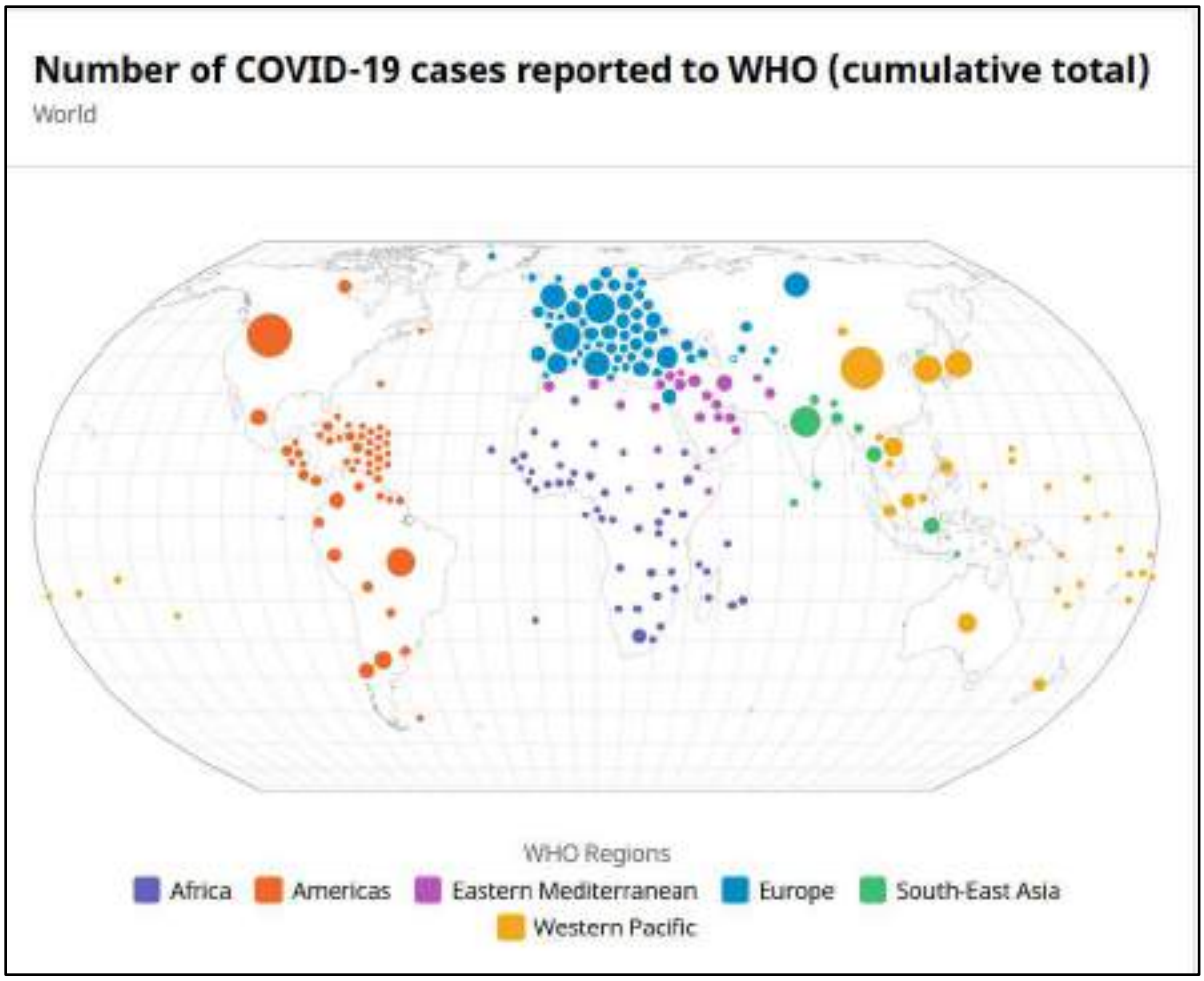


Figure 217: World Health Organization Map of Cumulative Number of COVID-19 Cases Report (August 2025)[762]

Figure 218 shows COVID-19 positivity rates, based on molecular tests, per 100,000 people by municipality during epidemiological week 30 (from July 20, 2025 through July 26, 2025). The positivity rate for all of Puerto Rico was 27% during this week.[763] The highest number of cases per 100,000 inhabitants was reported in Ciales at 227.6. and the lowest was in Loiza at 17.9. The municipality with the highest number of cases reported was San Juan, which had 105.7 cases per 100,00 inhabitants. The distribution shown in Figure 218 indicates that the number of cases per population tends to be higher in the southern municipalities.

[762] World Health Organization, "WHO Covid-19 Dashboard," 2025, https://data.who.int/dashboards/covid19/cases?n=c.
[763] Puerto Rico Department of Health, "Department of Health Executive Summary of COVID-19 Situation in Puerto Rico," September 2025, https://datos.salud.pr.gov/covid-19/publications.

Figure 218: COVID-19 Cases Per 100,000 People

On December 15, 2015, the first case of Zika virus was confirmed in Puerto Rico, followed by 22 confirmed cases of infected persons from different regions of the island.

The Puerto Rico Department of Health has reported that there have been no confirmed reported cases of Chikungunya in Puerto Rico.[764]

Table 95 presents the distribution of accumulated cases of dengue by municipality of residence for weeks 1–29, 2025. The municipalities with the larger number of reported accumulated cases for this period are San Juan with 284 cases (13.18%), Caguas with 137 cases (6.36%), Carolina with 131 cases (6.08%), Bayamon with 103 cases (4.78%), and Guaynabo with 93 cases (4.32%). Figure 219 shows the geographic distribution of these reported dengue cases.

[764] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.

Table 95: Distribution of Dengue Cases per Municipality[765]

Municipality	Frequency	Percentage
Adjuntas	14	0.65
Aguada	12	0.56
Aguadilla	18	0.84
Aguas Buenas	39	1.81
Aibonito	29	1.35
Añasco	2	0.09
Arecibo	64	2.97
Arroyo	15	0.70
Barceloneta	22	1.02
Barranquitas	24	1.11
Bayamón	103	4.78
Caba Rojo	16	0.74
Caguas	137	6.36
Camuy	11	0.51
Canóvanas	49	2.27
Carolina	131	6.08
Cataño	45	2.09
Cayey	6	0.28
Ceiba	5	0.23
Ciales	13	0.60
Cidra	17	0.79
Coamo	26	1.21
Comerio	6	0.28
Corozal	28	1.30
Dorado	41	1.90
Fajardo	26	1.21
Florida	6	0.28
Guánica	2	0.09

[765] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.

Municipality	Frequency	Percentage
Guayama	75	3.48
Guayanilla	11	0.51
Guaynabo	93	4.32
Gurabo	26	1.21
Hatillo	15	0.70
Hormigueros	3	0.14
Humacao	31	1.44
Isabela	19	0.88
Jayuya	1	0.05
Juana Díaz	10	0.46
Juncos	28	1.30
Lajas	23	1.07
Lares	25	1.16
Las Marías	3	0.14
Las Piedras	12	0.56
Loíza	24	1.11
Luquillo	4	0.19
Manatí	50	2.32
Maricao	5	0.23
Maunabo	3	0.14
Mayagüez	9	0.42
Moca	7	0.32
Morovis	10	0.46
Naguabo	12	0.56
Naranjito	11	0.51
Orocovis	2	0.09
Patillas	10	0.46
Penuelas	20	0.93
Ponce	28	1.30
Quebradillas	7	0.32
Rincón	1	0.05

Municipality	Frequency	Percentage
Río Grande	15	0.70
Sabana Grande	35	1.62
Salinas	13	0.60
San Germán	4	0.19
San Juan	284	13.18
San Lorenzo	53	2.46
San Sebastián	7	0.32
Santa Isabel	7	0.32
Toa Alta	28	1.30
Toa Baja	88	4.09
Trujillo Alto	28	1.30
Utuado	15	0.70
Vega Alta	20	0.93
Vega Baja	50	2.32
Yabucoa	13	0.60
Yauco	9	0.42
Total	**2,154**	**100.00**

Figure 219: Confirmed Cases of Dengue Fever January 1–July 2025

Previous Occurrences

FEDERAL DISASTER DECLARATIONS

COVID-19 PANDEMIC

On March 27, 2020, a major disaster was declared for the COVID-19 Pandemic in Puerto Rico (DR-4493-PR). The incident period covered COVID-19 events between January 20, 2020, and May 11, 2023. All municipalities of Puerto Rico were designated eligible for FEMA Individual Assistance and Public Assistance (Category B, Emergency Protective Measures) grant funding (see Figure 220 below).

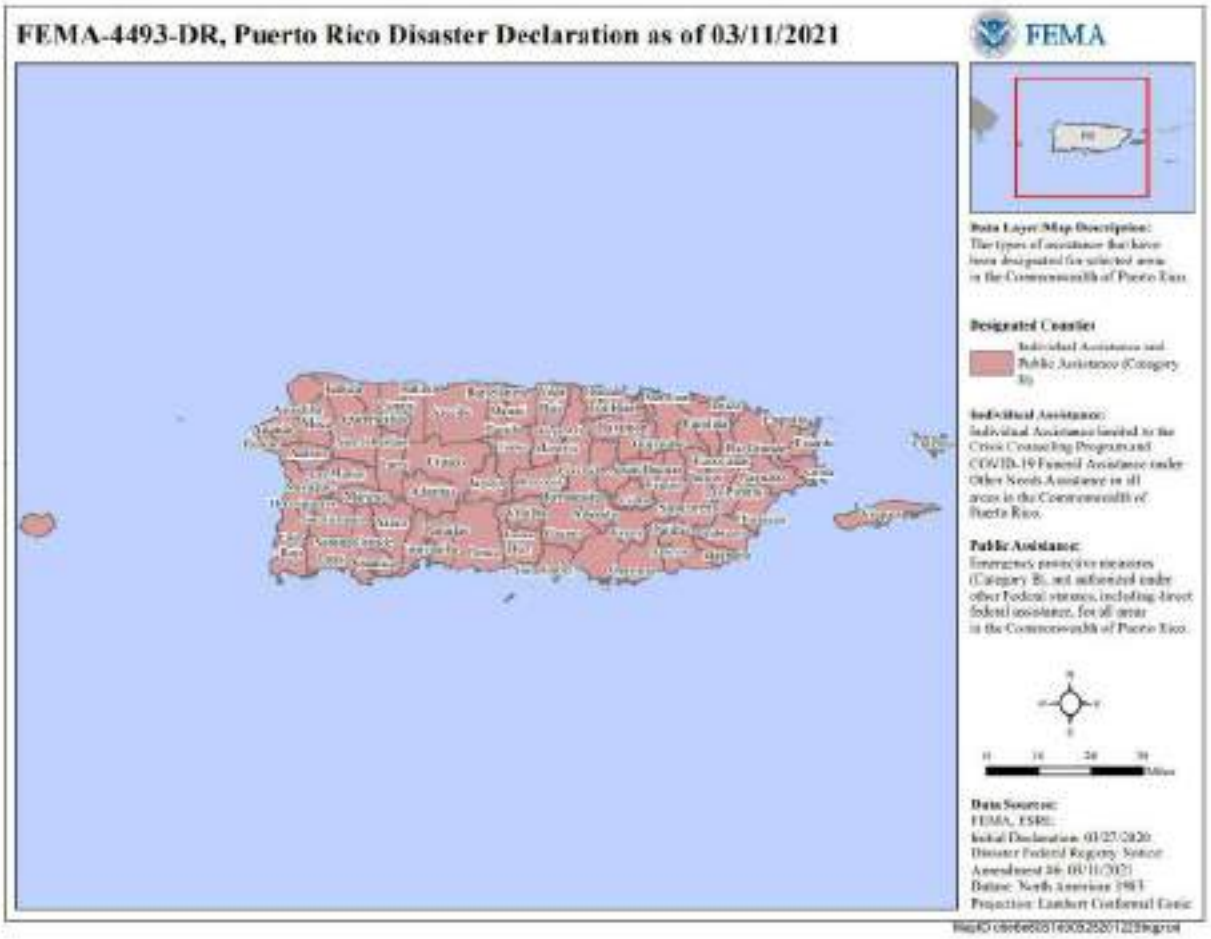


Figure 220: DR-4493 COVID-19 Pandemic in Puerto Rico Map of Designated Counties[766]

Table 96 provides information on FEMA grant funding obligations for DR-4493-PR, COVID-19 Pandemic.

Table 96: DR-4493 COVID-19 Pandemic FEMA Grant Funding Obligations[767]

Funding	Amount	Type
Total Other Needs Assistance (ONA) Dollars Approved	$10,854,159.03	Individual Assistance
Total Individuals and Households Program Dollars Approved	$10,854,159.03	Individual Assistance
Emergency Work (Category A & B) Dollars Obligated	$174,252,108.76	Public Assistance
Total Public Assistance Grants Dollars Obligated	$186,509,264.44	Public Assistance

[766] Federal Emergency Management Agency, "Disasters and Other Declarations-Puerto Rico Pandemic DR-4493," 2025, https://www.fema.gov/disaster/4493.
[767] Federal Emergency Management Agency, "Disasters and Other Declarations-Puerto Rico Pandemic DR-4493-Funding Obligations," 2025, https://www.fema.gov/disaster/4493.

PUERTO RICO DISASTER DECLARATIONS

CORONAVIRUS (COVID-19), 2020

On March 12, 2020, the Governor of Puerto Rico issued Executive Order 2020-020, which declared a state of emergency in view of the imminent impact of Coronavirus (COVID-19) on the island of Puerto Rico. A state of emergency was declared across Puerto Rico regarding the coronavirus or COVID-19 outbreak that had threatened people around the world to make all efforts and implement all measures as necessary to safeguard the health, well-being, and public security of the people to minimize the risk or avoid any situation that posed or constitute a threat to public health or safety as a result of the COVID-19 outbreak.[768]

ZIKA VIRUS, 2016

On February 5, 2016, the Governor of Puerto Rico issued Executive Order 2016-003, which declared a state of emergency due to the Zika virus, establishing the Puerto Rico Emergency Management Bureau to lead the development of a National Integrated Plan for Prevention, treatment of the disease, and other related purposes. After receiving a recommendation from the Emergency Committee, WHO decided to declare a public health emergency of international concern associated with cases of microcephaly and Guillain Barre syndrome. On December 15, 2015, the first case of Zika virus in Puerto Rico was reported.

SIGNIFICANT EVENTS

COVID-19 PUERTO RICO

Figure 221 presents a comparative view of positive COVID-19 test results in Puerto Rico over a 5-year period, segmented by test type.[769] The graph illustrates the trends in COVID-19 positive test results in Puerto Rico from 2020 to 2025, distinguishing between molecular and antigen tests. A significant surge in positive cases occurred in early 2022, with antigen tests peaking near 20,000, reflecting the widespread use of rapid diagnostics during the Omicron wave. Molecular tests also showed notable peaks, though generally lower, likely due to slower processing and more targeted application. Following the 2022 peak, both test types exhibited a steady decline, with only minor fluctuations through early 2025. Periodic resurgences in 2023 and 2024 may indicate localized outbreaks or seasonal trends.

[768] Government of Puerto Rico, Department of State, "Executive Order 2020-020," 2025, https://docs.pr.gov/files/Estado/OrdenesEjecutivas/2020/Executive%20Order%202020-020_English%204.27.20.pdf.
[769] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indica dores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.

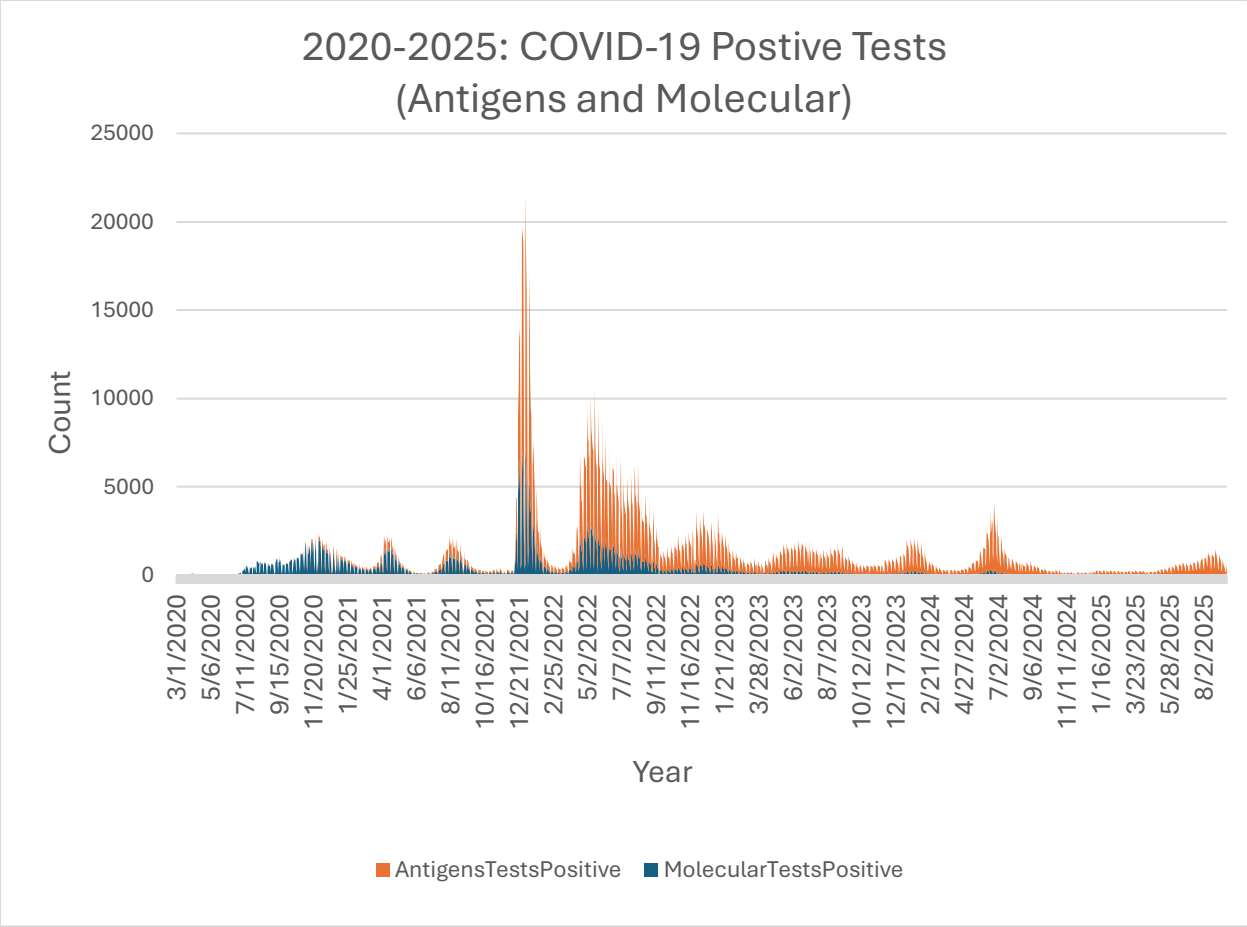


Figure 221: Puerto Rico Confirmed COVID-19 Cases (2020–2025)[770]

Between December 1, 2020, and May 31, 2025, Puerto Rico recorded a total of 244,343 hospitalizations associated with COVID-19, according to official data from the Puerto Rico Department of Health (see Figure 222). This number reflects the cumulative burden on the healthcare system over the course of the pandemic and underscores the severity of illness among affected individuals. Hospitalization trends are critical for understanding health care capacity, identifying vulnerable populations, and informing mitigation strategies.[771]

[770] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indicadores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.
[771] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indicadores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.

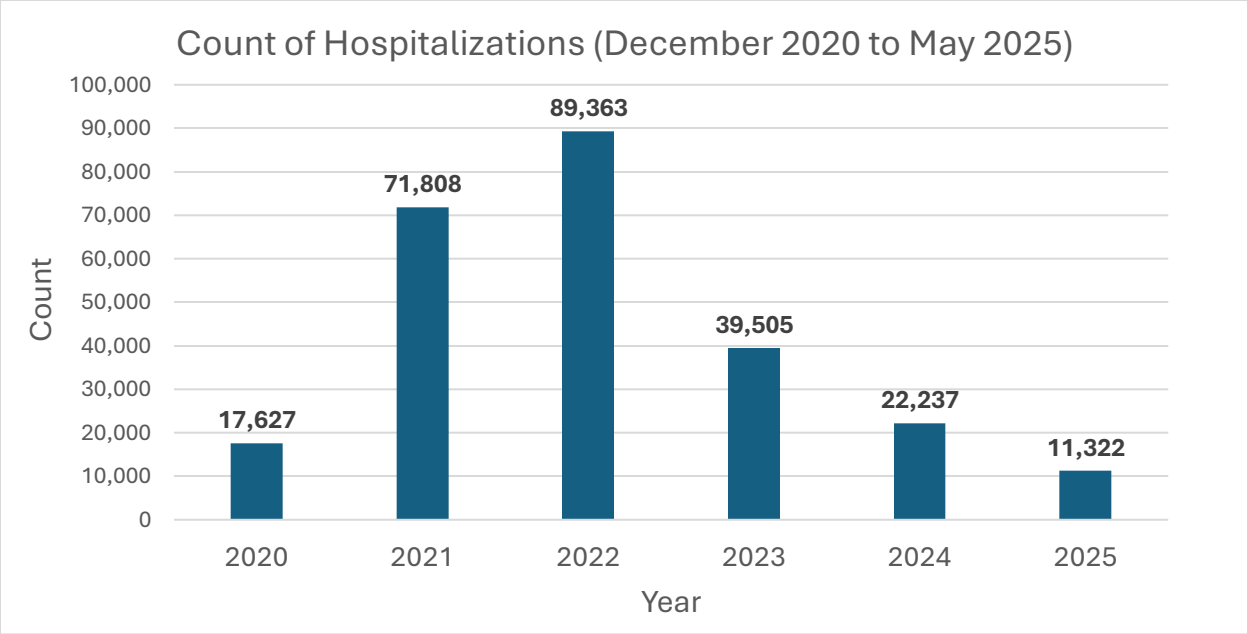


Figure 222: Puerto Rico Confirmed Hospitalizations (December 2020–May 2025)[772]

Figure 223 provides a detailed view of mortality trends associated with COVID-19 in Puerto Rico over a 5-year period. The data on COVID-19 deaths in Puerto Rico shows distinct peaks and a gradual decline over time. The initial surge occurred in November 2020 with 446 deaths, followed by another spike in January 2021 with 347 deaths, reflecting the early waves of the pandemic. The highest peak was recorded in January 2022, with 650 deaths, coinciding with the Omicron variant surge. After 2022, the number of reported deaths steadily declined, with only minor fluctuations in 2023 and 2024. By 2025, the death count appears to have stabilized at lower levels, suggesting improved disease management, increased vaccination coverage, and reduced severity of circulating variants.[773]

[772] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indicadores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.
[773] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indicadores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.

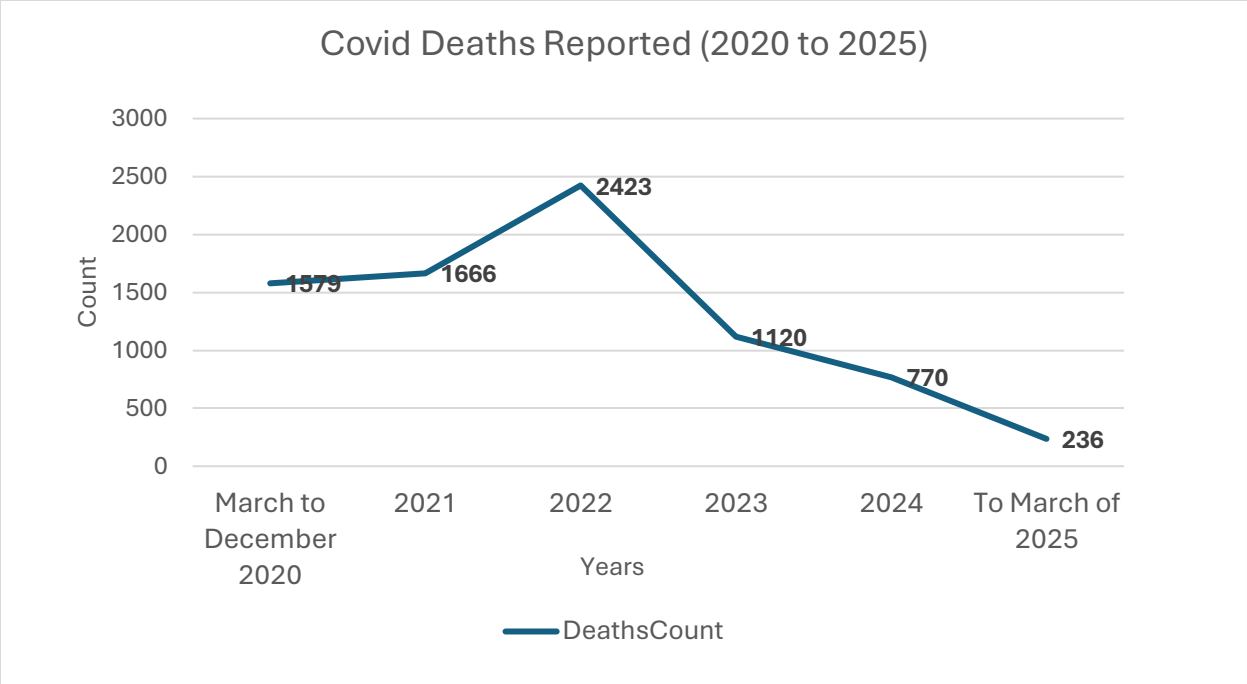


Figure 223: Puerto Rico COVID-19 Deaths Reported (2020–2025)[774]

CHIKUNGUNYA IN PUERTO RICO

The Puerto Rico Department of Health has reported there have been no confirmed reported cases of Chikungunya in Puerto Rico.[775]

DENGUE IN PUERTO RICO

The Puerto Rico Department of Health conducted surveillance of dengue cases starting in 2024 and continued to week 29 of 2025. Cases are concentrated in the regions of San Juan, Caguas, and Bayamon; therefore, the dengue emergency remains for Puerto Rico at the writing of this document. Figure 224 shows dengue reported cases with historic median and epidemic thresholds for 2024 and 2025.[776]

[774] Departamento de Salud de Puerto Rico, "Resumen ejecutivo: Situación COVID-19 en Puerto Rico – Indicadores para la semana epidemiológica número 30," 2025, https://covid19datos.salud.pr.gov/CMS/DOWNLOAD/9503.
[775] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[776] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.

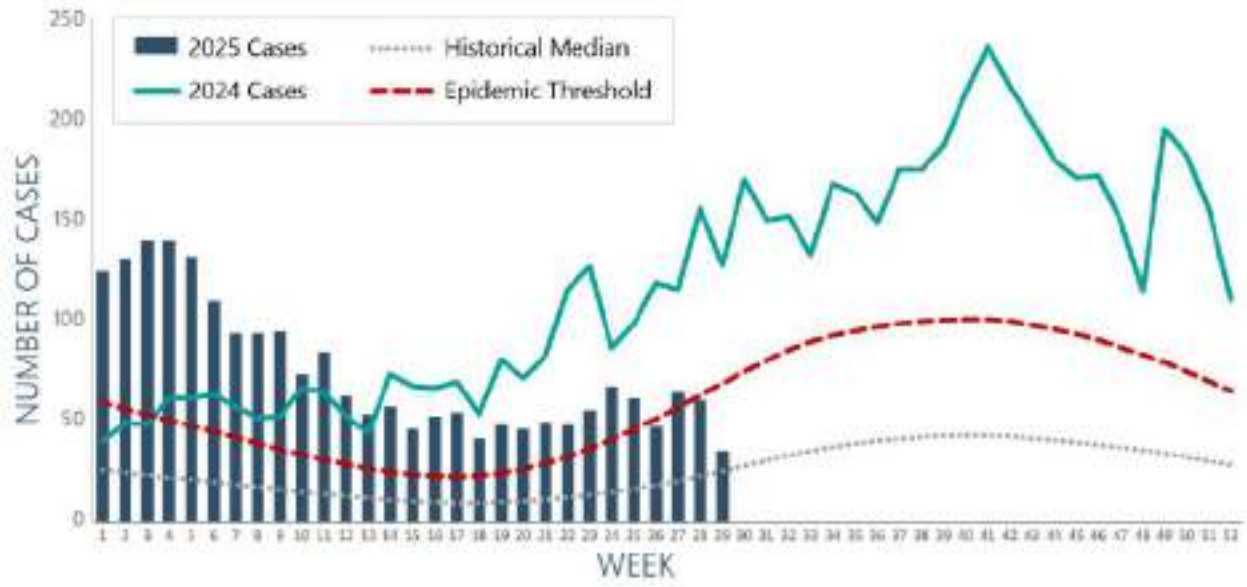


Figure 224: Dengue Cases Reported with the Historic Median and Epidemic Threshold (2024–2025)[777]

MPOX IN PUERTO RICO

On August 21, 2024, Puerto Rico Department of Health issued a warning through the Puerto Rico Health Alert Network, alerting the medical community of the WHO declaration of a Public Health Emergency of international interest because of the global mpox outbreak. In Puerto Rico, from the start of the Epidemiological Surveillance System for the mpox virus, 265 confirmed cases were registered for the *Orthopoxvirus*.[778] Figure 225 shows the distribution of confirmed Mpox cases by municipality. The highest number of cases have been in the region around San Juan and the neighboring municipalities. Most of the southern part of the island has had a moderate number of cases, and the western and northeast coastal municipalities have had a very low number of cases.

[777] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[778] Puerto Rico Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.

Figure 225: Confirmed Cases for Mpox

From January 2024, the Department of Heath of Puerto Rico categorized mpox at outbreak level 2, which is, in operational terms, the preparation and monitoring stage. It was thus classified since 83% of the confirmed cases for the month of January 2024 and 100% of the confirmed cases for the month of February 2024 did not indicate having travel history, and the transmission route mostly reported was close, prolonged, and direct contact of skin-to-skin type.[779]

Potential Severity of Event

COVID-19 CLASSIFICATION LEVELS

WHO declares a pandemic when a disease's growth is exponential. This means the growth rate increases rapidly, with daily increases in the number of cases of contraction of the virus. Being declared a pandemic

[779] Puerto Rico Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.

has nothing to do with virology, population immunity, or disease severity.[780] The following is the event severity terminology for SARS-CoV-2 (the virus that causes COVID-19) variant pandemic. [781]

- **SARS-CoV-2 PCR percent positivity**: The data presented in this section shows the volume of testing, the number of detections, and the percent positivity for SARS-CoV-2 over time from sentinel surveillance and other systematically conducted virologic surveillance.
- **Percent positivity** is calculated using the reported number of samples positive and processed for SARS-CoV-2. Number of processed samples is either provided by countries or calculated from the number of positive and negative samples.
- **Variant under monitoring (VUM)**: A term used to signal to public health authorities that a SARS-CoV-2 variant may require prioritized attention and monitoring. The main objective is to investigate if this variant may pose an additional threat to global public health.
- **COVID-19 variant:** It is usual for viruses to change and evolve as they spread between people over time. When these changes become significantly different from a previously detected virus, these new virus types are known as "variants."
- **Variant of interest (VOI)**: A SARS-CoV-2 variant with changes affecting its behavior or potential impact on human health, such as its ability to spread, cause serious disease, or respond to treatment. A VOI may also have an increased ability to spread, suggesting an emerging risk to global public health.
- **Wastewater surveillance**: Sampling and testing of wastewater to analyze and interpret results, including assessing the presence or concentration of pathogens and substances, aimed at enhancing our understanding of disease dynamics within a community.
- **Environmental surveillance**: Systematic monitoring and assessment of various aspects of the environment, including air, water, soil, and biodiversity.

The Centers for Disease Control and Prevention (CDC) established four classification levels of the community transmission level based on a 7-day positivity resulting in the following levels: low (less than 5.00%), moderate (5.00%–7.99%), substantial (8.00%–9.99%) and high (more than 10.00%).[782] Figure 226 outlines a comprehensive approach to assessing COVID-19 community levels to inform decisions about layered COVID-19 prevention strategies, including vaccination and masking, with explicit goals of reducing medically significant disease and limiting strain on the healthcare system.[783]

[780] Columbia University Mailman School of Public Health, "Epidemic, Endemic, Pandemic: What Are the Differences?" February 19, 2021, https://www.publichealth.columbia.edu/news/epidemic-endemic-pandemic-what-are-differences.
[781] World Health Organization, "WHO Covid 19 Dashboard-Reported Positivity Rates, August 2025," 2025, https://data.who.int/dashboards/covid19/summary?n=c.
[782] Centers for Disease Control and Prevention, "Science Brief: Indicators for Monitoring COVID-19 Community Levels and Making Public Health Recommendations," August 12, 2022, https://stacks.cdc.gov/view/cdc/120247.
[783] Centers for Disease Control and Prevention, "Science Brief: Indicators for Monitoring COVID-19 Community Levels and Making Public Health Recommendations," August 12, 2022, https://stacks.cdc.gov/view/cdc/120247.

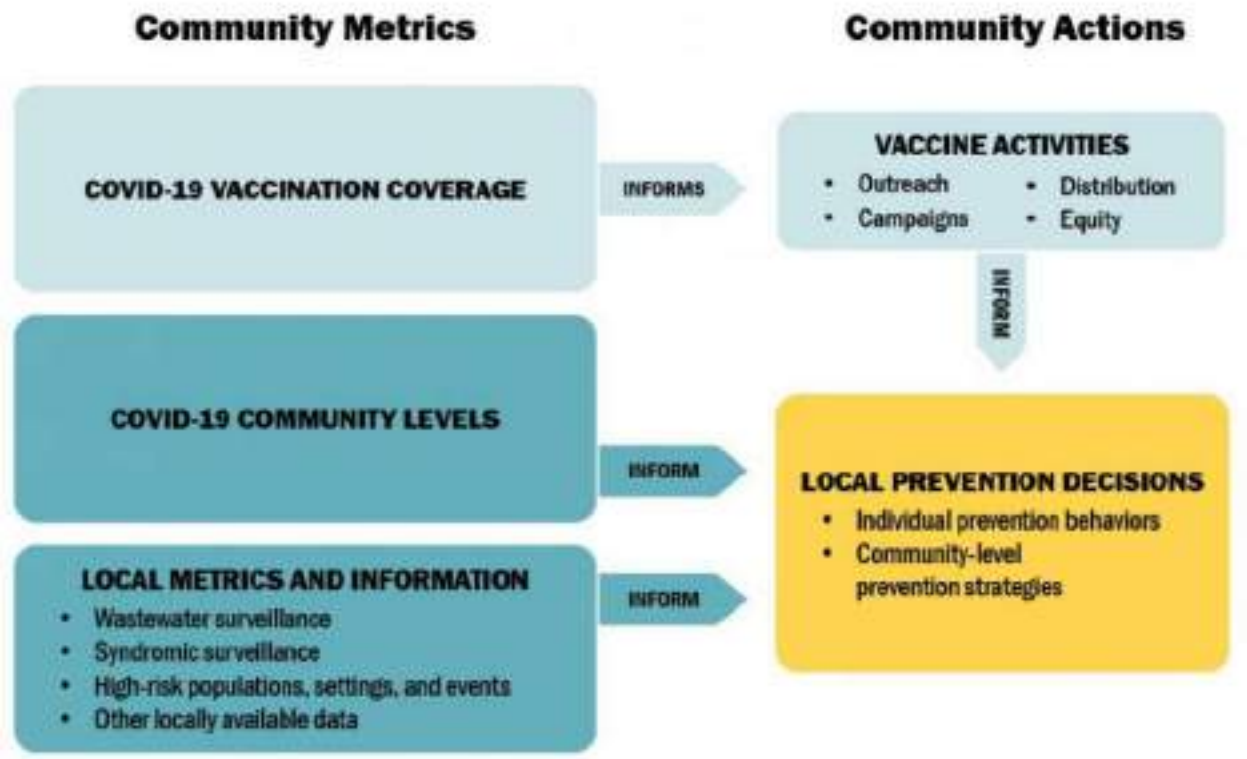


Figure 226: CDC Recommendation for Community Metrics and Community Actions[784]

MPOX CATEGORIZATION SYSTEM

The United Kingdom Health Security Agency (UKHSA) designed an outbreak categorization system to describe the potential scenarios for the transmission of mpox. This system consists of four classifications ascending in order of magnitude of transmission:[785]

- **Outbreak level 1:** There is a presence of cases imported from other countries in the jurisdiction, with a small potential of local transmission.
- **Outbreak level 2:** There already exists a local transmission scenario within a defined subpopulation.
- **Outbreak level 3:** A local transmission scenario is described within various subpopulations or one large subpopulation.
- **Outbreak level 4:** A scenario is described with significant community transmission, where the virus has the potential of remaining in the population.[786]

[784] Centers for Disease Control and Prevention, "Science Brief: Indicators for Monitoring COVID-19 Community Levels and Making Public Health Recommendations," August 12, 2022, https://stacks.cdc.gov/view/cdc/120247.
[785] Government of Puerto Rico, Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.
[786] Government of Puerto Rico, Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.

Probability of Future Hazard Events

After several hurricanes and earthquake events in Puerto Rico, the COVID-19 pandemic affected the infrastructure of the public and private health system, the economy, and daily life within each community due to the uncertainty of a novel virus, the stay-at-home order (curfew), and eventually the high levels of contagion.[787]

COVID-19 WORLDWIDE

WHO collects data from a global network of sentinel and systematic virologic surveillance sites. In the week of August 11–17, 2025, a total of 47,842 samples were tested for SARS-CoV-2, the virus that causes COVID-19, across 83 countries. Of these, 2,229 (4.7%) samples tested positive for the virus (Figure 227). During this period, SARS-CoV-2 activity was stable globally, with variations observed across some WHO regions (Figure 228). Elevated activity or increases were reported in several countries in Central America and Caribbean and Tropical South America; Southwest, Northern, and Eastern Europe; and Western, Southern, Southeast, and Eastern Asia.[788] The quality and consistency of current data are influenced by changes in health-seeking behaviors, routines in sentinel sites, national testing priorities, and capacities.[789]

WHO Region	10 Aug 2025	17 Aug 2025
World	4.4%	4.7%
Africa	1.6%	1.2%
Americas	4.5%	5.3%
Eastern Mediterranean	5.2%	4.9%
Europe	17%	19%
South-East Asia	2%	1.2%
Western Pacific	3.2%	2.5%

Figure 227: WHO Regions SARS-CoV-2 Test Positivity Rates (August 2025)[790]

[787] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.
[788] World Health Organization, "WHO Covid 19 Dashboard-Reported Positivity Rates -August 2025," 2025, https://data.who.int/dashboards/covid19/summary?n=c.
[789] World Health Organization, "WHO Covid 19 Dashboard-Definitions," 2025, https://data.who.int/dashboards/covid19/summary?n=c.
[790] World Health Organization, "WHO Covid-19 Dashboard-Reported Positivity Rates, August 2025," 2025, https://data.who.int/dashboards/covid19/summary?n=c.

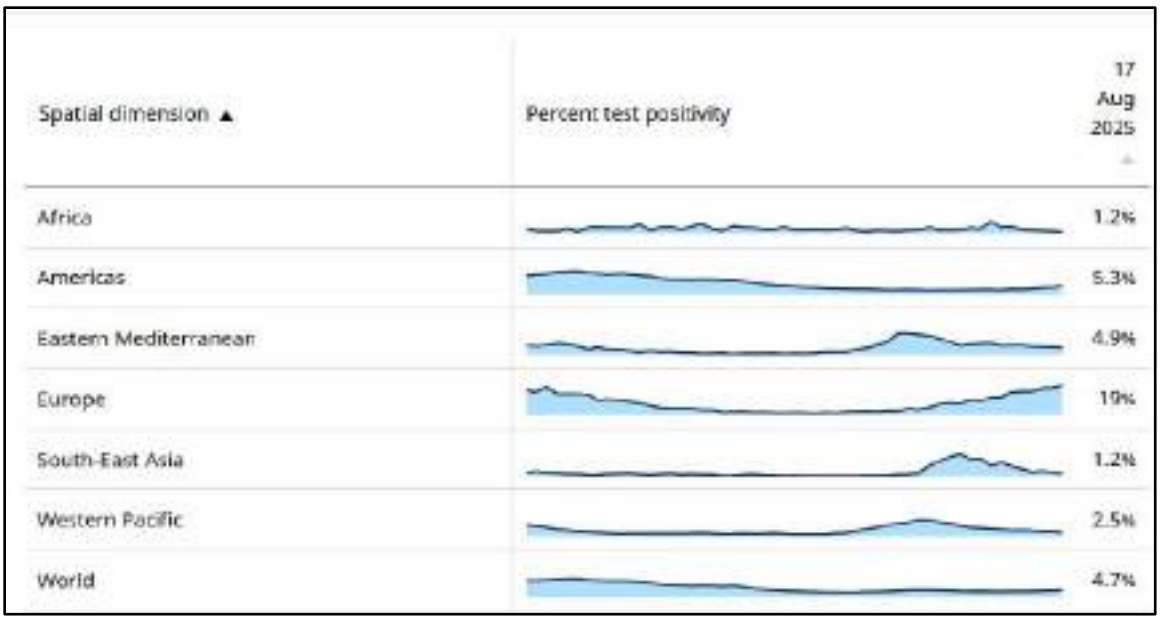


Figure 228: WHO Report of Change in SARS CoV-2 Test Positivity[791]

COVID-19 PUERTO RICO

Because Puerto Rico is vulnerable to future pandemic and epidemic events, the Puerto Rico Department of Health (PRSD), through the Office of Public Health Preparedness and Response Coordination (OPCRSP), conducts a Hazard, Vulnerability and Risk Analysis (HRVA) of the health system every 5 years to decrease vulnerability. This analysis establishes the probability of occurrence of these threats and then scores the consequences of these threats on the health system and to be able to estimate the risk. This assessment, in turn, includes the determination of the severity of the consequences considering the following impacts: human impact, interruption of key services, and impact on infrastructure and community impact.[792]

Puerto Rico Department of Health Surveillance Summary of positive COVID-19 rates for the period of April 27, 2025, to July 26, 2025, shows a trend of low positivity levels at the beginning of the period, indicating estimated positivity rate of 2.94%. The maximum positivity reached on July 23, 2025, was 28.06%. Preliminarily, Puerto Rico is in an increasing positivity trend, with the latest value estimated at 27.00% (July 26, 2025). Therefore, the community transmission level (red color) was classified as **high**.[793]

[791] World Health Organization, "WHO Covid-19 Dashboard-Reported Positivity Rates, August 2025," 2025, https://data.who.int/dashboards/covid19/summary?n=c.
[792] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.
[793] Puerto Rico Department of Health, "Department of Health Covid-19 Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.

The Threats, Vulnerability, and Risks Analysis conducted from 2018 to 2022 determined that the threats with the highest likelihood of occurrence in Puerto Rico and the greatest severity are hurricane, influenza pandemic, earthquake, arboviral epidemic, and Sahara dust/heat wave (see Figure 229).[794]

Figure 229: Probability of Occurrence and Severity of Consequences Risk Matrix[795]

DENGUE, ZIKA, CHIKUNGUNYA IN PUERTO RICO

The arboviral diseases included in the 2025 Puerto Rico Department of Health surveillance are dengue, Zika, and chikungunya. The confirmed cases are those with a molecular laboratory test (PCR) or from positive antigen (NS1 for dengue). The probable cases are those with positive serological laboratory tests (IgM).

Table 97 presents a summary of confirmed and probable cases of arboviral disease for week 29, with symptom start dates from July 16, 2025, to July 22, 2025. Table 98 summarizes accumulated arboviral diseases in 2025 with symptoms starting from January 1, 2025, to July 22, 2025. The data surveillance cutoff period closed on July 30, 2025. The data in this report is preliminary and is subject to update.[796]

Table 97: Arboviral Cases Week 29, July 2025[797]

Arbovirus	Confirmed	Probable	Total
Dengue	21	14	35
Zika	0	0	0

[794] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.
[795] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023 https://www.salud.pr.gov/CMS/597.
[796] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[797] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.

Arbovirus	Confirmed	Probable	Total
Chikungunya	0	0	0

Table 98: Arboviral Cases January 1 to July 22, 2025[798]

Arbovirus	Confirmed	Unconfirmed	Total
Dengue	1,643	511	2,154
Zika	0	0	0
Chikungunya	0	0	0

MPOX IN PUERTO RICO

Since the world outbreak of mpox caused by MPXV Clade II started in 2022, there continues to be notification of cases worldwide. Over 120 countries have reported mpox between January 2022 and August 2024, with over 100,000 laboratory-confirmed cases reported and over 220 deaths among confirmed cases. The CDC evaluated the general risk for two U.S. inhabitants, taking into consideration the possibility of contracting an mpox infection and the impact of this infection on the population. Based on this, the CDC considers that the general risk for the U.S. population is Very Low.[799]

Vulnerability Assessment

Puerto Rico is vulnerable to COVID-19 and arboviral diseases that can affect public health, medical services, and mental health systems. Influenza pandemics are uncommon, only occurred during the 20th century. Most people have little or no immunity because they have no previous exposure to the virus or similar viruses. Healthy people also may be at high risk for serious complications. An assessment of how these pandemic and epidemic diseases have the potential to generate emergencies and disasters is a fundamental exercise for the planning and preparation of Puerto Rico's health system.

LOCATIONS

Pandemic or epidemic outbreaks island-wide may have major impact on the general public, such as travel restrictions and school or business closings. Puerto Rico Department of Health regions with the highest positive percentage of COVID-19 cases in 2025 was Mayaguez and lowest percentage was Bayamon (see Figure 218). Of the 2,154 positive dengue cases, municipalities with the highest percentage of cases as of

[798] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[799] Government of Puerto Rico, Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.

July 2025 were San Juan, Caguas, and Bayamon; therefore, the dengue emergency remains for Puerto Rico (see Table 95).[800]

POPULATIONS

Some people are at higher risk of developing serious complications from influenza (flu). People at increased risk and who are not or will not be vaccinated can increase their risk of getting sick with flu and possibly being hospitalized or dying from serious flu complications.[801] Adults with certain chronic conditions are at higher risk of developing serious complications from flu. During recent flu seasons, 9 out of 10 people hospitalized with flu had at least one underlying health condition. The population 65 years and older is represented in multiple municipalities on the island, representing 50% to 85% of the population, approximately 3,203,295 people (see State Profile). Many municipalities have 25% to 100% of their population reported as having some type of disability, totaling 734,989 people (see State Profile).

INFRASTRUCTURE AND COMMUNITY LIFELINES

The function of critical infrastructure like hospitals can be affected by supply chain and personnel disruptions, and COVID-19 provides an example of the kinds of impacts that could occur during a pandemic or epidemic event. Transportation infrastructure can experience a decline in revenue due to stay-at-home orders that impose limits on passengers. Other critical infrastructure such as water systems and energy experienced a loss of revenue during the height of COVID-19 due to delinquent accounts, which diminishes capacity to improve service delivery.

The stay-at-home orders also led to the partial or total interruption of health services, the cancellation of planned treatments, the decrease in available public transportation, and the lack of key personnel. In addition, public trust in the safety of going to health care centers was eroded.[802]

There were disruptions in supply chains, as well as challenges in the distribution of medicines and health products. Telemedicine and telehealth services were implemented, strategies that helped minimize the impact of COVID-19 and improved public health, promoting physical distancing in the face of the pandemic and ensure the continuity of health care.[803]

[800] Puerto Rico Department of Health, "Department of Health Dengue, Zika, Chikungunya Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[801] Centers for Disease Control and Prevention, "People at Increased Risk of Flu Complications," 2025, https://www.cdc.gov/flu/highrisk/index.htm.
[802] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.
[803] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.

The stay-at-home orders caused a significant increase in the unemployment and poverty levels in Puerto Rico. The education system was also affected. The pandemic initially shut down classes before an eventual transition to virtual education.[804]

PROBLEM STATEMENTS

- A pandemic or epidemic outbreak could have severe impact on Puerto Rico's domestic economy, as disruptions in the imported goods supply chain can impact on the availability of basic necessities of life on the island.
- Health care providers and hospitals may become overwhelmed in areas where access to medical facilities is limited. Alternate care sites may not be available to meet public and patient needs.
- Although the U.S. government maintains a limited stockpile of pandemic vaccine, a vaccine may not be available in the early stages of a pandemic.
- The supply of antiviral medications may not be adequate to meet demand.
- Two doses of the vaccine may be needed to ensure immunity to exposure from pandemic or epidemic outbreaks. Some people may not want to undergo multiple vaccine injections over time, reducing individual and herd immunity levels.
- Pandemic and epidemic impacts can increase demand for laboratory services that may overwhelm Puerto Rico's public health system, requiring support from the CDC Lab Network.
- A lack of adequate staffing levels may impact on the Public Health Department's ability to process test samples and perform other duties.
- Puerto Rico's Public Health Department may have difficulty acquiring frontline personal protective equipment for employees to maintain safe working conditions.
- The Public Health Department may experience supply shortages (i.e., alcohol wipes, test kits, disinfectants, vaccines) that can impact the ability to provide testing.

Impact Assessment

The COVID-19 pandemic had profound and far-reaching impacts on Puerto Rico's economy, public health infrastructure, and social systems. One of the most immediate and measurable effects was the sharp rise in unemployment. Between March 16 and March 30, 2020, approximately 76,928 Puerto Ricans applied for unemployment benefits. By July 2020, the number of unemployment claims had surged to over 300,000, directly attributed to the pandemic's disruption of economic activity.[805]

[804] Puerto Rico Department of Health, "Hazard, Vulnerability and Risk Analysis," 2023, https://www.salud.pr.gov/CMS/597.
[805] American University, "The Impact of the Covid-19 Pandemic in Puerto Rico," https://www.american.edu/cas/news/catalyst/covid-19-in-puerto-rico.cfm#:~:text=Puerto%20Rico%20has%20been%20hit,Ricans%20applied%20for%20unemployment%20benefits;

The pandemic disproportionately affected service-sector workers, informal laborers, and small business owners, many of whom lacked access to financial safety nets. The tourism industry, a key economic driver, experienced near-total shutdowns, while retail, education, and healthcare sectors faced operational constraints and workforce reductions.

Public health systems were strained by the rapid increase in COVID-19 cases, hospitalizations, and deaths. The demand for medical supplies, personal protective equipment (PPE), and intensive care units (ICUs) exceeded available resources, prompting emergency procurement and federal assistance. Vulnerable populations. This included the elderly, immunocompromised individuals, and those living in congregate settings, facing heightened risks of infection and mortality. The pandemic also exposed gaps in epidemiological surveillance, data integration, and emergency response coordination. School closures, mental health challenges, and disruptions to essential services compounded the social and psychological toll on communities across the island.

STATE ASSETS

The COVID-19 pandemic exposed critical vulnerabilities in Puerto Rico's state-owned assets, particularly in public health infrastructure, correctional facilities, and government continuity systems.

HOSPITALS AND PUBLIC HEALTH INFRASTRUCTURE

Between March and July 2020, Puerto Rico reported 225 COVID-19–associated deaths, of which 83.6% occurred in hospitalized individuals, and 41.3% required mechanical ventilation. The most common contributing conditions listed on death certificates included influenza and pneumonia (48%), sepsis (28.9%), and respiratory failure (27.1%).[806] These figures reflect the strain placed on hospital systems, which faced challenges in maintaining adequate staffing, equipment, and infection control protocols.

The Puerto Rico Department of Health relied on enhanced surveillance systems, including the CDC's National Electronic Disease Surveillance System Base System, to track mortality and classify deaths as confirmed or probable. However, limitations in testing, reporting delays, and misclassification contributed to underestimation of COVID-19–related deaths. CDC estimates suggest that up to 638 deaths may have occurred during this period, 413 more than originally reported, indicating significant gaps in public health data infrastructure.[807]

CORRECTIONAL FACILITIES AND CONGREGATE SETTINGS

Federal guidance from the CDC and DOJ emphasized the importance of infection control in correctional facilities and among law enforcement personnel. To maintain continuity of operations, critical infrastructure workers, including officers in correctional settings, were permitted to continue working after potential

New York Times, "Pandemic Plunges Puerto Rico into Yet Another Dire Emergency," https://www.nytimes.com/2020/07/08/us/coronavirus-puerto-rico-economy-unemployment.html.

[806] Polytechnic University: Vulnerability Assessment of Puerto Rico's Health Department Webserver https://prcr.cobimet.org/server/api/core/bitstreams/f6636e3b-ef91-4db9-9277-cbc01416cb80/content.

[807] Azofeifa, A., et al. (2021). Estimating and characterizing COVID-19 deaths, Puerto Rico, March–July 2020. *Public Health Reports, 136*(3), 354–360. https://doi.org/10.1177/0033354921991521.

exposure, provided they remained asymptomatic and followed strict protocols such as daily temperature checks, mask usage, and social distancing.[808]

GOVERNMENT CONTINUITY AND TELEWORK INFRASTRUCTURE

The shift to remote work during the pandemic required rapid adaptation across government agencies. The Cybersecurity and Infrastructure Security Agency (CISA) issued extensive guidance to support secure telework practices for state, local, tribal, and territorial governments. Key vulnerabilities included: 1. Inadequate cybersecurity training and awareness among staff., 2. Increased exposure to phishing and ransomware attacks due to expanded attack surfaces., and 3. Limited access to secure networks and devices, especially in rural or under-resourced areas.[809] CISA recommended the use of multi-factor authentication, encrypted communications, and secure home network configurations to mitigate risks. Despite these efforts, the pandemic underscored the need for long-term investment in digital infrastructure and cybersecurity resilience across Puerto Rico's public sector.

LOCAL ASSETS

Local assets across Puerto Rico played a vital role in pandemic response and community resilience. Municipal health clinics, nonprofit organizations, and community-based groups provided essential services such as testing, vaccination, food distribution, and mental health support.

Many municipalities leveraged local emergency management offices to coordinate logistics, disseminate public health information, and support vulnerable populations. However, disparities in funding, staffing, and infrastructure capacity created uneven response capabilities across jurisdictions. Local schools and educational institutions adapted to remote learning with varying degrees of success, depending on internet access, device availability, and digital literacy. Faith-based organizations and mutual aid networks emerged as critical support systems, especially in rural and underserved areas.

COMMUNITY LIFELINES

Human infectious diseases can greatly impact several community lifelines, primarily in the following sectors.

SAFETY AND SECURITY

Infectious disease outbreaks can substantially strain public health resources and impact law enforcement and emergency services, leading to challenges in maintaining public safety and order. The repercussions of outbreaks can be felt across various sectors, making it vital to address these interconnected issues comprehensively.

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[808] Browne, E. E., et al. (Eds.). (2025). Law Enforcement Officer Exposure to COVID-19 U.S. Department of Justice. https://portal.cops.usdoj.gov/resourcecenter/RIC/Publications/cops-w0434-pub.pdf; National Center for Immunization and Respiratory Diseases (U.S.), Influenza Division. (2020). *Interim guidance for businesses and employers to plan and respond to coronavirus disease 2019 (COVID-19), May 2020: Plan, prepare and respond to coronavirus disease 2019*. Centers for Disease Control and Prevention. https://stacks.cdc.gov/view/cdc/88409.

[809] Cybersecurity and Infrastructure Security Agency, "Telework guidance and resources," U.S. Department of Homeland Security. https://www.cisa.gov/topics/risk-management/coronavirus/telework-guidance-and-resources.

FOOD, HYDRATION, AND SHELTER

Disruptions in the supply chain due to quarantines or outbreaks can affect food distribution and access to clean water, thereby impacting individuals' basic needs for food, hydration, and shelter. Additionally, there may be an increased demand for shelters for those needing isolation or care, further straining community resources.

HEALTH AND MEDICAL

The health and medical sector is perhaps the most directly affected, as outbreaks can overwhelm health care systems, lead to increased mortality rates, and disrupt health services. The pressure on hospitals and clinics can hinder care for non-infectious issues, compounding the primary effects of the disease.

ENERGY

The energy sector can also be impacted by the effects of infectious disease outbreaks. The workforce responsible for maintaining energy supplies and infrastructure may be severely impacted, leading to potential shortages or disruptions in energy availability, which can affect other critical services.

COMMUNICATIONS

Effective communication during outbreaks is crucial for disseminating public health announcements and safety guidance. A well-coordinated communication strategy is essential to counter misinformation, maintain public trust, and ensure order. Any reduction in qualified communications staffing can impede critical and timely public crisis communication.

TRANSPORTATION

Transportation networks can face significant disruptions due to movement-related restrictions stemming from quarantine measures or fear of contagion. These interruptions can hinder the delivery of goods and impact access to healthcare services, potentially exacerbating the crisis.

HAZARDOUS MATERIALS

The management of hazardous materials becomes a pressing concern during outbreaks. In some cases, such as in the transport of contaminated waste and the treatment of infected individuals, there is a need to handle biohazardous materials, and this poses additional challenges to public health and safety efforts.

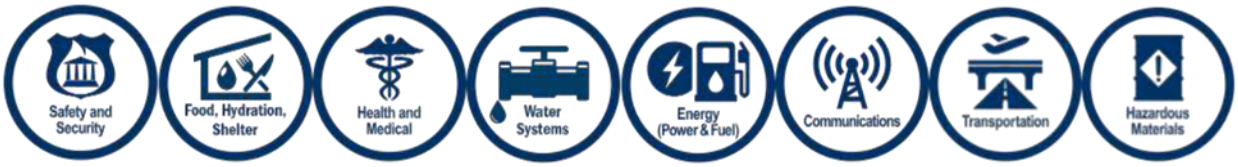


Figure 230: FEMA Community Lifelines

Changes in Development

Puerto Rico has had changes in development as it relates to human infectious disease, including population changes impacting exposure rates and public health legislation related to epidemiological surveillance. Information related to those changes in development and identifying how they impact vulnerability to human infectious diseases follows.

ADMINISTRATIVE ORDER 597

On October 22, 2024, the Puerto Rico Department of Health enacted Administrative Order 597 (AO 597), to improve epidemiological surveillance in Puerto Rico. AO 597 facilitates efficient data capture to improve epidemiological surveillance, develop more effective communication strategies for the community, and strengthen the research component.[810] Puerto Rico Department of Health administration provides these resources to positively impact vulnerability to pandemic and epidemic cases across the island.

Under AO 597, all health care professionals, hospitals, health care facilities, laboratories, state institutions, and other places that provide health services must report to the Department of Health the diseases, conditions, and health events, including the positive, negative, and suspected laboratory test results associated with them.[811] This improvement to Puerto Rico's human infectious disease public health initiative has **decreased vulnerability**.

POPULATION CHANGES

The 2024 U.S. Census estimates the population of Puerto Rico at approximately 3,203,295, indicating a decrease in population from 3,285,874 in 2020, or approximately 2.5% decrease over a 4-year period.[812] Since 2017, Puerto Rico has experience population reduction directly linked to patterns of outmigration, as Puerto Ricans moved to the mainland United States following Hurricane Maria in 2017.[813] However, decades of increase in urban sprawl in over 40% of the island has **increased vulnerability.** There has also been a large decrease in population for people ages 65 and older, with only 24% of the population in this age range in 2023.[814] In 2020, there were 726,148 people 65 and older, compared to the current population count of 432,281.[815] Overall population decrease and the decrease in population age 65 and older has **decreased vulnerability to that population** to pandemic and epidemic in Puerto Rico.

[810] Government of Puerto Rico, Department of Health, "Surveillance Summary-Improving Epidemiological Surveillance," 2025, https://www.salud.pr.gov/CMS/496.
[811] Government of Puerto Rico, Department of Health, "Surveillance Summary-Administrative Order 597," 2025, https://www.salud.pr.gov/CMS/DOWNLOAD/9388.
[812] U.S. Census Bureau, "Quick Facts Puerto Rico," https://www.census.gov/quickfacts/fact/table/PR/PST045224.
[813] Federal Reserve Bank of New York, "The Causes and Consequences of Puerto Rico's Declining Population," https://www.newyorkfed.org/medialibrary/media/research/current_issues/ci20-4.pdf.
[814] U.S. Census Bureau (2023), "American Community Survey 1-Year Estimates," 2023 http://censusreporter.org/profiles/04000US72-puerto-rico.
[815] U.S. Census Bureau, "Puerto Rico Commonwealth Population by Characteristics: 2020–2024," https://www.census.gov/data/tables/time-series/demo/popest/2020s-detail-puerto-rico.html.

Mitigation Success Stories

PUERTO RICO DEPARTMENT OF HEALTH BIOPORTAL ELECTRONIC REPORTING SYSTEM

Over the past 5 years, the Puerto Rico Department of Health has implemented several mitigation strategies to reduce the risk of pandemic and epidemic exposure to the public. One such initiative is the introduction of its BioPortal electronic system, the main tool for reporting diseases and conditions. This portal is exclusive to health care providers and must be used via website.[816] This portal allows for a more agile and efficient notification process, facilitating the collection and analysis of crucial data for epidemiological surveillance and public health protection.[817]

During the period of April 20, 2025, to July 19, 2025, a total of 104 home tests were registered on the BioPortal platform.[818] Of these, 86 (82.69%) were positive COVID-19 home tests. The next step in the process is to provide a referral to all positive cases to have a diagnostic test performed to verify the findings, preferably a molecular test, administered by a health professional. A 21.15% (n=22) of the home tests were followed by a diagnostic test with an average interval of 1.64 days between the home and diagnostic test. From the home tests that resulted positive, 80.95% showed a positive result in the laboratory evaluation and 19.05% a negative result. During this period, there were no home tests with negative results that were submitted to follow up with laboratory tests.[819]

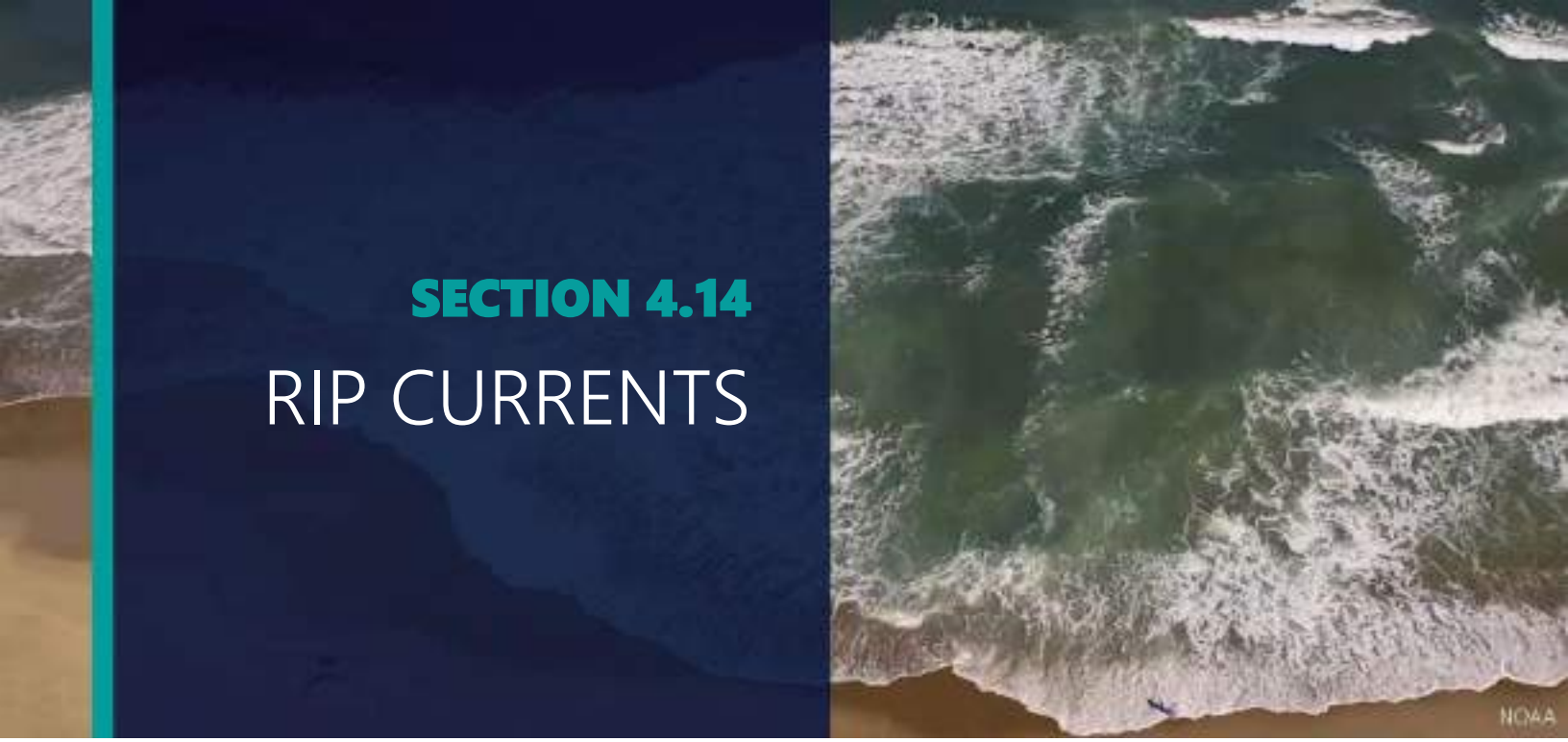
MPOX SURVEILLANCE SYSTEM

On August 4, 2022, the federal government issued a public health emergency declaration in order to coordinate national efforts, and ended the emergency declaration on January 31, 2023. However, in May 2022, Puerto Rico Department of Health developed a response to the outbreak in Puerto Rico and continue to focus on early detection, prevention (e.g., vaccination strategies for close contacts and high-risk populations), treatment (for the eligible population), and public education (e.g., health providers, general community, school community, among others) to mitigate the impact of the disease. One mitigation strategy is its mpox surveillance system. The mpox surveillance system investigates cases of mpox, a disease transmitted by direct contact, identifying outbreaks and at-risk populations to contribute to prevention and control (see Figure 231).[820]

[816] https://bioportal.salud.pr.gov.
[817] Government of Puerto Rico, Department of Health, "Surveillance Summary-Implementation of the BioPortal," 2005, https://www.salud.pr.gov/CMS/496.
[818] https://bioportal.salud.pr.gov/covid-19/self-tests.
[819] Puerto Rico Department of Health, "Department of Health Covid-19 Surveillance Summary," July 2025, https://www.salud.pr.gov/CMS/496.
[820] Government of Puerto Rico, Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.

Figure 231: Puerto Rico Department of Health Mpox Surveillance System[821]

[821] Government of Puerto Rico, Department of Health, "Monkey Pox Surveillance System (Mpox)," 2025, https://www.salud.pr.gov/CMS/379.



SECTION 4.14

RIP CURRENTS

Rip Currents

RIP CURRENTS DEFINITION

Rip currents are strong, narrow, seaward flows of water that extend from close to the shoreline to outside of the surf zone. They are found on almost any beach with breaking waves and act as "rivers of the sea," moving sand, marine organisms, and other material offshore.[822]

Rip currents are caused by the interaction of breaking waves and the shape of the shoreline or underwater features. When waves break strongly in some locations and weakly in others, water can be funneled back out to sea in narrow, fast-moving channels. These currents are often formed under the following conditions[823]:

- Wave action pushing water toward the shore
- Presence of topographical features like sandbars, piers, or jetties that channel the water
- Sudden changes in wave height or direction, which can create flash rip currents

[822] National Weather Service, National Oceanic and Atmospheric Administration, "Rip Current Science," https://www.weather.gov/safety/ripcurrent-science.
[823] National Weather Service, National Oceanic and Atmospheric Administration, "Rip Current Science," https://www.weather.gov/safety/ripcurrent-science.

Figure 232: Example of Rip Currents

Rip currents typically form on beaches with breaking waves, where water pushed toward the shore by incoming waves must return to the sea. This return flow concentrates in narrow, fast-moving channels, creating rip currents as shown in Figure 233, which illustrates surf zone and offshore exchange via exiting flow (left) and re-circulation within the surf zone (right). These currents often occur near sandbars, piers, or jetties, which help funnel the water seaward. Structurally, a rip current consists of three main parts: the feeder, where water accumulates near the shore; the neck, the narrow, fast-moving channel flowing away from the beach; and the head, where the current dissipates beyond the surf zone. Circulation patterns around rip currents can include adjacent areas of onshore flow and rotational eddies, creating complex and sometimes hazardous swimming conditions. These currents act like underwater rivers, transporting sand, marine life, and debris offshore, and pose a serious hazard to swimmers due to their strength and unpredictability.

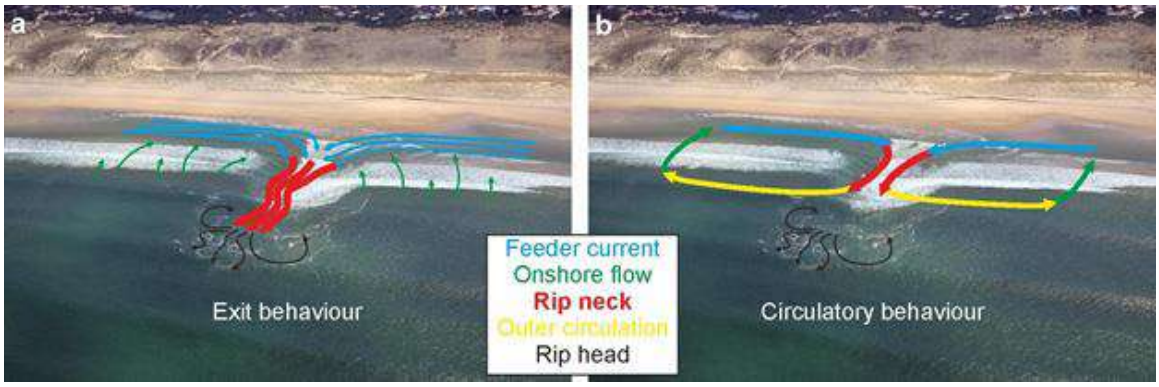


Figure 233: Structure of Rip Currents and Circulation Patterns

Rip currents pose a significant hazard to swimmers and beachgoers because they can quickly pull people away from shore, often faster than a person can swim. Further, they are not always visible, making them hard to detect. These danger conditions are responsible for many surf zone fatalities and rescues a year.

Location

Figure 234 shows the distribution of rip current-related fatalities across Puerto Rico from 2020 to 2024, with a total of 97 deaths. Most fatalities occurred in the northern part of the island, indicating that rip currents are present along the entire coastline.[824]

The distribution shows a significant gender disparity: 80 men versus 17 women. Additionally, based on the available data, March has the highest number of reported deaths (25), followed by September (15) and November (11). The other months show low, single-digit figures.[825]

[824] National Weather Service, National Oceanic and Atmospheric Administration, "Rip Current Science," https://www.weather.gov/safety/ripcurrent-science.
[825] National Oceanic and Atmospheric Administration, "NOAA Dam Safety Dashboard," ArcGIS Online, https://noaa.maps.arcgis.com/apps/dashboards/60d29733f7e44d49a25cfe1178ea6798.

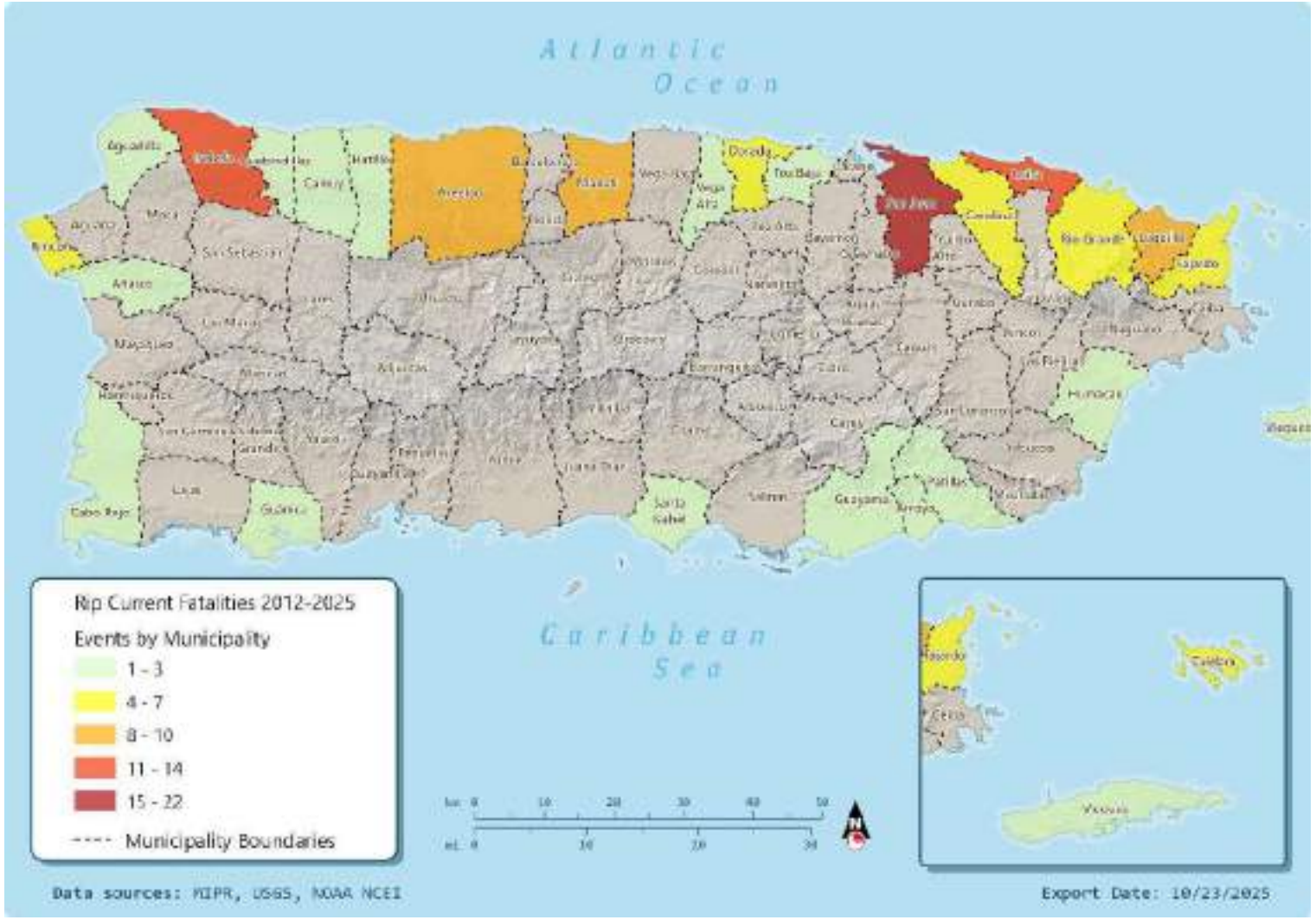


Figure 234: Rip Currents fatalities from 2020 to 2024[826]

[826] National Oceanic and Atmospheric Administration, "NOAA Dam Safety Dashboard," ArcGIS Online, https://noaa.maps.arcgis.com/apps/dashboards/60d29733f7e44d49a25cfe1178ea6798.

Previous Occurrences

Table 99 presents the monthly distribution of rip current-related fatalities in Puerto Rico from 2020 to 2024, totaling 97 deaths. The data reveals a distinct seasonal pattern, with March showing the highest number of fatalities (25), followed by September (15) and November (13). These peaks may correspond to periods of increased beach activity and changing ocean conditions, such as stronger swells or transitional weather patterns that intensify rip current formation. most fatalities occurred along the northern coast, indicating that rip currents are not only present but particularly hazardous in that region. This aligns with the National Weather Service (NWS) designation of high rip current risk areas in northern, northwestern, and northeastern Puerto Rico, including Culebra and the U.S. Virgin Islands.

Table 99: Monthly Distribution of Rip Current-Related Fatalities in Puerto Rico from 2020 to 2024

Month of Occurrence	Number of Deaths
January	6
February	7
March	25
April	4
May	5
June	3
July	4
August	4
September	15
October	6
November	13
December	5

FEDERAL DISASTER DECLARATIONS

There is no federal declaration related to rip currents in Puerto Rico to date.

PUERTO RICO DISASTER DECLARATIONS

To date, there are no disaster declarations in Puerto Rico specifically related to rip currents.

SIGNIFICANT EVENTS

SEPTEMBER 9, 2024, TOURIST MISSING IN RIP CURRENTS AT CONDADO BEACH

A 22-year-old American woman from Indianapolis went missing on Sunday night while swimming off Condado Beach in San Juan, Puerto Rico. She was with two friends when all three were caught in strong rip currents. Bystanders and authorities rescued the two friends, but the woman was found dead. The U.S. Coast Guard led the search with multiple aircraft and a boat, in coordination with local emergency services.[827]

AUGUST 25, 2025 – HURRICANE ERIN RIP CURRENT DEATHS

Three people died in separate incidents along Puerto Rico's northern coast due to dangerous rip currents and rough surf conditions. The U.S. Coast Guard responded to four rescue cases on, with one person found near Chatarra Beach, another swept away off Kikita Beach in Dorado, and a third found unresponsive in Manatí. Additionally, four surfers in distress were rescued safely.[828]

These hazardous conditions are linked to Hurricane Erin, which intensified to a Category 5 storm, bringing life-threatening rip currents, high surf (up to 15 feet), coastal flooding, and beach erosion. NWS issued warnings for Puerto Rico and the U.S. Virgin Islands, advising swimmers and boaters to avoid the water due to ongoing risks.

OCTOBER 16, 2025 – LIFE-THREATENING RIP CURRENTS

Powerful northerly swells are forecast to build seas to 6–8 feet offshore, with breaking waves of 10–15 feet along coastlines.[829]

These swells lead to life-threatening rip currents from Friday, October 17, 2025, into the early days of the following week.

NWS warns of the following:

- The highest risk period is Sunday, October 19, 2025, through Tuesday, October 21, 2025.
- Beachgoers and boaters are urged to avoid entering rough surf and stay alert for changing conditions.

[827] M. Deliso, "Search Underway for American Tourist Who Got Caught in Rip Current Off Puerto Rico Beach. *ABC News*, September 9, 2024, https://abcnews.com/US/missing-american-tourist-puerto-rico-rip-currents-search/story?id=113518438.
[828] E. Speck, "3 Killed in Rough Surf, Rip Currents in Puerto Rico as Dangerous Coastal Conditions Continue," *FOX Weather,* August 25, 2025, https://www.foxweather.com.
[829] J. Daley, "NWS Expects Unsettled Weather, Rough Seas for USVI and Puerto Rico; NHC Monitoring Tropical Wave," *Virgin Islands Source*, October 16, 2025, https://stthomassource.com/content/2025/10/16/nws-expects-unsettled-weather-rough-seas-for-usvi-and-puerto-rico-nhc-monitoring-tropical-wave/.

Potential Severity of Event

In Puerto Rico, NWS uses several alert levels to communicate the risk of rip currents and related coastal hazards. These alerts are part of broader Hazardous Weather Outlooks and Rip Current Statements, and they vary based on severity and expected impact:

- **Moderate Rip Current Risk**
  - Description: Life-threatening rip currents are possible, especially in the surf zone.
  - Areas Affected: Typically, northern and eastern Puerto Rico, including Culebra.
  - Advice: Beachgoers should exercise caution, especially near piers, jetties, and channels.
- **High Rip Current Risk**
  - Description: Life-threatening rip currents are likely.
  - Areas Affected: Northern, northwestern, and northeastern Puerto Rico, Culebra, and US Virgin Islands.
  - Impacts:
    - Can sweep even strong swimmers into deeper water.
    - Dangerous swimming conditions.
  - Advice: Avoid entering the water. Heed lifeguard warnings and beach flags.

Both types of rip current risks can occur around communities in Puerto Rico.

Probability of Future Hazard Events

Table 100 illustrates the regional risk levels for rip current hazards across Puerto Rico, derived from the number of reported fatalities between 2020 and 2024. The northern region experienced the highest concentration of deaths, with 80 out of 97 fatalities occurring there, indicating a significantly elevated risk. In contrast, the southern, eastern, and western regions reported fewer incidents, aligning with a moderate risk designation.

This matrix is informed by both historical fatality data (Figure 234 and Table 99) and NWS hazard outlooks, which consistently identify northern Puerto Rico—including Culebra and nearby coastal areas—as high-risk zones for rip currents.

Table 100: Rip Current Hazard Probability of Occurrence Matrix for Puerto Rico by Region

Region	Probability of Future Hazard Events	Risk Level
Northern	High	High
Southern	Moderate	Moderate
Eastern	Moderate	Moderate

Region	Probability of Future Hazard Events	Risk Level
Western	Moderate	Moderate

Vulnerability Assessment

Table 101 presents the vulnerability matrix for rip current hazards in Puerto Rico, highlighting the top four month-region combinations based on seasonal exposure and hazard conditions. This assessment is informed by fatality data. Vulnerability levels are determined by factors such as tourism intensity and hurricane season impacts, which increase the likelihood of hazardous conditions and human exposure.[830]

For example, March in the northern region is identified as having high vulnerability due to elevated tourism during spring break, while August, September, and November show moderate vulnerability in other regions due to rough surf and transitional weather patterns associated with hurricane season.

Table 101: Rip Current Vulnerability Matrix by Month and Region in Puerto Rico

Month	Region	Vulnerability Level	Reason
March	Northern	High	High tourism exposure during spring break season
September	Eastern	Moderate	Increased beach activity and start of hurricane season
November	Western	Moderate	Transitional weather patterns and moderate tourism
August	Northern	Moderate	Peak hurricane season with rough surf conditions

LOCATION

Based on Table 101, Northern Puerto Rico in March shows the highest vulnerability, primarily due to increased tourism during spring break, which raises human exposure to hazardous surf conditions.

Eastern Puerto Rico in September, Western Puerto Rico in November, and Northern Puerto Rico in August: These combinations are marked as moderately vulnerable, influenced by seasonal weather patterns, hurricane activity, and moderate tourism.

POPULATION

The population most vulnerable to rip currents are tourists, as vulnerability levels are closely tied to periods of high beach attendance and recreational use. This is especially evident in the northern region during peak tourism months like March.

[830] National Oceanic and Atmospheric Administration, "Rip Current Dashboard," NOAA ArcGIS Online, https://noaa.maps.arcgis.com/apps/dashboards/60d29733f7e44d49a25cfe1178ea6798.

STRUCTURES INCLUDING CRITICAL FACILITIES

Because rip currents are classified as a low-scale impact hazard that primarily affects human safety, particularly swimmers and tourists, they are not expected to cause damage to infrastructure. Critical infrastructure is not considered vulnerable to rip current hazards in either state or local contexts.

INFRASTRUCTURE AND COMMUNITY LIFELINES

There are no community lifelines currently identified as being affected by rip currents.

Impact Assessment

Table 102 presents the Impact/Risk Matrix for rip current hazards across Puerto Rico, combining regional hazard probability and vulnerability levels to assess overall risk. This evaluation is based on documented fatality data, seasonal exposure patterns, and National Weather Service hazard.

The matrix concludes that the northern region faces a high impact/risk level, due to both elevated hazard probability and vulnerability—particularly during high-tourism months like March. In contrast, the southern, eastern, and western regions are assessed as having moderate impact/risk levels, reflecting consistent but less severe exposure and hazard conditions.

Table 102: Rip Current Impact/Risk Matrix by Region in Puerto Rico

Region	Probability of Future Hazard Events	Vulnerability Level	Impact/Risk Level
Northern	High	High	High
Southern	Moderate	Moderate	Moderate
Eastern	Moderate	Moderate	Moderate
Western	Moderate	Moderate	Moderate

Reducing the impact of rip currents begins with strong public education and awareness efforts. Teaching beachgoers how to recognize rip currents and respond effectively is critical. Campaigns often emphasize the "Flip, Float, and Follow" method, which encourages individuals caught in a rip current to flip onto their back to float, conserve energy, and follow the current until it weakens before swimming parallel to the shore. Additionally, placing warning signs, flags, and lifeguards at high-risk beaches helps prevent accidents and ensures rapid response when incidents occur. Designating safe swimming zones away from piers and jetties also minimizes exposure to dangerous currents.[831]

Forecasting and real-time alerts play a vital role in mitigating rip current hazards. NWS issues Rip Current Statements and High Surf Advisories based on wave height, wind direction, and other oceanographic data. These alerts inform the public when conditions are dangerous, allowing individuals to make safer choices.

[831] National Weather Service, National Oceanic and Atmospheric Administration, "Rip Current Science," https://www.weather.gov/safety/ripcurrent-science.

Behavioral recommendations—such as avoiding swimming alone, staying out of the water during high surf, and never fighting the current—further reduce risk. Together, these strategies form a comprehensive approach to protecting lives and enhancing coastal safety.

STATE ASSETS

No state assets have been identified as being affected by rip currents.

LOCAL ASSETS

No local assets have been identified as being affected by rip currents.

COMMUNITY LIFELINES

Community lifelines are essential services that enable the continuous functioning of critical government and societal operations. Because rip currents are considered a low-impact hazard that primarily affects human safety, particularly among tourists, they do not possess the intensity or magnitude necessary to damage FEMA-designated community lifelines. As such, the probability that rip currents could cause system disruptions to transportation, communications, food supply, energy, health and medical services, hazardous materials management, or water systems at the state or local level is extremely low.

SAFETY AND SECURITY

No Safety and Security Lifelines have been identified as being affected by rip currents.

FOOD, HYDRATION, AND SHELTER

No Food, Hydration, and Shelter Lifelines have been identified as being affected by rip currents.

HEALTH AND MEDICAL

No Health And Medical Lifelines have been identified as being affected by rip currents.

ENERGY

No Energy Lifelines have been identified as being affected by rip currents.

COMMUNICATIONS

No Communications Lifelines have been identified as being affected by rip currents.

TRANSPORTATION

No Transportation Lifelines have been identified as being affected by rip currents.

HAZARDOUS MATERIALS

No Hazardous Materials Lifelines have been identified as being affected by rip currents.

WATER SYSTEMS

No Water Systems Lifelines have been identified as being affected by rip currents.

Changes in Development

Rip currents are a coastal hazard that occur exclusively along beaches, driven by oceanographic and topographic conditions rather than inland development. As such, changes in land use or built environment across Puerto Rico have not significantly influenced the vulnerability to rip currents over the past five years. There have been no notable development changes—such as new construction, population shifts, or redevelopment—that have increased the risk of rip current exposure.

Instead, the most effective strategies for mitigating rip current impacts remain beach maintenance, public education, and awareness campaigns. These efforts focus on informing beachgoers about safe swimming practices, recognizing hazardous conditions, and responding appropriately when caught in a rip current. Tools such as signage, lifeguard presence, and real-time alerts continue to be the primary means of reducing risk in affected coastal areas.

LAND USE AND BUILT ENVIRONMENT CHANGES

Recreational beach land use—where the majority of rip current incidents have occurred, particularly in northern Puerto Rico—has remained stable over the past five years. There have been no significant changes in land use patterns, coastal development, or environmental conditions that have influenced the frequency or intensity of rip currents. No land use or environmental changes have been identified as catalysts for rip currents, nor have they been found to increase or decrease the occurrence of this coastal phenomenon.[832]

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

While land use along recreational beaches in Puerto Rico has remained stable over the past five years, tourism activity has significantly increased, particularly in coastal areas, which directly affects vulnerability to rip current hazards. This is because higher beach attendance, especially during peak seasons, correlates with greater human exposure to hazardous surf conditions.

According to Discover Puerto Rico and Tourism Economics, Puerto Rico received a record 7.5 million non-resident visitors in 2024, surpassing pre-pandemic levels and marking a 15% increase in visitor spending compared to 2023. The island also saw record-breaking passenger arrivals at Luis Muñoz Marín International Airport, with over 6.6 million arrivals in 2024—an 8% increase from the previous year. This upward trend has continued into 2025, with over 1 million stayover visitors reported by mid-year.[833]

[832] National Oceanic and Atmospheric Administration, *Final Evaluation Findings: Puerto Rico Coastal Zone Management Program, September 2015 to September 2023*. Office for Coastal Management, National Ocean Service, U.S. Department of Commerce, 2025, https://coast.noaa.gov/data/czm/media/puertorico-cmp.pdf.
[833] Charles Taylor, "Puerto Rico's Comeback: How 'Boricua' Is Driving Tourism," *Forbes,* March 25, 2024, https://www.forbes.com/sites/charlesrtaylor/2024/03/25/puerto-ricos-comeback-how-boricua-is-driving-tourism/.

The post-pandemic tourism rebound has been driven by increased airlift, expanded lodging options (especially short-term rentals), and aggressive marketing campaigns like "Live Boricua." These factors have led to higher beach occupancy, particularly in northern Puerto Rico, where rip currents are most prevalent. Consequently, the vulnerability to rip current incidents has increased, not due to environmental or land use changes, but because of greater human exposure during high-tourism period.[834]

POPULATION CHANGES

Although there have been no significant shifts in permanent residential population along Puerto Rico's coastlines, tourism-related population exposure has increased notably. In 2024, Puerto Rico experienced record-breaking tourism. This trend has continued into 2025, driven by expanded air travel, short-term rental growth, and aggressive tourism campaigns. As a result, the number of people present in high-risk coastal areas, particularly during peak seasons, has grown, increasing the population's vulnerability to rip current hazards. This rise in temporary population, especially in the northern region, directly correlates with higher exposure to dangerous surfing conditions.

VULNERABILITY OF STATE ASSETS CHANGES

Rip currents are considered low-scale coastal hazards that primarily threaten human safety, especially swimmers and beachgoers. While they are responsible for numerous fatalities and rescues each year, they do not cause structural damage to state assets or infrastructure. This is confirmed along this profile, which notes that no critical infrastructure or essential facilities have been identified as being affected by rip currents.

In contrast, shorelines, although vital state assets are more significantly impacted by larger-scale hazards such as coastal erosion and hurricanes. These events have measurable impacts on the physical landscape and environment.

Thus, while rip currents are a serious public safety concern, they do not pose a threat to state assets in the same way that hurricanes and erosion do. Their impact is best addressed through public education, lifeguard presence, and real-time alerts, rather than infrastructure mitigation.

VULNERABILITY OF LOCAL ASSETS CHANGES

Rip currents represent a localized coastal hazard with limited physical impact, but they pose a significant threat to individuals in the surf zone, especially swimmers and recreational users. In San Juan, particularly at Ocean Park Beach, rip currents have led to fatalities and rescues, but they do not cause physical damage to local infrastructure or assets such as buildings, roads, or utilities.

[834] Charles Taylor, "Puerto Rico's Comeback: How 'Boricua' Is Driving Tourism," *Forbes,* March 25, 2024, https://www.forbes.com/sites/charlesrtaylor/2024/03/25/puerto-ricos-comeback-how-boricua-is-driving-tourism/.

Mitigation Success Stories

WATCH THE WAVES – A BEACH SAFETY INITIATIVE, 2022

"Watch the Waves" is a beach and ocean safety initiative developed by Discover Puerto Rico to reduce rip current–related incidents and promote safe coastal recreation. The program focuses on empowering beachgoers with practical knowledge and tools to stay safe while enjoying Puerto Rico's stunning shorelines.

The key components of the initiative are as follows:

- **Rip Current Awareness**: The initiative educates visitors on how to recognize rip currents—narrow, fast-moving channels of water pulling away from shore—and how to respond if caught in one. Memorable safety phrases like "Feel the grip? That's a rip" and "Go wide to escape the tide" help reinforce lifesaving actions.[835]
- **Behavioral Guidance**: Swimmers are advised to stay calm, conserve energy, and swim parallel to the shore to escape the current. The program also warns against swimming near structures like piers, jetties, and groins, where rip currents often form.
- **Safety Toolkits for Tourism Partners**: Discover Puerto Rico provides free, bilingual (English and Spanish) flyers and educational materials to hotels, tour operators, and beach vendors. These resources help businesses inform guests and reinforce safe swimming practices.
- **National Oceanic and Atmospheric Administration (NOAA) Forecast Integration**: Visitors are encouraged to check real-time beach conditions and forecasts from NOAA before entering the water.

This initiative is part of a broader strategy to enhance visitor safety and build trust in Puerto Rico as a world-class, welcoming destination. It is especially impactful in high-risk areas like Condado Beach, which has historically experienced multiple drownings due to rip currents.

RINCÓN – SURFER-LED LIFEGUARD ADVOCACY, 2019

Rincón, a renowned surf town on Puerto Rico's west coast, has become a focal point for grassroots beach safety advocacy, driven by local experts and community members responding to frequent drownings at popular beaches like Domes and Sandy Beach.[836]

Ruperto Chaparro Serrano, Director of the Sea Grant College Program at the University of Puerto Rico in Mayagüez, has spent decades studying the link between beach safety and tourism sustainability. He and his team, in collaboration with the United States Lifesaving Association (USLA), developed a comprehensive Aquatic Safety Assessment and Recommendations for the Commonwealth of Puerto Rico in 2008. This

[835] Discover Puerto Rico, "Watch the Waves," DiscoverPuertoRico.com, 2025, https://www.discoverpuertorico.com/watch-waves.
[836] Gabriel Pacheco Santa, "In Puerto Rico, Investing in Lifeguards Keeps Beaches Safe and Sustains Coastal Tourism," NOAA Sea Grant, May 19, 2019, https://seagrant.noaa.gov/In-Puerto-Rico-investing-in-lifeguards-keeps-beaches-safe-and-sustains-coastal-tourism/.

blueprint identified safety needs at 25 of the island's most popular beaches and was shared with multiple government agencies, including the Puerto Rico Tourism Company and Rincón's municipal government.

- **Key Advocacy Efforts:**
  - Local surfers and diving instructors, including Greg Carson of Taino Divers, have voiced urgent concerns about the lack of lifeguards. Carson, who serves as the water safety expert for the annual Corona Surf Contest at Domes Beach, emphasized that tourists are dying simply because no one is warning them when ocean conditions are too dangerous.
- **Supporting Data and Recommendations:**
  - Studies by Sea Grant researchers show that nearly 30 people drowned annually in Puerto Rico during the 1990s, mostly young local men. More recent data suggests this trend continued through 2010, with little improvement in beach safety until at least 2014.
  - He advocates for redirecting tourism funds or implementing a targeted hotel occupancy tax to support lifeguard services, similar to Florida's Tourism Development Tax.

Both Carson and Chaparro Serrano agree lifeguards are essential not only for saving lives but for sustaining Rincón's tourism-driven economy. Without investment in coastal safety, the town risks losing its reputation as a world-class surf destination.

SECTION 4.15

SARGASSUM

Sargassum

SARGASSUM DEFINITION

Sargassum is a floating, non-toxic, brown seaweed (a type of algae) found in the Atlantic Ocean. It is made up of two plant species, and several morphotypes, that cling together leaving air bladders for floatation. The plants have many leafy appendages, branches, and pneumatocysts, which are round berry-like oxygen filled structures that assist in floatation.[837] *Sargassum* can propagate asexually and double its biomass within 11 days, forming large floating mats or long windrows of weed that can stretch for miles as it travels with ocean currents and wind. Its biomass varies significantly depending on the season and location where it occurs, but it always does best over the open ocean, where it is mostly fueled by vertical seawater mixing that produces nutrients.[838]

Although *Sargassum* has long been present in the Atlantic Ocean, unprecedented quantities began washing ashore in the Caribbean in 2011. Since then, recurring large-scale influxes—often reaching record levels—have posed serious challenges to coastal ecosystems, disrupted fishing and tourism industries, and raised concerns about human health due to the gases released during decomposition. While the seaweed has some positive aspects, such as acting as a place for forage and refuge and as breeding grounds for many marine animals,[837] it has many more negative impacts. *Sargassum* can block sunlight coral reefs need to survive, affecting the many aquatic species that depend on coral. It has several negative biochemical impacts on ecosystems, including reduced oxygen levels (hypoxia) and increased acidity (acidification). Due to its

[837] National Oceanic and Atmospheric Administration (NOAA) Ocean Exploration, "What is Sargassum?" 2014, https://oceanexplorer.noaa.gov/ocean-fact/sargassum/.

[838] H. Oxenford, "The Tropical Atlantic Sargassum Story: 2011–2021," Centre for Resource Management and Environmental Studies (CERMES), 2021, https://www.cavehill.uwi.edu/cermes/wp-content/uploads/sites/38/Research-Projects/Sargassum/Docs/Presentations/OXENFORD_2021_Tropical_Atlantic_Sargassum_story_2011-2021_All-Atlantic_Conference.pdf?redirectried=1.

tendency to arrive in large quantities that obstruct waterways, *Sargassum* can significantly disrupt maritime activities such as boating and fishing. It also clogs vital infrastructure, including intake pipes, which has previously led to power plant shutdowns. When decomposing on land, it emits sulfur compounds that produce a strong sulfurous odor and creates a visual nuisance, diminishing the appeal of coastal tourist destinations. When the fishing industry struggles, it is significantly harmful to Puerto Rico's economics, reducing food and export sales, and putting stress on other food industries to make up for it. *Sargassum* influxes have also adversely affected Puerto Rico's tourism industry, prompting travelers to cancel beach vacations during major events, particularly in 2015 and 2018, when shoreline accumulations were especially severe.[838]

Live *Sargassum* is non-toxic; however, as it begins to decay on land, it releases harmful gases like ammonia and hydrogen sulfide, which can lead to mild to serious health effects on respiratory, cardiovascular, and neurological systems. *Sargassum* can harbor dangerous materials, organisms, and pollutants, such as jellyfish, pesticides, and arsenic that can cause irritations to humans and utilities such as water quality and pipelines.[839]

Figure 235 shows a sample ecosystem with some benefits (blue) and drawbacks (brown) of *Sargassum*.

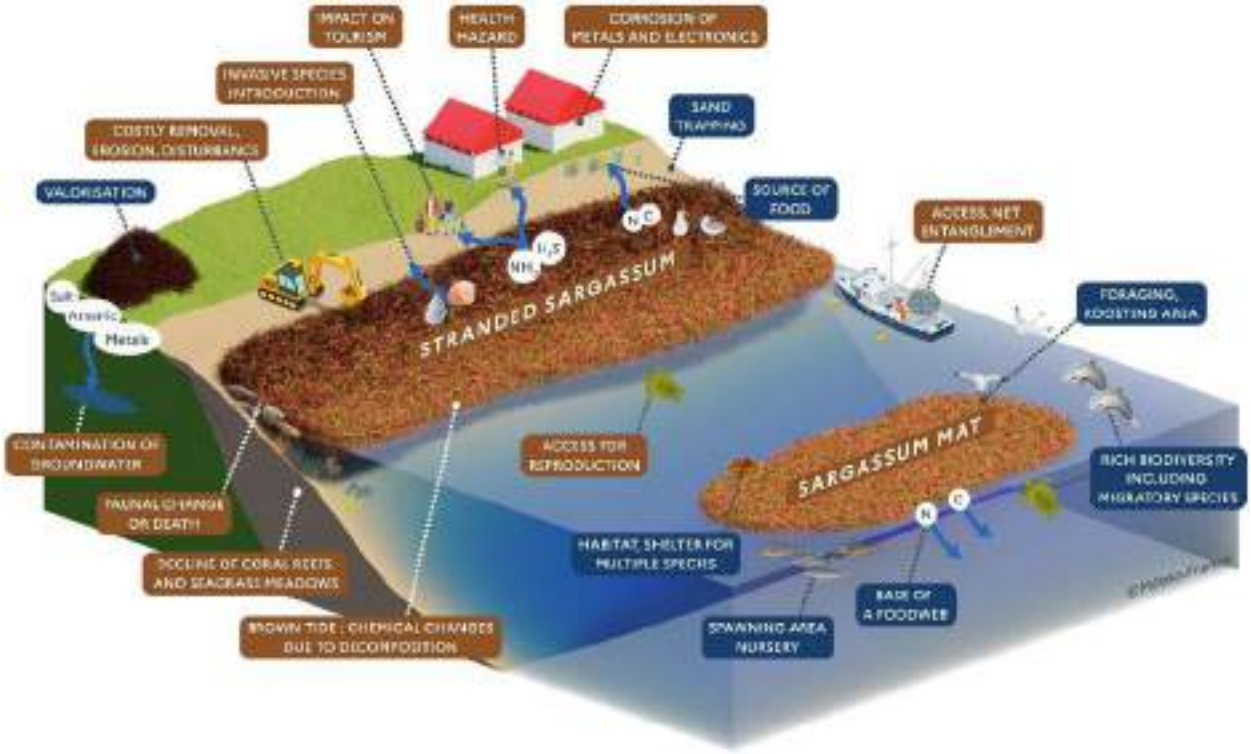


Figure 235: *Sargassum* Benefits and Issues in an Ecological System.[840]

[839] Environmental Protection Agency (EPA), "Sargassum Inundation Events (SIEs): Impacts on Human Health," 2025.
[840] M. Debue, et al., "Understanding the Sargassum phenomenon in the Tropical Atlantic Ocean: From satellite monitoring to stranding forecast," 2025, *Marine Pollution Bulletin,* Volume 216 (117923), https://doi.org/10.1016/j.marpolbul.2025.117923.

Location

During peak influx periods, *Sargassum* can accumulate extensively along Puerto Rico's coastline, forming dense mats that encircle large portions of the shore and severely impact coastal access and marine activity. It can be present on any beach or surrounding waters of the island. Out of the entire Caribbean, *Sargassum* biomass tends to be highest near Puerto Rico and the Dominican Republic, with higher overall biomass on the southern and eastern sides of the islands. As seen in Figure 236, in September 2025, *Sargassum* was at its highest concentration on the coast of Lajas, in southern Puerto Rico and Fajardo in eastern Puerto Rico. Off the coast of Ponce, there is a high concentration of *Sargassum* stretching southeast into the ocean. While most of the northern and western coasts do not have a high concentration in September of 2025, small beaches in Arecibo, Loiza, Aguada, and Anasco do have high *Sargassum* concentration.[841]

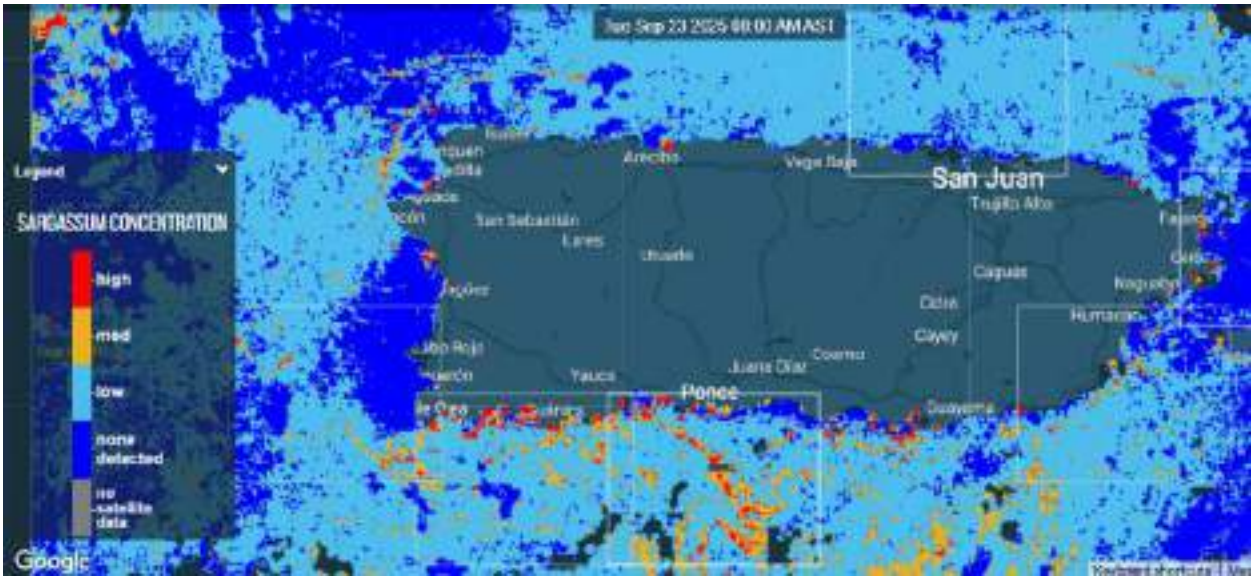


Figure 236: CARICOOS Short Term *Sargassum* Forecast for September 23, 2025[841]

The location of *Sargassum* fluctuates significantly throughout the year, with higher concentrations completely surrounding the island from May to August within the past decade. For the week of September 16–22, 2025, the National Ocean and Atmospheric Administration (NOAA) categorized almost the entire state of Puerto Rico as high on the coastal risk for *Sargassum* scale, indicating 60%–100% of the shoreline was at risk of being inundated by *Sargassum*. Only a small section of the northern coast near San Juan, as seen in Figure 237, had a low coastal risk level, which means the potential for *Sargassum* to reach the coast is low. Figure 237 overall shows a snapshot *Sargassum* coastal risk levels for September 16–22, 2025, from 0%–100% shoreline coverage of the Greater Antilles, including Puerto Rico, Cuba, Jamaica, Haiti, Dominican Republic, and smaller surrounding islands of the Bahamas, British Virgin Islands, and Cayman Islands. Fifty percent of the coast of Puerto Rico has a medium or high risk of *Sargassum* inundation, with only the northern edge near San Juan having low risk at this time. Farther west near Cuba and Jamaica, coastal risk

[841] CARICOOS, "Live Sargassum Tracker: Short Term Forecasts," 2025, https://www.caricoos.org/sargassum/sso/PR.

levels vary much more, with large portions of the coast having low risk. In general, the eastern islands of the Greater Antilles have a much higher *Sargassum* inundation risk to their respective coasts.[842]

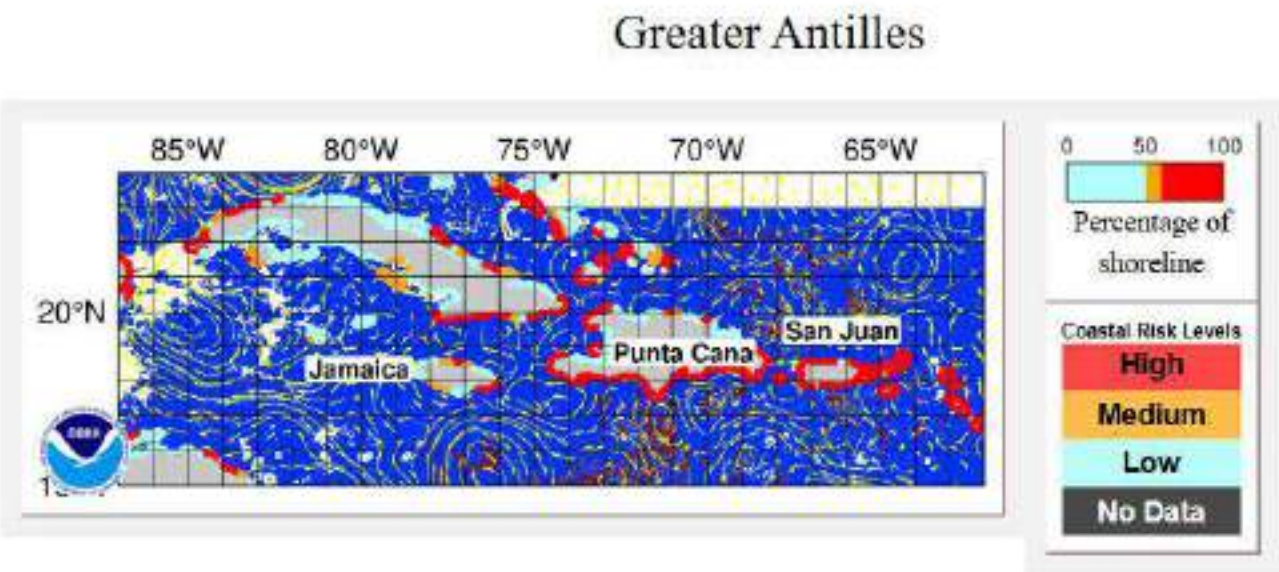


Figure 237: Weekly *Sargassum* Risk for the Greater Antilles September 16–22, 2025[842]

Previous Occurrences

Sargassum has inundated large parts of the Caribbean Sea, particularly the entire coast of Puerto Rico, since 2011. These occurrences have happened every summer since, except for 2013. After a massive influx in 2018, the *Sargassum* Outlook bulletin was created by the Optical Oceanography lab at the University of South Florida, detailing the multiple ongoing *Sargassum* events in the Caribbean Sea. These events primarily affect critical infrastructure, tourism, and both recreational and commercial fishing. Large accumulations of *Sargassum* along the coastline can degrade environmental and aesthetic quality, producing foul odors similar to rotten eggs and creating visually unappealing conditions that deter visitors.

Over the past 14 years, researchers have identified certain ecological benefits associated with *Sargassum*, including its role in supporting oceanic food webs, providing shelter for endangered sea turtles, and serving as a foraging ground for shorebirds. However, these benefits remain uncertain, as they depend on the ability of wildlife to rapidly adapt. For instance, excessive *Sargassum* accumulation may obstruct nesting sites, preventing turtles from reaching the beach to lay eggs. Moreover, while *Sargassum* can function as a nursery habitat, not all species are able to utilize it effectively.[838]

[842] NOAA Atlantic Oceanographic and Meteorological Laboratory, "Weekly Sargassum Inundation Risk (SIR v1.4)," 2025, https://cwcgom.aoml.noaa.gov/SIR/.

FEDERAL DISASTER DECLARATIONS

There have been no federal disaster declarations for Sargassum in Puerto Rico.

PUERTO RICO DISASTER DECLARATIONS

Puerto Rico declared a state of emergency (Executive Order 2025-037) due to record amounts of sargassum on June 30, 2025. This order expedited processes to contain and mitigate the proliferation of algae, allowing government agencies to act quickly.

SIGNIFICANT EVENTS

Sargassum has been an ongoing warm season event. The amount of *Sargassum* on Puerto Rico beaches can fluctuate day to day, but there has generally always been an ongoing presence of golden-brown seaweed in the warm months since 2011.

FIRST MAJOR ARRIVAL OF *SARGASSUM* IN PUERTO RICO, 2011

The first mass influx of *Sargassum* occurred in the Caribbean Sea in the spring of 2011, staying throughout summer. While *Sargassum* has long been present in other areas of the Atlantic, such as the Sargasso Sea, 2011 was the first notable presence of the seaweed in the coastal areas of the Caribbean Sea and tropical Atlantic Ocean.[843] This influx was attributed to an extreme phase of the North Atlantic Oscillation (NAO), which altered ocean currents and facilitated the transport of *Sargassum* into the tropical Atlantic. The sudden and widespread arrival of *Sargassum* across Caribbean islands in 2011 caused considerable confusion and concern among scientists and government officials, who were initially uncertain about its origin, ecological and economic impacts, and appropriate mitigation strategies.

As shown in Figure 238, taken from a 2020 *Sargassum* study, Section A shows Puerto Rico in the CA region. Section B shows a large spike (10 times previous years) in the Maximum Chlorophyll Index (MCI) from the MERIS satellite, indicating a significant spike in *Sargassum* in the CA region.[843] Section C of the graphic shows the other regions in the study, also indicating significant spike in MCI after 2011. Section D of the graphic shows the total area coverage in square kilometers and mixed layer depth in meters of *Sargassum* from 2009 to 2019 in the Atlantic Ocean. While the depth stays relatively steady throughout the recorded decade, the surface area increases significantly in the summers of 2015 (~2,000 km^2) and 2018 (~4,000 km^2).

[843] E. M. Johns, et al., "The establishment of a pelagic Sargassum population in the tropical Atlantic: Biological consequences of a basin-scale long distance dispersal event" *Progress in Oceanography*, 182 (2020) 102269, https://www.sciencedirect.com/science/article/pii/S0079661120300070.

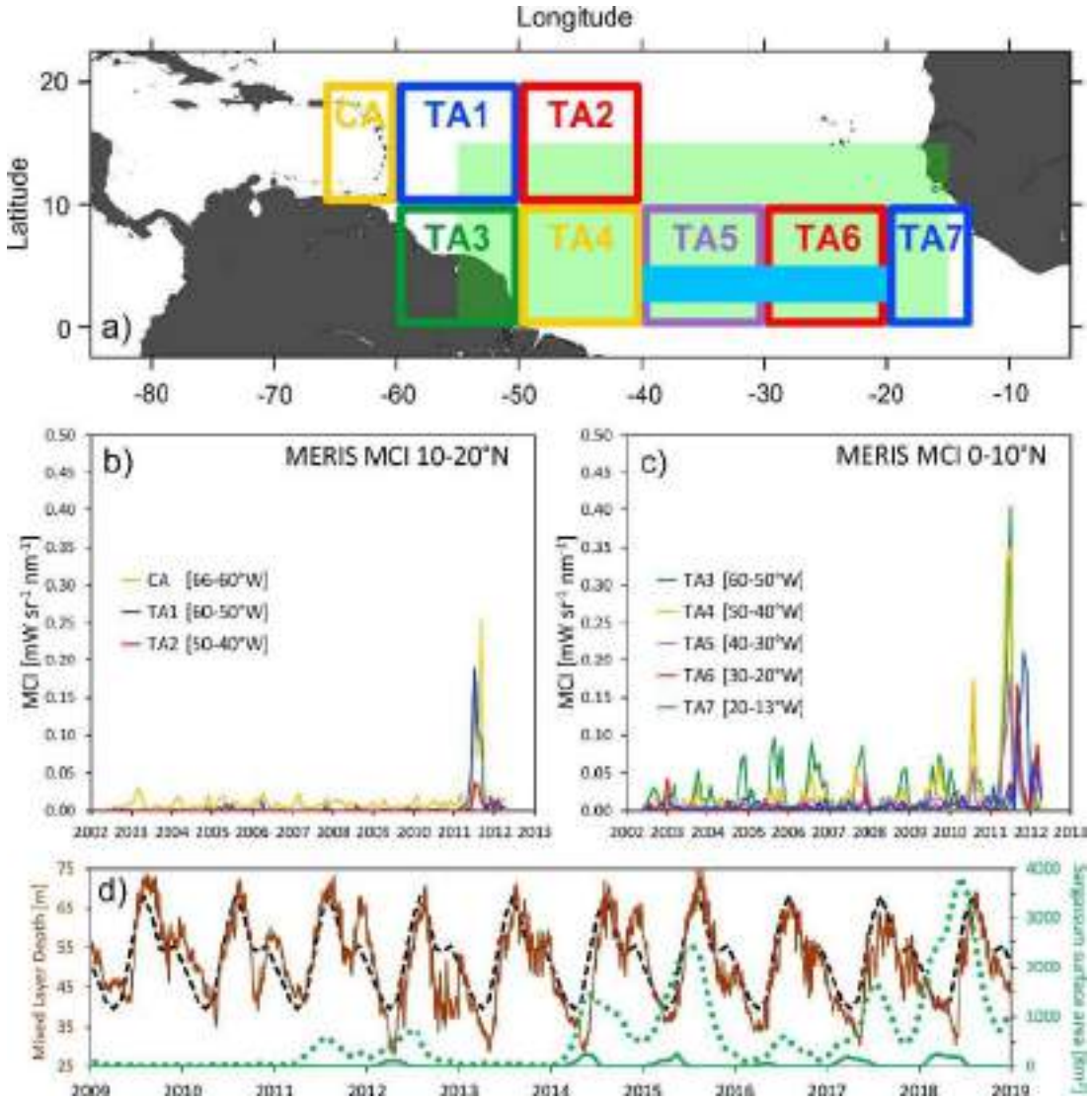


Figure 238: Table of *Sargassum* in Puerto Rico from 2002[843]

UNUSUAL STOP IN *SARGASSUM*, 2013

After two consistent summers with large amounts of *Sargassum* in the Caribbean Sea, 2013 saw a significant decline in the seaweed, which was caused by a 2012 oceanic anomaly of strong eastward flow of the north Brazil current retroflection to the Equatorial counter current.[844]

SARGASSUM INFLUXES MAKE NATIONAL HEADLINES, DISRUPTING TOURISM, 2015

Sargassum made its first major press headlines with its largest bloom on record at that time, (>10 million metric tons of *Sargassum* biomass), causing many tourists to cancel their Caribbean beach vacations. The tourism industry is one of Puerto Rico's most significant economic sectors, so this led to a socioeconomic

[844] Nathan F. Putman, et al., "Simulating transport pathways of pelagic Sargassum from the Equatorial Atlantic into the Caribbean Sea," *Progress in Oceanography* 165 (2018): 205–214.

disaster. *Sargassum* began disrupting livelihoods and damaging property. The *Sargassum* stained and tarnished pipes and paint work, leading to human health impacts as well.[1] Figure 239 shows an example of *Sargassum* inundation on a beach in Puerto Rico.

Figure 239: *Sargassum* Buildup on Puerto Rico Beach[845]

MAJOR BLOOM PROMPTS "THE GREAT ATLANTIC *SARGASSUM* BELT," JULY 2018

During the winter months of 2017, the *Sargassum* change rate was very high, benefitting from a lower sea surface temperature and higher availability of nutrients. These conditions led to what has been named by researchers as "The Great Atlantic *Sargassum* Belt" (GASB). As Figure 240 shows, the area of the determined GASB was 8,850 km, and in June 2018, it contained >20 million metric tons of *Sargassum* biomass, double the amount in 2015. As a result of this abnormally large bloom in 2018, University of South Florida Optical Oceanography Laboratory began keeping *Sargassum* Outlook Bulletin records, initiating a major focus on *Sargassum* research and innovative mitigation strategies, such as deploying collection barges and raising public awareness.[845]

[845] Mengqiu Wang, et al., "The Great Atlantic Sargassum Belt," *Science* 365.6448 (2019): 83–87.

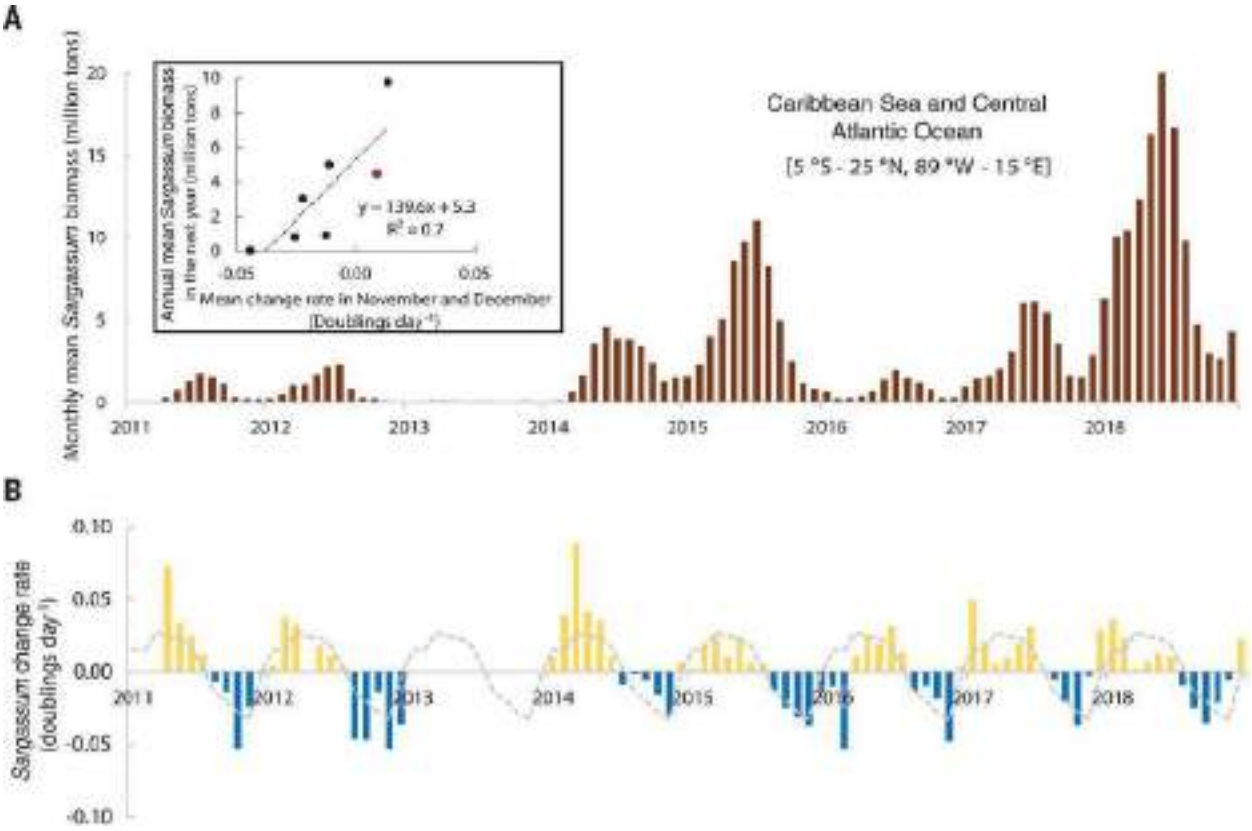


Figure 240: *Sargassum* Biomass Change Rate from April 2011 to December 2018[845]

POWER PLANT SHUTDOWNS LEAVE THOUSANDS WITHOUT SERVICE FOR DAYS, MOST RECENT SEPTEMBER 2021

Sargassum can drift as far as the northern metropolitan area, where it can get very close to the pumping systems of nearby power plants, like San Juan, Palo Seco, Salinas and the Aguirre plants.[846] In 2021, Unit 1 of the Aguirre plant went offline when large patches of *Sargassum* entered and disrupted machinery. The filters failed and retention grates were perforated, leaving 100,000 customers without service for 3 days. Similarly, in 1993, when *Sargassum* was not yet a notable problem, Unit 3 of the San Juan plant was shut down because there were no filters to exclude the *Sargassum*, leaving 90,500 people without power for 4 days.[847] These power plants are particularly vulnerable to *Sargassum* intrusion during north-to-south current shifts, reinforcing the need for proactive infrastructure protections and contingency planning.

[846] Primera Hora, "El sargazo vuelve a poner en jaque el sistema eléctrico de Puerto Rico," 2025, https://www.primerahora.com/noticias/gobierno-politica/notas/el-sargazo-vuelve-a-poner-en-jaque-el-sistema-electrico-de-puerto-rico/.

[847] El Vocero, "Genera evalúa cómo mitigar el sargazo en centrales de Palo Seco y Aguirre," 2025, https://www.elvocero.com/gobierno/agencias/video-genera-eval-a-c-mo-mitigar-el-sargazo-en-centrales-de-palo-seco-y/article_318cd24e-0b16-401a-ab9f-24fe6432a735.html.

RECORD BREAKING AMOUNTS OF *SARGASSUM*, PREDICTED TO GET WORSE, AUGUST 2025

The 2025 arrival of *Sargassum* was forecasted to be 40% larger than previous major events, and the following data shows the exponential growth from the previous year.[849] The amount of *Sargassum* in the GASB reached a new record biomass of 37.5 million tons in May 2025.[848] This is separate from the estimate 7.3 million tons regularly in the Sargasso Sea. The largest part of this mass is along the entire coast of Puerto Rico, Haiti, and the Dominican Republic (Eastern Caribbean region), but it spreads across the entire GASB.[849] The months of May, June, July, and August of 2025 had the highest recorded *Sargassum* biomass for each of their respective months on record. With changing future conditions and a continued exponential growth in *Sargassum* biomass, the annual amounts are predicted to keep increasing. *Sargassum* has already spread now as far north as Florida and will continue reach areas outside the GASB as it expands in size.

Potential Severity of Event

The CARICOOS system has been tracking *Sargassum* concentration and abundance in Puerto Rico and the U.S. Virgin Islands region since mid-2020. It produces a short-term *Sargassum* forecast that uses a scale from none, low, medium, or high *Sargassum* concentration.[841] Based on the 7-day short-term *Sargassum* forecast project, the forecast integrates numerical model predictions with in-situ biomass measurements, specifically around La Parguera, Puerto Rico. The legend description is as follows as determined by the product developer, based empirically on MCI data:

- **High:** High-density *Sargassum* patches identified in satellite imagery
- **Med:** Med-density *Sargassum* patches as identified in satellite imagery
- **Low:** Low-density *Sargassum* patches as identified in satellite imagery
- **None detected:** Particles that may or may not be *Sargassum* patches
- **No data:** Particles that are not identified due to cloud contamination

CARICOOS has developed biomass arrival forecasts per kilometer of coastline, tools to support beach cleaning and management decisions, and an ongoing development of biochemical impact forecasting models. Puerto Rico experiences varying levels of *Sargassum* concentration throughout the year, with the highest abundance typically occurring from May to August. This increase is influenced by fluctuations in ocean currents and winds. During the transitional months of March, April, September, and October, *Sargassum* concentration remains high along the southern and eastern coast, particularly in Lajas, Guánica, Ponce, Salinas, and Guayama. While areas like San Juan, Arecibo, and Aguada can also experience high concentrations according to the CARICOOS tracker, they are more likely to have low to medium levels during these months. In the cooler winter months from November to February, the entire coast has the

[848] G. Galoustian, "FAU Tells 'Story' of Atlantic's Sargassum Surge Using 40 Years of Data," 2025, https://www.fau.edu/newsdesk/articles/sargassum-story-forty-years-data.
[849] University of South Florida College of Marine Science Optical Oceanography Lab (USF COOL), "Outlook of 2025 Sargassum blooms," 2025, https://optics.marine.usf.edu/projects/SaWS/pdf/Sargassum_outlook_2025_bulletin08_USF.pdf.

potential for high *Sargassum* concentrations, but it is more common to see none to low levels.[841] Figure 241 shows the areas where impacts from sargassum are highest.

Figure 241: Sargassum Natural Impacts Ranking

Additionally, the *Sargassum* Management Prioritization Index (SMPI) was developed to identify potential areas that are impacted by *Sargassum* accumulation and decomposition. This helps highlight the areas that management interventions must be prioritized if *Sargassum* accumulates.[850] The SMPI *Sargassum* Natural Impacts Ranking is a classification developed by Dr. William J. Hernández as part of the Sea Grant Puerto Rico project that is based on a combination of geospatial data. The SMPI natural impacts scale includes a classification of the coastline according to environmental sensitivity, presence of sensitive habitats, and an assessment of the potential ecological damage caused by *Sargassum* accumulation. The ranking is on a scale of 1 (Low Impact) to 8 (Very High Impact), Puerto Rico has the potential to rank 8 (Very High Impact) in any location. The ranking values explain the expected impact level.[851]

- **6–8: Very High Impact:** Areas with high ecological sensitivity and a high probability of *Sargassum* accumulation that can cause severe damage to natural ecosystems.
- **4–6: High Impact:** Areas with significant sensitivity, where *Sargassum* can alter important habitats but with less intensity than those in the very high impact category.
- **3–4: Moderate Impact:** Areas with intermediate sensitivity, where the effects of *Sargassum* are relevant but less critical.
- **1–2: Low Impact:** Areas with low ecological sensitivity or lower probability of *Sargassum* accumulation, with limited effects.

The SMPI reveals that most potential for severe *Sargassum* impacts is generally on the southern and eastern coasts of the state, such as Lajas and Guánica, as well as Fajardo and Ceiba.

The NOAA Atlantic Oceanographic and Meteorological Laboratory also has a scale for *Sargassum* concentration, they produce a *Sargassum* Inundation Risk (SIR) model. While this is for a broader area of the Atlantic than the CARICOOS produces, it still offers good insight into the potential severity of *Sargassum* in the area. The SIR is a weekly report of fields derived from satellite-based observations, using a 7-day floating algae density field to estimate the potential for *Sargassum* to wash ashore. It uses a scale from low, medium, or high coastal risk.[842] As with the CARICOOS system, Puerto Rico's entire coastline is susceptible to high coastal risk year-round according to the SIR model. However, risk levels tend to peak during the summer months, and shift toward southeastern coastal cities during cooler seasons.

Probability of Future Hazard Events

In recent years, *Sargassum* concentrations have repeatedly broken historical records, reaching unprecedented levels for their respective months. For instance, August 2025 recorded the highest

[850] SeaGrant UPRM and the NASA OCEAN MUREP Program, "Pilot Sargassum Management Prioritization Index (SMPI)," 2025, https://uprm.maps.arcgis.com/apps/webappviewer/index.html?id=4ea1bdad90d64cb1a1946e11d87a1fd6&extent=-7497895.3419%2C2012268.2742%2C-7424515.7948%2C2047849.7109%2C102100.

[851] W. J. Hernández, "Development of a Pilot Sargassum Management Prioritization Index," *Puerto Rico Sea Grant College Program and NASA OCEAN MUREP Program,* 2023, https://seagrantpr.org/wp-content/uploads/2023/10/Sargassum-Management-Prioritization-Index-2.pdf.

Sargassum concentration ever documented for that month. Similarly, July 2025 saw concentrations more than double those observed in July 2024. The probability of a future *Sargassum* hazard event is **high.**

Predicting the *Sargassum* levels on an individual beach is difficult, because it depends on local factors such as wind and ocean currents.[849] However, the overall *Sargassum* concentration is likely to increase in the Caribbean sea, mostly due to increased likelihood of rising sea temperatures, shift in wind patterns, and river discharges.[852] Algae thrives in warm water, which speeds up its metabolism and growth rate, and where there is more nutrient availability and sunlight exposure.[853] Due to an increased concentration of greenhouse gases (GHG), the atmosphere has been trapping more heat, leading to a rise in ocean temperatures.[854] This rise in temperatures also causes a shift in wind patterns, as there is a higher temperature gradient between the land and ocean, producing pressure differences that change wind distribution.[855]

Sargassum does not originate in Puerto Rico; rather, its presence is linked to shifting wind patterns that began in 2011, redirecting existing *Sargassum* westward from the Sargasso Sea. As these wind patterns continue to deviate from historical norms, the likelihood of *Sargassum* reaching Puerto Rico increases.

These atmospheric changes also influence rainfall patterns by altering circulation and moisture availability, which can result in elevated river discharge. Combined with rising GHG concentrations, these factors contribute to the continued growth and accumulation of *Sargassum* around the island, posing ongoing environmental and infrastructure hazards.

While nutrient runoff near the Amazon River can initiate *Sargassum* growth, its proliferation is primarily driven by vertical ocean mixing, an effect intensified by warmer temperatures. This mixing enhances nutrient availability, supporting rapid *Sargassum* expansion.[856]

Vulnerability Assessment

Although *Sargassum* can be helpful to wildlife in some ways, its potentially hazardous effects on humans, ecosystems, and the economy outweighs its benefits. As it continues to grow at an exponential rate, *Sargassum* can completely inundate beaches, halting tourism and both recreational and commercial fishing. This inundation requires cleanup resources, which in turn require funding. *Sargassum* hurts the economy from every direction as the tourism and fishing are the largest industries in Puerto Rico.[843] If coastal

[852] NOAA Southeast and Caribbean Regional Team (SECART), "Coordinating Management Efforts and Response to Sargassum Inundation Events," 2025, https://www.noaa.gov/coordinating-management-efforts-and-response-to-sargassum-inundation-events.
[853] Algae Research and Supply, "Warm Water Promotes Algae Growth: So What Happens if the Ocean Warms Up?" 2025, https://algaeresearchsupply.com/blogs/news/warm-water-promotes-algae-growth-so-what-happens-if-the-ocean-warms-up.
[854] NOAA GHG Monitoring & Services, "Current GHG Levels," 2025, https://www.climate.gov/ghg/current-levels.
[855] Hsiao, et al., "Observed Relationships between Sea Surface Temperature, Vertical Wind Shear, Tropical Organized Deep Convection, and Radiative Effects," *AMS J. Climate*, 2024, 37, 1277–1293, https://doi.org/10.1175/JCLI-D-23-0262.1.
[856] Sargassum Monitoring, "Sargassum: A New Study Reveals the True Cause of Massive Blooms," February 12, 2025, https://sargassummonitoring.com/en/the-true-cause-of-massive-blooms/.

Sargassum concentrations continue to rise or persist beyond their typical seasonal retreat, cleanup resources may become overwhelmed, unable to manage widespread accumulation across the island. This could result in prolonged exposure to decaying seaweed, which emits a strong sulfur-like odor, degrades beach environments, releases harmful compounds, damages infrastructure such as pipelines, and increasingly disrupts daily life by forcing school closures and event cancellations.[839]

LOCATIONS

The entire island of Puerto Rico is vulnerable to *Sargassum* inundation, particularly along coastal areas and during the warmer months of May through August. As *Sargassum* begins its seasonal retreat, it typically recedes first from the northern coast, leaving persistent concentrations along the southern and eastern shores for extended periods throughout the year.

POPULATIONS

While *Sargassum* inundation may affect the entire population, those with coastal property, tourism businesses, commercial fishing businesses, or individuals with higher health vulnerabilities are most at risk to impacts from *Sargassum*. While these impacts can vary greatly—from monetary to medical—the whole population is vulnerable in some way.

The vulnerability of populations can be represented by the exposure of residents to areas with high impacts from sargassum. Table 103 indicates the number of residences in each municipality within areas of potential sargassum impacts. Humacao has the highest number of residences that are vulnerable, followed by Fajardo.

Table 103: Count of Residences Exposed to Sargassum

Municipality	Total Residences
Cabo Rojo	948
Ceiba	5,677
Fajardo	20,184
Guánica	6,115
Humacao	41,874
Lajas	4,567
Loíza	1,217
Luquillo	3,252
Maunabo	7,188
Naguabo	5,033
Río Grande	2,860
Yabucoa	544

Municipality	Total Residences
Grand Total	**99,459**

STRUCTURES, INCLUDING CRITICAL FACILITIES

In the ocean *Sargassum* can ruin potential detection systems such as buoys and radars and block access to these technical resources by boat. When *Sargassum* travels into metropolitan areas or through seawater pipes, it impacts critical structures such as power plants and water systems. Exposure to structures is primarily concentrated in 12 municipalities. The replacement value of structures is summarized by different building use types in Table 104.

Table 104: Value of Structures Vulnerable to Sargassum

Municipality	Residential	Commercial	Industrial	Agricultural	Religion	Government	Education	Total Exposure
Cabo Rojo	$298,484	$0	$0	$0	$0	$0	$0	$298,484
Ceiba	$4,139,017	$0	$0	$0	$0	$0	$64,280	$4,203,297
Fajardo	$23,233,720	$19,340	$25,810	$0	$0	$0	$0	$23,278,870
Guánica	$5,481,173	$9,092	$0	$0	$0	$0	$0	$5,490,265
Humacao	$36,856,388	$0	$0	$0	$0	$0	$0	$36,856,388
Lajas	$1,921,507	$0	$0	$0	$0	$0	$0	$1,921,507
Loíza	$503,114	$0	$0	$0	$53,088	$12,880	$0	$569,082
Luquillo	$5,711,484	$14,652	$0	$0	$0	$0	$0	$5,726,136
Maunabo	$2,140,512	$0	$0	$0	$0	$6,510	$0	$2,147,022
Naguabo	$1,647,722	$3,766	$540	$0	$0	$0	$0	$1,652,028
Río Grande	$4,659,692	$0	$0	$0	$0	$0	$0	$4,659,692
Yabucoa	$1,178,888	$0	$0	$0	$0	$0	$0	$1,178,888
Total	**$87,771,701**	**$46,850**	**$26,350**	**$0**	**$53,088**	**$19,390**	**$64,280**	**$87,981,659**

INFRASTRUCTURE AND COMMUNITY LIFELINES

Sargassum poses a significant threat to infrastructure and essential community lifelines, primarily by obstructing the systems these services rely on. It can clog intake and filtration systems, leading to power plant shutdowns and degraded water quality—both of which disrupt emergency response, hospital operations, food safety, and public safety across the island. Additionally, dense *Sargassum* accumulation can halt boat traffic, impeding emergency transport, food imports and exports, and maritime security operations.

PROBLEM STATEMENTS

- *Sargassum* originates in the ocean but washes up on the beaches of Puerto Rico, where it generally creates havoc for the coastal waters and beach itself. It can easily be dragged into cities and towns by humans (particularly boat trailers) and animals, but incursion more often occurs by way of waterways such as inlets, rivers, and pipelines that connect to the ocean.
- From May to August, concentrations are highest for the entire state, with the largest amount of *Sargassum* generally in the southern and eastern areas such as Fajardo, Guayama, and Lajas, although this fluctuates greatly.
- Throughout the transitional months in the spring and fall, such as March, April, September, and October, *Sargassum* is just arriving or retreating, so *Sargassum* concentration is highest on the southern coast of Puerto Rico, particularly in Lajas, Guánica, Ponce, Salinas, and Guayama.
- Decaying *Sargassum* releases toxic chemicals that can irritate the skin and the respiratory system, which can be a significant health hazard, especially to those with health risks, such as the elderly, those with breathing problems like asthma, those with autoimmune diseases, and children.
- Tourism is one of the largest industries in Puerto Rico, generating around $3 billion each year.[857] A large portion of the population works for the tourism industry. Tour guides, water sport instructors, business owners, artists, bartenders, waiters, restauranters, and many others all depend on tourists for their jobs. When tourists cancel their plans due to *Sargassum* rise (such as in 2015 and 2018), many residents have no work, leaving them less able to spend money on local resources, hurting everyone in a trickledown effect.
- Commercial fishing is another dominant industry in Puerto Rico. *Sargassum* halts small boat traffic and any pier fishing because motors, propellors, and fishing lines easily get stuck in the algae.[858] Individuals employed in commercial fishing, along with restaurant businesses that depend on locally sourced seafood, are significantly affected by *Sargassum* inundation. The accumulation disrupts fishing operations, reduces catch availability, and threatens the economic stability of industries tied to Puerto Rico's coastal resources.

[857] Statistics Institute of Puerto Rico, "Visitor Profile: Fiscal Year 2023-2024," 2024, https://estadisticas.pr/files/Publicaciones/Visitor%20Profile%20Fiscal%20Year%202023-2024.pdf.
[858] NOAA SECART, "Sargassum Inundation Events (SIE) Addendum for the Guide to Integrated NOAA Disaster Resilience in the Southeast and Caribbean," 2024, https://www.noaa.gov/sites/default/files/2024-09/Sargassum_Addendum_Southeast_Caribbean_Disaster_Guide_2024.pdf.

- *Sargassum* has been known to clog areas of seawater that lead into power plants, which can shut down the entire plants and cause many residents to lose power for prolonged periods.[846]
- Structures that are in the water, such as technical monitoring resources like buoys or radar systems, may be damaged or become unreachable by surrounding *Sargassum*.
- As *Sargassum* clogs pipes, water quality decreases for pipe-borne waters. [859]
- *Sargassum* accumulation can bring boat transportation to a standstill, disrupting maritime travel and business operations that rely on water access.

Impact Assessment

STATE ASSETS

GIS overlay analysis shows that 56 critical facilities are in areas of potential sargassum impact with a total replacement value of over $58 million. 7 facilities are in low impact areas, 25 in moderate impact, 17 in high impact, and 7 in very high impact. Table 105 summarizes the facilities at risk by community lifeline. Almost half of the facilities in risk areas are Safety and Security community lifeline facilities, with a total value of over #36 million. 6 transportation facilities are at risk, and these represent the next highest replacement value at over $9 million. Hazardous Materials, Communications, and Energy lifeline facilities are also at risk.

Table 105: Community Lifelines in Sargassum Impact Areas

Community Lifeline	Number of Facilities	Replacement Value
Communications	8	$1,600,837
Energy	5	$4,805,862
Food, Hydration, and Shelter	0	$0
Hazardous Materials	10	$5,195,664
Health and Medical	1	$1,146,897
Safety and Security	26	$36,425,533
Transportation	6	$9,037,840
Water Systems	0	$0
Total	**56**	**$58,212,633**

Power plants and water filtration facilities are vulnerable to being clogged and shut down by an influx in *Sargassum*.[846] The loss of these state assets also puts other state assets, such as hospitals, government and emergency response buildings, and schools, at risk, along with all of the people and equipment within them.

[859] GOV.VG, "Environmental Health Advises on Sargassum and Pipe Water Safety," 2025, https://gov.vg/news/environmental-health-advises-sargassum-and-pipe-water-safety.

Sargassum can shut down the necessary power and water needed to function; keeping hospital patients healthy, air conditioning, general hygiene, and a safe visual of all areas.

Additionally, *Sargassum* releases bad smelling sulfur that is toxic to humans and wildlife as it decays. Schools, restaurants, and excursion sites near the coast have shut down due to the smell, exposure to chemicals, and unpleasant environment.[838]

LOCAL ASSETS

Small businesses, beaches, and parks are heavily affected by the decline in tourism caused by *Sargassum* accumulation. The unpleasant odor and unsightly appearance deter visitors, reducing travel to coastal areas and impacting businesses that rely on tourism to remain operational.[838] Additionally, *Sargassum* can clog pipelines and drainage systems, leading to the buildup of metals and deterioration in water quality—particularly in small coastal establishments such as beachside restaurants, hygiene facilities, and other local enterprises.

COMMUNITY LIFELINES

Community lifelines can be disrupted by *Sargassum*'s ability to clog waterways, impairing the functionality of water and power plants, as well as hindering boat transportation, which many communities rely on for essential services and commerce.

SAFETY AND SECURITY

Small boat travel for local officials becomes nearly impossible during an inundation, which may make coastal security difficult. Safety and security lifelines on land may be impacted by power shutdowns or water quality alerts caused by *Sargassum*, but are not directly impacted.[847]

FOOD, HYDRATION, AND SHELTER

Sargassum significantly affects the fishing industry, including access to marine food sources. Its accumulation makes fishing and swimming in affected areas difficult, disrupting traditional harvesting methods and reducing the availability of local seafood.[838] Water quality may be compromised when *Sargassum* mats clog pipelines, leading to reduced flow and potential pipe corrosion. These blockages can introduce contaminants and disrupt water treatment processes, particularly in coastal areas.[859]

HEALTH AND MEDICAL

Although there are no recorded occurrences, hospital pipelines or water resources may be impacted by *Sargassum*, especially near the coast. Emergency medical boat transport can be severely hindered by dense *Sargassum* accumulation, posing a serious risk when individuals are injured in coastal waters. The obstruction of navigable routes delays response times and limits access to critical care.[838]

ENERGY

Past incidences of power plants (specifically Aguirre and San Juan Plants) becoming clogged with *Sargassum* have left thousands without power for multiple days. The facilities must shut down in when filters become clogged and retention gates are perforated so that *Sargassum* must be completely removed.[847] Extended power interruptions pose a serious risk to the health and hygiene of Puerto Rican residents. They can also disrupt tourism, driving visitors away and weakening the economy.

COMMUNICATIONS

There are no *Sargassum* impacts on the Communication Lifeline.

TRANSPORTATION

Sargassum significantly inhibits the use of boats, especially smaller boats, that are regularly used for tourists, resident transportation, coastal security, and fishermen as transportation and access. Puerto Rico is surrounded by ocean on all sides, so boat transportation is essential for daily functions. Car and air travel are not impacted directly.

HAZARDOUS MATERIALS

Decaying *Sargassum* produces sulfur gas, which is a bad smelling, low toxicity chemical that irritates airways and skin.[860] The decay releases hydrogen sulfide (sulfur) and ammonia, chemicals that require the use of personal protective equipment such as masks and gloves and proper disposal or recycling to minimize exposure for the population.[839] *Sargassum* contributes to harmful biochemical changes in the ecosystems it inhabits, including hypoxia (low oxygen levels) and acidification. These conditions can lead to the release of hazardous compounds that require proper treatment to prevent environmental degradation. Additionally, *Sargassum* can accumulate heavy metals, like arsenic, cadmium, and lead, posing toxic risks to both humans and wildlife.

WATER SYSTEMS

Sargassum can travel in large quantities through rivers and pipelines that are connected to the ocean, clogging and corroding these pipes.[859] When these clogs occur, not only does the flow of water decrease, but the quality of water is degraded. Without proper filtration and blockage from the incoming *Sargassum*, water systems are at risk.

Changes in Development

Land use and development patterns in Puerto Rico significantly influence vulnerability to *Sargassum*. Recent urban expansion predominantly has occurred coastal areas, where critical infrastructure like power and water treatment facilities are often located near water access. This proximity heightens exposure to Sargassum risks. Much of the critical infrastructure is outdated and susceptible to damage due to

[860] National Pesticide Information Center, "Sulfur General Fact Sheet," 2025, https://www.npic.orst.edu/factsheets/sulfurgen.html.

Sargassum. Although in general the resident population is declining, rising *Sargassum* concentrations further endanger growth in coastal areas where population is still increasing.

LAND USE AND BUILT ENVIRONMENT CHANGES

The vulnerability to *Sargassum* is significantly influenced by the land use and development patterns in Puerto Rico. The location of houses, businesses, and critical infrastructure, especially relative to water access, directly outlines the areas of most exposure to *Sargassum* risk.

In recent decades, there has been significant urban built-up cover throughout the island, most specifically large urban clusters in coastal plains and valleys. Most urban construction must take place in flat areas, and with the mountainous center of Puerto Rico varying greatly in elevation, this means the construction shows an easily distinguishable "coastal ring." The most densely populated cities are directly on the coast, like San Juan, which is also a huge tourist destination. Critical facilities such as power plants and water treatment plants must be within a reasonable distance from the urban areas they provide resources for, and their need for flat land to build leaves them near the coast and waterways that are impacted by *Sargassum*.[861]

The ongoing development of coastal resorts has increasingly displaced residents, degraded mangroves and wetlands, and heightened exposure to *Sargassum* inundation. The construction of additional hotels and excursion sites demands greater resources, including water, food, security, and emergency personnel. The everyday requirements for these resources are already stretched due to the building process, but the situation is exacerbated by rising *Sargassum* levels, which further strain the systems that support them.[862]

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Because the tourism remains one of the largest industries in Puerto Rico, growth and upgrades to resorts and excursion areas on the coast is only predicted to expand in the future, putting a strain on state and local resources. As *Sargassum* concentrations are expected to increase alongside coastal construction, the state will face heightened vulnerability to power outages and water quality alerts related to *Sargassum*. This poses risks for both tourism development and the challenges brought about by *Sargassum* growth, highlighting the importance for proper mitigation actions to take place, such as code enforcement and upgrades to utility protection.[862]

POPULATION CHANGES

The overall resident population of Puerto Rico is declining, and these aging demographics shift large-scale development patterns. As a result, development and infill are anticipated to rise, particularly in regions with existing infrastructure such as coastal cities of San Juan and Lajas. This may result in the installation of new utilities, towers, and energy assets in areas that are at high risk. In general, there is ongoing urban expansion in coastal areas such as San Juan, Cayey, and Rio Grande that already have a high population density, have

[861] Martinuzzi et al., "Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data," 2006, https://data.fs.usda.gov/research/pubs/iitf/ja_iitf_2007_martinuzzi001.pdf.
[862] The Conversation, "Coastal gentrification in Puerto Rico is displacing people and damaging mangroves and wetlands," 2022, https://theconversation.com/coastal-gentrification-in-puerto-rico-is-displacing-people-and-damaging-mangroves-and-wetlands-184214.

a large (and growing) tourism population, and are heavily dependent on critical facilities that can be damaged by *Sargassum*. While some are deterred from visiting the island when large *Sargassum* inundations occur, there is still much coastal resort growth with more clean-up and maintenance resources than local beaches. A growing population, along with growing *Sargassum* concentration, highly increases the vulnerability of these areas to *Sargassum* inundation.[863]

CHANGES IN VULNERABILITY OF STATE ASSETS

While some mitigation actions have helped reduce *Sargassum* vulnerability to state assets, a lack of major upgrades to critical infrastructure amid a rise in *Sargassum* concentration raises the vulnerability of assets such as power plants, water treatment sites, hospitals, schools, and government buildings. Although there are some ongoing modernization projects, such as enhancing the resilience of the power grid and installing filters around power and water plants, the majority of the critical infrastructure is aging and located in areas of high population density that depend on them. Without modernization of these critical facilities, they will continue to age each year through weatherization, so an increased *Sargassum* concentration will have a much higher impact on them.

CHANGES IN VULNERABILITY OF LOCAL ASSETS

Puerto Rico has recently strengthened its building codes and regulations to improve infrastructure resilience, including protections against coastal hazards such as *Sargassum*. Nevertheless, insufficient enforcement and limited retrofitting initiatives leave many older, coastal infrastructure vulnerable, especially the piping systems.[864] New filtration systems actually use *Sargassum* as a water filter as well, which could help smaller scale businesses and beach areas improve their water quality. Although these systems are very new and fickle, installing them is a step in the right direction to try to reduce local vulnerability.

Mitigation Success Stories

Even with the significant risks associated with *Sargassum*, numerous communities and institutions throughout the island—and in comparable areas—have proven that implementing strategic mitigation measures can greatly enhance resilience and protect both lives and property.

EPA METHODS: FOCUS ON SAFE AND EFFICIENT REMOVAL, ONGOING SINCE 2011

The simplest and most effective mitigation action for *Sargassum* impacts is the safe and efficient removal of the seaweed. While this poses many challenges, like resource cost, time, upkeep, and waste disposal, the collection and removal of *Sargassum* has helped clear beaches and waterways for continued enjoyment and function of residents and tourists. The EPA highlights some best practices that jurisdictions have used for

[863] Financial Oversight and Management Board for Puerto Rico, "A Changing Population: Understanding Puerto Rico's Demographic Trends," 2024, https://oversightboard.pr.gov/a-changing-population-understanding-puerto-ricos-demographic-trends/.
[864] AD&V, "Why the Changes in the Puerto Rico Building Codes Matter," 2018, https://www.alvarezdiazvillalon.com/blog/why-the-changes-in-the-puerto-rico-building-codes-matter.

collection and removal of *Sargassum* from near coastal waters and beaches. The best practices for collection include implementing a careful collection process for dead or dying *Sargassum* that minimizes sand intake, protects marine life, ensures proper storage, and informs users of affected areas. In terms of disposal, best practices include monitoring air quality for hydrogen sulfide and ammonia in disposal areas, testing unlined landfills on karst substrates for harmful contaminants, and considering washing *Sargassum* before disposal to mitigate soil salinization and protect vegetation.[865] There are also many ways to reuse *Sargassum* as fertilizer, biosorbent, biofilter, biofuels, livestock and fish food, soap, and food supplements, but there are also many new regulations that do not allow for this use in order to reduce *Sargassum* exposure and damage.

AQUATIC PLANT BARRIERS AND NETS, SINCE 2024

Scheduled cleanup of *Sargassum* has helped deal with the smell, sight, and release of harmful chemicals. While it is hard to keep up with and does not help pipelines much, aquatic plant barriers called" Floating Boom Barrier" have been installed in the areas where *Sargassum* can spread out the most. These barriers help deflect *Sargassum* from designated areas, containing the *Sargassum* to less impactful areas. These barriers are marine friendly and do not cause any damage to aquatic life. However, there have been some challenges with this, because barriers such as these need permits from state and local governments in order to ensure the proper use of them, and many of the people putting up these barriers do not get permits before installation.[866]

"MURSARGAZ"– A NEW CONTAINMENT BARRIER, AUGUST 2025

A new product presented by the Beach Trotters company as a way to mitigate power plant failure, "Mursargaz" was introduced by the Genera PR in a Palo Seco facilities tour in August of 2025. The product is described as a containment barrier with rigid floats and woven with a net that is submerged up to 5 feet in water. The coast of two barriers in Palo Seco and Aguirre would be just over $100,000, which is considered "fairly economical" by the Vice President of Government and Public Affairs of Genera, Iván Báez. These barriers can be placed into the channels of Units 3 and 4 of the Palo Seco power plant. Barriers like this have already been installed in the hotel zone in Fajardo. As *Sargassum* begins to retreat from its highest concentration, smaller pieces of large floating mats break off, leaving the power plants most at risk from September to December. While there are some mechanisms that filter seawater that prevents *Sargassum* and algae from obstructing the machinery, they have failed in the past, causing a prolonged plant shutdown that left many without power for days. This barrier will allow for secondary protection against *Sargassum* damage.[847]

REUSING *SARGASSUM* FOR FILTRATION SYSTEMS, 2025

Sargassum has been revealed as an excellent source for various industries, including biofuel production, cosmetics, pharmaceuticals, food ingredients, and even as construction materials; in addition, *Sargassum*

[865] U.S. EPA, "Management Methods for SIEs," 2025, https://www.epa.gov/habs/management-methods-sargassum-inundation-events-sies.
[866] León-Pérez et al., "First steps towards untangling the sargassum legal regime in Puerto Rico," 2024, *Marine Policy,* Volume 165 (106202).

has potential for use in water purification and wastewater filtration systems. *Sargassum* can effectively treat a flow rate of water equivalent to a four-person household with minimal energy loss. With increased flow rate, the filtration efficiency is reduced, but this study promotes a possible solution for using *Sargassum* as a valuable resource such as a biofilter, rather than it going to waste.

REUSING *SARGASSUM* AS FERTILIZER AND FOR COASTAL EROSION, 2025

While there are many new policies against using *Sargassum* for fertilizer and recycling it due to safety concerns, it has been known to be effective as "hay" for use in sand to lessen coastal erosion and to contain seeds in farms. When distributed into the sand and soil, it acts as a net that keeps the integrity of the land, lessening its vulnerability to water and wind erosion. This is similar to protecting crops, by acting as a net to protect any seeds and crops from blowing away in the wind or washing away in rain.[865]

SECTION 4.16

SUBSIDENCE

Subsidence

SUBSIDENCE DEFINITION

Subsidence is a sinking of the ground due to the movement of underground material, such as by removing water, oil, natural gas, or mineral resources from the ground by pumping, fracking, or mining.[867]

The USGS Survey defines land subsidence as a gradual settling or sudden sinking of the Earth's surface due to the removal or displacement of subsurface earth materials. Figure 242 shows four types of land subsidence.

[867] National Oceanic and Atmospheric Administration, "What is Subsidence?" 2025, https://oceanservice.noaa.gov/facts/subsidence.html.

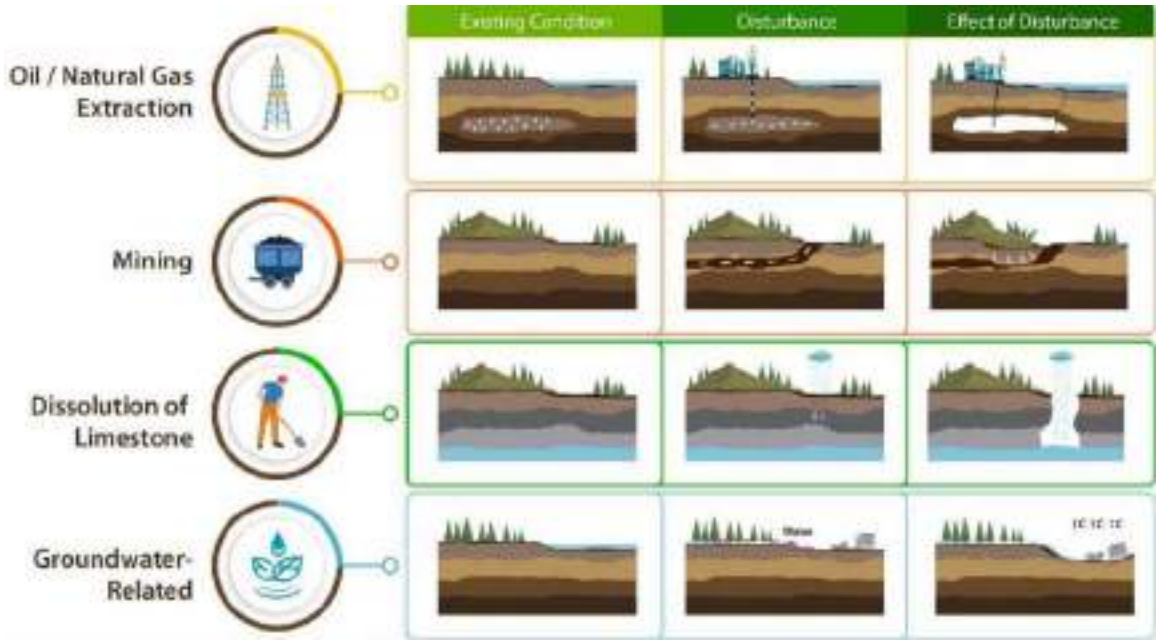


Figure 242: Types of Land Subsidence[868]

The principal causes of subsidence include the following:[869]

- Aquifer system compaction associated with groundwater withdrawals
- Drainage of organic soils
- Underground mining or unsupported excavation can create unbalanced stress in the soil
- Natural compaction or collapse, such as with sinkholes

In addition, natural events like earthquakes, soil compaction, glacial isostatic adjustment, erosion, sinkhole formation, and adding water to fine soils deposited by wind (a natural process known as loess deposits) can cause subsidence.[870]

On Puerto Rico, subsidence has resulted in the formation of collapse sinkholes in the northern limestone. These generally occur on blanket sands during or shortly after heavy rains. Percolating rainwater enlarges the network of drainage passages in the underlying limestone. Blanket sands sag on the surface when underground passages are of small diameter and nearby sands are drawn into them. Over time, a cavity forms above the bedrock contact (such as the caves in Figure 243). As drainage passages increase in

[868] Spacegen, "Disaster Management," https://spacegen.guru/landslip-and-land-subsidence/.
[869] U.S. Geological Survey, "Land Subsidence," 2025, https://www.usgs.gov/mission-areas/water-resources/science/land-subsidence.
[870] National Oceanic and Atmospheric Administration, "What is Subsidence?" 2025, https://oceanservice.noaa.gov/facts/subsidence.html.

diameter and more water percolates through them, the cavity increases in size because more sand is removed from above the contact zone. Collapse of the blanket sand layer results in the collapse sinkhole.[871]

Figure 243: Flank Margin Caves, Playa de Pájaros, Isla de Mona, Puerto Rico[872]

Location

Subsidence can happen over very large areas like whole states or archipelagos like Puerto Rico, or very small areas like the corner of a yard. In Puerto Rico, land subsidence may be caused by a combination of sediment loading (when rivers deposit sediment in an area that sinks under the additional weight) and sediment compaction after groundwater is removed.

The limestone region of Puerto Rico covers about 27.5% of the island and is subdivided into the northern, southern, and dispersed limestone areas. Researchers have found that subsidence can occur in regions with deep karst overlain by noncalcareous material—coastal deposits, alluvial deposits, or blanket deposits—that can leach acid waters which dissolve the limestone and cause subsidence. Karst is a terrain in which subterranean drainage follows cavities in readily soluble rocks (karstifiable rocks) and in which characteristic surface and underground features appear (karst phenomena) (see Figure 244). Readily soluble rocks are chiefly limestone, but include dolomite, other carbonate rocks, gypsum, and salt (see Figure 245).[873]

[871] U.S. Department of Agriculture, Forest Service, "Puerto Rican Karst-A Vital Resource," August 2001, https://data.fs.usda.gov/research/pubs/iitf/pr_karst_english.pdf.
[872] U.S. Geological Survey, "Karst Map of Puerto Rico," 2010, https://pubs.usgs.gov/of/2010/1104/.
[873] U.S. Department of Agriculture, Forest Service, "Puerto Rican Karst-A Vital Resource," August 2001, https://data.fs.usda.gov/research/pubs/iitf/pr_karst_english.pdf.

Figure 244: Rio Tanamá Cutting through Karstic Limestone Near Arecibo, Puerto Rico[874]

Figure 245: Uplifted Carbonate Platform of Isla de Mona, Puerto Rico[875]

Figure 246 shows areas where subsidence has been observed in Puerto Rico.

[874] U.S. Geological Survey, "Karst Map of Puerto Rico," 2010, https://pubs.usgs.gov/of/2010/1104/.
[875] U.S. Geological Survey, "Karst Map of Puerto Rico," 2010, https://pubs.usgs.gov/of/2010/1104/.

Figure 246: Potential Soil Subsidence in Puerto Rico

USDA's Natural Resource Conservation Service (NRCS) has collected data as part of the National Cooperative Soil Survey. The Soil Survey Geographic Database (SSURGO) contains a century's worth of information from field observations and laboratory analysis of soil samples. The database consists of maps and tabular data on the component soils and their properties.[876] Subsidence is among the attributes recorded in the SSURGO database. The values indicate the potential decrease in the surface elevation of wet soil in response to drainage.[877] There are areas along the north and west coasts of Cabo Rojo, where subsidence of over 100 cm is possible if the soil is drained.

Table 106 presents the estimated replacement costs for critical infrastructure assets located within the high subsidence risk areas identified in Figure 246. Assets are grouped by sector in accordance with the Department of Homeland Security's critical infrastructure classification framework.[878] Replacement cost values were derived from available federal and commonwealth data sources and reflect the exposure of existing facilities to subsidence-driven soil displacement and associated structural risk.

Table 106: Estimated Replacement Costs for Critical Infrastructure Assets Located Within the High Subsidence Risk Areas

Row Labels	Sum of Replacement Costs
Communications	$5,700,466.51
Energy	$131,658.48
Hazardous Materials	$6,005,439.01
Safety and Security	$251,489.81
Transportation	$3,672,129.07
Grand Total	**$15,761,182.89**

The SSURGO soil database identifies areas of high subsidence potential (greater than 100 cm if drained) concentrated along Puerto Rico's northern coastal plain and portions of the Cabo Rojo coast. The municipalities most exposed are Arecibo, Vega Baja, Toa Baja, and Cataño, with localized areas in Cabo Rojo containing a significant concentration of critical infrastructure assets whose replacement cost totals approximately $15.76 million across five sectors.

The largest single category is Hazardous Materials at $6.0 million, reflecting the presence of documented contaminated sites in the subsidence zone, including the Battery Recycling Company Superfund site in Arecibo and the Scorpio Recycling site in Toa Baja, both located in low-lying coastal soils susceptible to

[876] U.S. Department of Agriculture, Natural Resource Conservation Service, Soil Survey Geographic Database. SSURGO. https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.
[877] U.S. Department of Agriculture, Natural Resource Conservation Service, USA SSURGO – Soil Potential Subsidence. https://www.arcgis.com/home/item.html?id=3a1100ca5f6d4bd99a93601e156479bf.
[878] Cybersecurity and Infrastructure Security Agency (CISA), U.S. Department of Homeland Security, Critical Infrastructure Sectors, https://www.cisa.gov/topics/critical-infrastructure-security-and-resilience/critical-infrastructure-sectors.

differential settlement and groundwater disruption.[879] Communications infrastructure accounts for $5.7 million, consistent with the density of telecommunications assets serving the PR-22 corridor municipalities. Transportation assets represent $3.67 million, driven primarily by at-grade segments of PR-2 and the José de Diego Expressway (PR-22), which traverse the northern coastal plain through Toa Baja, Vega Baja, and Arecibo, including the longest bridge in Puerto Rico on PR-2 near Arecibo.[880] Safety and Security facilities total $251,489, covering police and fire infrastructure in these municipalities. Energy assets at $131,658 represent the lowest-cost category, likely limited to distribution-level infrastructure within the mapped subsidence boundary.

The concentration of Hazardous Materials and Communications assets as the two leading cost categories underscores the compounded risk profile of these areas. Beyond structural damage, the displacement or disruption of contaminated sites and communication nodes carries secondary cascading consequences for public health and emergency response capacity factors that warrant priority consideration in any mitigation strategy addressing subsidence hazard in Puerto Rico's northern and western coastal municipalities.

In addition, the Plan y Reglamento del Área de Planificación Especial del Carso (PRAPEC), adopted July 4, 2014, pursuant to Law No. 292-1999, provides additional regulatory and hazard context directly relevant to the subsidence risk analysis presented above.[881] Administered jointly by the Puerto Rico Planning Board (Junta de Planificación) and the Department of Natural and Environmental Resources (DRNA), PRAPEC establishes two overlay zoning districts across approximately 28.8% of Puerto Rico's land surface: the Restricted Karst Special Planning Area (APE-RC), covering the most ecologically sensitive 9.7% of the island, and the Karst Zone Special Planning Area (APE-ZC). The high-subsidence municipalities identified in Figure 246—Arecibo, Vega Baja, Toa Baja, and Cataño—fall within the northern karst belt that PRAPEC was specifically designed to govern, where limestone dissolution, subterranean drainage, and sinkhole formation are characteristic geologic processes.

PRAPEC documents prior hazard events that demonstrate the active nature of karst ground instability in these areas. Sinkhole collapses have been recorded in Manatí and Vega Baja, municipalities that share the same northern karst aquifer system and where sinkhole density has been documented at rates exceeding five events per square kilometer in portions of the limestone belt.[882] The Sumidero Tres Pueblos, a major collapse sinkhole at the convergence of the municipalities of Camuy, Hatillo, and Lares, illustrates the scale of karst void collapse possible in this geologic setting: the feature measures approximately 185 meters long, 145 meters wide, and 125 meters deep, with the Camúy River visible some 400 feet below the surface.[883]

[879] U.S. Environmental Protection Agency, "Superfund Sites in Reuse in Puerto Rico," Includes Battery Recycling Company (Arecibo) and Scorpio Recycling, Inc. (Toa Baja), https://www.epa.gov/superfund-redevelopment/superfund-sites-reuse-puerto-rico.

[880] Puerto Rico Highway 2, AARoads Wiki, Notes PR-2 contains the longest bridge in Puerto Rico, located in the eastern part of Arecibo, https://wiki.aaroads.com/wiki/Puerto_Rico_Highway_2.

[881] Departamento de Recursos Naturales y Ambientales (DRNA) and Junta de Planificación de Puerto Rico. Plan y Reglamento del Área de Planificación Especial del Carso (PRAPEC), adopted July 4, 2014, pursuant to Law No. 292-1999, https://www.drna.pr.gov/oficinas/division-de-geologia/.

[882] Sinkhole density data for the northern karst belt of Puerto Rico. See: Manatí, Puerto Rico — Karst and Geology section, Grokipedia, https://grokipedia.com/page/Manat%C3%AD,_Puerto_Rico.

[883] Sinkholes and Karst in Puerto Rico: Picturesque and Problematic. Sinkhole Conference 2020 Proceedings, University of South Florida Digital Commons. Includes documentation of Sumidero Tres Pueblos dimensions and the Rio Camuy

While the Sumidero Tres Pueblos represents a natural geologic feature, its scale is indicative of the void-forming capacity of the northern karst system, and PRAPEC identifies analogous collapse risk extending into the coastal municipalities where subsidence-sensitive soils overlie the same limestone formation.

The municipalities of Arecibo, Vega Baja, Toa Baja, and Cataño sit broadly within the high-subsidence coastal plain identified in the map above. As a result, critical facilities throughout these municipalities are subject to the same subsidence risk conditions. The following assets are confirmed within these high-risk municipal areas.

In the health sector, two acute care hospitals are located in Arecibo within the high-subsidence coastal plain: Hospital Metropolitano Dr. Susoni (120 beds) and Hospital Pavía Arecibo (172 beds).[884] In Vega Baja, the Wilma N. Vázquez Medical Center (120 beds) serves the municipality and sits within the northern karst coastal plain. The Bayamón Regional Wastewater Treatment Plant, the second largest on the island at 40 MGD design capacity, serves the municipalities of Bayamón, Guaynabo, Cataño, Toa Baja, and Toa Alta, and is located in the low-elevation coastal zone directly relevant to the subsidence area.[885]

In the water and wastewater sector, the Puerto Rico Aqueduct and Sewer Authority (PRASA) operates the Arecibo Regional Wastewater Treatment Plant (RWWTP) at the coast, regulated under the U.S. Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) Permit No. PR0023710, which discharges treated effluent to the Atlantic Ocean and has been identified by the EPA as a priority facility for infrastructure upgrades given its age and coastal exposure.[886] The Vega Baja Wastewater Treatment Plant (Planta de Tratamiento de Vega Baja) is situated in the Cabo Caribe coastal sector, adjacent to the Pantano del Cibuco nature reserve—a low-lying coastal wetland area with among the highest subsidence potential on the island. PRASA also maintains pump stations in Levittown (Toa Baja) that are critical conveyance infrastructure within the subsidence zone.

In the public safety sector, the Puerto Rico Police Bureau's Arecibo Region maintains its headquarters at 300 E. Hostos Avenue in Arecibo, serving Arecibo, Hatillo, Camuy, Barceloneta, and surrounding municipalities within the northern karst belt. The Bayamón Police Region, which covers Cataño, Toa Baja, Vega Baja, and adjacent municipalities, also operates multiple district precincts within the high-subsidence corridor. Municipal fire stations (Cuerpo de Bomberos) are present in Vega Baja and Toa Baja within the mapped risk zone. The Puerto Rico Department of Education's Arecibo Regional Office oversees schools

karst system. https://digitalcommons.usf.edu/sinkhole_2020/ProceedingswithProgram/Geomorphology_Formation_of_karst_and_sinkholes/1/.

[884] List of Hospitals in Puerto Rico. Wikipedia / American Hospital Directory. Includes Hospital Metropolitano Dr. Susoni (Arecibo, 120 beds), Hospital Pavía Arecibo (172 beds), and Wilma N. Vázquez Medical Center (Vega Baja, 120 beds). https://en.wikipedia.org/wiki/List_of_hospitals_in_Puerto_Rico.

[885] U.S. Environmental Protection Agency, "EPA and Puerto Rico Authorities Announce Funding to Enhance Bayamon's Wastewater Treatment Plant," June 2024. The Bayamón WWTP is the second largest in Puerto Rico (40 MGD design capacity) and serves Bayamón, Guaynabo, Cataño, Toa Baja, and Toa Alta. https://www.epa.gov/newsreleases/epa-and-puerto-rico-authorities-announce-funding-enhance-bayamons-wastewater-treatment.

[886] U.S. Environmental Protection Agency, Region 2. NPDES Permit Fact Sheet — Arecibo Regional Wastewater Treatment Plant, Permit No. PR0023710. 2025. Facility classified as a major discharger; coastal discharge to the Atlantic Ocean. https://www.epa.gov/system/files/documents/2025-09/2025-arecibo-rwwtp-fs-npdes-pr0023710.pdf.

across Arecibo, Vega Baja, Dorado, Vega Alta, and Manatí, all municipalities within or contiguous to the high-subsidence area, with individual school campuses distributed throughout the coastal plain.[887]

The concentration of health, water and wastewater, and public safety facilities within these high-subsidence areas underscores the need for facility-level exposure assessments. Assets that predate PRAPEC's 2014 adoption were sited without the benefit of its karst-aware permitting framework. PRAPEC's heightened review standards for the APE-RC and APE-ZC overlay districts are recommended as a baseline screening tool for any future mitigation investment or reconstruction of critical facilities in these municipalities.

Previous Occurrences

Subsidence in Puerto Rico dates back to the earliest recorded earthquakes, mining projects, and heavy rainfall events as well as impacts from soil compaction and erosion from water flow. It can be incredibly difficult to recover from subsidence occurrences, so these areas can worsen over time. Extreme earthquakes in 2020 still have small aftershocks occurring today. Thus, Puerto Rico remains on unstable ground that can easily be impacted by subsidence. However, area researchers state that there have been no confirmed subsidence events between 2019 and 2025. Nevertheless, subsidence will continue to increase the vulnerability of coastal communities.

FEDERAL DISASTER DECLARATIONS

There have been no federal disaster declarations due to subsidence.

PUERTO RICO DISASTER DECLARATIONS

There have been no disaster declarations in Puerto Rico due to subsidence.

SIGNIFICANT EVENTS

Most significant subsidence in Puerto Rico has been caused by major earthquakes. When faults begin to shift, the ground becomes unsteady and can subside, or the flow of water changes in a nearby river, leading to sediment compaction. This is most often caused by flooding in unusual areas.

LARGE DESTRUCTIVE EARTHQUAKE, OCTOBER 11, 1918

On the morning of October 11, 1918, Puerto Rico experienced one of its worst earthquakes. It originated in Mona Canyon, and it occurred before the invention of the Richter scale to measure earthquake intensity. The earthquake killed 116 people and cost the island more than $4 million. The earthquake caused a large

[887] Puerto Rico Department of Education. Directorio de Oficinas Regionales Educativas (ORE). "The Arecibo ORE oversees schools in Arecibo, Vega Baja, Dorado, Vega Alta, Manatí, Florida, Ciales, Barceloneta, Hatillo, Camuy, Lares, and Quebradillas." https://de.pr.gov/directorio/.

tsunami and many occurrences of subsidence on the island. Many buildings and homes sank into the ground or were shaken off their foundations.[888] One of them is shown in Figure 247.

Figure 247: Subsidence from an Earthquake, 1918

7.8 MAGNITUDE EARTHQUAKE, AUGUST 4, 1946

This was the largest earthquake to affect Puerto Rico. It generated a tsunami and caused major sand blows. Although its epicenter was on the neighboring island of the Dominican Republic, it caused many deaths on Puerto Rico and left damage that is still noticeable today. Subsidence was of particular concern after this earthquake, as many reports of sinking, abnormal flooding, and landslides were made. Although the tsunami was the deadliest and most damaging part of this event, subsidence took its toll on the island.[889]

SUBSIDENCE ON HIGHWAY PR 2, 1981

A drainage pit was located at the entrance of H.R. Robins Pharmaceutical at km 63 of Highway PR 2. From December 13 to 15, 1981, a 740 mm storm filled the pit to capacity. In 45 seconds, 5,500 m^3 (1.2 million gallons) of water drained into the ground with a roaring sound, as four large sinkholes (one with a diameter of 12 m) opened at the bottom of the pit.[890]

MASSIVE SINKHOLES AFTER HURRICANE MARIA, 2017

The strongest storm to hit Puerto Rico in 90 years caused a large influx of rainwater, damaging thousands of roadway sites and causing sinkholes. In Bayamon, a 100-ft-long sinkhole needed repair, a process that

[888] Public Seismic Network Inc, "1918 Earthquake," 2025, https://redsismica.uprm.edu/english/education/earthquakes/1918earthquake.php.
[889] Public Seismic Network Inc, "The 1946 Dominican Republic Earthquake & Tsunami," 2025, https://dpsninc.org/index.php/stories/37-the-1946-dominican-republic-earthquake-tsunami.
[890] US Department of Agriculture, Forest Service, "Puerto Rican Karst-A Vital Resource," August 2001, https://data.fs.usda.gov/research/pubs/iitf/pr_karst_english.pdf.

was incredibly difficult as rain continued long after the storm (see Figure 248). The reconstruction of these sinkholes became a financial and logistical nightmare for the entire state.[891]

Figure 248: Rebuilding a Sinkhole after Hurricane Maria

A study on the ongoing subsidence in Guayanilla since 2019 showed that there has been a 0.058 m subsidence in the El Faro community and a 0.082 m subsidence in Punta Ventana Beach. Both of these occurrences have led to coastal inundation. This suggests that coastal communities have a much higher vulnerability.[892] The largest earthquake, an M6.4 on January 7, 2020, caused ≤20 cm of shoreline subsidence near Guayanilla and many landslides and rock falls, including the collapse of a famous rock arch along the shore. Researchers have also identified seismic movement that activated a zone of diffuse deformation, where ruptures are transitioning from one fault to another. This activity may reflect the establishment of a new block boundary between Puerto Rico and Hispaniola, where Hispaniola is moving west and southwest relative to Puerto Rico.[893]

LARGE NUMBER OF EARTHQUAKES IN 2019 AND 2020

Hundreds of small earthquakes occurred in the same region near Ponce, PR from late December until the two largest earthquakes in recent record on January 6 and 7. These multiple small earthquakes led to several

[891] Investing, L. Kearney, et al. "In Puerto Rico, a sinkhole of rebuilding struggles," 2017, https://www.investing.com/news/economy-news/in-puerto-rico-a-sinkhole-of-rebuilding-struggles-841888.
[892] Rivera, et al. "Subsidence in Guayanilla: Challenges in the Southern Zone of Puerto Rico," University of Puerto Rico, 2024.
[893] U.S. Geological Survey, "Rapid-Response Seismic Reflection Survey to Identify the Fault Sources of the Southwestern Puerto Rico Seismic Sequence," November 30, 2020, https://www.usgs.gov/programs/cmhrp/news/rapid-response-seismic-reflection-survey-identify-fault-sources-southwestern.

instances of subsidence, particularly in small, flooded areas and building floors, that were worsened by the earthquake on January 7.[894]

SUBSIDENCE FROM 6.4 MAGNITUDE EARTHQUAKE, JANUARY 7, 2020

The strongest earthquake in the modern day—of M 6.4—occurred on January 7, 2020 at 4:24 local time. It struck 21 km WSW of Ponce, at 6 km in depth. This earthquake led to multiple subsidence occurrences throughout the state. In a study of 800 ground failure observations after this earthquake, the USGS observed several incidents of subsidence on the southwestern side of the state. For example, in Pole Ojea, there were multiple reports of subsidence ground failure as new settlements and flooding were observed. Most subsidence observations were made in Playa, revealed by abnormal flooding due to canal or coastal subsidence. There were many reports of building subsidence in the city of Playa, where business owners reported sinking and flooding.[895] A shop in Guánica experienced severe damage, with flooding occurring due to subsidence (see Figure 249).[896]

Figure 249: Shop in Guánica, Puerto Rico, Damaged by an Earthquake[897]

LARGE SUBSIDENCE OF INNER PUERTO RICO TRENCH WALL, 2024

Researchers found Pleistocene-age carbonate rocks on the southern side of Mona Block, a seamount near Puerto Rico. It was once an island over 1000 m high before subsiding and tilting due to the retreat of the North American slab, which contributed to the formation of the Puerto Rico Trench. The study suggests that the subsidence of the trench wall varies significantly and that the subsidence of the older carbonate platform

[894] U.S. Geological Survey, "Morning Update for Puerto Rico – January 7, 2020," 2020, https://www.usgs.gov/special-topics/2020-puerto-rico-earthquakes/news/morning-update-puerto-rico-january-7-2020.
[895] U.S. Geological Survey, "Field observations of ground failure triggered by the 2020 Puerto Rico earthquake sequence," 2020, https://usgs.maps.arcgis.com/apps/dashboards/8910b9cce56f486c9b129cc4ac95bac3.
[896] Anglican Ink, "Puerto Rico earthquakes severely damage churches," 2020, https://anglican.ink/2020/01/08/puerto-rico-earthquakes-severely-damage-churches/.
[897] Reuters/Ricardo Ortiz – RC20BE95VH2X, January 7, 2020.

to the north indicates a westward progression of trench collapse over time. This has made Mona Block a valuable site for examining mantle processes related to slab dynamics.[898]

Potential Severity of Event

The tool of choice used to detect and map land surface deformation is known as interferometric synthetic aperture radar (InSAR). InSAR uses repeat-pass radar images from Earth-orbiting satellites to monitor subsidence and uplift in incredible detail. Once subsidence is identified and mapped, assessments of the InSAR data can be conducted to improve our understanding of the subsidence processes.[899]

Another tool to measure land subsidence is the Global Positioning System (GPS). NOAA's National Geodetic Survey maintains a national network of high-precision GPS receivers, called a Continuously Operating Reference Station (CORS), that can be used to track changes in the height of the land. Areas without a CORS can measure subsidence from InSAR, temporary GPS receivers, repeated surveys of geodetic leveling, or installations of ground and water sensors.[900]

The University of Puerto Rico geological researchers use land-based techniques and ground-based instruments like tide gauges to provide localized measurements at specific coastal locations. This underscores a holistic approach to comprehending coastal subsidence.[901] There are 102 strong motion seismic stations in Puerto Rico, including 35 new stations installed in 2025 to accommodate seismic vibration studies that use accelerometers—essential instruments for measuring ground motion and detecting earthquakes. Ground subsidence risk levels are listed in Table 107 and are defined by combining ground subsidence susceptibility and intensity.

Table 107: Ground Subsidence Risk Matrix[902]

Susceptibility	Intensity	Risk
Very Low (0~0.3)	velocity > 0 mm/y	Very Safe (R1)
Low (0.3~0.5)	0 mm/y > velocity > −5 mm/y	Safe (R2)
Medium (0.5~0.7)	−5 mm/y > velocity > −10 mm/y	Medium (R3)
High (0.7~0.9)	−10 mm/y > velocity > −20 mm/y	Dangerous (R4)
Very High (0.9~1.0)	velocity < −20 mm/y	Very Dangerous (R5)

[898] Brink, et al., "Kilometers-scale subsidence of the inner Puerto Rico Trench wall since the Pleistocene," Open Access Geology (2025) 53 (8): 699–703.
[899] U.S. Geological Survey, "Land Subsidence," 2025, https://www.usgs.gov/mission-areas/water-resources/science/land-subsidence.
[900] National Oceanic and Atmospheric Administration, "What is Subsidence?" 2025, https://oceanservice.noaa.gov/facts/subsidence.html.
[901] University of Puerto Rico-Mayaguez, "Subsidence in Guayanilla: Challenges in the Southern Zone of Puerto Rico," 2024, https://www.uprm.edu/gerslab/wp-content/uploads/sites/214/2024/06/Perez_Agosto_2024.pdf.
[902] Taylor & Francis, "Ground Subsidence Risk Assessment Method Using PS-InSAR and LightGM: A Case Study of Shanghai Metro Network," January 1, 2024, https://www.tandfonline.com/doi/full/10.1080/17538947.2023.2297842#abstract.

Probability of Future Hazard Events

Based on historical events, available data, and the island's geography, there is a **high** likelihood that Puerto Rico will continue to experience subsidence incidents. Approximately 20% of the island is characterized by karst terrain, which includes jurisdictions ranging from Lozia to Auguada in the north and Cabo Rojo and San German in the south,[903] as illustrated in Figure 250.

[903] Estado Libre Asociado de Puerto Rico Departamento de Recursos Naturales y Ambientales, "El Carso de Puerto Rico," https://www.drna.pr.gov/wp-content/uploads/2015/04/El-carso-de-Puerto-Rico.pdf.

Figure 250: Karst Formations in Puerto Rico

The map shows various karst formations that will continue to subside. This includes the northern part of the island, which extends approximately 550 square miles and represents over 60% of the limestone in the north area. This area also has one of the biggest freshwater aquifers and significant coastal wetlands.[904]

Another factor that increases the future probability of these incidents is the climate. For example, on the northern coast, the weather can be very humid. Karst landscapes are shaped by the dissolution of soluble rocks, giving rise to distinctive features, such as sinkholes, caves, and intricate underground drainage networks. Therefore, high humidity may accelerate the weathering of carbonate rocks. The combined effects raise the probability of the collapse of sinkholes after storms, leaks, or concentrated drainage.[905]

In addition, a 2024 study conducted by the Geological Department at the University of Puerto Rico, Mayaguez, found a decline in elevation on the coastal areas and inundation of Guayanilla's coastal landscape. There was subsidence of 0.058 m in the El Faro community and 0.082 m in Punta Ventana Beach. These were the consequence of the aftershocks that were very active in 2020 and continued in 2024 but were less frequent. This event increased the vulnerability and the high probability of risks faced by the El Faro coastal community amid atmospheric events, storm tides, and potential tsunami events. The coastal environment continues to undergo dramatic changes, with an increase in flooding in swampy areas and potential disruptions in the ecological equilibrium. The study identified increasing subsidence between 2020 and 2024. Seismic activity in the southern region of Puerto Rico could precipitate not just subsidence but geological shifts. Researchers observed an integration of the intertidal lagoon into the ocean in the El Faro community and increased flooding in Punta Ventana Beach, which could lead to the fragmentation of the land and the formation of an islet apart from the mainland.[906]

Researchers have also identified a subsidence model for the January 7, 2020, M 6.4 earthquake. It predicts the location of maximum subsidence to be at the headwaters of the insular shelf and upper slope of the Guayanilla submarine canyon. Recurrent rupture of these faults could have helped create the shelf indentation in this area.[907]

Vulnerability Assessment

Subsidence continues to pose a significant hazard to areas of Puerto Rico with high susceptibility levels. With the increased frequency and intensity of atmospheric and geological hazard events prone to trigger subsidence, along with current land use activities, Puerto Rico can anticipate an increase in vulnerability to

[904] U.S. Forest Service, El Karso de Puerto Rico un Recurso Vital, https://jp.pr.gov/wp-content/uploads/2021/09/PLAN-DE-MANEJO-DEL-CARSO.pdf.
[905] Chudej, T, "The Karst Geology of Puerto Rico: Its History and Effect Today," 2021, https://storymaps.arcgis.com/stories/87369ce8de444282975f506ce65461a9.
[906] University of Puerto Rico-Mayaguez, "Subsidence in Guayanilla: Challenges in the Southern Zone of Puerto Rico," 2024, https://www.uprm.edu/gerslab/wp-content/uploads/sites/214/2024/06/Perez_Agosto_2024.pdf.
[907] U.S. Geological Survey, University of Puerto Rico Mayaquez Department of Geology, Jet Propulsion Laboratory "Mature Defused Tectonic Block Boundary Revealed by the 2020 Southwestern Puerto Rico Seismic Sequence," https://agupubs.onlinelibrary.wiley.com/doi/am-pdf/10.1029/2021TC006896.

subsidence events across the island. This can cause significant damage and disruption in high-susceptibility locations, populations, critical facilities and infrastructure, and community lifelines.

LOCATIONS

Puerto Rico is situated in a geologically active zone prone to seismic activity, which often triggers subsidence events. Along the north coast and the west coast of Cabo Rojo, subsidence of over 100 cm is possible if the soil is drained.

POPULATIONS

Populations in Puerto Rico in confirmed karst formations along the north coast and the west coast of Cabo Rojo are most vulnerable to these events, having a direct impact on property and potential for injury or fatality.

INFRASTRUCTURE, CRITICAL FACILITIES, AND COMMUNITY LIFELINES

Infrastructure, critical facilities, and community lifelines in confirmed high-susceptibility zones for subsidence are most likely to experience damage and disruption.

PROBLEM STATEMENTS

- Seismic activity can induce significant vertical movement of the soft and loose sedimentary soils in coastal areas, causing liquefaction of sandy substrates that trigger sudden subsidence.
- Seismic activity can often lead to the sinking of coastal land, coupled with the impact of sea-level rise, increasing the risk of flooding and posing substantial threats to coastal infrastructure and communities' integrity and resilience.[908]
- Coastal communities may face increased flooding as a result of subsidence and may require reconstruction or relocation due to increased susceptibility to such inundation events.
- Coastal communities with high susceptibility to subsidence are more vulnerable to extreme events like storm tides and spring tides, making them more at risk than other coastal areas in Puerto Rico.
- Other regions in southern Puerto Rico, such as Peñuelas and Ponce to the east and Yauco, Guánica, Lajas, and Cabo Rojo to the west, may be vulnerable to infrastructure damage from subsidence.
- There has been no recent susceptibility mapping of subsidence in Puerto Rico in areas other than the coastal areas of Guayanilla; thus, the ability to identify vulnerable structures and critical facilities inland is limited.
- There has been no recent susceptibility mapping of subsidence in Puerto Rico to identify vulnerable infrastructures and community lifelines that may impact these critical resources.

[908] University of Puerto Rico-Mayaguez, "Subsidence in Guayanilla: Challenges in the Southern Zone of Puerto Rico," 2024, https://www.uprm.edu/gerslab/wp-content/uploads/sites/214/2024/06/Perez_Agosto_2024.pdf.

- USGS states that most land subsidence incidents occur as a result of groundwater use and stem from the environmental consequence of local land and water-use practices.[909]
- Continued land development in Puerto Rico can worsen existing land-subsidence problems and initiate new ones.
- Subsidence detection and mapping are needed to understand and manage current and future land and water resources in areas where subsidence is a problem or may be in the future.
- Coastal communities may face increased flooding as a result of subsidence and may require reconstruction or relocation due to increased susceptibility to such inundation events.

Impact Assessment

STATE ASSETS

Figure 251 shows that residential structures overwhelmingly dominate exposure across Puerto Rico, which aligns with expectations given the island's housing density. Commercial and education facilities represent the next largest share, while industrial, government, and other uses remain comparatively minor. As anticipated, San Juan stands out as the most diverse and economically significant region, with substantial exposure not only in residential but also in commercial, industrial, and institutional categories. This diversity reflects the concentration of critical infrastructure and economic activity in the metropolitan area, underscoring its vulnerability to subsidence-related impacts.

[909] U.S. Geological Survey, "Land Subsidence," 2025, https://www.usgs.gov/mission-areas/water-resources/science/land-subsidence.

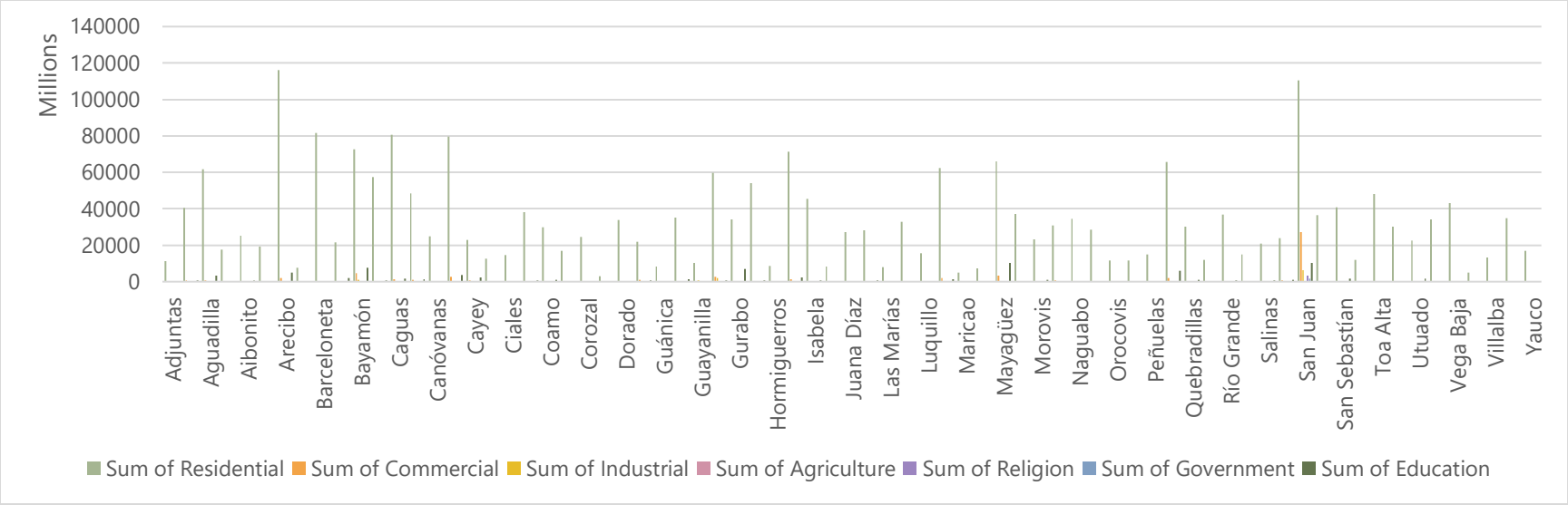


Figure 251: Replacement Value of Subsidence Exposure by Building Use

LOCAL ASSETS

Subsidence poses a serious threat to non-PRASA communities in Puerto Rico, which rely on community-managed aqueducts for their water supply. These systems depend on electricity to operate pumps and maintain water flow and supply. In a subsidence event, these systems could face an increased risk of service disruption and limited access to potable water due to damaged infrastructure and delayed emergency response, especially in remote areas with limited access, where restoration can take months. For instance, following Hurricanes María and Fiona, subsidence in a community in San Lorenzo began to affect a water tank that serves over 70 households. The shifting ground threatened the tank's structural integrity and the reliability of water service for residents. Subsidence poses a unique but critical hazard to Puerto Rico's infrastructure and community lifelines. The phenomenon occurs mainly through soil compaction, liquefaction during seismic events, and the settlement of coastal or reclaimed land. The challenges in the report on the Southern Zone of Puerto Rico by the University of Puerto Rico at Mayagüez notes that municipalities, such as Guayanilla, Yauco, Guánica, and Peñuelas, are located on soft sediments highly prone to vertical ground displacement during earthquakes. This vulnerability was demonstrated during the 2020 seismic sequence, when NASA interferometric mapping documented measurable ground subsidence and uplift in southern Puerto Rico.

Puerto Rico's energy infrastructure is particularly exposed. Substations built on coastal soils face foundation distress and lowered elevation, which increases their flood vulnerability. Transmission towers in soft soils may tilt or collapse, and renewable energy facilities (solar and wind) constructed on reclaimed or unconsolidated ground face long-term risks of misalignment and structural degradation.

Puerto Rico's water and wastewater systems also are sensitive to ground settlement. Subsidence alters the slope of gravity-fed sewer lines, causing blockages, infiltration, and exfiltration. Treatment plants in low-lying deltas or coastal areas, such as Arecibo and Mayagüez, are vulnerable to foundation cracks in basins and pump stations, while coastal outfalls may backflow if elevation drops further relative to sea level.

Puerto Rico's transportation assets experience direct operational consequences. Highways built across compressible soils in southern Puerto Rico are subject to cracking and depression. Bridge abutments in liquefaction-prone zones, such as Guayanilla and Peñuelas, may suffer differential settlement, compromising structural integrity. Coastal ports in San Juan, Ponce, and Guayanilla face deck settlement, which reduces elevation against tides and storm surge, while airports like Aguadilla's Rafael Hernández Airport risk runway deformation and ponding.

Puerto Rico's health, education, and public safety facilities also are vulnerable. Hospitals, schools, and EOCs in southern coastal municipalities face foundation damage from settlement, threatening their operational capacity during disasters. Since these facilities often double as shelters, their vulnerability directly impacts community resilience.

Puerto Rico's communications sector faces risks from tilted cell towers, ruptured fiber optic conduits, and foundation issues in data centers. These vulnerabilities are compounded by the sector's reliance on continuous power and stable ground conditions.

Geographically, subsidence hazards are most concentrated in the southwestern seismic belt, the southern coastal plain, and the northern metropolitan area. These regions combine soft sediments, high population density, and concentrations of critical assets, amplifying potential consequences.

The cumulative effects of subsidence include higher maintenance costs, reduced effectiveness of flood defenses, increased exposure to storm surge and flooding, and prolonged service interruptions across lifelines. Mitigation requires site-specific geotechnical investigations, flexible design approaches, monitoring of settlement, and integration of subsidence risk into capital planning.

COMMUNITY LIFELINES

Subsidence poses a growing threat to Puerto Rico's critical infrastructure and public safety, especially in areas vulnerable to ground instability. Its impacts extend across essential lifeline sectors, including safety and security, food and shelter, health, energy, communications, transportation, hazardous materials, and water systems. When subsidence damages roads, buildings, and utilities, it disrupts emergency response, service delivery, and daily life for the affected communities.

SAFETY AND SECURITY

Subsidence can lead to structural damage to Puerto Rico's buildings, roads, and bridges, creating hazardous conditions that threaten public safety. Sudden or severe subsidence can lead to ground collapses, posing direct risks to life and property. Access to emergency services (ambulances, fire trucks, etc.) can be hindered by damaged roads and blocked routes, making it difficult to respond to emergencies in a timely manner. This is especially challenging in areas with single-access road systems.

FOOD, HYDRATION, AND SHELTER

Subsidence events in Puerto Rico may damage homes and buildings and cause displacement, triggering the need for emergency sheltering. Subsidence can also affect water supply systems by damaging pipelines and reservoirs, leading to water shortages and contamination risks.

HEALTH AND MEDICAL

Subsidence can impact the integrity of healthcare facilities in high-susceptibility areas, affecting their ability to operate safely and affecting the delivery of medical services. In addition, if water supply systems are compromised by subsidence, which can lead to public health risks.

ENERGY

Puerto Rico's energy infrastructure could face major damage from subsidence events, including power lines, pipelines, and substations, leading to power outages and disruptions in fuel supply. This would have a direct effect on cooling systems and other essential services.

COMMUNICATIONS

Subsidence ground movement could damage Puerto Rico's communications infrastructure, such as above-ground cables and towers, disrupting phone and internet services and impacting island-wide emergency communication and coordination efforts.

TRANSPORTATION

In Puerto Rico, roads and bridges can be damaged by subsidence. Cracks, uneven surfaces, and structural failures can disrupt the movement of people and goods, leading to traffic delays and increased transportation costs.

HAZARDOUS MATERIALS

Subsidence can damage storage facilities or pipelines carrying hazardous materials, leading to leaks or spills that pose environmental and public health risks.

WATER SYSTEMS

Puerto Rico's utility infrastructure (water, electricity, and telecommunications) can be damaged by subsidence and lead to major, long-term service interruptions, leaks, or even hazardous situations, such as gas leaks and island-wide electrical failures.

Changes in Development

Recent development in Puerto Rico has been increasingly concentrated in coastal lowlands and the southern seismic belt—areas that are prone to geological challenges, such as subsidence and liquefaction. The 2020 Mw6.4 earthquake highlighted these vulnerabilities, with documented cases of ground failure in regions where infrastructure is being rebuilt. Current economic strategies favor redevelopment in these coastal areas due to their critical infrastructure and flat land, but this also raises concerns about the long-term stability of new construction.

CHANGES IN LAND USE AND THE BUILT ENVIRONMENT

Since 2017, development and redevelopment have been increasingly concentrated in coastal lowlands and the southern seismic belt, where unconsolidated marine and alluvial deposits, shallow groundwater, and earthquake shaking elevate the potential for subsidence and liquefaction. Field inventories from the January 7, 2020, Mw6.4 event documented widespread liquefaction, lateral spreading, and settlement across coastal municipalities—evidence that active redevelopment in these zones inherits measurable ground-failure susceptibility. Remote sensing (InSAR) mapped up to ~14 cm of vertical ground change near Ponce and

Guayanilla, confirming that parts of the coastal plain continue to experience differential ground motion that can interact with new or repaired infrastructure.[910]

Post-disaster rebuilding of roads, utilities, and public facilities has accelerated in these same corridors because they host critical lifelines and have flat, buildable land. Where reconstruction occurs on soft sediments or historic fill, even code-compliant designs can face long-term settlement, misalignment of gravity systems, and reduced freeboard at treatment plants and substations as ground surfaces gradually lower relative to water levels. Academic work in the southern zone, such as Guayanilla, Yauco, Guánica, and Peñuelas, links seismic shaking to subsidence signals and altered wetland/shoreline conditions since 2019, reinforcing that asset siting on these formations remains a key driver of future service interruptions unless there are geotechnical countermeasures.[911]

At the same time, coastal redevelopment and port-adjacent industrial activity remain strategic economic priorities, drawing investment to fill or reclaimed lands with higher compressibility. As relative elevation drops, effective flood protection declines, compounding exposure to surge and nuisance flooding. Adaptation reviews from Puerto Rico's Department of Natural and Environmental Resources (DRNA) highlight the need for setbacks, elevated pads, and design elevations in new public works.[912] More recent evaluations of Puerto Rico's Coastal Zone Management Program emphasize integration of sea level rise and land use planning to moderate subsidence impacts, although legacy footprints continue to anchor development in susceptible tracts.[913]

The modernization of Puerto Rico's energy and water sectors adds another development vector: utility-scale solar arrays, battery yards, and substation upgrades sited on flat coastal parcels, plus wastewater and stormwater rehabs on low-lying deltas. Without deep foundations, preload/ground improvement, and flexible connections, these assets can experience differential settlement, which degrades performance and reduces flood safety margins. Resilience assessments identify where population and infrastructure exposure overlaps with flood-prone coastal landscapes, which also tend to coincide with soft soil belts, amplifying subsidence-related consequences.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

The USGS identified land use as the main cause of the degradation of ground water quality in Puerto Rico. The northern limestone region of Puerto Rico is vulnerable to irreversible damage caused by dramatic

[910] U.S. Geological Survey (2020). "Ground failure and liquefaction inventories from the Jan 2020 Mw6.4 earthquake, Puerto Rico," 2020, https://www.usgs.gov/data/inventory-liquefaction-features-triggered-7-january-2020-m64-puerto-rico-earthquake.
[911] Pérez Agosto, D. (2024). Challenges in the Southern Zone of Puerto Rico. University of Puerto Rico at Mayagüez.
[912] Department of Natural and Environmental Resources (DRNA) (2015). Sea Level Rise Adaptation Review for Coastal Infrastructure in Puerto Rico.
[913] NOAA (2025). Puerto Rico Coastal Zone Management Program – Final Evaluation. National Fish and Wildlife Foundation (NFWF) (2020). Puerto Rico Coastal Resilience Assessment.

changes in the way people use the karst landscape. The functions and services of the karst belt are endangered by human activity; thus, the sustainability of human activity is placed in jeopardy.[914]

POPULATION CHANGES

Although Puerto Rico's overall population growth is flat to negative, risk does not diminish proportionally. Redevelopment tends to re-intensify existing footprints of ports, airports, industrial corridors, hospitals, and schools, keeping lifeline density high in subsidence-susceptible areas. The 2020 earthquake sequence and USGS ground-failure inventories provide empirical evidence of ground settlement. This underscores the importance of mandatory geotechnical investigations, settlement monitoring, pile or ground improvement solutions, and flexible design allowances for utilities[915] Unless development patterns shift inland or systematically adopt elevation, foundation, and flexible connection standards, subsidence will continue to magnify flood and service-continuity risk across Puerto Rico's most densely developed areas.

Mitigation Success Stories

RIO GUAYANILLA PROJECT ($63,600,000 TOTAL FEDERAL COST)

The Rio Guayanilla project area comprises the Guayanilla coastal floodplain, located about 16 kilometers west of the city of Ponce. Guayanilla lies in the floodplain, in the Playa de Guayanilla sector, and in other rural communities with an affected population of approximately 8,800 residents. A serious flood problem exists as the river passes directly through the middle of the town. Damage associated with flooding has been reported by the municipality 10 times in the last 25 years. Besides property damage, a serious risk exists to the lives and well-being of those residing in the floodplain. Frequent flooding seriously impedes the socioeconomic development of the community. DRNA completed the construction of one segment, Phase I, in 2006. No additional construction has been pursued by DRNA due to the financial conditions of the commonwealth. The Bipartisan Budget Act of 2018 (BBA18) appropriated $3M to complete a feasibility report. The feasibility study was brokered to the U.S. Army Corps of Engineers (USACE) Great Lakes and Ohio River Division (LRD). The Rio Guayanilla feasibility study was initiated in September 2018. A Chief of Engineers Report was signed on August 13, 2020.[916]

SEISMIC-RESILIENT SCHOOL RECONSTRUCTION – GUÁNICA AND YAUCO

Multiple schools in Guánica and Yauco were severely damaged by differential settlement and foundation cracking during the 2020 earthquakes. Reconstruction efforts, supported by FEMA's Public Assistance and Hazard Mitigation Grant Programs, integrated deep foundation systems, seismic retrofits, and soil improvement techniques to reduce settlement risk. These new schools were designed to serve as community shelters equipped with hardened infrastructure and backup systems. This approach ensures

[914] U.S. Department of Agriculture, Forest Service, "Puerto Rican Karst-A Vital Resource," August 2001, https://data.fs.usda.gov/research/pubs/iitf/pr_karst_english.pdf.
[915] National Fish and Wildlife Foundation (NFWF) (2020). Puerto Rico Coastal Resilience Assessment.
[916] U.S. Army Corps of Engineers, "Congressional Fact Sheet-Rio Guayanilla," May 2023, https://www.saj.usace.army.mil/About/Congressional-Fact-Sheets-2025/Rio-Guayanilla-PR-C/.

continuity of education and enhances emergency sheltering capacity, showing that rebuilding with geotechnical considerations can strengthen resilience at multiple levels.[917]

PORT AND COASTAL INFRASTRUCTURE ELEVATION – PONCE & GUAYANILLA

Settlement and relative sea-level rise have reduced flood protection for critical port facilities in Ponce and Guayanilla. To address this, the Puerto Rico Ports Authority, with FEMA recovery funding, elevated critical port equipment pads, fuel storage tanks, and access roads, and it reinforced foundations with geotechnical measures to account for soft soils. By raising infrastructure above design flood elevations and accounting for subsidence, these upgrades reduce flood risk and ensure continuity of maritime operations, which are vital for emergency supply chains. This success highlights the value of integrating subsidence allowances into elevation and foundation design.[918]

[917] COR3 (2022). Public Facilities – Infrastructure Recovery and Resiliency.
[918] Puerto Rico Ports Authority (2023). Coastal Resilience Projects Report.

SECTION 4.18
TORNADO

Tornado

DEFINITION

According to the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS), a tornado is a violently rotating column of air that extends from the base of a cumulonimbus cloud to the ground. Tornadoes develop when atmospheric instability, high humidity, and wind shear combine to create strong convective updrafts capable of producing rotation within a thunderstorm. When this rotation, known as a mesocyclone, tightens and stretches downward toward the surface, a tornado may form.[919]

In tropical and subtropical regions such as Puerto Rico, tornadoes are infrequent but not impossible. The island's geography, characterized by mountainous terrain and a relatively small land area, tends to inhibit the large-scale formation of tornado producing supercell systems. However, certain meteorological conditions such as atmospheric instability and vertical wind shear associated with tropical cyclones or strong convective storms may occasionally produce tornadic activity.

It is essential to distinguish between tornadoes and funnel clouds. A funnel cloud is a rotating condensation funnel extending from a storm base that does not reach the surface. Once the rotation makes ground or water contact, it becomes a tornado or waterspout, depending on the surface type.

Tornadoes in Puerto Rico are relatively rare and generally short lived; however, documented events demonstrate that localized tornadic activity does occur across the island, particularly in association with strong thunderstorms, tropical waves, and outer rainbands of tropical cyclones. Most recorded tornadoes in Puerto Rico have been classified within the lower end of the Enhanced Fujita (EF) Scale, primarily EF0 and

[919] NOAA National Severe Storms Laboratory (NSSL), "Tornado Basics," 2024, https://www.nssl.noaa.gov/education/svrwx101/tornadoes.

EF1, yet even weak tornadoes can produce damaging winds, flying debris, and localized structural failures that pose threats to public safety and critical infrastructure.[920]

An EF0 tornado produces wind speeds ranging from 65 to 85 mph and typically causes light damage, including broken tree branches, minor roof and siding damage, and the displacement of shallow-rooted trees. EF1 tornadoes generate wind speeds between 86 and 110 mph and can produce moderate damage, such as peeled roof surfaces, overturned mobile homes, snapped or uprooted trees, and damage to power distribution systems. While higher intensity tornadoes (EF2–EF5) have not been historically documented in Puerto Rico, their potential impacts must still be considered in mitigation planning, particularly as climate variability contributes to more frequent and intense convective storm environments.

Despite their limited frequency and generally low intensity, tornadoes in Puerto Rico present a disproportionate risk to vulnerable populations, informal housing, mobile homes, light-frame structures, temporary commercial facilities, agricultural installations, and overhead utility corridors. These vulnerabilities emphasize the importance of maintaining and enhancing tornado detection and warning capabilities, integrating tornado hazards into severe wind preparedness strategies, and applying tornado-resistant construction practices consistent with modern building codes and engineering standards.

Table 108: Tornado Intensity Classification and Damage Characteristics[921]

EF Rating	Wind Speed (mph)	Damage Description	Typical Impacts in Puerto Rico Context
EF0	65–85	Light damage; minor roof/siding, branches broken	Zinc roofing, kiosks, solar mounts, signage
EF1	86–110	Moderate damage; peeled roofs, mobile homes overturned	Wood structures, power lines
EF2	111–135	Considerable damage; roofs torn off	Housing collapse, outages
EF3	136–165	Severe damage; entire stories destroyed	Major infrastructure damage
EF4	166–200	Devastating damage; homes leveled	Near total destruction
EF5	>200	Incredible damage; structures swept away	Catastrophic loss

While Puerto Rico is not located within the primary tornado prone regions of the United States, the low-frequency but non-zero probability of tornado occurrence justifies its inclusion in the territory's multi-hazard risk assessment frameworks.

Location

Tornado activity in Puerto Rico is rare and spatially scattered, but available records confirm that such events have occurred across multiple regions of the island. According to the NOAA Storm Events Database and

[920] National Weather Service, *Storm Events Database – Puerto Rico Tornado Records*.
[921] NOAA EF Scale; NWS Storm Events Database; FEMA P-361; ICC 500-2023.

other climatological summaries, tornadoes in Puerto Rico are generally isolated, weak (EF0–EF1), and short-lived phenomena associated with intense convective systems or the outer rainbands of tropical cyclone.[922]

The central mountainous region of Puerto Rico tends to experience minimal tornado activity due to its elevation and the disruption of organized storm structures. In contrast, the northwestern, southwestern, and northern coastal plains where sea breezes and moist trade winds interact with convective boundaries appear to present a higher relative likelihood for isolated tornado development. The San Juan metropolitan area and surrounding municipalities may also be at limited risk due to dense urbanization and atmospheric instability occasionally triggered by nearby storm systems.

Despite these spatial tendencies, the overall frequency of tornadoes in Puerto Rico remains low and highly variable from year to year. The available data likely underrepresents true occurrences due to the island's limited radar detection coverage and the brief lifespan of weak tornadoes, many of which dissipate before being documented. These observational limitations underscore the need for continued meteorological monitoring and community awareness, ensuring that tornado hazards remain integrated into the island's multi-hazard risk assessment and emergency management strategies.[923]

While Puerto Rico is not located within the primary tornado-prone regions of the United States, tornado formation is possible under specific meteorological conditions. Spatial analysis suggests that tornadoes are more likely to occur in coastal and western municipalities characterized by flatter terrain and convective convergence, while the mountainous interior remains comparatively less exposed. Recognizing these spatial patterns supports improved risk communication, emergency preparedness, and the development of mitigation actions that consider the potential for rare but damaging tornado events.

Previous Occurrences

Tornadoes are a rare but documented hazard in Puerto Rico. Based on confirmed records from the NOAA Storm Events Database, 25 tornadoes were recorded across the island between 1974 and 2024. The majority of these events were classified as F0 or EF0, indicating weak intensity with localized and generally minor damage to structures and vegetation.

The earliest and strongest recorded tornado occurred on August 30, 1974, affecting the Gurabo Caguas area, and was rated F1. Since that time, tornado occurrences have been sporadic and geographically dispersed, with confirmed events documented in coastal, inland, and urban municipalities throughout Puerto Rico.

Most tornadoes in Puerto Rico are short-lived and occur under specific atmospheric conditions, commonly associated with severe thunderstorms, tropical disturbances, or the outer rainbands of tropical cyclones. While Puerto Rico's size and topography limit the development of long-track tornadoes, the historical

[922] National Centers for Environmental Information, Storm Events Database, 2024, https://www.ncdc.noaa.gov/stormevents/.
[923] Federal Emergency Management Agency, Hazard Mitigation Planning Resources, 2023, https://hazards.fema.gov.

record confirms that isolated tornado events remain a credible localized hazard, as summarized in Table 109, which presents the documented tornado events in Puerto Rico from 1974 through 2024.

Table 109: Documented Tornado Events in Puerto Rico, 1974–2024[924]

Location	County/Zone	St.	Date	Time	T.Z.	Type	Mag	Dth	Inj	PrD	CrD
Totals:								0	0	692.50K	1.00K
LARAMIE CO.	LARAMIE CO.	XX	06/30/1974	02:00	CST	Tornado	F1	0	0	250.00K	0.00K
Guaynabo	SAN JUAN CO.	XX	05/01/1995	16:45	AST	Tornado	F0	0	0	0.00K	0.00K
CABO ROJO	MAYAGUEZ CO.	XX	07/20/1999	14:15	AST	Tornado	F0	0	0	0.00K	0.00K
CABO ROJO	MAYAGUEZ CO.	XX	09/06/1999	14:55	AST	Tornado	F0	0	0	0.00K	0.00K
CEIBA	HUMACAO CO.	XX	09/06/1999	16:30	AST	Tornado	F0	0	0	0.00K	0.00K
CAGUAS	SAN JUAN CO.	XX	02/23/2000	14:35	AST	Tornado	F0	0	0	0.00K	0.00K
ADJUNTAS	WESTERN INTERIOR CO.	XX	08/25/2000	16:00	AST	Tornado	F0	0	0	5.00K	0.00K
ANASCO	MAYAGUEZ AND VICINITY CO.	XX	06/03/2001	17:10	AST	Tornado	F0	0	0	20.00K	0.00K
AGUADA	MAYAGUEZ AND VICINITY CO.	XX	10/04/2002	14:50	AST	Tornado	F0	0	0	5.00K	0.00K
CABO ROJO	SOUTHWEST CO.	XX	10/16/2004	18:17	AST	Tornado	F0	0	0	0.00K	0.00K
AGUADILLA	NORTHWEST CO.	XX	06/22/2005	14:20	AST	Tornado	F0	0	0	15.00K	0.00K
MAYAGUEZ	MAYAGUEZ AND VICINITY CO.	XX	06/16/2006	14:36	AST	Tornado	F0	0	0	30.00K	0.00K
ANASCO	MAYAGUEZ AND VICINITY CO.	XX	08/06/2007	14:20	AST-4	Tornado	EF0	0	0	35.00K	1.00K
AGUADILLA	AGUADILLA CO.	XX	08/25/2009	16:30	AST-4	Tornado	EF0	0	0	15.00K	0.00K
MOCA	MOCA CO.	XX	06/07/2011	13:35	AST-4	Tornado	EF0	0	0	80.00K	0.00K
LARES	LARES CO.	XX	09/13/2012	15:10	AST-4	Tornado	EF0	0	0	30.00K	0.00K
AGUADA	AGUADA CO.	XX	10/01/2013	14:43	AST-4	Tornado	EF0	0	0	10.00K	0.00K
MANATI	MANATI CO.	XX	11/18/2016	15:10	AST-4	Tornado	EF0	0	0	10.00K	0.00K
TRUJILLO ALTO	TRUJILLO ALTO CO.	XX	03/28/2017	15:00	AST-4	Tornado	EF0	0	0	0.00K	0.00K
LAJAS	LAJAS CO.	XX	07/27/2019	21:15	AST-4	Tornado	EF0	0	0	100.00K	0.00K
BAYAMON	BAYAMON CO.	XX	09/30/2019	13:30	AST-4	Tornado	EF0	0	0	0.00K	0.00K
ARECIBO	ARECIBO CO.	XX	05/01/2022	15:10	AST-4	Tornado	EF1	0	0	0.00K	0.00K
LAS PIEDRAS	LAS PIEDRAS CO.	XX	03/16/2023	15:10	AST-4	Tornado	EF0	0	0	40.00K	0.00K
AGUADA	AGUADA CO.	XX	07/16/2023	15:08	AST-4	Tornado	EF1	0	0	0.00K	0.00K
AGUADILLA	AGUADILLA CO.	XX	08/09/2023	13:00	AST-4	Tornado	EF0	0	0	40.00K	0.00K
ARECIBO	ARECIBO CO.	XX	05/02/2024	16:58	AST-4	Tornado	EF0	0	0	7.50K	0.00K
Totals:								0	0	692.50K	1.00K

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According to TornadoPath, which aggregates NOAA NCEI storm event records, the cumulative economic impact of all documented tornado events in Puerto Rico since 1950 is approximately $685,000 in property damage. The 1974 F1 Gurabo tornado accounts for the largest single-event loss at approximately $270,000, representing roughly 39% of all cumulative losses on record. Subsequent events including the May 2022 Arecibo EF1 tornado (~$100,000) and events in 2019 (~$100,000) and 2023 (~$70,000) represent the next most significant loss years. The 5-year moving average of annual property damage has trended upward since 2017, reflecting increased exposure in coastal municipalities. No crop damage has been recorded for any tornado event in Puerto Rico's history.

[924] NOAA Stom Events Data Base, https://www.ncei.noaa.gov/stormevents/.

The following figures show the location of past tornado events in Puerto Rico. Figure 252 shows the paths of past tornadoes, and Figure 253 shows the magnitude of past tornado events. As noted in the maps, most tornadoes recorded had low wind speeds and minor damage.[925]

[925] NOAA National Weather Service Storm Prediction Center, "SVRGIS," https://www.spc.noaa.gov/gis/svrgis/.

Figure 252: Historic Tornado Tracks

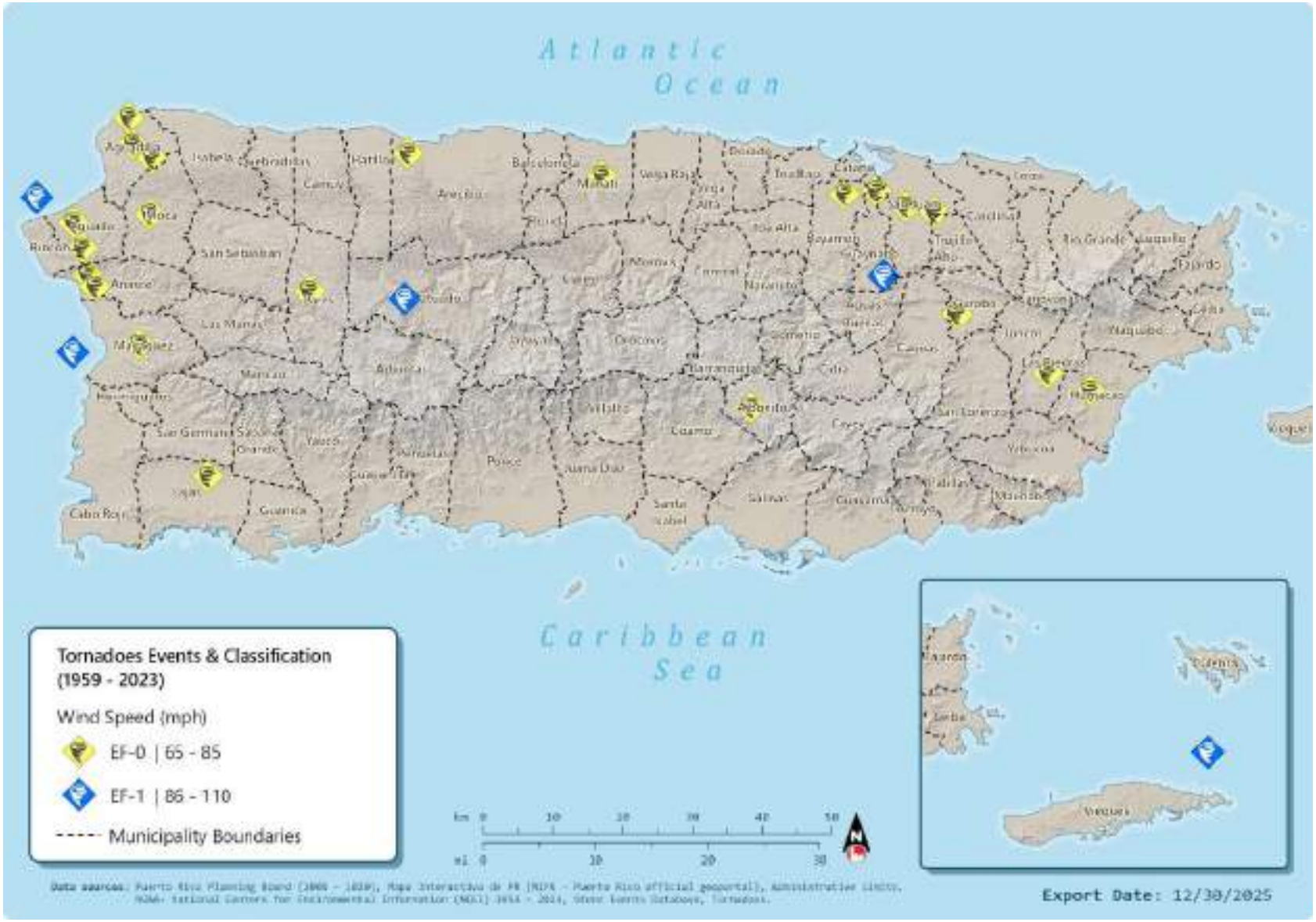


Figure 253: Past Tornado Events: 1959–2023

FEDERAL DISASTER DECLARATIONS

As of the summer of 2025, there have been no federal disaster declarations in Puerto Rico specifically attributed to tornado events.

PUERTO RICO DISASTER DECLARATIONS

There are no records of local disaster declarations issued exclusively for tornadoes in Puerto Rico. Tornado activity in Puerto Rico is generally short-lived, limited to a spatial extent, and often categorized by the NWS as minor or embedded phenomena within broader severe weather systems rather than independent disaster events.

SIGNIFICANT EVENTS

Based on records from the National Oceanic and Atmospheric Administration (NOAA), tornado occurrences in Puerto Rico are rare and infrequent, with most documented events classified as weak and short-lived (EF0–EF1). According to the NOAA Storm Events Database, the most recent confirmed tornado in Puerto Rico occurred on May 1–2, 2022, when a brief tornado affected the municipality of Arecibo, producing localized damage such as downed trees and minor structural impacts [926]. No fatalities were reported, and the event was consistent with the island's historical pattern of low-intensity tornado activity. As of the most recent NOAA database updates, no confirmed tornado events have been recorded for Puerto Rico during 2023–2025, underscoring the low frequency of such hazards on the island.

Looking further back, one of the most significant and well-documented tornado events in Puerto Rico's history occurred on August 30, 1974, near the municipality of Caguas. NOAA historical documentation identifies this event as the strongest confirmed tornado on record in Puerto Rico, classified as an F-1 tornado on the original Fujita Scale, with estimated wind speeds ranging from 73 to 112 miles per hour [927]. The tornado developed under unstable atmospheric conditions associated with late-summer convective activity and produced a damaging path approximately 2 miles (3.2 km) long and 50 yards (46 m) wide, based on post-event damage surveys (NOAA). Reported impacts included roof damage, uprooted trees, and downed power lines, with estimated property losses of approximately $250,000 in 1974 USD. No confirmed fatalities or serious injuries were reported (NOAA).

This 1974 tornado remains notable as the only tornado in Puerto Rico to receive an official Fujita Scale rating prior to the adoption of the Enhanced Fujita (EF) Scale in 2007. Because the event occurred before the installation of Doppler radar coverage in Puerto Rico, tornado characteristics were derived from post-event damage assessments rather than direct wind measurements. FEMA hazard assessments, in coordination with NOAA climatological data, recognize this event as evidence that Puerto Rico has a low but non-zero vulnerability to isolated tornadoes, particularly during strong convective storms or within the outer rainbands of tropical systems[928].

[926] NOAA, National Centers for Environmental Information (NCEI), Storm Events Database.
[927] NOAA, National Weather Service, Historical Severe Weather and Tornado Documentation for Puerto Rico.
[928] FEMA, Puerto Rico Hazard Mitigation Plan and FEMA Hazard Identification and Risk Assessment (HIRA) guidance.

Potential Severity of Event

The potential severity of tornado events in Puerto Rico is best understood through the Enhanced Fujita (EF) Scale, which serves as the national standard for assessing tornado intensity based on structural and vegetative damage indicators. The EF Scale estimates three-second gust wind speeds and expected damage potential, ranging from EF0 (65–85 mph) to EF5 (>200 mph), reflecting a continuum from weak to catastrophic damage potential.

In tropical and insular environments such as Puerto Rico, atmospheric and geographic conditions tend to constrain tornado development to the lower end of this scale. Historical observations confirm that most tornadoes documented on the island have ranged from EF0 to EF1, producing maximum winds between 65 and 110 miles per hour, which typically result in roof and siding damage, broken trees, and overturned light structures consistent with "minor to moderate" damage classifications under the EF framework.[929]

While the probability of an EF2 or stronger tornado remains very low, such an event cannot be entirely ruled out. Under rare circumstances such as when intense convective bands from tropical cyclones interact with strong vertical wind shear, Puerto Rico could experience a short lived EF2 tornado capable of tearing roofs from well-built structures, uprooting large trees, and causing localized infrastructure disruption. However, there are no recorded EF3 or higher tornadoes in Puerto Rico's meteorological history.

For hazard mitigation planning, the anticipated range of intensities to consider is as follows:

- **Most likely scenario:** EF0–EF1 events (65–110 mph) with limited and localized impacts.
- **Less probable but possible:** EF2 events (111–135 mph) with considerable damage potential, particularly in coastal or low-lying areas exposed to tropical cyclone rainbands.
- **Highly improbable:** EF3+ events (>136 mph), not historically observed but included in risk modeling as a low-probability, high-impact scenario.

Probability of Future Hazard Events

Based on available climatological records and NOAA's Storm Events Database, the occurrence of tornadoes in Puerto Rico remains infrequent and highly variable from year to year.[930] Historical data show that most documented events have been isolated and weak, typically associated with tropical rainbands or localized convective storms.

[929] National Oceanic and Atmospheric Administration, "Enhanced Fujita Scale (EF-Scale)," National Weather Service, 2023.
[930] National Centers for Environmental Information, "Storm Events Database (1950–2025): Tornado Events in Puerto Rico," National Oceanic and Atmospheric Administration, 2025, https://www.ncei.noaa.gov/stormevents/.

Given the island's tropical environment and limited historical frequency of 26 reported tornadoes[931] over the past five decades, the recurrence interval suggests that tornadoes may occur less than once every 5 years, corresponding to a **low** probability of future events.

While the probability is low, the potential for brief, localized tornadoes, particularly along coastal areas during tropical cyclone activity remains real. Therefore, continued meteorological monitoring and public awareness efforts are warranted to ensure preparedness for these rare but potentially damaging phenomena.

Vulnerability Assessment

Tornado hazards in Puerto Rico are considered rare and spatially limited; however, their occurrence remains possible under favorable atmospheric conditions. Areas with light construction materials, informal housing, or limited wind-resistant design are generally more susceptible to damage. Coastal and interior regions influenced by tropical convection or storm related shear environments may experience isolated tornado activity, warranting continued monitoring and integration of tornado risk considerations within broader severe wind mitigation strategies.

LOCATIONS

Historically, tornado activity in Puerto Rico has been reported across various municipalities, with a higher concentration along the northwestern and southwestern coasts where sea-breeze interactions and tropical rainbands enhance instability. Municipalities such as Aguadilla, Cabo Rojo, Añasco, Moca, and Arecibo have each experienced one or more recorded events. The central mountainous region experiences fewer occurrences due to topographic disruption of storm structures. Overall, tornado risk remains island-wide but spatially limited, with the highest likelihood in coastal and low-lying areas adjacent to the Atlantic and Caribbean shorelines.

PROBLEM STATEMENTS

- Tornado prone areas are mainly in coastal municipalities where population density and infrastructure exposure are greatest.
- Limited radar coverage may result in underreporting weak or short-lived tornadoes, leading to underestimation of risk.

POPULATIONS

Tornado hazards pose relatively low direct risk to the general population due to their rarity and small footprint. However, vulnerable populations living in lightly constructed homes, such as wooden or informal dwellings, are more susceptible to injury and displacement during EF0–EF1 events. Coastal communities in

[931] NOAA Storm Events Database, National Centers for Environmental Information.
Official federal database documenting tornado occurrences, dates, locations, and intensities in Puerto Rico (1974–2024).

municipalities such as Arecibo, Cabo Rojo, and Aguadilla may face short-notice exposure during tropical cyclone rainbands.

PROBLEM STATEMENTS

- Low-income and informal housing increases vulnerability to wind-related roof and wall damage.
- Short tornado lead times and rapid storm development, combined with the brief duration of tornado events, limit the ability of residents to receive warnings and take protective action, even when alerts are disseminated through established emergency notification systems such as WEA

STRUCTURES INCLUDING CRITICAL FACILITIES

Critical facilities such as hospitals, emergency operations centers, and utilities are generally designed to withstand high winds from hurricanes; therefore, most are structurally resilient to weak tornadoes. However, EF1–EF2 intensity events could still damage non-engineered components such as roofs, windows, and communication towers.

Small businesses, schools, and temporary structures are particularly vulnerable due to lightweight materials and limited anchorage.

PROBLEM STATEMENTS

- Non-engineered facilities may experience roofing or facade damage from high-speed rotational winds.
- Schools and public buildings often lack interior safe zones suitable for short-notice tornado sheltering.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Infrastructure systems could experience localized service interruptions during tornado events, especially where electrical distribution lines, communications towers, or transportation corridors intersect exposed coastal areas. Water and power systems may sustain minor but disruptive impacts if small tornadoes strike substations or lift stations.

PROBLEM STATEMENTS

- Overhead utilities and pole-mounted systems are susceptible to wind damage and debris impacts.
- Transportation routes in coastal or low-lying zones may experience short-term obstructions from debris and fallen trees.

Impact Assessment

Overall, the potential impacts of tornadoes in Puerto Rico are expected to be localized and low in magnitude, consistent with EF0–EF1 events. While the likelihood of widespread structural failure is minimal, targeted damage to individual homes, small businesses, and critical infrastructure can disrupt local services and pose short-term safety concerns.

Documented economic losses from tornado events in Puerto Rico total approximately $685,000 cumulatively since 1950, based on TornadoPath data aggregated from the NOAA NCEI Storm Events Database. This figure confirms that while aggregate losses are limited in absolute terms, individual events, particularly the 1974 Gurabo F1 (~$270,000) and the 2022 Arecibo EF1 (~$100,000), can produce concentrated, localized property losses in affected municipalities. Future EF0–EF1 events are expected to remain within this historical loss range, though the rising 5-year moving average trend observed since 2017 suggests that growing coastal exposure may result in incrementally higher losses from future events.

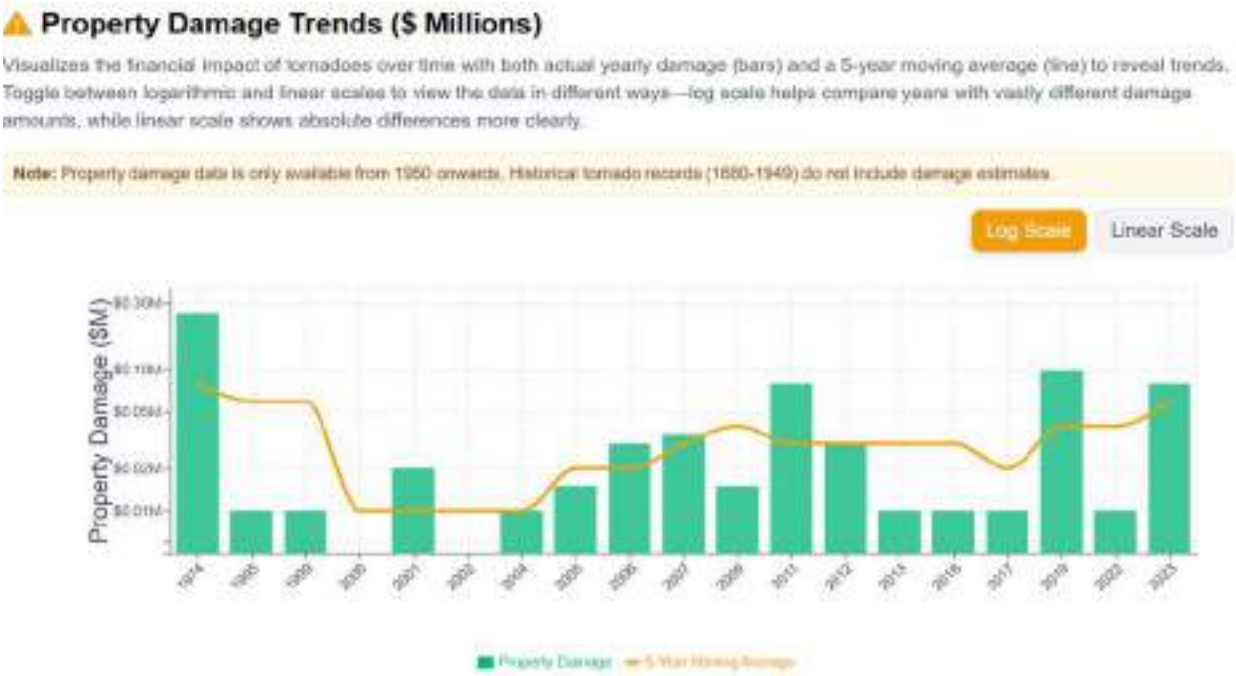


Figure 254: Property Damage Trends from Tornado Events in Puerto Rico ($ Millions), 1950–2023[932]

STATE ASSETS

State owned facilities including emergency management offices, universities, and transportation assets are generally built to hurricane resistant standards, reducing vulnerability to weak tornadoes. However, ancillary structures such as storage buildings, roof-mounted equipment, and outdoor installations remain susceptible to damage.

[932] TornadoPath, aggregated from NOAA NCEI Storm Events Database, https://www.tornadopath.com/puerto-rico.

LOCAL ASSETS

At the municipal level, most local assets, including public works facilities, community centers, and emergency shelters, are exposed to general wind hazards but not specifically designed for tornado resistance. Municipalities such as Aguadilla, Añasco, and Arecibo have previously reported tornado-related incidents, indicating the need for localized shelter and communication planning. Coordination between PREMB and local emergency managers can help identify priority structures for retrofitting or reinforcement.

COMMUNITY LIFELINES

Although tornadoes are rare in Puerto Rico, even short-lived events can disrupt one or more of the FEMA Community Lifelines, particularly those related to energy, communications, and transportation. The following subsections describe potential impacts.

SAFETY AND SECURITY

Localized tornadoes may cause temporary displacement of residents and pose debris of hazards. Maintaining public alert systems and rapid response capacity helps ensure timely protection of life.

FOOD, HYDRATION, AND SHELTER

Damage to homes or temporary shelters can affect short-term housing availability. Shelters designated for hurricane use generally suffice for tornado protection if reinforced interior spaces are available.

HEALTH AND MEDICAL

Health facilities are unlikely to sustain major damage from weak tornadoes, though access routes could be temporarily blocked by debris. Maintaining generator backup ensures continuity of emergency services.

ENERGY

Aboveground power lines are the most vulnerable components, with brief outages likely following EF0–EF1 events. Energy providers should continue vegetation management and pole hardening programs.

COMMUNICATIONS

Tornadoes may damage communication towers or antennas, briefly affecting mobile and broadcast networks. Hardening tower bases and securing backup power systems improve resilience.

TRANSPORTATION

Roadway and air transportation disruptions are possible due to fallen trees, debris, or short-term closures in impacted areas. Airports and ports remain largely unaffected beyond minor operational delays.

HAZARDOUS MATERIALS

Localized tornadoes could disturb unsecured materials in industrial or storage facilities. Regular inspections and proper containment practices minimize risks of release.

WATER SYSTEMS

Tornadoes may cause brief interruptions to localized pumping or treatment facilities if power loss occurs. Redundancy in electrical supply and backup generation supports continuity of operations.

Changes in Development

Development trends across Puerto Rico have altered how communities and assets may experience the impacts of tornadoes and localized tornadic winds. Although tornadoes are relatively rare on the island compared to the continental United States, changes in land use, urban expansion, and coastal redevelopment have created more built exposure in areas where these short-lived but destructive wind events could occur. According to the Puerto Rico Socioeconomic and Land Use Profile,[933] shifts in population distribution and critical infrastructure development have increased exposure within densely built coastal corridors particularly in the San Juan metropolitan region, where embedded tornadoes associated with tropical storms and hurricanes have historically been observed. These development changes, combined with aging infrastructure and uneven building code enforcement, have collectively influenced the island's vulnerability to tornadic hazards.

LAND USE AND BUILT ENVIRONMENT CHANGES

The expansion of Puerto Rico's built environment over recent decades has concentrated structures, power lines, and transportation networks in coastal and low-lying areas more susceptible to severe weather, including strong convective storms that can produce tornadoes. Suburban growth and the spread of critical infrastructure into open and flat terrain such as the northern and southern coastal plains have increased the number of assets exposed to high-velocity wind events. The replacement of natural vegetation with impervious surfaces and built structures has also intensified wind channeling effects and reduced aerodynamic buffering that vegetation once provided.[934]

In many municipalities, unregulated construction and informal housing have created concentrations of lightweight structures with limited wind resistance. These communities, often located on the urban fringe or near floodplains, are disproportionately vulnerable to structural failure even during short-duration tornadic events. Although the adoption of the 2018 and 2021 Puerto Rico Building Codes has improved design wind standards, enforcement remains inconsistent, and many existing buildings predate current codes, maintaining a legacy of vulnerability to localized wind hazards.[935]

[933] Puerto Rico Planning Board (JP), "Puerto Rico Socioeconomic and Land Use Profile Report," 2023.
[934] USGS, "National Land Cover Database (NLCD) Impervious Surface Dataset for Puerto Rico," 2021.
[935] OGPe, "Puerto Rico Building Code Implementation and Compliance Report," 2024.

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Future growth patterns suggest continued densification along the northern coastal belt, especially around San Juan, Bayamón, Carolina, and Dorado, where redevelopment following recent hurricanes is ongoing.[936] This concentration of mid-rise and high-rise structures increases potential exposure to debris impacts and wind pressure differentials that could occur during tornadic storms embedded in tropical systems. Tourism-driven coastal redevelopment also adds exposure, as new hotels and resorts frequently feature large glass facades and open layouts that are highly vulnerable to sudden pressure changes caused by tornadoes or waterspouts.

While reconstruction after Hurricanes Maria and Fiona has improved resilience through the use of reinforced materials and elevated designs, many rebuilding projects have restored facilities in the same high-exposure locations. Without broader integration of hazard-based sitting criteria, redevelopment could continue to reinforce patterns of vulnerability to tornado and high wind impacts.

POPULATION CHANGES

Puerto Rico's population decline and internal migration has shifted exposure patterns to tornadic hazards. As rural areas depopulate, more residents concentrate in urbanized municipalities where tornado-producing storm systems are most likely to interact with dense infrastructure. This shift means that even isolated tornadoes could now affect a larger number of people and assets within a smaller geographic footprint. Meanwhile, aging populations in rural towns may face challenges responding to emergency alerts or sheltering during sudden tornadic events.[937] These demographic changes have therefore indirectly increased vulnerability by reducing adaptive capacity and concentrating exposure in built environments that were not originally designed for intense wind resistance.

VULNERABILITY OF STATE ASSETS CHANGES

State-owned infrastructure such as power plants, water treatment facilities, and communication towers are increasingly located in open or exposed areas where localized tornado activity could cause significant damage.[938] Many of these facilities were designed primarily for hurricane-force winds but may not have been evaluated for the unique loading patterns or directional shear associated with tornadoes. For example, schools, hospitals, and emergency operation centers constructed before updated codes may not provide adequate sheltering protection from rapid tornadic wind bursts or flying debris. Although the Government of Puerto Rico and Central Office for Reconstruction, Recovery and Resiliency (COR3) have initiated infrastructure modernization projects under FEMA funding, the focus has largely been on hurricane resilience; the potential for embedded tornadoes within those systems remains a secondary consideration.[939]

[936] FEMA, "Puerto Rico Recovery Progress Report: Resilient Reconstruction after Hurricanes Irma and Maria." 2021.
[937] C. West et al., "Puerto Rico Social Vulnerability Index Report," University of Colorado Boulder, 2022.
[938] Department of Transportation and Public Works (DTOP), "Critical Infrastructure Exposure and Resilience Assessment," 2023.
[939] COR3, "Infrastructure Modernization and Reconstruction Progress Report," 2023.

VULNERABILITY OF LOCAL ASSETS CHANGES

Local assets including residential neighborhoods, small businesses, and municipal buildings are particularly susceptible to tornadic damage due to inconsistent construction quality and the prevalence of non-engineered structures. Informal settlements and low-income housing areas, such as those in Loíza, Toa Baja, and parts of Guayama, include lightweight materials that can be easily uplifted or displaced during even weak (EF0–EF1) tornadoes. Local infrastructure, such as power lines and communication networks, is also vulnerable to failure from debris impacts and falling trees, which can disrupt emergency response and recovery operations.

Additionally, the proximity of many coastal communities to the sea increases the potential impact of waterspouts that make landfall and transition into tornadoes. These phenomena, though short-lived, have historically caused structural and utility damage in municipalities such as Mayagüez, Cabo Rojo, and San Juan.[940] Because local planning frameworks have not traditionally included tornado-specific risk considerations, mitigation at this scale remains limited.

Although tornadoes are infrequent in Puerto Rico, the evolution of land use, redevelopment, and infrastructure expansion has increased the potential for concentrated impacts from such events. Population density along the coasts, informal housing growth, and inconsistent code enforcement have collectively heightened vulnerability. While broader hazard-resilient reconstruction efforts after recent hurricanes have improved the overall robustness of structures, tornado-specific vulnerability remains under-addressed in both state and local planning. As development continues, incorporating localized wind hazard mapping, designing wind-resistance verification, and improved early-warning systems will be essential to mitigating the risk of future tornado impacts on the island.

Mitigation Success Stories

Over the past 5 years, Puerto Rico has strengthened its efforts to address risks associated with extreme wind events, including tornadoes, through the implementation of mitigation strategies and the expansion of hazard-resistant infrastructure. Although tornadoes remain infrequent on the island, the Commonwealth's wind mitigation initiatives under FEMA's Hazard Mitigation Grant Program (HMGP) have produced projects that directly enhance resilience against both hurricanes and tornadoes.

Several mitigation initiatives have focused on constructing FEMA-compliant community safe rooms designed to withstand extreme winds, implementing building code updates, and investing in technical assistance for resilient design. These efforts represent a proactive approach to protecting life and property from multiple wind-related hazards, including tornadoes.

Between 2020 and 2025, Puerto Rico through COR3 has prioritized the inclusion of extreme wind mitigation as a core element of its infrastructure recovery portfolio. Although no tornado-specific mitigation "success story" has been documented locally due to the rarity of these events, the Commonwealth's investment in

[940] National Weather Service, "Waterspout and Tornado Events Database for Puerto Rico," 2024.

safe room construction and structural wind retrofits demonstrates a tangible advancement in preparedness for potential tornado hazards.

CONSTRUCTION OF 10 FEMA-APPROVED COMMUNITY SAFE ROOMS ACROSS PUERTO RICO (2022)

In 2022, FEMA approved approximately $24.4 million for the construction of 10 community safe rooms in eight municipalities: Ceiba, Guayama, Las Marías, Orocovis, Peñuelas, Ponce, San Germán, and San Juan. These facilities are built to meet FEMA P-361 and FEMA P-320 standards, offering near-absolute protection against extreme winds, including tornadoes.

IEM CONTRACT FOR ADVANCED ASSISTANCE AND STRUCTURAL MITIGATION SUPPORT (AUGUST 2023)

In August 2023, Puerto Rico executed a $24 million contract with IEM to support the design, risk analysis, and development of structural mitigation projects across the island. The scope includes Advanced Assistance Hurricane Safe Rooms, which are designed to withstand tornado-level wind forces, enhancing community resilience.

HAZARD MITIGATION RESILIENCE ACTIVITIES APPROVED UNDER HMGP (2023–2024)

Between 2023 and 2024, FEMA approved an additional $17 million in hazard mitigation projects under the HMGP. These include safe rooms, generators, flood control measures, and slope stabilization efforts. While primarily focused on hurricane resilience, these initiatives also bolster infrastructure against extreme wind events, including tornadoes.

SECTION 4.18
TSUNAMI

Tsunami

TSUNAMI DEFINITION

Tsunamis are powerful, long waves triggered by sudden shifts in the ocean floor, such as earthquakes, landslides, or volcanic eruptions. Puerto Rico's location above a Caribbean subduction zone makes it particularly prone to these events.[941]

Tsunamis affecting Puerto Rico, the Virgin Islands, and nearby islands are primarily driven by the interaction between the North American and Caribbean tectonic plates. These islands sit atop the Caribbean plate, which is slowly converging with the North American plate at a rate comparable to the growth of a human fingernail, as Figure 255 confirms. This gradual but powerful movement creates significant seismic activity, increasing the region's vulnerability to earthquakes and tsunamis. The entire island of Puerto Rico is vulnerable to tsunamis. Additional details on earthquake risks that can trigger tsunamis are available in the Earthquake hazard profile.

[941] U.S. Geological Survey, Natural Hazards Mission Area, "Puerto Rico Natural Hazards: Tsunamis | Peligros naturales de Puerto Rico: Maremotos," June 22, 2022, https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-natural-hazards-tsunamis-peligros-naturales-de.

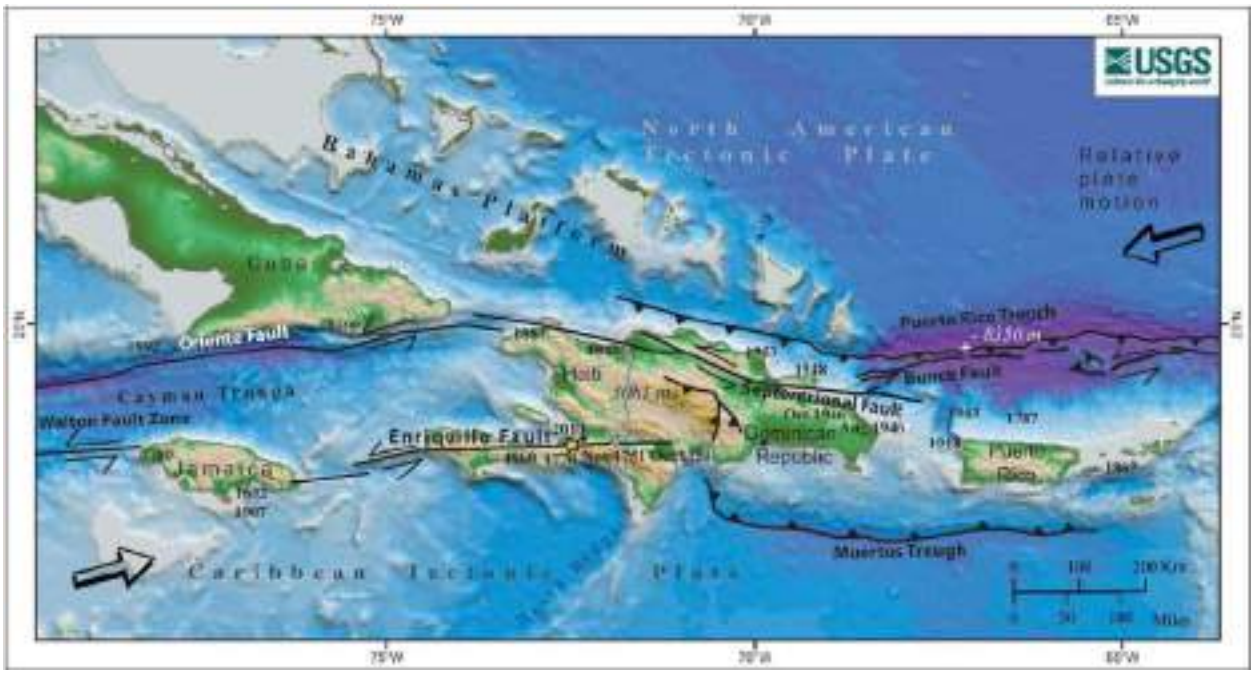


Figure 255: Map of the Caribbean Tectonic Plate Boundary[942]

Location

Figure 256 illustrates the underwater topography (bathymetry) and geological features of the northeastern Caribbean, emphasizing the Puerto Rico Trench, which is the deepest part of the Atlantic Ocean and lies just north of the island. This trench and surrounding seafloor structures are critical to understanding tsunami risk, as they are shaped by tectonic activity along the subduction zone where the North American and Caribbean plates meet. The steep underwater slopes and fault lines in this region can trigger tsunamis through earthquakes or landslides. Detailed mapping of these features helps scientists assess the origin and potential impact of future tsunami events on Puerto Rico.[943]

[942] U.S. Geological Survey, Woods Hole Coastal and Marine Science Center, "Caribbean Tsunami and Earthquake Hazards Studies," August 21, 2018, https://www.usgs.gov/centers/whcmsc/science/caribbean-tsunami-and-earthquake-hazards-studies.

[943] U.S. Geological Survey, Natural Hazards Mission Area, "Puerto Rico Natural Hazards: Tsunamis | Peligros naturales de Puerto Rico: Maremotos," June 22, 2022, https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-natural-hazards-tsunamis-peligros-naturales-de.

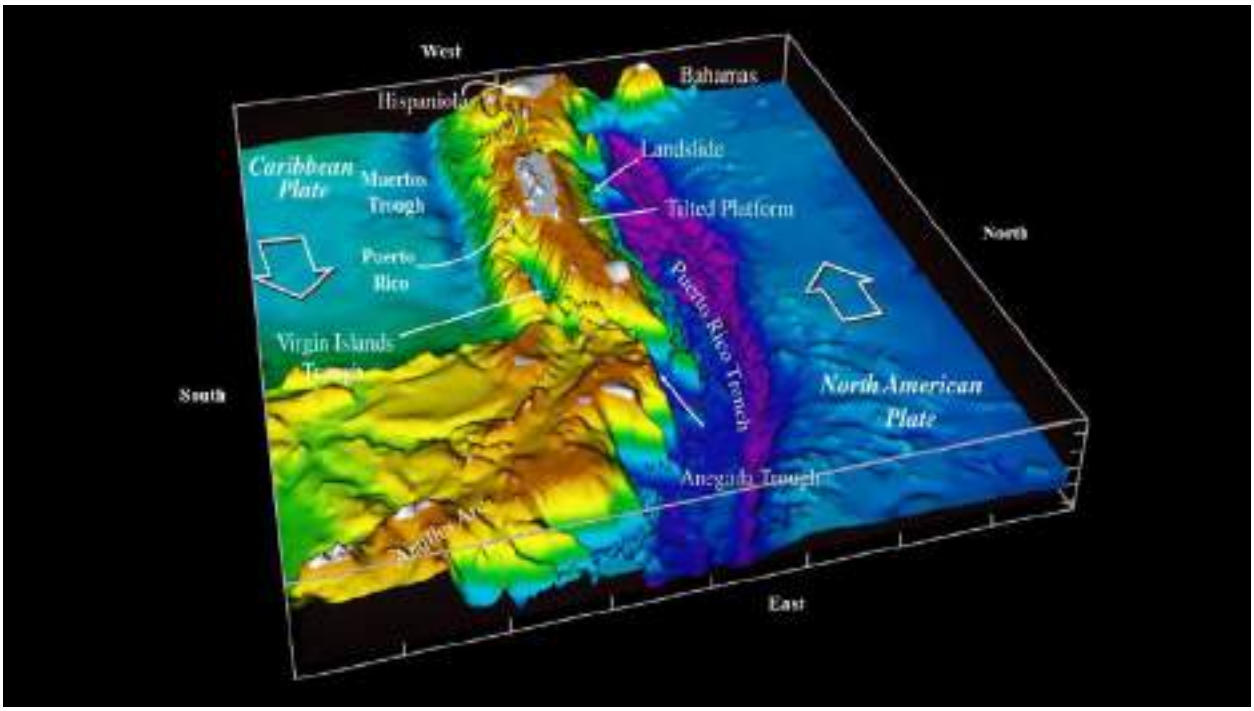


Figure 256: Morphology and Color-Shaded Bathymetry of the Northeastern Caribbean Region[944]

Puerto Rico is equipped with a network of tsunami-ready tide gauge stations, which play a critical role in detecting and responding to tsunami threats. These stations complement the 10 tide gauges operated by the National Oceanic and Atmospheric Administration (NOAA), which are part of a broader U.S. Tsunami Warning System. The tide gauges measure real-time water level changes every minute, allowing scientists to detect sudden shifts in sea level that may indicate the arrival of a tsunami following an earthquake.[945]

To determine whether a tsunami has been generated following a seismic event, these tide gauges monitor changes in the ocean's response. The data is transmitted to Tsunami Warning Centers, which use it to update forecasts, estimate wave arrival times, and issue alerts to emergency managers. This system provides critical lead time for evacuations and other protective actions.[946]

This tide gauge network is integrated with the Puerto Rico Seismic Network (PRSN) and the Puerto Rico Strong Motion Program (PRSMP). PRSN monitors seismic activity across the region, detecting earthquakes that could trigger tsunamis. PRSMP complements this by recording strong ground motions, which help assess the intensity and potential impact of seismic events. Together, these systems provide a

[944] U.S. Geological Survey, Natural Hazards Mission Area, "Puerto Rico Natural Hazards: Tsunamis | Peligros naturales de Puerto Rico: Maremotos," June 22, 2022, https://www.usgs.gov/mission-areas/natural-hazards/science/puerto-rico-natural-hazards-tsunamis-peligros-naturales-de.
[945] National Oceanic and Atmospheric Administration, National Ocean Service, "NOAA Tide Gauges Support Tsunami Response," September 18, 2025, https://oceanservice.noaa.gov/news/sep25/tide-gauges-tsunami-response.html.
[946] National Oceanic and Atmospheric Administration, National Ocean Service, "NOAA Tide Gauges Support Tsunami Response," September 18, 2025, https://oceanservice.noaa.gov/news/sep25/tide-gauges-tsunami-response.html.

comprehensive approach to understanding and assessing tsunami hazards in Puerto Rico, enhancing both early warning capabilities and long-term hazard mitigation planning.

The gauge network is also important for estimating the arrival time of tsunami waves, a factor that depends on the location of the earthquake's epicenter. This factor is critical for emergency planning, as it determines how much time coastal communities have to evacuate before the first wave reaches land.[947] Figure 257 illustrates tsunami wave arrival times across Puerto Rico, based on the location of the earthquake's epicenter.

The classification is as follows:

- **Local:** If the tsunami wave is expected to arrive in less than or equal to one hour, it is considered a local tsunami. These events offer very limited time for evacuation, often requiring immediate action or vertical evacuation due to the short window.
- **Regional:** If the wave is expected to arrive in one to three hours, it is classified as a regional tsunami. This allows for more time to evacuate horizontally but still requires rapid coordination and public alert systems.
- **Distant:** If the wave is expected to arrive in more than three hours, it is considered a distant tsunami. These events typically originate from far-field sources, such as the Lisbon earthquake of 1755, which sent waves to the Caribbean several hours later.

[947] Negociado para el Manejo de Emergencias y Administración de Desastres. "Guía para desalojo vertical en Puerto Rico" (1ra ed.) Caguas, PR, 2022.

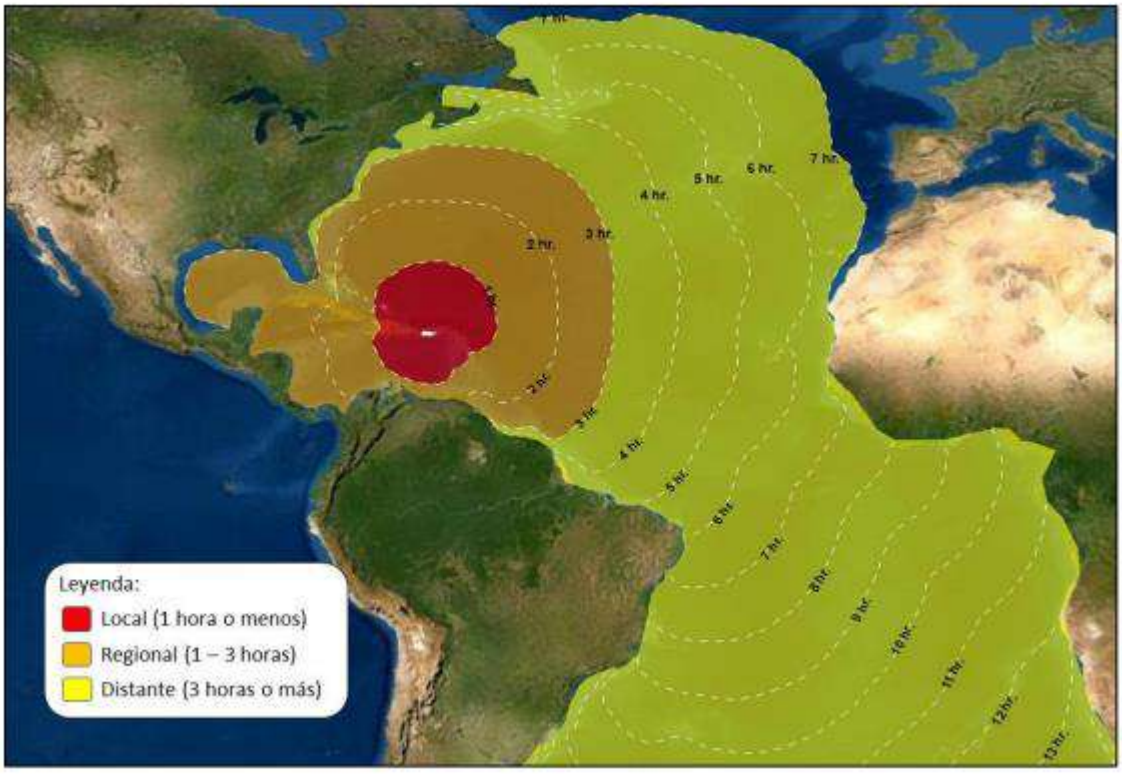


Figure 257: Tsunami Wave Arrival Times in Puerto Rico, Which Vary Based on the Earthquake's Epicenter[948]

Previous Occurrences

Tsunamis in Puerto Rico are relatively rare, with the most notable events occurring in 1867 and 1918. Despite their infrequency, the region remains at risk due to nearby active seismic zones, such as the Puerto Rico Trench, which can generate tsunamis through earthquakes or underwater landslides.[949]

The 1867 tsunami was triggered by a magnitude 7.5 earthquake near the Virgin Islands, causing significant damage and fatalities. The 1918 event followed a magnitude 7.3 earthquake off the coast of western Puerto Rico, resulting in a tsunami that impacted coastal communities and led to loss of life (see Figure 258).

Following a magnitude 7.9 earthquake north of Hispaniola on August 4, 1946, a powerful tsunami struck the northeastern coast of Hispaniola and impacted parts of Puerto Rico. Reports indicate that the tsunami moved inland several kilometers and, tragically, around 1,800 people drowned in Hispaniola. While Puerto

[948] Taken from the 2022 Tsunami Alert Focal Point Operators Guide.
Negociado para el Manejo de Emergencias y Administración de Desastres. "Guía para desalojo vertical en Puerto Rico" (1ra ed.) Caguas, PR, 2022.
[949] Hincapie, J., & McCreery, C. (2024). *PRVI User's Guide: PTWC tsunami products for Puerto Rico, the U.S. Virgin Islands, and the British Virgin Islands* (Version 1.22). NOAA / National Weather Service, Pacific Tsunami Warning Center. https://www.weather.gov/media/itic-car/PRVI%20User's%20Guide%20-%20Version%201.22_042824.pdf.

Rico was not the epicenter, the event demonstrated the island's vulnerability to tsunamis generated by seismic activity in nearby fault zones.[950]

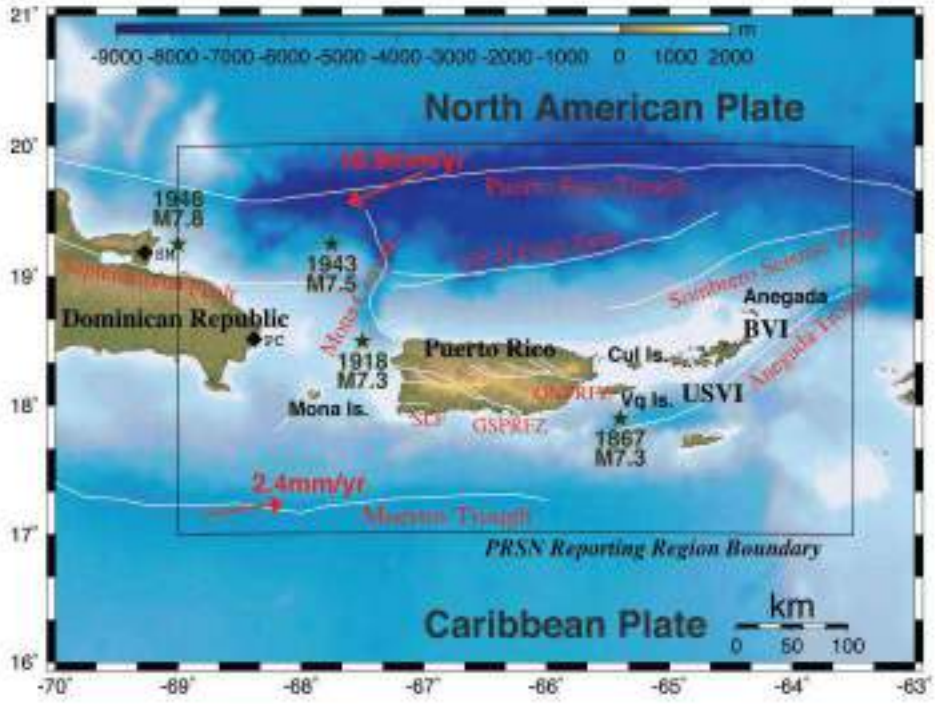


Figure 258: Major Tectonic Structures and Approximate Locations for Damaging Earthquakes in Recent History

According to NOAA's National Center for Environmental Information (NCEI), these events are part of a broader historical record of tsunami runups in the region. Additional evidence of past tsunamis is being uncovered through paleo-tsunami studies, which analyze buried marine sediments likely deposited by ancient waves.

FEDERAL DISASTER DECLARATIONS

While these events have not led to federal disaster declarations specifically for tsunamis, they are critical for hazard assessment and planning.

PUERTO RICO DISASTER DECLARATIONS

There have been no disaster declaration for Puerto Rico due to tsunami. As mentioned, the last tsunami that significantly affected Puerto Rico occurred in 1918. However, that does not mean it cannot happen again tomorrow. Therefore, acknowledging this hazard is critical to reducing future economic disruptions and, most importantly, preventing the loss of hundreds of lives.

[950] Hincapie, J., & McCreery, C. (2024). *PRVI User's Guide: PTWC tsunami products for Puerto Rico, the U.S. Virgin Islands, and the British Virgin Islands* (Version 1.22). NOAA / National Weather Service, Pacific Tsunami Warning Center. https://www.weather.gov/media/itic-car/PRVI%20User's%20Guide%20-%20Version%201.22_042824.pdf.

While a formal disaster declaration has not been declared, recent research indicates that some residents whose homes were damaged or destroyed submitted petitions describing the damage. Based on these petitions, they were granted funds to repair or rebuild their residences. Records from this program were recently discovered in the General Archive in San Juan, Puerto Rico, after having apparently remained untouched for nearly 100 years.[951]

SIGNIFICANT EVENTS

Puerto Rico has experienced several tsunamis throughout its history. Though relatively rare, these events have had devastating impacts when they occurred. The most significant tsunamis in modern times are illustrated in Table 110 and were triggered by powerful earthquakes and submarine landslides, particularly in the Mona Passage and surrounding regions.

Table 110: NCEI Data for Tsunami

Date	Location	Description	Damages	Tsunami Event Validity
11/18/1867	The epicenter of the 1867 earthquake was located between Saint Thomas and Saint Croix in the Virgin Islands. The magnitude was M=7.3. Pacheco, J. & L.R. Sykes, 1992.[952]	A significant tsunami was generated by this earthquake, particularly affecting the Virgin Islands, where wave heights reached approximately twenty feet. Tsunami activity was also recorded along the eastern and southern coastlines of Puerto Rico.	Peak wave altitudes observed in Puerto Rico ranged from three to five feet near the municipality of Arroyo, located on the southeastern coast.	No data available
10/11/1918	The epicenter of the 1918 earthquake was located about 35 km northwest of Aguadilla, Puerto Rico, in Mona Canyon. The magnitude was	This earthquake generated a tsunami that reached 20 feet in Punta Agujereada, 12 feet in Aguadilla, and 5 feet in Mayagüez as a result of the earthquake.	Punta Agujereada (8 people reported drowned), Aguadilla (32 people drowned), and Mayagüez (116 people died because of the earthquake, including 40 victims of the tsunami). The losses due to property damage were estimated at more than $4	4[953]

[951] LaForge, R., & McCann, W. R. (2017). Address-level effects in Aguadilla, Puerto Rico, from the 1918 Mw 7.3 earthquake and tsunami. *Seismological Research Letters, 88*(5), 1316–1321. https://doi.org/10.1785/0220170044.
[952] Puerto Rico Seismic Network. (n.d.). *Significant earthquakes in Puerto Rico*. University of Puerto Rico at Mayagüez, https://redsismica.uprm.edu/english/education/earthquakes/significant.php
[953] National Centers for Environmental Information. (n.d.). *Global Historical Tsunami Database*. National Oceanic and Atmospheric Administration, https://www.ngdc.noaa.gov/hazel/view/hazards/tsunami/event-data?area=PR&country=USA%20TERRITORY.

Date	Location	Description	Damages	Tsunami Event Validity
	M=7.3. Pacheco, J. & L.R. Sykes, 1992.		million Reid, H.F. y L. Taber, 1919.	

Note: Tsunami event validity ranges from 1 to 4, with a lower score (1 or 2) indicating a questionable event and a higher score (3 or 4) indicating a definite tsunami. Events scored −1 are considered erroneous.[954]

Potential Severity of Event

If a tsunami were to strike Puerto Rico today, the consequences could be catastrophic due to the island's geographic vulnerability and dense coastal population. Puerto Rico lies near the Puerto Rico Trench, one of the most seismically active regions in the Atlantic, making it highly susceptible to tsunamis generated by local, regional, or distant earthquakes, as well as submarine landslides.[955] Historical events such as the 1918 tsunami, which followed a magnitude 7.3 earthquake and caused over 100 deaths and millions in damage, demonstrate the destructive potential of such events.[956] Modern simulations of that event show wave heights exceeding 20 feet in northwestern Puerto Rico, underscoring the risk to coastal communities.

Today, approximately 250,000 people live within designated Tsunami Evacuation Zones, and all 78 municipalities could be affected, depending on the tsunami's source and magnitude.[957] The Probabilistic Tsunami Hazard Assessment (PTHA), conducted by AECOM, outlines multiple fault scenarios capable of generating significant inundation across the island's coastlines, with modeling based on updated bathymetric and seismic data.[958] While Puerto Rico has made strides in preparedness through the TsunamiReady program and public education efforts led by the Puerto Rico Seismic Network, the potential for infrastructure damage, disruption of essential services, and loss of life remains high without a rapid and coordinated emergency response.

Figure 259 from the Mona 1918 tsunami study shows simulated tsunami impacts in Aguadilla using high-resolution modeling. Panel (a) illustrates maximum runup, which refers to the highest vertical elevation the tsunami reaches above the mean high-water level: essentially, how far and high the water climbs onto land.

[954] National Centers for Environmental Information. (n.d.). *Global Historical Tsunami Database*. National Oceanic and Atmospheric Administration, https://www.ngdc.noaa.gov/hazel/view/hazards/tsunami/event-data?area=PR&country=USA%20TERRITORY.
[955] Puerto Rico Emergency Management Bureau**.** (2021). *Annex H-1: Tsunamis (Annex to PREMB Puerto Rico All-Hazards Plan)*. Government of Puerto Rico, https://manejodeemergencias.pr.gov/wp-content/uploads/2021/09/Annex-H-1-TSUNAMIS-Annex-to-PREMB-Puerto-Rico-All-Hazard-Plan.pdf.
[956] Mercado Irizarry, A., et al., "Numerical recreation of the 1918 Puerto Rico tsunami using NOAA's MOST model," Prepared for the USA National Tsunami Hazard Mitigation Program, 2010, https://redsismica.uprm.edu/spanish/tsunami/documentos/informes/1918_tsunami_v4.pdf.
[957] Puerto Rico Emergency Management Bureau. (2021). *Annex H-1: Tsunamis (Annex to PREMB Puerto Rico All-Hazards Plan)*. Government of Puerto Rico. https://manejodeemergencias.pr.gov/wp-content/uploads/2021/09/Annex-H-1-TSUNAMIS-Annex-to-PREMB-Puerto-Rico-All-Hazard-Plan.pdf.
[958] Hio, H. K., & Vanacore, E. (2024). *Offshore probabilistic tsunami hazard Puerto Rico: Version 0.1*. AECOM. https://redsismica.uprm.edu/spanish/tsunami/documentos/informes/AECOM_PuertoRico_PTHA.pdf.

Panel (b) shows maximum inundation depth, which is the depth of water over land during the event, calculated by subtracting the land elevation from the sea level elevation. While runup indicates the peak reach of the wave, inundation depth reflects how deep the flooding is in specific areas.[959]

If this scenario occurred today, Aguadilla would face severe flooding, with water depths reaching 6 meters (19.6 ft) in some urban zones. The town square would be inundated, though some landmarks like the San Carlos Borromeo Church might remain dry. These results highlight the vulnerability of coastal infrastructure and underscore the importance of hazard mitigation planning, especially in densely populated or historically significant areas.

The scenario modeled in the study is a numerical simulation of a tsunami generated by a submarine landslide in the Mona Passage, replicating the conditions of the October 11, 1918 earthquake and tsunami near Puerto Rico. Specifically, it assumes that a similar landslide-triggered tsunami occurs today; the simulation uses modern bathymetric data, high-resolution topography, and advanced computational grids to model wave propagation and inundation in coastal areas like Aguadilla. The goal is to understand how such an event would impact current infrastructure, population centers, and emergency response planning, given today's urban development and coastal vulnerability.

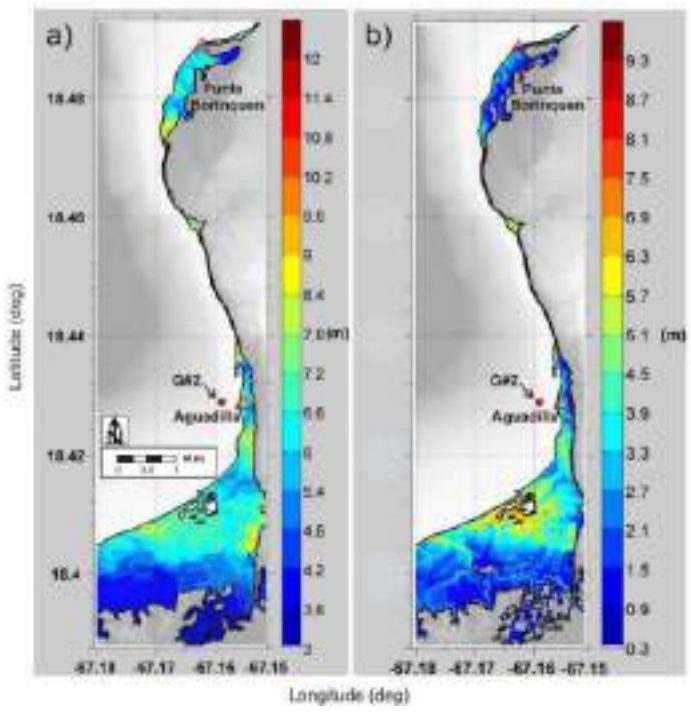


Figure 259: Tsunami Numerical Simulations of the 1918 Mona Passage Tsunami[960]

[959] López-Venegas, A. M., et al. (n.d.). *Advanced tsunami numerical simulations of the Puerto Rico October 11, 1918 Mona Passage tsunami*. Texas A&M University at Galveston. Retrieved from https://www.tamug.edu/tsunami/Files/Pure_applied_GEO_Mona1918.pdf.

[960] López-Venegas, A. M., Horrillo, J., Huérfano, V., Mercado, A., & Pampell-Manis, A. (n.d.). *Advanced tsunami numerical simulations of the Puerto Rico October 11, 1918 Mona Passage tsunami*. Texas A&M University at Galveston. https://www.tamug.edu/tsunami/Files/Pure_applied_GEO_Mona1918.pdf.

This worst-case scenario is used in hazard mapping across Puerto Rico to represent tsunami flooding at specific locations through the Tsunami Flood Elevation, known as the Maximum of the Maximums (MOM). MOM refers to the highest tsunami inundation heights derived from multiple modeled scenarios. The outputs of MOM include maximum water surface elevation, maximum flood depth, and maximum current speed (measured in knots). In Puerto Rico, the Puerto Rico Seismic Network (PRSN) has developed MOM maps in collaboration with the National Tsunami Hazard Mitigation Program (NTHMP) and FEMA. These maps are based on high-resolution inundation modeling that incorporates detailed bathymetric and topographic data.[961] While the inundation maps are dated 2012, they are still considered the best available data, which is the baseline for more recent products including the NTHMP 2025 Annual Report and the Puerto Rico Tsunami Program Map Tool.

FEMA uses MOM data to inform Advisory Base Flood Elevations (ABFE), which guides building elevations to reduce flood damage. MOM is a hazard metric, not a risk metric. It describes the physical characteristics (such as flood depth and extent) of a tsunami event independent of exposure or vulnerability. MOM relates to intensity, specifically the impact level (such as depth, velocity, and extent) of tsunami flooding. Figure 260 illustrates MOM heights in meters across the island of Puerto Rico. It is evident that the eastern, western, and northern coasts are expected to experience greater impacts from a potential tsunami. However, the southern region is also significantly exposed to this hazard.[962]

[961] Andrade von Hillebrandt, C. G., & Mercado-Irizarry, A. (2018). *Assessment of the tsunami-induced marine currents hazard for Arecibo Bay, Puerto Rico*. Report submitted to the Puerto Rico Component of the USA National Tsunami Hazard Mitigation Program and the Puerto Rico Seismic Network, Department of Geology, University of Puerto Rico at Mayagüez.

[962] Federal Emergency Management Agency, (2019, November). *Hazus Program U.S. Territory Data Updates: Detailed Methodology*. FEMA Region II. https://www.fema.gov.

Figure 260: Tsunami Flood Elevation MOM, in Meters

Based on data from the USGS, FEMA, and Texas A&M University at Galveston, the tsunami risk in Puerto Rico can be classified as moderate to high, depending on the region and specific coastal vulnerabilities.

Table 111: Tsunami Potential Severity Classification for Puerto Rico[963];[964].

Region	Risk Level	Justification
Northwestern Coast	High	Site of the 1918 tsunami triggered by a magnitude 7.2 earthquake in the Mona Passage. Runup heights reached 6 (20ft) meters. Numerical simulations confirm significant inundation potential from submarine landslides.
Northern Coast (Puerto Rico Trench)	High	Located near the deepest part of the Atlantic Ocean and a major subduction zone. USGS identifies this area as having significant seismic and tsunami risk.
Southern and Eastern Coasts	Moderate	Less directly exposed to the Puerto Rico Trench but still vulnerable due to regional seismic activity and potential landslide sources.
Inland Areas	Low	Bayamón, Canóvanas, and other inland municipalities are less exposed but could be affected by tsunami wave propagation through rivers.

Probability of Future Hazard Events

The probability of a tsunami occurring in Puerto Rico is considered real and significant, based on historical events as well as scientific assessments. The island's proximity to the Puerto Rico Trench and other active seismic zones makes it vulnerable to tsunamis generated by local, regional, and distant earthquakes, as well as submarine landslides. Although less likely, volcanic eruptions and meteorite impacts are also potential sources.[965]

Historically, Puerto Rico has experienced at least two major tsunamis—in 1867 and 1918—which caused substantial loss of life and property. The island's seismic activity and coastal geography make tsunamis a high-impact hazard. The plan emphasizes that a tsunami could affect all 78 municipalities, with approximately 250,000 residents living within evacuation zones, and that such an event could also indirectly impact the entire population of the island.[966] However, not all of the 250,000 residents would be affected simultaneously, as the impact varies depending on the earthquake's epicenter and intensity. Therefore,

[963] López-Venegas, A. M., Horrillo, J., Huérfano, V., Mercado, A., & Pampell-Manis, A. (n.d.). *Advanced tsunami numerical simulations of the Puerto Rico October 11, 1918 Mona Passage tsunami*. Texas A&M University at Galveston. Retrieved from https://www.tamug.edu/tsunami/Files/Pure_applied_GEO_Mona1918.pdf.
[964] U.S. Geological Survey. (2022, June 22). *Puerto Rico Natural Hazards: Tsunamis*. U.S. Department of the Interior. https://maptool.uprm.edu/.
[965] Red Sísmica de Puerto Rico. (2025). *Programa de Tsunamis: Información educativa, mapas de desalojo y protocolos de comunicación*. Universidad de Puerto Rico en Mayagüez. https://maptool.uprm.edu/.
[966] Puerto Rico Emergency Management Bureau. (2021). *Annex H-1: Tsunamis (Annex to PREMB Puerto Rico All-Hazards Plan)*. Government of Puerto Rico. https://manejodeemergencias.pr.gov/wp-content/uploads/2021/09/Annex-H-1-TSUNAMIS-Annex-to-PREMB-Puerto-Rico-All-Hazard-Plan.pdf.

further studies are recommended to provide a more accurate estimation of the population at risk under different scenarios.

Table 112 shows the results of a regional descriptive analysis that used historical data and geological risk factors to provide tsunami hazard probability in Puerto Rico:

Table 112: Tsunami Hazard Probability by Region – Puerto Rico

Region	Historical Frequency	Key Factors	Probability Rating
Northwestern Coast	1918 tsunami; no major events since	Near Mona Passage; submarine landslide potential; historical tsunami impact	Low/Moderate probability
Northern Coast	No recent tsunamis; high seismic activity	Adjacent to Puerto Rico Trench; potential for megathrust earthquakes	Low/Moderate probability
Eastern Coast	No recorded tsunamis; exposed to Atlantic basin	Vulnerable to regional seismic events; coastal development increases exposure	Low probability
Southern Coast	Rare tsunami events; moderate seismic activity	Less direct exposure to trench; potential for localized landslide-induced tsunamis	Low probability
Inland Areas	No direct tsunami impact	Secondary flooding possible via rivers and estuaries	Low probability

Areas along the northwestern and northern coasts show a moderate probability of future tsunami events due to their proximity to active seismic zones, such as the Mona Passage and Puerto Rico Trench. These regions have experienced significant tsunamis in the past and remain vulnerable to future events. The eastern and southern coasts, while exposed to regional seismic activity, have fewer recorded tsunami events and are classified as having a low probability. Inland areas are least likely to be directly affected and are also classified in the low probability category. This classification helps prioritize hazard mitigation efforts and emergency planning.

Vulnerability Assessment

Puerto Rico is highly vulnerable to tsunamis due to its location along the complex boundary between the North American and Caribbean tectonic plates. Historical events such as the 1867 and 1918 tsunamis have demonstrated the destructive potential of locally generated seismic activity. The island's exposure is compounded by dense coastal development, high population concentrations, and limited vertical evacuation options in many areas.

According to the Puerto Rico Seismic Network (PRSN), tsunami hazard maps have been developed using fault characterization and inundation modeling to identify vulnerable zones. These maps show that coastal municipalities—particularly in the northern, western, and southern regions—are at greatest risk.

Municipalities such as San Juan, Arecibo, Mayagüez, Ponce, and Aguadilla stand out due to their combination of high population density, critical infrastructure, and proximity to the coast.[967]

Puerto Rico's vulnerability to tsunamis is not just a theoretical concern—it is a tangible reality shaped by its geography, population distribution, and infrastructure. Positioned at the boundary of the North American and Caribbean tectonic plates, the island is exposed to seismic activity capable of generating devastating tsunamis. Historical events such as the 1867 and 1918 tsunamis serve as stark reminders of this threat.

Puerto Rico's hazard mitigation planning includes tsunami-specific emergency protocols (such as siren systems) and the TsunamiReady program. Figure 261 shows municipalities with TsunamiReady or StormReady status and the distribution of coastal sirens. The integration of local and federal agencies, including the Puerto Rico Seismic Network and NOAA, ensures that hazard assessments and alerts are continuously updated to reflect evolving seismic data and modeling. This coordinated approach is especially critical given FEMA's designation of a magnitude 8.5 earthquake as the worst-case scenario for Puerto Rico: a seismic event capable of generating a catastrophic tsunami. This scenario has been used in modeling efforts to assess tsunami-induced marine currents and flooding hazards, reinforcing the importance of preparedness and interagency collaboration.[968]

[967] Red Sísmica de Puerto Rico. (2025). *Programa de Tsunamis: Información educativa, mapas de desalojo y protocolos de comunicación*. Universidad de Puerto Rico en Mayagüez. https://maptool.uprm.edu/.
[968] Andrade von Hillebrandt, C. G., & Mercado-Irizarry, A. (2018). *Assessment of the tsunami-induced marine currents hazard for Arecibo Bay, Puerto Rico*. Report submitted to the Puerto Rico Component of the USA National Tsunami Hazard Mitigation Program and the Puerto Rico Seismic Network, Department of Geology, University of Puerto Rico at Mayagüez.

Figure 261: 49 TsunamiReady Communities in Puerto Rico

LOCATIONS

The official Tsunami Evacuation Zones, developed by PRSN in collaboration with NOAA's TsunamiReady program, are based on the 2012 tsunami inundation model. These zones highlight areas where vertical evacuation may be necessary due to the lack of natural high ground or elevated structures. The evacuation polygons are designed to guide emergency planning and public awareness efforts, especially in urban centers like San Juan, where vertical evacuation strategies are being considered due to limited horizontal escape routes.

Although this section displays only one map per region (Western, Northern, Eastern, or Southern), each municipality has its own detailed map. These maps highlight areas at risk, safe zones for evacuation, and critical infrastructure. They are essential for emergency planning, especially in municipalities with high population density and coastal development.

The numbers are sobering: over 250,000 people in Puerto Rico live in areas that are exposed to some degree of tsunami risk. This includes urban centers like San Juan, Ponce, Mayagüez, Arecibo, and Aguadilla, where the combination of low elevation, proximity to the coast, and dense infrastructure amplifies the potential impact. In many of these areas, natural high ground is scarce, making vertical evacuation—the use of elevated buildings or structures—a necessary strategy.[969]

These evacuation maps are not just reflections of hazard—they are mirrors of vulnerability. They show us where people live, where they work, and where they are most at risk. They remind us that vulnerability is not just about geography; it's about people, infrastructure, and preparedness. And in Puerto Rico, where the sea is both a source of life and a potential threat, these maps are a vital part of the island's resilience.[970]

[969] Red Sísmica de Puerto Rico. 2017. Tsunami: Guía para los medios de Puerto Rico. 7ma ed. Mayagüez, PR. http://www.prsn.uprm.edu/mediakit/Documentos/Guias/Tsunami%20Guia%20para%20los%20medios%20de%20Puerto%20Rico%20Version%20Carpeta.pdf.

[970] Puerto Rico Seismic Network. (2025). *Puerto Rico tsunami evacuation maps*. University of Puerto Rico at Mayagüez. https://maptool.uprm.edu/.

Figure 262: Northern Tsunami Evacuation Zone for Arecibo, Puerto Rico; Tsunami Evacuation Zone for Arecibo, Puerto Rico.

Figure 263: Eastern Tsunami Evacuation Zone for Guaynabo, Puerto Rico

Figure 264: Southern Tsunami Evacuation Zone for Ponce, Puerto Rico

Figure 265: Western Tsunami Evacuation Zone for Aguada, Puerto Rico

Puerto Rico's Tsunami Evacuation Zones encompass 46 coastal municipalities, many of which have experienced significant urban development despite their exposure to tsunami hazards, as Figure 266 illustrates. These zones were delineated using hydrodynamic modeling and historical tsunami data, and they represent areas where wave run-up and inundation are expected during a tsunami event.[971] In Loíza and other municipalities, evacuation modeling has shown that residents may require up to 184 minutes to reach safety, which far exceeds the estimated tsunami arrival time of 2 to 45 minutes for Puerto Rico's western coast.[972]

Additionally, Figure 266 highlights two tsunami events that illustrate stark contrasts in hazard severity: the 1918 tsunami and the minor 2020 tsunami reported in the southern part of the island. The 1918 tsunami, triggered by a magnitude 7.3 earthquake in the Mona Passage, produced waves up to 6 meters (20 feet) and caused catastrophic damage, including more than 100 fatalities and millions of dollars in property losses, making it one of the most destructive tsunamis in Puerto Rico's history. In contrast, the 2020 event was a very small tsunami, detected only by tide gauges and posing no real danger to life or property; it did not result in inundation or damage and served primarily as a reminder of ongoing seismic activity in the region. This comparison underscores why evacuation zones are designed for worst-case scenarios like 1918, even though most modern events, such as 2020, are negligible in impact.

[971] Cordero, E., Ruiz Vélez, R., Huérfano Moreno, V., & Sherman, C. (2025). Enhancing tsunami evacuation strategies in Puerto Rico using open-source least-cost path analysis. *Journal of Disaster Science and Management*, 1(18). https://doi.org/10.1007/s44367-025-00018-y.

[972] Cordero, E., Ruiz Vélez, R., Huérfano Moreno, V., & Sherman, C. (2025). Enhancing tsunami evacuation strategies in Puerto Rico using open-source least-cost path analysis. *Journal of Disaster Science and Management, 1*(18). https://doi.org/10.1007/s44367-025-00018-y.

Figure 266: Tsunami Evacuation Zone (highlighted in red).
The map Includes (a) the Main Island of Puerto Rico and the Smaller Islands of (b) Culebra and (c) Vieques.

Although population estimates within Tsunami Evacuation Zones vary in precision, the Puerto Rico Seismic Network and USGS have identified that many of these zones include densely populated urban and informal settlements, where evacuation infrastructure is limited and environmental degradation—such as the removal of protective dunes—has further increased exposure. These land use patterns not only complicate evacuation logistics but also exacerbate the ecological fragility of coastal systems.[973]

Incorporating tsunami risk into land use planning is essential for sustainable development and disaster resilience. As Puerto Rico continues to urbanize, especially in coastal areas, integrating hazard maps, evacuation modeling, and environmental restoration into planning frameworks will be critical to reducing future losses and protecting vulnerable populations.[974]

HAZUS EXPOSURE

The exposure data was derived from census tract-level inventory across Puerto Rico, covering 939 census tracts and over 1.400.000 buildings. Vulnerability assessments were conducted using fragility curves, which estimate damage states (moderate, extensive, complete) based on structural characteristics and tsunami inundation depth, which have an aggregate total replacement value of 459,449 (millions of dollars). Residential structures account for 100% of the building exposure in tsunami hazard zones across Puerto Rico, based on census tract-level inventory data covering over 1.4 million buildings

CRITICAL INFRASTRUCTURE

Table 113 summarizes the number of assets by type, based on the HAZUS scenario tsunami economic loss dataset developed for this plan update.

Table 113: Critical infrastructure

Asset Type	Count
Safety and Security	323
Hazardous Materials	321
Communication Towers	235
Other	119
Energy	106
Transportation	68
Hospitals or Health Related	62
Food, Shelter, Hydration	60
Government	53
Total	**1347**

[973] U.S. Geological Survey, "Pedestrian evacuation time maps for Puerto Rico tsunami-hazard zones," 2025, https://www.usgs.gov/data/pedestrian-evacuation-time-maps-puerto-rico-tsunami-hazard-zones.
[974] U.S. Geological Survey, "Pedestrian evacuation time maps for Puerto Rico tsunami-hazard zones," 2025, https://www.usgs.gov/data/pedestrian-evacuation-time-maps-puerto-rico-tsunami-hazard-zones.

POPULATIONS

More than 250,000 people in Puerto Rico live in areas exposed to tsunami hazards. This includes major urban centers such as San Juan, Ponce, Mayagüez, Arecibo, and Aguadilla, where the combination of low elevation, proximity to the shoreline, and infrastructure density significantly increases the risk.[975]

Additionally, Aguada, Loíza, Arecibo, Humacao, and other municipalities are highlighted in the evacuation planning documents as particularly vulnerable. For example[976]:

- Loíza has over 23,000 residents in Tsunami Evacuation Zones, making it one of the most exposed municipalities in Puerto Rico. Its flat terrain and limited vertical evacuation options amplify the risk. Some models have suggested that this area has the longest evacuation time (184 minutes).[977]
- Aguada and Humacao also feature prominently due to their coastal location and the presence of residential and commercial infrastructure within inundation zones.
- Arecibo, with its large population and critical facilities near the coast, faces similar challenges in evacuation and preparedness.

Table 114 summarizes the estimated number of residents in tsunami hazard zones for each municipality in Puerto Rico, under two earthquake-generated tsunami scenarios.[978] As stated above, Loíza, San Juan, Aguadilla, Mayagüez, Ponce, and other municipalities are regions with documented tsunami hazard zones due to their proximity to the Puerto Rico Trench and other seismic sources. These areas were selected because:

- They have high residential exposure to tsunami hazards.
- They represent diverse coastal geographies and urban densities.
- They are part of the National Tsunami Hazard Mitigation Program (NTHMP) focus areas.

Two tsunami scenarios—a local tsunami from a magnitude 7.5 earthquake and a distant tsunami from a magnitude 8.5 earthquake—were modeled to reflect the different types of tsunami threats that these coastal regions and communities may face. The numbers in Table 114 represent exposure, not risk.[979]

[975] Negociado para el Manejo de Emergencias y Administración de Desastres. (2022). *Guía para desalojo vertical en Puerto Rico* (Primera edición). Caguas, PR.
[976]Negociado para el Manejo de Emergencias y Administración de Desastres. (2022). *Guía para desalojo vertical en Puerto Rico* (Primera edición). Caguas, PR.
[977] Cordero, E., Ruiz Vélez, R., Huérfano Moreno, V., & Sherman, C. (2025). Enhancing tsunami evacuation strategies in Puerto Rico using open-source least-cost path analysis. *Journal of Disaster Science and Management*, 1(18). https://doi.org/10.1007/s44367-025-00018-y.
[978] Cordero, E., Ruiz Vélez, R., Huérfano Moreno, V., & Sherman, C. (2025). Enhancing tsunami evacuation strategies in Puerto Rico using open-source least-cost path analysis. *Journal of Disaster Science and Management*, 1(18). https://doi.org/10.1007/s44367-025-00018-y.
[979] Wood, N., Peters, J., Sheehan, A., & Bausch, D. (2025). *National population exposure and evacuation potential in the United States to earthquake-generated tsunami threats*. *International Journal of Disaster Risk Reduction, 123*, 105511. https://doi.org/10.1016/j.ijdrr.2025.105511.

Table 114: Estimated Number of Residents in Tsunami Hazard Zones for Each Municipality in Puerto Rico, under Two Earthquake-Generated Tsunami Scenarios

Municipality	Scenario 1 - Local Tsunami (M7.5 Earthquake)	Scenario 2 - Distant Tsunami (M8.5 Earthquake)
Loíza	10,700	14,200
San Juan	8,500	11,200
Aguadilla	6,200	8,700
Mayagüez	5,400	7,600
Ponce	4,900	7,100

These municipalities exemplify the broader vulnerability of Puerto Rico, where infrastructure, such as hospitals, schools, ports, and tourist areas, is often located within tsunami-prone zones. The evacuation maps not only identify these risks but also guide emergency planning, route selection, and public education efforts to enhance resilience.

Figure 267: Four Municipalities Recommended to Have Vertical Evacuation Structures

STRUCTURES INCLUDING CRITICAL FACILITIES

Critical infrastructure in Puerto Rico is particularly vulnerable to tsunamis due to its concentration along coastal zones, where the risk of inundation is highest. Hospitals, emergency response centers, power substations, water treatment plants, and other facilities are often located near the shoreline to serve densely populated areas. However, this proximity exposes them to direct wave impact, flooding, and debris flow during a tsunami event. If these facilities are damaged or rendered inaccessible, this could severely hinder emergency response, healthcare delivery, and utility services during a crisis.

Moreover, many transportation and communication systems that support critical infrastructure—such as bridges, coastal highways, ports, and cell towers—are also at risk. Disruption to these systems can delay evacuations, interrupt supply chains, and isolate affected communities. Schools and public shelters, which often serve as safe havens during disasters, may themselves be located in tsunami hazard zones, requiring careful planning and retrofitting.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Infrastructure and community lifelines in Puerto Rico are highly vulnerable to tsunamis due to their geographic exposure and functional interdependencies. In Puerto Rico, many lifeline systems—transportation, energy, water, communications, and emergency services—are concentrated in low-lying coastal areas. Ports, bridges, and coastal highways are particularly exposed to tsunami inundation, which can sever access routes and delay emergency response. Power substations and water treatment facilities located near the shore are at risk of flooding and structural damage, potentially disrupting electricity and clean water supply for thousands. These vulnerabilities are compounded by limited redundancy and aging infrastructure, making recovery slower and more complex.

Community lifelines also include healthcare, public safety, and sheltering systems, which are essential during and after a disaster. Hospitals and emergency operation centers in tsunami-prone zones may be overwhelmed or inaccessible if evacuation routes are compromised. Schools and community centers, often designated as shelters, may themselves be located within hazard zones, requiring relocation or retrofitting.

Impact Assessment

Puerto Rico's proximity to the Puerto Rico Trench and other seismic zones makes it particularly susceptible to tsunami hazards. FEMA's Hazus tool, which uses inundation depth grids, building inventory data, and fragility curves to simulate damage scenarios, provides a standardized method for estimating tsunami impacts. In Puerto Rico, Hazus can be customized with local datasets from the Puerto Rico Planning Board, PREMB, and other agencies, enhancing the accuracy of loss estimates. These simulations inform land-use planning, building codes, and emergency response strategies, helping reduce long-term vulnerability.

Tsunami impact assessments are a foundational element of disaster risk reduction, especially in coastal regions like Puerto Rico. According to FEMA, these assessments help quantify the potential consequences of tsunami events by analyzing exposure, vulnerability, and expected losses. They support emergency management by identifying areas at greatest risk, estimating casualties and economic damage, and

informing mitigation strategies. By integrating scientific modeling with local data, impact assessments enable communities to prepare more effectively and allocate resources where they are most needed.

STATE ASSETS

Figure 268 provides a consolidated view of tsunami-related building exposure across Puerto Rico, categorized by occupancy types such as residential, commercial, industrial, and critical facilities. It aggregates data from Hazus modeling outputs, which estimates potential economic losses and structural vulnerability under tsunami scenarios. Residential structures dominate the exposure profile, reflecting the high density of housing along coastal areas, while commercial and educational facilities show significant concentrations in urban municipalities like San Juan, Bayamón, and Carolina. These patterns highlight the disproportionate risk faced by densely populated and economically active regions.

The total replacement value for state assets based on Hazus outcomes is $198.87 billion, whereas Figure 268 confirms that the San Juan metropolitan area has the largest share, with $47.7 billion, or 23% of the total state assets concentrated in a single municipality. This concentration aligns with the country's economy and population density. Following San Juan, Carolina ranks second, accounting for 12% of the total infrastructure value with around $24,4 billion.

This visualization is essential for hazard mitigation planning because it identifies where the greatest structural and economic impacts could occur during a tsunami event. By comparing totals across municipalities, planners can prioritize interventions such as evacuation planning, retrofitting critical infrastructure, and enhancing community resilience in high-exposure zones. The chart also underscores the need for tailored strategies for sectors like education and government facilities, which play a vital role in emergency response and recovery. Overall, the data serves as a foundation for risk-informed decision-making and resource allocation in coastal hazard management.

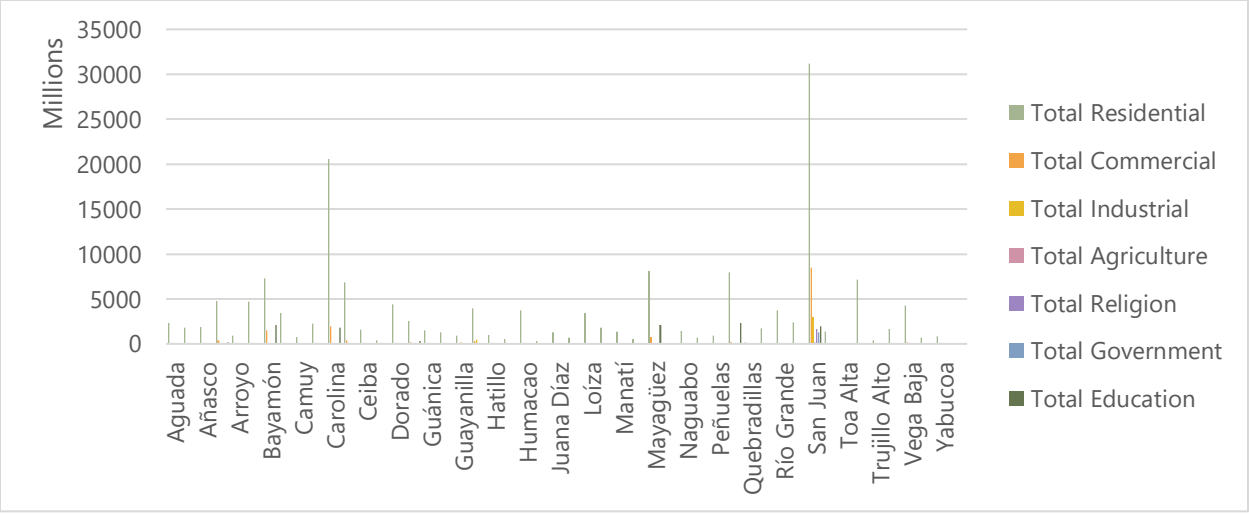


Figure 268: Tsunami Replacement Value by Occupancy Type Across Puerto Rico Municipalities.

CRITICAL INFRASTRUCTURE

Critical infrastructure in Puerto Rico is highly concentrated along coastal areas, making it particularly vulnerable to tsunami impacts. These assets include hospitals, emergency response centers, power substations, water treatment plants, transportation hubs, and communication towers—all essential for maintaining community lifelines during and after a disaster. If damaged or rendered inaccessible, these facilities could severely hinder emergency response, healthcare delivery, and utility services, leading to cascading failures across sectors such as energy, water, and transportation. The exposure of these assets is compounded by limited redundancy and aging infrastructure, which increases the risk of prolonged service disruptions following a tsunami event.

FEMA's Hazus-based tsunami risk assessment emphasizes that infrastructure losses are not only a function of hazard intensity but also of asset concentration and design standards. In Puerto Rico, many critical facilities are located within tsunami evacuation zones, where inundation depths can exceed six meters in worst-case scenarios. This geographic vulnerability underscores the need for targeted retrofitting and elevation strategies to protect essential services and reduce economic losses.

Table 6 provides a breakdown of the percentage of total critical infrastructure value by municipality, highlighting areas with the greatest exposure. San Juan accounts for 53.11% of the total infrastructure value, reflecting its role as the island's economic and administrative hub. Other municipalities with significant shares include Carolina (13.71%), Toa Baja (5.63%), and Ponce (3.58%). Coastal municipalities such as Mayagüez (2.71%) and Salinas (2.56%) also show notable exposure levels. These figures indicate that tsunami impacts in a few key municipalities could disrupt lifeline systems for the entire island, given their concentration of energy, transportation, and communication assets.

The distribution pattern aligns with FEMA's national findings that urbanized coastal areas bear the highest tsunami risk due to dense infrastructure and population clusters. In Puerto Rico, this concentration amplifies potential losses and complicates recovery efforts, making infrastructure hardening and redundancy planning critical priorities for hazard mitigation.

Table 115: Distribution of Critical Infrastructure Value by Municipality

City	% of Total Infrastructure Value
Aguada	0.24%
Aguadilla	1.21%
Añasco	0.28%
Arecibo	1.16%
Arroyo	0.05%
Barceloneta	0.15%
Bayamón	0.48%
Cabo Rojo	1.42%

City	% of Total Infrastructure Value
Camuy	0.24%
Canóvanas	0.02%
Carolina	13.71%
Cataño	2.34%
Ceiba	0.10%
Culebra	0.45%
Dorado	0.61%
Fajardo	0.65%
Guánica	1.14%
Guayama	0.25%
Guayanilla	0.25%
Guaynabo	0.42%
Hatillo	0.06%
Hormigueros	0.04%
Humacao	1.07%
Juana Díaz	0.68%
Lajas	0.06%
Loíza	1.54%
Luquillo	0.99%
Manatí	0.00%
Maunabo	0.02%
Mayagüez	2.71%
Naguabo	0.00%
Patillas	0.13%
Peñuelas	0.76%
Ponce	3.58%
Rincón	0.50%
Río Grande	0.24%
Salinas	2.56%
San Juan	53.11%
Santa Isabel	0.29%

City	% of Total Infrastructure Value
Toa Baja	5.63%
Vega Alta	0.02%
Vega Baja	0.74%
Vieques	0.06%
Yabucoa	0.03%

Beyond geographic distribution, understanding the functional composition of critical infrastructure is essential for tsunami risk mitigation. Table 116 summarizes exposure by occupancy type, illustrating which sectors dominate Puerto Rico's critical asset profile. Industrial facilities represent the largest share, with Food/Drugs/Chemicals (IND3) accounting for 40.10% of total assets and Light Industrial (IND2) contributing 12.17%. These figures highlight the vulnerability of Puerto Rico's manufacturing and pharmaceutical sectors, which are concentrated in coastal zones and play a vital role in the island's economy.

Educational facilities (EDU1 – Grade Schools) comprise 10.76%, underscoring the need for school retrofitting and evacuation planning. Commercial assets, particularly Professional/Technical Services (COM4), represent 21.93%, while healthcare facilities, including Hospitals (COM6) and Medical Offices (COM7)—account for over 6% combined. Emergency response facilities (GOV2) make up 2.64%, emphasizing the importance of safeguarding lifeline services during a tsunami event.

This breakdown demonstrates that tsunami impacts would not only disrupt residential areas but also cripple essential services and economic drivers. Prioritizing mitigation measures for high-value and high-function assets, such as industrial plants, schools, and hospitals will be critical to reducing cascading failures across community lifelines.

Table 116: Critical Infrastructure Exposure by Occupancy Type

Occupancy Type	Percentage of Total Assets (%)
IND2 – Light Industrial	12.17%
IND3 – Food/Drugs/Chemicals	40.10%
IND4 – Metals/Minerals Processing	0.93%
IND5 – High Technology	2.75%
IND6 – Construction	0.52%
EDU1 – Grade Schools	10.76%
EDU2 – Colleges/Universities:	0.19%
GOV1 – General Services	1.79%
GOV2 – Emergency Response	2.64%
COM4 – Professional/Technical Services	21.93%

Occupancy Type	Percentage of Total Assets (%)
COM6 – Hospital	2.13%
COM7 – Medical Office/Clinic	4.09%

LOCAL ASSETS

Puerto Rico's coastal municipalities, particularly those impacted by the 1918 tsunami such as Aguadilla and Mayagüez, remain highly vulnerable to future tsunami events. Modern simulations of the 1918 scenario show inundation depths reaching up to six meters in urban zones, which would devastate residential areas and critical infrastructure if repeated today. These findings underscore the urgent need to retrofit local assets, such as schools, hospitals, and emergency shelters to withstand extreme flooding and wave forces. Retrofitting measures should prioritize structural reinforcement, elevation of essential facilities, and integration of vertical evacuation options, especially in densely populated coastal towns where horizontal evacuation is limited. Without these upgrades, the potential severity of a tsunami event could result in catastrophic loss of life and prolonged disruption of lifeline services, including energy, water, and transportation systems.

Although tsunamis in Puerto Rico are relatively rare, the probability of future events remains significant due to the island's proximity to the Puerto Rico Trench and other active seismic zones. Historical evidence and probabilistic hazard assessments indicate that northwestern and northern coasts face moderate probabilities of tsunami occurrence, driven by fault activity and submarine landslide potential. This risk profile demands proactive investment in retrofitting local assets to reduce exposure and enhance resilience. Municipalities like Aguadilla, Arecibo, and Loíza, where critical facilities and housing clusters are concentrated in low-lying areas should prioritize upgrades that meet FEMA and ASCE standards for tsunami-resistant design. Incorporating these measures into local hazard mitigation plans will not only protect lives but also safeguard essential services during high-impact events, ensuring that communities can recover more quickly and effectively.

COMMUNITY LIFELINES

In Puerto Rico, tsunamis pose a serious threat to community lifelines, especially in the 46 coastal municipalities within the designated Tsunami Evacuation Zones. A tsunami can disrupt transportation routes, damage energy infrastructure, contaminate water systems, and overwhelm health and medical services. Communications lifelines may be compromised, hindering the dissemination of warnings and coordination of emergency operations. The Puerto Rico Seismic Network's TsunamiReady Program, in partnership with FEMA and local agencies, has developed evacuation maps and public education materials to mitigate these risks and enhance lifeline resilience[980].

Tsunami impact assessments in Puerto Rico must, therefore, consider how each lifeline could be affected and how quickly it can be restored. For example, evacuation planning not only directly supports the Safety

[980] Federal Emergency Management Agency. (n.d.). *Community lifelines*. FEMA.gov. Retrieved October 9, 2025, from https://www.fema.gov/emergency-managers/practitioners/lifelines.

and Security lifeline but also ensures access to shelters and medical care, which supports the Health and Medical and Food, Hydration, and Shelter lifelines. FEMA's lifeline-based approach supports survivor-centric and outcome-driven response operations, helping Puerto Rico prepare for and recover from tsunami events more effectively.

SAFETY AND SECURITY

When a tsunami strikes, the Safety and Security lifeline is critical for coordinating evacuations, securing impacted areas, rescuing survivors, and maintaining civil order. Disruption to this lifeline can severely hinder emergency response and recovery efforts, especially in densely populated coastal zones.[981]

A recent study by Pacheco-Crosetti et al. (2022) assessing tsunami evacuation strategies in Puerto Rico revealed significant challenges in the municipality of Loíza, a coastal town within the Tsunami Evacuation Zone. The study found that average pedestrian evacuation times in Loíza ranged from 55 to 125 minutes, far exceeding the recommended threshold of 20 minutes for safe evacuation. Poor road conditions, lack of signage, and inadequate infrastructure were identified as major barriers to effective evacuation. These issues directly impact the Safety and Security lifeline by limiting the ability of emergency services to reach and assist vulnerable populations in time.

The study further underscores the vulnerability of critical infrastructure, particularly schools, in tsunami-prone areas of Puerto Rico. It highlights the following:

- A comprehensive database identified numerous schools located within tsunami hazard zones, with San Juan and Cataño selected for detailed case studies.
- Many schools exhibited excessive evacuation times, with some requiring significantly more than the 20-minute safety threshold for students and staff to reach higher ground.
- Evacuation routes were often unsafe or inadequate, with poor road conditions, limited signage, and lack of pedestrian infrastructure.
- Surveys revealed low levels of preparedness among school staff and students, indicating a need for improved training and drills.
- The study recommends vertical evacuation strategies and infrastructure retrofitting for schools where horizontal evacuation is not feasible within the required time.

These findings reinforce the urgent need for targeted mitigation strategies in municipalities like Loíza, where both community-wide and school-specific vulnerabilities converge, putting thousands of lives at risk during a tsunami event.[982]

[981] Federal Emergency Management Agency. (n.d.). *Community lifelines*. FEMA.gov. Retrieved October 9, 2025, from https://www.fema.gov/emergency-managers/practitioners/lifelines.
[982] Pacheco-Crosetti, G., Collazos-Ordóñez, O., Rodríguez, V., & Vázquez, J. (2022). Vulnerability of schools in Puerto Rico to tsunamis. *Revista Internacional de Desastres Naturales, Accidentes e Infraestructura Civil*, 22. https://www.scipedia.com/public/Pacheco-Crosetti_et_al_2022a.

The Safety and Security lifeline in Puerto Rico is highly vulnerable to tsunami impacts, particularly in underserved coastal communities. The case of Loíza illustrates how infrastructure deficits and planning gaps can delay evacuation and compromise public safety. Strengthening this lifeline requires targeted investments in evacuation route improvements, signage, vertical evacuation structures, and community education. Integrating these efforts into local hazard mitigation plans and FEMA's lifeline framework will enhance Puerto Rico's resilience and reduce life-threatening delays during tsunami events.

FOOD, HYDRATION, AND SHELTER

A tsunami could severely disrupt access to food, water, and shelter, especially in low-lying areas within the Tsunami Evacuation Zone. The island's heavy reliance on imported food (about 85%) and centralized distribution systems makes it particularly susceptible to supply chain breakdowns following a disaster.[983]

While not a tsunami, Hurricane Maria (2017) provides a relevant case study for understanding how a tsunami could impact the Food, Hydration, and Shelter lifeline:

- In Las Marías, a rural municipality, families lost their homes and were forced to shelter in unfinished sheds. With roads blocked and communications down, they faced severe food insecurity, relying on salvaged canned goods and fallen fruit for survival.
- The Nutrition Assistance Program (NAP), Puerto Rico's version of SNAP, was slow to respond. It took six months for disaster-related benefits to reach affected populations, compared to just 47 days in the U.S. Virgin Islands, which uses SNAP. This delay highlights how systemic inequities in food assistance could be exacerbated in a tsunami scenario.[984]

HEALTH AND MEDICAL

Puerto Rico's coastal exposure to tsunamis—due to its proximity to the Puerto Rico Trench—poses a significant threat to its already fragile healthcare infrastructure.[985]. A tsunami could:

- Damage hospitals and clinics in low-lying areas.
- Disrupt medical supply chains, especially for medications and dialysis.
- Isolate vulnerable populations from emergency medical services due to road damage or flooding.
- Overwhelm emergency response systems, especially in rural or underserved areas.

[983] Horn-Muller, Ayurella, "Puerto Ricans Are Devising the Food System of Tomorrow," Grist, September 3, 2025, https://grist.org/food-and-agriculture/puerto-ricans-are-devising-the-food-system-of-tomorrow/.
[984] Meyers, Gabrielle, "The Inequities in Food Assistance Programs in Puerto Rico," Human Rights Research Center, July 9, 2025, https://www.humanrightsresearch.org/post/the-inequities-in-food-assistance-programs-in-puerto-rico.
[985] Ramirez-Rios, D., Wallace, W. A., Kinsler, J., Martinez Viota, N., & Mendez, P. (2022). *Exploring Post-Disaster Transportation Barriers to Health Care for Socially Vulnerable Puerto Rican Communities*. Natural Hazards Center. https://hazards.colorado.edu/public-health-disaster-research/exploring-post-disaster-transportation-barriers-to-healthcare-of-socially-vulnerable-puerto-rican-communities.

Although not a tsunami, Hurricane Maria (2017) offers a critical proxy for understanding how a tsunami could impact the Health and Medical lifeline.

A recent study assessing tsunami evacuation strategies in Puerto Rico revealed significant challenges in the municipality of Loíza, a coastal town within the Tsunami Evacuation Zone. The study found that average pedestrian evacuation times in Loíza ranged from 55 to 125 minutes, far exceeding the recommended threshold of 20 minutes for safe evacuation. Poor road conditions and inadequate infrastructure were identified as major barriers to effective evacuation. These issues directly impact the Health and Medical lifeline by limiting the ability of emergency services to reach and assist vulnerable populations in time.[986]

Further compounding these vulnerabilities, the collapse of Puerto Rico's health care system during Hurricane Maria offers a cautionary proxy for what could occur in the event of a tsunami. The health system's failure was not solely due to the storm itself but rather the culmination of decades of austerity, infrastructure neglect, and inadequate disaster planning. Health care providers and administrators described the post-Maria landscape as one of total systemic collapse, where power outages, communication breakdowns, and lack of coordination left communities without access to life-saving services.[987]

In a tsunami scenario, similar cascading failures could be expected. The fragility of Puerto Rico's electrical grid, already exposed during Maria, would likely result in widespread blackouts, disrupting emergency response, medical care, and evacuation logistics. The study also revealed a deep sense of abandonment and mistrust toward both local and federal governments; this hindered effective disaster response and could again undermine public confidence in tsunami warnings and evacuation orders.

Despite these challenges, the study highlighted grassroots resilience as a critical factor in disaster recovery. Community-led health initiatives, such as mobile clinics and improvised care centers, filled gaps left by institutional failures. These examples underscore the importance of integrating community-based organizations into tsunami preparedness and response planning, especially in municipalities like Loíza, where formal infrastructure is insufficient.

In sum, the lessons from Hurricane Maria's impact on the health care system serve as a stark warning: without robust, inclusive, and localized disaster planning, a tsunami could trigger a similar or worse collapse of essential services, disproportionately affecting the most vulnerable populations.

A tsunami could severely disrupt the Health and Medical lifeline by:

- Flooding hospitals and clinics in the Tsunami Evacuation Zone
- Interrupting power and water supplies, which are critical for medical operations

[986] Pacheco-Crosetti, G., Collazos-Ordóñez, O., Rodríguez, V., & Vázquez, J. (2022). Vulnerability of schools in Puerto Rico to tsunamis. *Revista Internacional de Desastres Naturales, Accidentes e Infraestructura Civil*, 22. https://www.scipedia.com/public/Pacheco-Crosetti_et_al_2022a.

[987] Rodríguez-Madera, S. L., Varas-Díaz, N., Padilla, M., Grove, K., Rivera-Bustelo, K., Ramos, J., Contreras-Ramirez, V., Rivera-Rodríguez, S., Vargas-Molina, R., & Santini, J. (2021). The impact of Hurricane Maria on Puerto Rico's health system: post-disaster perceptions and experiences of health care providers and administrators. *Global Health Research and Policy, 6*(1), 1–11. https://doi.org/10.1186/s41256-021-00228-w.

- Delaying emergency response due to impassable roads and damaged infrastructure
- Increasing demand for trauma care, mental health services, and infectious disease control

ENERGY

When the energy system is disrupted, all other lifelines are at risk of failure, because without it, no other lifeline can be stabilized. This is why FEMA prioritizes rapid restoration of energy systems in disaster response planning.[988]

If a tsunami were to strike Puerto Rico today, particularly impacting the southern coast where the Costa Sur Power Plant is located, the consequences would be catastrophic. This plant is one of the island's largest generation facilities. A real incident on December 31, 2024, involving a switchyard failure at Costa Sur led to a near-total blackout across the island, with cascading outages lasting into January 2025.[989] If this same facility were inundated by a tsunami:

- Immediate loss of generation capacity would occur.
- Transmission lines and substations, many of which are still in fragile condition post-Hurricane Maria, would be destroyed.
- Fuel supply chains—especially for petroleum and natural gas, which power 75% of the grid—would be disrupted.
- Battery and solar systems, while growing, are still insufficient to support island-wide demand.

Puerto Rico's energy system remains highly vulnerable to natural disasters, including tsunamis. Despite over $15 billion in federal funding allocated for grid modernization after Hurricane Maria in 2017, much of the infrastructure, particularly in coastal areas, remains fragile, centralized, and exposed.

Five years after Hurricane Maria, Hurricane Fiona struck Puerto Rico and once again caused a widespread blackout. This highlighted how little progress had been made in hardening the grid despite billions in aid. A tsunami today would likely trigger a full-system collapse, especially if it impacts key coastal generation and transmission assets like the Costa Sur Power Plant. The consequences would include:

- Loss of power island-wide
- Inability to operate water treatment plants
- Failure of communications infrastructure
- Disruption of medical services and emergency response

This would lead to cascading failures across all community lifelines, as FEMA's Community Lifelines framework identifies energy as a foundational enabler for all other critical services.

[988] FEMA, Community Lifelines, https://www.fema.gov/emergency-managers/practitioners/lifelines.
[989] Congressional Research Service, "Electric Reliability and Resiliency in Puerto Rico," February 19, 2025, https://www.congress.gov/crs_external_products/IF/PDF/IF12913/IF12913.3.pdf.

However, NPR also noted a glimmer of hope: around 50,000 solar-plus-battery systems had been installed in homes across Puerto Rico, and most of them continued to function during Fiona. This suggests that decentralized renewable energy systems could play a key role in building resilience.[990] [991]

Figure 269: Photographic Evidence of Energy Infrastructure Collapse After Hurricane Fiona in Puerto Rico[992]

COMMUNICATIONS

If a tsunami were to strike Puerto Rico today—especially in a densely populated coastal area like San Juan or Loíza—the communications infrastructure would likely suffer immediate and widespread damage:[993]

- Cell towers and fiber-optic lines, often located along roads and coastal zones, would be destroyed by wave impact and flooding.
- Emergency alert systems, including NOAA radios and sirens, may fail if not hardened or backed by redundant power.
- Local emergency management offices (MEMOs), which are already under-resourced, would struggle to reach vulnerable populations, especially the elderly and those in poverty.

[990] Congressional Research Service, "Electric Reliability and Resiliency in Puerto Rico," February 19, 2025, https://www.congress.gov/crs_external_products/IF/PDF/IF12913/IF12913.3.pdf.
[991] Hernandez, Nicole, "Puerto Rico's Recovery from Fiona Will Take Time: Live Updates," September 22, 2022, https://www.npr.org/live-updates/live-updates-puerto-rico-fiona-recovery.
[992] Hernandez, Nicole, "Puerto Rico's Recovery from Fiona Will Take Time: Live Updates," September 22, 2022, https://www.npr.org/live-updates/live-updates-puerto-rico-fiona-recovery.
[993] Natural Hazards Center, "Municipal-Level Risk Communication Practices in Puerto Rico," 2024, https://hazards.colorado.edu/public-health-disaster-research/municipal-level-risk-communication-practices-in-puerto-rico.

After Hurricane Maria, Puerto Rico experienced a total collapse of communications:[994]

- 95% of cell towers were offline in the immediate aftermath, leaving most of the population without access to emergency alerts, news, or the ability to contact loved ones.
- The Government of Puerto Rico lacked a formal Crisis and Emergency Risk Communication (CERC) plan, and key spokespersons were not trained in CERC best practices.
- Power and telecommunications outages, combined with the absence of communication contingencies, created a substantial information vacuum. This vacuum allowed misinformation and rumors—particularly regarding the death toll—to spread rapidly, which became a major source of public confusion and controversy.
- The post-disaster media environment was saturated with conflicting unofficial death counts and contradictory statements from government officials, further eroding public trust.
- The lack of transparent, timely, and credible communication significantly hindered the government's ability to manage the disaster, especially in terms of public health messaging and mortality reporting.

The study concluded that these communication failures were not just logistical, but systemic, stemming from inadequate planning, lack of training, and the absence of national guidelines for communication during catastrophic disasters. The researchers emphasized that transparent and trustworthy communication is critical to maintaining public safety and confidence during crises.[995]

TRANSPORTATION

FEMA emphasizes that transportation is essential for emergency response, supply chain continuity, and access to critical services. When disrupted, decisive intervention is required to restore mobility and enable the stabilization of other lifelines.

If a tsunami were to strike Puerto Rico today—particularly in low-lying coastal areas like Loíza, San Juan, or Ponce—the transportation network would face immediate and severe disruption:

- Coastal highways and bridges would be inundated or destroyed.
- Ports and ferry terminals (e.g., Vieques and Culebra), which are critical for inter-island transport, would be rendered inoperable.
- Airports, especially regional ones near the coast, could be flooded, which would delay aid and evacuations.
- Evacuation routes would be blocked by debris, flooding, or structural collapse.

[994] Andrade, E., & Milken Institute School of Public Health. (2020, March 5). *Communication failures led to confusion, rumors and widespread public distrust after Hurricane Maria's devastation of Puerto Rico*. The George Washington University. https://publichealth.gwu.edu/communication-failures-led-confusion-rumors-and-widespread-public-distrust-after-hurricane-marias.

[995] Andrade, E., & Milken Institute School of Public Health. (2020, March 5). *Communication failures led to confusion, rumors and widespread public distrust after Hurricane Maria's devastation of Puerto Rico*. The George Washington University. https://publichealth.gwu.edu/communication-failures-led-confusion-rumors-and-widespread-public-distrust-after-hurricane-marias.

Figure 270: Puerto Rico Transportation Network

After Hurricane Maria, Puerto Rico's transportation system experienced widespread collapse:[996]

- Less than 8% of roads were functional one month after the storm.
- FEMA reported that only 392 miles out of 5,073 miles of roads were cleared after 12 weeks.
- Buenos Aires (in Caguas) and other remote communities were cut off for weeks, with residents unable to access medical care or supplies.
- Dialysis patients in Vieques had to be airlifted to San Juan for treatment. Five out of fifteen patients died before receiving care.
- Traffic signs and infrastructure failed across the island due to wind and poor construction standards, as documented in a study by the Polytechnic University of Puerto Rico.

Puerto Rico's transportation infrastructure remains highly vulnerable to natural disasters. A tsunami today would likely:

- Isolate entire communities
- Delay emergency response
- Exacerbate health outcomes

This underscores the need for:

- Pre-disaster evacuation route planning
- Hardening of coastal and bridge infrastructure
- Redundant and alternative transport systems, such as heliports

HAZARDOUS MATERIALS

This lifeline is critical in incidents involving chemical spills, industrial accidents, or natural disasters that disrupt containment systems and expose communities to toxic materials.

In tsunami events, especially in coastal regions, such as Puerto Rico, the HAZMAT lifeline becomes vital due to:

- Flooding of industrial zones, leading to the release of hazardous chemicals
- Damage to wastewater treatment plants, causing sewage and biohazard exposure
- Contamination of drinking water systems and agricultural lands
- Marine debris and vessel damage, which may include fuel and chemical leaks

[996] Natural Hazards Center, "Exploring Post-Disaster Transportation Barriers to Health Care for Socially Vulnerable Puerto Rican Communities," 2022, https://hazards.colorado.edu/public-health-disaster-research/exploring-post-disaster-transportation-barriers-to-healthcare-of-socially-vulnerable-puerto-rican-communities.

Puerto Rico's vulnerability to tsunamis was highlighted in February 2025, when a 7.6 magnitude earthquake triggered a tsunami alert across the island and the U.S. Virgin Islands. Authorities urged residents to stay away from the coast while monitoring for potential environmental hazards.

Although not a tsunami, Hurricane Maria serves as a powerful example of how the HAZMAT lifeline can be severely impacted:

- Massive flooding led to the overflow of chemical storage sites and landfills.
- Collapse of infrastructure disrupted containment systems for hazardous waste.
- Prolonged power outages affected water treatment and environmental monitoring.

WATER SYSTEMS

Puerto Rico's water sector is composed of several key components:[997]

6. Drinking Water and Wastewater Systems
   - Operates primarily through PRASA (Puerto Rico Aqueduct and Sewer Authority)
   - Includes non-PRASA systems, often community-managed in rural areas
   - Provides intake, treatment, storage, and distribution for potable water, as well as collection, treatment, and discharge for wastewater
7. Stormwater and Flood Mitigation
   - Incorporates drainage systems, retention basins, and flood control infrastructure
   - Suffers from outdated design and poor maintenance, especially in urban areas
8. Integrated Water Management
   - Limits coordination across drinking water, wastewater, stormwater, and flood control systems
   - Hinders effective planning due to fragmented governance and insufficient data

Puerto Rico's water infrastructure is a complex and fragile network, shaped by decades of underinvestment, aging systems, and the island's unique geography. Much of the drinking water and wastewater infrastructure hugs the coastline, where the land meets the sea in a delicate balance. In a tsunami scenario, this proximity becomes a liability.[998]

If a powerful wave were to surge inland, it would not just flood streets and homes but overwhelm water intake stations, rupture pipelines, and inundate wastewater treatment plants. Saltwater would seep into freshwater reservoirs and aquifers, rendering them undrinkable. The very systems designed to deliver clean

[997] Preston, B. L., Miro, M. E., Brenner, P., Gilmore, C. K., Raffensperger, J. F., Madrigano, J., Huttinger, A., Blackhurst, M., & Catt, D. (2020). *Beyond recovery: Transforming Puerto Rico's water sector in the wake of Hurricanes Irma and Maria* (RR-2608). RAND Corporation. https://www.rand.org/pubs/research_reports/RR2608.html.
[998] Preston, B. L., Miro, M. E., Brenner, P., Gilmore, C. K., Raffensperger, J. F., Madrigano, J., Huttinger, A., Blackhurst, M., & Catt, D. (2020). *Beyond recovery: Transforming Puerto Rico's water sector in the wake of Hurricanes Irma and Maria* (RR-2608). RAND Corporation. https://www.rand.org/pubs/research_reports/RR2608.html.

water and remove waste would become vectors of contamination. In such a moment, the lifeline that sustains public health would be severed.

This vulnerability is not theoretical. Hurricane Fiona in 2022 offered a grim preview. Though not a tsunami, Fiona's torrential rains and flash floods devastated rural water systems. Community aqueduct—many operated by volunteers—were buried under landslides or rendered inoperable by power outages. In one town, residents spent hundreds of dollars weekly on diesel just to keep water flowing. The storm revealed how easily isolated communities could be cut off from safe water, and how long it could take to restore service[999].

But Puerto Rico is not standing still. Guided by the RAND report and FEMA's Community Lifelines framework, the island is charting a path toward resilience. This vision is not just about rebuilding pipes and pumps—it's about reimagining the entire water sector. Resilience begins with hardening infrastructure: elevating treatment plants, reinforcing intake stations, and designing systems that can withstand both hurricanes and tsunamis. It means equipping facilities with solar panels and backup generators so that water keeps flowing even when the grid goes dark. It also means empowering communities. The thousands of residents who manage non-PRASA systems are no longer seen as fringe actors; they are frontline responders.

Puerto Rico is moving toward a model where drinking water, wastewater, stormwater, and flood control are no longer siloed but coordinated. Real-time monitoring, GIS mapping, and emergency planning are being woven together to ensure that when the next wave comes, whether literal or metaphorical, the island's water lifeline will bend—but not break.

These components ensure that communities have access to clean drinking water and proper sanitation, which are critical during emergencies like hurricanes, earthquakes, and tsunamis.

In a tsunami scenario, water systems are highly vulnerable due to:

- Saltwater intrusion into freshwater sources
- Damage to treatment plants and pipelines from wave impact
- Contamination of wells and aquifers

Water systems are a critical lifeline that underpins public health, sanitation, and community resilience. In Puerto Rico, events like Hurricane Fiona have exposed deep vulnerabilities in both centralized and community-managed water infrastructure, especially in rural and mountainous areas. The Community Lifelines framework from FEMA provides a structured approach to assess and stabilize these systems during disasters, including tsunami scenarios, where saltwater intrusion and infrastructure damage pose serious risks. Efforts to strengthen Puerto Rico's water systems—through infrastructure upgrades, backup power,

[999] Preston, B. L., Miro, M. E., Brenner, P., Gilmore, C. K., Raffensperger, J. F., Madrigano, J., Huttinger, A., Blackhurst, M., & Catt, D. (2020). *Beyond recovery: Transforming Puerto Rico's water sector in the wake of Hurricanes Irma and Maria* (RR-2608). RAND Corporation. https://www.rand.org/pubs/research_reports/RR2608.html.

and community capacity-building—are essential to ensure equitable access to safe water and to enhance disaster preparedness and recovery across the island.

Changes in Development

LAND USE AND BUILT ENVIRONMENT CHANGES

Over the past five years, Puerto Rico has strengthened its approach to tsunami hazard mitigation through updated planning, mapping, and public safety initiatives. While the 2018 Puerto Rico Building Code is older than five years, it remains the most current and comprehensive code in effect. No7tably, it includes Appendix M, which provides guidance for constructing vertical evacuation refuge structures in tsunami hazard zones. These provisions, based on FEMA P646 and ASCE 7 standards, offer communities a framework for designing buildings that can serve as safe havens during tsunami events.[1000]

In 2022, Puerto Rico updated its official Tsunami Evacuation Zones, refining them based on improved modeling from earlier inundation scenarios. These zones are now integrated into interactive GIS platforms, making it easier for residents and planners to visualize risk and plan evacuation routes.[1001]

Additionally, annual drills such as Caribe Wave, coordinated by PRSN, NOAA, and PREMB, engage schools, government agencies, and communities in evacuation exercises and alert system tests. The 2025 drill included siren tests, mobile alerts, and amateur radio coordination across the island.[1002]

These advancements reflect Puerto Rico's proactive stance in preparing for tsunami hazards. While FEMA provides technical support, it is Puerto Rico's own agencies—such as the Puerto Rico Seismic Network (PRSN), the Planning Board, and local emergency managers—that are leading the charge in integrating tsunami risk into land use, building design, and public safety planning.

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Demographic trends further complicate vulnerability. While Puerto Rico's overall population has declined over the past decade due to outmigration and lower birth rates, coastal areas still host a significant share of residents. According to the Puerto Rico Coastal and Estuarine Land Conservation Plan, approximately 77% of the population lives in coastal municipalities, and this concentration has remained relatively stable in the last five years. This means that despite a shrinking population, the exposure to tsunami hazards in coastal zones remains substantial.[1003]

[1000] International Code Council. (2020). *2018 Puerto Rico Building Code Appendix M: Tsunami-Generated Flood Hazard* (3rd ed.). https://maptool.uprm.edu.
[1001] Puerto Rico Seismic Network. (2025). *Puerto Rico evacuation maps*. University of Puerto Rico at Mayagüez. https://maptool.uprm.edu.
[1002] Santana, A. (2025, March 28). *Caribe Wave 2025 Tsunami Exercise in Puerto Rico*. ARRL – The National Association for Amateur Radio. https://www.arrl.org/news/caribe-wave-2025-tsunami-exercise-in-puerto-rico.
[1003] Junta de Planificación. (2020). *Población por municipio y barrio: Censo 2010–2020*. US Census Bureau. https://maptool.uprm.edu.

POPULATION CHANGES

Urban expansion in Puerto Rico's coastal and peri-urban municipalities, such as San Juan, Cayey, and Río Grande, has significantly increased exposure to tsunami hazards. Including in the last five years, these areas have experienced concentrated growth in residential, commercial, and critical infrastructure, placing more people and assets in zones vulnerable to inundation. The clustering of populations in these regions complicates evacuation logistics, especially in locations where tsunami arrival times may be under 35 minutes. This rapid onset of hazard heightens the urgency for effective planning and resilient infrastructure to protect lives and property.[1004]

The Single-Family Housing Mitigation Program has identified over 600,000 housing units across Puerto Rico located in medium to high-risk zones. Many of these homes are in poor condition and lack resilient design features, making them especially vulnerable to cascading impacts from coastal disasters. Disruptions to transportation and communication networks could further hinder emergency response and recovery efforts. FEMA and the Puerto Rico Department of Housing emphasize the need for targeted investments in both high-risk coastal zones and under-resourced inland areas to strengthen overall resilience.

VULNERABILITY OF STATE ASSETS CHANGES

Land use planning in Puerto Rico regarding tsunami risk is increasingly focused on integrating hazard mitigation strategies into development decisions, especially in coastal and peri-urban areas, which helps reduce vulnerability. Puerto Rico has 46 coastal municipalities within designated Tsunami Evacuation Zones. These zones help planners identify areas most vulnerable to tsunami inundation. Municipal emergency managers use evacuation time estimates—often under 35 minutes in many areas—to guide land use decisions and prioritize infrastructure improvements. Tools like least-cost path analysis are used to model pedestrian evacuation routes, helping communities understand the spatial relationship between development and safety zones.[1005]

Regulatory frameworks in Puerto Rico emphasize avoiding development in frequently inundated areas and promoting resilient design in vulnerable zones. FEMA and local agencies encourage municipalities to incorporate tsunami hazard data into their land use plans, especially for new developments near the coast. Additionally, public education efforts, such as the Puerto Rico Tsunami Education portal, support community awareness and preparedness, reinforcing the importance of land use decisions that prioritize safety and resilience.

[1004] Government of Puerto Rico Portal, Single-Family Housing Mitigation Program, https://recuperacion.pr.gov/en/single-family-housing-mitigation-program/.
[1005] "Puerto Rico State Hazard Mitigation Plan," Chapter V: Local Hazard Mitigation Capabilities, August 2021, https://manejodeemergencias.pr.gov/wp-content/uploads/2021/08/2021_PR_State_Hazard_Mitigation_Plan_Aug2021_2of2.pdf.

VULNERABILITY OF LOCAL ASSET CHANGES

At the local level in Puerto Rico, changes in vulnerability are most evident in the exposure of local facilities and community lifelines within tsunami evacuation zones.[1006] Updated evacuation mapping and route analysis have helped municipalities better identify schools, hospitals, shelters, emergency response facilities, government buildings, ports, substations, water and wastewater facilities, communication towers, and key roadway connections that remain exposed to tsunami inundation and short warning times.[1007] In many coastal municipalities, these findings show that vulnerability is driven not only by the location of individual facilities, but also by the risk of cascading lifeline disruption if transportation access is cut off, power is lost, communications fail, or water and wastewater systems are damaged. As a result, local asset vulnerability is now understood more clearly in terms of both facility exposure and lifeline interdependence, especially in communities such as Loíza, San Juan, Cataño, Aguadilla, and Ponce, where essential services may be difficult to protect, access, or restore without continued investments in retrofits, evacuation improvements, redundancy, and vertical evacuation options.

Mitigation Success Stories

FEMA P-2426, 2025: ESTIMATED AVERAGE ANNUALIZED TSUNAMI LOSSES FOR THE UNITED STATES, INLCUDING PUERTO RICO

Over the past five years, Puerto Rico has taken meaningful steps to address tsunami hazards through a combination of risk assessment, infrastructure resilience, and data-driven planning. The territory participated in FEMA's Estimated Average Annualized Losses from Earthquake-Generated Tsunamis study, which provided the first national-level analysis of tsunami risk across U.S. coastal regions, including Puerto Rico. This study helped quantify potential building and population losses, guiding future mitigation priorities. Additionally, Puerto Rico has invested in coastal infrastructure improvements through the Infrastructure Mitigation Program (IMP), the Risk and Asset Data Collection Program, and other programs that enhance lifeline systems and support regional planning against high-impact hazards such as flooding and wave action. While these efforts are not exclusively focused on tsunamis, they contribute to reducing exposure and improving emergency response capabilities in tsunami-prone areas. Together, these initiatives reflect a growing commitment to resilience and hazard-informed development across the island.

CDBG-MIT PROGRAM GUIDELINES

A strong mitigation success story in Puerto Rico that could serve as a reference for tsunami impact reduction is the Infrastructure Mitigation Program (IMP), funded through CDBG-DR/MIT recovery funds and administered by the Puerto Rico Department of Housing. While not specifically designed for tsunami

[1006] Cordero, E., Ruiz Vélez, R., Huérfano Moreno, V. *et al* Enhancing tsunami evacuation strategies in Puerto Rico using open-source least-cost path analysis. *J. Disaster Sci. Manag.***1**, 18 (2025). https://doi.org/10.1007/s44367-025-00018-y.

[1007] United States Geological Survey, "Pedestrian Evacuation Time Maps for Puerto Rico Tsunami Hazard Zones," May 12, 2025, https://www.usgs.gov/data/pedestrian-evacuation-time-maps-puerto-rico-tsunami-hazard-zones.

hazards, the program targets coastal and infrastructure vulnerabilities that are highly relevant to tsunami risk, such as flooding, erosion, and lifeline fragility.[1008]

The IMP is built on the principle that risk is regional but disasters often affect interconnected infrastructure systems across municipal boundaries. Therefore, the program encourages strategic, high-impact projects that strengthen one or more of FEMA's seven community lifelines, including transportation, communications, energy, and public safety. Eligible projects include fortifying maritime and mass transit corridors, modernizing water and wastewater systems, and enhancing emergency response infrastructure, all of which could reduce the impact of high-wave events like tsunamis.

Importantly, the program promotes eco-conscious and self-sustaining solutions, such as nature-based infrastructure and green engineering, which can buffer coastal zones against wave energy. These approaches align with tsunami mitigation goals by reducing exposure and improving resilience in vulnerable communities. The program also uses a Risk-Benefit Score (RBS) to prioritize projects that mitigate the most risk for the greatest number of people at the lowest cost, ensuring that investments are both equitable and effective.

While the IMP does not directly address tsunami barriers, its emphasis on regional planning, lifeline protection, and resilient infrastructure makes it a valuable model for future tsunami mitigation efforts in Puerto Rico. One of its key goals—backed by over $4.5 billion—is to implement transformative, self-sustaining solutions that reduce risk across Puerto Rico's most vulnerable regions. Projects include:

- Fortifying maritime and mass transit corridors to withstand wave and flood impacts
- Modernizing water and wastewater systems to prevent contamination during coastal inundation
- Improving flood control infrastructure that supports emergency services and community safety

These efforts contribute to regional resilience and could help mitigate the effects of tsunami-like events by reducing exposure and improving emergency response capabilities. While not a direct tsunami barrier, the program's emphasis on coastal infrastructure hardening and lifeline protection makes it a valuable reference for future tsunami mitigation planning.

[1008] Puerto Rico Department of Housing. (2024, June 17). *Infrastructure Mitigation Program (IMP) – Program Guidelines (V.6)*. Recuperación PR. https://recuperacion.pr.gov/en/download/infrastructure-mitigation-program-strategic/.

SECTION 4.19

WATERSPOUTS

Waterspouts

WATERSPOUT DEFINITION

The National Oceanic and Atmospheric Administration defines a waterspout as a whirling column of air and water mist.[1009] Waterspouts, which are typically smaller and weaker than tornadoes, follow a mostly vertical path and can appear dark gray or yellowish when lit by the sun. They grow after formation and usually last approximately 30 minutes before dissipating. Despite their brief duration, waterspouts can be dangerous, posing threats to boats, aircraft, swimmers, and coastal infrastructure should they move inland.[1010]

[1009] National Oceanic and Atmospheric Administration. (n.d.). *What is a waterspout?* NOAA's National Ocean Service. https://oceanservice.noaa.gov/facts/waterspout.html.
[1010] EcoExploratorio: Museo de Ciencias de Puerto Rico. (n.d.). *Trombas Marinas*. https://ecoexploratorio.org/amenazas-naturales/tornados-trombas-marinas/trombas-marinas/.

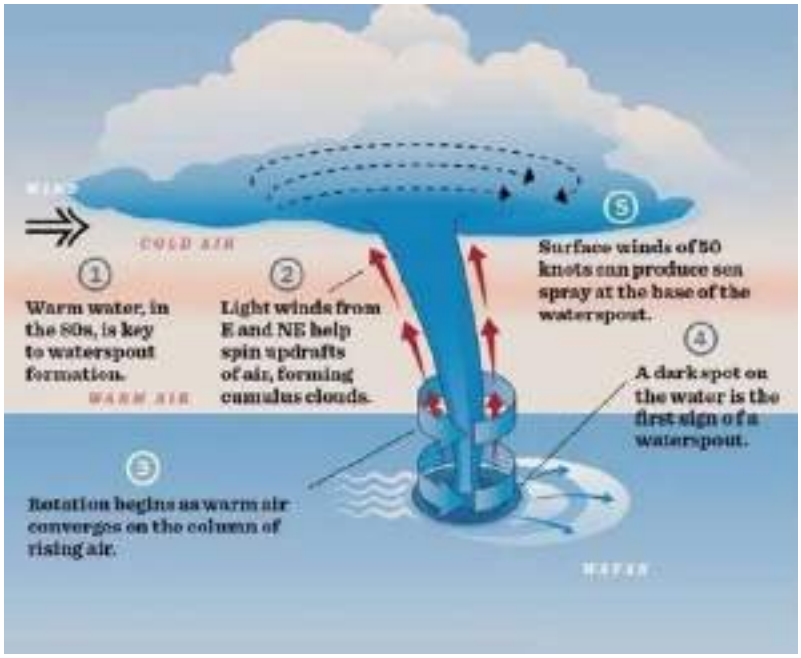


Figure 271: Waterspout Formation[1011]

Waterspouts are classified into two types: tornadic and fair weather. Tornadic waterspouts[1012] are essentially tornadoes that form over water or move from land to water. They share the same characteristics as land-based tornadoes and are associated with severe thunderstorms, often producing strong winds, rough seas, large hail, and frequent lightning. For the purposes of this profile, we are not including this phenomenon once it moves onshore, as it is then classified as a tornado.

Fair weather waterspouts[1013], on the other hand, typically form beneath lines of developing cumulus clouds and are not associated with thunderstorms. Unlike tornadic waterspouts, which descend from storm clouds, fair weather waterspouts begin at the water's surface and rise upward. By the time the funnel becomes visible, they are nearly fully developed. These usually occur in calm conditions and move very little.

If a waterspout moves onshore, the National Weather Service may issue a tornado warning, as some can cause damage and injuries. However, fair weather waterspouts usually weaken quickly upon landfall and rarely travel far inland.

[1011] IAS Gyan. (2025, October 30). *Waterspout*. IAS Gyan. https://www.iasgyan.in/daily-current-affairs/waterspout-6.
[1012] National Oceanic and Atmospheric Administration. (n.d.). *What is a waterspout?* NOAA's National Ocean Service. https://oceanservice.noaa.gov/facts/waterspout.html.
[1013] National Oceanic and Atmospheric Administration. (n.d.). *What is a waterspout?* NOAA's National Ocean Service. https://oceanservice.noaa.gov/facts/waterspout.html.

Location

Puerto Rico experiences two peak seasons for waterspouts: from March to May, and from August to November. On average, about 42 waterspouts are reported each year. The most frequent observation times are between 6:00–9:30 a.m. and 3:00–5:30 p.m.[1014]

The areas with the highest occurrence of waterspouts in Puerto Rico are between the Virgin Islands and the eastern coast, and from the western coast to the Mona Passage.[1015] Although they usually form in tropical regions, waterspouts can also appear in temperate zones. They are more common within 60 miles of the coastline than in open waters. Waterspouts can occur over coastal bodies of water, such as oceans, bays, and lakes.

Previous Occurrences

Waterspouts are a recurring meteorological phenomenon in Puerto Rico, particularly along its northern and northeastern coasts. These events typically form during unstable weather conditions, such as strong thunderstorms, and have been observed near San Juan, the surrounding Atlantic waters, and other coastal areas. Although generally short-lived and less destructive than land-based tornadoes, waterspouts can still pose hazards to vessels, recreational users, and coastal infrastructure.

FEDERAL DISASTER DECLARATIONS

Although waterspouts are a known weather phenomenon in Puerto Rico, they have not led to any federal disaster declarations. These rotating columns of air over water typically occur during unstable weather conditions and, although usually brief and localized, can pose risks to coastal infrastructure and marine operations.

PUERTO RICO DISASTER DECLARATIONS

To date, Puerto Rico has not issued disaster declarations specifically due to waterspouts. However, the National Weather Service in San Juan regularly monitors and issues warnings when conditions favor the formation of waterspouts. These alerts are crucial for public safety, especially in coastal and marine areas where waterspouts can pose risks to vessels, recreational users, and infrastructure.

SIGNIFICANT EVENTS

Waterspouts are a common occurrence in Puerto Rico, especially in coastal areas. While most waterspouts are short-lived, one of the most notable events in Puerto Rico occurred in Mayagüez.

[1014] EcoExploratorio: Museo de Ciencias de Puerto Rico. (n.d.). *Trombas Marinas*. https://ecoexploratorio.org/amenazas-naturales/tornados-trombas-marinas/trombas-marinas/.
[1015] EcoExploratorio: Museo de Ciencias de Puerto Rico. (n.d.). *Trombas Marinas*. https://ecoexploratorio.org/amenazas-naturales/tornados-trombas-marinas/trombas-marinas/.

MAYAGÜEZ BAY – SEPTEMBER 14, 2005

On the afternoon of September 14, 2005, one of the largest waterspouts ever observed in the western region formed near Mayagüez Bay. It was visible from multiple locations around the city, including El Seco, El Maní, and State Road No. 2, near the Mayagüez Mall. The event occurred between 2:00 and 2:15 p.m.

Figure 272: Mayagüez Bay Waterspout, September 14, 2005[1016]

CONDADO ISLA VERDE, PUERTO RICO – NOVEMBER 17, 2020

The National Weather Service in San Juan confirmed that a waterspout formed as part of a line of showers moving through the area near Isla Verde. The phenomenon was visible from several locations across San Juan and occurred just off the northern coast, drawing attention from residents and recreational users. Meteorologists attributed the event to unstable atmospheric conditions associated with the passing weather system.[1017]

[1016] EcoExploratorio: Museo de Ciencias de Puerto Rico. (n.d.). *Trombas Marinas*. https://ecoexploratorio.org/amenazas-naturales/tornados-trombas-marinas/trombas-marinas/.
[1017] El Vocero. (n.d.). *Avistan tromba marina entre Condado e Isla Verde*. El Tiempo. https://www.elvocero.com/el-tiempo/avistan-tromba-marina-entre-condado-e-isla-verde/article_5f0d6984-2903-11eb-b364-9fec76d32b9d.html.

Figure 273: Waterspout in Condado, Puerto Rico[1018]

PICO DE PIEDRA BEACH, AGUADA – AUGUST 17, 2023

The National Weather Service in San Juan issued a special marine advisory urging small boats to stay docked due to hazardous wind conditions linked to a tropical wave. The unstable weather system triggered severe thunderstorms, one of which produced a waterspout spotted near Pico de Piedra Beach in Aguada. The phenomenon highlights the risks posed by tropical disturbances, especially for coastal and marine activities.[1019]

GUAJATACA LAKE – OCTOBER 4, 2025

At approximately 4:07 p.m., the U.S. National Weather Service issued a severe thunderstorm warning for the northeastern areas of Las Marías, Lares, and San Sebastián. According to the alert, Doppler radar detected a strong thunderstorm over Lares moving northwest at 15 mph. The storm was accompanied by wind gusts reaching 40 mph and pea-sized hail. These conditions could result in broken tree branches, displaced unsecured objects, and minor damage to vegetation.

Later, shortly after 5:00 p.m., the NWS confirmed receiving a report of a waterspout in the region.

[1018] El Vocero. (n.d.). *Avistan tromba marina entre Condado e Isla Verde*. El Tiempo. https://www.elvocero.com/el-tiempo/avistan-tromba-marina-entre-condado-e-isla-verde/article_5f0d6984-2903-11eb-b364-9fec76d32b9d.html.
[1019] Tolentino Rosario, C. (2023, August 17). *Reportan una tromba marina cerca de la costa de Aguada*. El Nuevo Día. https://www.elnuevodia.com/noticias/el-tiempo/notas/reportan-una-tromba-marina-cerca-de-la-costa-de-aguada/.

Potential Severity of Event

Waterspouts rotate columns of air and mist that form over bodies of water and are classified into two types: tornadic and fair weather. Tornadic waterspouts are essentially tornadoes that either form over water or move from land to water. They are often accompanied by severe thunderstorms, high winds, hail, and lightning, and they can be just as destructive as land-based tornadoes. In contrast, fair weather waterspouts form in calmer conditions and are generally less intense. Importantly, when any waterspout moves onshore, it is reclassified as a tornado, and a tornado warning is issued due to the potential for damage and injury. However, since most waterspouts remain over water and dissipate quickly upon landfall, their overall severity is considered low, especially for fair weather types that rarely cause significant harm unless they impact marine vessels or coastal areas.

Probability of Future Hazard Events

Waterspouts are a known phenomenon in Puerto Rico, particularly during the warmer months when atmospheric conditions, such as high humidity and warm sea surface temperatures, are favorable. Although not as frequent in Puerto Rico as they are in the Florida Keys, waterspouts do occur several times a year in Puerto Rican coastal waters, especially during the Atlantic hurricane season and periods of tropical wave activity. These events are typically observed in the early morning or afternoon and are more likely to be of the fair weather type, which are less intense and short-lived. Given their occasional but recurring nature, the probability of occurrence in Puerto Rico is classified as **moderate**: they are not rare, but they are not frequent enough to be considered high-risk on a year-round basis.

Vulnerability Assessment

The vulnerability associated with waterspouts in Puerto Rico is considered low, primarily because these phenomena typically remain over open water and rarely make landfall. When they do, they are reclassified as tornadoes and may pose a greater threat. However, most waterspouts observed around the island are fair weather types, which are short-lived and less intense. The primary assets exposed to this hazard are marine vessels, recreational users, and limited marine infrastructure, such as docks or small harbors. These assets are often mobile or temporary in nature, and detailed exposure data is highly variable and limited, making it difficult to quantify consistent impacts. As a result, while waterspouts can pose localized risks, the overall vulnerability of Puerto Rico's population and infrastructure to this phenomenon remains **low**.

LOCATION

Waterspouts have been observed in several coastal areas of Puerto Rico. Notable occurrences include Isla Verde near San Juan, where a waterspout was seen on November 17, 2020; Pico de Piedra Beach in Aguada, where one was reported on August 17, 2023; and Guajataca Lake, which experienced a waterspout on October 4, 2025. One of the most significant events took place in Mayagüez Bay on September 14, 2005, where a large waterspout was visible from multiple locations around the city. These events highlight the vulnerability of Puerto Rico's coastal zones to this meteorological phenomenon.

POPULATION

Since waterspouts are considered only while they remain over water, the vulnerability of Puerto Rico's population to this hazard is very low. These phenomena typically occur offshore and dissipate quickly, rarely making landfall. As a result, the only population segment at potential risk consists of individuals aboard marine vessels during the brief moments when a waterspout is active. Such encounters are rare and usually avoidable with timely weather advisories, further minimizing the threat to human life.

STRUCTURES INCLUDING CRITICAL FACILITIES

Due to the nature of waterspouts as offshore phenomena, critical infrastructure in Puerto Rico is not considered vulnerable to this hazard. Waterspouts typically form and remain over bodies of water, rarely making landfall. As such, they pose minimal risk to land-based critical facilities such as hospitals, emergency services, and government buildings. Any potential threat would only arise if a waterspout were to move onshore and be reclassified as a tornado, which is an infrequent occurrence.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Vulnerability to waterspouts is minimal for Puerto Rico's infrastructure and community lifelines, primarily due to the offshore nature of these phenomena. Waterspouts typically form and remain over water, rarely making landfall or impacting land-based systems. As a result, critical lifelines such as transportation, energy, communications, and health services are not considered vulnerable to waterspouts. Any potential disruption would only occur if a waterspout were to move onshore and be reclassified as a tornado, which is an uncommon event.

Impact Assessment

While vulnerability to waterspouts in Puerto Rico is low due to their typical confinement to marine environments and limited exposure of critical assets, the impact is also considered low for similar reasons. Waterspouts typically occur offshore and dissipate quickly. They rarely affect critical infrastructure or populations. Historical data shows minimal damage or disruption, and vulnerability is low due to limited exposure of assets.[1020] Impact refers to the actual consequences or damage resulting from a hazard event. In the case of waterspouts, even when they do occur, they rarely result in significant damage or disruption. Most events dissipate quickly or remain offshore, affecting only a small number of vessels or marine operations. Additionally, the lack of consistent data on damages or disruptions caused by waterspouts in Puerto Rico further supports the classification of their impact as low. This distinction is important: while vulnerability assesses the potential for harm based on exposure and sensitivity, impact reflects the realized effects, which in this case have historically been minimal.

[1020] United Nations Office for Disaster Risk Reduction. (2023). Global assessment report on disaster risk reduction 2023. UNDRR. https://www.undrr.org/media/105782/download.

STATE ASSETS

Given the low vulnerability of Puerto Rico to waterspouts and the limited severity of this hazard—primarily because waterspouts are classified as such only when they occur over water—the expected impact or risk to state-owned structures is also low. Waterspouts rarely make landfall and typically dissipate quickly, meaning that the likelihood of damage to permanent infrastructure is minimal. Consequently, the anticipated economic losses associated with this hazard are low.

LOCAL ASSETS

Due to the offshore nature of this phenomenon, local assets in Puerto Rico, which are primarily inland, are not considered vulnerable to waterspouts. Since waterspouts are only classified as such while they remain over water, they pose minimal risk to inland infrastructure or community assets. The potential for damage is extremely low, and any impact would only occur if a waterspout moved onshore and was reclassified as a tornado—an event that is rare and typically results in limited damage. Therefore, the expected economic losses to local assets from waterspouts are considered low.

COMMUNITY LIFELINES

FEMA's Community Lifelines framework identifies eight essential systems that enable the continuous operation of critical government and societal functions:

- Safety and Security
- Food, Hydration, Shelter
- Health and Medical
- Energy
- Communications
- Transportation
- Hazardous Materials
- Water Systems

These lifelines are used to assess and prioritize response efforts during disasters. In the context of Puerto Rico, waterspouts—defined here strictly as phenomena that remain over water—pose minimal risk to these lifelines. Historical records and hazard assessments indicate that waterspouts have not caused major disruptions to any of these systems on the island. Since their impact is typically limited to marine environments, the exposed assets are primarily vessels and small-scale marine infrastructure, which are not central to the core lifeline systems. Furthermore, the limited and variable data on waterspout-related damages supports the conclusion that this hazard does not significantly threaten Puerto Rico's critical infrastructure or essential services.

SAFETY AND SECURITY

A waterspout near coastal areas in Puerto Rico could pose risks to the safety and security lifeline by triggering search and rescue operations, especially if vessels are affected. While no major damage from waterspouts has been recorded to date, their sudden appearance could pose risks to community safety.

FOOD, HYDRATION, AND SHELTER

Waterspouts are unlikely to directly impact the Food, Hydration, and Shelter lifeline in Puerto Rico, as they typically remain over water and are reclassified as tornadoes if they reach land. Because of this transition, any potential threat to agriculture, food supply, or shelter infrastructure would fall under tornado-related assessments rather than waterspout-specific impacts.

HEALTH AND MEDICAL

Waterspouts are unlikely to directly impact the Health and Medical lifeline, as they remain over water for shorter periods of time and rarely affect land-based infrastructure.

ENERGY

A waterspout near Puerto Rico's coast could potentially impact the Energy lifeline by damaging power plants located near the shoreline, such as Costa Sur and Aguirre. If strong enough, it could disrupt electrical infrastructure, leading to outages and requiring immediate restoration efforts to maintain energy stability.

COMMUNICATIONS

A waterspout near Puerto Rico's coast could potentially impact the Communication lifeline by damaging undersea cable landing points and microwave relay stations. If strong enough, it could disrupt voice, data, and/or internet service.

TRANSPORTATION

A waterspout could significantly disrupt maritime transportation by damaging docks, endangering vessels, and creating hazardous sea conditions that could force the suspension of ferry and cargo operations.

HAZARDOUS MATERIALS

The Hazardous Materials lifeline involves safe management and containment of dangerous substances that could threaten public health or the environment. Due to the localized and short-lived nature of waterspouts, it is unlikely they would significantly impact this lifeline unless they directly strike a vessel or facility handling hazardous materials near the coast.

WATER SYSTEMS

Even if a waterspout remains offshore, it could stir up sediment, debris, and contaminants in coastal waters, which may affect the quality of water drawn into desalination or treatment facilities.

Changes in Development

The waterspout phenomenon is inherently confined to aquatic environments, typically forming over warm bodies of water such as oceans, seas, or large lakes. As a result, its occurrence and potential impacts are geographically restricted to these areas, making it largely irrelevant to inland development patterns or population growth trends. Unlike other hazards that may expand in scope due to urbanization or demographic shifts, waterspouts do not pose a direct threat to terrestrial infrastructure or communities unless they move onshore, which is rare and typically results in minimal damage. Therefore, changes in development and population density do not factor in the assessment of risk associated with this hazard. No recent developments have altered the overall vulnerability to this hazard.

LAND USE AND BUILT ENVIRONMENT CHANGES

No offshore-specific building codes or regulations were identified that have either increased or decreased vulnerability to waterspouts in Puerto Rico. Since waterspouts are only classified as such when they occur over water, and because they rarely impact land-based development, current land use changes and built environment trends have not influenced the risk associated with this hazard. Given the limited understanding and data on waterspout behavior and impacts, additional research and funding are recommended to improve monitoring and hazard assessment capabilities for this phenomenon.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Waterspouts are inherently confined to offshore environments and typically form over warm bodies of water, such as oceans and large lakes. Because waterspouts are only classified as such when they occur over water, and because they rarely make landfall, projected future growth and re-development in Puerto Rico—particularly inland—does not influence vulnerability to this hazard. Unlike other natural hazards that may be affected by urban expansion or population shifts, waterspouts pose minimal risk to terrestrial infrastructure or communities. Therefore, changes in development patterns, population density, or land use are not relevant factors in assessing future vulnerability to waterspouts.

POPULATION CHANGES

Population changes in Puerto Rico do not significantly affect vulnerability to waterspouts, as waterspouts are only classified as such when they occur over water. Waterspouts rarely make landfall and typically dissipate quickly, meaning that inland population growth or urban expansion does not increase exposure to this hazard. The only population segment at potential risk consists of individuals aboard marine vessels during the brief moments when a waterspout is active encounters that are rare and usually avoidable with timely weather advisories. For example, during the waterspout event near Pico de Piedra Beach in Aguada on August 17, 2023, the National Weather Service issued a special marine advisory instructing small boats to remain docked, which helped protect the population from potential harm.

VULNERABILITY OF STATE ASSETS CHANGES

Given the low vulnerability of Puerto Rico to waterspouts and the limited severity of this hazard—primarily because waterspouts are only classified as such when they occur over water—the expected impact or risk

to state-owned structures is also low. Waterspouts rarely make landfall and typically dissipate quickly, meaning that the likelihood of damage to permanent infrastructure is minimal. Consequently, the anticipated economic losses associated with this hazard are low, and no significant changes have occurred in the vulnerability of state assets over time.

VULNERABILITY OF LOCAL ASSETS CHANGES

Local assets in Puerto Rico, which are primarily inland, are not considered vulnerable to waterspouts due to the offshore nature of this phenomenon. Since waterspouts are only classified as such while they remain over water, they pose minimal risk to inland infrastructure or community assets. The potential for damage is extremely low, and any impact would only occur if a waterspout moved onshore, an uncommon event that may cause limited damage and result in its reclassification as a tornado. Therefore, no significant changes have occurred in the vulnerability of local assets over time.

SECTION 4.20

WILDFIRE

Wildfire

Definition

The USFS defines wildfire as an unplanned, unwanted wildland fire, including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out.[1021]

Wildfires are an emerging but significant natural hazard in Puerto Rico. Unlike the large, forest-driven fires common in the western United States, Puerto Rico's wildfire risk is shaped by its tropical climate, seasonal droughts, flammable grasses and secondary forests, and the expansion of the wildland–urban interface (WUI). Most fires on the island are human caused, often linked to open burning of debris, agricultural practices, or intentional ignitions. Once started, fires can spread quickly due to low humidity, high winds, and prolonged dry conditions, particularly during the January–April dry season.

Rising global temperatures intensify these risks by driving higher temperatures, causing more frequent droughts and shifting rainfall patterns, which leave fuels drier for longer periods.[1022] Abandoned agricultural lands that revert to invasive grasses add to the fuel load, while urban expansion places more people and infrastructure in harm's way.

Unlike temperate ecosystems, where fire may play an ecological role, Puerto Rico's forests and drylands are not fire adapted, making them highly vulnerable to damage from wildfire. The impacts of these fires extend

[1021] Avitt, Andrew, "Wildfire: A Modern-Day Paradox," US Forest Service, January 10, 2024, https://www.fs.usda.gov/about-agency/features/wildfire.
[1022] Avitt, Andrew, "Wildfire: A Modern-Day Paradox," US Forest Service, January 10, 2024, https://www.fs.usda.gov/about-agency/features/wildfire.

beyond vegetation loss, as they also generate smoke and ash that contribute to poor air quality, threaten nearby communities, and disrupt ecosystems.

The *State of the Climate 2014–2021* report documents that baseline temperatures are increasing across the island, especially in southern and western regions, and that more-frequent drought conditions combined with the spread of fire adapted invasive grasses have significantly elevated the risk of wildfires.[1023] This warming is more pronounced at night in mountainous regions, reducing natural cooling periods and increasing vegetation stress, which further increases the likelihood that fires will start and spread.

Although many wildfires are small in scale, their cumulative impacts are significant. Beyond ecological damage and smoke-related health issues, Puerto Rico has sustained millions of dollars in direct economic losses from wildfires each year. For example, in 2013, wildfires burned nearly 6,800 hectares and caused an estimated $13.8 million in damage. In 2014, more than 6,400 hectares burned and losses exceeded $8.6 million.[1024] These figures do not capture indirect costs, such as impacts on agriculture and air quality and the need for emergency response.

The WUI is any area where human-made structures are in or near a boundary of natural terrain and fuel and a high potential for wildland fires exists. Fuel types in Puerto Rico's WUI include many grasses, forbs, shrubs, trees, and forest residues. All kinds of vegetation can increase the likelihood of fire near structures. Other fuels, such as piles of firewood near a structure, can contribute to the risk that fire poses to a structure. Similarly, certain construction materials, such as wood shingles, can make a home more vulnerable to fire in the vicinity. Mitigating the risk of fire in the WUI involves different practices, depending on the fuels in the vicinity. Figure 274 shows firefighters in action in 2023.

Location

Wildfire vulnerability in Puerto Rico is closely linked to the island's geography and climate. The National Weather Service (NWS) San Juan Fire Weather Zones provide an operational framework to identify areas most at risk. Since 2015, zones, such as PRZ014 (Southeast Coastal Plains) and PRZ027 (Southwest Coastal Plains & Mona Island), have been most frequently placed under Fire Danger Statements and Red Flag Warnings, reflecting their persistent exposure during drought and periods of low humidity. Figure 275 shows the island's fire weather zones, the geographic areas where fire danger alerts are most common. PRZ014 (Southeast Coastal Plains) and PRZ027 (Southwest Coastal Plains & Mona Island) are the areas with the most frequent Red Flag Warnings and Fire Danger Statements.

[1023] Puerto Rico Climate Change Council (PRCCC). (2022). Puerto Rico State of the Climate 2014–2021. Department of Natural and Environmental Resources (DRNA). https://staging.pr-ccc.org/en/publications/summary-of-the-climate-of-puerto-rico-and-the-us-virgin-islands/.

[1024] Méndez-Lázaro, P., et al. (2020). *Characterization of Fire Regimes and Climate Drivers in Puerto Rico.* Natural Hazards.

Figure 274: Firefighters in Lajas Parguera, April 2023

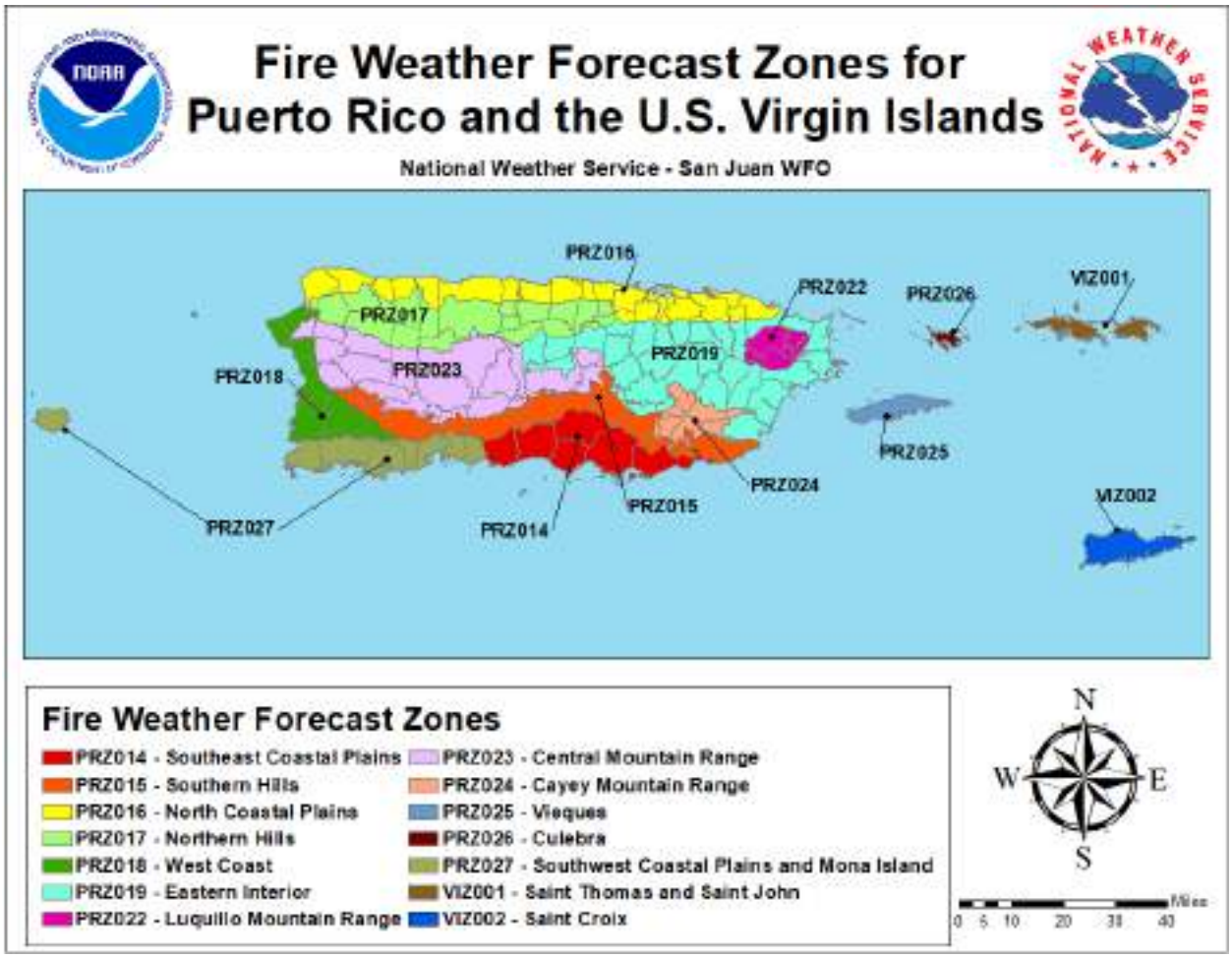


Figure 275: Fire Weather Zones, March 2024

SOUTHERN AND SOUTHWESTERN MUNICIPALITIES

Wildfire occurrence is most frequent in the southern and southwestern coastal plains, where subtropical dry forests and open grasslands are highly fire prone. Municipalities such as Salinas, Coamo Guayama, Guánica, Peñuelas, and Yauco are especially vulnerable because their location in drier ecosystems results in frequent ignitions and rapid fire spread.[1025]

MOUNTAINOUS INTERIOR MUNICIPALITIES

Wildfire risk is also significant in Puerto Rico's mountainous interior, where fuel accumulation and roadside ignition increase fire potential. Municipalities, such as Maricao and Adjuntas in the western uplands and Coamo, Aibonito, and Cayey in the central highlands, have experienced more frequent wildfire activity in recent decades. This inland expansion is strongly linked to hurricane debris and accumulated forest fuels, which create highly combustible conditions during the dry season.

EASTERN COASTAL MUNICIPALITIES

Although less frequent than in the south, wildfire activity is also recorded along the eastern coastal zone, particularly in Yabucoa and Naguabo. These municipalities are vulnerable due to the presence of dry coastal forests, seasonal droughts, and agricultural burning practices.

NORTHERN COASTAL MUNICIPALITIES

Smaller but recurring wildfire activity has also been observed along the northern coastal plain, where grasslands and agricultural lands create localized fuel conditions. Municipalities such as Vega Baja, Manatí, and Barceloneta occasionally appear in fire detection datasets, reflecting roadside ignitions and open fields that dry out seasonally.

NORTHEASTERN MUNICIPALITIES

The northeastern coast has also recorded wildfire activity, though at a lower intensity than other regions. Municipalities such as Loíza, Río Grande, and Luquillo occasionally appear in fire detection records, where grasslands, roadside vegetation, and small coastal forests create localized fuel conditions.

NORTHWESTERN MUNICIPALITIES

Wildfire activity is also observed in the northwestern coastal zone, where municipalities such as Aguadilla, Isabela, and Quebradillas have experienced recurring small to moderate fire events. These fires are commonly associated with grasslands, roadside vegetation, and agricultural burning practices. Although not as widespread as in the southern coastal plains, their occurrence demonstrates that wildfire exposure extends across all regions of Puerto Rico.

[1025] Puerto Rico State Forest Action Plan. San Juan, PR: DRNA & USDA Forest Service, International Institute of Tropical Forestry.

Satellite monitoring further validates these geographic patterns. NASA's Fire Information for Resource Management System (FIRMS), using Moderate Resolution Imaging Spectroradiometer (MODIS)and Visible Infrared Imaging Radiometer Suite (VIIRS) sensors, consistently showed hotspot clusters across Puerto Rico from 2000 through 2025. The densest concentrations appear in the southern and southwestern plains, but repeated detections are also visible in the mountainous interior (Coamo, Aibonito, Adjuntas, and Maricao) and in the eastern, northern, northeastern, and northwestern coasts. This evidence confirms that while wildfire risk is most severe in the south, it is increasingly geographically widespread, affecting diverse municipalities and ecosystems across the island. An example is shown in Figure 276, which maps FIRMS detections from March 2021, highlighting multiple fire events concentrated in the southern municipalities and the western interior, with smaller but notable detections in the north and east.

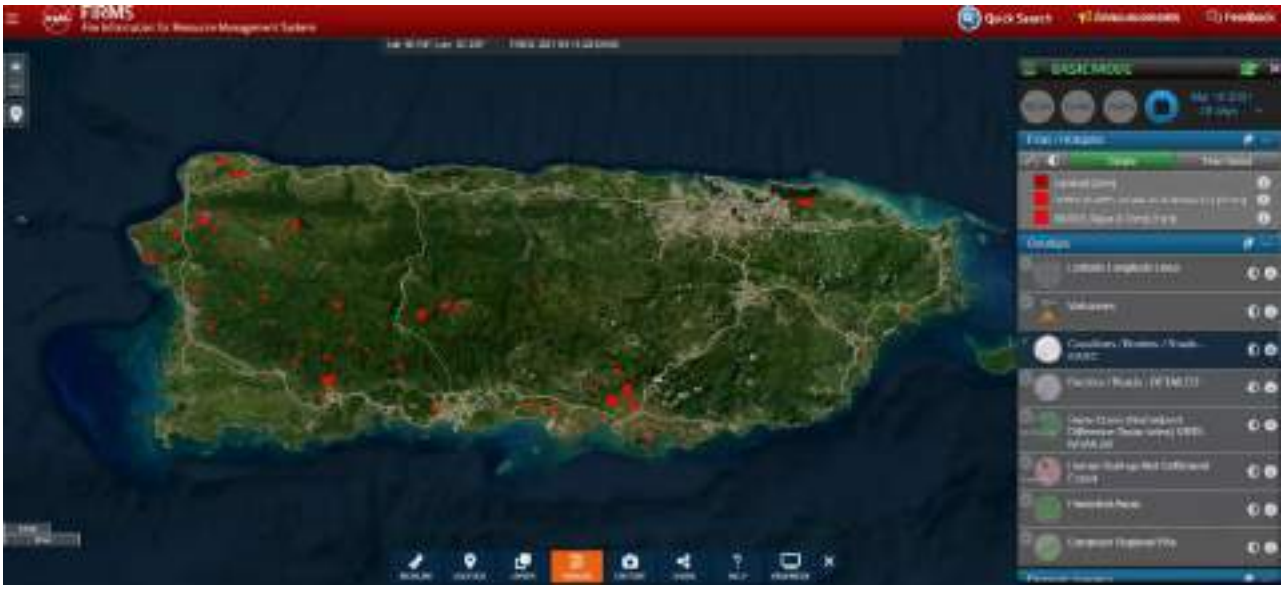


Figure 276: Active Fires Detected by NASA, March 2021

The WUI is an important consideration in identifying where a wildfire poses greatest risk to people due to the proximity of housing to vegetation. U.S. Forest Service produced a report that defined WUI zones for Puerto Rico that integrates census, land cover and land ownership information. The methodology used to define WUI interface and intermix classes is based on housing density and percent of vegetation cover.[1026] The percentage of each municipality that is in the WUI based on area is shown in Figure 277.

[1026] USDA Forest Service. Defining and Mapping the Wildland-Urban Interface of Puerto Rico and the U.S. Virgin Islands: 2010 Distribution and Implications. Martinuzzi et. al. 2025. https://data.fs.usda.gov/research/pubs/iitf/gtr_iitf_2025_001.pdf.

Figure 277: WUI Area by Municipality

Previous Occurrences

Wildfires have been a persistent challenge in Puerto Rico over the past decades, recorded across diverse ecosystems and jurisdictions. According to historical data from the Cuerpo de Bomberos de Puerto Rico, between 2003 and 2011 nearly 34,600 wildfires were documented, with around 5 % of them exceeding five hectares in size[1027]. Over those years, fires were mostly small grass and brush incidents, but their frequency demonstrated the recurrent nature of this hazard.

Data collected from the Cuerpo de Bomberos de Puerto Rico, covering reported incidents from 2019 to 2023, reveals a consistent and more finely resolved picture of the seasonal cycle of wildfires across the island. The records show that fire activity is strongly concentrated in the first half of each year, with the season typically beginning in January, peaking between February and March, and gradually declining by late spring (see Figure 278).

Figure

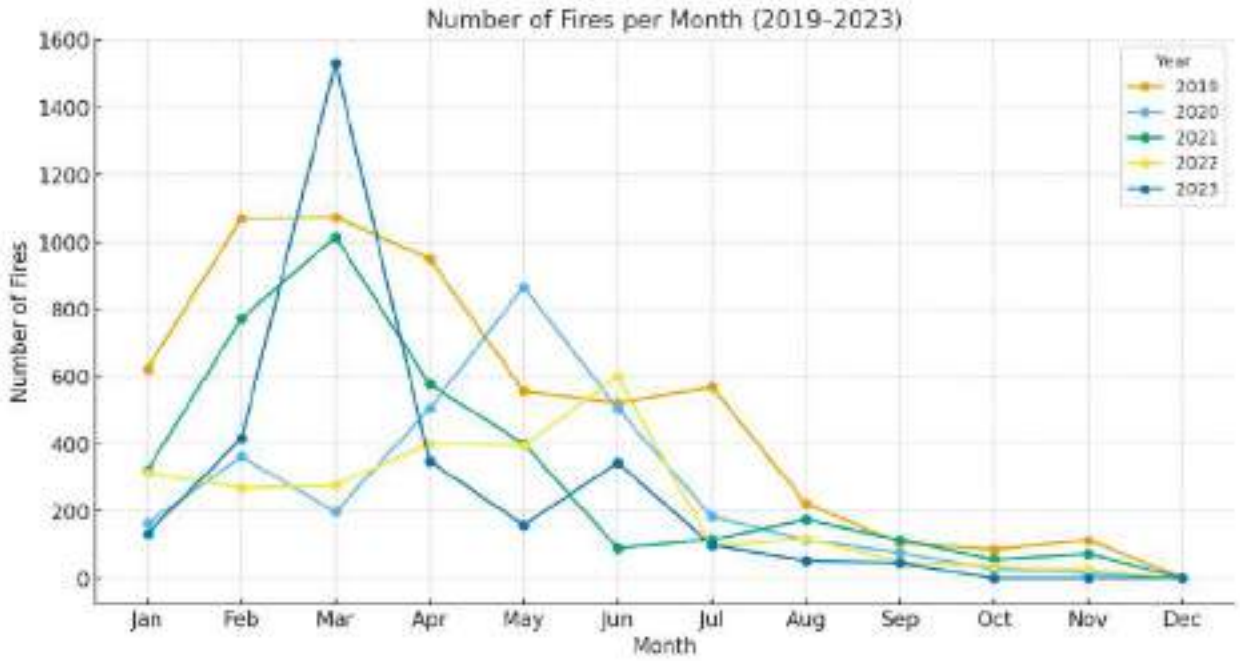


Figure 278: Number of Reported Fires per Month in Puerto Rico from 2019 to 2023 (Cuerpo de Bomberos Data)[1028]

- **Peak Season (January–April):** February and March consistently record the highest number of fires, making them the core months of Puerto Rico's fire season. Notably, March 2023 registered 1,530 fires, the highest single-month tally in the five-year dataset. Other high values include February 2019 (1,070 fires) and March 2019 (1,074 fires).

[1027] Monmany, A. C., Gould, W. A., Falk, D. A., & Van Beusekom, A. E. (2017). Fire History and Forest Dynamics in the Caribbean: A Case Study from Puerto Rico. Forest Ecology and Management, 390, 118–126.
[1028] The figure highlights the concentration of fires during the January–April period, with March 2023 standing out as the most active month in the five-year record.

- **Transition Months (May–June):** After April, fire counts decline but still reach significant levels in some years. For example, May 2020 saw 866 fires, and June 2022 saw 599 fires—indicating that under certain climatic or fuel conditions, the season can stretch into early summer.
- **Low Season (July–December):** From July onward, the number of fires drops sharply. By October, November, and December, fire activity becomes minimal or nearly absent across all years.

Together, the historic data and recent trend analysis affirm that Puerto Rico's wildfire regime is strongly seasonal, with a recurring high-risk window in late winter through early spring, and a generally quiet period in the late summer and fall. This pattern corresponds with the island's dry season, when reduced precipitation, higher temperatures, and increased fuel dryness favor ignition and fire spread recorded during the same period in 2014 and affecting 11,920 acres.

Satellite data confirm the scale of this trend. From 2001 through 2024, Global Forest Watch recorded approximately 3,470 hectares of tree cover loss due to wildfire, reflecting the cumulative impact of repeated burns.[1029] Table 117 shows recent wildfire events that caused significant damage in Puerto Rico between 2003 and 2023.

Table 117: Previous Occurrences of Wildfires in Puerto Rico (2003–2023)[1030]

Time Period	Location/ Coverage	Number of Fires/ Area Burned	Observed Intensity	Key Notes & Sources
2003–2011	Puerto Rico (island wide, incl. Vieques & Culebra)	~34,600 fires; ~5% exceeded 5 hectares	Mostly small grass/brush fires; occasionally large burns	Human caused, concentrated in dry season; influenced by temperature & forest cover[1031]
February 19, 2014	El Faro Natural Reserve, Cabo Rojo	~11 hectares burned	Moderate–high intensity	Significant ecological impact; mortality of native cacti and expansion of invasive grasses
March 2014	Bosque Modelo/ Bosque del Pueblo, Adjuntas (Casa Pueblo)	~60 hectares	Moderate–high intensity	Fire suspected to be intentional;~ 40% of local forest affected; suppression required Bomberos, DRNA, AEMEAD, Guardia

[1029] Global Forest Watch. (2024). *Puerto Rico: Fires and Tree Cover Loss Dashboard (2001–2024)*. World Resources Institute.
[1030] AEMEAD = State Agency for Emergency Management and Disaster Assistance, DRNA = Department of Natural and Environmental Resources, PRFD = Puerto Rico Fire Department.
[1031] Monmany, A. C., Gould, W. A., Falk, D. A., & Van Beusekom, A. E. (2017). Fire History and Forest Dynamics in the Caribbean: A Case Study from Puerto Rico. Forest Ecology and Management, 390, 118–126.

Time Period	Location/ Coverage	Number of Fires/ Area Burned	Observed Intensity	Key Notes & Sources
				Nacional, and municipal brigades[1032]
2015–2020	Southern and Southwestern PR (Guayama, Salinas, Guánica, Peñuelas, Yauco, Ponce)	Annual dry season fire clusters	Moderate to high intensity during drought years	Fires exacerbated by invasive grasses and repeated in the same corridors[1033]
2023	San German–Maricao (incl. Maricao State Forest)	Several hundred acres (exact estimate varies)	Moderate–high intensity	One of the most complex incidents in recent years; required extended suppression by PRFD[1034]
2023–2025	Vieques & Culebra (Fire Weather Zones PRZ025–026)	Limited records; sporadic brush fires	Generally small, fast spreading	Dry forest ecosystems and limited firefighting resources increase vulnerability[1035]

Looking beyond the seasonal cycle, recent reporting also highlights clear differences in how wildfire activity is distributed among municipalities. The Puerto Rico Fire Department (PRFD) provided information regarding the number of wildfires that have occurred in each municipality between 2019 and 2024 as shown in Figure 279. Mayaguez and Ponce have had the highest count of wildfires, with many other municipalities experiences hundreds of wildfires during that time. Wildfire density, or the number of wildfire incidents per square mile, for this same time period is shown in Figure 280. Density of occurrences are highest along the western coastal municipalities as well as Ponce and Juncos.

[1032] Primera Hora (2014), Business Standard (2014), Tu Noticia PR (2014). Wildfire at Bosque Modelo/Bosque del Pueblo, Adjuntas.
[1033] Puerto Rico Climate Change Council (PRCCC). (2022). Puerto Rico State of the Climate 2014–2021. San Juan, Puerto Rico.
[1034] Primera Hora (2023). Jefe de Bomberos: Fuego forestal en San German y Maricao.
[1035] National Weather Service San Juan (2024). Fire Weather Forecast Zones (PRZ025–PRZ026 for Vieques and Culebra). National Oceanic and Atmospheric Administration. Retrieved from https://www.weather.gov/sju/fire.

Figure 279: Wildfires by Municipality from 2019 to 2024

Figure 280: Wildfire Density 2019 to 2024

In addition to event-based records, satellite-derived fire alerts provide a broader perspective of wildfire occurrence across Puerto Rico. NASA's VIIRS dataset has tracked high-confidence fire detections each year since 2012. These alerts, while not the same as confirmed ground reports, are reliable indicators of fire activity over time.

Figure 281 shows the annual accumulation of VIIRS fire alerts compared with the historical range. It shows that the number of fire alerts in Puerto Rico has declined since 2013, when 36 alerts were recorded. As of August 2025, only six alerts have been reported. This suggests that the combined efforts of government agencies, such as the Puerto Rico Fire Department (PRFD) and the Department of Natural and Environmental Resources (DRNA in Spanish); the U.S. Forest Service (USFS); and nonprofit organizations like *Protectores de Cuencas*, *Casa Pueblo*, and The Nature Conservancy, are helping reduce wildfire occurrence through education campaigns, community outreach, and risk-reduction programs. Nonetheless, this remains an ongoing challenge, as Puerto Rico is facing unprecedented levels of extreme heat and drought which continue to increase wildfire risk. Sustained prevention and preparedness initiatives are essential to prevent the reversal of these gains under worsening climate conditions.

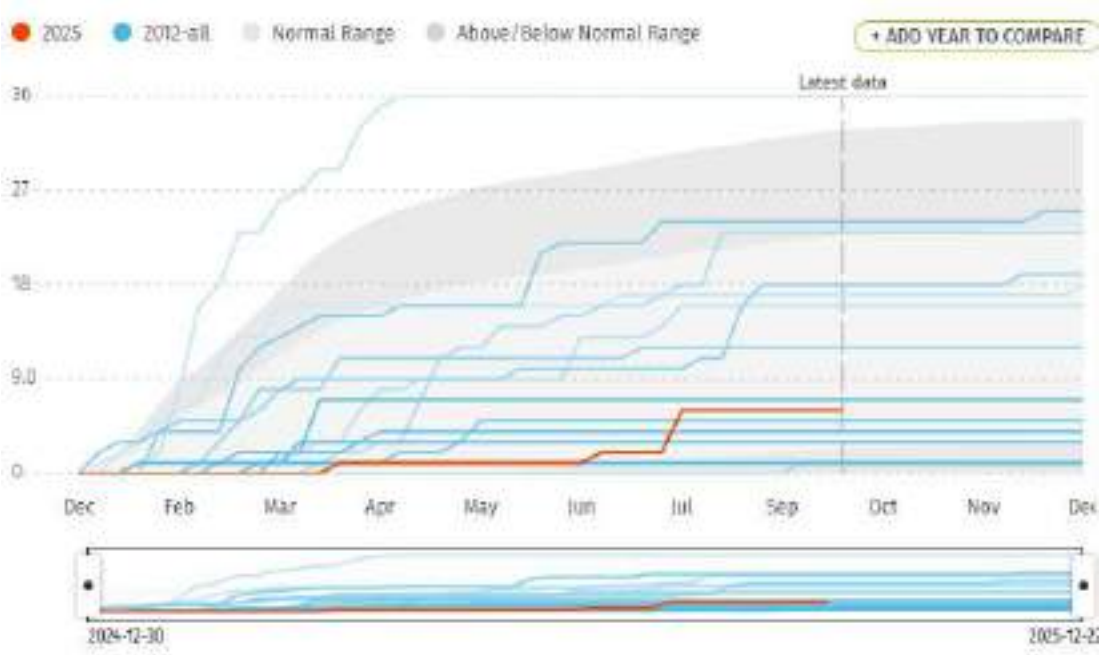


Figure 281: Fire Alerts for Puerto Rico by Month, 2012–2025[1036]

FEDERAL DISASTER DECLARATIONS

FEMA has issued no Major Disaster or Emergency declarations specific to wildfires in Puerto Rico in 2025. However, Puerto Rico is eligible for Fire Management Assistance Grants (FMAGs), and FEMA posts annual FMAG cost thresholds for the Commonwealth.

[1036] NASA. Active fires reported by the Fire Information for Resource Management System, 2025. https://firms.modaps.eosdis.nasa.gov.

PUERTO RICO DISASTER DECLARATIONS

As of 2025, there has not been any disaster declarations for wildfire in Puerto Rico.

The Puerto Rico Fire Department provided details about wildfires that occurred in Puerto Rico from 2019 to 2024, including their causes. Table 118 summarizes the number of fires that occurred each year and their cause. For most of these fires, the cause remains undetermined. This suggests a lack of clarity regarding the origins of most wildfires. Improved capabilities to identify causes of fires could inform efforts to minimize fire risk more effectively. 262 fires were set intentionally and another 38 were caused by negligence, which highlights a concerning aspect of human involvement in wildfire incidents. The overall decline in the number of wildfires that occurred in 2024 compared to 20204 may indicate there have been improvements in environmental conditions or fire management.

Table 118: Causes of Wildfires by Year

Cause	2019	2020	2021	2022	2023	2024	Sum	% of total
Intentional	65	39	48	25	53	32	262	**3.49**
Lightning	0	0	0		1	1	2	**0.03**
Negligence	1	9	2	6	5	15	38	**0.51**
Power line contact	5	0	2	2	23	15	47	**0.63**
Spontaneous	0	1	1	6	1	0	9	**0.12**
Unknown	1,978	1,008	1,307	977	1,286	596	7,152	**95.19**
Power transformer fault	1	0	0	1	1	0	3	**0.04**
Total	**2,050**	**1,057**	**1,360**	**1,017**	**1,370**	**659**	**7,513**	

SIGNIFICANT EVENTS

Although most wildfires in Puerto Rico tend to be small in scale, several incidents stand out due to their ecological and social impacts. These events highlight how prolonged drought and high temperatures create conditions for larger, more destructive fires. For example, in Cabo Rojo's Boquerón State Forest, a wildfire in 2015 damaged sensitive habitat, while in Guánica in 2024, flames spread rapidly through dry coastal vegetation, prompting an emergency response. Recurring fire outbreaks in forested areas, such as Maricao, also illustrate the persistent vulnerability of Puerto Rico's ecosystems to ignition sources. Table 119 summarizes some of the most significant wildfire events reported in recent years.

Table 119: Significant Wildfire Events in Puerto Rico

Date	Location/ Coverage	Description & Impacts	Estimated Damages/Notes
Jan 20, 2024	Guánica (near PR-116)[1037]	Large wildfire required extended PRFD suppression operations; local evacuations reported by media.	Not quantified; significant suppression costs and community disruption.
2023–2024 Dry Seasons	Lajas–Boquerón–Cabo Rojo (Southwest PR)	Multiple brush and forest fire clusters along coastal plain and WUI areas, consistent with historic hotspots.	Repeated seasonal burns; cumulative ecological and agricultural impacts.
March 12, 2015	Boquerón State Forest, Cabo Rojo	~30 acres burned; DRNA reported long-term ecological damage risk in dry forest ecosystems.	No official monetary damage reported; loss of habitat noted.
Annual Trend (2024)	Island wide (concentrated in South & West)[1038]	PRFD and USFS documented 1,681 wildland fires affecting 3,695 acres during the 2024 season (Jan–Aug).	Direct damage not fully quantified; significant strain on PRFD resources.
Mar 9, 2023	Maricao State Forest (Monte del Estado)	Multi-day wildfire affecting forested areas	Fire lasted ~4 days; described as an ecological disaster due to damage to local ecosystems.

Beyond localized incidents, major hurricanes have played a critical role in shaping wildfire risk. Hurricanes often cause widespread deforestation, treefall, and accumulation of vegetative debris, which once dried serves as highly combustible fuel. This dynamic was most evident in the aftermath of Hurricane María in 2017, when tree cover loss surged to more than 4,000 hectares far above the long-term annual average of 1,100–1,400 hectares[1039] (see Figure 282).

[1037] Telemundo Puerto Rico – Reportan fuego forestal en Guánica (Jan 20, 2024). https://www.telemundopr.com/noticias/puerto-rico/reportan-fuego-forestal-en-guanica/2570971.
[1038] U.S. Forest Service – Puerto Rico State & Private Forestry Fact Sheet (2025). https://apps.fs.usda.gov/nicportal/temppdf/sfs/naweb/pr_std.pdf.
[1039] Global Forest Watch (GFW). (2024). Tree Cover Loss by Driver: Puerto Rico (2001–2024). Retrieved from https://www.globalforestwatch.org.

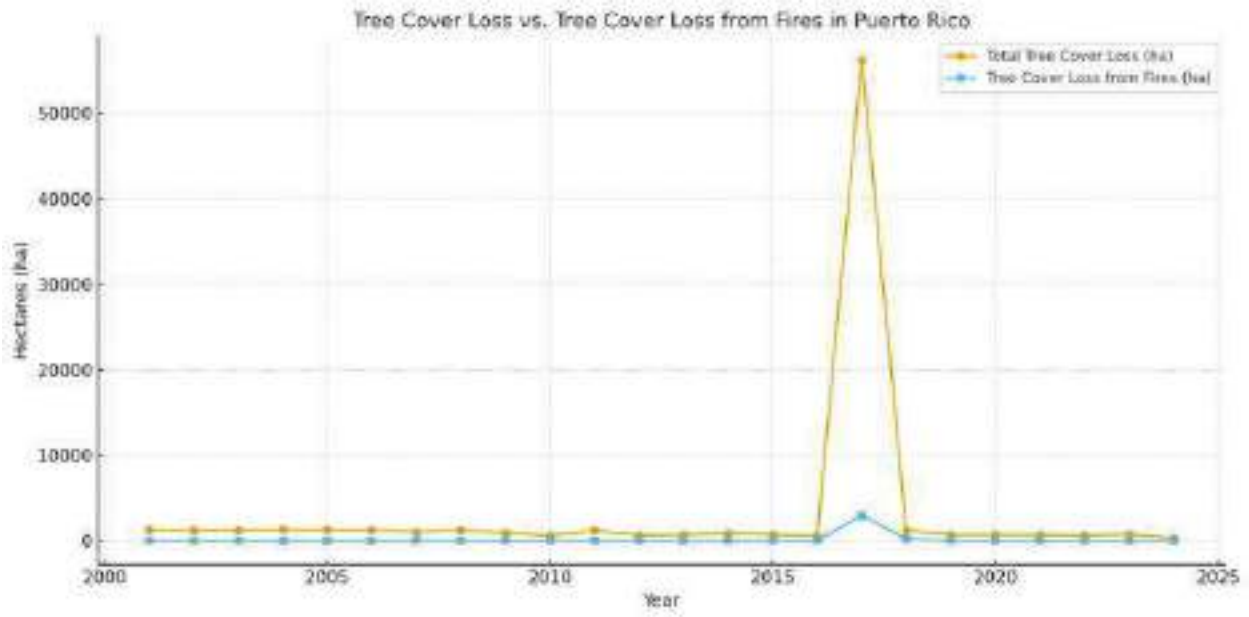


Figure 282: Annual Tree Cover Loss and Fire-Related Tree Cover Loss in Puerto Rico (2001–2024)

Data from Global Forest Watch (GFW) indicate that, from 2001 to 2024, Puerto Rico lost approximately 3.47 thousand hectares of forest specifically to fires, with nearly 3.0 thousand hectares lost in 2017 alone.[1] Although fire-driven losses usually represent only a small fraction of annual deforestation (10–20 hectares), in 2017 they accounted for 5.3% of all tree cover loss, underscoring how post-hurricane conditions can dramatically amplify wildfire risk.

The massive deforestation and debris left behind by María not only reduced forest cover directly but also created a dangerous fuel load that dried out in subsequent months. This illustrates how deforestation and hurricane impacts are directly linked to wildfire hazard, as vegetative debris accelerates ignition and intensifies fire behavior across the landscape.

NCEI DATA

The National Centers for Environmental Information (NCEI) maintains a comprehensive national database of hazard events, including hurricanes, floods, droughts, and severe storms. However, a review of the NCEI Storm Events Database indicates that wildfires are not systematically tracked for Puerto Rico.

This absence of wildfire data in NCEI does not imply that wildfires have not occurred in Puerto Rico but rather that such events have not been cataloged in this federal hazard inventory. In fact, other sources, including reports from the PRFD, DRNA, and academic studies, document wildfire activity on the island, particularly in dry southern and southwestern regions.

Potential Severity of Event

The severity of wildfires in Puerto Rico is shaped by a combination of human activity, fuel conditions, and climate stressors, such as drought and rising temperatures. Although most fires on the island are human

caused, periods of prolonged drought and elevated heat create conditions that significantly increase the likelihood of larger and more intense events. The Keetch–Byram Drought Index (KBDI), a widely used scale that measures soil moisture deficit on a scale from 0 (saturated soils) to 800 (extreme drought), is particularly relevant for Puerto Rico.[1040] High KBDI values indicate drier conditions, which translate into greater wildfire potential due to the high flammability of invasive grasses and degraded dry forests that dominate much of the southern and western regions.

According to the PRCCC, increases in temperature and extended drought periods have already heightened the potential for more frequent and intense wildfires on the island. Under severe drought conditions, fires can escalate from low-intensity grass burns to high-intensity wildfires that can kill woody vegetation, limit native forest regrowth, and promote the spread of invasive grasses, such as African buffelgrass (*Cenchrus ciliaris*).[1041]

Projected climate scenarios for Puerto Rico further indicate rising risks. Downscaled models suggest temperature increases of 4.5°C under low-emission pathways and up to 7°C under high-emission scenarios by the end of the century.[1042] These changes are expected to lengthen the dry season and add 150–200 extremely hot days annually by mid-century, which would push KBDI values higher and create sustained conditions for severe fire activity.[1043]

The potential severity of wildfires in Puerto Rico can therefore be expressed using the KBDI scale,

Table 120: Severity Levels of the Keetch–Byram Drought Index

KBDI Range	Drought Severity	Wildfire Potential in Puerto Rico
0–200	Minimal to Low	Soil moisture is adequate; only isolated surface fires likely in dry grass.
200–400	Moderate	Frequent grass and brush fires occur, especially in southern/coastal plains during the dry season (December–March).
400–600	High	Fires spread rapidly through dry forests and along road corridors. Fire management becomes more difficult.
600–800	Extreme	Conditions enable large, high-severity wildfires with potential for deep burning and significant ecological and community impacts, particularly in wildland–urban interface zones like Guánica, Lajas, Yauco, and Cabo Rojo.

Probability of Future Hazard Events

Wildfire in Puerto Rico is a seasonal hazard that is expected to continue annually, with varying levels of recurrence that depend on location and climate conditions. Historic and modern analyses confirm that

[1040] Keetch, J.J., & Byram, G.M. 1968. A Drought Index for Forest Fire Control. USDA Forest Service Research Paper.
[1041] PRCCC (2022) – Puerto Rico's State of the Climate 2014–2021.
[1042] Gould, W. et al. (USDA Caribbean Climate Hub, 2013)
[1043] Meir & Pennington (2011). *Hydraulic failure and Tree Mortality in Tropical Dry Forests.*

wildfire activity is strongly tied to departures from normal rainfall and temperature, with drought periods greatly increasing ignition and spread potential. Data from the National Interagency Fire Center show that, in 2019, Puerto Rico recorded 97 wildfires that burned 2,906 acres. This shows that, even in non-extreme years, wildfire remains a measurable and recurring threat.[1044] The island is classified as having a **High** (annual) likelihood of conditions conducive to wildfire, with a probability greater than 50% each year that such conditions could escalate into events affecting communities or infrastructure.[1045]

Satellite-based assessments complement this outlook. Between 2001 and 2024 Puerto Rico lost approximately 3,470 hectares of tree cover due to fire.[1046] Although smaller in scale than losses from storms or development, this confirms that wildfire impacts are a consistent element of the island's land cover dynamics. Recent advances in climate fire modeling reinforce this probability. Remote sensing and machine learning studies for Puerto Rico report strong predictive accuracy (0.8–0.89 for fire occurrence), projecting that future conditions will increase the likelihood of larger wildfires (>5 ha) as drought and heat intensify.[1047] Research indicates that wildfire occurrence in Puerto Rico is not exceptional but expected every year, with the highest recurrence in southern and southwestern municipalities, consistent but less frequent fire activity in the south-central corridor, and episodic risk in wetter regions during drought years.

[1044] National Interagency Fire Center (NIFC). 2019. *Wildfires by State – Includes Puerto Rico*. Insurance Information Institute. https://www.iii.org/table-archive/23284.
[1045] ThinkHazard. 2025. *Puerto Rico (U.S.) – Wildfire Hazard Classification*. https://thinkhazard.org.
[1046] Global Forest Watch (GFW). 2025. Puerto Rico Fire Dashboard and Tree Cover Loss (2001–2024). https://www.globalforestwatch.org.
[1047] Monmany, A.C., Van Beusekom, A.E., et al. 2017–2018. Fire weather and likelihood: characterizing climate space for fire occurrence and extent in Puerto Rico.

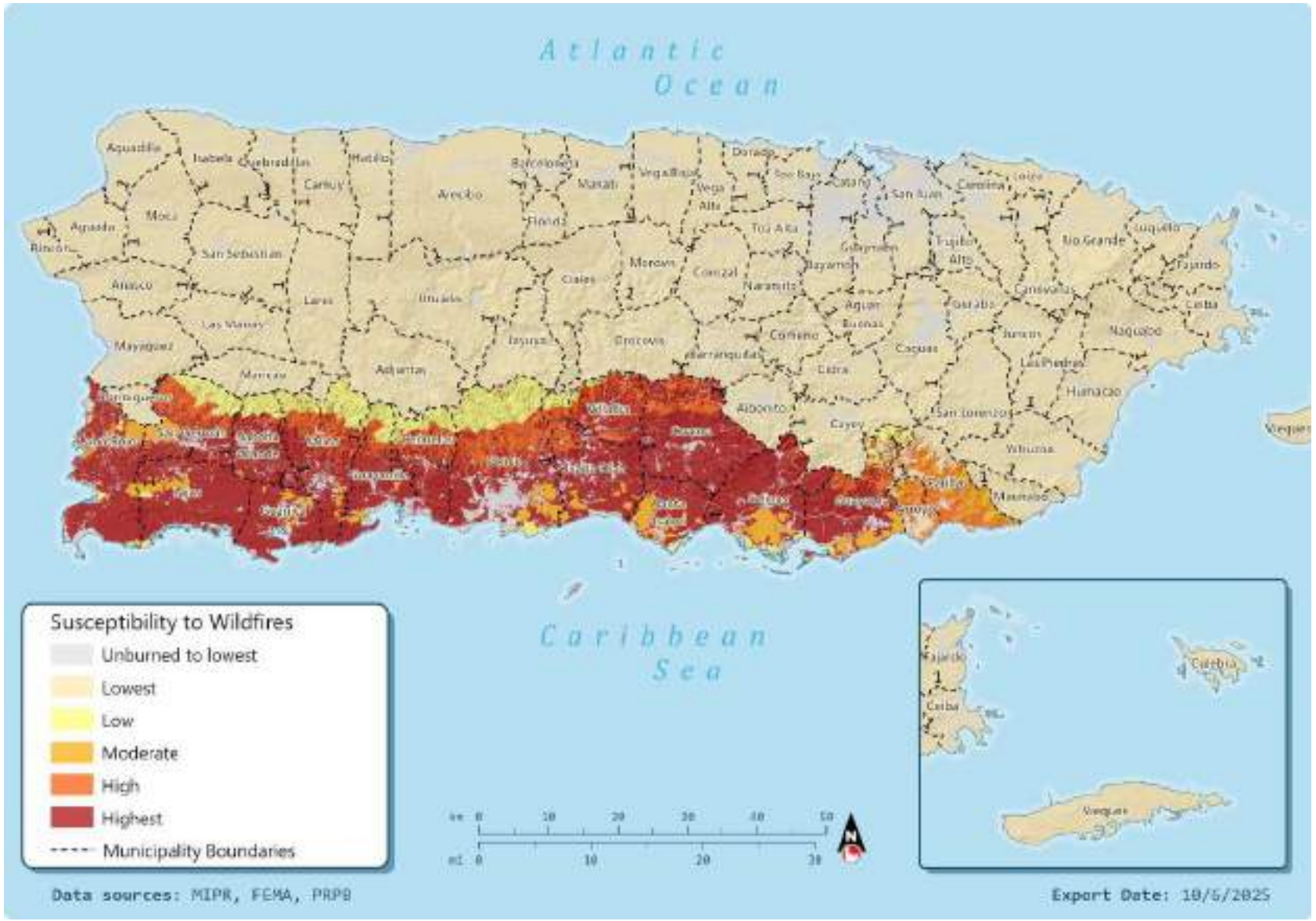


Figure 283: Wildfire Susceptibility

Vulnerability Assessment

Wildfire vulnerability in Puerto Rico is concentrated in southern and southwestern municipalities, where seasonal droughts, invasive grasses, and human-caused ignitions intersect. Although most fires are small grass or brush burns, the WUI exposes people, buildings, and infrastructure to recurring risk. Vulnerability is shaped not only by biophysical factors (vegetation, climate, and topography) but also by social and infrastructural conditions, such as limited defensible space, high social vulnerability, and constrained emergency response capacity in rural areas. Spatial clusters of past burn severity and fire perimeters support this pattern, and NWS Fire Weather products provide the operational geography for readiness and alerts.[1048]

The Puerto Rico Forest Action Plan further identifies the southern coastal plain as the island's primary fire-prone landscape, where people, dry fuels, and climatic conditions converge to create recurring ignition potential. In this region, rapid suppression and sustained public education are recognized as essential strategies, with PRFD leading suppression efforts and DRNA providing critical support in the Ponce and Mayagüez regions.[1049]

A central vulnerability driver is the predominance of human-caused ignitions. Most fires are deliberately set, often without regard for wind, humidity, or weather conditions. When numerous ignitions occur simultaneously, suppression resources become stretched, increasing the likelihood of larger, more damaging burns. Although dry forest zones remain the most fire prone, extended drought and ongoing landscape fragmentation threaten to expand fire risk into moist and wet tropical forests that have historically been less vulnerable.

Social vulnerability further magnifies wildfire exposure. Rural communities often face gaps in defensible space management, limited public awareness, and fewer emergency response resources. These conditions, combined with recurring fire clusters, create sustained risk to people and ecosystems. The Forest Action Plan underscores the need for mitigation strategies, such as prescribed burning, hazardous-fuel reduction, community education, and improved data on fire occurrence, as ways to address these vulnerabilities.[1050]

In sum, wildfire vulnerability in Puerto Rico reflects both ecological and social dimensions where climate and land cover interact with human behaviors and community capacity, making it a persistent and complex hazard across the island's southern and western landscapes.

LOCATIONS

Wildfires have occurred most frequently in the southern and southwestern plains, such as Guánica, Lajas, Yauco, Cabo Rojo, and the Salinas–Coamo–Cayey corridor. These regions align with NWS Fire Weather Zones where ignition and spread are most common. Recent zone updates (e.g., PRZ014 split into PRZ014 and PRZ027) better reflect danger areas. Western interior municipalities also report recurring fires, while

[1048] National Weather Service (NWS) San Juan. Fire Weather Zone Changes (PRZ014/PRZ027). https://www.weather.gov/sju/fire_zonechanges.
[1049] Puerto Rico Forest Action Plan (2015). Section: Fire-Prone Landscape, pp. 123–135.
[1050] Puerto Rico Forest Action Plan (2015). Recommendations for Prescribed Burning, Education, and Data Collection, pp. 93–101.

moist and montane forests, such as El Yunque, face low but possible risk during prolonged droughts. Historical burn severity mapping corroborates repeated impacts in the south and west.[1051] Table 121 shows the jurisdictions most threatened by wildfire in Puerto Rico.

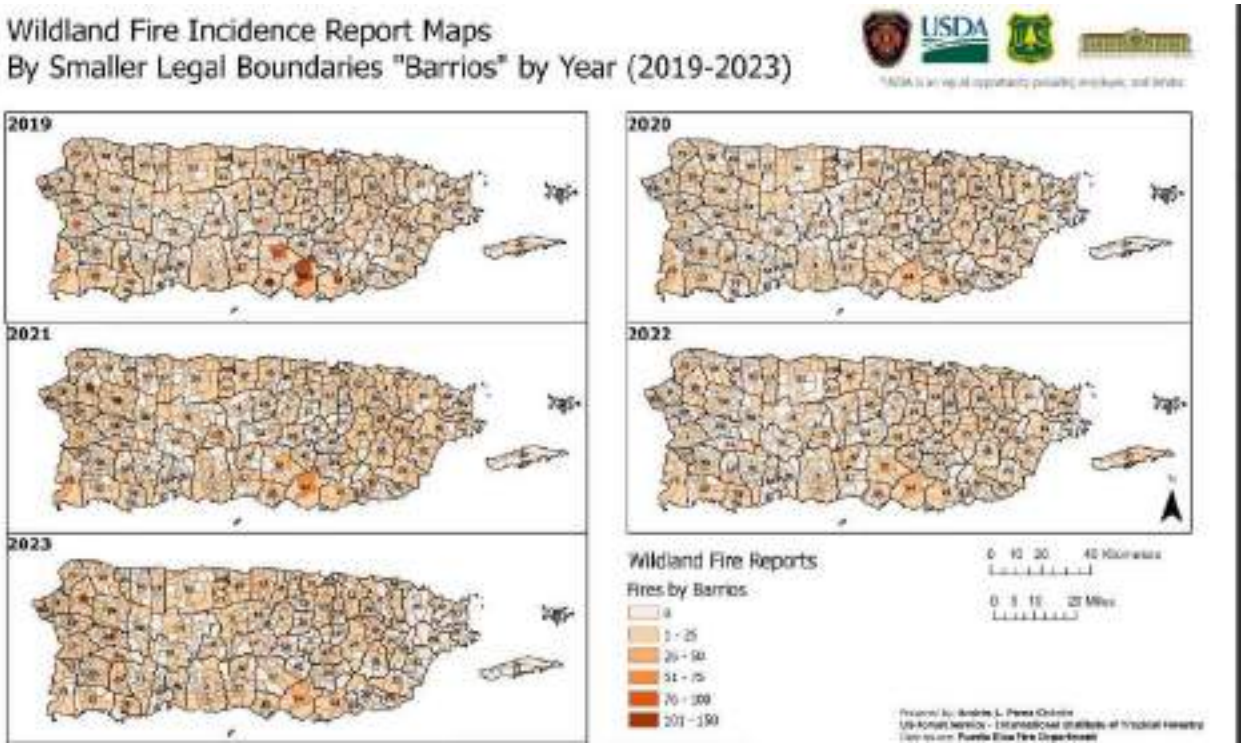
Table 121: Wildfire Vulnerability of Municipalities and Regions

Risk Level	Municipalities/Regions
Very High	Guánica, Lajas, Yauco, Cabo Rojo (southwest coastal plains)
High	Salinas, Coamo, Aibonito, Cayey (south-central corridor); Guayama, Santa Isabel (southeast)
Moderate	Mayagüez, Hormigueros, San Germán, Peñuelas, Ponce (western & southern interior)
Low	Northeastern moist forests (El Yunque); central uplands (except during severe drought)

Recent data compiled by the PRFD, in collaboration with the USFS and the International Institute of Tropical Forestry, provide a detailed picture of wildfire occurrence at the barrio level between 2019 and 2023. This dataset, mapped annually, highlights the spatial distribution and clustering of wildfire activity across the island.

The maps in Figure 284 reveal consistent concentrations of fire reports along the southern and southwestern coastal municipalities, with additional clusters in the central interior zones, such as Guayama, Salinas, Coamo, and Villalba. These patterns align with previously identified fire-prone landscapes, where prolonged drought, grassland fuels, and human-caused ignitions intersect. The barrio-level resolution further emphasizes how wildfire incidence is not evenly distributed but is instead concentrated in recurring hotspots, reflecting both ecological conditions and human land use pressures.

[1051] U.S. Forest Service – Monitoring Trends in Burn Severity (MTBS), Puerto Rico datasets. https://data-usfs.hub.arcgis.com/datasets/3f2e218cebe9471f95412e206051b325.



Municipality Number	Municipality Number	Municipality Number	Municipality Number
1-Mayagüez	19-Añasco	36-Sabana Grande	59-Barranquitas
2-Carolina	20-Moca	38-Isabela	60-Camuy
3-Ponce	21-Guaynabo	39-Barceloneta	63-Cayey
4-Ciales	22-Naranjito	40-Peñuelas	64-Salinas
5-Corozal	23-Lajas	41-Maricao	65-Quebradillas
7-Hormigueros	24-Guayama	42-Aibonito	67-Manatí
8-Utuado	25-Caguas	43-Morovis	68-Las Marías
10-Cabo Rojo	27-Cidra	45-Vega Alta	69-Lares
11-San Juan	28-Trujillo Alto	47-Villalba	71-Aguas Buenas
12-Arroyo	29-Gurabo	51-Cataño	72-Aguadilla
13-Bayamón	30-Patillas	53-Florida	73-Toa Baja
14-Dorado	31-Yauco	54-Orocovis	75-Comerío
15-Jayuya	32-Adjuntas	55-Arecibo	76-Toa Alta
16-Guayanilla	33-Vega Baja	56-San Germán	77-Hatillo
17-Juana Díaz	34-Guánica	57-Coamo	
18-San Sebastián	35-Santa Isabel	58-San Lorenzo	

Figure 284: Incidence of Wildland Fires, 2019–2023

By visualizing five years of incident data, this mapping provides critical evidence of where exposure is greatest, reinforcing the vulnerability of southern municipalities and communities in the WUI. It also underscores the importance of targeting prevention, suppression capacity, and public education efforts in areas where fire frequency and cumulative exposure are highest.

POPULATIONS

Populations most vulnerable to wildfire include those in WUI zones, where homes and communities directly abut flammable vegetation. Older adults, children, pregnant people, and individuals with respiratory or cardiovascular conditions are disproportionately impacted by smoke exposure. The Center for Disease Control and Prevention (CDC) and the Environmental Protection Agency (EPA) identify these groups as at higher risk of adverse health effects from wildfire smoke.[1052] Outdoor workers (agriculture, construction) and socially vulnerable groups, such as low-income households and persons experiencing homelessness, face elevated exposure, with fewer resources to adapt or relocate.

The U.S. Forest Service that identified WUI zones for Puerto Rico indicated that over 1 million housing units and a population of 2,369,995 individuals are within the WUI. This represents 65.3 percent of the houses and 63.6 percent of the total population of Puerto Rico.[1053] Using data from this report, Figure 285 below indicates municipalities where a higher percentage of population are located within the WUI, followed by a map of the percentage of housing exposed to the WUI (see Figure 286).

[1052] CDC. 2024. Wildfire Smoke and Children (risk factors). https://www.cdc.gov/wildfires/risk-factors/wildfire-smoke-and-children.html. EPA. 2025. Which populations experience greater risks from wildfire smoke?, https://www.epa.gov/wildfire-smoke-course/who-increased-risk-health-effects-wildfire-smoke-exposure.
[1053] USDA Forest Service. Defining and Mapping the Wildland-Urban Interface of Puerto Rico and the U.S. Virgin Islands: 2010 Distribution and Implications. Martinuzzi et. al. 2025. https://data.fs.usda.gov/research/pubs/iitf/gtr_iitf_2025_001.pdf.

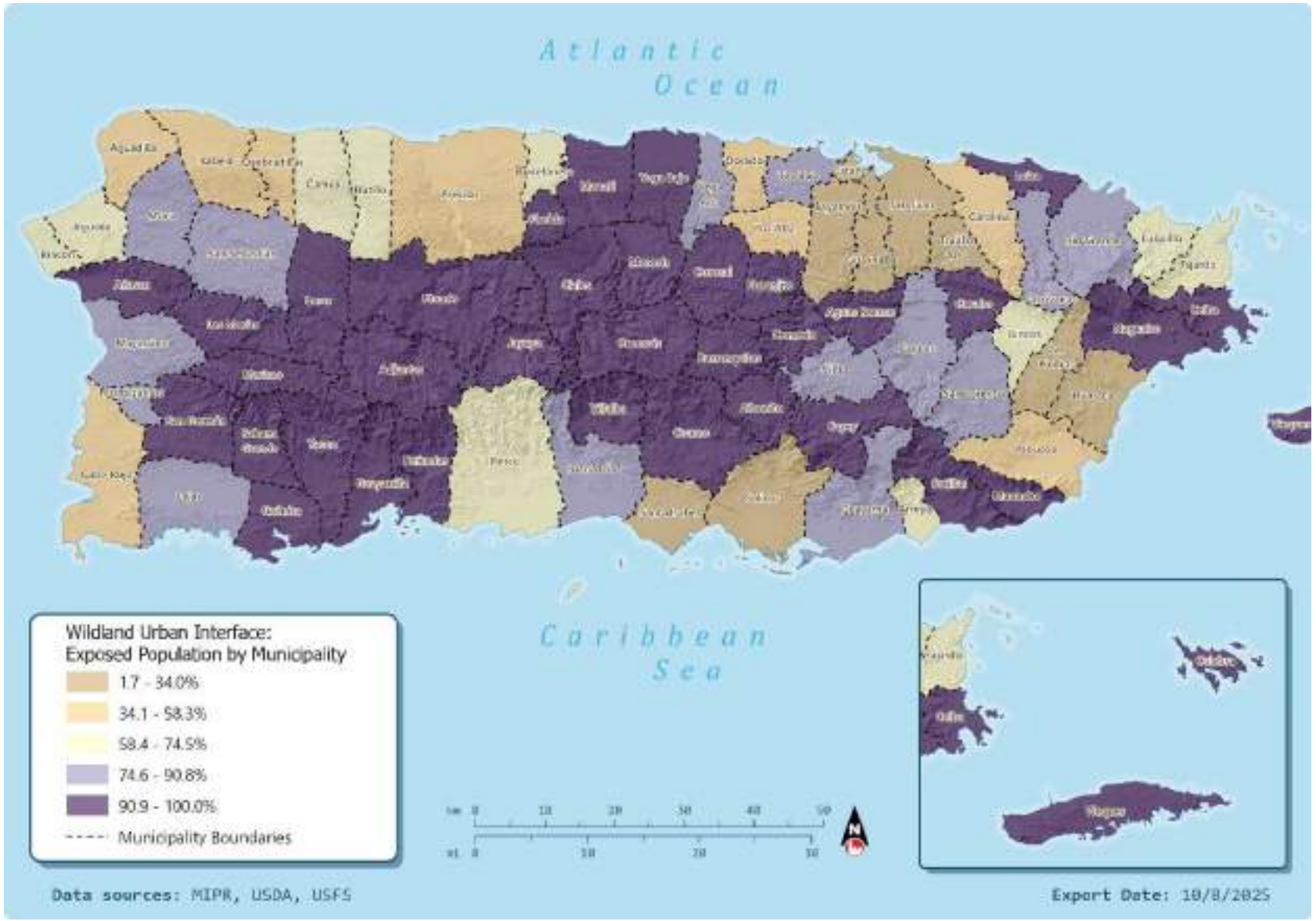


Figure 285: Population Exposed to WUI by Municipality

Figure 286: Housing Units Exposed to WUI by Municipality

STRUCTURES INCLUDING CRITICAL FACILITIES

Residential structures in the WUI are highly exposed to fast-moving grass and brush fires, particularly in areas with narrow access roads and limited defensible space. Critical facilities in fire-prone zones, such as schools, healthcare centers, and emergency shelters, may be disrupted by direct flame contact, radiant heat, or smoke. Utility assets, including electrical substations and water pumping stations, are often located along vulnerable corridors, where wildfire can impair operations.

INFRASTRUCTURE AND COMMUNITY LIFELINES

Figure 287 shows the Share of Replacement Value Exposure by Lifeline Category illustrates how much financial exposure each critical infrastructure lifeline has if damaged by wildfire. Based on Table 122, the total replacement value for all lifelines is approximately $4.42 billion, and the largest share—nearly half—belongs to the Hazardous Materials category. This dominance reflects the high cost and complexity of facilities that store or manage hazardous substances, such as fuel depots, industrial plants, and waste sites. These assets require specialized containment systems, environmental safeguards, and compliance with strict safety standards, making their reconstruction far more expensive than simpler lifelines like transportation or water systems.

Hazardous Materials also rank highest because of their geographic and operational vulnerability. Many of these sites are located in southern and southwestern Puerto Rico, where dry vegetation and seasonal drought create conditions for frequent ignitions. Fires near these facilities can escalate into secondary disasters—explosions or toxic smoke—causing severe damage and requiring costly remediation. Unlike roads or power lines, recovery involves not only rebuilding structures but also cleaning up contamination and restoring environmental safety, which drives up replacement costs. This combination of high asset value, complex restoration requirements, and cascading risk explains why Hazardous Materials represent the largest share of wildfire-related exposure among Puerto Rico's lifelines.

Table 122: Community Lifeline Exposure to Wildfire

Lifeline	Replacement Cost (Thousands)
Communications	$434,086,305
Energy	$36,672,987
Food, Shelter, Hydration	$479,334,080
Hazardous Materials	$2,085,198,593
Health and Medical	$324,589,028
Safety and Security	$909,158,967
Transportation	$102,223,466
Water Systems	$52,281,140
Grand Total	**$4,423,544,569**

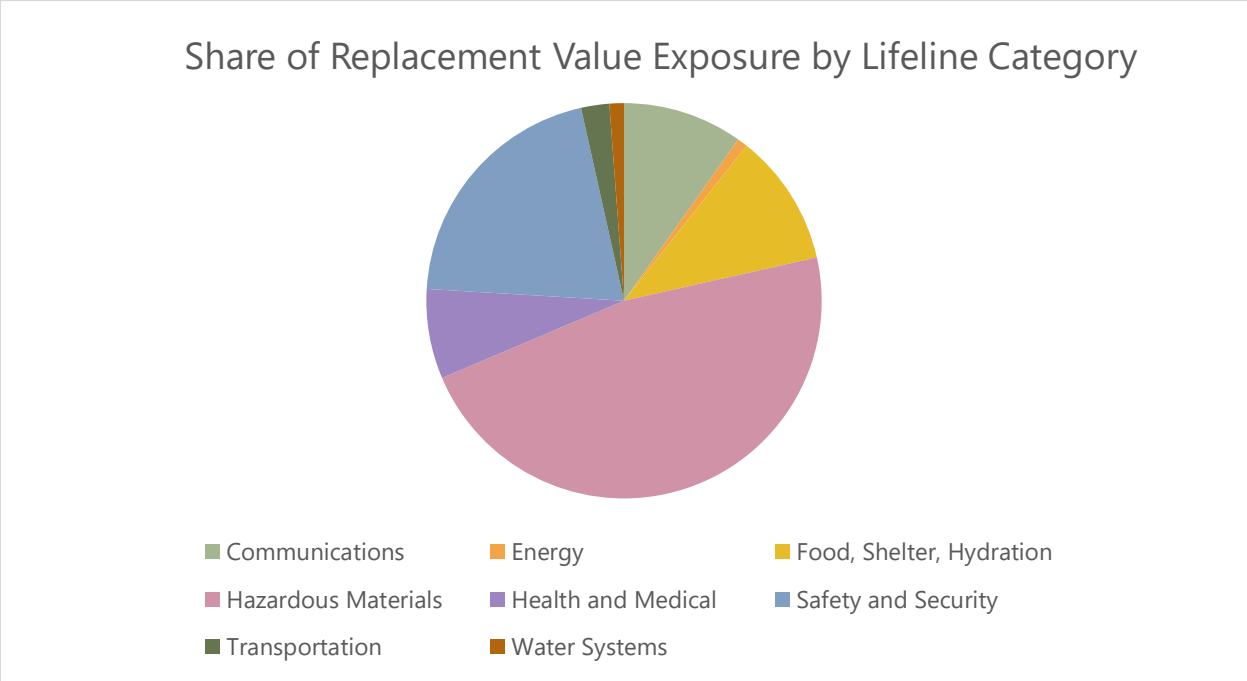


Figure 287: Replacement Value of State Assets by Community Lifeline

Wildfires can disrupt transportation, power, water, and telecommunications lifelines, even without causing major structural losses. Grass and brush fires frequently occur along transportation corridors, such as PR-2 and PR-52, creating hazardous conditions for evacuation and response. Above-ground power lines are susceptible to fire damage and smoke-related outages. A recurring vulnerability identified by local emergency managers is the lack of systematic vegetation maintenance around critical infrastructure, including power substations, water pumping facilities, backup generators, and electric transmission towers. When unmanaged grasses and brush accumulate in these areas, they become highly flammable, and small

ignitions can escalate into fires that damage essential systems. NWS Fire Weather guidance supports operational readiness and preplanned triggers (e.g., KBDI values and thresholds set by the National Fire Danger Rating System) for surge staffing and public communications. Smoke can also reduce air quality in urban centers, placing stress on healthcare systems and increasing emergency demand.[1054]

Problem Statements:

- Southern and southwestern municipalities face annual wildfire recurrence, straining limited local suppression resources.
- Growing WUI areas increase exposure in historically fire-prone regions.
- Moist/wet forests have low baseline risk but could experience ecological stress and unexpected ignitions during severe drought.
- WUI residents in high-risk municipalities lack defensible space and hardened structures, increasing direct exposure.
- Social vulnerability (poverty, limited mobility) amplifies wildfire health and evacuation risks.
- Smoke-related respiratory hazards disproportionately impact sensitive populations, especially during extended fire weather periods.
- Many WUI homes in southern municipalities are not hardened against wildfire, increasing loss potential.
- Critical facilities in fire-prone zones lack consistent vegetation management and smoke protection measures.
- Fire-related smoke and restricted access may disrupt healthcare delivery and emergency shelter operations.
- Transportation corridors in southern and central Puerto Rico are repeatedly impacted by roadside fires, limiting evacuation and response mobility.
- Above-ground electrical infrastructure is exposed to fire- and smoke-related disruptions, contributing to service outages.
- Insufficient vegetation management around critical facilities (power plants, substations, water pumps, and generators) increases the risk of direct fire damage and prolonged service interruptions.
- Smoke and closures threaten the continuity of lifelines, including water pumping, healthcare, and communications.

Impact Assessment

Wildfires in Puerto Rico produce localized but recurring losses that affect people, state and local assets, critical facilities, and community lifelines. Although most incidents are grass and brush fires, the combination of drought, invasive grasses, and limited vegetation management near infrastructure increases the potential

[1054] CDC. 2023. Health Alert Network (HAN) 00495 – Wildfire Smoke Exposure Risks. https://www.cdc.gov/han/2023/han00495.html.

for more damaging events. Even when flames do not destroy structures, smoke and access disruptions can significantly affect public health, emergency operations, and essential services.

STATE ASSETS

Figure 288 shows the locations of critical facilities in areas susceptible to wildfire. These facilities correspond to those included in the replacement costs of exposed facilities in Table 122 above. A total of 1,444 facilities valued at a total of over $4.4 billion are at risk to wildfire damage. The 493 Safety and Security facilities represent the community lifeline category with the highest number of sites potentially vulnerable to damage or disruption due to wildfire. This may seriously impact the ability of response agencies being able to operate normally to ensure the safety of residents during a wildfire. Communications, Food, Shelter and Hydration, Hazardous Materials, and Water Systems also are among the large number of facilities in areas susceptible to wildfire. Food, Shelter, and Hydration facilities are the next highest count of facilities with 275, with a replacement cost of $479 million. Disruption to these facilities and the services they provide could have significant impacts in the ability to provide for the basic food and sheltering needs of residents who may be displaced by wildfire. Hazardous materials facilities have the highest total replacement value of critical facilities vulnerable to wildfire, indicating that these facilities are potentially very expensive to replace or restore.

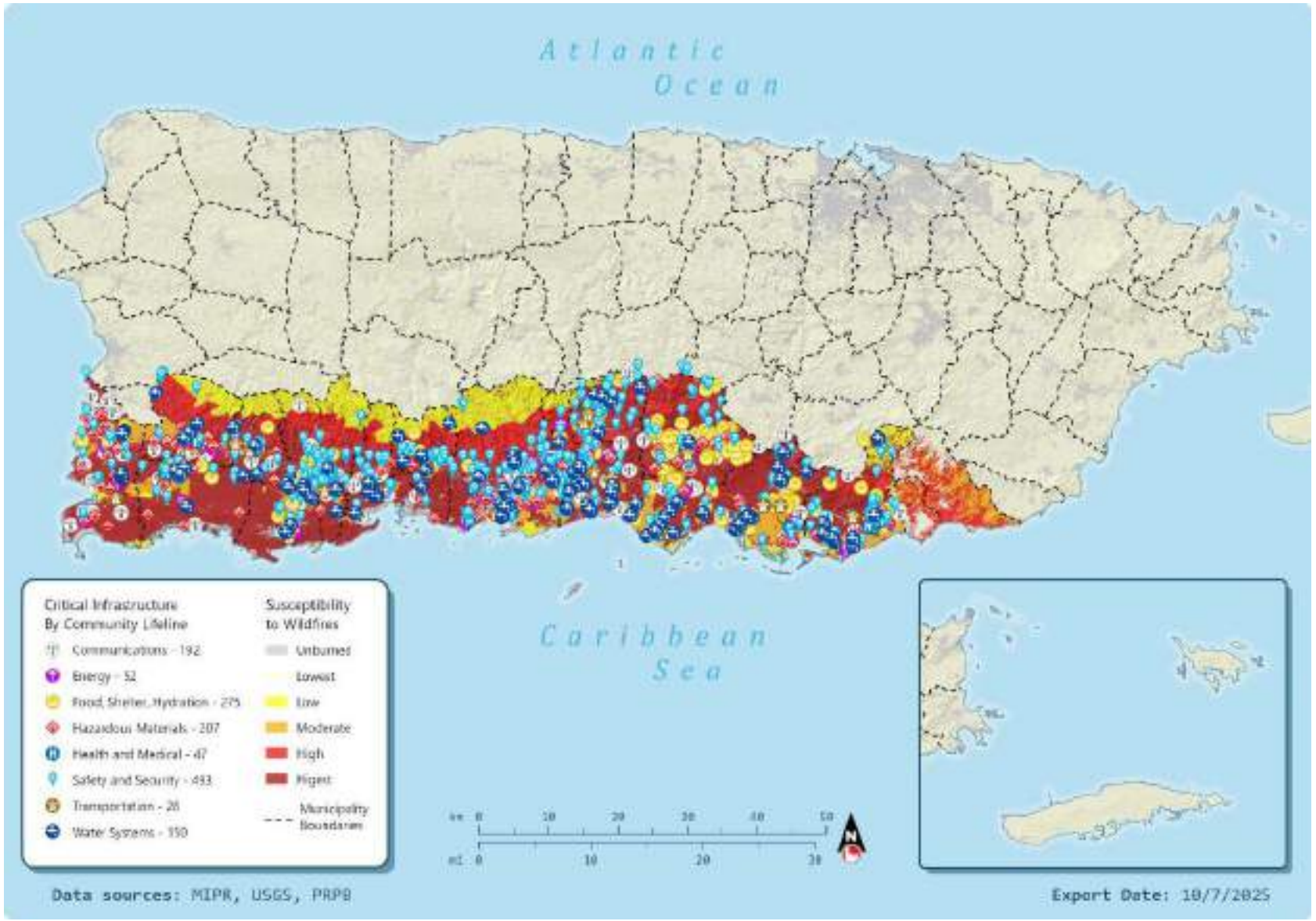


Figure 288: Critical Infrastructure Susceptible to Wildfire

State-owned facilities, including schools, government offices, and emergency shelters, are often in or near fire-prone areas, and many lie in or adjacent to areas that experience recurring wildland fires island wide. In 2024, the PRFD reported 1,681 wildland fires, and leadership noted that thousands of incidents occur annually throughout the island, with notable events, such as the 2023 San Germán–Maricao fire, underscoring risks to inland communities.[1055] Structures with limited defensible space or outdated building materials are particularly vulnerable to wildfire exposure. Beyond direct flame damage, critical functions may be disrupted by smoke infiltration, power outages, or restricted access along narrow road corridors.

The 2019 Puerto Rico Infrastructure Report Card by the American Society of Civil Engineers (ASCE) assigned the island an overall grade of "D," signifying poor condition and significant risk of failure without substantial investment. The ASCE grading scale ranges from A (exceptional) to F (failing), with "D" indicating that infrastructure is in poor condition, approaching the end of its service life, and at risk of failure under stress. Specific sectors relevant to wildfire vulnerability also received low marks, including Energy (D+), Drinking Water (D), and Wastewater (D), all of which are critical lifelines during wildfire response and recovery.[1056]

Economic damage to the state from wildfires extends beyond physical assets. Agriculture, valued at approximately $703 million annually across 494,481 acres of farmland,[1057] is highly exposed to repeated burns, particularly pasturelands and dry forest crops, which can lead to a loss of production and soil degradation. Tourism also is at risk, as wildfires affecting natural reserves, beaches, and recreational areas can reduce visitation and revenue. These cascading impacts highlight how wildfire vulnerability affects not only the built infrastructure but also the broader economy and state services.

LOCAL ASSETS

Wildfires pose recurring threats to communities across Puerto Rico, where residential areas, community facilities, and critical services are frequently in the WUI. In these zones, homes and public facilities directly border fire-prone vegetation, often without sufficient defensible space or buffer zones. Narrow access roads and limited egress further compound vulnerability, creating challenges for evacuation and emergency response during fast-moving fire events.

Analyses by the PRFD and the USFS confirm that wildfire activity occurs island-wide, affecting both coastal and interior municipalities. These patterns demonstrate that wildfire is not confined to traditionally dry southern plains but is now a widespread hazard driven by recurring drought, invasive grasses, and human-caused ignitions.[1058]

[1055] Telemundo Puerto Rico (2024). Bomberos reportan 1,681 fuegos forestales en 2024; miles ocurren en toda la isla según el Negociado. Retrieved from Telemundo PR.
[1056] ASCE Puerto Rico Section. (2019). Puerto Rico Infrastructure Grades by Sector. American Society of Civil Engineers, Palm Beach Branch Webinar. Retrieved from ASCE Palm Beach.
[1057] News Is My Business (2024). Puerto Rico's agricultural production grows to $703M in 2022. Retrieved from News Is My Business.
[1058] Puerto Rico Fire Department (PRFD) & U.S. Forest Service (USFS). (2024). Wildfire Occurrence and Hotspot Data.

Fire suppression capacity at the local level is anchored by the PRFD, which operates through 11 districts and 91 fire stations distributed across Puerto Rico.[1059] These stations provide the first line of defense for neighborhoods, schools, and local infrastructure. However, high incident volumes during the dry season often strain personnel and resources, particularly when multiple ignitions occur simultaneously.

The consequences of wildfire at the local scale extend beyond housing. Community resources, such as schools, healthcare centers, and emergency shelters, may be disrupted by direct flame contact, radiant heat, or smoke infiltration. Local water and power distribution assets, which are frequently co-located along vulnerable corridors, also are at risk of service interruption. As reflected in Local Hazard Mitigation Plans, municipalities consistently identify wildfire as a hazard of concern, underscoring that exposure to wildfire affects the continuity of community services and the resilience of local economies.[1060]

COMMUNITY LIFELINES

SAFETY AND SECURITY

Wildfires can trigger localized evacuations and require police and emergency services for traffic control and public safety. Repeated roadside fires along major corridors (PR-2, PR-52) create visibility hazards and force closures that complicate evacuation and response.

FOOD, HYDRATION, AND SHELTER

Fires in southern agricultural zones damage crops, reduce soil productivity, and contribute to long-term losses in local food security. Post-fire erosion increases sedimentation in reservoirs, reducing water storage capacity and affecting irrigation and potable water supplies.[1061]

HEALTH AND MEDICAL

Wildfire smoke contributes to elevated levels of particulate matter (PM2.5) in Puerto Rico, which combines with seasonal Saharan dust events to exacerbate respiratory and cardiovascular conditions.[1062] Sensitive populations, including children, older adults, and individuals with asthma or chronic obstructive pulmonary disease (COPD), are particularly at risk. Puerto Rico already experiences a higher baseline asthma prevalence than the mainland United States, making these populations more susceptible to smoke-related health impacts.[1063]

During wildfire events, emergency departments and urgent care clinics may experience surges in respiratory cases, while power outages and transportation disruptions complicate continuity of care. Health facilities and emergency shelters are further challenged by HVAC system limitations. Without advanced filtration,

[1059] Cuerpo de Bomberos de Puerto Rico. (n.d.). Organización. Government of Puerto Rico. Retrieved from Agencias PR.
[1060] Loíza Municipio. (2021). *Plan de Mitigación de Riesgos – Loíza.* Approved by Planning Board, San Juan, PR.
[1061] NRCS Caribbean Area. 2022. Post-Fire Sedimentation and Watershed Impacts.
[1062] U.S. Environmental Protection Agency (EPA). (2022). *Health and Environmental Effects of Particulate Matter (PM).* https://www.epa.gov/.
[1063] Puerto Rico Department of Health. (2021). *Asthma Surveillance Report – Puerto Rico.* San Juan, PR

smoke intrusion can degrade indoor air quality, exposing sheltered populations to fine particles. This creates heightened risks for individuals predisposed to respiratory or cardiovascular complications.

Collectively, these dynamics demonstrate how wildfire not only threatens outdoor populations but can also disrupt the Health and Medical Community Lifeline, reducing the ability of hospitals, clinics, and shelters to deliver essential services during periods of high demand.

ENERGY

Puerto Rico's electrical grid is vulnerable to fire-related disruptions, including those that could be triggered by wildfires in vegetation surrounding power plants, substations, and transmission lines. Fires can cause direct equipment damage, smoke-induced faults, and precautionary shutdowns.

Facility fires, such as the San Juan substation fire in 2021 and the Costa Sur breaker fire in 2022, were not wildfires, but they demonstrate the scale of outages a single fire incident can create, affecting hundreds of thousands of customers.[1064] These incidents illustrate how wildfire advancing into energy corridors could generate similar cascading failures.

Recognizing this risk, LUMA Energy has committed to developing a holistic wildfire ignition risk reduction strategy for electrical corridors, emphasizing vegetation management and hazard monitoring.[1065]

COMMUNICATIONS

Wildfires threaten Puerto Rico's Communications Lifeline in multiple ways. Direct flames and radiant heat can damage telecommunications lines, relay towers, and fiber-optic cables in rural and mountainous areas. Even without physical destruction, dense smoke and high heat can impair signal transmission quality and create unsafe conditions for maintenance crews.

When fires force access restrictions around perimeters, telecommunications personnel may be delayed in reaching damaged towers or cable routes, prolonging outages. Antenna towers located in the WUI are particularly exposed, as they are often sited on ridgelines and hilltops for coverage areas that also experience rapid fire spread.

Wildfires can also cause cascading communications failures. Outages at local relay sites can quickly escalate into regional service disruptions, particularly if fiber-optic lines or microwave links are compromised. In turn, these failures impair emergency response coordination, hinder the transmission of alerts, and limit residents' ability to access emergency information.

[1064] T&D World (2022). *Circuit breaker fire knocks out power to Puerto Rico, affects 500,000 customers.* Retrieved from https://www.tdworld.com/disaster-response/article/21238447/circuit-breaker-fire-knocks-out-power-to-puerto-rico.
[1065] UMA Energy (2024). *Motion in Compliance with Directives of Resolution and Order – Wildfire Ignition Risk Strategy.* Puerto Rico Energy Bureau. https://energia.pr.gov/.

Taken together, wildfire damage and access delays represent a critical vulnerability for Puerto Rico's Communications Lifeline, where continuity is essential for public warning, response coordination, and recovery operations.

TRANSPORTATION

Wildfires can disrupt Puerto Rico's Transportation Lifeline by reducing visibility along road corridors, forcing temporary closures, and delaying both evacuation and emergency response. Dense smoke and active fire perimeters create hazardous driving conditions, while access restrictions limit the ability of response crews to move equipment and personnel where they are most needed. The Puerto Rico Forest Action Plan emphasizes that when large numbers of fires occur in a short period, response to any individual fire may be slower, compounding delays along critical road networks.[1066]

In identified fire-prone landscapes, rapid suppression and public safety operations require reliable transport and logistical access. Roads, bridges, and rural routes are essential for moving firefighting resources into priority areas, yet these same access routes may be compromised by advancing flames, falling debris, or fire-related closures.[1067] Airports and seaports, already highlighted in federal and territorial risk assessments as vulnerable nodes, also face operational risks from wildfire smoke and nearby fire activity, which can degrade visibility and interfere with safe operations, even without direct physical damage.

HAZARDOUS MATERIALS

Wildfires near fuel storage sites, industrial facilities, or abandoned landfills can ignite hazardous materials and generate toxic smoke. The EPA and DRNA have documented elevated risks from unmanaged waste and combustible vegetation around critical sites.

WATER SYSTEMS

Water pumping stations and distribution infrastructure in fire-prone areas are threatened by direct flame exposure and loss of power. Post-fire sediment runoff also accelerates reservoir siltation, reducing potable water and irrigation availability.

Changes in Development

Over the past several decades, Puerto Rico's development patterns have expanded the WUI, concentrating population and infrastructure in fire-prone areas and reducing natural buffers that once limited fire spread. Research confirms that changes in land use and land cover driven by urban expansion and agricultural

[1066] Puerto Rico Department of Natural and Environmental Resources, 2016. *Puerto Rico Statewide Forest Resource Assessment and Strategies (Forest Action Plan)*, p. 147.
[1067] Puerto Rico DRNA. (2016). *Puerto Rico Forest Action Plan*, pp. 123–135.

abandonment have reshaped fire regimes, leading to more frequent and spatially extensive wildfires than in the past.[1068]

In the last five years, this trend has accelerated. A 2022 investigation found a 239% increase in approvals for coastal construction permits compared with 2015, reflecting rapid expansion into sensitive coastal and dry forest zones.[1069] Large-scale development proposals, such as a 1,100-acre project planned for eastern Puerto Rico's forested coastline, further illustrate how new construction is moving deeper into fire-prone landscapes.[1070] At the same time, mapping analyses show that WUI already covers over 60% of Puerto Rico's houses and population, underscoring the magnitude of exposure to fire risk.[1071]

Recent reporting further highlights that many new projects are being sited in coastal, hillside, and dry forest areas without adequate environmental review or vegetation management, increasing ignition potential and exacerbating vulnerability to fire-related losses.[1072] These changes demonstrate that recent development has directly intensified wildfire vulnerability across the island, reshaping Puerto Rico's risk profile in ways not present in earlier planning cycles.

CHANGES IN LAND USE AND THE BUILT ENVIRONMENT

In recent decades, urban growth and changes in land management have altered Puerto Rico's fire environment. Expansion of residential areas into previously undeveloped hillsides, coastal zones, and former agricultural lands has created new WUI areas beyond the traditionally fire-prone south and southwest. The conversion of croplands to unmanaged grasslands and the spread of invasive species have increased the continuity of fine fuels, allowing small ignitions to spread more rapidly.[1073] At the same time, inadequate vegetation maintenance around critical facilities, such as power substations, water pumping stations, and backup generators, has been identified by local emergency managers and USFS field assessments as a recurring ignition hazard. Together, these development and maintenance patterns have expanded the geographic footprint of wildfire vulnerability beyond historic hotspots and heightened the exposure of both built assets and essential services.

[1068] Monmany, A.C., Van Beusekom, A.E., Gould, W.A., Falk, D.A. (2017). *Fire weather and likelihood: Characterizing climate space for fire occurrence and extent in Puerto Rico.* USDA Forest Service, International Institute of Tropical Forestry. https://research.fs.usda.gov/treesearch/54146.

[1069] Center for Investigative Journalism (CPI). (2022, January 27). *Construction permit approvals for coastal projects increased 239% under Pierluisi administration.* https://periodismoinvestigativo.com/2022/01/construction-permit-approvals-for-coastal-projects-fast-pierluisi.

[1070] Crain Currency. (2024, March 5). *One developer's nine-figure plan to build "Palm Beach Puerto Rico" on 1,100 acres of forested coastline.* https://www.craincurrency.com/lifestyle-and-luxury/one-developers-nine-figure-plan-build-palm-beach-puerto-rico.

[1071] González-Morales, L., Gould, W.A., & Quiñones, M. (2024). *Defining and Mapping the Wildland–Urban Interface of Puerto Rico: Estimation of Area, Houses, and Population.* USDA Forest Service, International Institute of Tropical Forestry. https://research.fs.usda.gov/treesearch/69229.

[1072] The Guardian. (2022, November 19). *Why New Construction Projects Are Making Puerto Rico's Climate Disasters Worse.* https://www.theguardian.com/world/2022/nov/19/puerto-rico-climate-crisis-new-construction.

[1073] Monmany, A.C., Van Beusekom, A.E., et al. 2017. Fire Weather and Likelihood: Characterizing Climate Space for Fire Occurrence and Extent in Puerto Rico. USDA Forest Service, International Institute of Tropical Forestry. https://link.springer.com/article/10.1007/s10584-017-2045-6.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

Looking forward, post-disaster reconstruction and new housing demand are expected to accelerate development into areas of high wildfire hazard. Reporting indicates that permitting weaknesses have allowed new subdivisions and infrastructure projects in vulnerable coastal zones and steep slopes, where flammable vegetation and drought conditions are common.[1074] Without stronger land use controls and vegetation management, this trend is projected to expand the WUI, lengthen suppression perimeters, and increase the exposure of both people and assets.

POPULATION CHANGES

Puerto Rico's population has continued to decline over the past two decades, dropping from 3.8 million in 2000 to an estimated 3.2 million in 2023.[1075] Between 2020 and 2022, the island's population decreased by about 2%, reflecting ongoing out-migration and natural decline.[1076] Despite this overall reduction, exposure to wildfire risk has not diminished.

Population shifts on the island have reinforced settlement in southern, coastal, and WUI zones, where wildfire hazards are more pronounced. Vulnerable groups, including low-income residents, older adults, and individuals with chronic health conditions, remain concentrated in these areas, heightening potential impacts from wildfire smoke exposure and evacuation challenges. These demographic dynamics demonstrate that declining population totals do not automatically translate to reduced hazard vulnerability.

CHANGES IN THE VULNERABILITY OF STATE ASSETS

State assets continue to face elevated wildfire exposure due to aging infrastructure and deferred maintenance. The 2019 ASCE Puerto Rico Infrastructure Report Card rated the island's energy and water systems as poor ("D"), highlighting systemic weaknesses. Development near power plants, substations, and water facilities has been accompanied by insufficient vegetation clearance, which heightens the risk of fire ignition and service disruption. As population growth pressures lead to re-development in high-risk areas, more government facilities, including schools and emergency shelters, are likely to face recurring smoke, access limitations, and potential fire exposure.

Redevelopment pressures in high-risk zones also place more government facilities, including schools, emergency shelters, and municipal offices, in areas affected by recurring smoke, reduced air quality, and temporary access restrictions. During large fire events, these facilities may experience operational interruptions, either from direct exposure to flames or from cascading service outages that limit electricity and water supply. Taken together, these conditions illustrate how state-owned facilities and critical lifelines remain vulnerable to wildfire.

[1074] The Guardian. 2022. Why New Construction Projects Are Making Puerto Rico's Climate Disasters Worse. November 19, 2022. https://www.theguardian.com/world/2022/nov/19/puerto-rico-climate-crisis-new-construction.
[1075] U.S. Census Bureau. (2023). *Puerto Rico Municipios Population Totals: 2020–2023.* https://www.census.gov/.
[1076] U.S. Census Bureau. (2022). *Puerto Rico Population Drops 2.0% from 2020 to 2022.* https://www.census.gov/.

CHANGES IN THE VULNERABILITY OF LOCAL ASSETS

At the municipal level, new housing and community development in the south and west have expanded exposure in the WUI. The PRFD and USFS continue to document recurrent wildfires in these areas, indicating that fire is an annual hazard despite an overall decline in population. Changes in land cover from agriculture to grasslands has increased the frequency of small but fast-moving fires, particularly near road corridors and residential zones. Informal or unregulated construction further compounds vulnerability by placing homes and residents in areas without adequate fire protection, infrastructure resilience, or environmental safeguards.

Mitigation Success Story

PROTECTORES DE CUENCAS IN BOSQUE SECO DE GUÁNICA

The Bosque Seco de Guánica is a United Nations Biosphere Reserve and one of the most extensive tropical dry forests in the Caribbean (see Figure 289) It faces frequent wildfire ignitions driven by human activity and invasive grasses. These fires threaten biodiversity, nearby communities, and critical natural resources. To address this persistent hazard, the community-based organization Protectores de Cuencas (PDC) has partnered with local residents, DRNA, the PRFD, the USFS, the Natural Resources Conservation Service (NRCS), and the U.S. Fish and Wildlife Service (USFWS) to implement proactive wildfire mitigation and ecological restoration strategies.

Figure 289: Areas of the Bosque Seco de Guánica

ACTIONS TAKEN

- **Fuel Reduction and Reforestation:** PDC and partners cleared 50 acres of highly flammable invasive grasses and planted over 24,000 native trees and shrubs, restoring natural vegetation that is more resistant to wildfire spread (see Figure 290).
- **Community Engagement:** More than 600 volunteers, students, and local residents participated in restoration and education activities, building long-term awareness of wildfire risks and prevention.

- **Community Wildfire Protection Plans (CWPPs)**: PDC is working with agencies and local governments to develop landscape-level wildfire protection plans for southern Puerto Rico, incorporating fuel management, evacuation planning, and WUI risk reduction.
- **Watershed Protection:** By restoring native dry forest and stabilizing soils, the project reduces post-fire erosion and sedimentation, safeguarding reservoirs and water supplies critical for nearby municipalities.

Figure 290: Community Engagement in Fuel Reduction and Reforestation

OUTCOMES AND BENEFITS

This initiative demonstrates how community-led restoration and interagency collaboration can directly mitigate wildfire risk in Puerto Rico's most fire-prone ecosystems. The project has achieved the following:

- Reduced ignition potential by limiting invasive grass fuels.
- Enhanced ecosystem resilience in the Guánica dry forest, protecting biodiversity and cultural resources.
- Built local capacity through volunteer training and community education.
- Improved the resilience of water and energy infrastructure near fire-prone landscapes.

Together, these actions illustrate how integrated land management and community stewardship can serve as effective wildfire mitigation strategies for Puerto Rico, reducing vulnerability to recurring fire hazards while enhancing ecological and community resilience.

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SECTION FIVE

STATE MITIGATION CAPABILITIES

State Mitigation Capabilities

Introduction

During the hazard mitigation planning process, a comprehensive review was conducted of Puerto Rico's current tools and resources for reducing risk and enhancing community resilience. Evaluating existing capabilities helps determine which mitigation actions can be accomplished. This is imperative for understanding the strengths and limitations of the government of Puerto Rico which enable the development of targeted actions. Mitigation capabilities are commonly grouped into the following four categories (see Figure 291):

- **Planning and Regulatory:** This includes laws, policies, plans, and regulations that influence how the Puerto Rico government prepares for and responds to hazardous events. These tools help shape how the entity manages land use and infrastructure development.
- **Administrative and Technical:** This includes people, expertise, and systems on which Puerto Rico can rely to create and carry out mitigation efforts. This can be within government agencies themselves or supported by outside entities, such as universities, regional organizations, nonprofit groups, or private sector partners.
- **Financial:** This category covers funding sources that can support mitigation actions. These may include funding from public budgets at various levels of government or from private and nonprofit organizations.
- **Education and Outreach:** This area evaluates capabilities to promote public awareness of hazard risk and enhance support for mitigation efforts. This includes training programs, public information campaigns, and community engagement initiatives that aim to strengthen resilience.

Capabilities are also divided based on the timing of their use—pre-disaster capabilities focus on preparedness activities, and post-disaster activities are implemented after a disaster has occurred. Disasters require a coordinated response that involves both preparedness and recovery activities, making it critical for Puerto Rico to maintain strong capabilities in these areas. Local capabilities, including additional efforts the Puerto Rico's government has taken to coordinate local plans, are outlined in Section 6: Local Mitigation Assessment.

Figure 291: Examples of Mitigation Capabilities

This section provides an evaluation of Puerto Rico's financial, legal, regulatory, and programmatic capabilities to carry out mitigation goals and actions identified in this plan. These capabilities include a network of Puerto Rican agencies whose work touches on mitigation, Puerto Rico laws on land use and building codes, current plans, mitigation programs, and private, nonprofit, and federal funding opportunities. These capabilities are evaluated based on how they contribute to Puerto Rico's overall hazard mitigation program, including any obstacles and opportunities for improvement. This section also identifies any changes in Puerto Rico's hazard mitigation program since the previous plan update.

Agencies Involved in Hazard Mitigation

Puerto Rico recognizes the concept of shared responsibility in mitigation, and the importance of strengthening the interagency planning process, ensuring coherence and alignment with Puerto Rico's objectives and protocols. Table 123 describes the agencies that play an integral role in hazard mitigation and emergency management in Puerto Rico.

Table 123: Agencies Involved in Hazard Mitigation

Organization	Description
American Red Cross	The American Red Cross was founded in Puerto Rico in 1893 when the Provincial Commission of the Spanish Red Cross emerged on the island. Since then, the Red Cross has attended events whose impact has been important and significant for Puerto Ricans. As part of the organization's role in educating communities to prepare for, prevent, and respond to different types of disasters, Red Cross volunteers provide educational workshops for the community.
Board of Investment for the Puerto Rico Industry	Law No. 203 of December 29, 1997, as amended, repealed Law No. 423 of May 14, 1950, as amended, and transferred all powers and functions of the Economic Development Authority to the Industrial Development Company. Reorganization Plan No. 4 of June 22, 1994, created the Department of Economic Development and Commerce, and the Industrial Development Company was attached to it. Law No. 188 of May 11, 1942, as amended, also applies. Its mission is to create and retain jobs to improve Puerto Rico's quality of life.
Community Foundation of Puerto Rico	The Community Foundation of Puerto Rico (FCPR) is a philanthropic platform that has mobilized resources in communities for more than 39 years. It is considered a nonprofit organization, exempt under Section 1101.01 of the Internal Revenue Code of Puerto Rico and Section 501(c)(3) of the Internal Revenue Code of the United States. Since 1984, donors have contributed to the development of Puerto Rican communities through the FCPR. Individuals, families, corporations, or foundations have found in the FCPR the ideal philanthropic ally, an entity that has helped them realize their desire to support the causes they are passionate about through the establishment, stewardship, and administration of funds, which provide scholarships to university students or donations to nonprofit organizations. In addition, the FCPR has programmatic approaches that also facilitate transformation processes in the communities. These promote access to water and energy; racial and gender equity; and the United Nations' sustainable development goals. In addition, they support the activation of economic development.
Department of Agriculture	The Department of Agriculture is the government agency that develops agriculture and provides for the livelihood of the people. It strengthens all components of Puerto Rico's agricultural sector through its affiliated agencies—the Agricultural Enterprise Development Administration (ADEA), the Land Authority (TA), the Agricultural Insurance Corporation (CSA), and the Innovation Fund for Agricultural Development of Puerto Rico (IFAD)—as well as eight agricultural regions: Arecibo, Caguas.
Department of Corrections and Rehabilitation	Reorganization Plan No. 3 of December 9, 1993, created the Department of Corrections and Rehabilitation, to which the following agencies are attached: Corrections Administration, Administration of Juvenile Institutions, Parole Board, Office of Pretrial Services, and the Corporation of Training and Labor Enterprises. The department is responsible for structuring, developing, and

Organization	Description
	coordinating the public policy of the Government of Puerto Rico on the correctional system and the rehabilitation of both adult and juvenile correctional populations.
Department of Economic Development and Commerce	The Land Administration was created by Law No. 13 of May 16, 1962. It is a public corporation of the Government of Puerto Rico and forms part of the Department of Economic Development and Commerce. The agency is dedicated to promoting the economic, social, and urban development of Puerto Rico and collaborates with other government entities to bring their projects to life and effectively implement public policies and work plans through the orderly acquisition and development of land.
Department of Justice	The Office of the Attorney General, as it is now known, was established by Law No. 7 of May 15, 1959. The Attorney General's core functions remained largely unchanged with the passage of Law No. 205 of August 9, 2004, known as the Department of Justice Organization Act ("Law No. 205"). Under this law, the Attorney General represents the State before the highest courts and is responsible for standardizing the Puerto Rico's government's legal positions before top judicial forums. Article 60 of Law No. 205 provides, among other things, that the Attorney General shall represent the Government of Puerto Rico in all civil and criminal matters in which it is a party or has an interest, and which are processed on appeal or otherwise before the appellate courts of Puerto Rico, the United States, or any other federated state, territory, or possession of the United States, except where the Secretary determines otherwise.
Department of Labor	Law No. 115 of June 21, 1968, as amended, known as the Right to Work Act, created the Administration of the Right to Work. Reorganization Plan No. 2 of May 4, 1994, reorganized the Department of Labor and Human Resources and assigned the Administration of the Right to Work to the Department of Labor. The department combats unemployment in Puerto Rico by promoting the development of human resources through an integrated system of services. The system provides universal access to orientation services, labor market information, skills assessment, counseling, referrals to training and education programs, job placement and retention, and collaboration with the business sector.
Department of Labor and Human Resources	Law No. 15 of April 14, 1931, Organic Law of the Puerto Rico Department of Labor. This was ratified by the Constitution of the Government of Puerto Rico in 1952. Law No. 100 of June 23, 1977, renamed the Department of Labor and Human Resources. The Reorganization Plan of May 2, 1994, created its current organizational structure. Law No. 180 of July 27, 1998, repealed the Minimum Wage Board and transferred its powers to the Department. Administrative Order 99-05 of June 16, 1999, issued by the Secretary of Labor, transferred by the Employment Security Bureau to the Administration of the Right to Work.

Organization	Description
Department of Public Safety	This department serves as the umbrella organization within the Executive branch of Puerto Rico, consolidating the Puerto Rico Law Enforcement and Emergency Response agencies. The department was formed on April 10, 2017, when legislation was signed into law to unify all safety agencies. Today, all agencies operate as bureaus within the department.
Federal Emergency Management Agency	The Federal Emergency Management Agency (FEMA) is an agency of the U.S. Department of Homeland Security (DHS), initially created by Presidential Reorganization Plan No. 3 of 1978 and implemented by two Executive Orders on April 1, 1979. The agency's primary purpose is to coordinate the response to disasters in the United States that overwhelm the resources of local and state authorities. When a disaster occurs, the governor of the affected state must declare a state of emergency and formally request that the president authorize a federal response through FEMA.
General Services Administration	Reorganization Plan No. 2 (Substitute) of 1971 and Law No. 73-2019, known as the General Services Administration for the Centralization of Government Procurement of Puerto Rico Act, established the agency's current structure. Its mission is to establish public policy and provide the necessary and advanced tools for acquiring quality goods and services at the lowest cost for government agencies.
Integrated Transport Authority	The Integrated Transportation Authority (ATI) is the government entity established to comprehensively implement public policy for the planning, management, and operation of collective transportation services. It also promotes coordinated decisions in line with the mission of standardizing and promoting the development of public transportation for Puerto Rico. Transportation systems within ATI's jurisdiction include, but are not limited to, the Metropolitan Bus Authority (AMA), the Maritime Transportation Authority (ATM), Intermodal Bus Services, and the Urban Train.
Mental Health and Anti-Addiction Services Administration	The Mental Health and Anti-Addiction Services Administration (ASSMCA) in Puerto Rico is a key agency in the island's mental health and addiction services. Established by Law No. 67 on August 7, 1993, ASSMCA is responsible for addressing mental health conditions and substance use disorders. The agency offers a range of services, including mental health care, substance abuse treatment, crisis intervention, and community education. ASSMCA aims to provide comprehensive care and support to individuals and families facing mental health and addiction challenges. The agency also conducts outreach programs to educate the public and ensure access to essential resources and support.
National Firefighters Corps Bureau of Puerto Rico	The Puerto Rico Firefighters Corps (PRFC) is the islandwide fire department that provides fire protection, rescue, and protection from other hazards in Puerto Rico. It was established in 1942 under the Puerto Rico Fire Services. The agency also provides fire protection at all airports under the jurisdiction of the Puerto Rico Ports Authority, including Rafael Hernández Airport and

Organization	Description
	Mercedita Airport, where they serve as aircraft rescue and firefighting divisions.
Office Commissioner Insurance	Pursuant to Law No. 133 of August 8, 2002, the Office of the Commissioner of Insurance is an entity that reports directly to the Governor of the Government of Puerto Rico. Its mission is to promote the solvency, soundness, competitiveness and development of the insurance industry as a vital sector of the economy through the creation of an agile, innovative, and flexible regulatory and supervisory environment that supports meeting the insurance needs of citizens and protecting the public interest.
Office of People with Disabilities Advocacy	Law No. 207 of May 14, 1948, as amended, creates the Puerto Rico Corporation for the Industries of the Blind. It was later renamed the Corporation for the Industries of the Blind, Mentally Retarded and Other Disabled Persons of Puerto Rico by Law No. 127 of June 24, 1968, to change its name to the. Reorganization Plan No. 1, approved on July 28, 1995, by the Legislative Assembly, assigned the Corporation to the Department of the Family and outlined procedures for analyzing the public corporation and determining its status within the Department's new organizational structure. The Corporation's mission is to provide means for the social and economic rehabilitation of blind persons, individuals with intellectual disabilities, and other people with disabilities in Puerto Rico through paid work opportunities in nonprofit workshops that produce items for sale to the public.
Office of Management and Budget	Law No. 147 of June 18, 1980, known as the Office of Management and Budget Organization Act, was amended by Law No. 110 of August 3, 1995, to rename the agency the Office of Management and Budget (OGP), expand its functions, and establish the Governor's Committee on Auditing and the Governor's Committee on Information Systems (COGSI). Law No. 93 of August 20, 1997, increased the automatic contribution to the Budget Fund and the Emergency Fund to 1% of the total net income of the previous fiscal year, and Law No. 74 of May 2, 2000, expanded the functions of the COGSI. The OGP assists and advises the Governor and the three branches of government in the administration and use of public resources and other managerial aspects, promoting an effective government that guarantees the results that citizens value.
Public-Private Partnership Authority	The Puerto Rico Authority for Public-Private Partnerships (P3A) is a key entity in facilitating infrastructure development and economic transformation in Puerto Rico through strategic partnerships with the private sector. P3A was created to lead investment initiatives aimed at improving Puerto Rico's infrastructure. The authority seeks to secure private capital for public projects, thereby enhancing the efficiency and quality of public services. Since its inception, P3A has been instrumental in launching multiple public-private partnership (P3) projects that support the island's economic sustainability and resilience.

Organization	Description
Puerto Rico Electric Power Authority	Law No. 83 of May 2, 1941, as amended, established a corporate body that constituted a public corporation under the name Puerto Rico River Sources Authority. Subsequently, by virtue of Act 57 of May 30, 1979, it was renamed the Puerto Rico Electric Power Authority. Its mission is to provide electric power services to customers in the most efficient, economical, and reliable way possible, without harming the environment.
Puerto Rico National Guard	Law No. 62 of June 23, 1969, as amended, is known as the Military Code of Puerto Rico. The Puerto Rico National Guard's mission is to protect lives and property effectively and expeditiously; to preserve peace, order, and security for the general public in emergency situations caused by natural disasters and civil unrest; and to serve as the national security corps of the U.S. Army.
Puerto Rico Police	Law No. 53 of June 10, 1996, known as the Puerto Rico Police Act, ensures the safety of citizens and reduces the incidence of crime and violations of the law to maintain order and peace among the people. It also aims to ensure the multisectoral integration of government agencies and to promote citizen participation in crime prevention and control.
Puerto Rico Seismic Network	The Puerto Rico Seismic Network (PRSN)—in partnership with the University of Puerto Rico, Mayagüez Campus's Department of Geology—provides data to federal agencies, including the U.S. Geological Survey (USGS), FEMA, and the National Oceanic and Atmospheric Administration (NOAA), to fulfill their functions. These include issuing tsunami warnings and maintaining the necessary catalogs to update seismic hazard maps and response plans.
Recreation and Sports Department	The Department of Recreation and Sports is the government agency in charge of promoting recreation and sports throughout Puerto Rico. It works to ensure that citizens enjoy their free time in healthy ways and benefit from recreational and sports activities.
Telecommunications Bureau of Puerto Rico	Law No. 213 of September 12, 1996, as amended, known as the Puerto Rico Telecommunications Act, creates the Puerto Rico Telecommunications Regulatory Board as the agency in charge of regulating telecommunications services in Puerto Rico. It seeks to ensure the availability of telecommunications services at a reasonable cost to all citizens of Puerto Rico. It also monitors the efficiency of telephone and cable television services, as well as other telecommunications services, and supports other related purposes.
United States Geological Survey	The USGS conducts extensive geological research and mapping in Puerto Rico, providing valuable resources on the island's geology, seismic activity, and mineral resources. The USGS is located in Guaynabo, Puerto Rico.
University of Puerto Rico–Río Piedras Campus	Law No. 1 of January 20, 1966, as amended, known as the University of Puerto Rico Act, established the University of Puerto Rico as a public institution of higher education, with the mandate of serving the people of Puerto Rico, in line with the democratic ideals of Puerto Rican society. Its main mission is to transmit and increase knowledge through the sciences

Organization	Description
	and arts, and to contribute to the development, cultivation, and enjoyment of the ethical values of culture.
9-1-1 Emergency System Bureau	The 9-1-1 Emergency System Bureau directs and administers the provision of services for answering calls from the public to 9-1-1, as well as to 311, and distributes such calls to the bureaus of the Department of Public Safety (DSP), other agencies or instrumentalities, other emergency service providers, or any other entities authorized by the Department for their effective attention.
Puerto Rico Bureau for Emergency Management and Disaster Administration	The Puerto Rico Bureau for Emergency Management and Disaster Administration (PREMB) coordinates all government resources of the Government of Puerto Rico, as well as those of the private sector, to provide services before, during, and after emergency situations. These services are delivered in the fastest and most effective manner to ensure the protection of citizens' lives and property.
Bureau of Emergency Medical Services	The Bureau of Emergency Medical Services establishes coordination measures so that the services provided by the Emergency Medical Corps benefit from the operational structure of the police. It provides pre-hospital medical care and emergency transportation to appropriate medical facilities, effectively, quickly, and safely to all who require them in order to preserve health.
Special Investigation Bureau	The Special Investigation Bureau, a division of DSP, is responsible for investigations related to organized crime, prison gangs, terrorist groups, gaming and white-collar crime, and fugitives. It was created by the Bureau of Special Investigations for the Government of Puerto Rico Act, Law No. 38 of July 13, 1978, enacted by the Legislative Assembly of Puerto Rico.
Department of Consumer Affairs	The Department of Consumer Affairs was established by Law No. 5 of April 23, 1973, as amended. Other laws related to the agency are Law No. 228 of May 13, 1942, and Law No. 120 of June 17, 1993, as amended. The department works to protect and defend consumers and maintain a balance in the prices of goods and services for use and consumption, in accordance with supply and demand, inflationary trends, and the establishment and supervision of price controls.
Department of Recreation and Sports	The Department of Recreation and Sports operates under Law No. 126 of June 13, 1980, which serves as its Organic Law. Its responsibilities are further supported by Law No. 120 and Law No. 119 of August 17, 2001, which address the municipal management of community sports facilities and the development of full-time Puerto Rican high-performance athletes, respectively. The department promotes innovative strategies for the development of recreation and sports as alternatives for the productive use of free time and the improvement of the quality of life for the citizens of Puerto Rico.

Organization	Description
Department of State	Article IV, Section 6 of the Constitution of the Government of Puerto Rico of July 25, 1952, established the Department of State. The department works to foster effective relations between the Government of Puerto Rico and the U.S. Government, foreign countries, and international organizations. It aims to maintain a good image of Puerto Rico and its public institutions. It also guarantees the authenticity of the laws passed and certifies the signatures of notaries and public officials. In addition, it oversees trademark registration, corporations, and intellectual property. The department facilitates the movement of U.S. citizens and foreign nationals traveling to other countries. Finally, it contributes to the excellence of services provided to the public through the Professional and Trades Examination Boards.
Department of Treasury	Reorganization Plan No. 3 of June 22, 1994, reorganized the Department of Finance as the umbrella department. The department works to guarantee tax justice and fiscal stability that fully contributes to the social and economic well-being of Puerto Rico. It also aims to formulate and implement the fiscal, tax, and financial policy of the Government of Puerto Rico.
Highways and Transportation Authority	Law No. 74 of June 23, 1965, as amended, established the Highway Authority. Law No. 4 of August 24, 1990, authorizes it to enter into contracts with private entities for the construction, operation, and maintenance of roads, bridges, avenues, highways, and other transit facilities. Law No. 1 of March 6, 1991, renamed it the Puerto Rico Highway and Transportation Authority. The authority works to provide the Puerto Rican people with an integrated, efficient, reliable, and safe transportation system that contributes to the development of Puerto Rico's economy and improves the quality of life. It also seeks to develop government management of excellence that fosters the confidence of the people.
Institute of Forensic Science	The Institute of Forensic Science works to guarantee, through scientific participation and research, an important role in the criminal justice system by clarifying beyond reasonable doubt the causes, modes, and circumstances of deaths and other crimes through forensic sciences.
Institute of Emergency Management and Disaster	The Institute of Emergency Management and Disaster is a key player in the island's disaster management and recovery efforts. It is responsible for coordinating all emergency activities— including mitigation, preparation, recovery, and response—to ensure the protection of life and property. The agency works closely with the federal government and other international partners to provide rapid and effective services during emergencies.
Maritime Transportation Authority	The Maritime Transportation Authority provides maritime transportation services for cargo and passengers between Puerto Rico and the municipalities of Vieques and Culebra.
Metropolitan Bus Authority	Law No. 5 of May 11, 1959, as amended, established the Metropolitan Bus Authority. Plan No. 6 of 1971 transferred the powers of the AMA Board of Directors to the Secretary of the Department of Transportation and Public Works and abolished the board. The authority manages and continuously

Organization	Description
	develops a collective transportation system to facilitate the mobility of the population of the metropolitan area of San Juan. This action is carried out in coordination with the Department of Transportation and Public Works and in collaboration with the Highway and Transportation Authority, to improve the quality of life for citizens.
Office of Public Energy Policy	The State Office of Public Energy Policy (OEPPE) was created by virtue of Law 57-2014 (Puerto Rico Energy Transformation and RELIEF Act) in response to the need to transform both the energy industry of Puerto Rico and the Electric Power Authority. Under this law, a range of functions were delegated to the OEPPE, with the primary purpose of developing, promoting, regulating, and supervising compliance with the government's public energy policy and advising the Governor's Office on energy issues.
Office of the Advocate for Persons with Disabilities	The Office of the Advocate for Persons with Disabilities was established to create the Puerto Rico Ombudsman for Persons with Disabilities Act; to establish the Office of the Ombudsman for Persons with Disabilities of the Government of Puerto Rico, which has fiscal, programmatic, and administrative autonomy and independence to carry out its oversight work and establish its administrative organization; to create the position of Ombudsman for Persons with Disabilities; to repeal Law 78-2013, known as the Ombudsman for Persons with Disabilities of the Government of Puerto Rico Act; and for other related purposes.
Public Housing Administration	The Public Housing Administration works to ensure the maintenance, rehabilitation, and effective management of public housing projects to increase the availability of affordable housing, promote economic development, and improve the quality of life of families until they achieve self-sufficiency.
Puerto Rico Innovation and Technology Services	The Government of Puerto Rico bases its socioeconomic development model on science, technology, and innovation. To implement this model, the Puerto Rico Innovation and Technology Service (PRITS) was created through Act 75 of July 25, 2019. The mission of PRITS is to lead the digital transformation of the Government of Puerto Rico in the face of the challenges and trends of the modern era, through innovation, technology, and a collaborative approach. Its vision is to develop a centralized, agile, and transparent government where citizen services are provided efficiently through the use of new technologies and world-class innovations.
Puerto Rico Tourism Company	The Puerto Rico Tourism Development Act of 1993 was established to provide the Government of Puerto Rico with the necessary tools to develop a world-class infrastructure in response to the growing demand for more facilities to accommodate a new generation of businesses and tourists.
The Governor's Office	The Fortress/Palace of Santa Catalina was the first fortification built to defend the city of San Juan and the first in a series of military forts, including Castillo San Felipe del Morro, Fort San Cristobal, and Fortin de San Geronimo. Construction was authorized by King Charles I of Spain as a

Organization	Description
	measure of protection against attacks by corsairs and pirates. Construction began in 1533 and was completed on May 25, 1540.
University of Puerto Rico–Mayaguez	The University of Puerto Rico–Mayagüez is one of the most important centers in the Atlantic region for the study of tropical marine science due to its location, facilities, and researchers. Its research infrastructure includes the Puerto Rico Water Resources and Environmental Research Institute, the Caribbean Coral Reef Institute, the Research and Development Center, the Agricultural Research Station, and the Caribbean Atmospheric Research Center.
Caribbean Coastal Ocean Observing System	The Caribbean Coastal Ocean Observing System (CARICOOS) is the regional association for the coastal and ocean observing system serving Puerto Rico and the U.S. Virgin Islands. CARICOOS engages stakeholders from tourism and marine recreation, maritime transportation, security, and human and ecosystem health, as well as economics, who rely on coastal and marine weather and ocean data for decision-making.
Department of Education	The Department of Education identifies and implements mitigation measures designed to save lives, reduce harm, and ensure the safety of students, teachers, and non-teaching staff during or after a natural or technological event. It develops and maintains measures for immediate and effective action in the event of an emergency. These measures include evacuation plans, the identification of safe places to mobilize students, communication with support agencies, parents, and individuals associated with the campus, and provisions to minimize hazards affecting the school community. The Department coordinates with the Secretary of Housing to designate schools as shelters.
Department of Health	The Department of Health is the lead agency responsible for coordinating public health and medical response activities and supporting mass fatality response during all-hazards emergency or disaster events. It plays a key role in mitigating hazards related to potential medical surges, water quality problems, storm permitting, air pollution monitoring, hazardous materials issues, or monitoring of critical infrastructure such as wastewater treatment plants and drinking water systems. The Department detects and investigates diseases and leads efforts in environmental epidemiology. It develops and coordinates health emergency response plans, assesses natural and human-caused disasters, and strengthens public health response to such events. The Department integrates public health and medical systems with other local and Puerto Rico's partners, trains public health, medical, and emergency response partners on the latest protocols for health, medical, and mortuary response, and disseminates health information while maintaining systems for effective, redundant communications among stakeholders involved in public health detection and response. It identifies and implements mitigation measures in hospitals and other healthcare facilities to save lives, reduce damage, and ensure continuity of services following a natural or technological event. The Department also coordinates environmental health

Organization	Description
	services to address health risks arising from emergencies or disasters, leverages private sector health resources, and conducts inspections to ensure the quality of water provided to the public.
Department of Housing	The Department of Housing evaluates and recommends alternatives, prepares plans, and implements response strategies for emergencies caused by natural events such as floods and landslides. It provides temporary or permanent housing for families and individuals displaced by disasters or emergencies, and coordinates assistance for minimal home repairs. The Department works in partnership with FEMA and Government of Puerto Rico agencies to deliver aid and financial support to families whose homes have been destroyed or require major repair following a disaster. It coordinates with the U.S. Department of Housing and Urban Development (HUD) to develop adequate, affordable, and accessible housing solutions for disaster survivors. The Department is responsible for administering Community Development Block Grant–Disaster Recovery (CDBG-DR) funds in close coordination with the Central Office for Recovery, Reconstruction and Resilience (COR3). It develops the CDBG-DR Action Plan to ensure that funds support long-term community recovery, particularly in areas of housing, infrastructure restoration, and economic revitalization. The Department also conducts damage assessments for homes and buildings affected by disasters, assisting local government officials with repair or replacement cost-benefit analysis.
Department of Natural and Environmental Resources	The Department of Natural and Environmental Resources (DRNA) is the primary public agency that includes the Puerto Rico Environmental Quality Board and the Solid Waste Authority. It is the lead agency for implementing the Coastal Zone Management Program. The Department is mandated to conserve, protect, promote sustainable development, and regulate the use and enjoyment of government natural resources, including water, soil, and air conservation, management of government lands, wildlife, parks, outdoor recreation, and geological features. It promotes the conservation of Puerto Rico's water sources to ensure optimal use and to prevent flooding. The Department serves as Co-Chair of the Drought Task Force when activated and monitors the Puerto Rico Comprehensive Water Resource Plan. It promotes efficient water usage and provides public information, technical support, and financial assistance for water conservation planning. The Department also promotes drought planning, encourages and assists communities in preparing and implementing drought mitigation plans through technical and financial support, monitors drought impacts, and informs the public, media, and government officials.
Department of Family	The Department of Family collects information on the affected population immediately after an emergency or disaster. It collaborates with other agencies to determine the type of assistance to be provided to individuals and families, including support for relocation when necessary. This includes relocating families or structures situated in high-risk areas, such as those vulnerable to floods, landslides, or other natural hazards.

Organization	Description
Department of Transportation and Public Works	The Department of Transportation and Public Works restores public roads, removes obstacles and debris that obstruct traffic following emergencies or disasters. It provides technical assistance to Puerto Rico' agencies and municipal governments to determine the most effective means of transporting personnel and supplies to, from, and within affected areas. The Department maintains and cleans stormwater system ducts on government highways as a flood risk prevention measure. It designs bridges, culverts, and highways based on 100-year, 50-year, and 25-year flood consequence analyses; performs cost-benefit analyses and 100-year flood consequences analyses; signs off on all projects and reviews existing work by other agencies; and conducts additional work necessary to design structures in floodplains. It reviews, updates, and prioritizes islandwide action strategies using U.S. Army Corps of Engineers and FEMA reports, as well as hydrologic and hydraulic analyses. The Department performs new analyses where needed and creates action plans to reduce the risk of bridge scour. It has expanded the authority and capabilities of its internal Office of Emergency Management to better manage incidents and emergencies islandwide, with increased focus on resilience and hazard mitigation.
Puerto Rico Bureau for Emergency Management and Disaster Administration	PREMB provides a comprehensive management program that supports all local governments agencies. It addresses all phases of emergency management and supports all-hazards and disaster emergencies. The Bureau integrates emergency management efforts across all levels of government, including local, and federal. It provides planning and training services to local governments, including exercise support, mitigation, domestic preparedness, and disaster recovery, and sponsors workshops for elected local officials and staff. It coordinates government response and recovery program in support of local governments and maintains the State Emergency Operations Center (SEOC), where Emergency Support Function (ESF) representatives from other departments, agencies, and federal entities coordinate disaster response efforts. The Bureau facilitates islandwide-level training and works with local agencies to ensure coordination in the planning and implementation of local and regional exercises.
Department of Public Safety Fire Department Bureau	The Department of Public Safety (DSP) Fire Department Bureau regulates the safety standards that each structure must comply with for residential, educational, commercial, or other uses, as part of mitigation measures. It supports the PREMB in educating the community about fire prevention, earthquake preparedness, hazardous materials management, and other hazards. It provides PREMB and the Puerto Rico Planning Board (PRPB) with information on estimates of fire damage, when available. The Bureau carries out inspections of all structures designated for use as emergency shelters. It provides fire prevention and code enforcement; wildfire preparedness, response, suppression, coordination, and management; training and certification; public information and education; and technical assistance to local governments.

Organization	Description
Office of Permits and Management	Responsible for overseeing new development compliance with applicable regulations related to the mitigation of natural hazards.
Public Buildings Authority	Collect damage assessments on public facilities and buildings not assigned to other agencies. Identify and implement mitigation measures to protect and reduce loss to public critical facilities under the PBA jurisdiction, to ensure continuity of operations and rapid recovery of services after natural or technological events.
Transportation and Other Public Services Bureau	The Transportation and Other Public Services Bureau determines transportation capacity to support government entities and voluntary organizations and coordinates the contracting of necessary resources through the Puerto Rico General Services Administration. It enforces Puerto Rico's government against hazardous materials, laws, rules, and regulations related to highway transportation. The Bureau also enforces routing, permitting, and the safe transportation of hazardous materials, and performs spot inspections of drivers and vehicles to determine compliance with applicable standards. Additionally, the Bureau identifies access routes for the transportation of high-risk materials. It identifies transportation resources and requirements and coordinates their use.
LUMA Energy	LUMA Energy identifies and implements mitigation measures to protect electrical installations and reduce the risk of loss, ensuring continuity or rapid recovery of the electrical system following emergencies or disasters. It inspects, maintains, and takes any necessary mitigation measures on water reservoirs and dams under its jurisdiction.
Puerto Rico Planning Board	The PRPB coordinates islandwide efforts to collect, analyze, process, report, and deploy the essential elements of information, and facilitates support for planning efforts in emergency operations. It is responsible for the education and promotion of the National Flood Insurance Program (NFIP). The Board maintains maps (e.g., land-use zoning maps, FEMA flood maps) and interactive tools related to land use suitability classification. It supports the implementation of substantial damage and substantial improvement requirements under the NFIP. The Board is responsible for the implementation of Planning Regulation No. 13: Regulation of Flood Susceptible Zones. It coordinates efforts to revise and update local hazard mitigation plans. It also develops and incorporates into current public policies the principles related to the appropriate management of flood plains and the safe use of land for natural hazard mitigation.
Puerto Rico Ports Authority	The Puerto Rico Ports Authority prepares plans for the early rehabilitation of ports and airports following emergencies and determines alternate uses for these facilities. It identifies and implements mitigation measures to prevent and protect port authority facilities from damage or loss. The Authority also guarantees continuity and rapid recovery of services after natural or technological events.

Organization	Description
Puerto Rico Aqueducts and Sewer Authority	The Puerto Rico Aqueducts and Sewer Authority (PRASA) identifies and implements mitigation measures to prevent and protect PRASA facilities from damage or loss to guarantee continuity and rapid recovery of the system after natural or technological events. It inspects, maintains, and takes necessary mitigation measures on water reservoirs and dams under its jurisdiction. PRASA implements emergency operational procedures at all of its facilities. In addition, it maintains communication with PREMB regarding water levels and discharges into dams and reservoirs to take action that safeguards lives and property. It also reserves water supplies for use by the fire department as required.
Telecommunications Regulatory Board	The Telecommunications Board coordinates with PREMB to strengthen communications through equipment and technical staff. It coordinates the restoration of communication facilities and services in disaster-affected areas. The Board joins efforts to restore and reconstruct telecommunications infrastructure to meet emergency needs. It also establishes plans and procedures to manage, assign, prioritize, and use local and federal communications equipment.
Central Recovery, Reconstruction and Resilience Office of Puerto Rico	A division of Puerto Rico's Fiscal Agency and Fiscal Advisory Authority, the Central Recovery, Reconstruction and Resilience Office supports and empowers Puerto Rico communities in building stronger, safer, and more resilient systems in the face of natural disasters and other major challenges. It maintains the website www.recovery.pr to provide open access to information from federally funded recovery programs and resources for individuals and local governments. The Office supports PREMB in maintaining and updating the Puerto Rico State Natural Hazards Mitigation Plan and serves as the State Reviewer for local hazard mitigation plans.

Interagency Coordination

Partnerships play a vital role in effective hazard mitigation efforts. Robust partnerships offer invaluable opportunities to share resources, expertise, and information. By working together, decision-makers can leverage the collective expertise and resources of multiple partners to identify hazards and vulnerabilities, assess solutions, and mitigate risk. These collaborations also help reduce duplication of efforts and ensure that high-priority actions are completed efficiently. Together, partners can fund, develop, and implement innovative solutions to build resilience, reduce risk, and address the specific needs of communities across Puerto Rico.

Among other opportunities, government agencies involved in hazard mitigation benefit from two main partnership-building opportunities in Puerto Rico: coordinated initiatives between the Puerto Rico Planning Board (PRPB) and the Federal Emergency Management Agency (FEMA), and participation in the Silver Jackets program.

Puerto Rico Bureau for Emergency Management and Disaster Administration

The Puerto Rico Bureau for Emergency Management and Disaster Administration (PREMB) works in close partnership with FEMA Region 2 to prepare for, respond to, and recover from disasters. Many federally funded mitigation opportunities, policies, and programs are administered by FEMA and carried out at the government level by PREMB and the Central Office for Recovery, Reconstruction and Resilience (COR3). The Silver Jackets program supports the development of the Puerto Rico government-led teams focused on reducing flood risk and other natural hazards.

PREMB coordinates all resources of the Government of Puerto Rico, and those of the private sector to provide services before, during, and after emergency situations in the fastest and most effective manner to ensure the protection of the life and property of citizens. PREMB provides mitigation planning and training services to local governments, along with sponsored workshops for elected local officials and staff. PREMB serves as the lead agency responsible for coordinating the State Hazard Mitigation Team. It also supervises maintenance of Puerto Rico State Natural Hazard Mitigation Plan, along with COR3 and the PRPB.

Central Recovery, Reconstruction and Resilience Office of Puerto Rico

COR3 supports the prioritization of funding for Hazard Mitigation Grant Program (HMGP) projects that protect federal investment in Puerto Rico's public infrastructure. HMGP projects must meet minimum eligibility criteria to qualify for funding. In addition, proposals considered for funding under any disaster declaration must support the Puerto Rico's Recovery Plan. COR3 ensures all projects benefit the designated disaster area and solve a problem independently or serve as a functional part of a solution with reasonable certainty that the entire project will be completed. COR3 ensures all projects conform to all local and federal ordinances, policies, regulations, laws, and statutes related to environmental and historic preservation, and to both Puerto Rico State Hazard Mitigation Plans (SHMPs) and Local Hazard Mitigation Plans (LHMPs). Finally, COR3 ensures that all projects are cost-effective and substantially reduce the risk of future damage, loss, hardship, or suffering from a major disaster.[1077]

[1077] Government of Puerto Rico, "Central Recovery, Reconstruction and Resilience Office of Puerto Rico, Hazard Mitigation Assistance (FEMA)," 2025, https://recovery.pr.gov/en/recovery-programs/hazard-mitigation-assistance.

Silver Jackets

Silver Jackets teams are interagency teams that facilitate collaborative solutions to flood risk priorities in the Government of Puerto Rico. Silver Jackets teams bring together multiple local and federal, and sometimes tribal and local agencies to share knowledge and collaborate to reduce risks from floods and other natural disasters. By applying their shared knowledge, the teams enhance preparedness, mitigation, response, and recovery efforts. The Government of Puerto Rico sets the priorities, with each agency member supporting the team using its own programs and resources within the constraints of available budgets and agency authorities.[1078]

The Puerto Rico Silver Jackets Team (recipient of the 2020 Silver Jackets Team of the Year award) is composed of the Government of Puerto Rico and its agencies, municipalities, non-governmental organizations, academia, and federal partners, who share the vision of promoting best practices to enhance community resilience and recovery from natural disasters with a focus on sound flood risk management practices. In Puerto Rico, the Silver Jackets team consists of the following agencies:[1079]

- Government of Puerto Rico, Governor's Office
- Puerto Rico Central Office for Recovery, Reconstruction and Resiliency (COR3)
- Puerto Rico Department of Natural Resources
- Puerto Rico Planning Board
- University of Puerto Rico – Mayagüez
- University of Puerto Rico – Río Piedras
- U.S. Army Corps of Engineers (USACE)
- FEMA Region 2
- U.S. Geological Survey (USGS)
- National Oceanic and Atmospheric Administration–National Weather Service (NOAA-NWS)
- NOAA, Office of Coastal Management (NOAA-OCM)
- U.S. Coast Guard
- U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)
- Environmental Protection Agency (EPA)

[1078] U.S. Army Corps of Engineers, "What Is Silver Jackets?," 2025, https://www.iwr.usace.army.mil/Silver-Jackets/About-Silver-Jackets/.
[1079] U.S. Army Corps of Engineers, "Silver Jackets State Teams-Puerto Rico," 2025, https://www.iwr.usace.army.mil/Silver-Jackets/State-Teams/Puerto-Rico/.

- U.S. Department of the Interior
- U.S. Department of Transportation

The Silver Jackets team meets periodically throughout the year to accomplish the program's desired outcomes as follows:

- Reduce flood risk.
- Help agencies better understand and leverage each other's programs.
- Promote collaboration between various agencies, coordinated programs, and cohesive solutions.
- Serve as a multi-agency technical resource for Puerto Rico's government and municipal agencies.
- Provide a mechanism for establishing relationships to facilitate integrated solutions post-disaster.
- Work with PREMB to improve levee inventory databases.

The Puerto Rico National Flood Insurance Program (NFIP) Manager serves as a point of contact with Silver Jackets. The Silver Jackets program initiates projects, provides information to PRPB and PREMB throughout the process, and participates in meetings and calls. Projects are ongoing with the municipality of Toa Baja (Toa Baja High Water Mark Signage Project).[1080]

The Business Emergency Operations Center

The Puerto Rico Business Emergency Operations Center (BEOC) is an initiative that brings together multiple sectors of the private domain—including telecommunications, energy, banking, critical infrastructure, and financial services—with the purpose of strengthening resilience and operational continuity during emergencies in Puerto Rico. Since Hurricane Maria (2017), the BEOC has maintained active and effective collaboration with government agencies, particularly with PREMB, facilitating communication, coordination, and joint response between the public and private sectors during critical situations.

Following Hurricane Fiona in September 2022, the BEOC played a key role as a liaison between PREMB and the private sector. The PREMB Commissioner highlighted that communication with the BEOC was constant from the days prior to the impact of the tropical system, continuing during and after the emergency. This collaboration allowed for the following:

- Maintaining a smooth flow of information between the federal and local government's essential industries
- Identifying the priority needs of the private sector in terms of telecommunications, banking, insurance, and essential services

[1080] U.S. Army Corps of Engineers, "Silver Jackets State Teams-Puerto Rico," 2025, https://www.iwr.usace.army.mil/Silver-Jackets/State-Teams/Puerto-Rico/.

- Coordinating more effective recovery efforts, facilitating the restoration of critical infrastructure and supply chains
- Optimizing Puerto Rico's response through direct information about service disruptions and operational requirements from the business sector

Through this partnership relationship, the Government of Puerto Rico was able to have accurate, real-time information on the conditions of the private sector, enabling a faster, more coordinated response focused on the areas of greatest need.

On May 30, 2023, the BEOC and PREMB formalized their collaboration through the signing of a Memorandum of Understanding. PREMB is currently close to signing a new joint agreement with the Puerto Rico Department of Public Safety (DSP), Puerto Rico Department of Economic Development and Commerce (DDEC), and the Department of State. This agreement established a structured framework for cooperation to share critical information before, during, and after emergencies; develop joint strategies for preparedness, mitigation, and response; and integrate the private sector into Puerto Rico's emergency and recovery plans. Although the agreement was formalized in 2023, the working relationship between the BEOC and the government of Puerto Rico had effectively existed since 2017, demonstrating tangible results in events such as Hurricane Fiona and other emergencies.

The collaboration between BEOC and PREMB has strengthened the Puerto Rico's capacity to manage large-scale emergencies by facilitating multisectoral coordination between the government and private companies, providing critical operational information that aids governmental decision-making, and improving the continuity of essential services for citizens. Together, this public–private partnership has proven to be a key component for efficient emergency management in Puerto Rico, serving as a model of strategic collaboration between the government and the business sector.

Policies, Programs, and Plans

Numerous programs, policies, and acts support the planning, administrative, and technical capabilities across the island. Several strategic plans and policies have been adopted by the Government of Puerto Rico that address its environmental, transportation, emergency management, and public health needs. These plans address a wide array of sectors and are essential in ensuring long-term resilience, promoting sustainable development, and safeguarding public safety. Table 124 presents the mitigation initiatives conducted by various government agencies and affiliated partners, indicating pre- or post-disaster activities. This section also includes detailed program information on the NFIP.

Table 124: Policies, Programs, and Plans

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
Preparedness and Response Plan for COVID-19	Department of Health	This plan outlines the activities associated with preparedness and response to a public health emergency in Puerto Rico caused by the detection of COVID-19.	X	X
Department of Health Emergency Operations Plan	Department of Health	The EOP provides guidelines and tools necessary to establish preparedness at the municipal, regional, and Government levels to achieve an adequate response before, during, and after an emergency or disaster that impacts the public health, medical services, and mental health systems in Puerto Rico.	X	X
Strategic Plan 2020–2024	Department of Education	The Strategic Plan 2020–2024 was developed by identifying and articulating six strategic goals with their respective strategic objectives, strategic interventions, priority level, intervention period, activities, expected results, and milestones. The plan is the foundation for annual plans and future action plans. It provides direction toward the achievement of the agency's goals and objectives and strategically guides the actions for the implementation of the various plans.	X	
Multimodal Long Range Transportation Plan (MLRTP) 2050	Department of Transportation	The 2050 MLRTP is a central and unifying document that summarizes goals, objectives, and performance measures. The MLRTP provides an assessment of the current system performance, inventories future challenges, and analyzes needs. It also proposes investment strategies to be funded over the next 27 years. It aims to improve the performance of transportation in Puerto Rico and move toward those goals.	X	
Community Development Block Grant–Disaster Recovery	Department of Housing	This plan ensures that the use of CDBG-DR funds supports the long-term recovery of communities, specifically in areas of housing, infrastructure restoration, and economic revitalization.		X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
(CDBG-DR) Action Plan				
Comprehensive Water Resource Plan	Department of Natural and Environmental Resources	This plan specifies the current uses of the country's water bodies, projects future uses, and describes the hydrological cycle, as well as the needs of the natural, social, and economic systems that depend on the resource for their subsistence and development. The goals are to (1) conserve water supply sources to ensure the well-being, security, and development of the country; (2) achieve the most equitable and fair distribution of water; and (3) use the waters in accordance with the public interest and criteria of optimal, beneficial, and reasonable use.	X	
Emergency Operations Plan (EOP) – Ports Authority	Puerto Rico Ports Authority	The EOP aims to promote interagency integration under the implementation of the National Incident Management System (NIMS) to cover all phases of the emergency cycle—namely, prevention, preparedness, response, mitigation, and recovery. It strengthens coordination, cooperation, efficient resource use, and effective communication. It also facilitates mutual aid agreements and provides an integrated, timely, and proactive response for local and federal agencies in the face of natural and human-caused events. It ensures an effective response from the onset of the incident through full recovery, taking into account all airport, maritime, office, and departmental facilities under its jurisdiction.	X	X
Strategic Five Year Plan 2020–2025	Puerto Rico Aqueduct and Sewer Authority (PRASA)	The plan is supported by PRASA's core values and expands into five focus areas. Within these focus areas are 10 objectives from which 24 initiatives translate the strategic plan into action. The progress of the initiatives is then monitored through key performance indicators to measure the overall	X	

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		performance of the Strategic Plan and its initiatives.		
Capital Improvement Plan (CIP)	Puerto Rico Aqueduct and Sewer Authority	The purpose of the CIP is to modernize and maintain PRASA's infrastructure. Its objectives are as follows: • Optimize operational efficiency • Protect public health • Safeguard the environment • Promote continuous economic development • Comply with regulatory requirements • Properly maintain and renew infrastructure • Reduce non-revenue water • Address emergencies • Increase resilience	X	X
Emergency Action Plan – Carraizo Dam	Puerto Rico Aqueduct and Sewer Authority	The Emergency Action Plan – Carraizo Dam, known by its Spanish acronym, PAE, revised in 2019, is designed to guide PRASA officials when abnormal conditions arise that could jeopardize the dam's integrity and lead to dangerous flooding. It outlines the actions PRASA officials and employees must take during emergencies that pose risks to human life and cause significant economic and environmental damage.	X	X
Puerto Rico Dam Safety State Program	Puerto Rico Energy Power Authority	The Government of Puerto Rico established legislation to create the Puerto Rico Dam Safety State Program under Law 133. The purpose of this program is as follows: • Carry out detailed and comprehensive periodic inspections every three years, establishing an order of priorities to determine the safety conditions of the dams and reservoirs, and to make assessments about the hydraulic and hydrologic capacity, the structural stability, and the sufficiency of the components and structures to minimize the risks for life and	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		property, and to make recommendations to the owners of the dams and reservoirs about the measures that should be taken to remedy any dangerous situation. • Review and approve the plans and specifications to build, extend, modify, or remove any dam or reservoir, when plans and specifications are accompanied by studies, investigations, analysis, and designs facts that allow the unit to determine its safety. • Carry out periodic inspections during the construction, extension, abandonment, or removal of a dam to ensure compliance with the plans and specifications it has approved. • Issue notifications when necessary to require the owner or person in charge of the dam or reservoir to correct defects or unsafe conditions, carry out necessary conservation work, review operational processes, or take any other necessary action. • Approve and issue the corresponding certification of approval and permit after completing the construction, extension, or modification of a dam or reservoir, provided it complies with the plans and specifications for its safety. • Organize, verify, and approve the Emergency Action Plans for the dams in the program. • Prepare and maintain a risk-based inventory of dams under the jurisdiction of the Government of Puerto Rico. • Require and propose interim risk reduction measures for dams that do not meet societal risk standards, as defined by FEMA.		

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		• Engage in hydrological and hydraulic studies to verify the spillway capacity of dams, such as through islandwide Probable Maximum Precipitation analysis. • Organize and provide dam safety training to dam owners. • Organize and conduct dam break exercises to owners. The Dam Safety State Program monitors the performance of 37 dams classified as high risk, in order to preserve the lives and property of downstream residents.		
Intended Use Plan (IUP)	Department of Natural and Environmental Resources	This IUP serves as the planning document that explains the use of funds expected to be available to the Clean Water State Revolving Fund (CWSRF), including the following: the undrawn balance of Federal capitalization grants and State matching funds; projected repayments; interest earnings from the CWSRF program equity; and the Federal Fiscal Year (FFY) 2024 Federal capitalization grant with its associated State match. As currently developed, this IUP identifies the specific projects and activities associated with the federal allocations for FFY-2024 under the BIL Act, as well as the repayment funds.	X	
Water Pollution Control Revolving Fund Program	Department of Natural and Environmental Resources	The Puerto Rico Water Pollution Control Revolving Fund Program is a crucial initiative aimed at improving water quality and infrastructure across the island. It is part of the CWSRF and is designed to finance projects that enhance, maintain, or protect water quality. The program includes funding for wastewater treatment, nonpoint source pollution control, and watershed management. Puerto Rico's CWSRF provides interest-free or low-interest financing for various water quality infrastructure projects, including the construction or restoration of sewers and	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		wastewater treatment facilities, stormwater management projects, and habitat restoration and protection projects. The program is administered by the Department of Natural and Environmental Resources and is supported by the U.S. Environmental Protection Agency (EPA) to ensure effective management and funding of water pollution control projects in Puerto Rico.		
Puerto Rico Bureau for Emergency Management and Disaster Administration (PREMB) Emergency Operations Plan	Puerto Rico Bureau for Emergency Management and Disaster Administration	The purpose of this plan is to establish strategies and responsibilities, and to coordinate and integrate the efforts and resources of governmental agencies, non-governmental entities, and the private sector in preparedness, mitigation, response, and recovery in the event of an emergency or disaster. The plan requires the participation and coordination of all chiefs of Government agencies, departments, or regional offices, and mandates the faithful fulfillment of the duties and responsibilities assigned within it. It also aims to sustain and maintain the integration of private organizations, industry, commerce, local and federal agencies, providing human, economic, technical, and professional resources to stabilize lifelines and meet the basic needs of citizens during an emergency or disaster, in collaboration with the Federal Government and the resources it provides.	X	X
Joint Operational Catastrophic Incident Plan of Puerto Rico	Multiple	The Joint Operational Catastrophic Incident Plan of Puerto Rico (JOCIP), approved in June 2019, was developed through the coordination of federal, state, local, and private sector committees. The JOCIP planning team was composed of the Puerto Rico Department of Public Safety, the PREMB, the U.S. Department of Homeland	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		Security, FEMA, the primary agencies of the Government of Puerto Rico, local governments, and critical infrastructure private sector representatives. For the first time, the new JOCIP was designed following FEMA's *Community Lifelines Implementation Toolkit*, Version 1.0, February 2019; the Homeland Security Presidential Directive #5; the National Incident Management System (NIMS); the *National Response Framework*, Third Edition, June 2016; FEMA's *Comprehensive Preparedness Guide 201 – Threat and Hazard Identification and Risk Assessment (THIRA)*, Third Edition; FEMA's *Comprehensive Preparedness Guide 101: Developing and Maintaining Emergency Operations Plans (CPG 101), Second Edition*, 2010; the National Fire Protection Association's *Standard 1600 – Standard on Disaster/Emergency Management and Business Continuity Programs*; and other guidelines and standards.		
Puerto Rico Land Use Plan	Puerto Rico Planning Board	Established under Act No. 550 (2004), the Puerto Rico Land Use Plan serves as the primary instrument for territorial planning, promoting sustainable development and optimal land use through a comprehensive approach and broad stakeholder participation. It provides a uniform system of land classification and zoning (calificación del suelo) to guide urban growth, protect natural resources, and support resilience planning across municipalities.	X	X
Regulation on Special Flood Risk Areas	Puerto Rico Planning Board	The Regulation on Special Flood Risk Areas (Planning Regulation No. 13), as amended, establishes security measures to regulate buildings and land development in areas declared to be at risk of flooding. Regulation No. 13 has, among others, the following purposes: • Protect human life and health.	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		• Reduce the need to use public funds for flood control projects and mitigation plans. • Reduce the need for rescue and relief efforts associated with flooding. • Avoid changes to the natural hydrology of flood-prone valleys in order to protect and conserve wetlands.		
The Write Your Own Program		The Write Your Own (WYO) program began in 1983 as a partnership between insurance companies and FEMA. This agreement allows property and casualty insurance companies to write and service federal flood insurance policies under their own names. What is unique about this type of policy is that all companies participating in the WYO program provide the same coverage, and the rates must comply with the provisions and regulations concerning the National Flood Insurance Program (NFIP).		
Four-Year Investment Program	Puerto Rico Planning Board	The Four-Year Investment Program (PICA) document is prepared in compliance with the provisions of the Puerto Rico Planning Board, Law No. 75 of June 24, 1975, as amended. PICA integrates the investments to be made by the Government of Puerto Rico through its various agencies and responds to the need to effectively allocate and distribute funds by directing them to the areas of highest priority. It constitutes a short- and medium-term planning instrument aligned with the goals of the Government and contributes to a sound and effective public administration.		
Protocol for Drought Management in Puerto Rico		During the 2014–2016 drought, and as a measure to document and enable the Government of Puerto Rico to act in a coordinated manner, a guiding document was developed titled *Protocol for Drought Management in Puerto Rico*. This first Protocol was prepared as an	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		initial response to the 2014 drought, to guide interagency efforts to monitor and coordinate actions in the face of drought events. Droughts manifest in different ways throughout the island, affecting some regions while others remain under humid or normal conditions. Of all the island's areas, the southern coastal sector is the most vulnerable due to its low rainfall and limited water reserves.		
Plan and Regulation for the Karst Special Planning Area	Department of Natural and Environmental Resources	This plan establishes the protection and conservation of the Karst Physiography to preserve and manage the Karst region—also known as the Carso Restricted Area or the Carso Restricted Special Planning Area—for the benefit of current and future generations.	X	
Plan for the Conservation of Sensitive Areas for Adjuntas and Adjacent Municipalities	Department of Natural and Environmental Resources	This plan contains intervention strategies to maintain the aesthetic, cultural, and historical value of these areas, which are considered important sources of economic growth for Puerto Rico. It focuses on the following planning areas: flora and fauna, resource tolerance levels, watersheds, flood zones, existing communities, special planning zones, agricultural land, water bodies (rivers and lakes), scenic routes, biological corridors, and forests. The plan also serves as a critical tool that contributed to the analysis of risks and vulnerabilities following the hurricanes of 2017 and the earthquakes of 2020 for the central and southwestern regions of Puerto Rico.	X	X
Regulation for the Use, Surveillance, Conservation and Administration of Territorial Waters, Submerged Lands Under These and the Terrestrial Maritime Zone,	Department of Natural and Environmental Resources	This regulation establishes the use, surveillance, conservation, and administration of terrestrial and maritime public domain assets, including territorial waters, submerged lands, and the maritime terrestrial zone.	X	

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
DNR Regulation No. 4860				
Puerto Rico Forest Action Plan	Department of Natural and Environmental Resources	This plan provides islandwide strategies for the assessment of forest resources to conserve working forest landscapes, protect forests from harm, and enhance public benefits associated with trees and forests. It addresses concerns related to the following: • The fragmentation of forest systems • Water resources and watershed conservation strategies • Information needs related to ecosystem services and other benefits from public and private forest lands • Disturbances affecting forests (hurricanes, floods, fires, pests, etc.) • Concerns over invasive species • Economic opportunities and alternative market development	X	X
Auxiliary Forests Program	Department of Natural and Environmental Resources	The program promotes conservation of private forestlands by providing tax-exempt status to eligible properties enrolled in the program. Eligibility requirements include minimum area (more than 5 *cuerdas*, or 4.855 acres), a Department of Natural and Environmental Resources (DRNA) inspection, and a signed contract between the landowner and DRNA. Enrollment in the program is voluntary and may be renewed yearly upon request by the landowners and confirmation of continued eligibility.	X	
Puerto Rico Seismic Network	University of Puerto Rico, Mayagüez Department of Geology	The Puerto Rico Seismic Network (PRSN), in partnership with the University of Puerto Rico, Mayagüez Department of Geology, provides data to federal agencies (USGS, FEMA, NOAA) to fulfill their functions—both to issue tsunami warnings and to maintain the necessary catalogs to update seismic hazard maps and response plans. The PRSN has been	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		accredited by the U.S. Advanced National Seismic System (ANSS). At the national level, it is an active member of the TsunamiReady Program of Puerto Rico. At the international level, the PRSN actively participates in the working committees of the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). In addition, PRSN serves as an alternate tsunami information focal point for Puerto Rico and the Virgin Islands and is a fundamental part of Puerto Rico's tsunami response protocol according to UNESCO standards.		
Caribbean Coastal Ocean Observing System		The Caribbean Coastal Ocean Observing System (CARICOOS) tools identify communities, structures, or other assets vulnerable to hazards, serving real-time data on wind, waves, and coastal hazards. While real-time data may have more limited applications, over 40 years of wave height records make extreme events visible. The Caribbean and Atlantic Ocean Science and Engineering (CAOSE) lab provides statistical products, including a maximum wave height contour map—roughly every 50 years, a 7-foot wave event is expected. Compound flooding—storm surge combined with flooding from rainfall—is also addressed. CARICOOS collaborates with colleagues in Georgia and another university on flood scenarios and worst-case projections. The Coastal Emergency Risks Assessment (CERA) in Louisiana runs hurricane and storm surge modeling. Additional resources include the following:	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		• Puerto Rico Climate Change Council's assessment of exposure (2015 is the most current) • A wave atlas and extreme wave analysis to evaluate the frequency of extreme wave events • The Caribbean Regional Ocean Partnership (CROP), which focuses on coastal and power infrastructure • Sargassum forecasts, which help assess risks to seawater intake systems and potential impacts on power generation • Information on ports and strategies for keeping them operational • The Environmental Research Division's Data Access Program (ERDDAP) catalog, wind modeling, coral reef restoration efforts, and other green infrastructure initiatives		
Landslide Ready	University of Puerto Rico	The Landslide Hazard Mitigation Office at the University of Puerto Rico Mayagüez (UPRM), led by Dr. K. Stephen Hughes, operates a tool based on hydrology and soil saturation to predict future landslides. This UPRM team developed a landslide vulnerability map for Puerto Rico and uses this mapping product as part of its public outreach and education efforts. The UPRM Landslide Hazard Mitigation Office currently maintains 19 monitoring stations across the island that measure soil saturation approximately every five minutes. The team is also developing an experimental forecasting tool that is intended to identify, in advance, where landslides may occur based on hydrological and soil-moisture conditions. In addition, the Landslide Ready program, coordinated by this same UPRM team, is structured similarly to the Tsunami Ready program. The certification	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		process involves initial acceptance and recertification every four years. As part of this program, UPRM personnel collaborate with municipal emergency management offices, deliver community presentations, and conduct workshops for EM staff focused on landslide tools and operational usage during events. The team also prepares tailored guidance manuals for participating municipalities to facilitate management and communication of the Landslide Ready program. After certification, the UPRM Landslide Hazard Mitigation Office continues to support participating municipalities, provides educational information to schools upon request, and utilizes municipal social media platforms and WhatsApp groups for ongoing communication and preparedness messaging.		
Caribbean Collaborative Action Network		The Caribbean Collaborative Action Network is a regional knowledge-to-action initiative that brings together researchers and stakeholders. Its purpose is to evaluate needs, provide technical and scientific expertise, facilitate communication, and strengthen cross-regional connections and capacity for climate adaptation. These efforts span multiple levels—from the community micro level to the territorial meso level and up to the macro level of regional networks.	X	X
Epidemiological Syndromic Surveillance System	Department of Health	In March 2020, a public health initiative was launched to establish the Epidemiological Syndromic Surveillance System (ESSS) as a collaboration between academia and nonprofit organizations. This tool offers pre-diagnostic symptom data for public health decision-making. The ESSS was developed in response to	X	X

Policy, Program, or Plan	Lead Agency	Description	Pre-Disaster	Post-Disaster
		COVID-19 in Puerto Rico as a novel, crowd-sourced, geocoded passive online strategy. It uses the Survey123 for ArcGIS platform to address gaps in local, islandwide infrastructure for testing, tracing, and confirming cases. The ESSS platform asks participants to share the signs and symptoms of COVID-19 that they experienced in the past 24 hours. This self-reported ESSS was implemented when COVID-19 cases were confirmed in Puerto Rico. Trends in signs and symptoms can be tracked as responders enter their own information daily. By collecting zip code information, the system allows for the detection of areas with high symptoms or clusters of symptoms across Puerto Rico municipalities.		
Public Health Recovery Plan	Department of Health	This plan is currently in process of being created.	X	X
EcoExploratorio Institute of Resilience	EcoExploratorio Museum	The EcoExploratorio Institute of Resilience is an initiative of the EcoExploratorio Museum of Puerto Rico that educates people of all ages on how to prepare for and protect themselves from the natural hazards that Puerto Rico may face. The purpose of the institute is to make information and education on risk mitigation at personal and community levels accessible to all citizens. In this context, the institute has launched various initiatives in collaboration with academic entities and specialized services, supporting the development of research and student projects. These efforts contribute to the academic development of students, helping them gain a deeper understanding of resilience and risk management issues.	X	

TsunamiReady

TsunamiReady is a voluntary community recognition program created by NOAA-NWS to minimize the loss of life and property caused by tsunamis and to promote preparedness for tsunami hazards. In Puerto Rico, the Seismic Network (RSPR) manages funds from the National Tsunami Hazard Mitigation Program and the TsunamiReady® Program, in partnership with the NWS Forecast Office in San Juan, FEMA, PREMB, Municipal Offices for Emergency Management, and communities. Through this program, several tools and educational materials have been developed, including tsunami flood and evacuation maps, web applications, tsunami evacuation signs, tutorials for seminars and training, pamphlets, brochures, educational materials, media guides, and the Tsunami Curriculum for schools.

There are 46 municipalities in Puerto Rico that have achieved TsunamiReady® recognition from the NWS, with 44 coastal and 2 non-coastal municipalities (Canóvanas and Bayamón) (see Table 125). Currently, the RSPR is working diligently to implement the TsunamiReady® Supporter Program, which primarily recognizes private sector entities, such as resorts, supermarkets, and other facilities located in evacuation zones. As part of the TsunamiReady® Program, and to meet recognition guidelines, RSPR provides 24/7 Enterprise Mass Warning Notification systems, NOAA radios, and other systems to enhance alert reception capabilities at Tsunami Warning Centers. Technical assistance is also provided for the preparation of response plans and community presentations.[1081]

Table 125: TsunamiReady® Municipalities in Puerto Rico[1082]

Participating Municipalities			
Aguada	Ceiba	Lajas	Río Grande
Aguadilla	Culebra	Loíza	Salinas
Añasco	Dorado	Luquillo	San Juan
Arecibo	Fajardo	Manatí	Santa Isabel
Arroyo	Guánica	Maunabo	Toa Baja
Barceloneta	Guayama	Mayagüez	Vega Alta
Bayamón	Guayanilla	Naguabo	Vega Baja
Cabo Rojo	Guaynabo	Patillas	Vieques
Camuy	Hatillo	Peñuelas	Yabucoa
Canóvanas	Humacao	Ponce	Yauco
Carolina	Isabela	Quebradillas	
Cataño	Juana Díaz	Rincón	

[1081] Puerto Rico Seismic Network, "TsunamiReady© Program," https://redsismica.uprm.edu/english/tsunami/tsunamiready.php.
[1082] National Weather Service, "TsunamiReady® in Puerto Rico," 2025, https://www.weather.gov/tsunamiready/pr-tr.

StormReady®

StormReady® helps arm America's communities with the communication and safety skills needed to save lives and property—before, during, and after hazardous weather events. The program helps community leaders and emergency managers strengthen local safety programs and uses a grassroots approach to help communities develop plans to handle all types of extreme weather—from tornadoes to hurricanes. The program encourages communities to take a proactive approach to improving local hazardous weather operations by providing emergency managers with clear guidelines for enhancing hazardous weather operations.

StormReady® communities must meet the following criteria:

- Establish a 24-hour warning point and emergency operations center.
- Have more than one way to receive severe weather warnings and forecasts and to alert the public.
- Create a system that monitors weather conditions locally.
- Promote the importance of public readiness through community seminars.
- Develop a formal hazardous weather plan, which includes training severe weather spotters and holding emergency exercises.

Seven municipalities have earned StormReady® recognition (see Table 126).

Table 126: StormReady® Municipalities in Puerto Rico

Participating Municipalities	
Aguada	Manatí
Camuy	Mayagüez
Carolina	Toa Baja
Dorado	

The National Flood Insurance Program

In 1968, the U.S. Congress established the NFIP to offer property owners a way to financially safeguard against flood damage. Flood insurance is accessible to homeowners, renters, and business owners, provided their community has joined the NFIP. As part of the program, participating communities commit to reducing flood risks by implementing and upholding floodplain management regulations that meet or surpass the NFIP's minimum standards. Flood insurance then becomes available to all residents and businesses within those communities.

NATIONAL FLOOD INSURANCE PROGRAM COORDINATION

The Hydrology Office is responsible for implementing flood ordinances, managing and enforcing flood maps (including Regulation No. 13), conducting community outreach, and supporting building code compliance across Puerto Rico.

Key partnerships include the following:

- FEMA, the primary partner, especially in post-disaster damage assessments
- ForeRunners, which supports permit documentation through a dedicated application
- USACE, including its Silver Jackets program
- Emergency Management Offices at the local and regional levels
- Municipalities and local permitting offices, which help implement and enforce floodplain regulations
- Cooperating Technical Partners Agreement, which provides technical assistance and map support

NATIONAL FLOOD INSURANCE PROGRAM PARTICIPATION

To participate in the NFIP, communities must adopt and enforce minimum floodplain management regulations so that development—including buildings—is undertaken in ways that reduce exposure to flooding.

The PRPB serves as the NFIP State Coordinating Agency. In Puerto Rico, the minimum standards for participation in the NFIP include the following:

- Recognize flood hazards in community planning.
- Adopt and enforce flood maps and a flood damage prevention ordinance.
- Require permits for all types of development in the floodplain.
- Assure that building sites are reasonably safe from flooding.
- Establish Base Flood Elevations (BFEs) where not determined on Flood Insurance Rate Maps (FIRMs).
- Require new and substantially improved homes and manufactured homes to be elevated above the BFE.
- Require non-residential buildings to be elevated above the BFE or dry floodproofed.
- Determine if damaged buildings are substantially damaged.
- Conduct field inspections, cite and remedy violations.
- Require and maintain surveyed elevation information to document compliance.
- Carefully consider requests for variances.
- Resolve noncompliance and violations of floodplain management requirements.
- Advise and work with FEMA and the Planning Board when updates to flood maps are needed.

- Maintain records for review and respond to periodic requests for reports to FEMA.

CHANGES IN PARTICIPATION

All 78 municipalities in Puerto Rico participate in the NFIP. The NFIP groups these municipalities into five NFIP communities: Guaynabo, Bayamón, Carolina, Ponce, and Añasco.[1083] There has been a noticeable increase in NFIP policies in force following Hurricanes Maria and Fiona, largely due to insurance requirements tied to mortgage lending.

Table 127 lists each NFIP community and the number of policies in force as of the writing of this document.

Table 127: NFIP Policies in Force by Community Identification Number, Puerto Rico[1084]

NFIP Communities (Identification Number, CID)	Number of Policies in Force
Guaynabo Municipio (CID# 720034)	0
Bayamón Municipio (CID#720100)	47
Carolina Municipio (CID#720102)	0
Ponce Municipio (CID#720101)	262
Añasco Municipio (CID# 720003), Aguada Municipio (CID#720002), Adjuntas Municipio (CID#720001)	3,393
Total NFIP Policies	**3,702**

Of the 78 municipalities in Puerto Rico, one NFIP community contains 74 municipalities, while the remaining four are independent NFIP communities.[1085] Currently, nine municipalities have a designated Special Flood Hazard Area (SFHA). In the Estuario de la Bahía de San Juan basin, 14.6% of Carolina's area is flood-prone. In Loíza, flood zones occupy 11.7% of the area, followed by San Juan (10.6%), Cataño (4.73%), and Guaynabo (1.46%).[1086]

Flood insurance is an important tool that communities can use to support post-disaster recovery. Between 2000 and 2024, there were 1,414 NFIP claims paid out island wide, totaling $22,608,406.72.[1087]

[1083] Federal Emergency Management Agency (FEMA), "Community Status Book – Puerto Rico," 2025, https://www.fema.gov/flood-insurance/work-with-nfip/community-status-book.
[1084] FEMA, "National Flood Insurance Program Policies in Force – Puerto Rico," 2025, https://www.fema.gov/about/openfema/data-sets#nfip.
[1085] FEMA, "Public Facilities Infrastructure Recovery and Resiliency: Puerto Rico Programmatic Environmental Assessment," 2022, https://www.fema.gov/sites/default/files/documents/fema_dr-4336-4339-4473-public-facilities-pea_08182022.pdf.
[1086] Estuario.org, "Flood Zones," 2025, https://estuario.org/flood-zones/.
[1087] FEMA, "Historical NFIP Claims Information and Trends – Puerto Rico (2000–2024)," 2025, https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=2000&maxy=2024&county=&gtype=tstate.

Figure 292 shows the number of NFIP claims submitted each year, ranging from zero claims to 800 claims, with the maximum number of claims submitted in 2004, 2008, and 2017 (after Hurricane Maria).

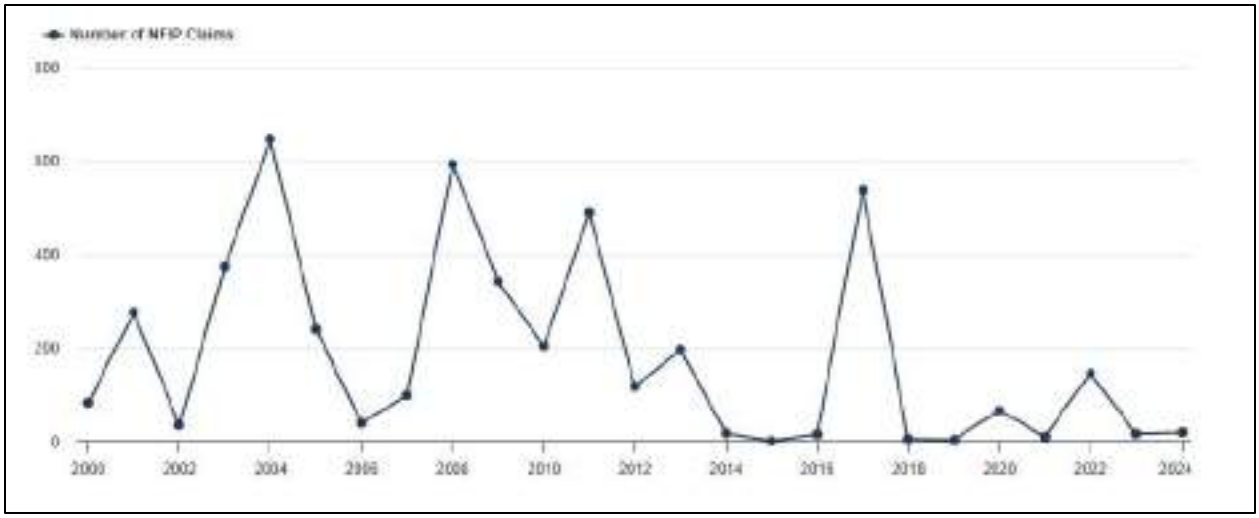

Figure 292: NFIP Claims for Puerto Rico, 2000–2024[1088]

Figure 293 shows a map of NFIP claims paid out (in dollars) by municipality. The legend indicates that between 2000 and 2024, Arecibo and Toa Baja received combined payouts ranging from $2,565,255.59 to $4,755,459.85. Other municipalities with NFIP claims are represented using the color coding provided in the legend.

Figure 294 shows a map of NFIP claims paid out by total number of claims per municipality. According to the legend, between 2000 and 2024, Arecibo, Toa Baja, and Carolina each had between 125 and 251 claims paid out. Other municipalities are also represented using the legend's color coding.

[1088] FEMA, "Historical NFIP Claims Information and Trends – Puerto Rico (2000–2024)," 2025, https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=2000&maxy=2024&county=&gtype=tstate.

Figure 293: Puerto Rico NFIP Total Paid Claims (Dollars) by Municipality[1089]

[1089] FEMA, "Historical NFIP Claims Information and Trends – Puerto Rico (2000–2024)," 2025, https://www.floodsmart.gov/historical-nfip-claims-information-and-trends?map=countries/us/us-pr-all&region=pr-3614&miny=2000&maxy=2024&county=&gtype=tstate.

Figure 294: Puerto Rico NFIP Total Paid Claims (Number of Claims) by Municipality

Table 128 presents data from the NFIP Policy and NFIP Claims FEMAOpen datasets for Puerto Rico, sorted and presented based on the five NFIP Communities and assigned NFIP Community Identification Number. The data provided shows the date the community entered the NFIP, the number of policies in force (as of December 9, 2025), the total policy coverage amount (building and contents), the property type (single-family/multi-family), the flood hazard zone, (A, AE, X, etc.), the number of NFIP claims filed since date of initial participation, total cost of annual premiums, average claims paid out and total claims paid out in dollars.

DRAFT

Table 128: National Flood Insurance Program Policy and Claims Information for Puerto Rico[1090]

Community Name	Community Number	Date Entered NFIP[1091]	#Policies In Force	Total Policy Coverage ($)	Property Type	Flood Hazards Zones	Number of Claims	Total Cost of Annual Premiums	Average Claims Paid Out ($)	Total Claims Paid Out ($)
Municipality of Bayamon	CID#720100	8/1/1978	0	$1,287,600	Single Family (9)	AE, X	5	$3,474	$12,555.45	$62,777.27
Municipality of Guaynabo	CID# 720034	11/18/2009	0	$129,000	Multi-Family (1)	AE	1	$654	$0	$0
Municipality of Ponce	CID#720101	8/1/1978	0	$2,555,000	Single Family (19) Multi-Family (1);	A, AE, AO, X	20	$7,075	$4,719.04	$94,380.82
Municipality of Carolina	CID#720102	11/18/2009	0	$95,000	Single Family (1)	AE	1	$381	$0	$0
Municipalities of Añasco, Aguada, Adjuntas (CID720000)	CID# 720003, CID#720002, CID#720001	8/1/1978	0	$71,569,800	Single Family (2,967) Multi-Family-<4 units=1,403)	A, A99, AE, AO, C, VE, X	4,370	$232,611	$4,577.63	$20,004,254.86

[1090] FEMA, "OpenFEMA Datasets: FIMA NFIP Redacted Policies and FIMA NFIP Redacted Claims-Puerto Rico", 2025, https://www.fema.gov/about/openfema/data-sets#hazard.
[1091] FEMA, "Community Status Book – Puerto Rico," 2025, https://www.fema.gov/flood-insurance/work-with-nfip/community-status-book.

RISK RATING 2.0

On April 1, 2023, as part of the NFIP, FEMA implemented Risk Rating 2.0—a new methodology for calculating flood insurance premiums that provides a more individualized assessment of flood risk for properties. This updated pricing approach enables communities leverage advanced technology and data to assess individual property-level flood risk more accurately, compared to the previous system, which relied heavily on flood zones and elevation data.[1092]

Risk Rating 2.0 offers rates that more accurately reflect flood risk and help ensure the NFIP's long-term sustainability. It has fundamentally changed the way FEMA prices insurance and evaluates individual property-level flood risk. Under Risk Rating 2.0, individuals now pay flood insurance premiums based on the valuation of their homes. Two-thirds of policyholders are seeing a decrease in premiums.[1093]

Figure 295 highlights 2021 NFIP policies in force in Puerto Rico with the greatest need for premium reduction assistance. The new Risk Rating 2.0 methodology provides policyholders with an opportunity to implement mitigation measures—especially those transitioning toward full risk-based premiums—to help reduce their current costs. Of those NFIP policies, 5,933 are at full risk, 1,008 are pre-FIRM subsidized, 49 are in high-risk coastal zones, 759 are preferred risk policies, and 240 are in newly mapped areas.[1094]

[1092] FEMA, "NFIP's Pricing Approach," 2025, https://www.fema.gov/flood-insurance/risk-rating.
[1093] FEMA, "Puerto Rico – Risk Rating 2.0," 2021, https://www.fema.gov/sites/default/files/documents/fema_puerto-rico-profile_2021.pdf.
[1094] FEMA, "Puerto Rico – Risk Rating 2.0," 2021, https://www.fema.gov/sites/default/files/documents/fema_puerto-rico-profile_2021.pdf.

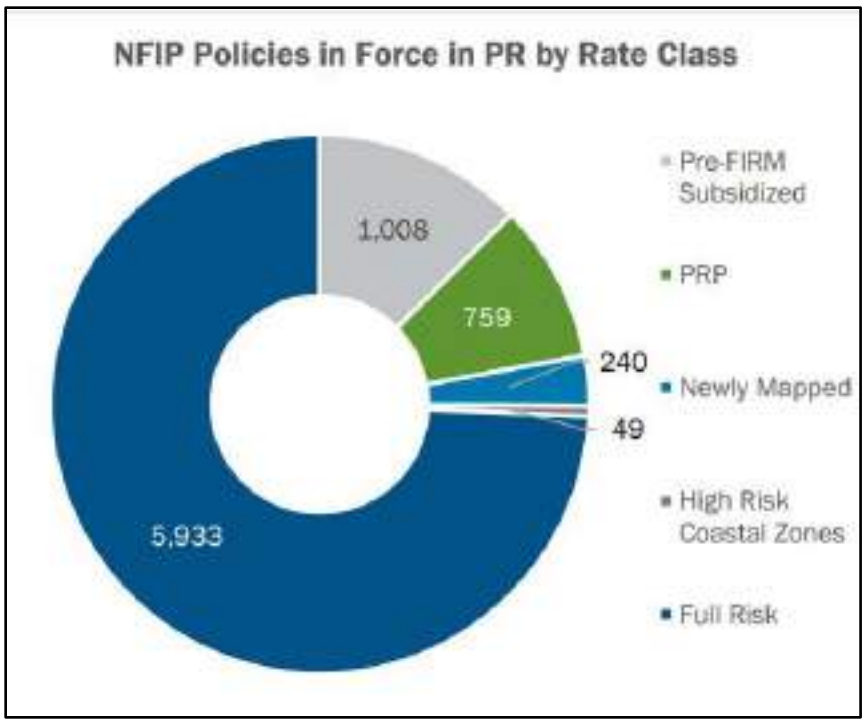

Figure 295: National Flood Insurance Program Policies in Force in Puerto Rico by Rate Class[1095]

COMMUNITY RATING SYSTEM

The NFIP recognizes communities that achieve enhanced flood resiliency above the NFIP standards by providing policyholders with reduced flood insurance premiums through the Community Rating System (CRS). Communities must apply to participate in CRS and commit to implementing and certifying activities that contribute to reduced flood risk. Examples of actions communities can take to meet CRS requirements and receive a reduced insurance premium include the following:

- Preserving open space in the floodplain
- Enforcing higher standards for safer development through zoning, stormwater, subdivision, and flood damage protection regulations
- Developing hazard mitigation plans alongside watershed and storm management plans
- Undertaking engineering studies and preparing flood maps
- Obtaining grants to buy out or elevate houses or to flood-proof businesses
- Maintaining drainage systems
- Monitoring flood conditions and issuing warnings
- Informing people about flood hazards, flood insurance, and how to reduce flood damage

[1095] FEMA, "Puerto Rico – Risk Rating 2.0," 2021, https://www.fema.gov/sites/default/files/documents/fema_puerto-rico-profile_2021.pdf.

Currently, Ponce is the only municipality in Puerto Rico that participates in the CRS. If requested, the Planning Board would be the agency responsible for supporting new communities interested in joining the CRS.

SUBSTANTIAL DAMAGE REQUIREMENTS

A damaged structure in the SFHA is considered substantially damaged (SD) if it requires 50% or more of the market value of the property in repair costs to bring it to its pre-damaged condition. A damaged structure is considered substantially improved (SI) if it requires 50% or more of the market value of the structure to reconstruct, rehabilitate, or make additions or other improvements to the structure in order to bring it into compliance with current local floodplain management standards. Community officials are responsible for making SI/SD determinations before structures are repaired or improved as part of the administration of local floodplain management regulations.

The Hydrology Office is designated as the agency responsible for substantial damage and substantial improvement permitting. The Hydrology Office receives applications, reviews construction documents, issues permit for the erection or alteration of buildings and structures, inspects the premises for which such permits have been issued, and enforces compliance with the provisions of the 2018 Puerto Rico Residential Building Code.[1096]

Substantial damage assessments following flood events are conducted by the Planning Board, including high-water mark documentation. FEMA guidance under Section 1206 of the Disaster Recovery Reform Act (DRRA) allows funding for code enforcement and substantial damage inspections for up to 180 days post-disaster.

FLOOD INSURANCE RATE MAPS

The PRPB maintains a collection of FIRMs that can be consulted to determine whether a property is located in a high-risk area or a low- to moderate-risk area. The FIRMs are the official maps developed and approved by FEMA and adopted by the PRPB to designate 100-year return flood risk zones (areas with a 1% annual chance of flooding). In addition, these maps serve as tools for the management of special areas due to their susceptibility to flooding.

RISK MAPPING ASSESSMENT AND PLANNING PROGRAM

The Planning Board, as the state coordinating agency for the NFIP administered by FEMA, supports FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) Program through a structured and ongoing coordination process. Communications with FEMA Region 2 and local communities are carried out through regularly scheduled coordination meetings, technical work sessions, and follow-up discussions that ensure progress on Risk MAP activities. These engagements take place both virtually and in person, enabling real-

[1096] ICC Digital Codes, "2018 Puerto Rico Residential Building Code," 2020, https://codes.iccsafe.org/content/PRRC2018/chapter-1-scope-and-administration#PRRC2018_Pt01_Ch01_SubCh1.

time collaboration among FEMA specialists, Planning Board staff, municipal representatives, and emergency management officials.

In addition to meetings, the exchange of geospatial and technical data is facilitated through secure platforms such as OneDrive, which allows the Planning Board and its partners to share map products, study updates, and supporting documentation efficiently. This coordinated approach enables the Planning Board to serve as the primary liaison between local communities and FEMA, ensuring that Risk MAP project milestones, outreach activities, and mapping questions are addressed throughout the process.

The Planning Board and the NFIP Coordinator organize and participate in local Risk MAP meetings, promote flood mitigation actions, and provide technical assistance related to flood mapping and risk information, responding to questions that may arise during outreach and project implementation. They collaborate with FEMA and municipalities to complete Risk MAP projects, share data, and address questions about flood zone designations.

Local floodplain managers initiate the process to identify areas that need to be studied or restudied as part of the Risk MAP program. The State will assist by answering questions from floodplain managers as well as setting up public meetings in conjunction with FEMA and the mappers completing the work. The State will also track the maps throughout the process to completion.

The Hydrology Office is responsible for implementing flood ordinances, managing and enforcing flood maps (including Regulation No. 13), conducting community outreach, and supporting building code compliance across Puerto Rico.

Municipal floodplain management for 74 municipalities is coordinated by the Hydrology Director and the Hydrology Engineer. The municipalities of Ponce, Bayamón, Guaynabo, and Carolina maintain their own floodplain management programs.

COMMUNITY OUTREACH PROGRAM

The Planning Board supports local engagement through a variety of outreach efforts, including the following:

- Regulation No. 13 and “causa mayor” are used as outreach frameworks.
- The Planning Board’s flood portal allows residents to input parcel numbers to assess flood risk levels.
- Success stories and local experiences are often shared via social media channels.
- Event photos or documentation of past occurrences are requested to highlight local successes.

ADVISORY BASE FLOOD ELEVATION MAPS

Following Hurricane Maria, FEMA, in coordination with the PRPB, developed new flood zone maps to provide the most up-to-date flood information available. These maps, known as Advisory Base Flood Elevation (ABFE) Maps, show the recommended base flood levels developed for Puerto Rico, corresponding to the 1% annual chance flood.

They identify newly designated flood zones, based on analyses and data from the effects of Hurricane Maria. Their primary objectives are to provide data based on the best information available, guide elevation decisions for rebuilding structures, minimize future flood damage, and establish which portions of communities are within the new flood zones.

ABFE Maps were developed using modern engineering methods, but they do not replace the current effective FIRMs for insurance-related matters. They include updated estimates of the following annual chance flood elevations:

- **Coastal:** 0.2%, 1%
- **Riverine:** 0.2%, 1%, 2%, 4%, and 10%

These estimates often reflect higher flood elevations than those shown on current effective FIRMs and extend beyond the SFHAs they depict.

ABFE Maps offer critical benefits for reconstruction and recovery efforts by providing more accurate, post-disaster flood data. Because they reflect current flood risks more effectively than existing FIRMs, elevating structures above the advisory BFEs can reduce flood risk and improve long-term investment outcomes for rebuilding homes affected by hurricanes.

In Puerto Rico, the adoption process for the ABFE Maps started on March 23 and ended on July 12, 2018, with their adoption via Administrative Order JP-ABFE-02. The process included 13 meetings related to ABFE Maps, using PREMB zones; municipal planners, permitting officials, and first responders; state agencies; realtors; and communities.

The main changes reflected in the ABFEs are focused on the Coastal A Zone, which includes areas of coastal flood hazard with an annual probability of 1% annual chance of flooding. These areas are subject to wave heights between 1.5 and 3 feet, where waves can cause damage to certain structures and are not currently identified in Puerto Rico's FIRMs. ABFE Maps introduce this designation, along with the Limit of Moderate Wave Action (LiMWA), which marks the inland extent of the Coastal A Zone.

In addition, the parameters established for the VE Zone in Regulation No. 13 also apply to any new construction or substantial improvement within the Coastal A Zone. Additional changes identified in the ABFE Maps include the following:

- Zone A areas now display ABFEs.
- Some X Zones have been reclassified as AE Zones.
- Some AE Zones have been reclassified as Coastal A Zones.
- Newly mapped areas have been added to the SFHA.

The purpose of these maps is to serve as a tool for professionals in charge of developing new communities, enabling them to make informed decisions based on possible settlement locations, infrastructure needs, and vulnerability to flooding. These maps are not a substitute for the FIRMs used for flood insurance determinations under the NFIP.

REPETITIVE AND SEVERE REPETITIVE LOSS PROPERTIES

Repetitive loss (RL) properties are documented as part of the NFIP. An RL property is an NFIP-insured building that has had two or more claims of more than $1,000 paid by the NFIP within any rolling 10-year period since 1978. An RL property may or may not currently be insured by the NFIP. As summarized in the Flood Hazard Profile, between 2000 and 2024, there have been 790 RL claims have been paid. RL buildings are eligible for the NFIP Flood Mitigation Assistance (FMA) Grant Program.[1097] A severe repetitive loss (SRL) building is defined by FEMA as any building covered under a standard flood insurance policy and that has either:

9. Incurred flood damage for which four or more separate claim payments have been made under a flood insurance policy, with the amount of each claim exceeding $5,000 and with the cumulative amount of the claim payments exceeding $20,000; or
10. Had at least two separate claim payments have been made under a flood insurance policy, with the cumulative amount of claim payments exceeding the fair market value of the property.

According to the PRPB and NFIP, there are 2,320 RL and SRL properties, but only 79 are insured and 37 have been mitigated. NFIP reports 2,134 RL and 215 SRL properties, while FMA lists 72 RL and 226 SRL, with total net payments of $140.4 million (see Flooding profile for more details).

Legal Authority

Legal authority spans emergency management, recovery, land-use/permitting, environmental review, coastal management, and municipal authorities.

- **Law No. 20-2017:** At the core, PREMB operates within the DSP under Law 20-2017, which establishes PREMB authority to direct emergency management across preparedness, response, mitigation, and recovery throughout the island.
- **OE-2017-65:** Long-term disaster recovery and mitigation funding coordination is led by COR3, which was created by this Executive Order (OE-2017-65) and housed within the P3 Authority. COR3 steers the implementation of Puerto Rico's recovery plan and oversees transparency for FEMA and other funds that often integrate mitigation components.
- **Law No. 75-1975:** Land use, permitting, and building safety are governed by a combination of Planning Board statutes and permit reform laws that created the Oficina de Gerencia de Permisos (OGPe). The Planning Board Organic Act (Law No. 75-1975) authorizes the island wide Land Use Plan and requires consistency between public works and adopted plans.
- **Law No. 19-2017:** The permit system is structured under Law 161-2009 (Permit Reform), as amended by Law 19-2017, which formalized the OGPe and the role of Profesionales Autorizados, and ties environmental compliance into the permit process. The Puerto Rico Building Code (PRBC) is

[1097] FEMA, "OpenFEMA Dataset: NFIP Multiple Loss Properties – v1," 2025, https://www.fema.gov/openfema-data-page/nfip-multiple-loss-properties-v1.

administered through OGPe and the International Code Council (ICC)-based codes adopted for Puerto Rico.

  - *Note:* The 2019/2020 Joint Regulations (*Reglamento Conjunto*, RC) underwent litigation and were annulled by the Puerto Rico Supreme Court in 2023, so planners should verify the currently effective permitting rules and any re-adoption actions before citing specific RC provisions.

- **Law No. 416-2004:** Environmental compliance for government actions is required under the Puerto Rico Environmental Public Policy Act (Law 416-2004) and its Regulation 8858 (2016), titled *Reglamento para el Proceso de Evaluación Ambiental*, which sets procedures for Environmental Assessments and Environmental Impact Statements. Under current law, OGPe directs the environmental document review process (including municipal submissions) through its Environmental Compliance Division.
- **DRNA Regulation No. 4860:** Coastal resources and projects within or affecting the Zona Marítimo-Terrestre and coastal waters are regulated by the Department of Natural and Environmental Resources (DRNA). DRNA Regulation No. 4860 governs the maritime-terrestrial zone, as well as Puerto Rico's Coastal Zone Management Program (PRCZMP), adopted in 1978 and administered by DRNA, which requires federal consistency and guides coastal hazard mitigation planning, erosion management, and resilience measures.
- **Law No. 81-1991:** Municipal roles are substantial. The former Autonomous Municipalities Act (Law No. 81-1991) has been superseded by the Municipal Code (Law No. 107-2020); municipalities may adopt land-use plans, receive delegated permitting powers, maintain Local Hazard Mitigation Plans (LHMPs), and implement mitigation actions consistent with Puerto Rico's and federal requirements. (Note: Law 81 authorized the delegation framework later reflected in coastal and planning documents; verify current delegation status under Law 107-2020 for any given municipality.)

Together, these authorities frame how mitigation actions are identified (Planning Board [JP]/Puerto Rico State Agency for Emergency and Disaster Management [NMEAD], and municipal LHMPs), permitted (OGPe/municipal permitting), environmentally reviewed (Law No. 416 and Regulation No. 8858), aligned with building and coastal standards (PRBC; DRNA 4860; PRCZMP), and funded/implemented (COR3/FEMA/other programs). A summary of these authorities is provided in Table 129.

Table 129: Key Puerto Rico Hazard Mitigation Authorities[1098]

Authority/Instrument	Admin/Lead	What it Covers (for HM Planning)	Practical Requirements/ Notes
Law No. 20-2017 (DPS/PREMB)	DPS/PREMB	Establishes DPS; integrates emergency management leadership and coordination with FEMA programs.	Confirm PREMB coordination for HMGP/BRIC pipelines; align project approvals with DPS/agency roles.

[1098] APA: Administrative Procedure Act, ASCE: American Society of Civil Engineers, BCA: Benefit-Cost Analysis, BFE: Base Flood Elevation, BRIC: Building Resilient Infrastructure and Communities, CFR: Code of Federal Regulations, CZM: Coastal Zone Management, DPS: Department of Public Safety, DRNA: Department of Natural and Environmental Resources, EO: Executive Order, ESA: Endangered Species Act, FEMA: Federal Emergency Management Agency, FIRMs:

Authority/Instrument	Admin/Lead	What it Covers (for HM Planning)	Practical Requirements/ Notes
Law No. 161-2009 (Permitting Reform), as amended including Law No. 19-2017	PRPB and OGPe	Creates the modern permit system; joint regulations; Authorized Professionals; Single Business Portal.	All mitigation projects must pass OGPe/municipal permit tracks; cite joint regulations in scope/eligibility.
Puerto Rico Building Code (PRBC 2018; ICC-based)	OGPe/PRPB	Structural, wind, flood, and critical facility design standards used in permits and retrofits.	Reference PRBC loads (ASCE wind, flood) in BCA/scope; adoption supersedes prior regulations; grace period noted by ICC.
Planning Regulation No. 13 (Eighth Revision, effective Jan. 9, 2021)	PRPB/OGPe; Municipal FPMs	NFIP-aligned floodplain management (SFHAs, FIRMs, BFE/freeboard, SD/SI, variances).	Document FIRM panel/BFE; apply SD/SI thresholds; variance findings; Spanish original available.
Law No. 107-2020 (Puerto Rico Municipal Code), as amended	Municipalities	Consolidates municipal powers including autonomous planning/ permitting and plan consistency.	Verify autonomous municipality status; ensure LHMP actions align with local land-use plans.
Coastal Zone Management Program (NOAA/DRNA)	DRNA (Lead CZM)	Federal consistency for coastal projects; erosion/ shoreline access; habitat; resilience.	Coastal projects require CZM consistency; coordinate USACE/DRNA permits where applicable.
Law No. 38-2017 (Uniform Administrative Procedure Act)	All Puerto Rico agencies	Rulemaking procedures for adopting/updating regulations (permit rules, codes, ordinances).	Use LPAU for new floodplain ordinances/joint regulations; allows alignment with federal APA to protect funding.
FEMA Planning & Cross-cutters (44 CFR Part 201; NEPA, NHPA, ESA; EO 11988/11990; NFIP 44 CFR 59–78)	FEMA/ applicant agencies	State plan standards; environmental/historic/ wildlife compliance; floodplain and wetlands policy.	Maintain environmental review records; tie LHMP priorities to compliant project scopes.

Flood Insurance Rate Maps, FPMs: Floodplain Managers, HM: Hazard Mitigation, HMGP: Hazard Mitigation Grant Program, ICC: International Code Council, LHMP: Local Hazard Mitigation Plan, LPAU: Ley de Procedimiento Administrativo Uniforme, NEPA: National Environmental Policy Act, NFIP: National Flood Insurance Program, NOAA: National Oceanic and Atmospheric Administration, OGPe: Oficina de Gerencia de Permisos, PR: Puerto Rico, PRBC: Puerto Rico Building Code, PREMB: Puerto Rico Emergency Management Bureau, PRPB: Puerto Rico Planning Board, SD/SI: Substantial Damage/Substantial Improvement, SFHAs: Special Flood Hazard Areas, USACE: U.S. Army Corps of Engineers

Land Use

LEGAL FOUNDATION AND INSTITUTIONS

Puerto Rico's land use authority is established in Title 21, Subtitle 6, Chapter 225, of the Laws of Puerto Rico (Land Use and Territorial Ordinance Act/Ley de Municipios Autónomos). This statute empowers the following entities: the Puerto Rico Planning Board (Junta de Planificación, PRPB) to set islandwide policies, adopt territorial plans, and ensure consistency across jurisdictions; municipal governments to adopt Planes de Ordenación Territorial (POTs, Ordinance Plans) that regulate local zoning, density, and land use consistent with Puerto Rico's policies; and the OGPe, created by Act 161-2009, to implement permitting aligned with PRPB and municipal plans.[1099]

PRPB's central role derives from the Planning Board Organic Act of 1975 (Law No. 75-1975), which designates the Board as Puerto Rico's lead authority for long-range spatial planning, zoning, and infrastructure coordination. The Puerto Rico Municipal Code (Act 107-2020) updates municipal powers and procedures of municipalities for assuming planning and permitting functions, maintaining the compatibility requirement with Puerto Rico's plans.[1100]

The Puerto Rico Land Use Plan, Plan de Uso de Terrenos (PUTPR), adopted by PRPB Resolution JP-P-2015-38, provides the primary spatial framework for Government-level land classification and policy.[1101] The PUTPR establishes five principal categories: **Urban, Planned Developable, Non-Scheduled Developable, Common Rustic,** and **Specially Protected Rustic**—which guide where growth can occur and where conservation or risk avoidance is prioritized. An updated, comprehensive PUTPR revision (2025) is underway and pending adoption. The revision integrates FEMA Risk MAP flood data, coastal/erosion mapping from DRNA, landslide susceptibility from UPRM (SLIDES), and PRCCC climate change scenarios, and aligns territorial policy with infrastructure planning by the Department of Transportation and Public Works/Infrastructure Financing Authority (DTOP/AFI) and other sector agencies.[1102]

ZONING, PERMITTING, AND INFRASTRUCTURE IMPLICATIONS

Land use controls regulate where specific uses are allowed, the intensity of those uses, and the conditions of approval (e.g., setbacks, buffers, elevation, nature-based measures. Through OGPe's electronic system, hazard and environmental layers are used during permit review to flag sites within floodplains, coastal erosion bands, landslide-susceptible slopes, and other constrained areas, enabling risk-informed approvals. These controls directly affect infrastructure siting and design by steering investments to lower-risk locations and conditioning projects to meet resilience standards.

[1099] Laws of Puerto Rico, Title 21, Subtitle 6, Chapter 225 – Land Use and Territorial Ordinance Act (Ley de Municipios Autónomos).
[1100] Act No. 161-2009 – Puerto Rico Permit Management Reform Act (OGPe).
[1101] Planning Board Organic Act of 1975 (Act No. 75-1975, 23 L.P.R.A. § 62 et seq.).
[1102] PRPB Resolution JP-P-2015-38 – Adoption of the Puerto Rico Land Use Plan (PUTPR).

COASTAL MANAGEMENT

Puerto Rico's coast is governed by the Zona Marítimo Terrestre (ZMT) under DRNA Regulation No. 4860, which defines the public maritime-terrestrial domain and prohibits unauthorized occupation or construction in areas affected by tides, storm surge, or sea level rise.[1103] DRNA maintains a parcel-level boundary certification process (deslindes ZMT), and in 2024 established a reference system to standardize ZMT delineation for planning and permitting.[1104]

The DRNA Coastal Erosion Maps and NOAA-supported shoreline-change analyses identify areas prone to chronic erosion or storm-driven retreat; these datasets are integrated into the PUTPR and municipal POTs to inform zoning, setbacks, and infrastructure siting. Functionally, the erosion maps extend the ZMT concept inland by highlighting future exposure zones, allowing PRPB, DRNA, and OGPe to prevent maladaptive development, reduce repetitive-loss exposure, and protect dunes, mangroves, and other natural buffers.[1105] DRNA has publicly clarified that a single, islandwide ZMT "national deslinde" is not currently viable; boundary work proceeds through ongoing certifications, reflecting the dynamic nature of the coast (erosion, storms, sea level rise).

MUNICIPAL IMPLEMENTATION AND CAPACITY

Most municipalities have approved or are revising POTs under Title 21 to align local zoning with Government policy.[1106] PRPB and OGPe provide technical assistance, model ordinances, and Geographic Information System (GIS) tools to municipal planners and permitting officers, supporting the integration of flood, erosion, and landslide constraints into local land-use maps and development standards.

The land-use framework is a core non-structural mitigation capability; it restricts high-risk development, preserves ecological buffers and agricultural lands (pervious cover, recharge areas), and aligns growth with lifeline infrastructure placement. The PUTPR update embeds climate adaptation by integrating PRCCC scenarios and coastal-hazard policies under the Coastal Zone Management Program (CZMP). Implementation is coordinated with the FOMB's PROMESA Fiscal Plan, aligning capital investment (roads, energy, water, education) with risk-informed land-use priorities to avoid future damages as well as operations and maintenance burdens.

Anchored in Title 21, Subtitle 6, Chapter 225, implemented through the PUTPR (2015; 2025 update pending), municipal POTs, OGPe permitting, and DRNA coastal/ZMT authorities, Puerto Rico's land-use system

[1103] Department of Natural and Environmental Resources (DRNA), *Regulation No. 4860 – Regulation for the Delineation and Management of the Maritime-Terrestrial Zone*, adopted December 1992, https://www.drna.pr.gov/oficinas/division-de-recursos-terrestres/.
[1104] Department of Natural and Environmental Resources (DRNA), "Official Reference System for the Delineation of Public Domain Assets in the Maritime-Terrestrial Zone," November 10, 2024, https://www.drna.pr.gov/avisos/sistema-de-referencia-oficial-para-el-deslinde-de-bienes-de-dominio-publico-maritimo-terrestre/.
[1105] Department of Natural and Environmental Resources (DRNA), "Ongoing ZMT Boundary Certifications; Island-Wide 'National Deslinde' Not Currently Viable," *Metro Puerto Rico*, October 22, 2025.
[1106] Laws of Puerto Rico, Title 21 – Autonomous Municipalities Act (Land Use and Territorial Ordinance), Chapter 225.

provides a unified legal and technical framework that directly supports hazard mitigation goals, risk-aware infrastructure planning, and climate adaptation.

Building Codes

Puerto Rico's building code framework is one of the Government's most significant mitigation capabilities. Through the PRBC 2018, adopted under Regulation No. 9049, the Government of Puerto Rico establishes minimum standards for design, construction, and occupancy to safeguard life, property, and public welfare from hurricanes, floods, earthquakes, and other natural hazards. The PRBC is based on the 2018 International Codes (I-Codes) published by the ICC and incorporates design standards from the American Society of Civil Engineers (ASCE 7-16 and ASCE 24-14) for wind, seismic, and flood loads.[1107]

INSTITUTIONAL FRAMEWORK AND CODE REVIEW PROCESS

In the aftermath of Hurricane Maria (2017), Puerto Rico strengthened its approach to resilient construction by establishing the Construction Codes Review Committee in 2018 under the coordination of the OGPe, in collaboration with the PRPB.[1108] The Committee functions as a technical advisory body responsible for reviewing new editions of the I-Codes, recommending local amendments that reflect Puerto Rico's hazard conditions, and maintaining a three-year review cycle to ensure continuous alignment with evolving structural, flood, wind, and seismic design standards. Professional input is supported by the College of Engineers and Land Surveyors of Puerto Rico (CIAPR) and other professional organizations, which participate in code-review discussions and disseminate official interpretations and guidance to practitioners. CIAPR publishes technical guidance and orientation manuals on hurricane, flooding, landslide, and seismic preparedness that help engineers and surveyors apply mitigation principles in design.[1109] Administrative orders and committee documentation, including OGPe Administrative Order 2021-04, can be accessed through the OGPe Information Portal (www.permisos.pr.gov).

PERMITTING, ENFORCEMENT, AND LOCAL IMPLEMENTATION

The OGPe, created by the Permit Reform Act (Law No. 161-2009, as amended by Law No. 19-2017), is the central permitting and code-enforcement authority.[1110] OGPe issues construction and occupancy permits, performs plan reviews, and conducts inspections to ensure compliance with the PRBC and related codes. It delegates these powers to 19 autonomous municipalities authorized to manage their own local permit offices and enforce building codes directly (see Table 130).

[1107] International Code Council, Puerto Rico Codes 2018 (Regulation No. 9049, effective November 15, 2018).
[1108] U.S. Congressional Research Service, *The Status of Puerto Rico's Recovery and Ongoing Challenges Following Hurricanes Irma and María: FEMA, SBA, and HUD Assistance* (R46609), https://www.congress.gov/crs-product/R46609
[1109] Colegio de Ingenieros y Agrimensores de Puerto Rico (CIAPR), *Comunicado 2018-05 – Amendment Process for the Puerto Rico Building Code; and Technical Guidance and Orientation Manuals*, 2018.
[1110] Permit Reform Act (Law 161-2009); Law 19-2017 (Reorganization of OGPe).

Table 130: Autonomous Municipalities with Delegated Permitting Authority in Puerto Rico, 2025

Number	Municipality	Administrative Region
1	San Juan	San Juan Metropolitan Region
2	Bayamón	Northern Region
3	Carolina	San Juan Metropolitan Region
4	Ponce	Southern Region
5	Caguas	East-Central Region
6	Guaynabo	San Juan Metropolitan Region
7	Mayagüez	Western Region
8	Arecibo	North-Central Region
9	Fajardo	Eastern Region
10	Cayey	Central Mountain Region
11	Aguadilla	Northwestern Region
12	Cidra	Central Region
13	San Germán	Southwestern Region
14	Toa Baja	Northern Coastal Region
15	Vega Baja	Northern Coastal Region
16	Gurabo	East-Central Region
17	Hormigueros	Western Region
18	Barceloneta	Northern Region
19	Coamo	South-Central Region

Each of these municipalities operates a local permitting office, with a designated Building Official serving as the Authority Having Jurisdiction (AHJ) for construction activities. OGPe retains direct oversight of permitting functions for the remaining 59 municipalities. The PRPB complements OGPe's role by regulating land use and flood-hazard areas through Regulation No. 13: Special Flood Hazard Areas, and by serving as the State Coordinating Agency for the NFIP.[1111]

[1111] Puerto Rico Planning Board (PRPB), *Special Flood Hazard Areas Regulation (Regulation No. 13), Eighth Revision*, effective January 9, 2021, Puerto Rico Planning Board (PRPB), *Regulation* https://www.scribd.com/document/838800861/22966-Reglamento-de-inundaciones-Feb-2021-English-RM-JP-Rev-3-29-21-Final-RM-cert.

CODE APPLICATION AND MITIGATION INTEGRATION

Puerto Rico's building codes form a unified system that integrates hazard-specific mitigation measures into construction practice. Structural engineers, architects, and surveyors licensed through CIAPR certify code compliance during design and construction phases. Key requirements include the following:

- **Wind and Hurricane Resistance**: PRBC 2018 adopts ASCE 7-16 wind-load provisions (up to 145 mph in coastal exposure zones) and debris-impact protection.
- **Flood Resilience:** PRBC references ASCE 24-14, mandating elevation of structures at or above BFE plus freeboard, flood-resistant materials, and anchoring to resist buoyancy and lateral forces. PRPB's Regulation No. 13 enforces Substantial Damage/Substantial Improvement (SD/SI) provisions requiring damaged buildings in SFHAs to be rebuilt to current standards.
- **Seismic Safety:** The PRBC applies ASCE 7-16 seismic provisions, requiring ductile detailing for essential facilities.
- **Energy and Lifeline Systems:** Incorporates the 2018 International Energy Conservation Code (IECC), ASHRAE Standard 90.1 (developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers), 2018 International Plumbing Code (IPC), and NFPA 70 (National Electrical Code, 2017 edition) for resilient energy and mechanical systems.

During post-disaster reconstruction, all FEMA-funded projects under Public Assistance (Section 406), HMGP, or Community Development Block Grant–Mitigation Disaster Recovery (CDBG-MIT/DR) must comply with the current PRBC. COR3 coordinates with OGPe and FEMA to confirm compliance, embedding hazard-resistant design in every federally funded recovery project.

RELATIONSHIP TO HAZARD MITIGATION

The enforcement of modern building codes serves as one of Puerto Rico's primary hazard mitigation strategies. By embedding wind-, flood-, and seismic-resistant standards directly into construction practices, the PRBC ensures that mitigation principles are systematically applied to all new development and reconstruction efforts. Compliance with requirements such as elevation above BFE, design for Category 4 hurricane wind speeds, and seismic ductility provisions reduces structural vulnerability and enhances community resilience. Through OGPe's centralized enforcement, PRPB's integration of floodplain management, and the participation of the 19 autonomous municipalities, Puerto Rico ensures that hazard-resistant design is institutionalized across all permitted construction activities.

PUERTO RICO CURRENT BUILDING CODE 2018

Puerto Rico's current building-code framework is based on 10 ICC model codes adopted under Regulation No. 9049. Collectively known as the Puerto Rico Codes 2018, these codes establish the island's minimum design and construction standards for structural, mechanical, energy, plumbing, fire, and maintenance systems—integrating hazard-resistant provisions for wind, flood, and seismic safety (see Table 131).

Table 131: Puerto Rico Codes 2018 – Adopted Building Code Package[1112]

Number	Code Title	Based On	Scope/Function
1	Puerto Rico Building Code 2018	International Building Code 2018	Structural design, occupancy, wind/flood/ seismic loads
2	Puerto Rico Residential Code 2018	International Residential Code 2018	One- and two-family dwellings (three stories or fewer)
3	Puerto Rico Energy Conservation Code 2018	IECC 2018 and ASHRAE 90.1-2016	Energy efficiency for buildings and systems
4	Puerto Rico Existing Building Code 2018	IEBC 2018	Repairs, alterations, and occupancy changes
5	Puerto Rico Plumbing Code 2018	IPC 2018	Water supply, drainage, storm systems
6	Puerto Rico Mechanical Code 2018	IMC 2018	HVAC systems, ventilation, refrigeration
7	Puerto Rico Fuel Gas Code 2018	IFGC 2018	Gas piping, combustion air, venting
8	Puerto Rico Fire Code 2018	IFC 2018	Fire prevention, suppression, hazardous materials
9	Puerto Rico Wildland–Urban Interface Code 2018	IWUIC 2018	Construction and defensible-space standards in WUI areas
10	Puerto Rico Property Maintenance Code 2018	IPMC 2018	Maintenance standards for existing buildings

CHALLENGES AND SOLUTIONS

Despite Puerto Rico's robust legal framework, achieving uniform code enforcement across all 78 municipalities remains challenging. Non-autonomous municipalities often face limited staffing capacity and a shortage of certified inspectors in structural, electrical, and floodplain disciplines. Additionally, fiscal controls and permitting backlogs can delay implementation during major recovery periods. Puerto Rico continues to address these challenges through technical support from OGPe, targeted training by CIAPR, and COR3's policy requiring that reconstruction projects comply with current PRBC standards. Together, these measures enhance uniform enforcement and strengthen hazard-resilient design across the island.

[1112] ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers, IBC: International Building Code, IEBC: International Existing Building Code, IECC: International Energy Conservation Code, IFC: International Fire Code, IFGC: International Fuel Gas Code, IMC: International Mechanical Code, IPMC: International Property Maintenance Code, IPC: International Plumbing Code, IRC: International Residential Code, IWUIC: International Wildland–Urban Interface Code, ICC: International Code Council

APPLICATION TO CRITICAL FACILITIES

Puerto Rico applies the current PRBC to the reconstruction and modernization of state-owned critical facilities, including emergency operations centers, health and medical facilities, schools, and essential infrastructure. Through COR3 and FEMA Public Assistance programs, the Government ensures these facilities are built or relocated in compliance with modern hazard-resistant standards, avoiding siting in repetitive-loss or high storm surge areas whenever practicable.

State Funding Capabilities

A comprehensive review of Puerto Rico's mitigation capabilities must include an overview of funding sources that support mitigation programs. The following section outlines both federal and local funding streams that contribute to hazard mitigation planning, implementation, and long-term resilience.

State Resources

Financial capabilities refer to the resources available to fund mitigation actions. Identifying these funding sources is essential for determining what kind of projects are feasible based on their associated costs. Lower-cost mitigation actions, such as outreach programs, can often be implemented using staff time and existing budgets. In contrast, higher-cost initiatives, such as earthquake retrofits, may require substantial investment from local and federal partners. Collaborative partnerships can also play a vital role, including contributions of land, supplies, in-kind services, or direct financial support.

Potential Puerto Rico's government-level funding sources may include any of the following:

- Tax levies
- Capital improvement project funding
- Utility fees
- Impact fees (e.g., fees assessed on homebuyers or developers for new developments)
- General obligation bonds
- Special tax and revenue bonds
- Private activity bonds
- Spending restrictions in hazard-prone areas
- State mitigation grant programs,
- CDBG programs

Table 132 lists Puerto Rico's government-level funding resources available to support mitigation projects.

Table 132: Puerto Rico's Government Funding Resources[1113]

Funding Resources	Description	Lead Agency
Puerto Rico Community Development Block Grant (CDBG) Low-Income Housing Tax Credits Program	A significant portion of the rental population needs housing options capable of mitigating the risks that affect Puerto Rico to the greatest extent possible. PRDOH recognizes that the challenges Puerto Rico faces in recovering from disastrous events are countless opportunities to institute true mitigation measures to address the pressing risk mitigation needs of renters who are disproportionately likely to reside in high-risk areas for flooding and/or landslides.	PRDOH
Puerto Rico State General Fund – Hazard Mitigation Allocation	These are the annual state budget resources allocated by the Puerto Rico Legislature to support mitigation projects, meet requirements for FEMA programs, or implement priority actions in high-risk communities. Funds may include direct appropriations for infrastructure resiliency improvements.	OGP/Legislature
Puerto Rico Capital Improvements Program (CIP)	This CIP is used to finance large-scale infrastructure projects, including resilient water, energy, transportation, and public building improvements that reduce disaster vulnerability.	AAFAF/lead infrastructure agencies
Impact Fees/ Construction Permits (OGPe Revenue)	Fees collected from development projects are reinvested in infrastructure support activities, resilience improvements, and planning, permitting, and compliance inspections that contribute to hazard mitigation capability.	OGPe
Puerto Rico Infrastructure Financing Authority (AFI) – Bonds & Special Revenue Funds	AFI finances construction and major rehabilitation of critical facilities and infrastructure, including bridges, ports, water systems, and public buildings. Financing tools include revenue bonds and capital investment instruments that help fund hazard-resilient design and upgrades.	AFI
Puerto Rico Aqueduct and Sewer Authority	This program supports improvements to public water and wastewater systems to increase resilience against hurricanes, droughts, coastal	PRASA

[1113] AAFAF (Puerto Rico Fiscal Agency and Financial Advisory Authority), ACT (Puerto Rico Highway and Transportation Authority), AFI (Puerto Rico Infrastructure Financing Authority), CDBG (Community Development Block Grant), CIP (Capital Improvements Program), FEMA (Federal Emergency Management Agency), LUMA (LUMA Energy), OGP (Puerto Rico Office of Management and Budget), OGPe (Puerto Rico Permits Management Office), PA (Public Assistance), PREMB (Puerto Rico Bureau for Emergency Management and Disaster Administration), PREPA (Puerto Rico Electric Power Authority), PRASA (Puerto Rico Aqueduct and Sewer Authority), and PRDOH (Puerto Rico Department of Housing)

Funding Resources	Description	Lead Agency
(PRASA) Capital Investment Program	flooding, and landslides through upgrades to pumping stations, storage tanks, and sewer lines.	
Puerto Rico Highway and Transportation Authority (ACT) Resiliency Program	This program funds transportation projects that improve resilient roadway and slope stability systems, drainage, and bridges vulnerable to flooding, landslides, and coastal erosion.	ACT
State Mitigation Grant Programs/Community Preparedness Funding	These programs support community hazard mitigation planning, evacuation resources, emergency shelters, public safety upgrades, and local risk reduction initiatives.	Puerto Rico Bureau for Emergency Management and Disaster Administration (PREMB)
Puerto Rico Electric Power Authority (PREPA) Distributed Energy/Solar Resiliency Programs	These programs support resilient electrical infrastructure, including distributed solar generation and battery backup systems for essential facilities. Funded through capital investment, revenue bonds, operating revenue, and federal programs such as FEMA PA and CDBG-MIT.	PREPA, LUMA, PREMB, AAFAF

The state mitigation funding notification process is managed by COR3, which provides oversight and monitors the HMGP in areas of procurement, recovery strategy, legal and regulatory support, grant claim review, project formulation, and data management.

TECHNICAL ASSISTANCE

COR3 provides direct technical assistance to municipalities and eligible sub-applicants through guidance on HMGP application requirements, project development, cost documentation, and grant management procedures. COR3's role includes supporting communities in preparing HMGP project applications, navigating eligibility and environmental review requirements, and coordinating with FEMA on project approvals and reimbursement. In addition, COR3 conducts workshops, issues program guidance, and offers one-on-one support to help applicants meet federal documentation standards and maintain compliance throughout the grant lifecycle.

PREMB continuously promotes the training and professional development of its personnel, ensuring adequate preparation for the fulfillment of their functions and the effective response to all hazards.

MITIGATION PLANNING

PREMB implemented the 2026 State Hazard Mitigation Plan to align with federal requirements of FEMA 2025 State Mitigation Planning Guidance, which is a technical step to strengthen mitigation capabilities. At the municipal level, the Natural Hazard Mitigation Plan template continues to be developed to align with the FEMA Local Mitigation Planning Guidance.

Most municipalities update their plans using Hazard Mitigation Grant Program (HMGP) planning funds administered by COR3 and PREMB following major federal disaster declarations, including local cost share when required.

COMMUNITY ASSISTANCE PROGRAM STATE SUPPORT SERVICES ELEMENT

Community Assistance Program–State Support Services Element (CAP-SSSE) helps states proactively identify, prevent, and resolve floodplain management issues in participating communities before a flood event occurs. The program supports state efforts in several key ways, including the following:[1114]

- Ensuring that the flood loss reduction goals of the NFIP are met
- Building state and community floodplain management expertise and capability
- Leveraging state knowledge and expertise in working with their communities

GRANT INCENTIVE PROGRAM

The Grant Incentive Program supports municipal participation in mitigation actions by encouraging eligible communities to apply for Hazard Mitigation Grant Program (HMGP) funding following major disaster declarations. Under this program, municipalities that complete and maintain an approved Natural Hazard Mitigation Plan become eligible for HMGP assistance, including planning grants and project funding administered by COR3 and PREMB. The program also promotes the implementation of mitigation measures identified in local plans by linking plan maintenance to future funding eligibility.

Federal Resources

Puerto Rico supports the non-federal cost share for mitigation grants, including the HMGP, FMA program, and Pre-Disaster Mitigation (PDM) program. This divides the cost of implementing a mitigation grant project in Puerto Rico into the following percentages: up to 75% of grant costs are covered by federal funds, and 25% of the cost share is covered by non-federal state funds (depending on funding availability), unless a higher federal percentage applies. This initiative—covering half of the grant's non-federal matching requirement (when state funding is available)—has allowed communities across Puerto Rico to implement successful mitigation projects that would not be possible without the Government's funding assistance.

FEMA's Hazard Mitigation Assistance (HMA) program plays an important role in funding hazard mitigation efforts in Puerto Rico. FEMA administers grant funding programs for eligible mitigation planning and projects that reduce disaster losses and protect life and property from future damage.[1115] The HMA programs include the FMA program, the PDM program, the HMGP, and the HMGP Post Fire program. Table 133 provides descriptions of each HMA grant. Table 134 provides descriptions of other federal mitigation grant programs.

[1114] FEMA, "Community Assistance Program – State Support Services Element," 2025, https://www.fema.gov/floodplain-management/community-assistance-program.
[1115] FEMA, "Hazard Mitigation Assistance Grants," https://www.fema.gov/grants/mitigation.

Table 133: FEMA Hazard Mitigation Assistance Grants

Program	Description
Hazard Mitigation Grant Program (HMGP)	The HMGP provides funding to state, local, tribal, and territorial governments to develop hazard mitigation plans and rebuild in ways that reduce, or mitigate, future disaster losses in their communities. This grant funding is available following a presidentially declared disaster. Eligible applicants include state and local governments, tribal organizations, and certain private nonprofits. These entities may apply for funding to support projects such as stormwater upgrades, drainage and culvert improvements, property acquisition, slope stabilization, infrastructure protection, seismic and wind retrofits, and structure elevations.
Flood Mitigation Assistance (FMA) Program	The FMA program is a competitive grant that provides funding to state, territorial, and local governments, as well as federally recognized Tribal Nations. The funds support projects that reduce or eliminate the risk of repetitive flood damage to buildings insured under the National Flood Insurance Program (NFIP).
Hazard Mitigation Grant Program (HMGP) Post Fire	The HMGP Post Fire program provides assistance to help communities implement hazard mitigation measures following wildfire disasters. Wildfires can destroy homes, businesses, infrastructure, natural resources, and agriculture. They can also increase secondary hazards such as floods, erosion, and mudflows, which may leave areas vulnerable for years.
Section 203 Hazard Mitigation Program (*including BRIC)*	Section 203 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act authorizes FEMA to provide competitive pre-disaster hazard mitigation funding to states, territories, Tribal Nations, and local governments to reduce natural hazard risk and enhance community resilience. Section 203 supports capability and capacity building, mitigation planning, and the implementation of innovative and climate-resilient mitigation projects that reduce reliance on future disaster assistance and address risks to critical infrastructure and vulnerable communities. This authority currently underpins FEMA's national pre-disaster mitigation program.

Table 134: Other Federal Mitigation Grant Programs

Program	Description	Lead Agency
FEMA Public Assistance (PA) Mitigation – 406	PA 406 provides grant funding attached to post-disaster PA program funding. It is limited to declared counties and eligible damaged facilities. The funding supports mitigation measures implemented in conjunction with the repair of disaster-damaged facilities.	FEMA
Section 428 Hazard Mitigation Program (PA Alternative Procedures)	Section 428 of the Stafford Act authorizes FEMA's Public Assistance Alternative Procedures, which allow recipients and subrecipients to incorporate hazard mitigation measures into Public Assistance (PA) permanent work projects following a presidential disaster declaration. Eligible mitigation activities under Section 428 must reduce future disaster damage to facilities that were damaged during the declared event and are tied to the specific repair or replacement scope of work. Section 428 encourages resilient reconstruction, improved performance standards, and cost-effective risk reduction for public infrastructure.	FEMA
Section 1206(Disaster Recovery Reform Act-DRRA)	Section 1206 of the Disaster Recovery Reform Act authorizes FEMA Public Assistance funding for eligible mitigation, management costs, and activities that improve building codes, enforcement, and post-disaster recovery capabilities. Section 1206 allows PA recipients to use funding to support resilient reconstruction, advance higher standards, and strengthen local capability to reduce future risk through planning, code administration, and enforcement activities performed after a major disaster. The authority prioritizes long-term resilience through improved codes and post-disaster implementation capacity.	FEMA
Our Town Grant	Our Town is a creative placemaking grant program that encourages the integration of arts, culture, and design into community and economic development initiatives. Project-based funding is available for partnerships between local governments and nonprofit organizations. Eligible project types include arts engagement (e.g., arts festivals, community co-creation of art, public art), cultural planning (e.g., cultural district planning, creative asset mapping, public art planning), design (e.g., public space design), and artist and creative industry support. Funding may be used to integrate arts, culture, and design into hazard mitigation activities. • **Mitigation Action Type:** Education and Outreach Programs	National Endowment for the Arts

Program	Description	Lead Agency
	• **National Mitigation Framework Core Capability:** Community Resilience	
Smart Growth Support	• The Environmental Protection Agency (EPA) Office of Community Revitalization works on smart growth issues by conducting research, producing reports and publications, showcasing examples of outstanding smart growth communities and projects, and partnering with state, local, tribal, and territorial governments through grants and technical assistance. Smart growth can incorporate elements of green infrastructure and/or land preservation, and it can create more resilient communities. • **Mitigation Action Types:** Local Planning and Regulations, Education and Outreach Programs • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EPA Office of Sustainable Communities
Brownfields Program Grant Funding	The EPA's Brownfields Program provides direct funding for brownfields assessment, cleanup, revolving loans, and environmental job training. It also provides technical information on brownfields financing matters. Separate grant programs are available for assessment, cleanup, environmental job training, and more. While not envisioned as a mitigation program, brownfield cleanup can prevent toxic materials from spreading during a hazard event. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EPA
Clean Water State Revolving Fund (CWSRF)	The EPA's CWSRF program is a federal-state partnership that provides communities with a permanent, independent source of low-cost financing for a wide range of water quality infrastructure projects. CWSRF can fund a variety of water quality protection efforts. The program's flexibility and broad project eligibilities enable states to target CWSRF funds to their specific water quality priorities. Water quality projects often meet flood mitigation goals and vice versa. States are responsible for operating their CWSRF programs. Under the CWSRF, states may provide various types of assistance, including loans, refinancing, purchasing or guaranteeing local debt, and purchasing bond insurance. States may also set specific loan terms, including interest rates from 0% to market rate and repayment periods of up to 30 years. States have the flexibility to target financial	EPA

Program	Description	Lead Agency
	resources to their specific community and environmental needs. • **Mitigation Action Types:** Natural Systems Protection, Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
Drinking Water State Revolving Fund (DWSRF)	Under the DWSRF, the EPA provides grants to all 50 states plus Puerto Rico to capitalize state DWSRF loan programs. The states contribute an additional 20% to match the federal grants. Water quality projects often meet flood mitigation goals and vice versa. The 51 DWSRF programs function like infrastructure banks by providing low-interest loans to eligible recipients for drinking water infrastructure projects. As money is paid back into the states' revolving loan funds, the states make new loans to other recipients. These recycled repayments of loan principal and interest earnings allow the DWSRF to "revolve" over time. States are responsible for operating their DWSRF programs. Under the DWSRF, states may provide various types of assistance, including loans, refinancing, purchasing or guaranteeing local debt, and purchasing bond insurance. States may also set specific loan terms, including interest rates from 0% to market rate and repayment periods of up to 30 years. • **Mitigation Action Types:** Natural Systems Protection, Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EPA
Environmental Finance Centers (EFCs)	The EPA's EFCs deliver targeted technical assistance and partner with states, Tribes, local governments, and the private sector to provide innovative solutions for managing the costs of environmental financing and program management. Potential environmental projects may include hazard mitigation projects. • **Mitigation Action Type**: Local Planning and Regulations • **National Mitigation Framework Core Capability:** Community Resilience	EPA
Centers for Disease Control and Prevention (CDC) Public Health Emergency Preparedness (PHEP) Program	The PHEP program is a critical source of funding, guidance, and technical assistance for state, local, tribal, and territorial public health departments to strengthen their public health preparedness capabilities and improve their response readiness. The Division of State and Local Readiness (DSLR) Friday Update provides information and resources for PHEP recipients and other preparedness planners.	CDC

Program	Description	Lead Agency
	• **Mitigation Action Type:** Education and Outreach Programs • **National Mitigation Framework Core Capability:** Community Resilience	
Community Development Block Grant–Disaster Recovery (CDBG-DR) and Mitigation (CDBG-MIT)	In response to presidentially declared disasters, Congress may appropriate additional funding, which can be leveraged for hazard mitigation. The U.S. Department of Housing and Urban Development (HUD) oversees two related programs, CDBG-DR and CDBG-MIT. CDBG-DR assistance may fund a broad range of recovery activities—housing, public infrastructure, long-term planning, and economic development—helping communities and neighborhoods that otherwise might not recover due to limited resources. CDBG-MIT assistance is intended to assist areas impacted by recent disasters to carry out strategic and high-impact activities to mitigate disaster risks and reduce future losses. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Operational Coordination	HUD
Section 108 Loan Guarantee Program	The Section 108 Loan Guarantee Program (Section 108 of the Housing and Community Development Act of 1974) provides communities with financing for economic development, housing rehabilitation, public facilities, and other physical development projects, including improvements to increase their resilience against natural disasters. The flexibility of the program makes it one of the most important public investment tools that HUD offers to state and local governments. Section 108 offers state and local governments the ability to transform a small portion of their CDBG funds into federally guaranteed loans large enough to pursue physical and economic revitalization projects capable of revitalizing entire neighborhoods. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Operational Coordination	HUD
Planning Assistance to States (PAS) Program	The PAS Program can encompass many types of studies dealing with water resources issues. Local governments are eligible applicants. Two types of planning assistance are offered through the PAS program: Comprehensive Plans and Technical Assistance. Any state, or group of states, may partner with the U.S. Army Corps of Engineers (USACE) under the PAS program.	USACE

Program	Description	Lead Agency
	• **Mitigation Action Type:** Local Planning and Regulations • **National Mitigation Framework Core Capability:** Risk and Disaster Resilience Assessment	
Environmental Justice Collaborative Problem-Solving (EJCPS) Agreement Program	The EJCPS Agreement Program provides funding to support community-based organizations in their efforts to collaborate and partner with local stakeholder groups (e.g., local businesses and industry, local government, medical service providers, and academia) as they develop and implement community-driven solutions that address environmental and/or public health issues for underserved communities. Eligible projects must demonstrate use of the EJCPS Model to support their collaborative efforts during the project period. Applying organizations should have a direct connection to the underserved community impacted by the environmental harms and risks detailed in the work plan. The long-term goals of the EJCPS Program are to help build the capacity of communities with environmental justice concerns and to create self-sustaining, community-based partnerships that will continue to improve local environments in the future. • **Mitigation Action Type:** Education and Outreach Programs • **National Mitigation Framework Core Capability:** Community Resilience	EPA
Environmental Justice Small Grants (EJSG) Program	The EPA's EJSG program awards grants that support community-driven projects designed to engage, educate, and empower communities to better understand local environmental and public health issues and develop strategies for addressing those issues, building consensus in the community, and setting community priorities. The grants can be used for education and outreach about hazard mitigation efforts. • **Mitigation Action Type**: Local Planning and Regulations • **National Mitigation Framework Core Capability:** Community Resilience	EPA
Greening America's Communities	Greening America's Communities (formerly known as Greening America's Capitals) is an EPA program that helps cities and towns develop an implementable vision of environmentally friendly neighborhoods that incorporates innovative green infrastructure, hazard mitigation, and other sustainable/resilient design strategies. EPA provides design assistance to help support sustainable communities that protect the environment, economy, and public health, and to inspire local and state leaders to expand this work elsewhere.	EPA

Program	Description	Lead Agency
	• **Mitigation Action Type:** Local Planning and Regulations • **National Mitigation Framework Core Capability:** Planning	
Nonpoint Source Water Quality (Section 319) Grants	Clean Water Act Section 319(h) funds are provided only to designated state and tribal agencies to implement their approved nonpoint source management programs. State and tribal nonpoint source programs offer a variety of components, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and regulatory programs. Water quality projects often meet flood mitigation goals and vice versa. Each year, EPA awards Section 319(h) funds to states in accordance with a state-by-state allocation formula that EPA developed in consultation with the states. Tribal funding is also available under Clean Water Act Section 319(h). • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Risk and Disaster Resilience Assessment	EPA
Urban Waters Small Grants	Healthy and accessible urban waters can help local businesses grow and enhance educational, recreational, social, and employment opportunities in nearby communities. The EPA's Urban Waters Small Grants are expanding communities' ability to engage in activities that improve water quality in a way that also advances community priorities. Water quality projects often meet flood mitigation goals and vice versa. Improving urban waters requires various levels of government and local stakeholders (e.g., community residents, local businesses) to work together in developing effective and long-term solutions with multiple benefits. EPA supports and empowers communities, especially in underserved areas, that are working on solutions to address multiple community needs and fostering successful collaborative partnerships. Since the inception in 2012, the Urban Waters Small Grants Program has awarded approximately $6.6 million in grants to 114 organizations across the country and Puerto Rico. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EPA

Program	Description	Lead Agency
Water Infrastructure and Resiliency Finance Center	The Water Infrastructure and Resiliency Finance Center provides financing information to help local decision-makers make informed decisions about drinking water, wastewater, and stormwater infrastructure, to protect human health and the environment. Water quality projects often meet flood mitigation goals and vice versa. • **Mitigation Action Type:** Local Planning and Regulations • **National Mitigation Framework Core Capability:** Community Resilience	EPA
Wetlands Protection Development Grants (WPDGs)	WPDGs provide eligible applicants an opportunity to conduct projects to strengthen wetland protection programs. Eligible projects promote the coordination and acceleration of research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution. Wetland protection is an important type of natural resource protection hazard mitigation project. **Mitigation Action Type:** Natural Systems Protection **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EPA
National Dam Safety Program (NDSP)	For 30 years, the federal government has used the NDSP to protect Americans from dam failure. The NDSP is a partnership of states, federal agencies, and other stakeholders that encourages and promotes the establishment and maintenance of effective federal and state dam safety programs to reduce the risks to human life, property, and the environment from dam-related hazards. Each state, or an equivalent state agency, is eligible to apply for the High Hazard Potential Dam (HHPD) grant. Each eligible state may submit only one HHPD grant application. Non-federal dams are eligible if they: (i) are in a state or territory with a state or territorial dam safety program; (ii) are classified as having "high hazard potential: by the dam safety agency in the dam's state or territory; (iii) have an emergency action plan approved by the state or territorial dam safety agency; and (iv) are determined by the state or territory to fail to meet minimum dam safety standards. An "eligible high hazard potential dam" does not include: (i) a licensed hydroelectric dam; or (ii) a dam built under the federal authority of the Secretary of Agriculture. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Risk and Disaster Resilience Assessment	FEMA

Program	Description	Lead Agency
Conservation District Innovation Grants (CIG)	Conservation Districts are grassroots organizations that work across counties to provide assistance to landowners and communities with natural resource conservation for forests, farms, and water resources. This grant program provides Districts with funding to implement innovative natural resources projects. CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program (EQIP) funds are used to award competitive grants to non-federal governmental or nongovernmental organizations, Tribes, or individuals. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	U.S. Department of Agriculture (USDA)
Conservation Reserve Program (CRP)	The CRP is a voluntary program for agricultural landowners to receive rental payments when they convert marginal farmlands to vegetated cover. Participants enroll in CRP contracts for 10 to 15 years. This practice helps reduce soil erosion, supports farmers, lowers sedimentation and pollution in water sources, and helps establish wildlife habitat. Wetland enhancement, shoreline protection, and riparian buffer practices under CRP enhance resilience by reducing downstream flooding during storm events. One effort, the Floodplain Wetlands Initiative, restores the functions and values of wetland ecosystems previously devoted to agricultural use. This wetland restoration reverses the degradation in areas characterized by marginal soil. For farmers and landowners facing crop damage from flooding, restoring wetlands to receive floodwaters can increase flood storage capacity and significantly reduce farming risks. • **Mitigation Action Type**: Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USDA
USDA Disaster Assistance Programs	The Farm Service Agency (FSA) provides several disaster assistance programs. These include the Emergency Conservation Program, Emergency Forest Restoration Program, Emergency Loan Program, and Tree Assistance Program, as well as a mix of other programs aimed at specific agricultural sectors. While focused on recovery, many of these programs provide funding for conservation practices that enhance long-term resilience.	USDA

Program	Description	Lead Agency
	• **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Community Resilience	
Source Water Protection Program (SWPP)	The SWPP is a joint project of the USDA FSA and the National Rural Water Association, a nonprofit water and wastewater utility membership organization. This program is designed to help prevent pollution of surface and groundwater used as the primary source of drinking water by rural residents. Water quality projects often align with flood mitigation goals and vice versa. SWPP funds can be used for flood mitigation when the projects also improve water quality. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USDA
Environmental Quality Incentives Program (EQIP)	EQIP provides financial and technical assistance to agricultural producers to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation, or improved or created wildlife habitat. While not designed to be an emergency response or hazard mitigation program, EQIP can play a vital role in helping producers prevent the worst impacts of and recover from natural disasters like floods, hurricanes, wildfires, and drought. Through EQIP, the Natural Resources Conservation Service (NRCS) provides financial assistance to repair and prevent excessive soil erosion caused by these events. These practices include activities like streambank restoration, grassed waterways, and buffers. NRCS-funded conservation practices protect land from erosion, support disaster recovery and repair, and can help mitigate loss from future natural disasters. • **Mitigation Action Type**: Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USDA NRCS
Wetland Mitigation Banking Program	The Wetland Mitigation Banking Program helps establish wetland mitigation banks to help producers meet their wetland conservation compliance responsibilities. Producers must comply to maintain eligibility for many USDA programs administered by the FSA and NRCS, and to maintain eligibility for the federal crop insurance premium subsidy administered by the Risk Management Agency. This program	USDA NRCS

Program	Description	Lead Agency
	assists with establishing the banks, but not with securing or managing the wetlands. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Community Resilience	
Conservation Stewardship Program (CSP)	The CSP helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resource concerns. CSP pays participants for conservation performance—the higher the performance, the higher the payment. Many conservation practices—such as riparian forest buffers, cover crops, and other soil- and water-conserving measures—reduce runoff and erosion, reducing flooding downstream. CSP provides two possible types of payments through five-year contracts: annual payments for installing new conservation activities and maintaining existing practices, and supplemental payments for adopting a resource-conserving crop rotation. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Community Resilience	USDA NRCS
Emergency Watershed Protection Program (EWPP)	Congress established the EWPP to respond to emergencies created by natural disasters. The EWPP offers technical and financial assistance to help local communities mitigate imminent hazards to life and property caused by floods, fires, windstorms, and other natural occurrences that impair a watershed. The NRCS administers the EWPP, which includes two components: EWP–Recovery and EWP–Floodplain Easement. In addition to recovery projects, NRCS may purchase EWPP floodplain easements instead of trying to recover damaged floodplain lands if it proves to be more cost-effective than recovery. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USDA NRCS
Housing Preservation Grants (HPGs)	The HPG program provides grants to sponsoring organizations for the repair or rehabilitation of low- and very-low-income housing. The grants are competitive and are made available in areas where there is a concentration of need. Those assisted must own very-low- or low-income housing, either as homeowners, landlords, or members of a cooperative. Very low income is defined as below 50% of the area median income (AMI); low income is between 50 and 80% of AMI.	USDA Rural Development

Program	Description	Lead Agency
	The funds can be used for the following: • Grants or low-interest loans to repair or rehabilitate housing for low- and very-low-income homeowners • Assistance to rental property owners if they agree to make units available to low- and very-low-income families • Eligible expenses, including the following: › Repairing or replacing electrical wiring, foundations, roofs, insulation, heating systems, and water/waste disposal systems › Handicap accessibility features › Labor and materials › Administrative expenses Eligible homeowners can apply for funding to repair damages caused by natural hazards or to harden their structures against future hazard events. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
Water and Environmental Programs (WEPs)	WEP provides technical assistance, loans, grants, and loan guarantees for drinking water, sanitary sewer, solid waste, and storm drainage facilities in rural areas and in cities and towns of 10,000 or fewer. WEP also makes grants to nonprofit organizations to provide technical assistance and training to help rural communities with their water, wastewater, and solid waste challenges. Water quality projects often meet flood mitigation goals and vice versa. WEP includes Emergency Community Water Assistance Grants, Grants for Rural and Native Alaskan Villages, Water & Waste Disposal Loans & Grants, and more. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USDA Rural Development
Community Forest Program	This U.S. Forest Service competitive grant program provides funding through local governments, qualified nonprofit organizations, and Indian Tribes to establish community forests. These forests provide benefits such as wildlife habitat, clean air and water, and economic opportunities from timber resources and recreation. Congress established the program in response to concerns about declining public access to forest lands, reduced outdoor recreation, and	U.S. Forest Service (USFS)

Program	Description	Lead Agency
	limited financial resources for local governments to acquire forest lands. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Community Resilience	
Forest Stewardship Program	The Forest Stewardship Program encourages long-term stewardship of important state and private forest landscapes by helping landowners more actively manage their forests and related resources. Protected forests can reduce flooding and downstream hazard impacts within a watershed, and well-managed forests can reduce wildfire risk. The program provides assistance to owners of forest land and other lands where good stewardship—including agroforestry practices—will enhance and sustain the long-term productivity of multiple forest resources and produce healthy, resilient forest landscapes. Special attention is given to landowners in landscape areas identified by State Forest Action Plans and those new to or in the early stages of managing their land in a way that embodies multi-resource stewardship principles. The program provides landowners with the professional planning and technical assistance they need to keep their land in a productive and healthy condition. Assistance offered through the Forest Stewardship Program also provides landowners with enhanced access to other USDA conservation programs, forest certification programs, and forest product and ecosystem service markets. • **Mitigation Action Type**: Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	U.S. Forest Service (USFS)
Forest Legacy Program (FLP)	The purpose of the FLP is to identify and conserve environmentally important forest areas that are threatened by conversion to non-forest uses. Providing economic incentives to landowners to keep their land as forests encourages sustainable forest management and supports strong markets for forest products. Forest protection can be a valuable tool for natural resource conservation and can reduce flooding and downstream hazard impacts within a watershed. Landowners may participate in the Forest Legacy Program by either selling their property outright or by retaining ownership and selling only a portion of the property's development rights; in both cases, the rights are held by state agencies or another unit of government. The use of a conservation easement—a legal agreement between a landowner and a nonprofit land trust or governmental	USDA Forest Service

Program	Description	Lead Agency
	agency—allows the land to remain in private ownership while ensuring that its environmental values are retained. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
Economic Development Administration (EDA) Disaster Recovery	The EDA has a long history of successfully supporting disaster recovery and resiliency efforts. EDA's role in disaster recovery is to facilitate the timely and effective delivery of federal economic development assistance to support long-term community economic recovery planning, project implementation, redevelopment, and resiliency. EDA is uniquely positioned to coordinate regional disaster recovery efforts in partnership with its extensive network of Economic Development Districts, university centers, institutions of higher education, and other partners in designated impact areas. • **Mitigation Action Types:** Structure and Infrastructure Projects, Education and Outreach Programs • **National Mitigation Framework Core Capability:** Operational Coordination	U.S. Department of Commerce, EDA
EDA Disaster Supplemental Funding	Congress often appropriates supplemental funds for economic recovery after significant disasters. Between Fiscal Years 2018 and 2019, EDA received $1.2 billion in supplemental disaster appropriations ($600 million each year) from Congress to help regions recover from the economic harm and distress caused by natural disasters in 2017-2019. With the support of these funds, American regions and communities hard hit by major disasters are rebuilding stronger, more resilient economies. • **Mitigation Action Type:** Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Operational Coordination	U.S. Department of Commerce, EDA
Five Star and Urban Waters Restoration Grant Program	The Five Star and Urban Waters Restoration Program seeks to develop nationwide community stewardship of local natural resources—preserving these resources for future generations and enhancing habitat for local wildlife. Projects aim to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. • **Mitigation Action Type:** Natural Systems Protection	National Fish and Wildlife Foundation (NFWF)

Program	Description	Lead Agency
	• **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
National Coastal Resilience Fund	The National Coastal Resilience Fund restores, increases, and strengthens natural infrastructure to protect coastal communities while also enhancing habitats for fish and wildlife. Established in 2018, the fund invests in conservation projects that restore or expand natural features such as coastal marshes and wetlands, dune and beach systems, oyster and coral reefs, forests, coastal rivers and floodplains, and barrier islands. These features help minimize the impacts of storms and other naturally occurring events on nearby communities. The fund is supported by the National Oceanic and Atmospheric Administration (NOAA), Shell Oil Company, and TransRe. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	NFWF
Resilient Communities Program	The Resilient Communities Program focuses on water quality and quantity declines, forest health concerns, and sea level rise. It emphasizes community inclusion and provides assistance to traditionally underserved populations in vulnerable areas. • **Mitigation Action Type:** Local Planning and Regulations • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	NFWF
Ecosystem Investment Partners (EIP)	EIP invests in large-scale ecological restoration projects that meet this growing demand. Their environmental investing initiatives address mitigation needs through private conservation finance capital. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	EIP
Coastal and Marine Habitat Grants	The NOAA Community-Based Restoration Program recognizes that habitat protection and restoration are essential elements of a strategy for sustainable commercial and recreational fisheries. Investing in habitat restoration projects leads to real, lasting benefits for communities, businesses, and the environment. The program supports restoration projects that use a habitat-based approach to rebuild productive and sustainable fisheries, contribute to the recovery and conservation of protected resources, and promote healthy ecosystems and resilient communities. Restoration includes activities that return degraded or	U.S. Department of Commerce, NOAA

Program	Description	Lead Agency
	altered marine, estuarine, coastal, and freshwater migratory fish habitats to functioning conditions, and techniques that return NOAA trust species to their historic habitats. These projects support economic recovery and can also prevent future hazards and hazard losses by protecting natural resources in critical areas of the coastal floodplain. • **Mitigation Action Types:** Natural Systems Protection, Structure and Infrastructure Projects, Education and Outreach Programs • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
National Coastal Wetlands Conservation Grants (NCWCG)	The NCWCG program annually provides grants of up to $1 million to coastal and Great Lakes states and territories to protect, restore, and enhance coastal wetland ecosystems and associated uplands. The grants are funded through the Sport Fish Restoration and Boating Trust Fund, which is supported by excise taxes on fishing equipment and motorboat fuel. Wetland conservation is a key form of natural resource protection and an effective hazard mitigation strategy. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	U.S. Department of the Interior, Fish and Wildlife Service (FWS)
North American Wetland Conservation Fund	The North American Wetland Conservation Fund Program provides matching grants to wetland conservation projects in the United States, Canada, and Mexico. It includes a Standard Program and a Small Grants Program. Wetland conservation is a key form of natural resource protection and an effective hazard mitigation strategy. • **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	FWS
Disaster Recovery Grants	Congress responds to some major disasters by appropriating Emergency Supplemental funding from the Historic Preservation Fund (ESHPF) for recovery. This funding allows state and tribal Historic Preservation Offices to carry out a range of recovery projects, including compliance activities, survey and inventory of historic resources in disaster-impacted areas, recovery and repair of damaged historic properties, and other activities related to disaster recovery, as approved by the National Park Service (NPS). All funded repair work must substantially mitigate the threat and include steps to mitigate future damages.	U.S. Department of the Interior, NPS

Program	Description	Lead Agency
	• **Mitigation Action Type:** Natural Systems Protection • **National Mitigation Framework Core Capability:** Operational Coordination	
U.S. Army Corps of Engineers (USACE) Continuing Authorities Program (CAP)	The CAP allows the USACE to plan, design, and implement certain types of water resources projects without additional project-specific congressional authorization. Under CAP, the USACE can plan and implement projects of limited size, cost, scope, and complexity. These include streambank and shoreline protection, hurricane and storm damage reduction, and flood damage reduction. All CAP projects include a feasibility phase and an implementation phase. • **Mitigation Action Type**: Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USACE
Ecosystem Restoration	Ecosystem restoration is one of the primary missions of the USACE. The purpose of USACE ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded. These efforts involve examining the problems contributing to system degradation, and developing alternative means to address them. The intent of restoration is to partially or fully re-establish the attributes of a natural, functioning, self-regulating system. Restoration opportunities associated with wetlands, riparian zones, and other floodplain and aquatic systems are especially appropriate for USACE involvement. The three ecosystem restoration authorities within the program are Project Modifications for Improvements to the Environment, Beneficial Use of Dredged Materials, and Aquatic Ecosystem Restoration. • **Mitigation Action Type**: Natural Systems Protection • **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	USACE
Emergency Operations	Emergency preparedness and response are primarily state and local responsibilities. However, when the nature of a disaster exceeds the capabilities of state and local interests, the USACE may provide assistance to save human life, prevent immediate suffering, or mitigate property damage. The USACE participates in the National Response Framework as the primary agency for planning, preparedness, and response under Emergency Support Function (ESF) #3, Public Works and Engineering. The purpose of ESF #3 is to provide lifesaving or life-protecting assistance to augment the efforts of the affected state(s) and local response operations	USACE

Program	Description	Lead Agency
	following a major or catastrophic disaster. The USACE's Rehabilitation and Inspection Program includes the inspection of flood control projects, the rehabilitation of damaged flood control projects, and the rehabilitation of federally authorized and constructed hurricane or shore protection projects. • **Mitigation Action Type**: Structure and Infrastructure Projects • **National Mitigation Framework Core Capability:** Operational Coordination	
Floodplain Management Services (FPMS) Program	The USACE provides a full range of technical services and planning guidance to support effective floodplain management. General technical assistance under this program includes determining site-specific data on obstructions to flood flows, flood formation and timing, flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after applying floodplain management measures. The types of studies conducted under the FPMS program include floodplain delineation and hazard mapping, dam failure analyses, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, flood-proofing, and inventories of flood-prone structures. • **Mitigation Action Type:** Local Planning and Regulations • **National Mitigation Framework Core Capability:** Risk and Disaster Resilience Assessment	USACE
Small Flood Control Program	The Small Flood Control Program enables the USACE to work with communities to plan, design, and construct certain small flood control projects that have not already been specifically authorized by Congress. The program considers both structural (levees, channels, or dams, for instance) and nonstructural (flood-proofing or evacuation, for example) solutions. Each potential project is evaluated through required studies. To be selected, a project must be economically justified—that is, the benefits resulting from a project must exceed the cost incurred to construct the project. It also must be environmentally acceptable and self-contained. In addition, each separate project is limited to a total federal cost of not more than $10 million, including studies, design, and implementation. • **Mitigation Action Type:** Structure and Infrastructure Projects	USACE

Program	Description	Lead Agency
	• **National Mitigation Framework Core Capability:** Long-term Vulnerability Reduction	
USACE Floodplain Management Services Program (FPMS)	FPMS provides technical services and planning guidance to support effective floodplain management under Section 206 of the Flood Control Act of 1960. Assistance includes data on flood flow obstructions, depths, timing, and frequency; natural and cultural floodplain resources; and flood loss potential. Studies may include floodplain delineation and hazard mapping, dam failure analysis, hurricane evacuation, flood warning, flood damage reduction, stormwater management, and flood-proofing. State, regional, or local governments and Native American Tribes may request assistance. When funding is available, USACE collaborates with requestors to define the scope and assemble a study team. Voluntary contributions and existing data may help expand or expedite services.	USACE

Changes, Challenges, and Proposed Solutions

The Government of Puerto Rico has taken this opportunity to evaluate its mitigation capabilities including success stories and challenges in order to identify any obstacles that may hinder progress, anticipate potential challenges, and develop solutions to address them throughout the mitigation planning process. In doing so, it has assessed opportunities to expand and improve the capabilities outlined in the plan, while evaluating whether these capabilities have been effectively used to reduce risk. The gaps or challenges can be supported through effective mitigation actions and capacity building projects as identified in the Mitigation Strategy Section. The best practices exemplify the progress the Government of Puerto Rico has made in creating a more resilient Puerto Rico.

Changes in Program Capabilities

Mitigation capabilities grow and change over time. The following highlights notable changes to Puerto Rico's mitigation capabilities since the last plan update:

- The State Hazard Mitigation Plan incorporates updated risk reduction strategies for natural and technological hazards, including specific mitigation actions for floods, earthquakes, hurricanes, and landslides.
- Community education in mitigation and preparedness is promoted through campaigns and workshops coordinated with municipalities and community organizations.
- PREMB has projects in collaboration with the USACE and the Silver Jackets program to help reduce the risk of flooding and other natural hazards. Its approach is comprehensive across the entire risk management cycle: planning, preparedness, response, recovery, and mitigation.

- COR3 has expanded staffing, experience, and transparency, enhancing the support for sub-applicants in applying for Hazard Mitigation Assistance (HMA) grants.

Changes in Agency Capabilities

Agencies involved in mitigation in Puerto Rico such as PREMB have implemented important changes since the last plan update. These changes reflect lessons learned after recent hazard events, such as Hurricane Maria in 2017, the COVID-19 pandemic between 2020 and 2022, the Southwest Puerto Rico earthquakes in 2020, and Hurricane Fiona in 2022.

Hazard Mitigation Planning Authority:

- The transfer of responsibility and delegation of authority for local hazard mitigation planning and updates has shifted from PREMB authority to the PRPB and now includes state review of municipal mitigation plans.
- Each municipality must comply with Puerto Rico's SHMP hazard mitigation requirements by maintaining an updated municipal hazard mitigation plans in order to receive federal funding for mitigation projects.
- COR3 is responsible for providing guidance to municipalities to meet hazard mitigation funding eligibility requirements.

Regionalized Planning:

- Communications with the PREMB Operational Zones were strengthened for more direct and effective coordination with municipalities and communities.
- PREMB participates in annual simulation exercises such as "Caribe Wave" and " Great ShakeOut," among others, that are organized by state, federal, and municipal agencies.

Multisectoral Coordination:

- PREMB strengthened its role as an interagency coordination center, integrating the Department of Health, Education, and Public Safety.
- Cold storage and controlled supply chain capabilities were developed, later used for vaccines and medical equipment. Experience was subsequently applied in the distribution of supplies during Fiona.
- Citizen communication strategies were adopted for uniform messaging and constant updates through digital media and social networks.
- Collaboration with private and nonprofit entities has been expanded. Agreements were formalized with the Red Cross, League of United Latin American Citizens (LULAC), and faith-based nonprofit organizations for post-disaster response and distribution.

Several agencies identified recommended opportunities for improvement when it came to their administrative and technical mitigation capabilities. In particular, having sufficient staff and emergency management training was noted as a priority. Additionally, coordination was highlighted an in-progress

change. While some additional coordination has begun, agencies were interested in further coordination both between agencies and with local and private entities. Additional agency level opportunities for improvement include:

- Workshops and training on hazard mitigation, including training in Spanish.
- A collaborative approach to dam safety management, such as the interagency mitigation committee, to facilitate coordination between public and private dam owners.
- Additional staffing to support the development of mitigation plans.
- Further technical assistance for preparing to use public assistance funding for hazard mitigation, including code enforcement and substantial damage assessments under DRRA (Section 1206) after federally declared disasters
- Need for NFIP floodplain management information in Spanish (E-273: Managing the Floodplain through the NFIP)

Changes in Technical Capabilities

Emergency management technologies continue to grow and evolve through time. Documenting and mapping technologies support not only response and recovery incidents, but proof of mitigation benefits or losses avoided. More advanced technology, such as additional GIS mapping support, could also enhance data analysis and mitigation project implementation. Some recent technological advances include:

Communication and Technological Redundancy:

- Satellite communication systems and interoperable radios were established between agencies and municipalities.

Technological Integration:

- Implementation of the WebEOC system, which allows monitoring of incidents and resources in real time, improved real-time data usage.

Challenges related to available technologies and documentation include the following:

- Lack of a centralized database for major hazardous materials incidents
- Inconsistencies in local natural hazard mitigation planning templates, including missing hazards and other vital data.
- Absence of a Subsidence Hazard Map Layer for Puerto Rico
- Absence of wildfire GIS mapping capabilities by Cuerpo de Bomberos
- Seismic building codes drafted but not yet adopted
- Lack of mapping tools to support dam failure mitigation

Proposed solutions include the following:

- Provide municipality-level outreach to warn of inundation impacts, risks, and dangers.
- Encourage the development of ADA-compliant evacuation routes with accommodations for those with ambulatory or sight disabilities.
- Add seismic retrofit requirements for homes built to code.
- Acquire additional management technologies.
- Implementation of DSPR-GIS with updated information on critical infrastructure, hospitals, shelters, etc.

Changes in Funding Sources

Since the last plan update, multiple changes have occurred in the available mitigation funding sources, including FEMA's introduction of two new programs. The BRIC program significantly expanded the amount of pre-disaster mitigation funding that was available for mitigation projects. Previously, most mitigation funding opportunities, such as HMGP, were available on a post-disaster basis. BRIC funding was determined by the total amount of overall disaster spending for a given year. Grant funding was not state-specific, and each state received an allocation. As such, each year the state would receive funding even if no disaster had been declared during the year. This gave eligible applicants more opportunity to plan and prepare for a grant application, knowing that there would be funds available annually. Additionally, since there was both an allocation, which could be used for projects at the state's discretion, and a competitive pool of funding, both smaller projects, such as hazard mitigation plan updates, and larger, community-based projects could potentially be awarded funding. However, the BRIC program was temporarily discontinued in 2025, and future funding may be redirected through other mechanisms.

The Rehabilitation of High Hazard Potential Dams (HHPD) program provides technical, planning, design, and construction assistance in the form of grants for the rehabilitation of eligible high hazard potential dams. Puerto Rico's HHPD program was awarded a grant for $2.75 million in 2024 for rehabilitation, planning, and construction of dam improvements.[1116] The National Dam Safety Program State Assistance Grant is confirmed for fiscal year 2025 at $7.48 million.

FEMA also established the Safeguarding Tomorrow Revolving Loan Fund Program, authorized by the Safeguarding Tomorrow through Ongoing Risk Mitigation Act (STORM Act), which became law in January 2021. The program provides capitalization grants to eligible entities to create revolving loan funds for hazard mitigation efforts. These funds offer low-interest loans to jurisdictions to enhance community resilience by reducing the loss of life and property, insurance costs, and reliance on federal disaster payments. In its first Notice of Funding Opportunity, released in December 2022, FEMA allowed eligible entities to define many local requirements, including what constitutes cost-effectiveness. The state is responsible for developing and administering the Revolving Loan Fund, which will require building new

[1116] FEMA, "High Hazard Potential Dams Grant Awards," 2025, https://www.fema.gov/grants/mitigation/learn/dam-safety/rehabilitation-high-hazard-potential-dams/awards.

programmatic capacity. This program may be a potential source of funding for Puerto Rico in the future; however, its funding is also uncertain at this time.

ADDITIONAL FUNDING NOTES

There have also been significant increases in funding available over the last five years, including in the aftermath of the COVID-19 pandemic. One example comes from COVID-19 federal legislation (passed in 2020 and 2025) that provided funding to support multiple scoping projects, an increase in funding that has proven beneficial for the state.

Since the last plan update, COR3 has received obligated funds totaling $2.2 billion from the CARES Act for the Coronavirus Relief Fund, and $3.9 billion from the American Rescue Plan Act for the State and Local Coronavirus Fiscal Recovery Fund.[1117]

For Hurricane Maria, the Government of Puerto Rico received approximately $3 billion in HMGP funds, which required a match of approximately $1 billion, for a total of approximately $4 billion in available hazard mitigation grant funding. CDBG-DR funding was used as a Global Match to satisfy this requirement.[1118]

Puerto Rico Port Authority received an estimated $2.8 million in obligated funding from FEMA for hazard mitigation work at Puerto Nuevo Seaport, Yabucoa Harbor, Rafael Hernandez International Airport in Aguadilla, and José Aponte de la Torre Airport in Ceiba. The funding for these projects covers hazard mitigation projects at each site, adding strength and resiliency to permanent work to prevent similar damage from future events. This work will include strengthening metal rooftops, improving exterior metal panels, and installing anchoring systems and impact-resistant windows.[1119]

In October 2025, FEMA obligated $75.9 million to support the construction of 27 safe rooms across Puerto Rico. These facilities will be designed to provide shelter and safety for residents during emergencies, particularly in light of the island's vulnerability to natural disasters such as hurricanes and flooding. The initiative comes as Puerto Rico continues to face challenges related to its infrastructure and disaster preparedness. The safe rooms will be managed by local municipalities, agencies, and nonprofit organizations, ensuring that they are accessible to those who need them most. This funding is part of a broader effort to enhance emergency response capabilities and protect communities often most impacted by disaster, and improve disaster resilience in Puerto Rico.[1120]

[1117] Government of Puerto Rico, "Central Recovery, Reconstruction and Resilience Office of Puerto Rico, Financial Summary," 2025, https://recovery.pr.gov/es/financial-analysis/financial-summary.
[1118] FEMA, "Hazard Mitigation Grant Program (HMGP) Overview," 2019, https://recovery.pr.gov/documents/HMGP%20LOI%20Presentation_English.pdf.
[1119] Puerto Rico Industrial Journal, "FEMA Awarded Over $54 Million to Repair Regional Airports and Shipping Docks," 2023, https://www.puertoricoindustryjournal.com/article/662188084-fema-awarded-over-54-million-to-repair-regional-airports-and-shipping-docks.
[1120] "FEMA Earmarks $75.9 Million to Build Safe Rooms in Puerto Rico to Protect the Most Vulnerable in Emergencies," October 29, 2025, *El Nuevo Día*, https://www.elnuevodia.com/english/news/story/fema-earmarks-759-million-to-build-safe-rooms-in-puerto-rico-to-protect-the-most-vulnerable-in-emergencies/.

Since January 2025, over 60 resilience projects have been approved by FEMA that cannot be completed without a Grant POP extension beyond October 31, 2026. This amount excludes Projects 4339-0139 and 4339-0173 which were initially approved by FEMA but were subsequently either terminated by FEMA or withdrawn by the Subrecipient.

- As of August 2025, a total of 215 projects have been approved under DR-4339.
- Of these, 153 are Phase 1 projects focused on planning and design activities, while 60 are fully approved projects.
- Additionally, two projects have advanced to Phase 2 approval.

Among the 215 approved projects, 209 are fully funded through HMGP, two are funded through CDBG-MIT, and four projects are funded with a combination of HMGP, CDBG, and local funding sources (see Table 135).

Table 135: Approved Mitigation Projects

Mitigation Type	Total Project Cost	Number of Projects
Advance Assistance	$10.0 million	2
Drought/Aquifer Storage and Recovery	$703.4 million	4
Emergency Power	$537.1 million	54
Flood Risk Reduction	$208.6 million	77
Green Infrastructure	$6.0 million	1
Infrastructure Retrofit	$8.0 million	2
Initiative	$366.1 million	5
Miscellaneous/Other	$558.6 million	4
Non-Structural and/or Structural Retrofit	$487.3 million	28
Planning	$8.2 million	3
Safe Room	$56.2 million	14
Soil/Shore/Slope Stabilization	$130.0 million	21
Grand Total	**$3.1 billion**	**215**

UTILIZING ALL AVAILABLE FUNDING

Local municipalities may not have sufficient funds available to meet the required local match for grant programs. Addressing these challenges is complicated by ongoing changes to federal programs and policies. As new guidance and initiatives are released, further research is needed to identify how the Government and local communities can maximize mitigation opportunities.

Changes to the NFIP

In addition, challenges to government mitigation efforts include issues such as lapses in flood insurance coverage, which result in residents becoming ineligible for flood mitigation assistance funding. Group flood insurance programs—offered by FEMA to individuals who lack flood insurance and have received assistance from FEMA following a presidentially declared disaster involving flooding, particularly those who enrolled after Hurricane Maria—are also lapsing due to non-payment of premiums. Policyholders who fail to maintain insurance coverage after receiving FEMA disaster assistance are subsequently deemed ineligible for flood mitigation assistance.

Puerto Rico's municipalities have difficulty obtaining flood insurance, as well as qualifying for Flood Mitigation Assistance grants. There were lines of credit that some municipalities were able to obtain in the past; however, those programs have since dissolved, and funds are no longer available.

NFIP coordination challenges include the language barrier related to training for floodplain managers, as well as Puerto Rico's unique legal framework (e.g., Law No. 101 and municipal permitting laws). The permitting processes vary depending on jurisdiction—regional permits in Ponce, environmental permits through the Environmental Office, and general permits via the Office of Permits (OGPE).

Conclusion

The 2026 State Hazard Mitigation Plan State Mitigation Capabilities Assessment seeks to provide an understanding of the strengths and limitations of both state and local mitigation resources, which enable the development of targeted actions. This section achieved that objective by engaging state stakeholders and subject matter experts to identify changes in priorities, changes in state capabilities, gaps in mitigation capabilities, challenges to those capabilities, and opportunities for improvement. Several new hazards were identified, and based on the level of risk, stakeholders identified mitigation goals to reduce that risk, which required an understanding of capacity levels across all state capability types (e.g., Plans and Regulations; Administrative and Technical; Financial; and Education and Outreach capabilities).

PREMB also underwent restructuring to better align with Puerto Rico's hazard mitigation mission, including coordination with COR3 and other agencies engaged in hazard mitigation planning. Going forward, PREMB and all agencies involved in mitigation will continue to lead interagency coordination efforts—alongside federal partners—to ensure that state capabilities are appropriate and available to support mitigation goals and actions that address both short- and long-term risk reduction at the state and municipal levels.

SECTION SIX

LOCAL MITIGATION ASSESSMENT

Local Mitigation Assessment

Puerto Rico's 78 municipalities each face unique hazard conditions, geographic constraints, and levels of mitigation capacity. To effectively evaluate local capabilities and promote coordinated risk reduction, this section utilizes the Puerto Rico Emergency Management Bureau (PREMB/NMEAD) Operational Zones as illustrated in Figure 296 as the organizing framework for assessing municipal hazard-mitigation capacity and needs. The use of NMEAD's regional zones allows for a consistent, regionally focused assessment of municipal strengths, challenges, and opportunities. Each zone, as showcased in Figure 296, represents a cluster of municipalities that share similar hazard exposure, geographic characteristics, and operational coordination structures. This approach supports a regional perspective on mitigation, recognizing that disasters often transcend municipal boundaries.

The Local Mitigation Assessment was conducted through a comprehensive review of local mitigation plans from each municipality, and it documents municipal capabilities within each zone across key functional areas, including:

- Hazard mitigation and vulnerability assessment
- Local policies and programs
- Administrative and financial resources

The assessment offers insight into each municipality's current capacity to plan, fund, and implement mitigation activities. It also identifies gaps and highlights opportunities for targeted technical assistance, training, and resource investment.

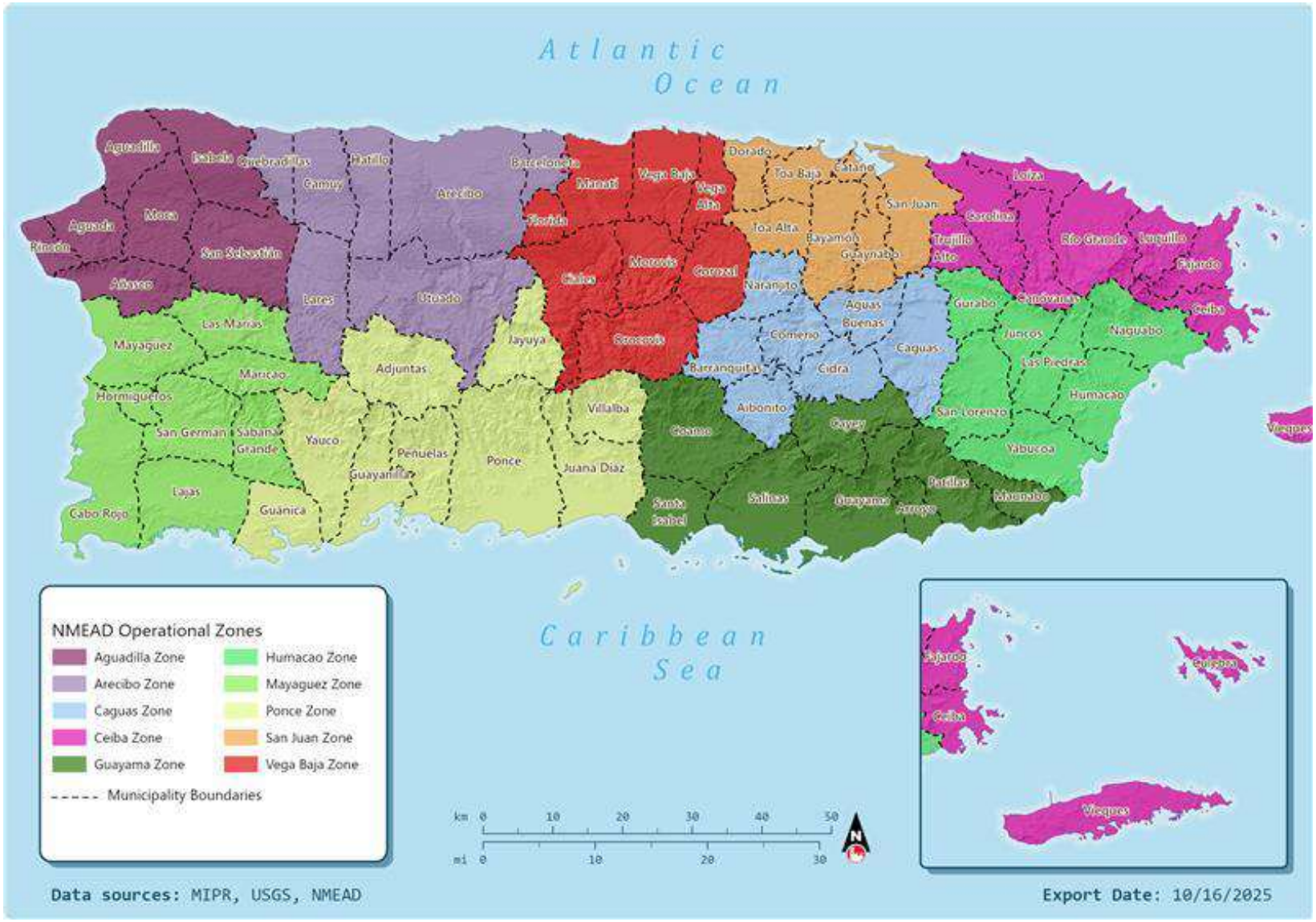

Figure 296: Puerto Rico Emergency Management Bureau (PREMB/NMEAD) Operational Zones

Table 136: Puerto Rico Emergency Management Bureau (PREMB/NMEAD) Operational Zones

Zone	Municipalities
Zona Aguadilla	Aguada, Aguadilla, Añasco, Isabela, Moca, Rincón and San Sebastián
Zona Arecibo	Arecibo, Barceloneta, Camuy, Hatillo, Lares, Quebradillas, and Utuado
Zona Caguas	Aguas Buenas, Aibonito, Barranquitas, Caguas, Cidra, Comerío, and Naranjito
Zona Ceiba	Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, Trujillo Alto, and Vieques
Zona Guayama	Arroyo, Cayey, Coamo, Guayama, Maunabo, Patillas, Salinas, and Santa Isabel
Zona Humacao	Gurabo, Humacao, Juncos, Las Piedras, Naguabo San Lorenzo, and Yabucoa
Zona Mayagüez	Cabo Rojo, Hormigueros, Lajas, Las Marías, Maricao, Mayagüez, Sábana Grande, and San Germán
Zona Ponce	Adjuntas, Guánica, Guayanilla, Jayuya, Juana Díaz Peñuelas, Ponce, Villalba, and Yauco
Zona San Juan	Bayamón, Cataño, Dorado, Guaynabo, San Juan Toa Alta, and Toa Baja
Zona Vega Baja	Ciales, Corozal, Florida, Manatí, Morovis, Orocovis, Vega Alta, and Vega Baja

Hazard Identification and Vulnerability Assessment

Puerto Rico's diverse geography, tropical climate, and coastal setting expose its 78 municipalities to a broad range of natural hazards. Local jurisdictions across Puerto Rico vary in their ability to assess, plan for, and mitigate hazards such as hurricanes, flooding, earthquakes, and landslides. Furthermore, each jurisdiction experiences these hazards differently depending on its location, topography, and level of urban development. To prioritize mitigation efforts, local governments commonly rank hazards using a Low, Medium, or High scale based on their frequency, potential impacts, and community vulnerability.

Each municipality assesses historical damage data, local knowledge, and vulnerability indicators (e.g., critical infrastructure exposure and population density).

- High = Frequent or severe hazard with major potential loss of life, property damage, or disruption.
- Medium = Periodic hazard with moderate impacts or limited geographic scope.
- Low = Infrequent or minor hazard with minimal community disruption.

This ranking process supports the development of tailored mitigation actions, ensuring that local Hazard Mitigation Plans address each community's unique risk profile while aligning with Puerto Rico's island-wide resilience strategies.

It is important to distinguish between hazards identified in the 2021 plan and those introduced during the 2025 plan update. The plan included previously recognized hazards, as listed in Table 137, which had been evaluated and ranked by local jurisdictions based on historical data, operational experience, and established risk assessments. Hazards with a single asterisk (*) are new to this plan.

Commonwealth of Puerto Rico Hazards

*Coastal Erosion, *Lightning, *Dam Failures, Liquefaction, Drought, *Pandemic/Epidemic, Earthquakes, *Rip Currents, *Extreme Heat, *Sargassum, *Subsidence, *Tornados, *Tsunami, Extreme Winds/ Hurricanes/ Tropical Storm, *Faults and Fissures, Floods, *Torrential Rains, *Hazardous Materials, *Invasive Species, *Waterspouts, Landslides, and *Wildfires

The following tables provide each municipality's ranking of the locally identified hazards, using the scale of Low, Moderate, and High risk. The municipalities are organized into corresponding zones (See Tables 3–12). This classification provides a clear and comparative view of each hazard's potential impact and likelihood. The information provided in these tables helps focus planning efforts on hazards that pose a significant threat to the community.

The 2025 plan incorporates some new hazards that may not have been previously evaluated by local jurisdictions; as a result, they are currently marked as "N/R", meaning "Not Ranked." Hazards with a double asterisk (**) indicate the hazard was identified by the local jurisdiction. Furthermore, any hazards with N/A indicate that the hazard was not evaluated by the jurisdiction.

This distinction helps ensure clarity in identifying which hazards are carried over from the previous plans, have been reassessed, are applicable to a specific jurisdiction, and are newly incorporated into the State Hazard Mitigation Plan.

Table 137: San Juan Zone Local-Identified Hazards Rankings by Municipality

Zona San Juan	Hazards Ranking						
	Bayamón	Cataño	Dorado	Guaynabo	San Juan	Toa Alta	Toa Baja
*Coastal Erosion	N/A	Low		N/A	High	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	low	N/A	Low	Low	High	Low	High
Earthquakes	low	N/A	High	Low	High	Moderate	Moderate
*Extreme Heat	Low	N/A	Low	Low	N/A	Low	N/A
Extreme Winds/Hurricane /Tropical Storm	high	N/A	High	High	High	High	High
*Faults and Fissures	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Floods	High		Moderate	High	High	High	High
*Hazardous Materials	N/R	High	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	Low	N/A	High	Low	Low	Low	Moderate
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	Low	Low	Low
**Storm Surge	Low	Low	Low	Low	Low	Low	Low
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zona San Juan	Hazards Ranking						
	Bayamón	Cataño	Dorado	Guaynabo	San Juan	Toa Alta	Toa Baja
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Tsunami	Low	Low	Moderate	Low	Low	Low	Low
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	Low	Low	Low	Low	Low	Low	Low

Table 138: Vega Baja Zone Local-Identified Hazards Rankings by Municipality

Zona Vega Baja	Hazards Ranking							
	Ciales	Corozal	Florida	Manatí	Morovis	Orocovis	Vega Alta	Vega Baja
*Coastal Erosion	N/A	N/A	N/A	Low	N/A	N/A	Low	Moderate
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	Moderate	High	Moderate	High	Low	High	High	Moderate
Earthquakes	High	High	High	Moderate	Moderate	Moderate	High	High
*Extreme Heat	Low	Moderate	Moderate	Low	Low	Low	N/A	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High	High
*Faults and Fissures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Floods	High	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	Moderate	Moderate	High	Moderate	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	High	High	High	High	High	Moderate	High	High
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	N/R	N/R	N/R	Moderate	N/R	N/R	Moderate	Low
**Storm Surge	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zona Vega Baja	Hazards Ranking							
	Ciales	Corozal	Florida	Manatí	Morovis	Orocovis	Vega Alta	Vega Baja
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	N/R	N/R	N/R	Low	N/R	N/R	Low	N/R
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	High	High	Low	Low	Low	High	Low	Low

Table 139: Arecibo Zone Local-Identified Hazards Rankings by Municipality

Zone - Arecibo	Hazards Ranking						
	Arecibo	Barceloneta	Camuy	Hatillo	Lares	Quebradillas	Utuado
*Coastal Erosion	Low	Low	Low	Low	N/A	Low	N/A
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	Moderate	Moderate	High	Low	Moderate	High
Earthquakes	High	Moderate	High	High	High	Moderate	Moderate
*Extreme Heat	Low	N/A	Low	Moderate	Low	Low	Moderate
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High
*Faults and Fissures	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Floods	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	Low	High	High	Moderate	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	High	Moderate	High	High	High	Moderate	Moderate
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	High	Moderate	N/R	High	N/R	Low	N/R
**Storm Surge	N/R	Moderate	N/R	N/R	N/R	Low	N/R

Zone - Arecibo	Hazards Ranking						
	Arecibo	Barceloneta	Camuy	Hatillo	Lares	Quebradillas	Utuado
***Subsidence**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
***Tornadoes**	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Torrential Rains**	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Tsunami**	High	Moderate	Low	High	N/A	Low	N/A
***Waterspouts**	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Wildfires**	Low	Moderate	Low	High	Low	Low	Low

Table 140: Aguadilla Zone Local-Identified Hazards Rankings by Municipality

Zone - Aguadilla	Hazards Ranking						
	Aguada	Aguadilla	Añasco	Isabela	Moca	Rincón	San Sebastián
*Coastal Erosion	High	Low	Low	Moderate	N/A	Low	N/A
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	High	High	High	Moderate	High	Moderate
Earthquakes	High	Moderate	Moderate	High	High	High	High
*Extreme Heat	Moderate	High	High	High	Low	High	Low
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High
*Faults and Fissures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Floods	High	High	High	High	High	High	Moderate
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	Moderate	Moderate	Moderate	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	High	Moderate	High	High	N/A	High	N/A
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	N/A	Low	N/A
**Storm Surge	Low	N/A	Low	Low	N/A	Low	N/A

Zone - Aguadilla	Hazards Ranking						
	Aguada	Aguadilla	Añasco	Isabela	Moca	Rincón	San Sebastián
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	Low	Low	Low	Low	N/A	Low	N/A
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	High	Low	Low	Low	Moderate	N/A	High

Table 141: Mayaguez Zone Local-Identified Hazards Rankings by Municipality

Zone - Mayagüez	Hazards Ranking						
	Cabo Rojo	Hormigueros	Las Marías	Maricao	Mayagüez	Sábana Grande	San Germán
*Coastal Erosion	Low	N/A	N/A	N/A	N/A	N/A	N/A
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	Low	Moderate	High	Low	High	Moderate	Moderate
Earthquakes	High	Moderate	High	High	High	Moderate	Moderate
*Extreme Heat	N/A	Low	Low	Low	Low	Low	Low
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High
*Faults and Fissures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Floods	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	Low	Moderate	High	High	High	Moderate	Moderate
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/A	N/A	N/A	N/A	N/A	N/A	Moderate
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Moderate	N/R	N/R	N/R	Low	N/R	N/R
**Storm Surge	Moderate	N/R	N/R	N/R	Low	N/R	N/R

Zone - Mayagüez	Hazards Ranking						
	Cabo Rojo	Hormigueros	Las Marías	Maricao	Mayagüez	Sábana Grande	San Germán
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	Moderate	N/R	N/R	N/R	N/R	N/R	N/R
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	Low	Low	High	High	Low	Low	Low

Table 142: Ponce Zone Local-Identified Hazards Rankings by Municipality

Zone - Ponce	Hazards Ranking								
	Ponce	Villalba	Juana Díaz	Peñuelas	Guayanilla	Yauco	Guánica	Jayuya	Adjuntas
*Coastal Erosion	Low	Low	Low	Low	Low	Low	Low	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	High	High	High	High	High	High	High	High
Earthquakes	High	High	High	High	High	High	High	High	High
*Extreme Heat	High	High	High	High	High	High	High	High	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High	High	High
*Faults and Fissures	Low	Low	Low	Low	Low	Low	Low	Low	Low
Floods	High	High	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	High	High	High	High	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	Low	Low	Low	Low	Low
**Storm Surge	Low	Low	Low	Low	Low	Low	Low	Low	Low

Zone - Ponce	Hazards Ranking								
	Ponce	Villalba	Juana Díaz	Peñuelas	Guayanilla	Yauco	Guánica	Jayuya	Adjuntas
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	High	High	High	High	High	High	High	High	High
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	High	High	High	High	High	High	High	High	High

Table 143: Guayama Zone Local-Identified Hazards Rankings by Municipality

Zone - Guayama	Hazards Ranking							
	Guayama	Cayey	Patillas	Maunabo	Arroyo	Salinas	Coamo	Santa Isabel
*Coastal Erosion	Low	Low	Low	Low	Low	Low	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	High	High	High	High	High	High	High
Earthquakes	High	High	High	High	High	High	High	High
*Extreme Heat	High	High	High	High	High	High	High	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High	High
*Faults and Fissures	Low	Low	Low	Low	Low	Low	Low	Low
Floods	High	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	High	High	High	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	Low	Low	Low	Low
**Storm Surge	Low	Low	Low	Low	Low	Low	Low	Low

Zone - Guayama	Hazards Ranking							
	Guayama	Cayey	Patillas	Maunabo	Arroyo	Salinas	Coamo	Santa Isabel
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	High	High	High	High	High	High	High	High
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	High	High	High	High	High	High	High	High

Table 144: Caguas Zone Local-Identified Hazards Rankings by Municipality

Zone - Caguas	Hazards Ranking						
	Caguas	Aguas Buenas	Cidra	Comerío	Barranquitas	Naranjito	Aibonito
*Coastal Erosion	Low	Low	Low	Low	Low	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	Low	High	High	High	High	High	High
Earthquakes	Low	High	High	High	High	High	High
*Extreme Heat	N/A	High	High	High	High	High	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High
*Faults and Fissures	N/R	NR	N/R	NR	N/R	NR	N/R
Floods	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	High	High	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	Low	High	High	High	High	High	High
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	N/R	N/R	N/R	N/R	N/R	N/R
**Storm Surge	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Zone - Caguas	Hazards Ranking						
	Caguas	Aguas Buenas	Cidra	Comerío	Barranquitas	Naranjito	Aibonito
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	Low	Low	Low	Low	Low	Low	Low
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	Low	High	High	High	High	High	High

Table 145: Humacao Zone Local-Identified Hazards Rankings by Municipality

Zone - Humacao	Hazards Ranking						
	Humacao	Naguabo	Las Piedras	Juncos	Yabucoa	San Lorenzo	Gurabo
*Coastal Erosion	Low	Low	Low	Low	Low	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	High	High	High	High	High	High
Earthquakes	High	High	High	High	High	High	High
*Extreme Heat	High	High	High	High	High	High	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High
*Faults and Fissures	Low	Low	Low	Low	Low	Low	Low
Floods	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	High	High	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	Low	Low	Low
**Storm Surge	Low	Low	Low	Low	Low	Low	Low
*Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Zone - Humacao	Hazards Ranking						
	Humacao	Naguabo	Las Piedras	Juncos	Yabucoa	San Lorenzo	Gurabo
*Tornadoes	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Torrential Rains	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Tsunami	High	High	High	High	High	High	High
*Waterspouts	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Wildfires	High	High	High	High	High	High	High

Table 146: Ceiba Zone Local-Identified Hazards Rankings by Municipality

Zone - Ceiba	Hazards Ranking									
	Ceiba	Fajardo	Luquillo	Río Grande	Loíza	Canóvanas	Carolina	Trujillo Alto	Culebra	Vieques
*Coastal Erosion	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
*Dam Failures	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Drought	High	High	High	High	High	High	High	High	High	High
Earthquakes	High	High	High	High	High	High	High	High	High	High
*Extreme Heat	High	High	High	High	High	High	High	High	High	High
Extreme Winds/Hurricane /Tropical Storm	High	High	High	High	High	High	High	High	High	High
*Faults and Fissures	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Floods	High	High	High	High	High	High	High	High	High	High
*Hazardous Materials	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Invasive Species	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Landslides	High	High	High	High	High	High	High	High	High	High
*Lightning	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
Liquefaction	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
*Pandemic/Epidemic	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Rip Currents	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
*Sargassum	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
**Sea Level Rise	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
**Storm Surge	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Zone - Ceiba	Hazards Ranking									
	Ceiba	Fajardo	Luquillo	Río Grande	Loíza	Canóvanas	Carolina	Trujillo Alto	Culebra	Vieques
Subsidence	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
***Tornadoes**	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Torrential Rains**	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Tsunami**	High	High	High	High	High	High	High	High	High	High
***Waterspouts**	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
***Wildfires**	High	High	High	High	High	High	High	High	High	High

Local Government Policies, Programs, and Capabilities

Local governments in Puerto Rico play a critical role in hazard mitigation through a range of policies, planning tools, and preparedness programs. These initiatives are designed to guide land use, infrastructure development, environmental protection, and emergency response, all of which contribute to building safer and more resilient communities. Key instruments such as the Territorial Land Use Plan (POT) and the Four-Year Investment Program (PICA) provide municipalities with strategic frameworks for sustainable development and capital improvement planning. Programs like the Stormwater Management Program (SWMP) and Municipal Recovery Planning (MRP) address environmental risks and post-disaster recovery, while regulatory tools such as PRAPEC ensure the protection of ecologically sensitive areas. Additionally, preparedness initiatives like TsunamiReady and StormReady enhance local capabilities to respond to natural hazards. Together, these policies and programs reflect the commitment of Puerto Rico's municipalities to proactive planning, interagency coordination, and community engagement in hazard mitigation efforts.

Plan de Ordenamiento Territorial (POT)

The Territorial Land Use Plan in Puerto Rico is a municipal planning tool used to manage land use, infrastructure, demographics, and the economic and social development of a municipality. It focuses on the balanced and efficient use of land, the protection of natural resources, and the integration of urban and rural development. Its main legal foundations are the Autonomous Municipalities Act and the current Municipal Code, which grant municipalities the authority to conduct local planning with citizen participation.[1121]

2018 Building Code

Building codes represent an important local tool for risk reduction. Additional information on building codes, including the Government of Puerto Rico's efforts to support building code adoption and enforcement, is included in the State Mitigation Capabilities. In addition to the state-level efforts to address building codes, 19 autonomous municipalities are authorized to manage their own building codes directly. As part of its permitting responsibilities, municipalities ensure strict compliance with the current building code regulations. These codes are designed to guarantee that new developments meet structural resilience standards against natural hazards, thereby minimizing potential losses during such events.

Stormwater Management Program (SWMP) and Municipal Storm Sewer System (MS4)

In Puerto Rico, a Stormwater Management Program (SWMP) is a mandatory plan for designated Municipal Separate Storm Sewer Systems (MS4s) to control stormwater pollution under the federal National Pollutant Discharge Elimination System permit. The MS4 is a system of drains, pipes, and roads that collect

[1121] For more information per municipality, visit https://www.jp.pr.gov/planificacion-fisica?tab=mitigacion#tab-section.

stormwater, distinct from sanitary sewers. The SWMP is structured around six minimum control measures (MCMs) and is overseen by the Puerto Rico Department of Natural and Environmental Resources (DNER) in coordination with the EPA.

Municipal Recovery Planning (MRP)

The Municipal Recovery Planning (MRP) initiative, led by the Puerto Rico Department of Housing, was created to address both current and future municipal needs in areas affected by Hurricanes Irma and/or María. The program provides funding to municipalities for planning activities that respond to conditions caused or worsened by these natural disasters. The planning process results in the development of Recovery Plans, which serve as strategic guides for building resilient communities across Puerto Rico. Throughout this process, municipalities receive technical assistance from Vivienda. This program presents a valuable opportunity for municipalities to strengthen their long-term resilience by leveraging funding and expert support to develop tailored recovery strategies. It also encourages proactive planning and coordination to better prepare for future disasters.

Plan y Reglamento del Área de Planificación del Carso (PRAPEC) Karst Planning Area Plan and Regulation

PRAPEC is a legal framework enacted by Puerto Rico's government to protect ecologically sensitive karst regions. Approved via Executive Order, it regulates land use and human activities in these areas through zoning changes, permitting rules, and planning amendments. Its main goal is to safeguard natural resources and prevent environmental degradation.

TsunamiReady

Puerto Rico's TsunamiReady program is a preparedness initiative aimed at helping municipalities strengthen their response capabilities to tsunami threats. By 2016, 46 municipalities—44 coastal and 2 inland (Bayamón and Canóvanas)—earned the TsunamiReady designation. To qualify, municipalities must meet specific criteria, including maintaining a 24/7 tsunami warning contact, having a clear evacuation plan and map, installing designated signage, implementing alert systems, and conducting public education. The program is jointly managed by the Puerto Rico Seismic Network (PRSN) and the National Weather Service (NWS), which provide technical support, evacuation maps, and educational resources to promote community resilience.

StormReady

Puerto Rico municipalities prepare for storms through initiatives like the StormReady and TsunamiReady programs, which involve certification for specific communities. Other preparation efforts include the development of municipal Hazard Mitigation Plans, coordination with the Puerto Rico Emergency Management Bureau (PREMB) for resources, and pre-positioning of materials by Luma Energy and other utility companies. The overarching goal is to create a more resilient and prepared network of local

governments capable of responding to severe weather events. Municipalities such as Aguada, Aguadilla, Camuy, Carolina, Dorado, Manatí, Mayagüez, Toa Baja, and Vega Baja are both StormReady and TsunamiReady certified. Many other municipalities hold TsunamiReady certification but not StormReady, such as San Juan, Ponce, and Fajardo.[1122]

The following tables summarize the local mitigation capabilities of each municipality in Puerto Rico, assigning each jurisdiction an effectiveness rating. This information was collected from various sources, including the most recent update of each municipality's LHMP. The tables assess capabilities across the following dimensions:

Table 147: Municipality-Specific Capabilities

Abbreviation	Community Capability	Reference
HMP	Hazard Mitigation Plan	Has the jurisdiction adopted a FEMA-approved Hazard Mitigation Plan?
NFIP	National Flood Insurance Program	Does the community participate in the FEMA National Flood Insurance Program?
CRS	Community Rating System	If the jurisdiction participates in the Community Rating System, what is the class rating? (Classes 1–10)
Zone	Zoning Ordinance	Does the jurisdiction administer a zoning ordinance?
Sub Reg	Subdivision Regulations	Does the jurisdiction administer subdivision regulations?
Bldg Code	Building Codes	Does the jurisdiction administer building codes?
BCEGS	Building Code Effectiveness Grade Schedule	To what degree does the jurisdiction assess the building codes in effect in a particular community, as well as how the community enforces its building codes?
PPC	Property Protection Classification	What community property protection class has been assigned by the Insurance Services Office, Inc. (ISO)?
Comp Plan	Comprehensive Plan	Within the last five years, has the jurisdiction adopted a comprehensive plan to guide the community's long-term (10- to 25-year) growth and development, or is its preparation or update still in progress?
CIP	Capital Improvement Plan	Does the jurisdiction's program include annual capital expenditures in a multi-year capital improvement plan?
Plnr	Planner	Does the jurisdiction have a full-time professional planner on staff?

[1122] National Weather Service, StormReady® and TsunamiReady® in Puerto Rico and the U.S. Virgin Islands, https://www.weather.gov/stormready/pr-sr.

Abbreviation	Community Capability	Reference
Engr	Engineer	Does the jurisdiction have a full-time professional engineer on staff?
CFM	Certified Floodplain Manager	Does the jurisdiction have a Certified Floodplain Manager on staff to administer its floodplain management ordinance?
Bldg Insp	Building Inspector	Does the jurisdiction have a full-time building inspector on staff?
GIS	Geographic Information System	Does the jurisdiction have a Geographic Information System?
SWMP & MS4*	Stormwater Management Program	Does the jurisdiction have a Stormwater Management Program (SWMP) and Municipal Storm Sewer System (MS4) certification?
MRP*	Municipal Recovery Planning	Does the jurisdiction participate in the PR Department of Housing's Municipal Recovery Planning program?
PRAPEC*	Karst Planning Area Plan and Regulation	*Plan y Reglamento del Área de Planificación del Carso* Does the jurisdiction participate in the Karst Planning Area Plan and Regulation?
Education*	Education and Outreach	Does the jurisdiction have education and outreach programs and platforms for the communities?

*New capabilities not listed in the 2021 SHMP.

Fields in the following tables are marked with a "Y" (Yes) if the area possesses the capability, or with an "N" (No) if the jurisdiction does not possess the capability. Other fields in the tables are indicated by "X" if the Hazard Mitigation Plan was not located, and "U" if the information is unknown. The municipalities are organized into corresponding zones (see Table 136).

Table 148: Legend

Category	Definition
Yes	Capability identified
No	Capability not identified
U (Unknown)	It is unclear whether the municipality has the capability
X (Not Found)	Hazard Mitigation Plan Not Found

Figure 297: NMEAD Operational Zones – San Juan Zone

All seven municipalities in the Zona San Juan (San Juan Zone) have Hazard Mitigation Plans (HMPs), participate in the National Flood Insurance Program (NFIP), and have adopted building codes, indicating a strong foundation in regulatory compliance and planning. However, none participate in the Community Rating System (CRS), and several lack confirmed engineering staff, Certified Floodplain Managers (CFMs), and building inspectors, which may limit technical capacity for mitigation implementation. GIS capabilities and other planning tools such as BCEGS, PPC, and comprehensive plans are largely unknown, and Capital Improvement Plans (CIPs) are missing in Bayamón and Toa Alta. Key strengths include consistent HMP adoption, NFIP participation, and planning staff presence, while key weaknesses lie in limited technical staffing, lack of CRS engagement, and gaps in data for critical planning tools and capabilities.

Table 149: San Juan Zone Local Capabilities by Municipality

Capability	San Juan	Guaynabo	Bayamón	Cataño	Toa Baja	Dorado	Toa Alta
HMP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NFIP	Yes	Yes*	Yes*	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub Reg	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bldg Code	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BCEGS	U	U	U	U	U	U	U
PPC	U	U	U	U	U	U	U
Comp Plan	U	U	U	U	U	U	U
CIP	Yes	Yes	U	Yes	Yes	U	Yes
Plnr	Yes	Yes	Yes	Yes	Yes	Yes	No
Engr	Yes	No	U	No	Yes	Yes	Yes
CFM	U	No	U	No	No	No	No
Bldg Insp	U	Yes	U	U	U	No	No
GIS	U	U	U	Yes	Yes	U	No
SWMP & MS4	Yes	U	U	U	U	U	Yes
MRP	Yes	Yes	No	Yes	Yes	Yes	Yes
PRAPEC	Yes	Yes	U	Yes	Yes	Yes	Yes
Education	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Yes represents those municipalities that participate as a community under NFIP. The remaining 74 municipalities are under the "Puerto Rico Community" category.

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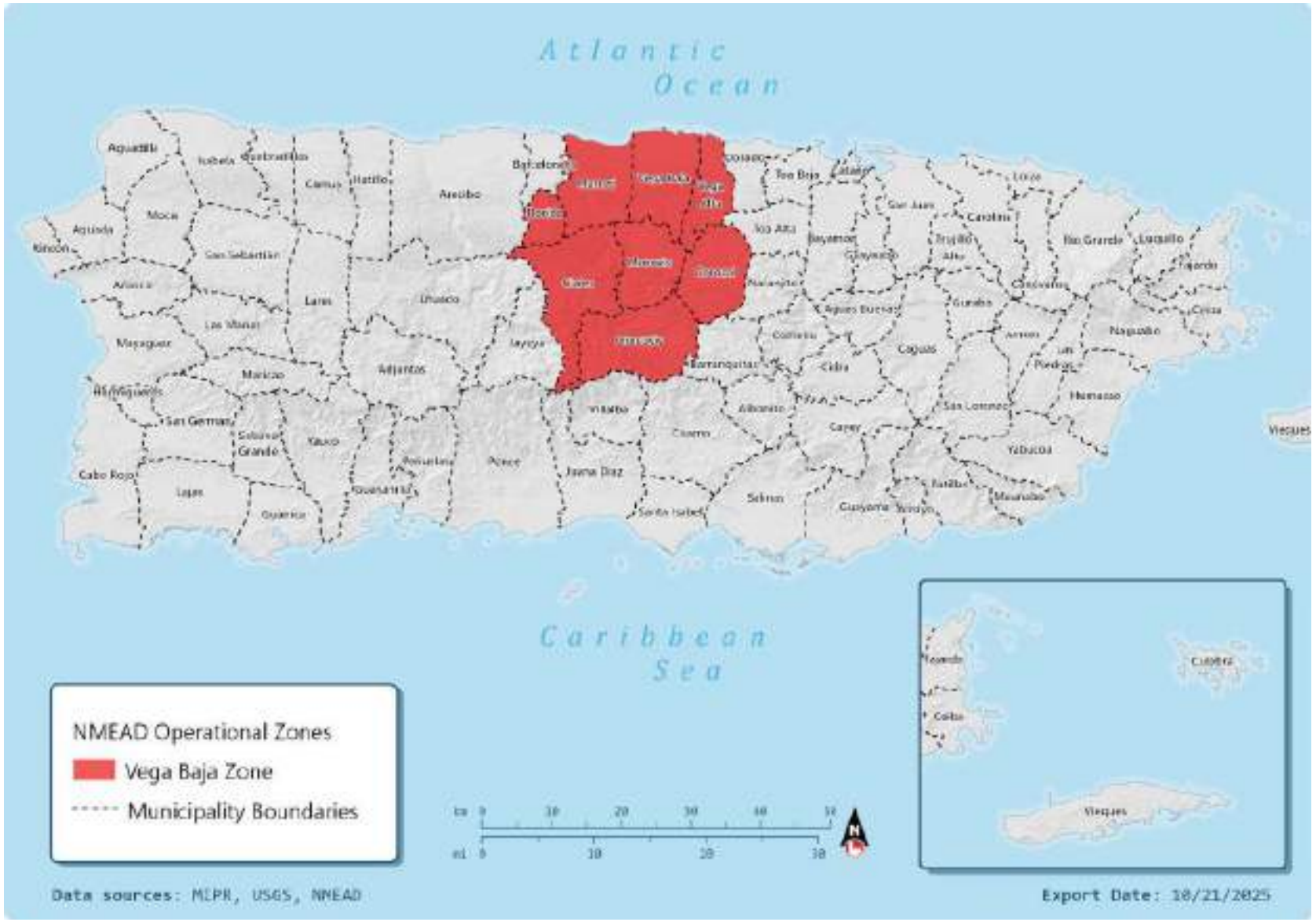

Figure 298: NMEAD Operational Zones – Vega Baja Zone

The municipalities of Vega Baja, Vega Alta, Corozal, Orocovis, Ciales, Morovis, Manatí, and Florida demonstrate a strong foundation in mitigation planning, with all having Hazard Mitigation Plans (HMPs), NFIP participation, building codes, and Municipal Recovery Plans (MRPs). However, none participate in the Community Rating System (CRS), and most lack key technical capabilities such as Certified Floodplain Managers (CFMs), building inspectors, and GIS support. Planning and engineering staff are unevenly distributed, and several municipalities lack Capital Improvement Plans (CIPs) or have unknown status for essential planning tools like BCEGS, PPC, and comprehensive plans. To strengthen local mitigation capabilities, municipalities should prioritize training CFMs and building inspectors, expand GIS infrastructure, develop or update CIPs, and improve data collection and transparency for planning tools. Additionally, joining the CRS program could enhance floodplain management and provide insurance incentives, while regional collaboration could help fill staffing and technical gaps.

Table 150: Vega Baja Zone Local Capabilities by Municipality

Capability	Vega Baja	Vega Alta	Corozal	Orocovis	Ciales	Morovis	Manatí	Florida
HMP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub Reg	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bldg Code	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BCEGS	U	U	U	U	U	U	U	U
PPC	U	U	U	U	U	U	U	U
Comp Plan	U	U	U	U	U	U	U	U
CIP	No	U	Yes	Yes	Yes	Yes	Yes	No
Plnr	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Engr	Yes	Yes	Yes	Yes	Yes	No	Yes	No
CFM	Yes	No	No	No	No	No	No	No
Bldg Insp	No	No	No	No	No	No	No	No
GIS	No	Yes	No	No	No	No	No	No
SWMP & MS4	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
MRP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PRAPEC	Yes	Yes	Yes	Yes	U	Yes	Yes	Yes
Education	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Figure 299: NMEAD Operational Zone – Arecibo Zone

The municipalities in Zona Arecibo generally show strong foundational capabilities in hazard mitigation, with most having Hazard Mitigation Plans, NFIP participation, building codes, and Municipal Recovery Plans. However, none participate in the Community Rating System (CRS), and technical staffing is notably limited, with most municipalities lacking planners, engineers, Certified Floodplain Managers (CFMs), building inspectors, and GIS capabilities. Additionally, key planning tools such as BCEGS, PPC, and comprehensive plans remain unknown across the zone. To improve local mitigation capabilities, municipalities should prioritize recruiting or training technical staff, especially planners and CFMs, establish or enhance GIS systems, and pursue CRS participation to improve floodplain management and reduce insurance costs. Strengthening data collection and transparency around planning tools and mitigation project experience will also support more informed decision-making and regional collaboration. The Hazard Mitigation Plan for Camuy could not be located; however, information on the municipalities included in the Municipal Recovery Plan (MRP) was found on the CDBG website.

Table 151: Arecibo Zone Local Capabilities by Municipality

Capability	Arecibo	Barceloneta	Hatillo	Camuy	Quebradillas	Utuado	Lares
HMP	Yes	Yes	Yes	X	Yes	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	X	Yes	Yes	Yes
Sub Reg	Yes	Yes	Yes	X	Yes	Yes	Yes
Bldg Code	Yes	Yes	Yes	X	Yes	Yes	Yes
BCEGS	U	U	U	X	U	U	U
PPC	U	U	U	X	U	U	U
Comp Plan	U	U	U	X	U	U	U
CIP	Yes	Yes	Yes	X	Yes	Yes	Yes
Plnr	No	No	No	X	No	No	No
Engr	No	No	No	X	Yes	Yes	No
CFM	No	No	No	X	No	No	No
Bldg Insp	No	No	No	X	No	No	No
GIS	No	No	No	X	No	No	No
SWMP & MS4	Yes	No	Yes	X	No	Yes	Yes
MRP	Yes	Yes	Yes	Yes	Yes	No	Yes
PRAPEC	Yes	Yes	Yes	X	Yes	Yes	Yes
Education	Yes	Yes	Yes	X	Yes	Yes	Yes

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Figure 300: NMEAD Operational Zone – Aguadilla Zone

Most of the municipalities in the Zona Aguadilla (Aguadilla Zone) have Hazard Mitigation Plans (HMPs) to guide their preparedness and resilience efforts. They also have NFIP participation, building codes, and Municipal Recovery Plans (MRPs). However, Moca's HMP could not be located, and several other capabilities are missing or unknown, and none of the municipalities participate in the Community Rating System (CRS). Technical staffing is inconsistent, with limited presence of planners, engineers, Certified Floodplain Managers (CFMs), building inspectors, and GIS support. Key planning tools such as BCEGS, PPC, and comprehensive plans are largely unknown or absent. To improve mitigation capabilities, municipalities should enhance technical staffing through recruitment or shared regional resources, implement GIS systems, and pursue CRS participation to strengthen floodplain management and reduce insurance costs. Improving data transparency and expanding planning tools will also support more effective and coordinated mitigation efforts across the zone.

Table 152: Aguadilla Zone Local Capabilities by Municipality

Capability	Aguadilla	Isabela	Moca	Aguada	San Sebastián	Añasco	Rincón
HMP	Yes	Yes	X	Yes	Yes	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No
Zone	Yes	Yes	X	Yes	Yes	Yes	Yes
Sub Reg	Yes	Yes	X	Yes	Yes	Yes	Yes
Bldg Code	Yes	Yes	X	Yes	Yes	Yes	Yes
BCEGS	U	U	X	U	U	U	U
PPC	U	U	X	U	U	U	U
Comp Plan	U	U	X	U	U	U	U
CIP	Yes	Yes	X	Yes	Yes	Yes	Yes
Plnr	Yes	Yes	X	No	Yes	No	Yes
Engr	U	Yes	X	No	Yes	Yes	Yes
CFM	U	No	X	No	No	No	No
Bldg Insp	U	No	X	No	No	No	No
GIS	U	No	X	No	No	No	No
SWMP & MS4	Yes	U	X	Yes	Yes	Yes	U
MRP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PRAPEC	No	Yes	X	Yes	Yes	No	U
Education	U	Yes	X	No		Yes	Yes

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Figure 301: NMEAD Operational Zones – Mayaguez Zone

Zona Mayagüez (Mayagüez Zone), located in western Puerto Rico, shows a solid foundation in hazard mitigation, with most municipalities having Hazard Mitigation Plans (HMPs), NFIP participation, building codes, and Municipal Recovery Plans (MRPs), which support disaster preparedness, public safety, and access to federal funding. However, none participate in the Community Rating System (CRS), and many lack essential technical staff such as planners, engineers, CFMs, and building inspectors, as well as GIS capabilities. Key planning tools like BCEGS, PPC, and CIPs are also missing or unknown. To strengthen resilience, municipalities should focus on filling staffing gaps, implementing GIS systems, joining CRS, and improving data transparency and planning documentation.

Table 153: Mayagüez Zone Local Capabilities by Municipality

Capability	Mayagüez	Hormigueros	Las Marías	Maricao	San Germán	Sábana Grande	Cabo Rojo	Lajas
HMP	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes
Sub Reg	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes
Bldg Code	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes
BCEGS	U	U	U	U	U	X	U	U
PPC	U	U	U	U	U	X	U	U
Comp Plan	U	U	U	U	U	X	U	U
CIP	U	Yes	U	Yes	Yes	X	U	Yes
Plnr	Yes	Yes	No	No	Yes	X	Yes	No
Engr	Yes	Yes	No	No	Yes	X	Yes	No
CFM	No	No	No	No	U	X	No	No
Bldg Insp	No	No	No	No	U	X	No	No
GIS	No	No	No	No	No	X	No	No
MRP	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
PRAPEC		Yes	U	U	Yes	X	Yes	Yes
SWMP & MS4	U	Yes	Yes	Yes	Yes	X	No	Yes
Education	Yes	Yes	Yes	U	Yes	X	Yes	U

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Figure 302: NMEAD Operational Zone – Ponce Zone

Zona Ponce (Ponce Zone), located in southern Puerto Rico, demonstrates important mitigation capabilities that support disaster preparedness, public safety, and access to federal resources. Municipalities with Hazard Mitigation Plans (HMPs), NFIP participation, and Municipal Recovery Plans (MRPs) are better positioned to reduce risk and recover more effectively from natural hazards. However, opportunities for improvement remain, particularly in expanding technical staffing, such as planners, engineers, and Certified Floodplain Managers, and implementing GIS systems to support data-driven decision-making. Increasing participation in the Community Rating System (CRS) could also help lower flood insurance costs and strengthen floodplain management. Enhancing planning tools and improving data transparency will further support coordinated, long-term resilience across the region.

Table 154: Ponce Zone Local Capabilities by Municipality

Capability	Ponce	Villalba	Juana Díaz	Peñuelas	Guayanilla	Yauco	Guánica	Jayuya	Adjuntas
HMP	Yes	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NFIP	Yes*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	Yes[1123]	No	No	No	No	No	No	No	No
Zone	Yes	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub Reg	Yes	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bldg Code	Yes	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BCEGS	U	X	U	U	U	U	U	U	U
PPC	U	X	U	U	U	U	U	U	U
Comp Plan	U	X	U	U	U	U	U	U	U
CIP	U	X	Yes	Yes	Yes	No	Yes	Yes	Yes
Plnr	Yes	X	Yes	Yes	No	No	No	No	No
Engr	Yes	X	Yes	Yes	No	Yes	No	No	No
CFM	No	X	No	No	No	No	No	No	No
Bldg Insp	No	X	No	No	No	No	No	No	No
GIS	No	X	No	No	No	No	No	No	No
SWMP & MS4	Yes	X	U	Yes	U	No	No	Yes	Yes
MRP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PRAPEC	U	X	U	U	Yes	Yes	Yes	U	No
Education	Yes	X	U	U	Yes	Yes	U	Yes	Yes
Cap Rat									

[1123] Currently, Ponce is the **only** municipality that falls under the Community Rating System "CRS."

Figure 303: NMEAD Operational Zone – Guayama Zone

Zona Guayama (Guayama Zone), in southeastern Puerto Rico, shows a mix of strengths and gaps in local mitigation capabilities. Several municipalities have Hazard Mitigation Plans, NFIP participation, and Municipal Recovery Plans (MRPs), which are essential for reducing disaster risk, improving emergency response, and securing federal funding. Knowing which municipalities possess these capabilities helps target resources and support where they're most needed. However, technical staffing is limited, with few planners, engineers, Certified Floodplain Managers (CFMs), and GIS systems. None of the municipalities participate in the Community Rating System (CRS), and key planning tools such as Capital Improvement Plans (CIPs), BCEGS, and comprehensive plans are often missing or unknown. To strengthen resilience, municipalities should prioritize filling staffing gaps, implementing GIS and floodplain management systems, and improving data transparency to support coordinated long-term mitigation efforts.

Table 155: Guayama Zone Local Capabilities by Municipality

Capability	Guayama	Cayey	Patillas	Maunabo	Arroyo	Salinas	Coamo	Santa Isabel
HMP	Yes	Yes	Yes	X	Yes	Yes	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	X	Yes	Yes	Yes	Yes
Sub Reg	Yes	Yes	Yes	X	Yes	Yes	Yes	Yes
Bldg Code	Yes	Yes	Yes	X	Yes	Yes	Yes	Yes
BCEGS	U	U	U	X	U	U	U	U
PPC	U	U	U	X	U	U	U	U
Comp Plan	U	U	U	X	U	U	U	U
CIP	Yes	Yes	Yes	X	U	Yes	No	Yes
Plnr	Yes	Yes	No	X	Yes	No	Yes	No
Engr	Yes	Yes	Yes	X	Yes	Yes	Yes	No
CFM	No	No	No	X	No	No	No	No
Bldg Insp	No	No	No	X	No	No	No	No
GIS	No	No	No	X	No	No	No	No
SWMP & MS4	U	Yes	Yes	X	Yes	No	U	No
MRP	No	No	Yes	Yes	Yes	Yes	Yes	Yes
PRAPEC	U	U	U	X	U	U	U	U
Education	Yes	U	Yes	X	Yes	U	Yes	Yes
Cap Rat				X				

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Figure 304: NMEAD Operational Zone – Caguas Zone

All the Hazard Mitigation Plans (HMPs) were found for Zona Caguas (Caguas Zone). This could be a key asset for guiding disaster preparedness, securing federal funding, and supporting long-term resilience. Knowing the specific capabilities of each municipality allows for more targeted support and efficient resource allocation. While foundational elements like NFIP participation and building codes are in place, opportunities for improvement include expanding technical staffing (e.g., planners, engineers, and Certified Floodplain Managers), implementing GIS systems, and increasing participation in the Community Rating System (CRS) to enhance floodplain management and reduce insurance costs. Strengthening planning tools and improving data transparency will further support coordinated mitigation efforts across the region.

Table 156: Caguas Zone Local Capabilities by Municipality

Capability	Caguas	Aguas Buenas	Cidra	Comerío	Barranquitas	Naranjito	Aibonito
HMP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No
Zone	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sub Reg	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bldg Code	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BCEGS	U	U	U	U	U	U	U
PPC	U	U	U	U	U	U	U
Comp Plan	U	U	U	U	U	U	U
CIP	Yes	No	Yes	Yes	Yes	Yes	Yes
Plnr	Yes	No	Yes	Yes	Yes	Yes	Yes
Engr	Yes	No	Yes	Yes	Yes	Yes	Yes
CFM	No	No	No	No	No	No	No
Bldg Insp	No	No	No	No	No	No	No
GIS	No	No	No	No	Yes	No	No
SWMP & MS4	Yes	No	Yes	No	Yes	U	Yes
MRP	Yes	Yes	Yes	Yes	Yes	No	Yes
PRAPEC	Yes	U	U	U	U	U	U
Education		No	Yes	Yes	Yes	Yes	Yes
Cap Rat							

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Figure 305: NMEAD Operational Zone – Humacao Zone

Zona Humacao, in southeastern Puerto Rico, shows a mix of established mitigation capabilities and areas needing attention. While most municipalities have Hazard Mitigation Plans (HMPs), the plans for San Lorenzo and Naguabo could not be located, underscoring the importance of maintaining accessible and up-to-date documentation. Knowing each municipality's capabilities, such as NFIP participation, building codes, and Municipal Recovery Plans (MRPs), is essential for guiding disaster preparedness, securing funding, and targeting support effectively. However, technical staffing is limited, with few planners, engineers, Certified Floodplain Managers (CFMs), and GIS systems, and none of the municipalities participate in the Community Rating System (CRS). Strengthening staffing, expanding GIS use, and improving transparency around planning tools would enhance coordination and long-term resilience across the region.

Table 157: Humacao Zone Local Capabilities by Municipality

Capability	Humacao	Naguabo	Las Piedras	Juncos	Yabucoa	San Lorenzo	Gurabo
HMP	Yes	X	Yes	Yes	Yes	X	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	No
Zone	Yes	X	Yes	Yes	Yes	X	Yes
Sub Reg	Yes	X	Yes	Yes	Yes	X	Yes
Bldg Code	Yes	X	Yes	Yes	Yes	X	Yes
BCEGS	U	X	U	U	U	X	U
PPC	U	X	U	U	U	X	U
Comp Plan	U	X	U	U	U	X	U
CIP	Yes	X	Yes	Yes	Yes	X	Yes
Plnr	Yes	X	U	Yes	Yes	X	Yes
Engr	Yes	X	U	No	Yes	X	Yes
CFM	No	X	U	No	No	X	No
Bldg Insp	No	X	U	No	No	X	No
GIS	No	X	U	No	No	X	No
SWMP & MS4	Yes	X	U	U	Yes	X	Yes
MRP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
PRAPEC	U	X	U	U	U	X	U
Education	Yes	X	U	Yes	Yes	X	Yes
Cap Rat		X				X	

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Figure 306: NMEAD Operational Zone – Ceiba Zone

Zona Ceiba (Ceiba Zone), in eastern Puerto Rico, shows a mix of established mitigation capabilities and areas needing improvement. Most municipalities have Hazard Mitigation Plans (HMPs), but the plans for Canóvanas and Culebra could not be found, highlighting the need for better documentation and accessibility. Understanding and tracking each municipality's capabilities, such as NFIP participation, building codes, and Municipal Recovery Plans (MRPs), is essential for effective disaster planning, securing federal support, and guiding targeted investments. However, technical staffing is limited, with few planners, engineers, Certified Floodplain Managers (CFMs), and GIS systems, and most municipalities do not participate in the Community Rating System (CRS). Strengthening staffing, expanding GIS use, and improving transparency around planning tools would enhance coordination and long-term resilience across the region.

Table 158: Ceiba Zone Local Capabilities by Municipality

Capability	Ceiba	Fajardo	Luquillo	Río Grande	Loíza	Canóvanas	Carolina	Trujillo Alto	Culebra	Vieques
HMP	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
NFIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CRS	No	No	No	No	No	No	Yes*	No	No	No
Zone	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
Sub Reg	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
Bldg Code	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
BCEGS	U	U	U	U	U	X	U	U	X	U
PPC	U	U	U	U	U	X	U	U	X	U
Comp Plan	U	U	U	U	U	X	U	U	X	U
CIP	Yes	No	U	Yes	Yes	X	U	Yes	X	Yes
Plnr	No	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
Engr	Yes	Yes	Yes	Yes	Yes	X	Yes	Yes	X	Yes
CFM	No	No	No	No	No	X	No	No	X	No
Bldg Insp	No	No	No	No	No	X	No	No	X	No
GIS	No	No	No	No	No	X	No	No	X	No
SWMP & MS4	U	Yes	Yes	Yes	Yes	X	U	U	X	U
MRP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
PRAPEC		U	U	U	U	X	U	U	X	U
Education	Yes	Yes	Yes	Yes	U	X	Yes	Yes	X	Yes

- **Financial:** Funding is essential for turning plans into action. Local mitigation efforts may be supported by municipal budgets, state and federal grants, private investments, or contributions from nonprofits. Knowing what resources are available and how to access them is crucial for implementing effective mitigation actions.
- **Education and Outreach:** Public awareness and engagement are powerful tools for risk reduction. Local programs that educate residents, train staff, and promote preparedness help build a culture of resilience. Outreach efforts also support community buy-in for mitigation projects.

The Puerto Rico Planning Board plays a central role in guiding land-use, zoning, and development across the island. Because hazards such as flooding, landslides, storm surge, and coastal erosion are closely tied to land development, the Planning Board regulations directly influence local mitigation strategies. By shaping upstream decisions—such as discouraging development in floodplains, karst zones, and steep slopes—the Planning Board empowers municipalities to reduce risk before disasters occur.

In coastal areas, the Planning Board serves as the lead agency for integrating land-use regulation with climate adaptation and mitigation strategies, including those addressing sea-level rise and erosion. It maintains critical spatial datasets—GIS layers, land-use maps, and parcel information—that help municipalities identify hazards and assess vulnerabilities. These tools are essential for crafting effective Local Hazard Mitigation Plans (LHMPs). Through the Planning Board, municipalities can gather data for

- Map flood-prone zones and landslide risks
- Identify karst terrain and subsidence areas
- Inform zoning updates and development decisions

This technical infrastructure enables local governments to design evidence-based and geographically targeted mitigation actions. Oversight of land-use and permitting ensures that hazard mitigation is built into development practices. This includes:

- Floodplain setbacks and elevation requirements
- Infrastructure siting that avoids high-risk terrain
- Alignment with updated flood hazard zones and building codes

Following Hurricane Maria, the Planning Board partnered with PREMB and the municipal government to support updates to Local Hazard Mitigation Plans (LHMPs) and to integrate mitigation into recovery and rebuilding efforts.[1124] The updates included:

- Reformatting and updating LHMPs for consistency and FEMA compliance
- Linking hazard mitigation priorities with land-use decisions
- Offering planning tools and guidance that go beyond emergency response

[1124] Torres, Rafael, "Planes de mitigación de los municipios costeros no incluyen el manejo del sargazo," Centro de Periodismo Investigativo, September 25, 2019. https://periodismoinvestigativo.com/2019/09/planes-de-mitigacion-de-los-municipios-costeros-no-incluyen-el-manejo-del-sargazo/.

Figure 307 illustrates the Planning Board's plans for the year 2022, indicating that out of 78 municipalities, 73 plans were updated with the Board's support.

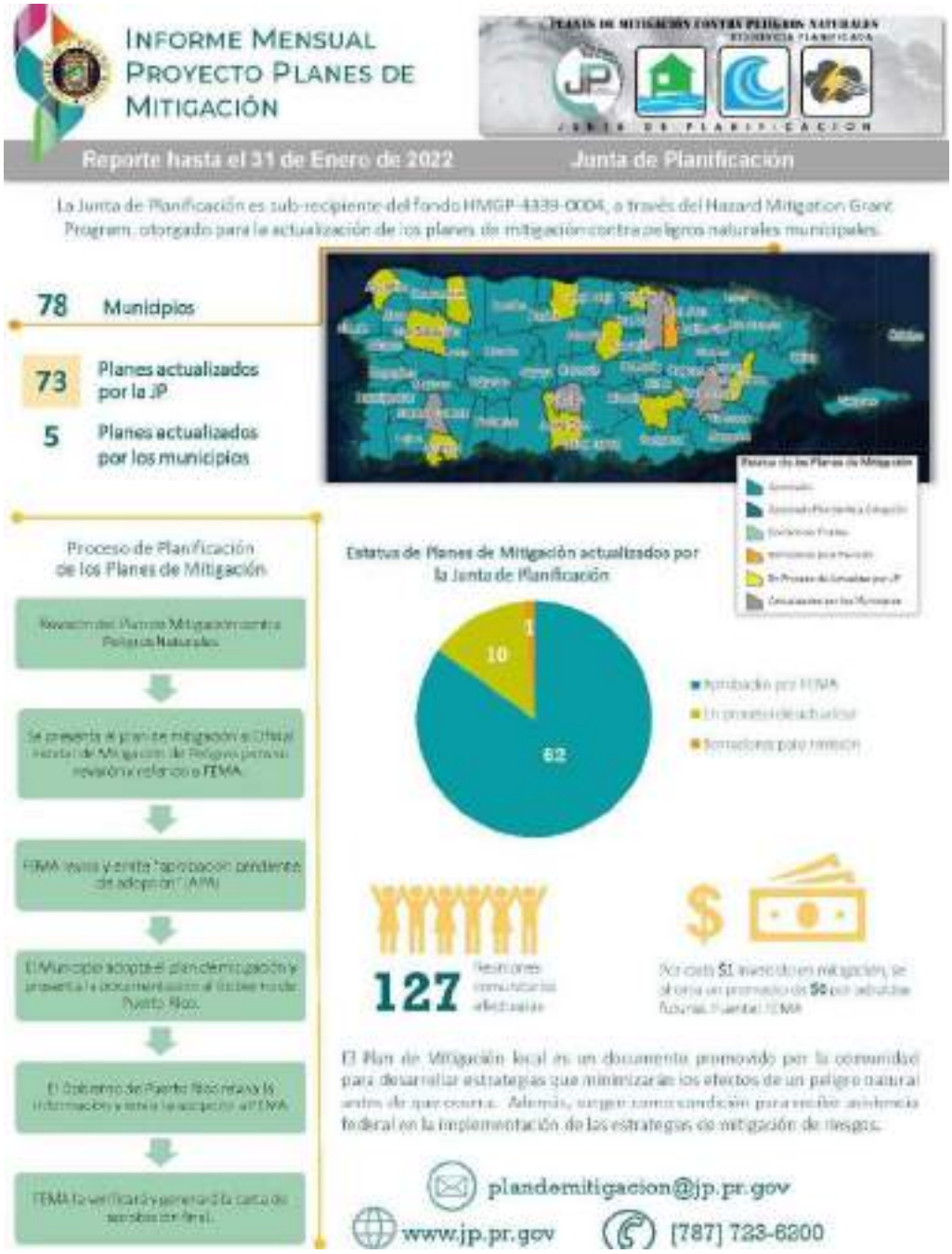

Figure 307: Puerto Rico Planning Board, Local Hazard Mitigation Plans Efforts for 2022

Local Mitigation Strategies

Each municipality has developed a mitigation strategy in its local mitigation plans to address localized and statewide vulnerabilities to the identified hazards. The mitigation strategy includes an analysis of relevant and viable mitigation actions, prioritized based on a set of criteria that consider local capabilities and the levels of risk posed by natural hazards to local assets. Table 159 provides examples of local mitigation projects, including the hazard addressed, the number of actions per mitigation action type, and a description of the mitigation action for both completed and ongoing projects. The Action Types include Local Planning and Regulations, Structure and Infrastructure Projects, Natural Systems Protection, and Education and Awareness Programs.

Table 159: Local Mitigation Actions and Description by Zone

Zone	Municipalities	Hazard Addressed	Description of Actions
Zona Aguadilla	Aguada, Aguadilla, Añasco, Isabela, Moca, Rincón and San Sebastián.	All	• Integrate the findings and recommendations of the HMP into the Territorial Plan, Operational Emergency Plan, and other relevant Emergency Preparedness Plans. • Develop a comprehensive digital inventory using GIS technology to identify and map structures vulnerable to strong winds and seismic activity. • Encourage and facilitate community participation in the National Flood Insurance Program (NFIP) to enhance resilience and financial protection.
Zona Arecibo	Arecibo, Barceloneta, Camuy, Hatillo, Lares, Quebradillas, and Utuado.	All	• Minimize and/or reduce damage to municipal road and street infrastructure as a result of rain, flooding, landslides, and other causes. • Protect critical infrastructure located in the municipality. • Develop education and public awareness campaigns.
Zona Caguas	Aguas Buenas, Aibonito, Barranquitas, Caguas, Cidra, Comerío, and Naranjito.	All	• Protect critical infrastructure located in the municipality. • Develop education and public awareness campaigns. • Support the preservation of open spaces.
Zona Ceiba	Canóvanas, Carolina, Ceiba, Culebra, Fajardo, Loíza, Luquillo, Río Grande, Trujillo Alto, and Vieques.	All	• Protect life and property. • Develop collaborative activities among all stakeholders. • Strengthen and optimize emergency management services.
Zona Guayama	Arroyo, Cayey, Coamo, Guayama, Maunabo, Patillas, Salinas, and Santa Isabel.	All	• Maintenance of drainage systems. • Scheduling of capital improvements. • Recanalization of riverbanks or movements of fault zones.
Zona Humacao	Gurabo, Humacao, Juncos, Las Piedras, Naguabo San Lorenzo, and Yabucoa.	All	• Continue to incorporate mitigation strategies adopted by the municipality to reduce its vulnerability to potential natural hazards. • Support personnel with expertise or training in the natural hazards and vulnerabilities that affect the community.

Zone	Municipalities	Hazard Addressed	Description of Actions
			• Define the levels of vulnerability presented by each of these hazards in different sectors of the municipality and prevent illegal or inappropriate development in areas vulnerable to them.
Zona Mayagüez	Cabo Rojo, Hormigueros, Lajas, Las Marías, Maricao, Mayagüez, Sábana Grande, and San Germán.	All	• Improve local capacity to restore critical facilities and essential infrastructure to ensure the continuity of municipal operations after natural disasters. • Ensure that mitigation activities are incorporated into long-term planning efforts.
Zona Ponce	Adjuntas, Guánica, Guayanilla, Jayuya, Juana Díaz Peñuelas, Ponce, Villalba, and Yauco.	All	• Provide citizens with safe and accessible places to be used as shelters, equipped to meet essential safety and food needs. • Establish partnerships with the central government and private companies to respond to the needs of communities in the event that basic water, energy, communications, and health services are unavailable during an emergency.
Zona San Juan	Bayamón, Cataño, Dorado, Guaynabo, San Juan Toa Alta, and Toa Baja.	All	• Protect life and property. • Develop collaborative activities among all stakeholders. • Strengthen and optimize emergency management services.
Zona Vega Baja	Ciales, Corozal, Florida, Manatí, Morovis, Orocovis, Vega Alta, and Vega Baja.	All	• Protect life and property against the effects of multiple natural hazards through mitigation. • Educate and raise awareness among citizens regarding the mitigation of natural hazards. • Develop collaborative activities between different sectors of society to effectively integrate disaster mitigation processes.

Connection to State HMP

The local mitigation Assessment plays a pivotal role in Puerto Rico's hazard mitigation strategy, forming the cornerstone of the State Hazard Mitigation Plan (SHMP). Through an understanding of local capabilities, local governments and the Commonwealth can identify shared strengths, persistent challenges, and key areas that require statewide support. This comprehensive process ensures that mitigation planning is both grassroots-driven and strategically coordinated, bridging local priorities with broader Commonwealth policies, programs, and funding mechanisms.

Additionally, effective hazard mitigation requires seamless coordination between local initiatives and state-level strategies. Vertical integration ensures that municipal actions not only reflect community-specific needs but also contribute to broader Commonwealth goals.

When municipalities identify priorities, such as those listed in Table 159, the State Hazard Mitigation Plan (SHMP) may incorporate them. In turn, the SHMP offers a structured framework and practical resources to help local governments enhance their planning and implementation efforts. This includes:

- Identifying capacity gaps that hinder local execution, such as limited grant management expertise or technical staffing.
- Guiding Commonwealth agency support, including training programs, technical assistance, and data-sharing initiatives.
- Targeting funding and investments toward high-risk, low-capacity municipalities or operational zones most in need of support.

This two-way alignment promotes a resilient and coordinated approach to disaster mitigation across Puerto Rico. Ultimately, the connection between the Local Capability Assessment and the State Hazard Mitigation Plan ensures that Puerto Rico's mitigation efforts are cohesive, data-driven, and scalable. Local assessments provide the foundation for understanding vulnerabilities and strengths, while the State Plan transforms that local intelligence into strategic, coordinated action across the island. Together, they create a unified framework where Local Plans identify needs and priorities. The State Plan consolidates and supports those needs through policy, funding, and technical assistance, reinforcing implementation through aligned investment and oversight.

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SECTION SEVEN

MITIGATION STRATEGY

Mitigation Strategy

Overview

The Mitigation Strategy defines the goals, objectives, and actions which reflect the Government of Puerto Rico's long-term proposal to achieve effective hazard mitigation in order to, whenever possible, reduce the loss of life and property that may result because of hazards. The strategy is designed to reduce the impacts of disasters through comprehensive planning, resource allocation, and the implementation of effective mitigation measures. It builds on previous efforts to identify progress and next steps for implementing effective mitigation measures. The approach outlined throughout this structure is designed to serve as a framework for state agencies and local governments in their efforts to minimize risk and enhance community resilience.

The goals, objectives, and mitigation actions from the 2016 plan were the basis of the 2021 plan update. During the 2026 plan update, the Planning Team and Steering Committee reviewed and revised the mitigation goals, objectives, and actions. Changes were made to the goals and objectives to emphasis mitigation, note new cross-sectional partnerships, clarify language, and combine similar topics. The status of each prior mitigation action was considered and in large part, the plan participants elected to keep the majority of the current actions. In some cases, the actions have been reworded or expanded to reflect the latest progress and current mitigation language. In addition to carrying forward actions from the prior plan, the plan participants evaluated and identified a comprehensive range of mitigation actions, including actions for the new hazards identified in the 2026 plan.

Mitigation Goals

Mitigation goals and broad, long-term policy and vision statements that explain what will be achieved by implementing the mitigation strategy. In the updated plan, Puerto Rico has introduced an additional goal and restructured several of the existing goals. These goals form the foundation for coordinated planning and implementation at the federal, state, and local levels. They prioritize the reduction of long-term risks to individuals, property, infrastructure, the environment, and the economy while fostering sustainability, resilience, and public awareness. The goals listed in Table 160 were developed by the Planning Team and encompass all mitigation needs identified by the plan participants and stakeholders. Goal #6 is a new goal which reflects the ongoing need to incorporate and engage the public in hazard mitigation activities. By addressing hazard mitigation through effective policy, education initiatives, and the development of strategic projects, Puerto Rico seeks to enhance agency capacities and mitigate vulnerabilities across its communities.

Table 160: 2026 Mitigation Goals

Goal	Description
Goal 1	Strengthen Puerto Rico's resilience to natural and non-natural hazards to reduce loss of life and protect property.
Goal 2	Prioritize mitigation for critical infrastructure and community lifelines in order to facilitate rapid recovery post-disaster.
Goal 3	Integrate risk mitigation and sustainable development into the foundation of land use planning initiatives.
Goal 4	Preserve, enhance, and restore aspects of the natural environment that are beneficial for risk mitigation.
Goal 5	Support risk-based and community-informed mitigation planning and project development for the benefit of the community.
Goal 6	Increase whole community awareness and support for hazard mitigation in Puerto Rico.

The goals are not prioritized and are written to apply to all identified hazards. However, as detailed in FEMA's State Mitigation Planning Policy Guide, although there is not a goal specific to high hazard potential dams (HHPDs) alone, multiple goals relate to HHPDs. Goals related to HHPDs include Goals 1, 2, 3, 4, and 6.

Mitigation Objectives

Table 161 outlines specific objectives that support Puerto Rico's hazard mitigation goals. These objectives help clarify mitigation goals by establishing a detailed framework for reducing risks, enhancing resilience, and promoting sustainable development across communities. By focusing on key areas such as policy development, infrastructure protection, property protection, public education, and natural resource conservation, these objectives guide strategic actions that strengthen hazard preparedness and response efforts.

Table 161: 2026 Mitigation Goals and Objectives

Goal and Objective Number	Description
Goal 1	**Strengthen Puerto Rico's resilience to natural and non-natural hazards to reduce loss of life and protect property.**
Objective 1.1	Expand the capacity of the Puerto Rico government and its municipalities to implement and sustain mitigation programs through policy development, regulatory updates, implementation of Law 20, and interagency coordination.
Objective 1.2	Foster partnerships among government entities, NGOs, and the private sector to promote collaborative mitigation efforts.

Goal and Objective Number	Description
Objective 1.3	Strengthen the capacity of Non-Governmental Organizations, private sector partners, and the public to mitigate natural and non-natural hazards.
Objective 1.4	Develop effective educational programs that focus on increasing the public's knowledge of the hazards and their associated risks.
Objective 1.5	Enhance local capacity to ensure the effective management of water resources and to reduce the risk of flooding.
Goal 2	**Prioritize mitigation for critical infrastructure and community lifelines in order to facilitate rapid recovery post-disaster.**
Objective 2.1	Strengthening the capacity of the PREMB, COR3, and the interagency committee to manage available hazard mitigation programs effectively.
Objective 2.2	Reduce vulnerability of critical facilities and community lifelines.
Goal 3	**Integrate risk mitigation and sustainable development into the foundation of land use planning initiatives.**
Objective 3.1	Encourage the adoption and implementation of land-use practices, building codes, laws, tools, and exercises across agencies, municipalities, and organizations to mitigate the identified hazards.
Objective 3.2	Support studies to identify and map high-risk areas that would support land use planning efforts.
Goal 4	**Preserve, enhance, and restore aspects of the natural environment that are beneficial for risk mitigation.**
Objective 4.1	Incorporate mitigation measures to increase the useful life of landfills to protect estuaries, structures, and communities from post-disaster debris and contamination.
Objective 4.2	Support green infrastructure for existing development and new construction.
Goal 5	**Support risk-based and community-informed mitigation planning and project development for the benefit of the community.**
Objective 5.1	Develop a central platform to house mitigation planning-related information, including hazard risks and capabilities.
Objective 5.2	Enhance the COR3 transparency portal.
Objective 5.3	Identify and promote local data sources, scientific studies, and post-disaster data analysis to enhance mitigation actions.
Objective 5.4	Encourage the municipalities to plan for and support mitigation activities.
Goal 6	**Increase whole community awareness and support for hazard mitigation in Puerto Rico.**
Objective 6.1	Expand interagency efforts to engage the public in outreach, training, workshops, mitigation planning, and project development.

Goal and Objective Number	Description
Objective 6.2	Assist municipalities in identifying and addressing the needs of vulnerable populations—including those with disabilities, limited mobility, and communication barriers—in mitigation planning and project development.

Mitigation Actions

Mitigation actions are vital steps for reducing risks associated with natural hazards and enhancing community resilience, and they can be classified into four key categories. First, Local Plans and Regulations establish frameworks for responsible development and land use, including zoning laws and building codes that help minimize vulnerabilities and promote sustainable growth. Second, Structure and Infrastructure projects involve constructing and retrofitting critical facilities, such as buildings and roads, to withstand specific hazards, thereby protecting lives and property. Third, the Natural Systems Protections focus on preserving and restoring ecosystems, such as wetlands and forests, which provide essential natural defenses against hazards while promoting biodiversity. Finally, Education and Awareness Programs aim to empower individuals and communities with knowledge about disaster risks and preparedness strategies, fostering a culture of safety and proactive participation in resilience efforts. Together, these diverse categories create a comprehensive approach to disaster risk reduction, equipping communities to better face the challenges posed by natural hazards.

Previous Mitigation Action Status

Table 162 lists previous mitigation actions listed in the 2021 State Hazard Mitigation Plan, the current status of the previous actions, and whether they are being carried forward into the 2026 SHMP update.

Table 162: Status of Previous Mitigation Actions

Action #	Description	Status	Status Description
Goal 1: Develop a more disaster-resistant Puerto Rico, reducing vulnerability to future incidents of natural and non-natural hazards.			
Objective 1.1: Increase the State's capacity to implement and maintain mitigation programs by identifying and developing policies, programs, and regulations to support practical risk mitigation efforts.			
1.1.1	Promote and encourage State Government agencies to publish on their websites the official information they receive about the hazards that affect Puerto Rico, their vulnerability, and alternatives on how to mitigate them.	In Progress, Carried Forward	State agencies such as the Office for Recovery, Reconstruction, and Resiliency (COR3) and the Puerto Rico Planning Board (PRPB) are expanding online hazard mitigation resources. The Puerto Rico Emergency Management Bureau (PREMB) will be developing a digital Hazard Mitigation Plan HMP) to achieve this action.
1.1.2	Guide state governments to incorporate hazard mitigation principles into their routine work operations.	Deferred, Carried Forward	This is an ongoing effort that is implemented through the day-to-day operations of Puerto Rico's agencies. It is still in progress and has been carried forward to this HMP for implementation.
1.1.3	Require each state agency participating in the Interagency Mitigation Committee to complete or update its risk analysis, hazard identification, and potential risk mitigation projects to reduce agency structures' vulnerability.	In Progress, Carried Forward	COR3 and the Puerto Rico Planning Board collaborate to strengthen municipal mitigation plans through technical support, funding, and FEMA compliance.[1125]
1.1.4	Identify specific state critical facility restoration or relocation projects that can be undertaken before a disaster, with funding sources such as US Federal Highway Administration and FEMA paired with local	In Progress, Carried Forward	The government center in Guánica, severely damaged by the January 2020 earthquakes, has been completely demolished as part of ongoing recovery efforts in the region.[1126]

[1125] Oficina Central de Recuperación, Reconstrucción y Resiliencia (COR3), "COR3 y Junta de Planificación firman acuerdo de colaboración para fortalecer planes de mitigación de riesgos municipales," 19 Noviembre 2025, https://recovery.pr.gov/documents/Firman-acuerdo-de-colaboracion-para-fortalecer-planes-de-mitigacion-de-riesgos-municipales_20251124T172614.778Z.pdf.

[1126] Oficina Central de Recuperación, Reconstrucción y Resiliencia (COR3), Puerto Rico Disaster Recovery, Transparency Portal, https://recovery.pr.gov/en/road-to-recovery/pa-qpr/map?disaster=4&sector=3&projectSize=1&qprPeriod=25.

Action #	Description	Status	Status Description
	funding or activated after a disaster with FEMA HMGP funding.		
1.1.5	Increase the number of qualified personnel, such as architects, engineers, and planners, within the government to evaluate and manage programs and projects that impact the hazard mitigation process.	In Progress, Carried Forward	The Puerto Rico Planning Board has an ongoing enforcement project which employs qualified personnel to evaluate potential mitigation projects. Additional staff in various agencies would help advance mitigation in Puerto Rico moving forward.
Objective 1.2: Strengthen the relationship between state and local government and organizations to mitigate natural and non-natural hazards.			
1.2.1	Establish a system for collecting historical data on events that occurred, which is necessary when preparing the BCA for mitigation projects included in local plans. Share information relevant to vulnerability and hazard analysis in Puerto Rico that is worked on by different sectors directly or indirectly related to the hazard mitigation process to disseminate information and systematically promote the need and benefits of hazard mitigation.	In Progress, Carried Forward	The Risk and Asset Data Collection Program consolidates hazard, risk, and asset information across Puerto Rico to strengthen vulnerability assessments and support informed mitigation planning. Community Development Block Grant (CDBG-MIT) funds further enable data-driven strategies and resilience initiatives.[1127] The PREMB Operational Zones also enable systematic data collection and dissemination.
1.2.2	Maintain communication and coordination with the Coastal Zone Management Program Office, DRNA Water Resources, NWS, PRASA, and other relevant agencies to increase safety and guidance to coastal communities to integrate actions identified can be developed to mitigate the effects of frequent and intensifying weather events. Also, work with	In Progress, Carried Forward	NOAA's evaluation of the Puerto Rico Coastal Zone Management Program notes that the program fosters inter-agency coordination and public engagement to strengthen coastal management and hazard mitigation.[1128] This action is carried forward, with revisions to match current U.S. policy regarding the benefits and impacts of mitigation.

[1127] Puerto Rico Department of Housing. (2023). *Risk and Asset Data Collection Program*. Recuperación PR. https://recuperacion.pr.gov/en/risk-and-asset-data-collection-program/.

[1128] National Oceanic and Atmospheric Administration. (2025). *Final evaluation findings: Puerto Rico Coastal Zone Management Program, September 2015 to September 2023*. U.S. Department of Commerce, Office for Coastal Management. https://coast.noaa.gov/data/czm/media/puertorico-cmp.pdf.

Action #	Description	Status	Status Description
	communities experiencing the impacts of risks caused by projected climate change.		
Goal 2: To achieve the rapid re-establishment of the State in case of disasters.			
Objective 2.1: Strengthen the capacity of COR3 to manage available hazard mitigation programs effectively.			
2.1.1	Maintain a communication process with agencies, municipalities, and organizations to know the implementation status of mitigation plans and projects and integrate them into future revisions of the PRSNHMP	In Progress, Carried Forward	COR3 maintains communication with sub-recipients including through updates to mitigation plans, incorporating new initiatives with the history of presidential declarations, and support for implementing future mitigation projects. Local hazard mitigation plans were reviewed for actions to be included in this plan update. Over the next five years, both local and Government of Puerto Rico action implementation should be monitored and incorporated into future plan updates.
2.1.2	Promote the participation of the coordinators of the State Inter-Agency Mitigation Committee in available processes, such as public hearings and being an active member of committees and working groups, to analyze, comment, and ensure the consideration of integration of mitigation actions in projects, plans or other initiatives that are proposed and may affect vulnerability to hazards.	In Progress, Carried Forward	COR3, in collaboration with FEMA, facilitates meetings to ensure that Puerto Rico and its interagency components meet the annual requirements of the Administrative Plan (HMA Sprint) in collaboration with critical state agencies.
Objective 2.2: Increase State emergency preparedness, response, and recovery by improving the State's ability to support emergency response and recovery operations.			
2.2.1	Promote the importance of maintaining updated vulnerability analyses of agency structures and facilities that are not regularly associated with hazard mitigation processes.	In Progress, Carried Forward	Puerto Rico is committed to expanding analyses that support understanding across a wide range of agencies and facilities of their vulnerability to natural hazards. PREMB promotes the importance of current vulnerability assessments through preparedness and response activities while COR3 is responsible for recovery initiatives. This is an ongoing activity.

Action #	Description	Status	Status Description
Objective 2.3: Reduce the degree of vulnerability of critical and essential buildings and vital and critical state infrastructure.			
2.3.2	Promote the importance of maintaining updated vulnerability analyses of Puerto Rico's critical infrastructure, which are managed by the following agencies: PRASA, PREPA, DTOP, and Telecommunications Bureau.	In Progress, Carried Forward	Hazards are identified through each agency's projects and reported at agency meetings to identify funds for retrofit activities and current codes. Government regulations will be highlighted through the "Code Enforcement" and Planning Board.
2.3.3	Distribute the analysis results with agencies related to the planning process and mitigation and identify measures to mitigate critical infrastructure vulnerability.	Completed	In 2024, the Puerto Rico Planning Board collaborated to update municipal hazard mitigation plans, delivering a comprehensive, data-driven approach that promotes resilience through tailored actions, sustainable development, and community engagement
2.3.4	Develop an Early Warning System to establish an alarm and notification system for the population of the area to be affected by dam failure.	In Progress, Carried Forward	FEMA approved over $41.3 million for the construction of Early Warning Systems at 17 dams in Puerto Rico, as part of a nearly $100 million project to strengthen dam safety and disaster preparedness. These systems will include alarms, GPS controls, evacuation signage, and community outreach to notify residents of emergencies such as floods or seismic activity.[1129]
2.3.5	Monitor with survey equipment for reduction of operational levels when any potential risk of dam failure is identified.	In Progress, Carried Forward	PREPA has implemented regular monitoring of at-risk dams, including for concerns related to hazards like earthquakes and hurricanes. By monitoring factors including reservoir levels, spillway flows, and seismic activity, PREPA is able to feed real-time data into emergency notifications for downstream communities to reduce the risk of potential dam-related emergencies. PREPA was awarded a grant and is currently in the process of implementing an Early Warning System project which should be completed by 2029.

[1129] Federal Emergency Management Agency. (2024). *FEMA approves construction funds for 17 Early Warning Systems*. Puerto Rico: FEMA.

Action #	Description	Status	Status Description
2.3.6	Establish a 24-hour surveillance plan at the dam facilities or for as long as necessary if a specific risk is identified (e.g., caused by earthquakes).	Deferred, Carried Forward	Staff was not previously available to complete this activity at all dam facilities. However, it remains a goal.
Objective 2.4: Strengthen critical infrastructure.			
2.4.1	Make improvements to obsolete, broken, or non-functioning infrastructure to reduce the amount of water lost annually due to broken pipes and damaged infrastructure.	In Progress, Carried Forward	The MAAA017 River Crossing project involved installing 16- and 24-inch pipes for the Comercio Water Plant in Puerto Rico as part of Hurricane Maria recovery efforts. It was a large Category F utility project under FEMA's 428 program, fully completed with a total cost of $1,135,627, managed by the Puerto Rico Aqueduct and Sewer Authority.[1130]
Goal 3: Integrate risk mitigation and sustainable development into the foundation of land use planning initiatives.			
Objective 3.1: Use the land use instruments, rulings, laws, appropriate analysis tools, and preparation exercises available in different agencies, municipalities, or organizations to mitigate the identified dangers.			
3.1.1	Work with local government and state agencies related to the planning, evaluation, and approval process of projects to integrate hazard analysis as a requirement in the assessment of projects or developments, both public and private, to prevent them from affecting the vulnerability of the territory to specific hazards. Also, use the land use planning instruments stipulated in the PUT and POT as hazard mitigation mechanisms.	Completed, Carried Forward	(PUT-PR) establishes the procedures for updating Puerto Rico's land-use plan, including stages for drafting, public presentation, and approval, in compliance with Law 550-2004 and related statutes. It aims to ensure interagency collaboration and provide guidance for integrating hazard mitigation and sustainable development principles into territorial planning. was last updated on October 7, 2025, according to Resolution JP-PUTPR-2025-01.[1131]

[1130] Puerto Rico Aqueduct and Sewer Authority. (2018, December 21). *MAAA017: 16 and 24-inch pipe river crossing for Comerio Water Plant (PW No. PA-02-PR-4339-PW-00764)* [Category F – Utilities]. FEMA 428 Project for Hurricane Maria recovery. Total cost: $1,135,627; obligated: $1,022,064; disbursed: $1,022,064. https://recovery.pr.gov/en/road-to-recovery/pa-qpr/map?disaster=1&sector=4&projectSize=1&qprPeriod=25.

[1131] Junta de Planificación de Puerto Rico. (2025, October 7). Guía interna para el proceso de revisión y actualización del Plan de Uso de Terrenos de Puerto Rico (Resolución Núm. JP-PUTPR-2025-01). San Juan, PR: Autor. JP-PUTPR-2025-01 - Guía PUT-PR 2025.pdf

Action #	Description	Status	Status Description
3.1.2	Promote the acquisition of flood insurance in all communities exposed to flooding throughout the Island, from the NFIP coordinated by the PRPB's Flood Valley Administration and promote practices to mitigate flooding in these communities to reduce losses associated with this hazard.	In Progress, Carried Forward	The Puerto Rico Planning Board has hosted regular public meetings and training sessions, including discussions of NFIP participation, floodplain management requirements, and flood mapping initiatives. Further, the agency has worked with both federal and local partners, enabling increased understanding of local flood mitigation concerns.
3.1.3	Promote the Guidelines for the Mitigation of Hazards and Adaptation to Climate Change provided by the Puerto Rico Land Use Plan (PUT), complying with the PUT provision that indicates that any planning instrument submitted after its effective date must include measures to mitigate and adapt to climate change.	In Progress, Carried Forward	The Puerto Rico Priority Climate Action Plan (PCAP), prepared by the Puerto Rico Department of Natural and Environmental Resources and published in March 2024, outlines strategies to reduce greenhouse gas emissions through targeted measures, projections, and benefits analysis for disadvantaged communities. It established a framework for implementing climate pollution reduction actions under EPA's Climate Pollution Reduction Grant program.[1132]
Goal 4: Preserve, enhance, and restore aspects of the natural environment that are beneficial for risk mitigation.			
Objective 4.1: Incorporate mitigation measures to increase the useful life of landfills.			
4.1.1	Proper disposal of comingled disaster debris in sanitary landfills.	In Progress, Carried Forward	The Open Window Debris Project, led by EPA and FEMA in collaboration with Puerto Rico's Department of Natural and Environmental Resources, aims to help municipalities integrate solid waste and disaster debris management into their hazard mitigation plans. Launched in September 2021, the initiative provides educational materials, funding guidance, and technical support to strengthen sustainable waste management and reduce disaster-related risks.[1133]

[1132] Puerto Rico Department of Natural and Environmental Resources. (2024, March). *Puerto Rico Priority Climate Action Plan*. U.S. Environmental Protection Agency. https://www.epa.gov/system/files/documents/2024-03/puerto-rico-pcap.pdf.

[1133] U.S. Environmental Protection Agency, "Federal and Puerto Rico Agencies Unveil Guide to Assist Municipalities in Integrating Solid Waste and Disaster Debris Management into Hazard Mitigation Plans," News Release, September 14, 2021, https://www.epa.gov/newsreleases/federal-and-puerto-rico-agencies-unveil-guide-assist-municipalities-integrating-solid.

Action #	Description	Status	Status Description
4.1.2	Source reduction of vegetative and soil debris.	In Progress, Carried Forward	Municipalities across Puerto Rico have been working on this project in conjunction with FEMA's Public Assistance program. It is an ongoing effort.
4.1.3	Reuse and recycling of built environment, vegetative, and other organic material.	In Progress, Carried Forward	Reciclaje del Norte Inc., a worker-owned Puerto Rican company with over 30 years of experience, is the leading recycling service provider in Puerto Rico and the Caribbean. The company operates four facilities, employs more than 200 people, and offers services such as material shredding, electronic equipment decommissioning, municipal recycling programs, and logistics, while also promoting a circular economy through initiatives like ReCreo—a line of 100% recycled construction materials.[1134]
4.1.4	Establish a disaster debris management plan for local governments.	Deferred, Carried Forward	While FEMA's PA program must establish the status and expiration dates of municipal debris collection plans, Puerto Rico is committed to working with local governments to ensure plans are up to date and effective. Currently some jurisdictions have FEMA approved debris management plans while others do not.
Objective 4.2: Incentivize green infrastructure retrofits on existing developments and new construction.			
4.2.1	Address illegal dumping through science to reduce impacts from flooding and landslides in Puerto Rico	In Progress, Carried Forward	RCAP Solutions, through Sustainable Materials Management Specialist Edwin Vázquez-Asencio, launched an ongoing project in 2024 to eliminate decades-long illegal dumping in Santa Rita, Guánica, Puerto Rico, which posed severe environmental and public health risks. The initiative includes community education, cleanup, enforcement, and long-term maintenance strategies, with collaboration from local stakeholders and agencies such as

[1134] Reciclaje del Norte. *Reciclaje del Norte Inc.* https://www.reciclajedelnorte.com/.

Action #	Description	Status	Status Description
			the Puerto Rico Department of Natural and Environmental Resources and USDA.[1135]
Objective 4.3: Encourage the use of renewable energy in new infrastructure developments.			
4.3.1	Establish assistance programs to support the implementation of renewable energy/alternative energy microgrids.	In Progress, Carried Forward	The U.S. Department of Energy's Grid Deployment Office (GDO) announced on September 19, 2024, a Funding Opportunity of up to $325 million under the Programa de Comunidades Resilientes to enhance energy resilience for vulnerable communities in Puerto Rico through solar and battery storage installations in healthcare facilities and multi-family housing. This initiative, part of DOE's ongoing grid recovery and resilience efforts, supports planning, capacity building, and stakeholder collaboration to strengthen Puerto Rico's energy infrastructure.[1136]
4.3.2	Workforce projections for the deployment of healthy buildings, energy efficiency, demolition, and debris handling and processing activities.	Deferred, Carried Forward	This action was unable to be completed in the previous HMP cycle due to capacity constraints. It is being carried forward to this HMP for implementation, with amendments.
Goal 5: Create organized and disaster-resistant communities.			
Objective 5.1: Develop effective educational programs that focus on increasing the public's knowledge of the hazards and their associated risks.			
5.1.1	Capacity building for Municipalities and Community Emergency Response Team (CERT) preparedness to design and implement drills for community evacuation plans after possible release of oil and chemicals after disasters.	In Progress, Carried Forward	The Community Emergency Response Team (CERT) program in Puerto Rico trains volunteers to prepare for and respond to disasters by teaching essential skills such as fire safety, light search and rescue, disaster medical operations, and team organization. Its goal is to strengthen community resilience so volunteers can assist first responders and support immediate

[1135] RCAP Solutions. (2024). *Solid waste case study: Guánica, Puerto Rico*. https://www.rcapsolutions.org/solid-waste-case-study-guanica-puerto-rico/.
[1136] U.S. Department of Energy, Grid Deployment Office. (2024, September). *Puerto Rico energy recovery and resilience newsletter*. Grid Deployment Office: September Newsletter.

Action #	Description	Status	Status Description
			needs during emergencies when professional help may be delayed.[1137] Additional trainings on fuel spills in particular could be expanded.
Objective 5.2: Increase the general population's knowledge and understanding of the natural hazards/risks that threaten Puerto Rico and the appropriate risk mitigation elements to counteract their effects.			
5.2.1	Coordinate educational institutions' efforts to incorporate natural and technological hazard mitigation issues into architecture, engineering, and planning curricula.	In Progress, Carried Forward	The project educates stakeholders on coastal resilience through training and workshops, partnering with FEMA, USGS, and NOAA to promote multi-hazard awareness and workforce development.[1138]
5.2.2	Prepare and distribute simple model building plans for single-family homes that incorporate protection measures against high winds, landslides, and earthquakes, and promote the importance of including these home construction measures.	Deferred, Carried Forward	This action was unable to be completed in the previous HMP cycle due to capacity constraints. It is being carried forward to this HMP for implementation.
Objective 5.3: Enhance the capacity building at the community level to ensure the efficient management of the water resources.			
5.3.1	Orient and encourage the community to obtain property insurance, flood insurance (property and contents), and insurance against other possible disasters.	In Progress, Carried Forward	Puerto Rico partnered with FEMA to implement a parametric insurance policy that provides rapid payouts based on predefined triggers like hurricane wind speeds or earthquake magnitude, ensuring faster access to recovery funds and reducing reliance on traditional claims processes. This innovative approach not only strengthens the island's disaster resilience but also satisfies FEMA's insurance requirements, marking the largest government-sponsored parametric transaction for Puerto Rico.[1139]

[1137] Negociado para el Manejo de Emergencias y Administración de Desastres. (n.d.). Programa de Equipos Comunitarios de Respuesta a Emergencias (CERT). https://manejodeemergencias.pr.gov/cert/.
[1138] Coastal Resilience Center. (n.d.). Education for improving resilience of coastal infrastructure. https://coastalresiliencecenter.org/project/puerto-rico/.
[1139] Sabo, K. (2025, February 5). Puerto Rico's innovative use of parametric insurance. *Insurance for Good*. https://www.insuranceforgood.org/blog/puerto-ricos-innovative-use-of-parametric-insurance.

Action #	Description	Status	Status Description
5.3.2	Establish a local circuit rider program to build technical, managerial, and financial capacity at self-serve community water systems to support the long-term resilience of drinking water service in rural communities.	In Progress, Carried Forward	The EPA launched a program to provide technical assistance through "circuit riders" to 45 rural, community-owned drinking water systems in Puerto Rico, helping them overcome longstanding economic and operational challenges. This initiative aims to build local capacity, ensure compliance with safe drinking water standards, and create sustainable systems resilient to future hurricanes and earthquakes.[1140]
5.3.3	Create effective water management districts, inter-jurisdictional commissions, compacts, or other approaches to build the resilience of septic systems in communities.	In Progress, Carried Forward	EPA is investing over $52 million in Puerto Rico to improve wastewater and sewer infrastructure, with nearly $30 million coming from the Bipartisan Infrastructure Law. This funding, through the Clean Water State Revolving Fund, will support projects such as wastewater treatment, stormwater management, and habitat restoration to ensure cleaner water and more resilient infrastructure across the island.[1141]
Goal 6: Reduce uncertainty and distrust in data analysis processes for the development of mitigation plans.			
Objective 6.1: Centralization of the data generated to address information gaps in searching, using, and analyzing data and tools for risk management.			
6.1.1	Create databases that specialize in each natural and/or anthropogenic risk to speed up the analysis processes and ensure their quality.	In Progress, Carried Forward	The FEMA Region 2 GeoHub page for Puerto Rico provides access to a variety of geospatial data, maps, and applications focused on emergency management, recovery projects, and hazard mitigation for the island. It includes tools for analyzing infrastructure, viewing flood risk studies, accessing hydraulic models, and exploring property and planning resources to support disaster preparedness and recovery efforts.[1142]

[1140] U.S. Environmental Protection Agency. (2025, February 6). EPA empowers rural community water systems in Puerto Rico with vital assistance. *EPA News Releases*. https://www.epa.gov/newsreleases/epa-empowers-rural-community-water-systems-puerto-rico-vital-assistance.
[1141] U.S. Environmental Protection Agency. (2023, November 14). *EPA makes $52 million investment to support wastewater infrastructure improvements across Puerto Rico*. U.S. EPA. https://www.epa.gov/newsreleases/epa-makes-52-million-investment-support-wastewater-infrastructure-improvements-across.
[1142] Federal Emergency Management Agency. (n.d.). *Puerto Rico | Region 2 GeoHub*. FEMA Region 2. https://gis-r2-fema.hub.arcgis.com/pages/puerto-rico.

Action #	Description	Status	Status Description
6.1.2	Update the water resources status database to ensure that all available information is correct.	In Progress, Carried Forward	The Puerto Rico Watershed Resources Registry (WRR) is a collaborative initiative led by the U.S. Environmental Protection Agency and local partners to create a centralized tool for identifying priority sites for wetland and stream preservation, restoration, and conservation using consistent geospatial data. Currently in its early development stage, the WRR aims to support a watershed-based approach to environmental planning and mitigation, addressing data gaps and fostering interagency cooperation across Puerto Rico.[1143]
6.1.3	Create metadata of the data used in the risk analysis to validate its legitimacy and recognize its nature.	In Progress, Carried Forward	Revised risk assessment during 2026 plan update. Currently in the process of developing final datasets and digital hazard mitigation plan to promote the mitigation planning process.
6.1.4	Create new sources of information that consider the effects of the severe seismic activity in late 2019 and early 2020 in the southwestern area of Puerto Rico.	In Progress, Carried Forward	The 2025 Puerto Rico and U.S. Virgin Islands National Seismic Hazard Model (NSHM) is an updated assessment of earthquake hazards for the region, incorporating over 20 years of new data, advanced modeling techniques, and improved ground motion predictions. This update enhances understanding of seismic risks by integrating revised seismicity catalogs, fault and subduction zone models, and region-specific variability, supporting hazard mitigation and building code development.[1144]
6.1.5	Establish a GIS database/mapping layer to inventory formal facility locations (environmental regulated facilities).	Deferred, Carried Forward	This action was unable to be completed in the previous HMP cycle due to data limitations. It is being carried forward to this HMP for implementation.

[1143] Watershed Resources Registry. (n.d.). *Puerto Rico*. Watershed Resources Registry. https://watershedresourcesregistry.org/states/puertorico.html.
[1144] U.S. Geological Survey. (2025). *2025 Puerto Rico and U.S. Virgin Islands long-term National Seismic Hazard Model*. Earthquake Hazards Program. Retrieved from https://www.usgs.gov/programs/earthquake-hazards/science/2025-puerto-rico-and-us-virgin-islands-long-term-national.

Action #	Description	Status	Status Description
Objective 6.2. Creation and establishment of public policy mechanisms to promote public funds' administrative transparency and management.			
6.2.1	Require that all organizations and contractors in charge of generating information under the geographic information system must contain metadata (and raw data) with specific fields.	Deferred, Carried Forward	This action was not completed in the previous HMP cycle. It is being carried forward to this HMP for implementation.
6.2.2	Identify funds and establish the necessary mechanisms to guarantee continuity in research and determine changes in the sequences of natural events' impacts.	In Progress, Carried Forward	The GAO report "Puerto Rico Disasters: Progress Made, but the Recovery Continues to Face Challenges" (GAO-24-105557) finds that FEMA has awarded about $23.4 billion in Public Assistance funds for Puerto Rico's recovery from hurricanes Irma and Maria and subsequent earthquakes, but only $1.8 billion has been spent, and significant permanent work remains. The report highlights ongoing challenges such as delays in project construction, rising costs that threaten budgets, and FEMA's incomplete implementation of risk management recommendations, which could hinder recovery efforts through 2030 and beyond.[1145]

[1145] U.S. Government Accountability Office. (2024). *Puerto Rico disasters: Progress made, but the recovery continues to face challenges* (GAO-24-105557). U.S. Government Accountability Office. https://www.gao.gov/products/gao-24-105557.

New Mitigation Actions

Table 163 provides information on new mitigation actions and actions carried forward from the previous plan. The mitigation action plan below identified the action, intent of the action, associated goals and objectives, potential funding sources, responsible agencies, and priority. Action priorities were determined based on the criteria outlined in Table 164.

Table 163: New Mitigation Actions

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
1.	Coastal Erosion	Implement Nature-Based Solutions to Protect Coastal Infrastructure	Implement nature-based solutions, such as living shorelines, strategic breakwater installations, and revetments, to reduce wave energy, stabilize shorelines, and protect coastal infrastructure.	2	2.4	FEMA Section 203, HMGP, USACE CAP 204 (Continuing Authorities Program), NOAA Coastal Resilience Grants, CDBG-MIT	DRNA, Municipal Governments, USACE	High
2.	Coastal Erosion	Monitor Coastal Erosion and Maintain Protective Structures	Establish a long-term monitoring program for shoreline change, sediment transport, and the condition of existing coastal structures.	3, 5	3.3, 5.3	General Fund, staff time	DRNA	High
3.	Coastal Erosion	Implement Coastal Erosion Control Measures	Implement coastal erosion control measures, including dune restoration, sand	4	4.2	Section 203, Public Assistance (PA), NOAA,	DRNA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			replenishment, vegetation stabilization, and slope protection.			US. Fish & Wildlife Service (USFWS)		
4.	Coastal Erosion	Restore Reefs Throughout the Coastal Area	Restore, enhance, and maintain coral reef ecosystems to serve as natural breakwaters that reduce wave energy and protect coastal communities.	7	7.1	Staff time	DRNA	Medium
5.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/ Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Communicating Hazard Information on Agency Websites	Promote and encourage Puerto Rico government agencies to publish on their websites the official information they receive about the hazards that affect Puerto Rico, their vulnerability, and alternatives on how to mitigate them.	5	5.1	Agency General Funds, Staff time	COR3, PREMB, All Puerto Rico Government Agencies	Medium
6.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical	Encourage Plan Integration and Capability Building	Guide Puerto Rico agencies to incorporate hazard mitigation principles into their routine work	1	1.1	FEMA HMGP HUD CDBG-MIT	COR3, PREMB, Interagency Mitigation Committee	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire		operations. Support agency capacity building initiatives, including expanded staffing and training.			State General Funds		
7.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Puerto Rico Agency Risk Analysis and Hazard Mitigation Plan Maintenance	Require each agency participating in the Interagency Mitigation Committee to complete or update its risk analysis, hazard identification, and potential risk mitigation projects to reduce agency structures' vulnerability.	1, 2, 5	1.1, 2.1, 5.1	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB, Interagency Mitigation Committee	Medium
8.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical	Identify State Critical Facility Restoration and Relocation Projects	Identify specific state critical facility restoration or relocation projects that can be	1, 2	1.1, 2.2	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB, FEMA	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Sargassum, Subsidence, Tornadoes, Tsunami, Wildfire		undertaken before a disaster, with funding sources such as US Federal Highway Administration and FEMA paired with local funding or activated after a disaster with FEMA HMGP funding.					
9.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Increase Qualified Personnel within Government to Manage Hazard Mitigation	Increase the number of qualified personnel, such as architects, engineers, and planners, within the state government to evaluate and manage programs and projects that impact the hazard mitigation process.	1, 2	1.1, 2.1	FEMA HMGP HUD CDBG-MIT State General Funds	State Agencies related to project evaluation and approval. Among them: PRPB, OGPe, and DRNA.	Medium
10.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding,	Collect Historical Data on Hazard Events	Establish a system for collecting historical data on events that occurred, which is necessary when preparing the BCA for mitigation projects	3, 5	3.1, 5.3	FEMA HMGP HUD CDBG-MIT State General Funds Staff Time	COR3, PREMB, PRPB, FEMA, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire		included in local plans. Share information relevant to vulnerability and hazard analysis in Puerto Rico that is worked on by different sectors directly or indirectly related to the hazard mitigation process to disseminate information and systematically promote the need and benefits of hazard mitigation. The PREMB Operational Zones reflect one effective way to document and share data.					
11.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum,	Track the Implementation Status of Mitigation Projects	Maintain a communication process with agencies, municipalities, and organizations to know the implementation status of mitigation plans and projects and integrate them into future revisions of the	1	1.1, 1.2, 1.3	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire		State Hazard Mitigation Plan					
12.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Promote the Participation of the Coordinators of the State Inter-Agency Mitigation Committee	Promote the participation of the coordinators of the State Interagency Mitigation Committee in available processes, such as public hearings and being an active member of committees and working groups, to analyze, comment, and ensure the consideration of integration of mitigation actions in projects, plans or other initiatives that are proposed and may affect vulnerability to hazards.	1, 2, 3	1.2, 2.1, 3.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB	Medium
13.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials,	Maintaining Vulnerability Analysis of Critical Infrastructure	Promote the importance of maintaining updated vulnerability analyses of Puerto Rico's critical infrastructure, which are managed by the following agencies:	2	2.2	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB, PRDoH, State Agencies	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire		PRASA, PREPA, DTOP, Telecommunications Bureau.					
14.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Integrate Hazard Analysis into Projects and Development	Work with local government and state agencies related to the planning, evaluation, and approval process of projects to integrate hazard analysis as a requirement in the assessment of projects or developments, both public and private, to prevent them from affecting the vulnerability of the territory to specific hazards. Also, use the land use planning instruments stipulated in the PUT and POT as hazard mitigation mechanisms.	3	3.1	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB, PRPB, OGPe, PRDoH, Municipal Governments	Medium
15.	Coastal Erosion, Dam Failure, Drought,	Promote the Guidelines for	Promote the mitigation and	3	3.1	FEMA HMGP	PREMB, PRPB, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	the Mitigation of Hazards and Adaptation to Climate Change	adaptation measures outlined in the Puerto Rico Land Use Plan (PUT), complying with the PUT provision that indicates that any planning instrument submitted after its effective date must include measures to mitigate and adapt to changing atmospheric conditions.			HUD CDBG-MIT State General Funds		
16.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Develop Workforce Projections for Sustainable Development Activities	Workforce projections for the deployment of healthy buildings, energy renewables, energy efficiency, demolition, and debris handling and processing activities.	1, 4	1.1, 4.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA, EPA, PR Labor Department, DDEC, El Colegio, PR agencies, Municipal Governments	Medium
17.	Coastal Erosion, Dam Failure, Drought,	Incorporate Hazard	Coordinate educational	1, 6	1.4, 6.1	FEMA HMGP	PREMB, COR3, Academia	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Mitigation Issues into Educational Curricula	institutions' efforts to incorporate natural and technological hazard mitigation issues into architecture, engineering, and planning curricula.			HUD CDBG-MIT State General Funds		
18.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Create Databases to Track Each Hazard	Create databases that specialize in each natural and/or anthropogenic risk to speed up the analysis processes and ensure their quality.	3, 5	3.1, 5.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, COR3, PRDoH	Medium
19.	Coastal Erosion, Dam Failure, Drought,	Document Metadata of	Collect the metadata of the data used in the	1, 5	1.1, 5.1	FEMA HMGP	DNER, PRDA, PRPB, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Data Used in Risk Analysis	State Hazard Mitigation Plan risk assessment to enable additional analysis and promotion of the plan's findings.			HUD CDBG-MIT State General Funds		
20.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Establish GIS Database to Inventory Locations	Establish a GIS database/mapping layer to inventory formal facility locations (environmental regulated facilities).	5	5.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, PRPB, PR Seismic Network, PRDoH	Medium
21.	Coastal Erosion, Dam Failure, Drought,	Require Generation of	Require that all organizations and	5	5.1	FEMA HMGP	PREMB, PRPB, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
	Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Metadata for GIS Data	contractors in charge of generating information under the geographic information system must contain metadata (and raw data) with specific fields.			HUD CDBG-MIT State General Funds		
22.	Coastal Erosion, Dam Failure, Drought, Earthquakes, Extreme Heat, Extreme Winds/Hurricanes/Tropical Storms, Faults and Fissures, Flooding, Hazardous Materials, Heavy Rain, Invasive Species, Landslides, Lightning, Liquefaction, Pandemic/Epidemic, Rip Currents, Sargassum, Subsidence, Tornadoes, Tsunami, Waterspouts, Wildfire	Fund Research on Natural Hazards	Identify funds and establish the necessary mechanisms to guarantee continuity in research and determine changes in the sequences of natural events' impacts.	1	1.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREMA, COR3, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
23.	Coastal Erosion, Earthquake, Extreme Winds/Hurricanes/Tropical Storms, Flooding, Landslides, Lightning, Liquefaction, Tornado, Tsunami, Wildfire	Maintain Vulnerability Analyses of Agency Structures	Promote the importance of maintaining updated vulnerability analyses of agency structures and facilities that are not regularly associated with hazard mitigation processes.	3, 5	3.2, 5.3	FEMA HMGP HUD CDBG-MIT State General Funds	PRPB, DRNA, PREMB, UPR, PRDoH	Medium
24.	Coastal Erosion, Earthquakes, Faults and Fissures, Flooding, Liquefaction, Landslides	Maintain Communication and Coordination Across Coastal Agencies	Maintain communication and coordination with the Coastal Zone Management Program Office, DRNA, NWS, PRASA, and other relevant agencies to increase safety and guidance to coastal communities to integrate actions identified can be developed to mitigate the effects of changing atmospheric conditions. Also, work with communities experiencing the impacts of these risks.	1	1.1, 1.2	FEMA HMGP HUD CDBG-MIT State General Funds	Coastal Zone Management Program Office, DRNA, PRASA, NWS	Medium
25.	Dam Failure	Increase Administrative and Technical	Develop, update, and exercise Dam Emergency Action	1, 2, 3	1.1, 1.2, 1.5, 2.1, 3.2	FEMA HMGP, Section 203, USACE PL-84-	PREPA/LUMA (for hydropower dams)	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
		Capacity for Emergency Action Plan Implementa-tion	Plans (EAPs) for all high- and significant-hazard dams, including inundation mapping, evacuation procedures, communication protocols, and coordination with emergency management agencies.			99, State Funds		
26.	Dam Failure	Install Early Warning Systems	Install or modernize early-warning capabilities, including automated water-level sensors, remote monitoring, siren systems, SMS alerts, and integration with PREMB/ PRASA emergency communications.	3	3.2	FEMA HMGP, Section 203, DHS Alert Grants, State Funds	Puerto Rico Aqueduct and Sewer Authority (PRASA), Municipalities, PREPA	High
27.	Dam Failure	Implement Structural Retrofitting for Dams, including High Hazard Potential Dams	Conduct engineering evaluations and retrofit spillways, gates, embankments, and drainage/ excess-flow infrastructure to improve structural integrity and reduce failure risk.	2	2.2	FMA, Federal/ State funding, CDBG	PRASA, PREPA, DRNA, Municipality of Comerio	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
28.	Dam Failure	Develop an Early Warning System for Dam Failure	Develop an Early Warning System to establish an alarm and notification system for the population of the area to be affected in a dam break or failure.	3	3.2	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA/Dam Safety Officer, PREMB	Medium
29.	Dam Failure	Monitor Reduction of Operational Levels at Dams	Monitor with survey equipment for reduction of operational levels when any potential risk of dam failure is identified.	2	2.2	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA/Dam Safety Officer, PREMB	Medium
30.	Dam Failure	Establish a 24-hour Surveillance Plan at Dam Facilities	Establish a 24-hour surveillance plan at the dam facilities or for as long as necessary if a specific risk is identified (e.g., caused by earthquakes).	2	2.2	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA/Dam Safety Officer, PREMB	Medium
31.	Dam Failure, Flooding, Heavy Rain	Dredge At-Risk Reservoirs	Dredge at least 11 reservoirs. Remove accumulated sediment and increase storage capacity, ensuring efficient operation of HHPDs.	2	2.2	HHPD	PREPA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
32.	Dam Failure, Flooding, Heavy Rain	Implement Guajataca Dam Rehabilitation	Rehabilitate discharge structures at the Guajataca Dam, an HHPD. Reduce downstream risk to people, properties, and infrastructure.	2	2.2	HHPD, USACE	PREPA, USACE PREPA, PREMB, FEMA	High
33.	Dam Failure, Flooding, Heavy Rain	Implement Patillas Dam Rehabilitation	Complete the rehabilitation of the dam wall at the Patillas Dam. Address structural vulnerabilities, restoring reservoir capacity.	2	2.2	HMGP, HHPD	PREPA, COR3	High
34.	Dam Failure, Flooding, Heavy Rain	Implement Comerío I & Comerío II Dam Analysis and Rehabilitation	Evaluate the structural stability of the dam(s) under extreme earthquake and flood loadings. Resolve all recommendations identified in the latest inspection reports.	2, 5	2.2, 5.3	HHPD, PA, HMGP	Municipality of Comerío, COR3	High
35.	Drought	Restore, Upgrade, or Expand Reservoirs	Restore, upgrade, or expand reservoirs that support municipal and agricultural water supply to improve drought resilience and increase long-term storage capacity. Increase the storage	2	2.2	FEMA HMGP, Section 203, USDA NRCS Watershed Programs, EPA DWSRF	PRASA, Puerto Rico Department of Agriculture (PRDA), DRNA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			capacity of the reservoirs and the accuracy of the dredging of the most critical reservoirs.					
36.	Drought	Harvest Runoff for Agricultural Use and Drought Resilience	Support harvesting runoff for agricultural use and storage. Construct or retrofit runoff harvesting systems, retention ponds, and on-farm water capture systems to provide a water supply during drought periods.	1, 2	1.2, 1.3, 2.2	USDA NRCS, Environmental Quality Incentives Program (EQIP), Section 203, HMGP, PRDA funds	PRDA	High
37.	Drought	Identify and Implement Alternative Water Storage Methods	Implement alternative water storage methods (cisterns, modular tanks, aquifer recharge) to reduce dependency on surface water during drought.	2	2.2	HMGP, Section 203, EPA DWSRF, USDA Rural Development	PRASA	Medium
38.	Drought	Conduct Student Drought Awareness Program	Create an educational program in the public system where students learn all about risks, what measures can be taken, and basic steps that citizens can take (at home, community)	1, 6	1.4, 6.1, 6.2	FEMA HMA (non-construction activities), USDA Extension Service	Department of Education, Department of Public Safety (DSP), Department of Natural and Environmental	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			to prepare/ mitigate risks.				Resources (DRNA), University of Puerto Rico (UPR)	
39.	Drought	Develop and Publicize Water Conservation Plan	Develop a Water Conservation Plan. Territory-wide public awareness campaign to promote water conservation, climate-adaptive irrigation, leak reporting, household cisterns, and drought-resilient landscaping.	1, 3, 6	1.4, 3.1, 6.1, 6.2	Staff time, HMGP, PA, FMA, EPA (Clean Water State Revolving Fund), State funding	PRASA	Medium
40.	Drought	Support Public Water Supply Management Educational Activities	Create workshops and announcements to help citizens manage and prioritize water consumption.	1, 4	1.4, 6.1, 6.2	HMGP, Section 203, EPA DWSRF	Puerto Rico Aqueduct and Sewer Authority (AAA), Department of Natural and Environmental Resources (DRNA), PREPA, Luma Energy	High
41.	Drought	Analyze and Reduce Risk of Drought on Generation Plans	Provide support for drought-impact reduction programs (equipment upgrades, irrigation modernization, crop	2	2.2	Staff time, USDA	PRDA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			diversification) for government-supported agricultural programs. Address obstruction in seawater intakes for cooling systems.					
42.	Drought	Assess and Implement Reservoir Drainage and Rehabilitation Program	Perform an island-level assessment of existing reservoirs, identify damage, execute priority dredging projects, and design maintenance to reduce problems.	2	2.2	PA, HMGP, State, and local funding	PREPA, AAA	High
43.	Drought	Update Water Resources Status Database	Update the water resources status database to ensure that all available information is correct.	1, 5	1.5, 5.3	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA, EPA, PRDoH	Medium
44.	Drought, Earthquake, Flooding, Heavy Rain, Extreme Winds/Hurricanes/Tropical Storms	Establish Local Circuit Rider to Support Community Water Systems	Establish a local circuit rider program to build technical, managerial, and financial capacity at self-serve community water systems to support the long-term resilience of drinking water service in rural communities.	1, 5	1.5, 5.4	FEMA HMGP HUD CDBG-MIT State General Funds	DNER, EPA, PRDoH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
45.	Earthquake, Flooding, Extreme Winds/ Hurricanes/Tropical Storms, Tornadoes	Reduction of Vegetative and Soil Debris	Encourage source reduction of vegetative and soil debris.	4	4.1, 4.2	FEMA HMGP HUD CDBG-MIT State General Funds	FEMA, DRNA, PRDA, PRDoH	Medium
46.	Earthquake, Flooding, Extreme Winds/ Hurricanes/Tropical Storms, Tornadoes	Promote the Reuse and Recycling of Material	Promote the reuse and recycling of built environment, vegetative, and other organic material.	4	4.1	FEMA HMGP HUD CDBG-MIT State General Funds	DNER, PRDoH, EPA, Municipal Governments	Medium
47.	Earthquakes	Implement Critical Facilities Seismic Reinforcement	Implement structural reinforcement of vulnerable public buildings and critical infrastructure (including bridges and facilities on slopes) to meet current seismic codes (PRBC/IBC), reduce collapse risk, and ensure life safety.	2	2.2	PA, HMGP, Federal/ State funding	DTOP	High
48.	Earthquakes	Implement Structural Retrofitting of Courts	Implement reinforcement projects and evaluation of soil in the courts of South-Central and Western PR. Guarantee the essential service of the courts to the citizenry.	2	2.2	PA, HMGP, Federal/ State funding	AEP/OAT	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
49.	Earthquakes	Implement Critical Lifeline Seismic Reinforcement Projects	Identify and reinforce critical lifeline facilities (police, fire, EOCs, hospitals, water plants), including SHPO buildings that do not meet current seismic performance standards.	2	2.2	PA, HMGP, Federal/ State funding	State Historic Preservation Office (SHPO), Institute of Puerto Rican Culture (ICP), AFI, COR3	High
50.	Earthquakes	Encourage Educational Buildings to be Built or Upgraded to Modern Seismic Standards	Ensure compliance with structural codes to reduce the vulnerability of educational buildings to earthquakes.	2	2.2	PA, HMGP, Federal/ State funding	State Historic Preservation Office (SHPO), Institute of Puerto Rican Culture (ICP), AFI, COR3	High
51.	Earthquakes	Operational Rehabilitation and Recovery Plan	Move operations and essential personnel to an alternate headquarters in the event of structural damage or mine closures. Develop and implement an operational recovery plan for government agencies and lifeline utilities to ensure continuity of operations after major earthquakes, including	1, 2	1.1, 2.1, 2.2	HMGP. State funding	PREMB, COR3.	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			alternative facilities, deployment protocols, and redundancy planning.					
52.	Earthquakes	Implement Structural Reinforcement Projects for Transportation and Water Infrastructure	Strengthening bridges, roads, substations, pumping stations, and water treatment facilities to withstand earthquake shaking and prevent service disruption	2	2.2	PA, HMGP, Federal/ State funding	DTOP, PRASA, PREPA/LUMA.	High
53.	Earthquakes	Install Earthquake Early Warning Systems	Install early warning systems and a real-time monitoring system. Implement earthquake early warning systems (sensors, communication protocols, automated shutdown systems for utilities) to reduce casualties and equipment damage.	3	3.2	HMGP, Section 203, NOAA/NWS grants, DHS science & technology grants.	PR Seismic Network (UPRM), PREMB	High
54.	Earthquakes, Extreme Winds/ Hurricanes/ Tropical Storms, Flooding, Hazardous Materials, Tornadoes	Establish a Disaster Debris Management Plan	Establish a disaster debris management plan for local governments.	5	5.4	FEMA HMGP HUD CDBG-MIT State General Funds	DNER, PRDoH, EPA, PREMB, Municipal Governments	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
55.	Earthquakes, Faults and Fissures	New Sources of Information on Seismic Activity	Create new sources of information that consider the effects of the severe seismic activity in late 2019 and early 2020 in the southwestern area of Puerto Rico.	5	5.3	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, COR3, PRDoH, PR Seismic Network	Medium
56.	Earthquakes, Flooding, Hazardous Materials, Extreme Winds/ Hurricanes/Tropical Storms, Tornadoes	Disposal of Disaster Debris	Promote the proper disposal of comingled disaster debris in sanitary landfills. Encourage the pre-disaster identification of areas designated for debris disposal in order to help avoid sanitary problems.	4	4.1	FEMA HMGP HUD CDBG-MIT State General Funds	DNER, EPA, PRPB, PRDoH, Municipal Governments with landfills	High
57.	Extreme Heat	Develop and Promote Heat-resistant Urban Design Guide	Develop a technical design guide promoting heat-resistant construction practices, including cool pavements, reflective materials, shading structures, and green infrastructure to reduce urban heat island impacts in high-risk municipalities.	3, 4	3.1, 4.2	FEMA Section 203/ Hazard Mitigation Grant Program (HMGP), HUD Community Development Block Grant (CDBG-DR/MIT), EPA Climate Pollution	Puerto Rico Planning Board (PRPB)	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
						Reduction Grants		
58.	Extreme Heat	Establish Emergency Supplies Warehouse Management Program	Establish a coordinated program to maintain climate-controlled storage of emergency supplies (water, cooling systems, medical materials) to support extreme heat emergencies.	2	2.1	FEMA HMGP, USDA Rural Development, CDC Public Health Crisis Preparedness	Puerto Rico Emergency Management Bureau (PREMB)	Medium
59.	Extreme Heat	Develop Interagency Public Health Extreme Heat Programs	Coordinate public agencies implementing actions that reduce heat exposure, such as cooling centers, heat-alert communications, occupational protection protocols, and heat-risk mapping & vulnerability assessments.	2	2.2	FEMA Section 203, CDC Climate & Health Program	Puerto Rico Department of Health (PRDOH)	Medium
60.	Extreme Heat	Implement Temperature Monitoring	Install real-time heat sensors and weather monitoring stations to provide accurate local heat data, enable predictive modeling, and enhance early warning systems.	2	2.1	FEMA Section 203, NOAA Climate Program Office, National Weather Service (NWS)	University of Puerto Rico/ Natural Resources & Meteorological Programs	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
61.	Extreme Heat	Update School Construction Code	Adopt heat-resilient school building standards, including energy-efficient envelopes, cool roofs, ventilation systems, shade structures, and passive cooling.	1, 2, 3, 6	1.1, 2.2, 3.1, 6.2	FEMA Section 203/ HMGP, USDA Community Facilities, DOE Resilient Schools Grant Program	Puerto Rico Department of Education	High
62.	Extreme Heat	Establish Green Roofs Program	Develop municipal and regional incentive programs for green roofs, living walls, and shaded public infrastructure to mitigate urban heat island effects and reduce indoor heat exposure.	4	4.2	FEMA, Section 203/ HMGP, EPA Green Infrastructure Grants, USDA Urban Forestry, CDBG-MIT	Puerto Rico Department of Housing (PRDoH)	High
63.	Extreme Wind/ Hurricanes/Tropical Storms, Flooding, Landslides	Strengthen Building Code Enforcement and Compliance for Hazard-Resilient Construction	Improve municipal and government capacity to enforce building codes, land-use regulations, and hazard-specific permitting requirements, including inspection frequency, issuance of violation orders, enforcement of construction standards, and	1, 3, 5	1.1, 3.2, 5.4	FEMA HMGP FEMA Section 428 USGS USDA NRCS University research funding	OGPe	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			compliance with requirements in flood zones, coastal areas, and high-risk landslide areas. Activities include staff training, inspector certification, digital permitting, compliance monitoring, and corrective enforcement to reduce exposure of structures built without adequate hazard protection.					
64.	Extreme Wind/ Hurricanes/Tropical Storms, Heavy Rain, Tornadoes, Flooding, Earthquakes	Support Safe Room and Shelter Project Development for Municipalities, Agencies, and Private Nonprofits (PNPs)	Provides technical assistance, standardized Scopes, and application support to municipalities, commonwealth agencies, and eligible PNPs for the development of safe room and emergency shelter projects, including scoping, cost estimating, code compliance, and alignment with FEMA safe room criteria	1, 2, 5	1.2, 1.3, 2.2, 5.4	FEMA Hazard Mitigation Grant Program (HMGP) FEMA Section 203 FEMA Section 428 CDBG-MIT CDBG-DR	COR3	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			(ICC-500 and FEMA P-361).					
65.	Extreme Wind/Hurricanes/Tropical Storms, Heavy Rain, Flooding, Earthquake	Support Public Education and Awareness Activities Such as EcoExplora-torio Public Education	Utilize public education and awareness tools to promote hazard mitigation and disaster awareness. Partner with programs such as EcoExploratorio to expand public outreach initiatives, including digital products.	1, 5, 6	1.4, 5.1, 6.1, 6.2	FEMA Hazard Mitigation Grant Program (HMGP) FEMA Section 203 Staff Time	COR3	Medium
66.	Extreme Winds/ Hurricane/Tropical Storms	Adopt a Wind Acceleration Map by Topography	Develop and implement a detailed wind acceleration map that incorporates topographical influences (e.g., escarpments, ridges, hills) to improve design parameters for infrastructure and buildings. This map will inform engineering design, permitting, and land-use planning.	3	3.1	FEMA Section 203, HMGP, USGS Cooperative Funding, NOAA	PRPB	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			Additionally, the map can be used to identify zones of wind acceleration. Adopt more conservative building codes.					
67.	Extreme Winds/ Hurricanes/Tropical Storms, Flooding, Tornadoes, Wildfires	Support Implementation of Alternative Energy	Establish assistance programs to support the implementation of renewable energy/ alternative energy solutions including but not limited to microgrids.	2, 3	2.2, 3.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA, EPA, PRDoH, Municipal Governments	Medium
68.	Extreme Winds/Hurricanes/Tropical Storms, Flooding	Install Resilient Microgrids for Critical Facilities and Vulnerable Communities	Plan, design, and implement resilient energy microgrids for critical community facilities and vulnerable neighborhoods to ensure continuity of power during disasters and prolonged grid outages. This action includes feasibility studies, engineering design, distributed renewable energy integration, battery storage, interconnection	2	2.2	FEMA HMGP, HUD CDBG-MIT USDA Rural Utilities Service DOE Grid Resilience Programs Municipal Capital Funds	PREPA/LUMA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			agreements, and deployment of microgrid controls. The objective is to reduce disruption to essential services such as water treatment, health centers, shelters, communications, and emergency response operations.					
69.	Extreme Winds/Hurricanes/Tropical Storms, Landslides, Earthquake	Distribute Model Building Plans for Protection Against Hazards	Prepare and distribute simple model building plans for single-family homes that incorporate protection measures against high winds, landslides, and earthquakes, and promote the importance of including these home construction measures.	2, 3	2.2, 3.1	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, COR3, PRPB	Medium
70.	Extreme Winds/Hurricanes/Tropical Storms, Tornadoes	Support Building Code Adoption and Upgrades	Updating codes regularly and establishing superior relationships with the university. Update and enhance Puerto Rico's building codes to	3	3.1	FEMA HMGP, Section 203, CDBG-MIT, State Funds	OGPe (Permits Office)	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			align with latest ASCE 7 wind design standards, ensuring structures are more resilient to extreme wind loads through improved materials, construction practices, and enforcement. Includes training for permitting officials and building inspectors.					
71.	Fault and Fissures	Develop, Update, and Maintain High-Resolution Geotectonic Maps	Develop, update, and maintain high-resolution geotectonic maps that identify active and potentially active faults, fissures, and ground-deformation zones across Puerto Rico. This action includes integrating LiDAR, satellite imagery, USGS seismic data, local geotechnical investigations, and historical seismicity records. The resulting maps will support safer land-use planning, inform	3	3.1, 3.2	HMGP, Section 203, USGS Earthquake Hazards Program, NOAA (data support), state geological or planning agency funds	Puerto Rico Planning Board (JP/-PRPB) – Geology and Risk Section	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			building code updates, guide infrastructure placement, and enhance risk assessments for critical facilities and communities located near tectonic features.					
72.	Flooding	Enhance Permitting Requirements in High-Risk Flood Zones	Develop and integrate stricter flood-resilient land-use criteria into municipal and state permitting processes to prevent construction in high-risk flood zones and guide safer site selection.	3, 5	3.1, 5.3	FEMA HMA (HMGP, Section 203), HUD CDBG-MIT, State/ Local Planning Funds	PRPB	High
73.	Flooding	Install Enhanced Runoff Support Management Systems	Implement enhanced stormwater runoff systems, including detention basins, culvert upgrades, green infrastructure, and improved drainage, to reduce flood impacts in vulnerable communities.	1, 5	1.1, 5.3	FEMA HMA (HMGP/ Section 203), NRCS Watershed Program, EPA, Municipal Capital Funds	PRASA, Municipal Public Works, DRNA	High
74.	Flooding	Establish Technical Criteria for	Develop standardized, data-driven technical criteria for flood-risk	3, 5	3.2, 5.3, 5.4	FEMA HMA (5% Initiative), State	the Office for Recovery, Reconstruction,	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
		Mitigation Project Selection	evaluation, including hydrologic modeling thresholds, design storms, and vulnerability scoring to guide mitigation project selection and grant application.			Mitigation Funds, USACE Planning	and Resiliency (COR3), PRPB	
75.	Flooding	Encourage Elevation of Structures	Elevate structures in repeatedly flooded or high-risk flood zones to meet or exceed Base Flood Elevation (BFE) and reduce long-term losses.	5, 6	5.4, 6.2	FEMA HMGP, Section 203, Flood Mitigation Assistance (FMA), NFIP ICC Coverage	COR3, Municipal Governments/ homeowners	High
76.	Flooding	Support Small, Rural, and Coastal Community Drainage System Improvements	Design and construct improved drainage systems for small rural or coastal communities, including open channels, culverts, and stormwater management features to reduce localized flooding. Encourage and support application for grant programs as applicable. Support system upgrades according to urban	1, 2, 5	1.1, 2.2, 5.4	FEMA HMGP/ Section 203, NRCS Watershed Protection, Municipal Capital Funds	COR3, Municipal Public Works	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			adaptation and development study.					
77.	Flooding	Prioritize and Support Acquisition and Relocation Programs in or near High-Risk Areas	Acquire and relocate at-risk homes from high-hazard flood zones to safer areas following voluntary buyout procedures in order to provide housing alternatives for citizens who live in localities near the waters that cause flooding.	1, 2, 5	1.5, 2.1, 5.4	FEMA HMGP/ Section 203, HUD CDBG-DR/MIT	COR3, Municipal Governments	Medium
78.	Flooding	Conduct Education and Outreach Initiatives on the NFIP	Conduct widespread outreach and education campaigns to increase public awareness of the National Flood Insurance Program (NFIP), flood insurance requirements, community flood risks, and flood mitigation techniques.	1, 6	1.2, 1.4, 6.1, 6.2	FEMA NFIP, Section 203, HMGP	PRPB, Municipal Governments, COR3	Medium
79.	Flooding	Relocate Properties with Critical Services	Assess and implement mitigation for essential facilities located in high-risk flood zones, including potential relocation,	1, 2	1.5, 2.2	Section 203, HMGP, PA 406 Mitigation	COR3, OGPe, Municipal Governments	High

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			elevation, floodproofing, or site hardening.					
80.	Flooding	Support Improvements to the Underground Pumping System of the Judicial Center of Aguadilla	Upgrade and retrofit underground pumping infrastructure to prevent floodwater intrusion, enhance drainage capacity, and reduce service interruptions. This includes drainage of internal areas of the Aguadilla Judicial Center to extract water from land areas.	2	2.2	Section 203, HMGP, CDBG-MIT	General Services Administration (GSA), Municipal Governments	High
81.	Flooding	Implement Stormwater Runoff Water Management Program	Implement a comprehensive program to reduce stormwater runoff by improving drainage systems, implementing green infrastructure, installing retention features, and monitoring.	2, 4	2.2, 4.2	Section 203, HMGP, EPA Grants	Municipalities, The Department of Natural and Environmental Resources (DNER) (DRNA), PRPB	High
82.	Flooding	Establish a Water Body Cleaning Program	Keep water bodies (rivers, lakes, etc.) and sinkholes free of vegetation to ensure	2, 4	2.2, 4.1, 4.2	PA, State funds, Staff time	DRNA, Municipalities	High

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			free-flowing runoff and prevent flooding. Conduct sediment and debris removal to restore natural flow capacity of rivers, streams, and channels as part of hazard-mitigation improvements.					
83.	Flooding	Improve Drainage Systems Flow Capacity	Upgrade, redesign, or harden drainage systems to improve flow capacity and reduce recurring flood impacts.	2	2.2	Section 203, HMGP, PA, EPA Grants	Edificio Arecibo	High
84.	Flooding	Develop and Implement Environmentally Friendly Runoff Solutions	Develop and implement engineered solutions such as bioswales, permeable pavements, and detention structures to manage excess runoff.	2, 4	2.2, 4.2	PA, HMGP, Federal (U.S. Army Corps of Engineers [USACE], Department of Transportation), State funds	DTOP, DRNA	High
85.	Flooding	Promote Adoption and Application of ASCE-24 Codes	Keep building codes up to date and enforce their exercise. Promote and require the implementation of ASCE-24 flood-resistant building	3, 5	3.1, 5.4	HMGP, Section 203	DTOP, NTOP/ AED, Office of Management and Permits (OGPE), ABE	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			standards for new construction and substantial improvements in flood zones					
86.	Flooding	Develop Flood Risk Reduction Infrastructure Projects	Design and construct engineered mitigation projects, including culvert upgrades, floodwalls, diversion channels, improved drainage basins, retention ponds, infiltration systems, and detention areas. Improve sewer systems in areas such as old San Juan.	2	2.2	HMGP, Section 203	COR3, Municipal Governments	High
87.	Flooding	Reduce Flood Risk to State Assets	Develop continuity plans and implement flood-resilient measures to sustain essential operations of critical facilities during and after a flood. This includes GSA offices on floors 11, 12, and 15 of the AEP internal measures proposed to maintain operations.	2	2.2	Section 203, HMGP, DHS Grants	General Services Administration (GSA), COR 3	Medium
88.	Flooding	Promote Flood Insurance	Promote the acquisition of flood	1, 5	1.4, 5.4	FEMA HMGP	PREMB, PRPB, PRDoH,	High

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			insurance in all communities exposed to flooding throughout the Island, from the NFIP coordinated by the PRPB's Flood Valley Administration and promote practices to mitigate flooding in these communities to reduce losses associated with this hazard.			HUD CDBG-MIT State General Funds	Municipal Governments	
89.	Flooding, Dam Failure	Plan for Control of Collective Thirst and Erosion, Including Dispersion.	Establish a plan that integrates effective reservoir/dam drainage to reduce failures and increase capacity. Adequate disposal of the extracted meteorium and a specialized reforestation program in the watersheds that affect the dams and flood zones to stop the effects of erosion/liquefaction. Also, implement erosion-control strategies using vegetation,	2	2.2	Section 203, HMGP, USDA NRCS, HHPD	DRNA, COR3, PRASA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			stabilization structures, and hydrologic design to reduce sediment transport and localized flooding.					
90.	Flooding, Extreme Winds/Hurricanes/Tropical Storms, Landslides, Earthquakes	Identify, evaluate, and estimate the vulnerability of critical state facilities	Identify, evaluate, and estimate the vulnerability of critical state facilities to identified hazards, emphasizing flood, hurricane, landslide, and earthquake hazards, to identify mitigation alternatives (e.g., structural improvements or relocation) that reduce or eliminate the vulnerability of these facilities.	2, 3	2.2, 3.2	FEMA HMGP HUD CDBG-MIT State General Funds	COR3, PREMB, PRDoH, State Agencies	Medium
91.	Flooding, Heavy Rain, Extreme Winds/ Hurricanes/Tropical Storms	Encourage Disaster Insurance Uptake	Orient and encourage the community to obtain property insurance, flood insurance (property and contents), and insurance against other possible disasters. Identify and encourage	1, 6	1.4, 6.1, 6.2	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, PRDoH, Municipal Governments, Nonprofit Agencies	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			opportunities to partner with insurance companies to reduce costs for people who do not have the resources to afford private insurance.					
92.	Flooding, Heavy Rain, Extreme Winds/ Hurricanes/Tropical Storms, Hazardous Materials	Build Resilience of Septic Systems in Communities	Create effective water management districts, inter-jurisdictional commissions, compacts, or other approaches to build the resilience of septic systems in communities. Promote public input and educational programs.	1	1.5	FEMA HMGP HUD CDBG-MIT State General Funds	DNER, EPA, PRDoH	High
93.	Flooding, Heavy Rain, Extreme Winds/Hurricanes/Tropical Storms, Invasive Species	Improve Water Infrastructure	Make improvements to obsolete, broken, or non-functioning infrastructure to reduce the amount of water lost annually due to broken pipes and damaged infrastructure.	2	2.2	FEMA HMGP HUD CDBG-MIT State General Funds	PREPA, PREMB, PRDoH, Municipal Governments	High
94.	Flooding, Landslides	Address Illegal Dumping	Address illegal dumping through science to reduce impacts from flooding	4	4.1	FEMA HMGP HUD CDBG-MIT	DNER, EPA, Municipal Governments	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			and landslides in Puerto Rico			State General Funds		
95.	Hazardous Materials	Public Education and Awareness Program on Landfill Waste and Hazardous Materials Management	Develop, fund, and implement public education campaigns and training programs to improve safe disposal of landfill waste, household hazardous waste, and post-disaster debris. Activities include educational materials, community outreach, school curriculum components, collection events, and coordination with municipal waste programs to reduce illegal dumping, toxic runoff, and contamination during extreme rainfall or flooding. The program will increase compliance with environmental rules, reduce contamination risk, and improve emergency debris management.	4	4.1	EPA Solid Waste and Resource Recovery Programs	Puerto Rico Environmental Quality Board (JCA)	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
96.	Hazardous Materials	Increase Capacity Building for Municipalities and CERT	Implement capacity building efforts for municipalities and Community Emergency Response Team (CERT) preparedness to design and implement drills for community evacuation plans after possible release of oil and chemicals after disasters.	5	5.4	FEMA HMGP HUD CDBG-MIT State General Funds	PREMB, OMME, DRNA	Medium
97.	Heavy Rain	Develop Community Education Programs for the reduction of Overflows in Rainwater Systems	Create an educational program with presentations and educational materials that address communities where clandestine dumping and flooding problems are observed, as evidenced by storm sewers clogged with garbage.	1, 4, 6	1.4, 1.5, 4.1, 6.1	FEMA HMGP, State Funds, Municipal Funds	Department of Natural and Environmental Resources (DRNA)	High
98.	Heavy Rain, Dam Failure, Flooding	Enhance Stormwater Retention Capacity	Construct or retrofit retention/ detention ponds, bioswales, and infiltration basins to temporarily store excess rainfall and	2	2.2	FEMA Section 203, HMGP, EPA SRF, CDBG-MIT	PRASA, DTOP, Municipalities	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			reduce peak runoff during storm events.					
99.	Heavy Rain, Flooding	Increase Storm Sewer Capacity	Install a new gravity storm sewer system. Upgrade, expand, and modernize stormwater conveyance systems (culverts, channels, inlets, drainage pipes) to increase capacity and reduce flooding impacts under heavy rainfall events.	1, 2	1.5, 2.2	FEMA Section 203, HMGP, CDBG-MIT, EPA Clean Water SRF	PRASA, Municipalities, DTOP	High
100.	Heavy Rain, Flooding	Implement Reforestation and Green Infrastructure Practices	Implement reforestation and green-infrastructure practices in clear or open areas to improve infiltration, reduce runoff, stabilize soils, and decrease localized flooding.	4	4.2	FEMA HMGP, USDA NRCS Programs, CDBG-MIT	DRNA	High
101.	Landslides	Establish Landslide Early Warning Network	Develop and deploy a real-time landslide early warning network using rainfall thresholds, geotechnical sensors, and automated alerts, integrated with municipal emergency response systems and	2	2.1	FEMA Hazard Mitigation Assistance (HMA), Section 203, HMGP, USGS Landslide Grants	USGS/PR Risk Management Office (RMD)	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			public warning platforms (e.g., IPAWS/RMD).					
102.	Landslides	Adopt the 2020 Rainfall and Subduction Landslide Susceptibility Map	Formally adopt, update, and maintain the PR 2020 landslide susceptibility map for planning, permitting, infrastructure design, and land-use decision-making. Provide municipalities with training on integrating GIS zoning tools.	3	3.1, 3.2	Section 203/CDBG-MIT/State Planning Funds	PREMB, Puerto Rico Electric Power Authority (PREPA), University of Puerto Rico at Mayagüez (UPRM)	Medium
103.	Landslides	Promote the Landslide Ready Program to All Municipalities	Expand outreach and municipal training for the Landslide Ready program, including planning, site assessments, evacuation procedures, monitoring, and community preparedness education.	1, 6	1.3, 1.4, 6.1, 6.2	Section 203/HMGP/ CDBG-MIT/DOE Resilience Education	PREMB, UPR	High
104.	Landslides	Support Risk-Informed Construction Planning in Areas	Strengthen local land-use planning and construction standards in high-risk landslide areas, including slope stability review,	3	3.1	State funds (OGPe Oficina de Gerencia de Permisos [Permits Management	Department of Public Safety (DPS), PRPB, OGPe Oficina de Gerencia de Permisos	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
		Susceptible to Landslides	geotechnical studies before permit approval, and engineering best practices.			Office]/ PRPB) Municipal funds		
105.	Landslides	Map Localized Landslide Risk and Integrate into Planning Decisions	Develop updated localized landslide hazard maps to support infrastructure risk assessments, zoning decisions, evacuation planning, and mitigation prioritization.	1, 3, 5	1.1, 3.1, 3.2, 5.3	FEMA Section 203/ CDBG-MIT/USGS	Department of Transportation and Public Works (DTOP), LAC	High
106.	Landslides	Support Community Education on Landslide Risk Reduction	Develop a multilevel community education program on landslide risks, safe construction practices, slope drainage improvements, household mitigation, emergency preparedness, and evacuation procedures.	1, 5, 6	1.4, 5.1, 6.1, 6.2	Section 203/HMGP/ DOE/CDC Resiliency Grants	PRPB, Municipal Governments	High
107.	Landslides	Implement Slope Stabilization and Vegetative Reinforcement Program	Implement slope stabilization projects using retaining structures, biotechnical stabilization, drainage	2, 4	2.2, 4.2	HMGP/Section 203/ CDBG-MIT	USGS, DRRA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			systems, and vegetation reinforcement in landslide-prone communities.					
108.	Landslides	Reduce Transportation Infrastructure Landslide Risk	Improve road drainage systems, including culverts, swales, channels, and stormwater controls, to reduce erosion and slope failure along vulnerable roads.	2	2.2	Federal Highway Administration (FHWA) Emergency Relief (ER) Program/ Section 203/HMGP/ PRDOT	DTOP, Program AOA	High
109.	Landslides	Retrofit Bridges at Risk of Landslides	Retrofit and reinforce bridges at risk of collapse due to landslide movement near abutments or structural foundation instability.	2	2.2	HMGP/Section 203/ FHWA	DTOP	High
110.	Landslides	Enhance Stormwater Drainage Capacity in Hillside Communities	Enhance stormwater drainage capacity in hillside communities to prevent slope saturation and failure through retention basins, infiltration trenches, and rainwater diversion engineering.	2, 4	2.2, 4.2	HMGP/Section 203/ USDA/Municipal Funds	Highways and Transportation Authority HTA), DTOP, FHWA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
111.	Landslides	Implement Bio-Engineering Approaches to Stabilize Slops in High-Risk Landslide Zones	Implement bio-engineering stabilization techniques, including vegetation, geotextiles, erosion control Section 203s, and structural reinforcement, to stabilize slopes in high-risk landslide zones. This includes engineering studies, modeling, and design.	2, 4	2.2, 4.2	FEMA HMGP, Section 203, USDA Natural Resources Conservation Service (NRCS) Emergency Watershed Protection Program, local match	HTA, PRPB, Municipal Governments	High
112.	Landslides	Implement Monitoring and Intervention of Drinking Water Systems Breaks	Install sensors and real-time monitoring systems to detect waterline ruptures in hillside communities and prevent soil saturation that triggers landslides. Includes replacement of deteriorated lines.	1, 2, 3	1.2, 2.2, 3.2	FEMA HMGP/ Section 203, EPA Drinking Water Drinking Water State Revolving Fund (SRF), and PRASA funding	PRASA/-PRDOH Water Program	High
113.	Landslides	Landslide Maintenance and Early Warning Network	Establish a landslide monitoring system using rain gauges, soil-movement instruments, and early warning alerts to at-risk communities. Includes public	1, 3, 6	1.4, 3.2, 6.1, 6.2	FEMA HMGP, Section 203, NOAA Weather Program, USGS Landslide	PREMB, PRPB	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			education and emergency notification integration.			Hazard Program		
114.	Landslides	Reduce Landslide Risk Associated with Illegal Development	Identify, regulate, and mitigate informal construction in unstable slope areas using inspections, stabilization requirements, and relocation when necessary.	3, 5	3.1, 5.4	State & Municipal funding, CDBG-DR, CDBG-MIT	OGPe, Municipal Permits Office, PRPB	High
115.	Landslides	Encourage Community Reforestation in Areas Vulnerable to Landslides	Establish community-based tree-planting and root-reinforcement campaigns in high-risk slope areas, using suitable native species and soil stabilization planning.	4, 5	4.2, 5.4	USDA Forestry Grants, Section 203, NGOs, Corporate sponsors	DRNA (Forestry), Municipal Governments	High
116.	Landslides, Flooding, Drought, Subsidence	Karst Zone Mapping and Vulnerability Assessment for Infrastructure Planning	Conduct an updated karst zone mapping and vulnerability assessment across priority municipalities in Puerto Rico to identify zones susceptible to collapse, sinkholes, subsurface drainage	3, 5	3.2, 5.1	FEMA HMGP FEMA Section 428 USGS USDA NRCS University research funding	DRNA	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			hazards, and groundwater pollution risks. The action includes acquisition of geospatial data, geomorphic analysis, hydrogeologic characterization, field verification, and publication of digital maps to guide land-use planning, infrastructure siting, permitting, and future mitigation investments. Map critical facilities including specifically mapping over 1,000 schools in high-risk seismic zones and developments on karst terrain. Results will be integrated into the municipal Land Use Plan, OGPe reviews, and the State Hazard Mitigation Plan.					
117.	Landslides, Heavy Rain	Integrate Landslide Alerts into the iPAQS Public Warning System	Expand the Integrated Public Alert & Warning System (iPAQS) to include real-time landslide	3	3.2	FEMA HMGP FEMA PA 406 Mitigation USGS Cooperative	PREMB (lead for public alert systems)	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			hazard messaging and automated public alerts triggered by rainfall intensity thresholds, soil saturation metrics, and USGS/UPR-M landslide modeling tools. Activities include system integration, communication protocols, mobile notification methods, geotargeted messaging, testing procedures, and public education materials for high-risk communities. This action improves early warning and reduces life-safety risk in areas susceptible to landslide events during extreme rainfall.			Programs State and Municipal funds		
118.	Lightning	Promote Lightning Frequency and Density Analysis	Conduct island-wide analysis of lightning frequency, density, and clustering using NOAA/ NLDN/Caricoos data to identify hotspots	3	3.2	FEMA HMGP, Section 203, USGS Cooperative Agreements	PREMB	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			and support targeted mitigation.					
119.	Lightning	Support Lightning Community Education and Awareness-Raising Activities	Develop education programs on lightning safety, safe sheltering, outdoor worker protocols, school safety plans, and communication materials for high-risk municipalities.	1, 6	1.4, 6.1	FEMA HMGP, Section 203, CDC (Public Health Preparedness)	PREMB, PRDOH, NOAA	High
120.	Lightning	Conduct Structural Level Lighting Risk Mapping and Evaluation	Create GIS-based lightning hotspot maps, evaluate vulnerable infrastructure (sports fields, schools, cell towers, critical lifelines), and recommend protective systems.	2, 3	2.2, 3.2	FEMA HMGP, Section 203, EPA (Environmental Data Grants)	PRPB/GIS Division, PREMB	Medium
121.	Lightning	Install Lightning Protection Pads in Critical Facilities	Install National Fire Protection Association (NFPA-780-compliant) lightning protection systems (pads, grounding, surge protectors) in critical facilities, including shelters, schools, hospitals, and water systems.	2	2.2	FEMA HMGP, Section 203, PA Mitigation (Section 406), USDA Community Facilities	PRASA, PREPA/ LUMA, Municipalities	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
122.	Lightning	Enhance Local Knowledge of Lightning Protection Standards and Emergency Protocols	Develop technical training for engineers, electricians, first responders, and school officials on lightning protection standards and emergency protocols.	1	1.1, 1.2, 1.3	FEMA HMGP, Section 203, DHS Training Grants	PREMB, College of Engineers & Surveyors (CIAPR)	Medium
123.	Lightning	Provide Emergency Personal Training	Develop specialized lightning response protocols and training for emergency responders, lifeguards, park rangers, and outdoor event personnel.	1	1.2, 1.3	Staff Time, FEMA HMGP, EMPG	PREMB	Medium
124.	Lightning	Implement Lightning Detection and Early Warning Systems	Implement lightning detection systems, sirens, and municipal alert systems, and integrate alerts into RKP/IPAWS for outdoor facilities, beaches, sports complexes, and schools.	1, 3	1.2, 1.3, 3.2	FEMA Section 203, HMGP, CDBG-MIT	PREMB, NOAA	Medium
125.	Liquefaction	Stabilize Soils Near Roadways through Grout Injection	Implement grout injection to improve the resistance of roads	2	2.2	PA, DTOP	DTOP	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
126.	Liquefaction	Conduct Port Risk Analysis	Analyze high risk of liquefaction caused by earthquake zones. Evaluate alternative ports to San Juan. Study and implement as applicable foundation reinforcement option.	2, 3	2.2, 3.2	PA, HMGP, FMA	Port Authority	High
127.	Liquefaction, Tsunamis	Study Risks to Generation Plants and Alternatives	Study the risk to San Juan generation plants from liquefaction. Conduct load flow studies to use these plants in case of loss of plants due to possible tsunamis and liquefaction effects. Evaluate and implement study recommendations as applicable.	2, 3	2.2, 3.2	HMGP, Staff time	PREPA	High
128.	Pandemic/ Epidemic	Strengthen Public Health Infrastructure	Enhance public health system capacity by upgrading laboratories, improving disease surveillance platforms, increasing hospital surge capacity, expanding regions, and expanding	2	2.1, 2.2	FEMA HMGP, Section 203, CDC Public Health Emergency Preparedness (PHEP), HHS	PRDOH	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			stockpiles of critical medical supplies (PPE, testing kits, ventilators).					
129.	Pandemic/ Epidemic	Prioritize Vulnerable Populations in Implementing Public Health Initiatives	Emphasize prioritizing the social determinants of health. Develop and implement targeted mitigation programs for high-risk populations, such as the elderly, immunocompromised, and isolated rural communities, including vaccination prioritization, mobile health units, and the distribution of essential supplies.	6	6.2	FEMA HMGP, CDC PHEP, HUD CDBG-MIT	PRDOH	High
130.	Pandemic/ Epidemic	Strengthen the Communication System in Isolated and Vulnerable Communities	Expand the internet and telephone network in areas of isolated and vulnerable communities. Ensure consistent communication with vulnerable populations before,	2, 6	2.2, 6.2	PA, HMGP, Federal/ State funding (National Tele-communications and Information Administration (NTIA))	Office of Management and Budget	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			during, and after a disaster event.					
131.	Pandemic/ Epidemic	Support Coordinated Containment Campaigns	Implement coordinated community-level containment strategies, including early detection, rapid isolation protocols, public information campaigns, hygiene stations, and distribution of mitigation resources to prevent disease spread.	2	2.1	FEMA HMGP, CDC PHEP, HHS, CDBG-MIT	PRDOH	High
132.	Rip Currents	Swim & Lifeguard Code Educational Program	Enhance public safety by deploying standardized beach signage and launching an educational campaign to inform visitors about safe swimming practices and beach selection. Establish and maintain a trained lifeguard corps at beaches identified as high-risk for rip currents to reduce fatalities and injuries.	1, 6	1.4, 6.1	FEMA HMA (Section 203, HMGP), NOAA Coastal Resilience Grants, PR Tourism Co., Municipal Funds	PREMB/ PR Tourism Company	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
133.	Rip Currents	Create a Rip Current Alert Communication Network	Establish a real-time beach hazard alert system using text alerts, beach flag systems, sirens, and mobile app notifications to warn the public about high-risk rip current conditions.	1, 3, 6	1. 4, 3.2, 6.1	HMGP, Emergency Management Performance Grant (EMPG), Federal/ State funding	PREMB/NWS San Juan	Medium
134.	Rip Currents	Enhance Lifeguard Training and Deployment	Enhance lifeguard capacity through specialized training on surf-zone rescue, rip current recognition, and emergency response. Expand lifeguard deployment in high-risk beach areas during peak seasons.	1, 2, 5, 6	1.4, 2.1, 5.4, 6.1	FEMA Section 203Capability & Capacity Building (C&CB), DOJ Public Safety Grants, Municipal Funds	PREMB/ Municipal Emergency Management Offices	High
135.	Rip Currents	Encourage Installation of Lifeguard Surveillance Net	Install lifeguard surveillance net and communication infrastructure to improve coverage on remote or high-risk beaches, allowing quick coordination during rescues.	2, 5	2.1, 5.4	FEMA HMA (Section 203/HMGP), Municipal Funds, Private Partnerships	PREMB, Municipal Emergency Management Offices	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
136.	Sargassum	Implement Comprehensive Sargassum Planning and Recycling Program	Create an educated system for collecting Sargassum at sea (before it reaches the coast/ beaches) and for recycling refuse in environmentally friendly ways. In addition, develop a coordinated monitoring and forecasting program using satellite imagery, oceanographic models, and beach surveys to identify sargassum arrival patterns. Integrate data into municipal emergency plans and develop operational guidance for seasonal accumulation.	2, 3	2.2, 3.1, 3.2	NOAA Coastal Resilience Grants, Section 203, HMGP, PR State Funds	DRNA – Coastal Zone Management Program	High
137.	Sargassum	Implement Excessive Sargassum Cleanup Program	Implement environmentally compliant removal programs for excessive sargassum accumulation on beaches that pose health hazards, block stormwater flow, or threaten critical	2	2.2	State Funds (DRNA/ Municipalities), Section 203, HMGP	DRNA (oversight), Municipal Governments	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			infrastructure. Removal must follow DRNA guidelines to protect dune systems and nesting habitats.					
138.	Sargassum	Prevent Large Sargassum Mats from Impacting High-Risk Areas	Install offshore or nearshore floating barriers and controlled collection points to prevent large sargassum mats from entering sensitive bays, estuaries, and stormwater inlets. Reduces impacts on coastal infrastructure and tourism facilities and prevents toxic decomposition gases from affecting communities.	2	2.2	Section 203, HMGP, NOAA Marine Debris Program, Public–Private Partnerships (tourism sector)	DRNA – Coastal Zone Management Program	High
139.	Subsidence	Strengthen Critical Infrastructure in Subsidence Areas	Identify and reinforce critical facilities in high-risk areas to mitigate ground movement.	2	2.2	HMGP, Federal/State funding (Department of Natural and Environmental Resources)	State Historic Preservation Office (SHPO), Institute of Puerto Rican Culture (ICP), AFI, Central Office for Recovery, eReconstruction,	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
							and Resiliency (COR3)	
140.	Tornadoes	Increase Early Warning Capacity and Shelter Education	Install microsensors with artificial intelligence. Identify nearby shelters and have emergency sites.	2	2.1, 2.2	Staff time, HMGP, State funding	Emergency Systems Bureau (NSE)	High
141.	Tsunami	Conduct Tsunami Evacuation Drills	Implement recurring tsunami evacuation drills for coastal communities, schools, and critical facilities to ensure preparedness and reduce evacuation times.	1, 2, 5	1.1, 1.2, 1.3, 2.1, 5.4	FEMA HMGP, Section 203, Local Municipal Funds	PREMB, Municipal Governments	Medium
142.	Tsunami	Support the Identification and Development of Vertical Evacuation Structures	Develop and construct safe vertical evacuation structures in high-risk coastal zones where horizontal evacuation is not feasible. This includes engineering design, land acquisition, and construction. Encourage dual use coastal structures (offices, shops) with the ability to climb to a third floor.	2, 5	2.2, 5.4	FEMA HMGP, Section 203, USACE	PRPB/PREMA/ Municipal Government	Medium

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
143.	Tsunami	Conduct Tsunami Education and Awareness Activities	Conduct continuous public education campaigns on tsunami signs, evacuation routes, tsunami zones, and preparedness measures. This includes incorporating tsunami awareness activities into school curricula and community outreach.	1, 6	1.4, 6.1, 6.2	FEMA HMA, Education Dept Grants, NOAA TsunamiReady Program	PREMB	Medium
144.	Tsunami	Ensure Accessibility of Education and Drills	Provide accessible educational materials for communities that include people with disabilities	6	6.2	FEMA HMGP, Section 203, ADA compliance grants	PREMB/PR Department of Health	High
145.	Tsunami	Install Tsunami Alarm Systems	Install alarms at risk sites.	2	2.4	HMGP, Federal/ State (NOAA)	PREMB, Municipalities	Medium
146.	Wildfire	Development and Implement Community Wildfire Early Warning and Preparedness System	Develop and implement a community-level wildfire early-warning system, including alerts, detection sensors, and evacuation notification protocols.	1, 2, 3, 6	1.4, 2.1, 3.2, 6.1	HMGP, Section 203, State Funds	Puerto Rico Firefighters Bureau (NCBPR)	High
147.	Wildfire	Expand Newsletter	Increase the distribution and	1, 6	1.4, 6.1	FMAG, State funds	NCBPR	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
		Outreach for Prevention and Mitigation	accessibility of wildfire prevention and mitigation newsletters across Puerto Rico. Incorporate clear guidance on reducing ignition risks, defensible space practices, and emergency preparedness to ensure residents island-wide receive timely and actionable information.					
148.	Wildfire	Expand Public Wildfire Education Programs and Partnerships	Establish public wildfire education programs focusing on defensible space, safe burning practices, vegetation management, and community preparedness.	1, 6	1.4, 6.1, 6.2	HMGP, Section 203, U.S. Fire Administration Grants	NCBPR	Medium
149.	Wildfire	Support Fire Suppression Needs Identification, Partnership Building, and Capabilities Building	Assess the area most prone to fires. Establish more relationships with the community and farmers for mitigation and prevention. Evaluate better	1, 2	1.2, 1.3, 2.1, 2.2	AFG (Assistance to Firefighters Grant), HMGP, State Funds	NCBPR	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
			response techniques, such as installing automatic water sprinklers in vulnerable areas. Acquire and upgrade firefighting equipment, water tanks, communications gear, and wildland fire response tools to enhance suppression capacity.					
150.	Wildfire	Establish Pre- and Post-Wildfire Drone Monitoring Program	Use of drones to cover grassland areas or areas vulnerable to forest fires, to monitor temperature changes another factor that can initiate the event. Also, implement a wildfire monitoring drone program for early detection, post-fire assessment, and surveillance of high-risk areas.	3, 5	3.2, 5.3	General Fund, staff time	NCBPR, PREMB, PRPB, DRNA	High
151.	Wildfire	Install Automatic Fire Sprinkler System in	Implement automatic fire sprinkler systems in vulnerable structures and	2	2.2	State Funds, FEMA 406	CBPR, PR Agencies, Municipal Governments	High

Action #	Hazards Addressed	Action Title	Action Description	Goals	Objectives	Funding Sources	Primary Agency	Priority
		Vulnerable Structures	encourage housing developers to incorporate sprinkler systems in areas with high forest density and vegetation, as a mitigation measure to reduce wildfire risk and prevent potential property losses.					

Evaluation and Prioritization of Mitigation Actions

To optimize the use of limited resources and prioritize the implementation of the most beneficial mitigation actions, a structured prioritization process has been established for evaluating mitigation action priorities. This process uses a comprehensive scoring system to evaluate potential projects and initiatives against a range of critical criteria. The primary objective is to identify and rank actions with the greatest potential to reduce risk, enhance public safety, preserve property, and increase the overall resilience of Puerto Rico.

Mitigation Ranking System

The following rubric prioritizes mitigation actions by evaluating them against six key criteria. Each criterion will guide decision-makers in assessing the potential effectiveness, feasibility, and impact of various actions aimed at mitigating risks.

11. Effectiveness in reducing loss of life
12. Reduction of disaster-related costs
13. Improvement of resilience for critical infrastructure and essential services
14. Hazard risk level addressed (low, medium, or high)
15. Contribution to Puerto Rico's economic development
16. Environmental benefits

Each criterion is scored on a scale, allowing participants to assign a numeric value from 1 to 5. During the in-person meeting on November 4, attendees proposed over 100 mitigation actions and rated them using the rubric. This created a dataset that reflects the perceived effectiveness and priorities for various hazards and types of actions.

After scoring each criterion, the total priority score is calculated by adding the scores across all criteria, with a maximum possible score of 30. Lower scores indicate lower priority, while higher scores indicate higher priority. The total score ranges are as follows:

- 0-10: Low priority
- 11-20: Medium priority
- 21-30: High priority

Table 164: Rubric for Mitigation Action Evaluation Questions*

Question	1	2	3	4	5
How effective is this action in reducing the loss of human life?	No effect	Minimally affective	Somewhat effective	Effective	Highly Effective
How well does this action reduce significant disaster costs?	No significant reduction	Minimal reduction	Some reduction	Significant reduction	Very significant reduction
To what extent does this action improve the resilience of critical infrastructure and essential community services?	No improvement	Minimal improvement	Moderate improvement	Significant improvement	Very significant improvement
Does this action address a hazard of low, medium, or high risk?	Low (2)	Medium (3)	High (5)	–	–
Does this action contribute to the economic development of Puerto Rico?	Does not contribute	Contributes a little	Moderate contribution	High contribution	Very high contribution
Does this action have significant environmental benefits?	Very low	Low	Moderate	High	Very high

**This approach reflects a planning level analysis of actions for HHPDs as well. Outside of the SHMP, Puerto Rico's dam safety agency, PREPA, prioritizes actions for HHPDs based on the level of structural risk and potential loss of human level.*

A brief analysis of how mitigation actions were prioritized indicate strong support for hazard mitigation in general, with multiple high-priority hazards along with education and construction focused actions leading the way:

1. Question 1 evaluates mitigation actions for Puerto Rico's SHMP using a scoring rubric of 1 (Low) and 5 (High) across six criteria. Hazards like Extreme Heat, Landslides, and Coastal Erosion received high ratings (mainly 4s and 5s), indicating strong prioritization. In contrast Lightning and Rip Currents show variability with lower scores (1s and 2s), suggesting uncertainty. Overall, average scores range from 2.6 to 3.8, with Heavy Rainfall, Sargassum, and Wildfires scoring higher, emphasizing their importance. Key insights include high ratings for life-threatening hazards, effectiveness of physical interventions, lower ratings for educational measures due to resilience on behavior, and moderate scores for regulatory measures, which are powerful if enforced.
2. Question 2 assesses the effectiveness of actions in reducing significant disaster costs, using a scoring scale from 1 (no reduction) to 5 (very significant reduction). It reveals that intensive hazards, such as earthquakes and tsunamis, average 4.4, while a broader definition of these hazards yields lower averages than non-intensive hazards. Construction-focused actions achieve an average score of 4.42, surpassing regulatory approaches at 4.06, suggesting that physical measures are viewed as more cost-effective than policy changes. Notably, educational initiatives lead with the highest average Q2 score of approximately 4.50, highlighting the strong perceived value of community engagement and training in effectively reducing disaster-related costs.
3. Question 3 measures how much an action improves the resilience of critical infrastructure and essential community services. The scoring scale runs from 1 (No improvement) to 5 (Very significant improvement). Question 3 scores reveal that actions to enhance critical infrastructure resilience differ by hazard intensity and action type. Intensive hazards (like earthquakes and tornadoes) have higher average scores (≈ 4.3) than other hazards (≈ 4.1), while broad intensive hazards (≈ 4.0) are slightly lower than non-intensive hazards. Construction measures (avg ≈ 4.25) outperform regulatory approaches (≈ 3.9), highlighting the importance of physical improvements. Educational initiatives lead with the highest average score (≈ 4.4), emphasizing the effectiveness of training and awareness programs.
4. Question 4 evaluates how well actions address hazards of varying risk levels. The results have been normalized to match the other questions. The analysis shows that intensive hazards score an average of 2.79, while non-intensive hazards score slightly higher at 2.84, suggesting that perceived risk does not solely determine prioritization. In terms of action types, construction and structural measures lead with an average score of 2.96, followed by regulatory actions at 2.83, and educational measures at 2.33. This indicates a clear preference for physical mitigation strategies, with regulatory actions still valued over education, reflecting a focus on enforceable standards. Ultimately, stakeholders prioritize high-impact solutions, such as retrofitting and infrastructure reinforcement, rather than educational approaches, revealing a gap in the emphasis of non-structural resilience strategies.
5. Question 5 in the rubric assesses the contribution of mitigation actions to Puerto Rico's economic development, with a scoring scale from 1 (No contribution) to 5 (Very high contribution). Results show that actions targeting intensive hazards (earthquakes, tsunamis, etc.) have a higher average score (3.51) than those targeting non-intensive hazards (3.33). The highest scores are linked to coastal resilience, retrofits for wind and seismic/liquefaction, wildlife mitigation, pandemic preparedness, and sargassum management, all of which support critical economic sectors like tourism, energy, and health while promoting local construction and engineering activities.

6. Question 6 evaluates environmental benefits of each mitigation action. The scales range from 1 (very low) to 5 (very high), reflecting how significantly the action contributes to ecological sustainability, such as improving habitat, reducing pollution, or enhancing natural resilience. The results show that actions tied to ecosystem-based approaches, such as drought management, coastal restoration, and wildfire mitigation, score highest for environmental benefits (average ≈ 3.78 overall). Non-intensive hazards slightly outperform intensive hazards (3.82 vs 3.63), reflecting the strong ecological co-benefits of nature-based solutions. Conversely, structural measures for hazards like extreme winds and tsunamis rank lower, suggesting an opportunity to integrate green infrastructure and habitat restoration into these strategies to enhance environmental outcomes.

The rating scores are shown in Table 165.

Table 165: Mitigation Actions Prioritization Scores

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
1.	5	5	5	5	4	5	29	High
2.	3	4	4	5	4	4	24	High
3.	4	3	3	5	5	5	25	High
4.	3	3	3	5	3	3	20	Medium
5.	3	3	2	5	3	3	19	Medium
6.	3	3	3	5	3	3	20	Medium
7.	2	4	5	5	1	1	18	Medium
8.	2	4	5	5	1	1	18	Medium
9.	2	4	4	5	2	2	19	Medium
10.	1	3	4	5	2	2	17	Medium
11.	3	4	4	5	3	3	22	High
12.	1	3	3	5	2	2	16	Medium
13.	2	5	5	5	2	1	20	Medium
14.	1	5	5	5	3	1	20	Medium
15.	1	5	3	5	4	1	19	Medium
16.	1	1	1	5	5	1	14	Medium
17.	2	2	1	5	3	1	14	Medium
18.	2	3	3	5	2	2	17	Medium
19.	1	2	2	5	2	2	14	Medium

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
20.	2	3	4	5	1	1	16	Medium
21.	1	2	2	5	2	2	14	Medium
22.	2	3	3	5	2	2	17	Medium
23.	3	4	4	5	3	1	20	Medium
24.	2	4	4	5	2	2	19	Medium
25.	3	5	5	5	3	4	25	High
26.	5	4	3	5	2	4	23	High
27.	5	4	5	5	5	4	28	High
28.	2	3	4	5	2	1	17	Medium
29.	5	2	2	5	1	1	16	Medium
30.	2	4	3	5	3	1	18	Medium
31.	5	5	5	5	3	4	27	High
32.	5	5	5	5	3	3	26	High
33.	5	5	5	5	3	4	27	High
34.	5	4	5	5	3	3	25	High
35.	4	5	5	5	3	5	27	High
36.	3	4	4	5	4	5	25	High
37.	1	2	4	5	4	3	19	Medium
38.	4	5	3	5	4	5	26	High
39.	3	3	3	5	3	3	20	Medium
40.	4	5	3	5	4	5	26	High
41.	4	4	3	5	5	5	26	High
42.	4	5	5	5	5	5	29	High
43.	1	3	3	5	2	2	16	Medium
44.	1	5	5	5	2	1	19	Medium
45.	1	3	2	5	2	4	17	Medium
46.	1	4	2	5	2	5	19	Medium
47.	5	5	5	5	4	4	28	High
48.	5	5	4	5	1	2	22	High

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
49.	5	5	5	5	3	2	25	High
50.	5	5	5	5	3	4	27	High
51.	4	3	2	5	2	2	18	Medium
52.	5	5	5	5	5	2	27	High
53.	5	5	5	5	5	5	30	High
54.	1	3	1	5	3	4	17	Medium
55.	3	3	3	5	3	1	18	Medium
56.	3	4	4	5	2	3	21	High
57.	5	5	5	5	5	5	30	High
58.	1	5	5	5	1	3	20	Medium
59.	4	2	2	5	1	5	19	Medium
60.	5	4	5	5	4	3	26	High
61.	5	5	5	5	5	5	30	High
62.	3	3	3	5	4	5	23	High
63.	5	5	5	5	5	1	26	High
64.	5	3	3	5	1	1	18	Medium
65.	3	3	1	5	2	1	16	Medium
66.	5	5	5	5	4	1	25	High
67.	1	3	1	5	2	5	17	Medium
68.	5	4	5	5	5	2	26	High
69.	3	4	1	5	3	1	17	Medium
70.	5	5	5	5	5	1	26	High
71.	3	4	4	5	2	3	21	High
72.	5	5	5	5	1	5	26	High
73.	5	4	4	5	4	5	27	High
74.	5	5	5	5	5	5	30	High
75.	4	5	5	5	4	2	25	High
76.	5	5	5	5	4	4	28	High
77.	2	2	2	5	3	1	15	Medium

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
78.	2	2	2	5	3	1	15	Medium
79.	3	5	5	5	4	4	26	High
80.	2	5	5	5	2	2	21	High
81.	2	5	5	5	2	2	21	High
82.	5	5	5	5	5	5	30	High
83.	3	3	4	5	1	3	19	High
84.	5	5	5	5	4	5	29	High
85.	4	5	4	5	4	1	23	High
86.	5	5	5	5	5	5	30	High
87.	4	3	3	5	2	2	19	Medium
88.	3	4	3	5	3	3	21	High
89.	5	5	5	5	5	5	30	High
90.	3	4	4	5	3	1	20	Medium
91.	1	5	3	5	3	1	18	Medium
92.	1	5	5	5	2	3	21	High
93.	5	2	4	5	3	3	22	High
94.	1	2	3	5	3	4	18	Medium
95.	2	5	3	5	4	5	24	High
96.	3	2	1	5	2	1	14	Medium
97.	3	4	4	5	3	5	24	High
98.	4	4	4	5	4	5	26	High
99.	5	4	4	5	4	5	27	High
100.	3	4	4	2	3	5	21	High
101.	3	3	2	5	2	2	17	Medium
102.	4	2	1	5	2	1	15	Medium
103.	5	3	4	5	5	3	25	High
104.	4	3	4	5	4	5	25	High
105.	5	3	4	5	5	3	25	High
106.	5	5	3	5	3	5	26	High

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
107.	5	4	5	5	4	5	28	High
108.	4	4	4	5	4	3	24	High
109.	4	4	4	5	4	3	24	High
110.	5	5	5	5	4	5	29	High
111.	5	4	4	5	3	3	24	High
112.	4	4	4	5	4	3	24	High
113.	5	5	3	5	2	5	25	High
114.	4	4	4	5	4	5	26	High
115.	3	5	5	5	5	5	28	High
116.	3	4	3	5	4	1	20	High
117.	5	3	4	5	3	2	22	High
118.	3	2	3	5	2	2	17	Medium
119.	5	5	3	5	2	5	25	High
120.	4	4	4	3	0	3	18	Medium
121.	4	2	3	3	1	1	14	Medium
122.	4	2	1	3	2	1	13	Medium
123.	4	2	1	3	1	1	12	Medium
124.	4	2	1	3	1	1	12	Medium
125.	5	5	5	3	4	5	27	High
126.	4	4	5	3	4	3	23	High
127.	4	4	5	3	4	3	23	High
128.	5	4	5	3	4	3	19	Medium
129.	5	5	5	5	4	2	26	High
130.	4	4	4	5	4	4	25	High
131.	4	4	4	5	4	4	25	High
132.	5	5	1	3	2	5	21	High
133.	4	2	1	3	1	1	12	Medium
134.	5	5	1	3	2	5	21	High
135.	5	5	2	3	4	1	20	Medium

Mitigation Action Number	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Total Weight	Priority
136.	3	4	4	5	5	5	26	High
137.	2	4	4	5	2	5	22	High
138.	4	5	5	3	5	5	27	High
139.	5	5	5	3	3	4	25	High
140.	5	4	4	3	3	4	23	High
141.	4	4	4	3	0	3	18	Medium
142.	5	3	5	3	3	1	20	Medium
143.	3	5	5	3	3	1	20	Medium
144.	5	5	5	3	4	5	27	High
145.	5	2	2	3	5	1	18	Medium
146.	5	4	4	3	4	5	25	High
147.	5	5	5	3	5	5	28	High
148.	3	3	2	3	2	1	14	Medium
149.	5	5	5	3	5	5	28	High
150.	4	4	4	3	3	4	22	High
151.	5	5	5	3	5	5	28	High

Conclusion

The mitigation strategy for Puerto Rico emphasizes a comprehensive approach to safeguarding the island's communities from hazards. Mitigation actions are crucial because they not only reduce the impact of disasters but also save lives, protect property, and minimize long-term economic losses. By focusing on structural and infrastructure projects, Puerto Rico aims to enhance the resilience of both public and private facilities against threats. The integration of natural systems protection initiatives underscores the commitment to preserving the vital functions of ecosystems, which are essential in reducing overall vulnerability.

Additionally, education and awareness programs play a crucial role in fostering a culture of preparedness among citizens, local officials, and stakeholders. By equipping these groups with knowledge about risks and mitigation strategies, Puerto Rico can create a proactive environment where effective responses to hazards are ingrained in the community's fabric.

By combining these strategies, Puerto Rico can build a more resilient future, ensuring the island is better prepared to withstand and recover from hazards while promoting sustainable growth and development.

The importance of implementing these mitigation actions cannot be overstated, as they form the foundation for a safer community. Ongoing collaboration among all sectors will be essential in realizing these goals and protecting the well-being of all residents and natural resources for generations to come.

SECTION EIGHT

PLAN MAINTENANCE

Plan Maintenance

Plan Monitoring, Evaluation, and Updates

Effective hazard mitigation planning is a dynamic, ongoing process that demands regular review, refinement, and active participation. The Plan Maintenance section ensures the Puerto Rico State Hazard Mitigation Plan (PRSHMP) remains practical, relevant, and aligned with evolving risks, community priorities, regulatory standards, and available resources. By following a structured monitoring and evaluation framework, stakeholders can measure progress toward mitigation goals, assess the success of implemented strategies, and identify new hazards or vulnerabilities that require attention.

Routine updates not only uphold compliance with federal requirements but also enhance interagency collaboration, foster transparent public involvement, and integrate hazard mitigation into local planning, development, and investment decisions. This section outlines the mechanisms for maintaining the plan, including annual reviews and the comprehensive five-year update required by FEMA.

Additionally, the PRSHMP is intended to be maintained as a living plan through a digital version of the plan, allowing updates to be conducted outside the formal five-year update cycle whenever new vulnerabilities emerge, significant events occur, or updated data becomes available. This flexible approach ensures the plan remains relevant, evidence-based, and reflective of evolving hazards, technological risks, and community needs. By incorporating new assessments, improved datasets, and stakeholder feedback as they arise, Puerto Rico can continuously strengthen its mitigation strategies, enhance decision-making, and maintain alignment with federal guidance and best practices. This dynamic process supports proactive risk reduction and ensures the plan remains an accurate tool for guiding mitigation investments across the island.

Interagency Committee for Natural Technological Hazard Mitigation

The Puerto Rico Management Bureau (PREMB) Mitigation Division, in coordination with Central Office for Recovery, Reconstruction, and Resiliency (COR3) and the Mitigation Committee members, is responsible for monitoring, evaluating, and updating the PRSHMP. The maintenance of the plan will be carried out through the Interagency Committee for Natural and Technological Hazard Mitigatio through an annual meeting or opportunity to monitor and review the effectiveness of the current plan. Participating agencies involved in hazard mitigation are listed in the following section.

MITIGATION COMMITTEE MEMBERS PARTICIPATING IN PLAN MAINTENANCE

- La Fortaleza (Governor's Mansion / Office of the Governor)
- Public Housing Administration (AVP)
- Telecommunications Bureau
- Department of the Family
- Emergency System 9-1-1 Bureau (NE9-1-1)
- Department of Natural Resources
- Department of Education (DE)
- Emergency Medical Services Bureau (NCEM)
- Office of Management and Budget (OGP)
- Puerto Rico Aqueduct and Sewer Authority (PRASA/AAA)
- Puerto Rico Bureau for Emergency Management and Disaster Administration (NMEAD)
- Department of Public Safety (DSP)
- Department of Transportation and Public Works (DTOP)
- Office of Energy Public Policy
- Puerto Rico Police Bureau (NPPR)
- Transportation and Other Services Bureau
- Department of Health
- Puerto Rico Fire Department Bureau (NCBPR)
- General Services Administration (ASG)
- LUMA (private operator of the electric grid)
- Department of Housing (Vivienda)
- Puerto Rico Public Broadcasting Corporation (WIPR)
- Puerto Rico Electric Power Authority (PREPA/AEE)

At a minimum, these agencies will be invited to participate in the plan maintenance process. Other agencies, such as the Puerto Rico Planning Board and Department of Agriculture, are encouraged to participate as available. Outreach to municipalities may occur concurrently, or separately, as they update their local hazard mitigation plans and submit grant applications.

The Interagency Committee for Natural and Technological Hazard Mitigation serves as the central coordinating body responsible for integrating, aligning, and advancing hazard mitigation efforts across the Government of Puerto Rico. Established to strengthen multi-sector collaboration and streamline decision-making, the committee brings together representatives from key stakeholders. The committee is responsible for the following:[1146]

- Preparation and implementation of the state hazard mitigation plan
- Identification and prioritization of mitigation projects
- Making recommendations to minimize future losses following a damage assessment after emergencies or disasters

[1146] "2024 Laws of Puerto Rico," tit. 25, § 172i, Justia, https://law.justia.com/codes/puerto-rico/title-twenty-five/subtitle-1/part-i/chapter-9b/subchapter-i/172i/.

Plan Maintenance Process

To ensure that the hazard mitigation plan remains current and relevant to Puerto Rico, the committee will convene **at least once per year** to review and discuss hazard mitigation initiatives, projects, and related issues within the island. By meeting annually, the committee will be able to effectively monitor the plan, document progress, and ensure that hazard mitigation efforts remain aligned with community needs and regulatory requirements.

These annual meetings provide committee members with the following:

- Assessment of state hazard mitigation plan (SHMP) goals and objectives
- Evaluation of mitigation actions and status
- Stakeholder updates on ongoing mitigation initiatives
- Revisions and enhancements to digital maps
- Updates on policy and procedural changes to ensure compliance with all applicable federal statutes and regulations
- Overview of eligibility for federal hazard mitigation assistance programs

In preparation for the annual meeting, the committee may conduct the following actions:

- Reach out to participants to review the PRSHMP mitigation goals and objectives.
- Request a review of mitigation action status reports to maintain visibility on the implementation of mitigation strategies.
- Review the previous annual report.

Appendix A includes the Plan Maintenance Checklist, designed to support the ongoing implementation of the plan maintenance process. This checklist provides a tool for tracking progress and documenting changes, ensuring the PRSHMP is compliant with current federal requirements.

Digital Hazard Mitigation Plan (Digital SHMP)

The PRSHMP incorporates a Digital Hazard Mitigation Plan (Digital SHMP) to ensure that mitigation information remains accessible, current, and actionable. This digital platform serves as both a living repository of strategies and a communication hub for residents and partners. It expands the reach of the traditional plan by providing real-time updates on hazard data, risk maps, projects, and funding opportunities, integrating interactive tools such as surveys, GIS mapping, and comment portals.

The Digital SHMP is designed for flexibility, allowing revisions to be shared immediately with all stakeholders, ensuring up-to-date information. The “living” nature of the digital SHMP enables an ongoing update process. Updates will follow a structured workflow of data collection and internal review. Additionally, the digital platform may increase public engagement, which can be continuous through

interactive maps or educational modules, ensuring that communities remain involved beyond the formal update cycle. Overall, the Digital SHMP enhances Puerto Rico's mitigation ecosystem by promoting equitable and ongoing participation.

Annual Reports

The annual progress report provides a comprehensive evaluation of the island's efforts to address the impacts of natural hazards. It assesses the relevance, scope, and effectiveness of ongoing mitigation initiatives, while also prioritizing strategies for continued resilience. The report is prepared by COR3 in coordination with the Mitigation Committee, and the finalized report is then submitted to the Governor, providing a summary of the mitigation actions that have taken place. The report may include information on the goals, objectives, and progress on the various mitigation initiatives; information on local mitigation efforts, including providing updates on project closeouts; and highlights on notable mitigation success stories from across the Island, showcasing achievements that enhance community resilience and underscore the importance of sustained hazard mitigation planning.

As part of the annual report, the following steps may be taken:

- Engage stakeholders for a mitigation action status report from applicable agencies.
- Review and consolidate status reports to ensure accuracy and completeness.
- Incorporate feedback from stakeholders.

Evaluation Process

Evaluation is designed not only to assess what has been accomplished but also to identify where strategies, coordination, and implementation can be refined, strengthened, and accelerated. The committee will help identify and recommend solutions to barriers that affect plan implementation. As part of the evaluation process, the committee may consider the following questions:

- Do the mitigation objectives and goals outlined in the SHMP still effectively address present-day hazards?
- Have any new or previously unanticipated hazards emerged since the plan's approval?
- Are the current resources sufficient to support the implementation of mitigation projects identified in the strategy?
- Did the results of proposed mitigation actions or projects achieve the intended outcomes in reducing risks from the specific hazard events they were designed to address?
- What challenges, if any, exist in carrying out one or more of the mitigation strategies?

Five-Year Plan Update

At least once every five years, as mandated by 44 CFR § 201.4(d), the plan undergoes a comprehensive review and update. This process incorporates new hazard information, legal requirements, and community input to maintain FEMA approval and funding eligibility.

Updates to the hazard mitigation plan are guided by the evaluation process and federal requirements. When evaluation findings indicate the need for adjustments—such as new hazard data, emerging vulnerabilities, or changes in local priorities—updates are initiated to refine strategies and strengthen alignment with state and local plans.

At least once every five years, as required by 44 CFR § 201.4(d), the plan undergoes a comprehensive update. This process incorporates evaluation results, stakeholder input, and public feedback, ensuring that the plan reflects current conditions and priorities. Draft updates are circulated for review, revisions are made based on comments, and the finalized plan is formally adopted by the jurisdiction before submission to the Government of Puerto Rico and FEMA for approval.

The five-year plan update may include, but not be limited to, the following steps:

- Engage stakeholders, determine planning timeline, tasks, and resources needed.
- Review risk assessment and begin the update process.
- Update mitigation strategies and funding initiatives.
- Solicit stakeholder (e.g., public) feedback.
- Initiation of Update: The Planning Committee may begin the update process no later than one year prior to the plan's expiration date.
- Evaluation of Active Plan: A thorough review of the existing hazard mitigation plan should be conducted to assess its effectiveness, identify gaps, and integrate new data, policies, or hazard information.
- Preliminary State Review: The updated hazard mitigation plan will be submitted to FEMA for initial review at least six months before expiration. This allows sufficient time for revisions, additions, or corrections before final submission to FEMA.
- Final Submission: The completed plan will be submitted to FEMA for formal review and approval before the expiration deadline.
- Continuous Improvement: This cyclical update process ensures that the hazard mitigation plan remains a living document—responsive to evolving hazards, community needs, and regulatory requirements. By adhering to the five-year update schedule, the jurisdiction maintains eligibility for federal funding and strengthens its resilience against future disasters.

Integration of the PRSHMP into Other Plans

A comprehensive hazard mitigation plan does not function in isolation. It is most effective when aligned with related local, regional, and sector-specific planning efforts. Integration ensures consistent strategies, avoids duplication of effort, maximizes funding opportunities, and strengthens Puerto Rico's overall resilience.

The following paragraphs serve as an example to illustrate how the PRSHMP integrates with key Puerto Rico government and local planning mechanisms. This method ensures a unified approach to Puerto Rico's resiliency against emergencies and disasters. By aligning its mitigation strategies with land-use plans, emergency operations plan, capital improvement programs, and local plans, the PRSHMP strengthens coordination across all levels of government. This integration ensures that mitigation efforts are implemented while promoting the efficient use of resources and enabling Puerto Rico to continue building a more resilient future.

Integration with Local Hazard Mitigation Plans

Local hazard mitigation plans (LHMPs) provide essential on-the-ground knowledge, project proposals, and hazard data at the municipal level. The PRSHMP incorporates these local priorities to ensure a coordinated, islandwide mitigation strategy. Integration supports FEMA requirements by maintaining municipal eligibility for local project funding programs, such as the Hazard Mitigation Grant Program (HMGP). At the same time, the PRSHMP ensures Puerto Rico's eligibility and provides overarching strategies that local plans can reference.

Integration with Emergency Operations Plans

The PRSHMP focuses on long-term prevention and risk reduction, while emergency operations plans (EOPs) emphasize response and short-term emergency actions. Both must be aligned to ensure a complete emergency management cycle. Integration occurs by maintaining consistent hazard profiles, as the PRSHMP provides the underlying natural hazard analysis that EOPs use to identify operational priorities and planning assumptions. Both plans also reference shared capability gaps in response, recovery, and mitigation, creating a unified roadmap for capability development.

Integrated Hazard Mitigation and Land Use Planning in Puerto Rico

The Puerto Rico Planning Board (JP), holds statutory authority over the Territorial Plan, zoning maps, special planning districts, and regulations guiding urban development. By integrating the SHMP into JP's planning frameworks, hazard data can be embedded into zoning classifications, density restrictions, and development reviews, ensuring FEMA compliance and enhancing long-term community resilience across Puerto Rico.

Integrating Hazard Mitigation into Capital Improvement Programs

Capital Improvement Programs (CIPs) shape how Puerto Rico invests in essential public infrastructure, including roads, utilities, drainage systems, schools, energy networks, and ports. Incorporating the SHMP into CIPs processes ensures that these investments are informed by risk, resilient, and eligible for federal mitigation funding. All proposed projects may be screened against hazard data to prevent impacts to vulnerable areas unless mitigation measures are applied. This integration prioritizes resilient infrastructure and safeguards critical facilities.

Conclusion

The strategies outlined in this section provide a clear framework, ensuring the plan remains current and focused on maintaining mitigation strategies, thereby reducing the community's exposure to hazards and strengthening its capacity to withstand future events. By maintaining risk assessment findings with targeted mitigation actions, the plan promotes proactive decision-making that protects lives, property, and essential infrastructure. Furthermore, the maintenance process described in the section continues the collaboration among all stakeholders, which is critical to maintaining momentum and ensuring these measures are effectively implemented. Through sustained commitment, the Government of Puerto Rico can enhance the island's resilience and build a safer, more secure future for all.

Appendix A: Plan Maintenance Checklists

Hazard Mitigation Plan Maintenance Survey

Categories	Task	Response	Comments
State Profile	Have there been notable changes in demographics, development patterns, state assets, or other key factors?	Yes ☐ No ☐	
Capability Assessment	What programmatic or policy changes have occurred at the local, state, or federal levels?	Yes ☐ No ☐	
	Are there any capabilities that should be added to the State Capability Assessment?	Yes ☐ No ☐	
Hazard Risk Assessment	Has the nature or magnitude of hazard risks changed?	Yes ☐ No ☐	
	Is there any new information or data on recent emergencies or disasters that must be incorporated into the plan?	Yes ☐ No ☐	
	Do the current goals remain relevant to present and anticipated conditions?	Yes ☐ No ☐	
	Are there any changes to priorities? If so, describe.	Yes ☐ No ☐	

Categories	Task	Response	Comments
	Provide any notable updates on the implementation progress of mitigation actions.	Yes ☐ No ☐	
	Review existing mitigation action items to assess whether funding remains appropriate. Note changes in available funding sources, programs, or priorities.	Yes ☐ No ☐	
Stakeholder Engagement	Are there any changes in federal legislation or regulation that should be reviewed with stakeholders? If so, describe.	Yes ☐ No ☐	
	Is there any input from stakeholders that should be incorporated into the plan's five-year update? If so, describe.	Yes ☐ No ☐	

Mitigation Actions Survey

Mitigation Strategy Action Title		
Project Description		
Location		
Sponsoring Agency		
Hazards Mitigated		
Categories	**Task**	**Comments**
Status	Not Started ☐	
	In Progress ☐	
	Completed ☐	
	Deferred/No Longer Required ☐	
Milestones	Please identify any milestones achieved.	
If the project is in progress or has been completed, please fill out the following.		
Funding Capabilities	What are the funding sources?	
	What are the benefits and costs associated?	
	What is the anticipated project costs?	
	What additional funds, if any, are still needed?	
Laws and Regulations	Are there any changes in policies that will further support this initiative?	
	Have there been any changes to local priorities now that this project is in progress/completed?	

Mitigation Strategy Action Title		
Benefit Assessment	How many people will benefit from this initiative?	
	What are the projected benefits to structures, infrastructure, and community lifelines, if any?	
	Will this project provide any other types of benefits, such as economic or environmental benefits?	
	Have any losses been avoided already because of this project? If so, describe.	
Obstacles and Lessons Learned	What lessons have been learned from this process?	
	Are there any new barriers preventing the initiative's progress?	
	What additional support, including funding, planning, training, or technical assistance, could have made this project easier?	
Next Steps	If this is a phased project, what new initiatives should be pursued?	

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Appendix B: Dam Failure

Appendix B: Dam Failure

DAM FAILURE DEFINITION

A dam failure occurs when a dam or any mechanism with the dam gives way, shifts, or can no longer contain the water, leading to a sudden release of a significant volume of water, creating a serious threat to life, property, and infrastructure located downstream.[1147]

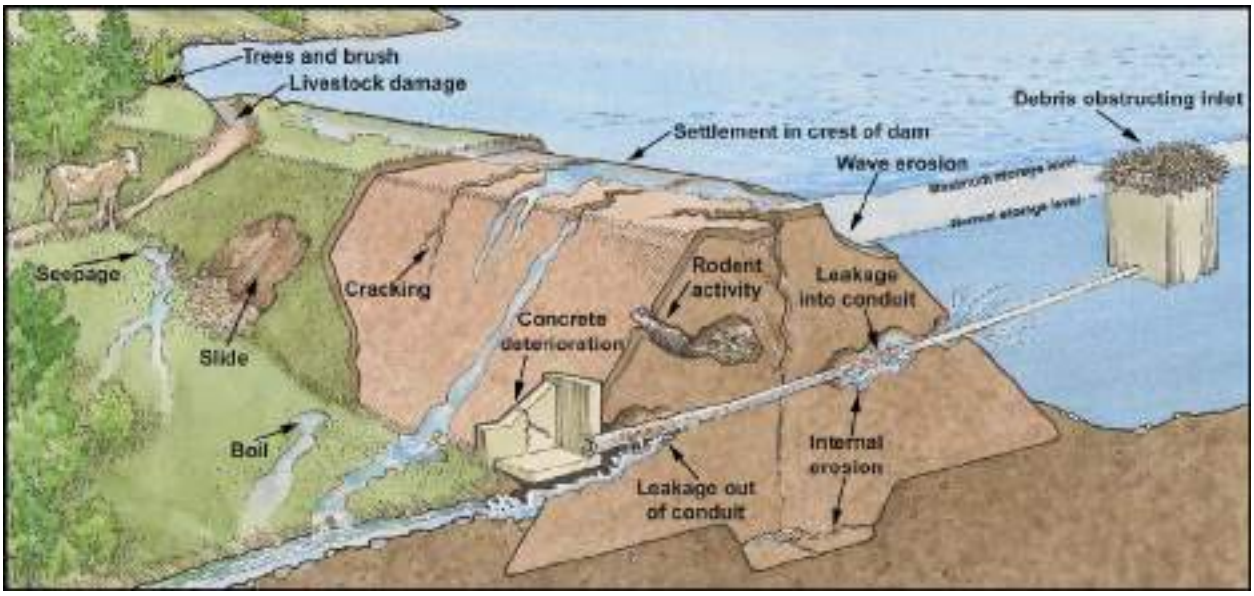


Figure 308: Common Problems at Dams[1148]

Dam failure is one of the most severe hazards associated with aging or inadequately maintained infrastructure. The consequences of such failures can be catastrophic, leading to loss of life, extensive property damage, and long-term environmental impacts. Recognizing these risks, the National Dam Safety Program (NDSP) has prioritized efforts to reduce the likelihood of dam-related disasters through strategic planning, technical training, and interagency collaboration.[1149]

According to FEMA and the American Society of Civil Engineers (ASCE), dam failures in the U.S. typically fall into the following categories.[1150]

[1147] International Commission on Large Dams. Definition of a Large Dam. https://www.icold-cigb.org/GB/dams/definition_of_a_large_dam.asp.
[1148] Nebraska Department of Water, Energy, and Environment Services. (n.d.). *Common problems at dams*. State of Nebraska. https://dnr.nebraska.gov/dam-safety/common-problems-dams.
[1149] Federal Emergency Management Agency. "Year-in-Review: National Dam Safety Program Calendar Year 2023." March 2024. https://www.fema.gov/sites/default/files/documents/fema_ndsp-fy23-annual-year-in-review.pdf.
[1150] Federal Emergency Management Agency. (2023). *Federal guidelines for dam safety*. FEMA P-93. Retrieved from https://www.fema.gov/grants/mitigation/learn/dam-safety/federal-guidelines.

- **Overtopping** – Caused by excessive rainfall or inadequate spillway capacity. This was the primary failure mode at Guajataca.
- **Foundation failure** – Due to unstable geology or landslides, as seen in Guajataca's construction on a landslide complex.
- **Structural failure** – Weakness in materials or aging infrastructure.
- **Piping/internal erosion** – Water seeping through the dam body, eroding it from within.
- **Sabotage or operational error** – Less common but considered in risk assessments.
- **Seismic failure** – Earthquake-induced damage, relevant in seismically active regions like Puerto Rico.

These failure modes are used in risk analyses to guide emergency planning and infrastructure upgrades.

FEMA All Dam Risk Requirements

The concept of "all dam risk" is defined in FEMA's *Local Mitigation Planning Policy Guide (2025)* as a requirement for local hazard mitigation plans to address risks associated with all regulated dams, not just high-hazard dams. Its purpose is to ensure comprehensive planning for dam-related hazards, which is essential for eligibility under programs such as the High Hazard Potential Dam (HHPD) Rehabilitation Grant Program. This aligns with the Stafford Act and 44 CFR Part 201.[1151]

"All dam risk" covers hazards from dams in and outside the jurisdiction that could affect the planning area. It includes:

- Incremental (or breach) risk: Impacts from dam failure.
- Non-breach risk: Risks from normal operations, such as controlled releases or spillway flows.
- Residual risk: Remaining risk even after mitigation measures or dam safety improvements are implemented.

To comply with the HHPD planning requirements, local hazard mitigation plans should follow five key steps:

7. Risk identification involves creating an inventory of all dams, classifying their hazard potential, and gathering supporting data, such as inundation maps, EAPs, and technical studies like HEC-RAS or DSS-WISE.
8. Coordination requires engaging dam owners and state dam safety agencies to integrate existing plans and datasets into the mitigation plan.
9. Risk assessment focuses on describing vulnerabilities related to dam failure and acknowledging data limitations while outlining strategies to close gaps.

[1151] Federal Emergency Management Agency. Local Mitigation Planning Policy Guide, FP-206-21-0002. April 11, 2025. https://www.fema.gov/sites/default/files/documents/fema_hmd_local-mitigation-planning-policy-guide_2025.pdf.

10. The Mitigation Strategy sets goals to reduce dam-related risks through actions such as rehabilitation projects, land use controls, and structural protections.
11. Plan maintenance ensures that the plan is updated every five years, with no interim updates required when dam inventories change.

Location

Puerto Rico is home to 37 dams, which serve multiple critical functions, including potable water storage, flood control, hydropower generation, and recreation (see Figure 309). Of these, 36 are classified as High Hazard Potential Dams (HHPDs), meaning their failure would likely lead to loss of life; the remaining structure, Icacos Dam in Naguabo, carries a low-hazard classification, as documented in the Compendio de Presas y Embalses de Puerto Rico (October 2002). Table 166 presents the 36 HHPD dams consistent with the scope of the High Hazard Potential Dam (HHPD) Rehabilitation Grant Program and 44 CFR Part 201. According to the ASCE's 2019 Puerto Rico Infrastructure Report Card, all but one of these dams are classified as HHPD, meaning their failure would likely lead to loss of life. The report highlights that many of these dams are aging and face challenges related to deferred maintenance and sedimentation, which significantly reduces reservoir capacity. In addition, the National Inventory of Dams (NID), maintained by the U.S. Army Corps of Engineers (USACE), provides detailed data on each dam's type, purpose, and regulatory status. The NID categorizes dams by structural type (e.g., earthfill, concrete) and use (e.g., water supply, recreation, power generation), offering a searchable database that supports planning and hazard mitigation efforts.[1152]

[1152] U.S. Army Corps of Engineers. (n.d.). *National Inventory of Dams*. https://nid.sec.usace.army.mil/nid/. American Society of Civil Engineers. (2019). *2019 Puerto Rico Infrastructure Report Card*. https://infrastructurereportcard.org/wp-content/uploads/2019/11/2019-Puerto-Rico-Report-Card-Final.pdf.

Figure 309: Dam Locations in Puerto Rico

Puerto Rico's dams serve critical functions, such as water supply and flood control, helping maintain reservoir and stream levels for both urban and rural communities across the island. Among the most common types are earthen embankment dams, such as Guajataca, which are often constructed with semi-hydraulic fill and can be vulnerable to deformation over time. Larger reservoirs, such as Carraízo and La Plata, typically rely on concrete gravity dams designed to withstand immense water pressure through their own weight. In addition, the island features off-channel reservoirs strategically located to reduce sedimentation, as seen in areas like Fajardo and Naguabo. These diverse dam types reflect the engineering adaptations required to meet Puerto Rico's geographic and hydrologic challenges while supporting essential water management and hazard mitigation efforts.[1153]

Dams in Puerto Rico are engineered structures that fall into six categories: gravity, earthfill, rockfill, concrete, arch, and buttress, as illustrated in Table 166. Gravity dams rely on their own weight to resist water pressure and are typically made of concrete or masonry. Earthfill dams are constructed from compacted earth materials like clay and gravel, making them economical and suitable for wide valleys. Rockfill dams use layers of rock with an impervious core, offering stability in seismic regions. Concrete dams are a broad category that includes gravity, arch, and buttress designs, all made from concrete. Arch dams are curved upstream to transfer water pressure to the canyon walls, making them ideal for narrow, rocky locations. Buttress dams feature a sloping deck supported by buttresses, which reduces material use and overall weight. Each type serves specific purposes and is selected based on geography, hydrology, and engineering requirements.

[1153] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* (White Paper). American Society of Civil Engineers, Puerto Rico Section. https://www.reservoirsedimentation.com.

Table 166: Inventory of Dams in Puerto Rico Data Updated 2025 [1154]

Dam Name	Hazard Potential Classification	Emergency Action Plan	Owner	Primary Purpose	Dam Type	Last Inspection Date	Condition Assessment
Adjuntas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	8/8/2019	Satisfactory
Ajies Dam Structure 2a	High	Yes	Natural Resources and Environmental Dept.	Flood Risk Reduction	Earth	04/16/2021	Poor
Ana Maria II Dam	High	Yes	Sucesion Serralles Inc.	Irrigation	Earth	2/12/2022	Satisfactory
Ana Maria V Dam	High	Yes	Sucesion Serralles Inc.	Irrigation	Earth	2/12/2022	Satisfactory
Caonillas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Concrete, Gravity	9/4/2019	Satisfactory
Carite Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Earth	12/15/2021	Poor
Cerrillos Dam	High	Yes	Natural Resources and Environmental Dept.	Flood Risk Reduction	Rockfill	6/16/2021	Satisfactory
Cidra Dam	High	Yes	Puerto Rico Aqueduct and	Water Supply	Gravity	3/17/2022	Satisfactory

[1154]U.S. Army Corps of Engineers. (n.d.). *National Inventory of Dams*. https://nid.sec.usace.army.mil/nid/.

Dam Name	Hazard Potential Classification	Emergency Action Plan	Owner	Primary Purpose	Dam Type	Last Inspection Date	Condition Assessment
			Sewer Authority				
Coamo Dam	High	Yes	Commonwealth Of Puerto Rico	Irrigation	Buttress	8/22/2019	Satisfactory
Comerio I Dam	High	Yes	Municipality Of Comerio	Hydroelectric	Gravity	09/17/2019	Poor
Comerio II Dam	High	Yes	Municipality of Comerio	Hydroelectric	Buttress	09/17/2019	Poor
Daguey Dam Structure 3	High	Yes	Natural Resources and Environmental Dept.	Flood Risk Reduction	Earth	04/16/2021	Poor
Dos Bocas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	02/07/2020	Satisfactory
Fajardo Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Water Supply	Earth	04/05/2019	Satisfactory
Garzas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Earth	5/2/2019	Unsatisfactory
Guajataca Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Earth	10/23/2019	Poor

Dam Name	Hazard Potential Classification	Emergency Action Plan	Owner	Primary Purpose	Dam Type	Last Inspection Date	Condition Assessment
Guayo Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	12/11/2021	Poor
Guineo Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Rockfill	1/23/2020	Poor
La Plata Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Water Supply	Gravity	10/21/2020	Satisfactory
Lago Guayabal Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Irrigation	Buttress	12/21/2021	Poor
Lago Regulador	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Water Supply	Earth	11/18/2020	Satisfactory
Las Curias Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Recreation	Earth	12/09/2020	Satisfactory
Loco Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Irrigation	Gravity	12/10/2021	Satisfactory

Dam Name	Hazard Potential Classification	Emergency Action Plan	Owner	Primary Purpose	Dam Type	Last Inspection Date	Condition Assessment
Loiza Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Hydroelectric	Gravity	03/17/2022	Satisfactory
Lucchetti Dam	High	Yes	Puerto Rico Electric Power Authority	Irrigation	Gravity	09/3/2020	Satisfactory
Matrullas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Earth	02/15/2022	Unsatisfactory
Melania Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Irrigation	Earth	12/15/2021	Satisfactory
Patillas Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Hydroelectric	Concrete, Earth	03/05/2020	Poor
Pellejas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	01/10/2020	Satisfactory
Poncena Dam	High	Yes	Sucesion Serralles Inc.	Irrigation	Earth	08/22/2019	Satisfactory
Portugues Dam	High	Yes	Natural Resources and Environmental Dept.	Flood Risk Reduction	Concrete, Arch, Gravity	6/15/2021	Satisfactory

Dam Name	Hazard Potential Classification	Emergency Action Plan	Owner	Primary Purpose	Dam Type	Last Inspection Date	Condition Assessment
Prieto Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	12/11/2021	Satisfactory
Rio Blanco Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Water Supply	Earth	5/7/2019	Satisfactory
Toa Vaca Dam	High	Yes	Puerto Rico Aqueduct and Sewer Authority	Irrigation	Concrete, Earth	4/16/2019	Satisfactory
Vivi Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	01/10/2020	Satisfactory
Yahuecas Dam	High	Yes	Puerto Rico Electric Power Authority	Hydroelectric	Gravity	8/8/2019	Satisfactory

Previous Occurrences

Puerto Rico has experienced significant dam-related emergencies that required formal disaster declarations at both the federal and state levels. These declarations were issued in response to events that posed imminent threats to life and property, such as structural failures and spillway damage during extreme weather. Federal disaster declarations authorized emergency protective measures and technical assistance, while state executive orders enabled the rapid mobilization of local resources and coordination with municipal authorities. As noted in Table 167 and Table 168, the 2017 Guajataca Dam emergency triggered both federal and state actions to stabilize the structure and protect downstream communities.

FEDERAL DISASTER DECLARATIONS

Table 167: Federal Declarations Due to Dam Failure Incidents

Disaster Number	Declaration Date	Incident Period	Description	Location
FEMA-4339-DR-PR	September 20, 2017		This declaration enabled federal assistance for emergency protective measures, including dam stabilization efforts at Guajataca Dam, which was in an active state of failure due to spillway damage and overflow risks	Guajataca Dam

PUERTO RICO DISASTER DECLARATIONS

Table 168: State of Emergency Executive Order Issued in Puerto Rico

Disaster Number	Declaration Date	Description
OE-2017-047	September 17, 2017	A state of emergency was declared across Puerto Rico due to the impending impact of Hurricane Maria, which later caused structural damage to the Guajataca Dam[1155]

SIGNIFICANT EVENTS

The failure of the Guajataca Dam spillway, triggered by Hurricane Maria in September 2017, is recorded as the only recorded significant dam-related emergencies in Puerto Rico in recent years. Constructed in 1928 on a geologically unstable landslide complex, the dam had long exhibited signs of structural stress and deformation. Hurricane Maria's intense rainfall—over 24 inches in the basin—caused overtopping of the

[1155] Rosselló-Nevares, R. A. (2017). *Executive Order of the Governor of Puerto Rico: Administrative Bulletin Number OE-2017-047*. Federal Motor Carrier Safety Administration. https://www.fmcsa.dot.gov/emergency/executive-order-governor-puerto-rico-administrative-bulletin-number-oe-2017-047.

spillway, which led to severe erosion and the collapse of multiple spillway slabs. This failure created a scour hole over 300 feet long (see Figure 310).

Figure 310: Damage to the Guajataca Dam Spillway Following Hurricane Maria[1156]

The dam's failure was linked to its foundation on a deep-seated, actively deforming landslide complex. Decades of gradual movement caused cracking and deformation in the embankment and spillway, and Hurricane Maria's intense rainfall accelerated this instability, resulting in structural distress and spillway damage. The failure also severed a critical water supply line (see Figure 311), prompting the evacuation of 70,000 residents and a rapid emergency response by USACE and FEMA.

Emergency repairs were carried out by the USACE and local agencies to stabilize the structure and prevent further deterioration. This involved innovative measures, such as helicopter-deployed Jersey barriers and gravel-filled sacks, to prevent further erosion. Subsequent engineering assessments revealed ongoing landslide creep and foundational instability, prompting the implementation of Interim Risk Reduction Measures (IRRMs) and long-term structural reinforcements. The Guajataca event not only highlighted the vulnerability of aging infrastructure under extreme weather, but it also underscored the importance of integrated geotechnical, hydraulic, and emergency planning in dam safety management.[1157]

[1156] Hutsell, S. S., Cepero, C. E., & Loar, T. N. (2025). *Guajataca Dam (Puerto Rico, 2017) case study*. Association of State Dam Safety Officials. Retrieved from https://damsafety.org.
[1157] ASDSO Dam Failures and Lessons Learned. Guajataca Dam (Puerto Rico, 2017). https://damfailures.org/case-study/guajataca-dam-puerto-rico-2017.

Figure 311: Damaged 54-Inch Siphon Line, Which Cut Off Water Supply to the Western Side of the Island

Potential Severity of Event

Puerto Rico's 37 dams are overwhelmingly classified as **high hazard**, meaning their failure would likely lead to loss of life and severe property damage. According to FEMA's National Dam Safety Program, the potential severity of dam failure is assessed through hazard classification and a risk-informed approach that prioritizes rehabilitation funding based on factors such as downstream population exposure, critical infrastructure, emergency preparedness, and environmental consequences. Federal guidelines (FEMA P-93) emphasize scaling dam safety management to each structure's size, complexity, and hazard potential to prevent catastrophic failures. This framework not only quantifies risk but also guides funding decisions, emergency planning, and public safety strategies, ensuring proactive measures to protect vulnerable communities across the island.

Beyond their high-hazard classification, Puerto Rico's dams are exposed to multiple threats that compound their vulnerability. The most significant hazards are earthquakes and hurricanes, given the island's location in a seismically active zone and its frequent exposure to tropical cyclones. Other risks include landslides, which can undermine dam foundations, and human-related factors, such as operational errors and even acts of sabotage. The 2017 Guajataca Dam emergency illustrates the potential severity of these failures. If a similar event were to occur, the consequences for downstream communities could be catastrophic, underscoring the need for robust emergency planning and structural resilience across all 37 high-hazard dams in Puerto Rico.

LAGO DE MATRULLAS DAM, OROCOVIS, PUERTO RICO

The Hydrologic Engineering Center (HEC) at the U.S. Geological Survey conducted a detailed probabilistic simulation of dam failure scenarios for the Lago de Matrullas Dam in Orocovis, Puerto Rico. The study modeled four potential events: two extreme rainfall scenarios based on 6-hour and 24-hour Probable Maximum Precipitation (PMP), a 100-year rainfall event, and a non-precipitation condition structural failure. Using HEC's Hydraulic Modeling System (HEC-HMS) and River Analysis System (HEC-RAS), the analysis simulated flood wave propagation, estimating peak discharges, inundation extents, and impacts on downstream communities, such as Ciales, Manatí, and Barceloneta. These results provided critical insights for emergency planning by identifying high-risk zones and informing evacuation strategies under both hydrologic and structural failure conditions.[1158]

One of the most severe scenarios involves a 6-hour PMP event, which would exceed the dam's design capacity and trigger overtopping, where water flows over the dam crest, eroding the structure and leading to collapse. In this case, peak discharge is estimated at approximately 3,149 m^3/s immediately downstream. The resulting flood wave would travel through the Río Matrullas, Río Toro Negro, and Río Grande de Manatí, causing significant inundation of low-lying areas, such as those in Figure 312. Communities such as Ciales, Manatí, and Barceloneta would be heavily affected, and the levee near Barceloneta, built in 2000, would be overtopped, exposing populated areas to flooding. Prepared as part of the USGS study, the plate is intended to support EAPs and evacuation planning by depicting flood extents and critical routing paths under an extreme precipitation-induced breach.

This worst-case scenario underscores the vulnerability of downstream communities and the importance of proactive dam monitoring, maintenance, and robust emergency response planning. It highlights the need for accurate evacuation zones, well-developed EAPs, and effective risk communication strategies to mitigate the catastrophic consequences of a potential dam failure under extreme weather conditions.

[1158] Torres-Sierra, H., & Gómez-Fragoso, J. (2015). *Dam failure analysis for the Lago de Matrullas Dam, Orocovis, Puerto Rico* (Scientific Investigations Report 2015–5065). U.S. Geological Survey. https://doi.org/10.3133/sir20155065.

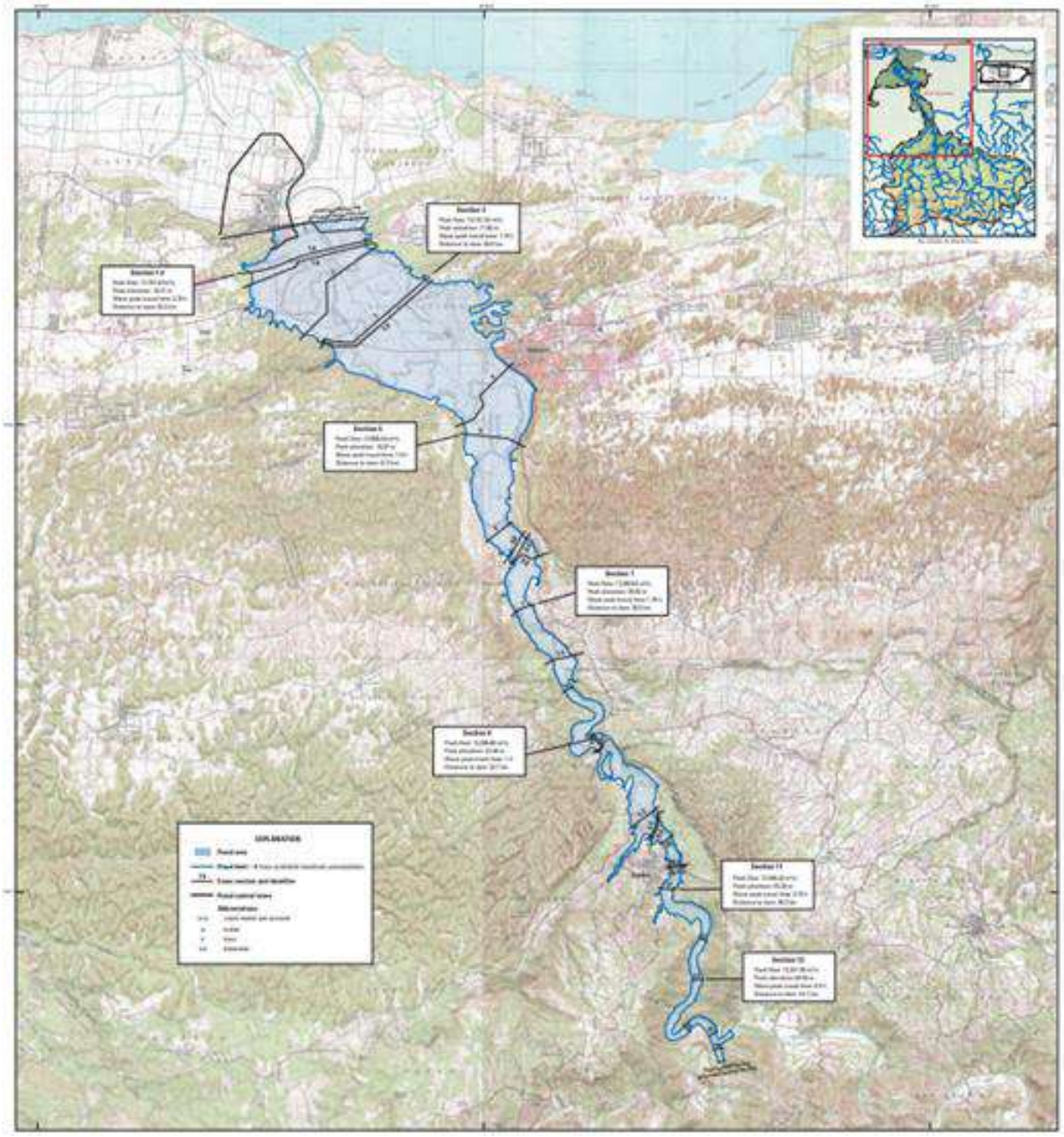


Figure 312: Six-Hour Probable Maximum Precipitation Event

The 24-hour PMP scenario in Figure 313 represents an extreme hydrologic loading condition that far exceeds the dam's design capacity, resulting in overtopping and structural failure at Lago de Matrullas. Compared to the 6-hour PMP event, this prolonged rainfall produces a significantly larger inflow volume, driving a peak discharge of approximately 3,605 m^3/s immediately downstream. Using HEC-HMS and HEC-RAS, the USGS analysis simulated breach formation and flood wave propagation through the Río Matrullas, Río Toro Negro, and Río Grande de Manatí corridors. The resulting inundation maps show greater flood extent and depth than the 6-hour PMP case, with critical infrastructure, such as the Barceloneta levee,

overtopped once again, exposing densely populated areas to catastrophic flooding. This scenario underscores the severe consequences of prolonged extreme precipitation, highlighting the need for robust EAPs, accurate evacuation zones, and proactive dam safety measures to protect downstream communities.

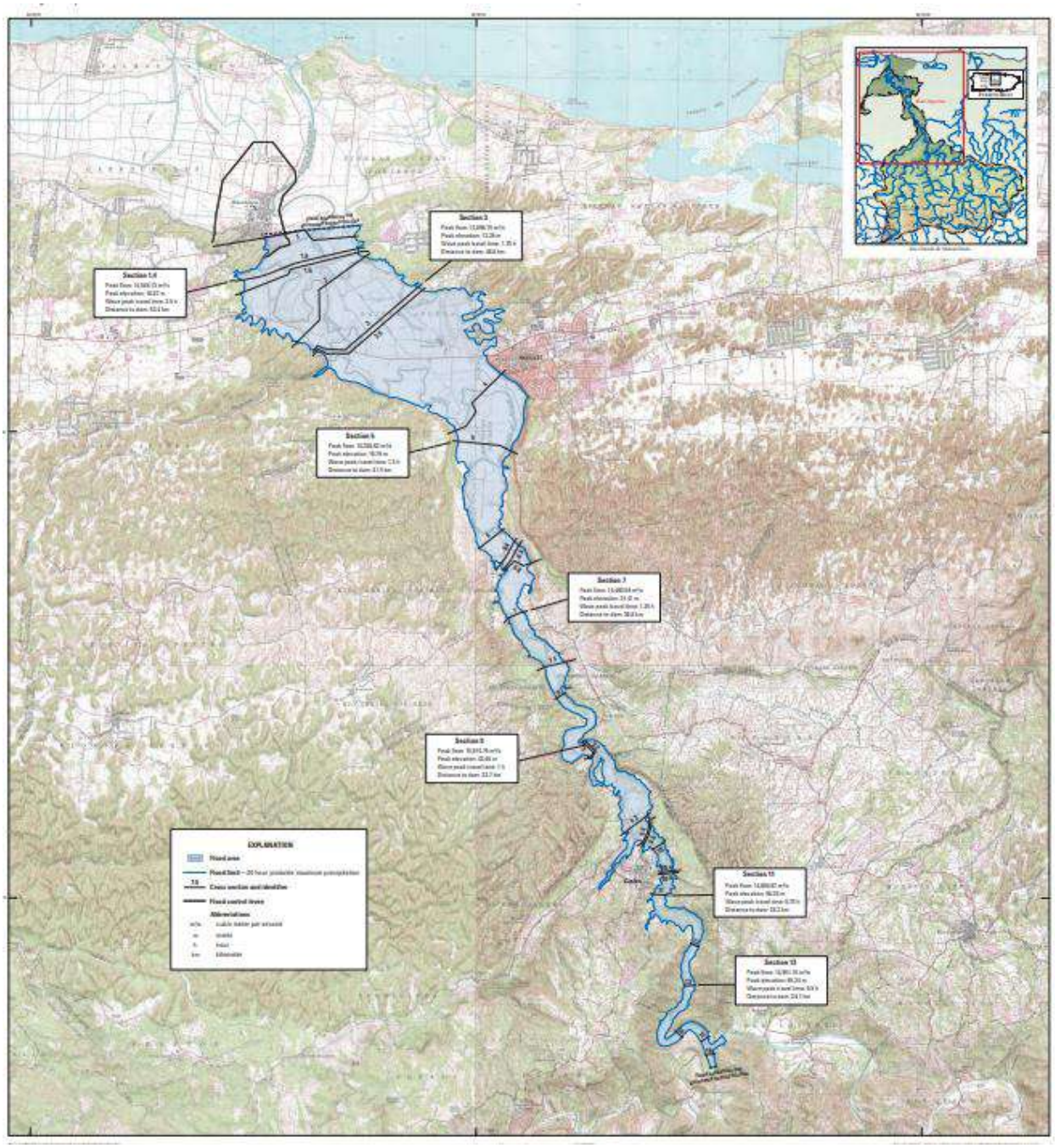


Figure 313: 24-Hour Probable Maximum Precipitation Event

Figure 314, the sunny day failure scenario, models a structural breach of Lago de Matrullas Dam under piping (internal erosion) conditions without any precipitation input. Unlike hydrologic stressors, such as PMP events, this failure mode assumes a sudden compromise of the dam's integrity during normal reservoir

operations, producing an estimated peak discharge of about 1,696 m^3/s immediately downstream. The USGS analysis, using HEC-HMS and HEC-RAS, simulated the breach formation and flood wave routing through the Río Matrullas, Río Toro Negro, and Río Grande de Manatí corridors. Although the levee near Barceloneta remains intact in this scenario, the rapid release of water still poses significant flooding risks to downstream communities, such as Ciales, Manatí, and Barceloneta, threatening homes, infrastructure, and agricultural lands. This case underscores that even in the absence of extreme rainfall, structural vulnerabilities can lead to catastrophic consequences, reinforcing the need for continuous monitoring, maintenance, and robust EAPs for high-hazard dams.

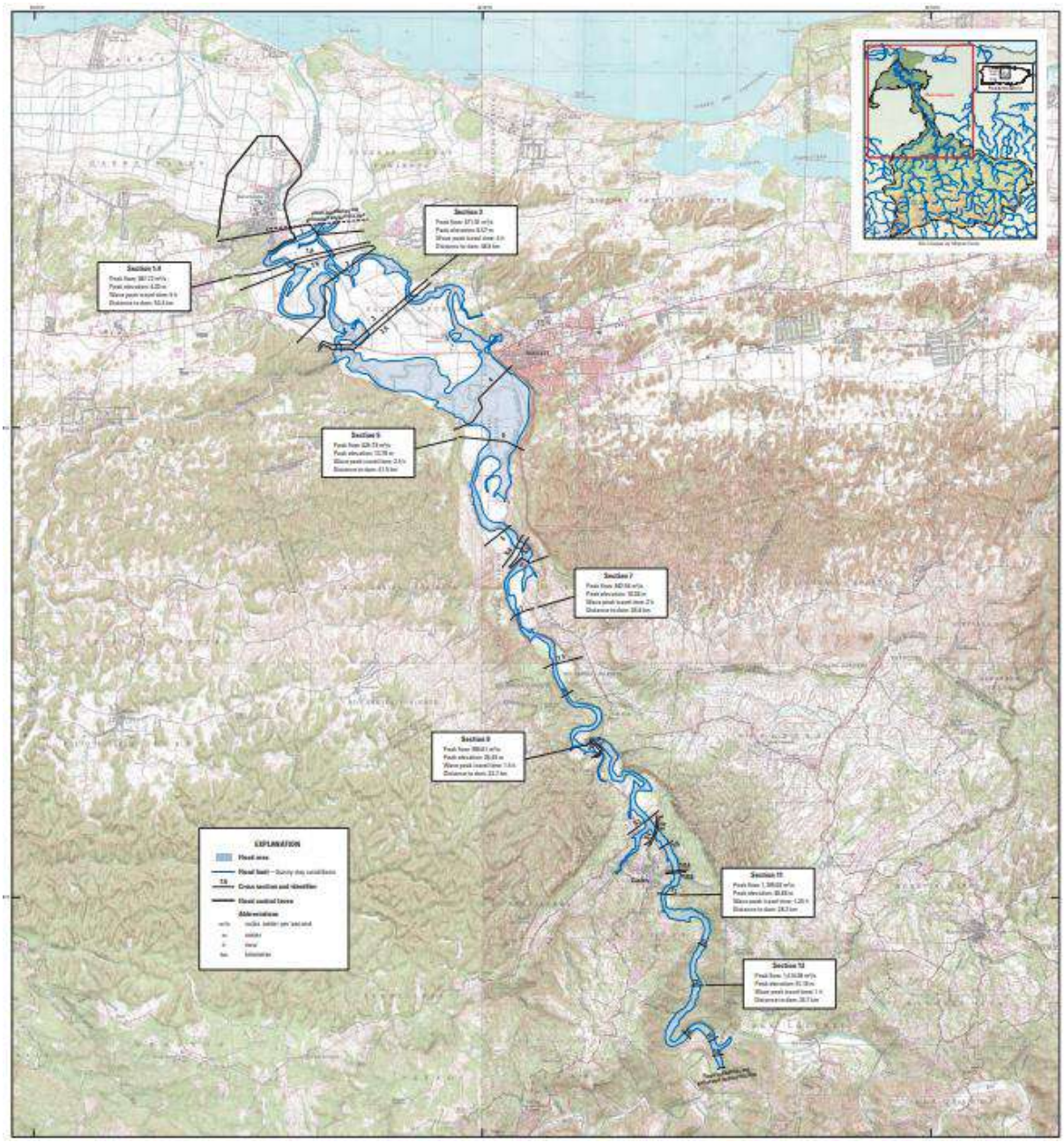


Figure 314: Sunny Day Conditions

Dam risk evaluation is a highly complex process that requires integrating multiple layers of analysis to capture the full spectrum of potential failure modes. The USGS study of Lago de Matrullas demonstrates how different scenarios—6-hour PMP, 24-hour PMP, and sunny day failure—produce distinct hazards and vulnerabilities for downstream communities. The 6-hour PMP event generated an intense but short-duration inflow, causing rapid overtopping and a peak discharge of approximately 3,149 m^3/s, which threatens communities like Ciales and Manatí with fast-moving flood waves. By contrast, the 24-hour PMP scenario introduces prolonged hydrologic stress, resulting in even greater inflow volumes and a peak discharge near 3,605 m^3/s, overtopping levees and inundating densely populated areas, such as Barceloneta. The sunny day failure case, driven by internal erosion rather than rainfall, produces a sudden breach with a peak discharge of about 1,696 m^3/s. This would still be catastrophic for downstream communities, despite the absence of extreme precipitation.

These differences underscore why hazard, vulnerability, and risk must be clearly distinguished in planning. Hazard refers to the physical event (e.g., PMP rainfall or structural piping); vulnerability reflects the susceptibility of exposed populations and infrastructure (e.g., urban density, levee conditions); and risk combines both with potential consequences, such as life loss and economic damage. Understanding these distinctions is critical for prioritizing mitigation actions, such as structural retrofits, sediment management, and early warning systems (EWSs), and for designing EAPs that account for scenario-specific impacts. A comprehensive dam safety strategy must therefore integrate probabilistic modeling, hydrologic forecasting, and structural integrity evaluations to ensure that emergency response and long-term resilience measures are tailored to the unique challenges posed by each failure mode.

Probability of Future Hazard Events

Based on the most recent significant dam-related emergency, the 2017 Guajataca Dam incident, and the following qualitative analysis, the probability of future dam failure events in Puerto Rico is generally assessed as **Low**. Given the very limited history of dam failure incidents in Puerto Rico, this profile qualitatively indicates a low probability of future hazard events. However, it is important to note that this assessment is based on secondary and limited information, including historical records and planning-level data, rather than on detailed structural inspections or probabilistic modeling. As such, these findings should be viewed as preliminary and underscore the need for further quantitative studies, such as fragility curve development and hydrologic hazard analysis, to provide a more precise understanding of failure likelihood and consequences. These advanced methods will enable risk-informed decision-making and support prioritization of mitigation actions for long-term resilience.

The probability of future hazard events emphasizes that modern dam safety practices increasingly rely on quantitative, probabilistic approaches to assess failure risk. Risk is defined as the product of three factors: the likelihood of a loading event (such as floods or earthquakes), the likelihood of an adverse structural response (such as dam failure), and the magnitude of consequences (including life loss and economic damage). Quantitative risk analysis uses numerical estimates to calculate the annual probabilities of failure and potential impacts, making it suitable for high-risk dams or complex portfolios where detailed data is available. This approach supports precise decision-making for prioritizing funding and infrastructure interventions but requires advanced modeling tools and comprehensive datasets. Conversely, qualitative

risk analysis employs expert judgment and categorical scales (e.g., low, moderate, and high) to evaluate credible failure modes and their consequences, often visualized through risk matrices. Although less precise, qualitative methods are valuable for initial screenings and rapid assessments when data are limited.[1159]

The section also highlights tools such as fragility curves and hydrologic hazard curves (HHCs) as essential for probabilistic risk management. Fragility curves model the probability of dam failure under varying stress conditions, such as hydrologic loads or seismic events, providing visual thresholds for concern and enabling comparative assessments across multiple dams. HHCs estimate the likelihood of different flood magnitudes over time, informing spillway capacity evaluations and emergency planning. These tools, combined with FEMA's guidelines (FEMA P-93 and P-1025[1160]), form a comprehensive framework for dam safety that prioritizes proactive planning, monitoring systems, and early warning technologies. In Puerto Rico, where dams face unique challenges from tropical storms, seismic activity, and sedimentation, this integrated approach is critical for guiding rehabilitation priorities, enhancing emergency preparedness, and building long-term resilience into water supply systems and hazard mitigation plans.[1161]

Figure 315 presents a qualitative classification of dam conditions into three categories: Satisfactory, Poor, and Unsatisfactory. These classifications are based on secondary information, such as structural integrity indicators, maintenance records, and operational performance data referenced in the figure. This categorization provides a planning-level snapshot of how well each dam is currently positioned to withstand stressors.

[1159] Federal Emergency Management Agency. "Federal Guidelines for Dam Safety Risk Management," FEMA P-1025. January 2015. https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_risk-management_P-1025.pdf.
[1160] Federal Emergency Management Agency. "Federal Guidelines for Dam Safety Risk Management," FEMA P-1025. January 2015. https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_risk-management_P-1025.pdf.
[1161] Federal Emergency Management Agency. "Federal Guidelines for Dam Safety Risk Management," FEMA P-1025. January 2015. https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_risk-management_P-1025.pdf.

Figure 315: Qualitative Classification of Dam Conditions in Puerto Rico, Based on Secondary Information

Vulnerability Assessment

Vulnerability assessment in dam safety, as outlined in the FEMA P-65 guidelines, is a critical component of risk analysis. It involves identifying and evaluating the potential failure modes of a dam—specific sequences of events that could lead to an uncontrolled release of water. This process considers the dam's design, construction, operational history, and environmental context. The goal is to understand how likely each failure mode is to occur and what consequences it might have, especially in terms of life loss, economic damage, and environmental impact. Vulnerability assessment helps prioritize safety actions and allocate resources effectively, ensuring that the most critical risks are addressed first.[1162]

The vulnerability of Puerto Rico's dams is compounded by their overwhelmingly **high-hazard** classification and aging infrastructure, which amplifies the consequences of any failure mode. As noted in the probability analysis, the likelihood of future dam-related emergencies is assessed as **low**, driven by exposure to extreme precipitation, seismic activity, and deferred maintenance. However, vulnerability is not static. It reflects systemic weaknesses, such as sedimentation, limited emergency preparedness, and gaps in structural resilience. Although qualitative assessments provide a planning-level view, the absence of quantitative tools, such as fragility curves and hydrologic hazard curves, highlights the need for advanced modeling to refine risk estimates. Ultimately, the convergence of high failure probability and significant downstream exposure demands proactive mitigation measures, including structural retrofits, EWSs, and robust EAPs, to reduce life-safety risks and protect critical lifelines across the island.

[1162] Federal Emergency Management Agency. "Federal Guidelines for Dam Safety Risk Management," FEMA P-1025. January 2015. https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_risk-management_P-1025.pdf.

Figure 316: View of Dam from the Municipality of Comerio

QUALITATIVE ASSESSMENT OF DOWNSTREAM DAM VULNERABILITY

Table 169 presents a qualitative assessment of downstream vulnerability for selected dams in Puerto Rico. This evaluation is based on secondary information compiled throughout this profile, including FEMA's dam safety guidelines (FEMA P-93 and P-1025), historical events, and emergency preparedness data. The dams included in this assessment were selected based on the following criteria:

- Significant downstream population exposure
- Availability of Emergency Action Plans (EAPs) or modeling studies
- Documented historical incidents
- Critical infrastructure dependence, including potable water supply and hydroelectric generation
- Secondary source coverage from USGS, FEMA, ASCE, or dam owner records available at the time of plan preparation

This evaluation is based on secondary information compiled throughout this profile, including FEMA's dam safety guidelines (FEMA P-93 and P-1025), historical events, emergency preparedness data, and modeling studies, such as the USGS analysis of Lago de Matrullas.

The vulnerability assessment in Table 169 reflects the dams for which sufficient data was available at the time of this plan update. As additional stakeholder data becomes available, this assessment will be expanded in the next update cycle.

While this update expands the qualitative assessment to include all dams identified in the Puerto Rico inventory, this evaluation remains a planning-level assessment based on secondary data sources, including National Inventory of Dams (NID) attributes, condition ratings, and stakeholder input from PRASA and PREPA.

Key data limitations include:

- Lack of consistent inundation mapping across all dams
- Limited availability of quantitative modeling (e.g., HEC-RAS, fragility curves)
- Incomplete downstream population exposure datasets for some rural basins
- Variability in Emergency Action Plan (EAP) detail and accessibility
- Limited real-time monitoring and instrumentation data for certain facilities

As a result, vulnerability classifications presented in Table 169 rely on professional judgment informed by hazard exposure (e.g., hurricanes, earthquakes, landslides), known condition ratings, dam function (e.g., water supply vs. flood control), and qualitative downstream consequence indicators.

Future plan updates will prioritize incorporation of quantitative risk modeling, standardized inundation mapping, and enhanced coordination with dam owners to refine vulnerability classifications and reduce uncertainty.

Table 169: Qualitative Vulnerability Matrix for Dams in Puerto Rico[1163]

Dam Name	Primary Purpose	Downstream Population Exposure	Summary of Concerns
Guajataca	Water Supply/ Recreation	~250,000 residents	Evacuation of 70,000 in 2017; critical water supply; aging infrastructure.
Carraízo	Water Supply	~500,000 residents (San Juan Metro)	Main source for San Juan; sedimentation issues; high social vulnerability.
La Plata	Water Supply	Urban areas downstream	Overdrafted reservoir; critical to metro water supply.

[1163] EAP = Emergency Action Plan and Plan de Acción para Emergencias, PMP = Probable Maximum Precipitation, USGS = United States Geological Survey

Dam Name	Primary Purpose	Downstream Population Exposure	Summary of Concerns
Lago de Matrullas	Irrigation/ Water Supply	Ciales, Manatí, Barceloneta	USGS modeling shows severe flooding risk under PMP scenarios.
Dos Bocas	Hydroelectric/ Water Supply	Moderate population	High hazard classification; less urban exposure.
Cerrillos	Flood Risk Reduction	Ponce area	Urban exposure but strong flood control purpose.
Caonillas	Hydroelectric	Utuado	Moderate exposure; aging infrastructure.
Patillas	Hydroelectric	Southeastern PR	Undergoing seismic retrofit; moderate population.
Comerío II (Salto II)	Hydroelectric/ Tourism	Comerío	Moderate exposure; lacks full-time operator and alert systems.
Guayabal	Irrigation	Rural areas	Limited downstream population.
Ana Maria V/II	Irrigation	Agricultural zones	Private ownership; low population density.
Las Curias	Recreation	San Juan outskirts	Small reservoir; limited impact zone.
Isabela	Water Supply	Isabela urban core and PR-112 corridor; moderate population exposure	Small off-channel reservoir (≈399 acre-feet) with 42.3 ft height; no permanent operators or guards; reliance on USGS monitoring and manual communications. Access via PR-112; inundation maps included in EAP.[1164]
Rio Blanco	Water Supply	Naguabo (PR-31/ PR-191 corridor) and nearby communities; moderate population exposure	Earth embankment on densified stone columns; extensive instrumentation (piezometers, seepage collection, level gauges) and an automated emergency warning system; emergency power for inflow controls.[1165]
Toa Vaca	Irrigation	Villalba and Coamo downstream along PR-150; communities identified in the EAP and hazard profile	Large reservoir (≈55,888 acre-feet); instrumentation present and 20 kW emergency generator, but no downstream automatic alert system and not staffed 24/7; downstream municipalities (Villalba,

[1164] Municipio Autónomo de Isabela. (2025). *Plan de Acción para Emergencias: Lago Regulador de Isabela*. Autoridad de Acueductos y Alcantarillados, Gobierno de Puerto Rico.
[1165] Municipio Autónomo de Naguabo. (2025). *Plan de Acción para Emergencias: Represa Río Blanco*. Autoridad de Acueductos y Alcantarillados, Gobierno de Puerto Rico.

Dam Name	Primary Purpose	Downstream Population Exposure	Summary of Concerns
			Coamo, Juana Díaz) flagged for Health & Medical vulnerabilities.[1166]
Cidra	Water Supply	Cidra, Aguas Buenas, and Bayamón; interconnected water system serving urban/ suburban areas	EAP anticipates uncontrolled releases/structural failure scenarios requiring mass evacuations across multiple municipalities; strong dependence on interconnected water systems increases consequence potential.
Fajardo	Water Supply	Fajardo municipality and coastal neighborhoods; moderate population exposure	EAP notes communications rely on phones/cellular/trunked radios and lacks automated downstream alert; manual notification processes may delay evacuations during a rapidly evolving failure.[1167]
Garzas	Hydroelectric	Utuado and rural downstream communities	Classified as Unsatisfactory; aging infrastructure and sedimentation issues noted across PREPA dams; downstream mountainous terrain limits evacuation routes and increases flash flood risk.
Guayo	Hydroelectric	Adjuntas and downstream rural corridors	Poor condition rating; exposure to extreme rainfall and sedimentation; SME input highlights overtopping risks during high rainfall events and limited monitoring capacity at some facilities.
Guineo	Hydroelectric	Jayuya and downstream riverine communities	Poor condition and high-hazard classification; located in mountainous terrain susceptible to landslides and intense precipitation; inspection programs ongoing but resource constraints noted.
Lago Guayabal	Irrigation	Juana Díaz basin agricultural and rural areas	Poor condition rating; SME prioritization identified Guayabal as a concern; limited population density but exposure to sedimentation and structural deficiencies increases risk.
Lago Regulador (Isabela)	Water Supply	Isabela and surrounding corridors	Small regulating reservoir with limited storage; moderate exposure but constrained downstream population; SME

[1166] Municipio Autónomo de Villalba. (2025). *Plan de Acción para Emergencias: Represa Toa Vaca*. Autoridad de Acueductos y Alcantarillados, Gobierno de Puerto Rico.
[1167] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de acción para emergencias de la Represa Fajardo 2025: Manual de infraestructura*. Puerto Rico: Autoridad de Acueductos y Alcantarillados.

Dam Name	Primary Purpose	Downstream Population Exposure	Summary of Concerns
			notes indicate lack of full-time staffing and reliance on manual systems.
Loco	Irrigation	Southern agricultural regions (Yauco/Guánica area)	Satisfactory condition; primarily agricultural exposure; low population density reduces life safety risk but sedimentation and drought variability remain concerns.
Loíza (Carraízo system)	Hydroelectric / Water Supply	San Juan metropolitan region	Critical water supply for major population center; significant sedimentation and operational stress; PRASA notes identify sedimentation and drought sensitivity as key vulnerabilities.
Melania	Irrigation	Agricultural zones in southern Puerto Rico	Satisfactory condition; primarily rural/agricultural exposure; limited downstream critical infrastructure reduces consequence severity.
Pellejas	Hydroelectric	Adjuntas and downstream mountain communities	Satisfactory condition but located in steep terrain; exposure to landslides and extreme rainfall; limited redundancy in evacuation routes.
Ponceña	Irrigation	Southern agricultural valleys (Ponce region)	Satisfactory condition with moderate population exposure; agricultural dependence and irrigation role increase economic consequence risk.
Portugués	Flood Risk Reduction	Ponce urban area	Critical flood control structure protecting urban population; high consequence if failure occurs despite satisfactory condition; downstream urban exposure is significant.
Prieto	Hydroelectric	Central mountainous regions	Satisfactory condition but located in high rainfall region; SME input identifies sedimentation and long-term maintenance challenges across similar facilities.
Vivi	Hydroelectric	Utuado and downstream rural communities	Satisfactory condition; mountainous topography increases flood velocity and limits evacuation; subject to rainfall-driven hydrologic loading.
Yahuecas	Hydroelectric	Adjuntas/Utuado region	Satisfactory condition but exposed to landslide and seismic hazards; PREPA

Dam Name	Primary Purpose	Downstream Population Exposure	Summary of Concerns
			identified earthquakes and slope instability as key risks.
Adjuntas	Hydroelectric	Adjuntas municipality	Satisfactory condition; moderate population exposure; located in mountainous terrain with landslide susceptibility and intense rainfall patterns.
Ajies (Structure 2a)	Flood Risk Reduction	Localized downstream communities	Poor condition rating; flood control function increases consequence of failure; structural deficiencies (Type A/B/C classification system noted by PREPA) indicate elevated risk.
Daguey (Structure 3)	Flood Risk Reduction	Naguabo and coastal corridors	Poor condition; located in flood-prone basin; reliance on flood control function elevates downstream life safety and infrastructure risk.
Comerío I	Hydroelectric	Comerío municipality	Poor condition; SME notes indicate lack of continuous staffing and limited monitoring; downstream communities rely on constrained transportation corridors.
Coamo	Irrigation	Coamo and downstream agricultural areas	Satisfactory condition; moderate exposure; irrigation dependence increases economic vulnerability though life-safety exposure is lower than urban systems.

It is important to emphasize that this matrix does not incorporate direct structural inspections, hydrologic modeling, or fragility curve analysis. Instead, it uses a planning-level approach to characterize vulnerability based on the following:

- Downstream population density
- Presence of critical infrastructure (e.g., hospitals, water treatment facilities)
- Emergency preparedness (e.g., existence and exercise of EAPs)
- Historical dam-related incidents (e.g., Guajataca Dam failure in 2017)
- Available modeling studies (e.g., USGS Matrullas flood scenarios)

Downstream vulnerability to dam failure in Puerto Rico is shaped by a combination of high population exposure, aging infrastructure, and gaps in emergency preparedness. As the qualitative matrix indicates, communities such as San Juan, Ciales, Manatí, and Barceloneta face high vulnerability due to dense populations, critical lifelines, and limited redundancy in water and transportation systems. These risks are compounded by systemic weaknesses, sedimentation, deferred maintenance, and insufficient integration of

land use planning, which increase the likelihood of catastrophic flooding and cascading impacts across FEMA Community Lifelines, including Safety and Security, Health and Medical, and Water Systems.

FEMA's PEA underscores that when public facilities, such as emergency operations centers, hospitals, and transportation corridors, fail during disasters, cascading effects ripple across all lifelines, magnifying the severity of the event. A dam breach would mirror these vulnerabilities, isolating communities, disrupting medical care, and overwhelming shelter capacity. The Guajataca incident demonstrated how quickly these failures escalate, forcing mass evacuations and straining response systems. Without proactive measures, such as structural retrofits, EWSs, and robust EAPs, the consequences of a dam failure could be catastrophic, resulting in widespread life loss and systemic disruption.[1168]

LOCATIONS

The Lago de Matrullas Dam in Orocovis, Puerto Rico, is an earthfill embankment dam built in 1934 as part of the Toro Negro Hydroelectric Project (see Figure 317). It serves two purposes: hydroelectric power generation and irrigation water supply. Over time, sedimentation has reduced its storage capacity, increasing its vulnerability to overtopping during extreme rainfall events. The dam lies in the Río Grande de Manatí hydrographic basin, and its failure could impact downstream communities, such as Ciales, Manatí, and Barceloneta, especially in low-lying areas.[1169]

[1168] Department of Homeland Security, Federal Emergency Management Agency. (2022, August 18). *Programmatic Environmental Assessment: Public facilities infrastructure recovery and resiliency, Puerto Rico (FEMA-DR-4336-PR, FEMA-DR-4339-PR, FEMA-DR-4473-PR)*. Region 2 Caribbean Area Office – Joint Recovery Office. Retrieved from https://www.fema.gov/sites/default/files/documents/fema_dr-4336-4339-4473-public-facilities-pea_08182022.pdf.
[1169] Torres-Sierra, H., & Gómez-Fragoso, J. (2015). *Dam failure analysis for the Lago de Matrullas Dam, Orocovis, Puerto Rico* (Scientific Investigations Report 2015–5065). U.S. Geological Survey. https://pubs.usgs.gov/sir/2015/5065/pdf/sir2015-5065.pdf.

Figure 317: Lago de Matrullas Dam in Orocovis

The vulnerability assessment conducted by the USGS and The Puerto Rico Electric Power Authority (PREPA) used advanced hydrologic and hydraulic modeling tools, HEC-HMS and HEC-RAS, to simulate dam failure under four scenarios: 6-hour and 24-hour PMP events, a 100-year flood, and sunny day conditions. These simulations incorporated breach parameters like formation time and breach width, and they evaluated both overtopping and piping failure modes. The study generated inundation maps and peak discharge estimates to assess downstream hazards. Metrics, such as peak flow, arrival time, and maximum water surface elevation, were used to quantify vulnerability. Although fragility curves were not explicitly mentioned, the methodology aligns with their principles—modeling structural response under stress to estimate failure probability. This approach reflects a probabilistic understanding of dam performance, in which varying degrees of loading (e.g., hydrologic, seismic) are used to assess the likelihood of structural compromise.[1170]

This assessment is crucial for emergency planning, particularly for developing an EAP. It highlights the dam's susceptibility to failure during extreme events and the potential for widespread flooding. The study concludes that failure under PMP conditions would lead to severe flooding, overtopping bridges and levees, while sunny day failures would pose significant risks due to sudden releases and downstream vulnerability.

POPULATIONS

A hypothetical failure of the Lago de Matrullas Dam poses a significant threat to downstream communities, particularly those located along the Río Grande de Manatí. The most vulnerable populations include residents of low-lying areas in the municipalities of Ciales, Manatí, and Barceloneta, where floodwaters could

[1170] Torres-Sierra, H., & Gómez-Fragoso, J. (2015). *Dam failure analysis for the Lago de Matrullas Dam, Orocovis, Puerto Rico* (Scientific Investigations Report 2015–5065). U.S. Geological Survey. https://pubs.usgs.gov/sir/2015/5065/pdf/sir2015-5065.pdf.

reach critical levels within hours of a breach. Inundation maps show that during extreme rainfall events, such as the 6-hour and 24-hour PMP scenarios, flooding could overtop protective infrastructure like levees and bridges, increasing the risk to homes, businesses, and agricultural lands. The flood wave would travel rapidly downstream, with peak discharges exceeding 14,000 m^3/s, potentially overwhelming emergency response capabilities. These findings underscore the importance of robust EAPs and community preparedness to mitigate risks to life and property.[1171]

STRUCTURES INCLUDING CRITICAL FACILITIES

All dams in Puerto Rico must be classified as critical infrastructure due to their essential role in public safety, water supply, energy generation, and flood control functions, and they are increasingly vulnerable due to aging infrastructure, sedimentation, and extreme weather events.

According to the 2019 ASCE Infrastructure Report Card, 97% of Puerto Rico's dams are classified as high-hazard potential, meaning their failure would likely lead to loss of life. Although Emergency Action Plans (EAPs) exist for all high-hazard dams, only 35% have been exercised in the past five years, highlighting a gap in preparedness. Many dams are over 50 years old and face increasing risks from sedimentation and seismic vulnerability, yet the state dam safety office lacks sufficient funding for comprehensive assessments and retrofits.[1172]

The 2020 ASCE Water Supply White Paper emphasizes that Puerto Rico's water infrastructure is not only aging but also mismanaged. Dams such as Carraízo and La Plata are overdrafted beyond their firm yield, leading to repeated water rationing during droughts. Despite billion-dollar investments like the Superaqueduct, water shortages persist due to poor integration and operation of reservoir systems. The paper argues that sedimentation and mismanagement, not infrastructure scarcity, are the root causes of water insecurity, and that better operational strategies are urgently needed.[1173]

The USGS 2015 Dam Failure Analysis of Lago de Matrullas demonstrated the catastrophic consequences of dam failure. Simulations showed that a breach during extreme rainfall events could produce peak discharges exceeding 3,600 m^3/s, inundating downstream communities such as Ciales, Manatí, and Barceloneta. Even under sunny day conditions, failure could lead to significant flooding. These findings underscore the life-threatening risks posed by dam failure and the need for robust emergency planning and infrastructure resilience.[1174]

[1171] Torres-Sierra, H., & Gómez-Fragoso, J. (2015). *Dam failure analysis for the Lago de Matrullas Dam, Orocovis, Puerto Rico* (Scientific Investigations Report 2015–5065). U.S. Geological Survey. https://pubs.usgs.gov/sir/2015/5065/pdf/sir2015-5065.pdf.

[1172] American Society of Civil Engineers. (2019). *2019 Puerto Rico Infrastructure Report Card*. ASCE Puerto Rico Section. https://infrastructurereportcard.org/wp-content/uploads/2019/11/2019-Puerto-Rico-Report-Card-Final.pdf.

[1173] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* [White paper]. ASCE Puerto Rico Section. https://sections.asce.org/puerto-rico/sites/sections.asce.org.puerto-rico/files/Morris%20-%202020%20ASCE%20water%20supply%20white%20paper%2016dec2020.pdf.

[1174] Torres-Sierra, H., & Gómez-Fragoso, J. (2015). *Dam failure analysis for the Lago de Matrullas Dam, Orocovis, Puerto Rico* (Scientific Investigations Report 2015–5065). U.S. Geological Survey. https://doi.org/10.3133/sir20155065.

CASE STUDY: EMERGENCY ACTION PLAN FOR THE REPRESA SALTO II DE COMERÍO

The Plan de Acción para Emergencias (EAP) for the *Represa Salto II de Comerío*, presented by the Municipality of Comerío in February 2021, is a critical document designed to safeguard the lives and property downstream of the dam. A EAP outlines the procedures and responsibilities for responding to emergency situations involving dams, including structural failures, natural disasters, and hazardous material spills. Its primary goal is to ensure coordinated, timely, and effective action to minimize risks to human life, infrastructure, and the environment.[1175]

The *Comerío II Dam*, also known as *El Salto Dam #2*, is a buttress-type structure located on the La Plata River in Puerto Rico. Originally built for water storage, it is currently being renovated for tourism and hydroelectric energy generation. The dam does not have a full-time operator, but it is monitored monthly by municipal staff. Although the dam is not currently classified as high risk, the absence of emergency alert systems, electrical backup, and operational manuals suggests a moderate level of vulnerability, especially in the event of sudden structural issues or natural disasters.

The EAP emphasizes the importance of annual updates, regular inspections, and coordination among municipal, state, and federal agencies. It includes detailed protocols for incident classification (internal alert, developing situation, imminent threat), decision-making routes, notification procedures, and expected actions during emergencies. The plan also outlines the roles of key personnel under the Incident Command System (ICS), ensuring clear lines of authority and communication during crises.

Key recommendations include installing emergency alert systems, improving communications infrastructure, maintaining operational manuals, and conducting annual drills, including dam failure simulations. The plan also stresses the need for proper documentation, coordination with external agencies, and readiness for hazardous material incidents. Overall, the EAP is a vital tool for protecting the lives of those living downstream and ensuring the dam's safe operation under all conditions.

In conclusion, the EAP for the *Represa Salto II de Comerío* plays a vital role in reducing vulnerability for communities living downstream. By establishing a structured framework for monitoring, response, and coordination, the EAP ensures that potential hazards are identified early and addressed systematically.

One of the key strengths of the EAP is its emphasis on periodic inspections and updates, which help maintain an accurate understanding of the dam's structural condition. These assessments are essential for detecting early signs of deterioration or risk, and they often lead to recommendations for further technical studies. This proactive approach is the first step in reducing vulnerability, as it builds awareness and readiness among stakeholders.

The insights gained from these evaluations pave the way for the next critical phase: structural retrofitting. By identifying weaknesses and planning targeted interventions, the EAP supports informed decision-making

[1175] Municipio Autónomo de Comerío. (2021, February). *Plan de Acción para Emergencias: Represa Salto II de Comerío*. Autoridad de Energía Eléctrica, Gobierno de Puerto Rico.

that can enhance the dam's resilience and safety. This progression—from monitoring to study to retrofitting—forms a comprehensive strategy for risk reduction.

Impact Assessment

Structural failure of a high-hazard dam in Puerto Rico would unleash a sudden and uncontrolled surge of water, devastating communities downstream. The immediate impacts include catastrophic flooding, destruction of homes, and loss of life, compounded by severe economic consequences from damaged infrastructure, agricultural lands, and transportation networks. Beyond the physical destruction, the interruption of the water supply would ripple across the island, affecting drinking water availability, sanitation, and food production. These cascading failures would strain emergency services and disrupt essential lifelines, leaving thousands vulnerable and amplifying recovery costs.

Dams are critical infrastructure, and their failure represents a dual threat: direct flooding and systemic disruption of water systems that sustain public health, energy, and economic stability.[1176] The 2017 Guajataca Dam emergency serves as a stark reminder of these risks. The partial collapse of its spillway forced the evacuation of 70,000 residents and required urgent stabilization to prevent a complete breach. Avoiding such an event demands proactive investment in dam safety, emergency planning, and monitoring systems. Without these measures, the consequences of a structural failure could be catastrophic, resulting in widespread life loss and billions in economic damage across Puerto Rico.

STATE ASSETS

Puerto Rico's network of high-hazard potential dams represents only one dimension of the state's exposure to catastrophic flooding. Equally critical are the public assets and lifelines located downstream of these structures. These assets include water treatment plants, electric power facilities, transportation corridors, and emergency services infrastructure that sustain daily life and disaster response. For example, hydroelectric dams, such as Dos Bocas and Caonillas, which feed the Superaqueduct system, are integral to both water and energy security. Sedimentation and aging infrastructure at these sites amplify the risk of service interruptions during extreme events.

Downstream communities also host critical transportation and communications assets. Primary highways like PR-167 near Comerio and PR-31 in Naguabo provide evacuation routes and access for emergency responders, yet these corridors lie in the inundation zones of high-hazard dams, such as Comerio I and Río Blanco. A breach of these structures would isolate municipalities, delay medical evacuations, and hinder delivery of essential supplies. Public safety facilities, including police stations, municipal emergency offices, and judicial buildings, are similarly vulnerable, as demonstrated during Hurricanes Irma and Maria when over 1,200 such facilities sustained damage. The concentration of hospitals and clinics in flood-prone areas

[1176] Finster, M., Hemphill, M., Marsh, K., Miles, P., & Freeman, C. (2023). *Dam risks in disasters: A Puerto Rico case study for Hurricane Fiona* [Conference poster]. International Association of Emergency Managers (IAEM) Annual Conference. https://www.iaem.org/Portals/IAEMconf/documents/2023/Competitive/Molly-Finster.pdf.

compounds these risks. Loss of access to dialysis, oxygen, and pharmaceuticals during a dam-related disaster would escalate life safety threats for medically fragile populations.

Beyond physical infrastructure, water systems themselves are a cornerstone of resilience. Failure of dams would not only inundate downstream communities but also cripple potable water delivery, sanitation, and food production, triggering cascading impacts across all FEMA community lifelines. These vulnerabilities highlight why state assets must be evaluated holistically, considering not only the structural integrity of dams but also the interconnected systems and critical facilities that depend on their safe operation. A comprehensive risk assessment must therefore integrate dam safety with strategies for protecting water treatment plants, energy infrastructure, transportation networks, and emergency services to ensure the continuity of essential functions during and after a catastrophic event.

COMMUNITY LIFELINES

Dam failure is not just a localized hazard; it is a failure of critical infrastructure that can trigger cascading impacts across all FEMA community lifelines. A dam failure involves the sudden uncontrolled release of impounded water, often resulting in catastrophic flooding downstream. These events can disrupt essential services, such as water supply, energy, transportation, communications, and public health systems, amplifying the disaster's scope and complexity. FEMA's community lifelines framework provides a structured approach for emergency managers to prioritize the restoration of these vital services during crises.

SAFETY AND SECURITY

Safety and Security is one of the most critical lifelines during disasters, as it ensures law enforcement, emergency operations, and public order when communities are most vulnerable. FEMA's Programmatic Environmental Assessment for Public Facilities Recovery (DR-4336, DR-4339, DR-4473) revealed that hurricanes and seismic events in Puerto Rico severely disrupted this lifeline. More than 1,200 public safety facilities, including police stations, municipal emergency offices, and judicial buildings, sustained damage or became inaccessible during Hurricanes Irma and Maria. These failures delayed emergency response, compromised evacuation efforts, and increased risks to life and property. The assessment underscores that when these facilities fail, cascading impacts ripple across other lifelines—transportation, communications, and health—magnifying the disaster's severity.

A catastrophic dam failure would mirror and amplify these vulnerabilities. Puerto Rico's 37 high-hazard dams, such as Carraízo, La Plata, and Lago de Matrullas, are located upstream of densely populated areas and critical government assets. USGS modeling of Lago de Matrullas showed that, under extreme rainfall scenarios, peak discharges could exceed 3,600 m^3/s, sending floodwaters through Orocovis, Ciales, and Barceloneta within hours. In the San Juan metropolitan area, the failure of Carraízo or La Plata would inundate police headquarters, emergency operations centers, and municipal offices, cutting off access routes and overwhelming response capabilities. These cascading failures would leave communities without

law enforcement presence, hinder rescue operations, and expose vulnerable populations to heightened security risks.[1177]

Mitigation requires a proactive, integrated approach. Strengthening the resilience of public safety facilities is paramount, through structural hardening, elevation above flood levels, and relocation outside dam inundation zones where feasible. Redundant communications systems, including satellite and radio backups, must be deployed to maintain command and control during infrastructure outages. EAPs for high-hazard dams should be fully aligned with municipal continuity plans, ensuring rapid mobilization of law enforcement resources during evacuations. Equally important is the expansion of EWSs that provide real-time alerts to public safety agencies and communities, coupled with regular training and exercises simulating dam failure scenarios. These measures will not only protect lives but also preserve the functionality of safety and security lifelines, enabling Puerto Rico to withstand and recover from the cascading impacts of a catastrophic dam failure.

FOOD, HYDRATION, AND SHELTER

A catastrophic dam failure in Puerto Rico would disrupt one of the most critical FEMA community lifelines: Food, Hydration, and Shelter. These lifelines ensure survival during disasters, yet they are highly vulnerable to the cascading impacts of sudden flooding.

Flooding caused by a dam breach can devastate agricultural zones, wiping out crops and livestock that sustain local food systems. For example, communities downstream of Río Blanco Dam in Naguabo, which supports irrigation and water supply, would face immediate disruption of potable water services if its raw water pipelines or pumping stations failed. The contamination of water sources by sediment and debris would compound the crisis, increasing the risk of gastrointestinal illnesses. In addition, floodwaters can damage food storage facilities and markets in low-lying areas, while washed-out roads, such as PR-31 near Río Blanco, would delay food distribution to isolated communities. These impacts ripple across the island, threatening food security and hydration for thousands.[1178]

The destruction of homes and critical infrastructure downstream of high-hazard dams would force mass evacuations. During the 2017 Guajataca Dam emergency, over 70,000 residents were evacuated when spillway collapse threatened a complete breach. Similarly, inundation maps for Río Blanco Dam show that neighborhoods in Naguabo and Humacao lie in flood zones, placing hundreds of families at risk of displacement. Emergency shelters would be quickly overwhelmed, requiring coordination between municipal authorities, FEMA, and the Puerto Rico Emergency Management Bureau to provide safe refuge,

[1177] Federal Emergency Management Agency. (2022). *Programmatic Environmental Assessment for Public Facilities Infrastructure Recovery and Resiliency, Puerto Rico (FEMA-DR-4336-PR, FEMA-DR-4339-PR, FEMA-DR-4473-PR)*. U.S. Department of Homeland Security. https://www.fema.gov/sites/default/files/documents/fema_dr-4336-4339-4473-public-facilities-pea_08182022.pdf.

[1178] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias de la Represa Río Blanco 2025: Manual de infraestructura*. Puerto Rico: Autoridad de Acueductos y Alcantarillados.

bedding, and essential supplies. FEMA-supported evacuation planning and shelter operations are vital to preventing humanitarian crises during such events.[1179]

Dam failure does not only destroy homes; it disrupts lifelines that sustain health. Washed-out bridges and roads hinder ambulance routes and emergency evacuations, isolating hospitals and clinics in affected areas. Medical supply chains for oxygen, pharmaceuticals, and dialysis treatments would be interrupted, particularly in rural municipalities like Naguabo and Ciales. Public health risks escalate as contaminated floodwaters spread disease, while mental health challenges—trauma, anxiety, and stress—compound recovery needs. FEMA and USACE have conducted tabletop exercises to strengthen evacuation and medical continuity plans, but gaps remain in preparedness for large-scale dam emergencies.[1180]

HEALTH AND MEDICAL

A catastrophic dam failure in Puerto Rico would severely disrupt the Health and Medical lifeline, creating cascading impacts on hospitals, clinics, and emergency services. Sudden flooding from a breach would isolate critical healthcare facilities, damage transportation routes, and overwhelm local emergency response systems. Contaminated floodwaters pose immediate public health risks, including waterborne diseases and hazardous material exposure, while mental health challenges—such as trauma and anxiety—would escalate during mass evacuations.

Downstream communities such as Villalba, Coamo, and Juana Díaz, identified in the Toa Vaca Dam EAP, are particularly vulnerable. These municipalities host clinics and small hospitals that could lose access to electricity, potable water, and medical supply chains if PR-150 and connecting roads are inundated. During an imminent failure scenario, evacuation orders would strain shelter capacity and require rapid coordination to relocate patients needing dialysis, oxygen, or critical care. The absence of full-time dam operators and limited alert systems at Toa Vaca further heightens the risk of delayed notifications, increasing the likelihood of life-threatening conditions for medically fragile populations.[1181]

Mitigation strategies must prioritize continuity of medical operations, including redundant power systems for hospitals, pre-positioned medical supplies in safe zones, and integration of dam failure scenarios into municipal emergency plans. Strengthening EWSs and conducting joint exercises with healthcare providers and emergency managers are essential to safeguard lives and maintain the Health and Medical lifeline during a dam-related disaster.

[1179] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias de la Represa Río Blanco 2025: Manual de infraestructura*. Puerto Rico: Autoridad de Acueductos y Alcantarillados.
[1180] Finster, M., Hemphill, M., Marsh, K., Miles, P., & Freeman, C. (n.d.). *Dam Risks in Disasters: A Puerto Rico Case Study for Hurricane Fiona*. Argonne National Laboratory; Federal Emergency Management Agency; Freese and Nichols, Inc. https://www.weather.gov/sju/fiona2022.
[1181]. Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias de la Represa Toa Vaca 2025: Manual de Infraestructura*. Puerto Rico: Autoridad de Acueductos y Alcantarillados.

ENERGY

Energy is one of FEMA's critical community lifelines, and in Puerto Rico, its stability is closely tied to water infrastructure. High-hazard dams, such as the Carraízo Reservoir (shown in Figure 318), are essential not only for potable water but also for sustaining operational continuity across the island.

Figure 318: Carraízo Reservoir[1182]

A failure at Carraízo would trigger cascading impacts: the Sergio Cuevas Filtration Plant, which supplies nearly 500,000 residents in the San Juan metropolitan area, would lose its primary water source, halt operations and disrupting electricity-dependent pumping systems. The EAP for Carraízo emphasizes redundant power systems, including multiple generators for gates and pumping units, because any electrical outage during a dam emergency could prevent controlled releases, increasing the risk of uncontrolled flooding and structural collapse.[1183] These vulnerabilities underscore how energy resilience is inseparable from dam safety and why integrated planning for lifelines is a priority in hazard mitigation efforts.

The broader energy implications extend beyond immediate operational failures. Puerto Rico's electric grid relies on hydropower reservoirs like Dos Bocas and Caonillas, which feed the Superaqueduct system. However, sedimentation and aging infrastructure have already reduced firm yields at these reservoirs, threatening both water and energy security. As the 2020 ASCE white paper explains, dredging alone cannot resolve these systemic issues; instead, strategies such as sediment-guided operations and conjunctive use of groundwater are critical to maintaining reservoir capacity and preventing outages that ripple through the energy lifeline.[1184] During Hurricane Maria, extreme rainfall and sediment load nearly compromised

[37] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* [White paper]. American Society of Civil Engineers, Puerto Rico Section. Retrieved from https://www.reservoirsedimentation.com.

[1183] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias de la Represa Carraízo 2025: Manual de infraestructura*. San Juan, Puerto Rico.

[1184] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* [White paper]. American Society of Civil Engineers, Puerto Rico Section. Retrieved from https://www.reservoirsedimentation.com.

Carazo's gates, illustrating the dual hazard of structural failure and power loss.[1185] If a major dam breach occurred, electrical substations, pumping stations, and transmission corridors downstream would be inundated, cutting off power to hospitals, emergency shelters, and communications hubs. This scenario highlights the urgent need for investments in EWSs, redundant energy supplies, and integrated water-energy planning to safeguard Puerto Rico's lifelines against future disasters.

COMMUNICATIONS

A catastrophic dam failure in Puerto Rico would severely disrupt the Communications Lifeline, which is essential for coordinating emergency response and maintaining public safety. Communications systems, phones, cellular networks, and trunked radios are the backbone of emergency notifications and interagency coordination. The EAP for Represa Fajardo highlights that its primary communication channels rely on these technologies, supported by a directory of agencies and personnel with designated frequencies and contact numbers. However, the plan also reveals critical vulnerabilities. There is no automatic alert system for emergencies, and communication depends on manual notifications following a structured diagram of calls to municipal, state, and federal authorities. In a dam failure scenario, these manual processes could be overwhelmed by the urgency and scale of the event, delaying evacuation orders and life-saving instructions.[1186]

Flooding from a breach would likely damage terrestrial infrastructure, such as fiber-optic lines, cellular towers, and power systems, causing cascading failures across the island's communication network. For example, the Fajardo EAP anticipates that the Centro de Información de Emergencias (CIE) must maintain continuous contact with the Incident Commander and external agencies, yet this requires functioning landlines and mobile networks. If these systems fail, coordination between the dam operator, municipal emergency offices, and the Puerto Rico Emergency Management Bureau would be severely compromised. The Guajataca Dam incident in 2017 demonstrated how urgent communication needs can overwhelm existing systems, forcing reliance on ad hoc measures, such as radio relays and in-person notifications. Without redundant systems, such as satellite phones or automated mass alert platforms, Puerto Rico faces a high risk of communication breakdown during dam-related disasters, jeopardizing timely evacuations and resource deployment.

In summary, dam failure would not only inundate communities but also cripple the very channels needed to manage the crisis. Strengthening this lifeline requires integrating redundant communications technologies, expanding EWSs, and ensuring interoperability among agencies. These measures are critical for preventing delays in alerts and maintaining situational awareness during emergencies that threaten lives and infrastructure across Puerto Rico.

[1185] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* [White paper]. American Society of Civil Engineers, Puerto Rico Section. Retrieved from https://www.reservoirsedimentation.com.

[1186] Municipio Autónomo de Fajardo. (2025). *Plan de Acción para Emergencias: Represa Fajardo* [PAE]. Unpublished internal report.

TRANSPORTATION

A dam failure in Puerto Rico would severely compromise the Transportation Lifeline, which is essential for evacuation, emergency response, and delivery of critical resources. Flooding from a breach at high-hazard dams like Lago Regulador de Isabela would inundate primary access routes, such as PR-112,[1187] the only road connecting the facility to the municipality of Isabela. The EAP for Lago Regulador explicitly notes that accessibility is limited to this corridor, making it highly vulnerable during extreme events. If PR-112 is washed out or blocked, emergency vehicles, including ambulances and law enforcement, would face significant delays, isolating downstream communities and hindering evacuation efforts.

Transportation failures amplify risks across health, safety, and shelter systems. During a dam emergency, washed-out bridges and damaged roads would prevent heavy equipment and repair crews from reaching affected areas, delaying stabilization and increasing life-safety risks. Historical lessons from the Guajataca Dam incident illustrate these vulnerabilities: road closures forced reliance on airlifts and alternate routes, which prolonged response times and raised costs. To mitigate these risks, planning must integrate dam failure scenarios into transportation contingency strategies, including redundant routes, GIS-based evacuation mapping, and pre-positioned resources for rapid deployment.

WATER SYSTEMS

A hypothetical dam failure in Puerto Rico would have profound implications for FEMA's Water Systems Community Lifeline, which ensures access to potable water and sanitation. The 2020 ASCE white paper notes that Puerto Rico's water infrastructure is already fragile, with reservoirs like Carraízo and La Plata operating far above their firm yield and subject to severe rationing during droughts. Despite a $1 billion investment in the Superaqueduct, which was intended to eliminate rationing, water shortages persisted in 2015 and 2020 because the system continued overdrafting Carraízo instead of adopting a conjunctive use strategy that integrates reservoirs and groundwater wells.[1188] This vulnerability means that if a high-hazard dam such as Carraízo or La Plata were to fail, the immediate loss of storage would cripple the water supply for the San Juan metropolitan area, affecting nearly 500,000 residents and cascading into public health crises, sanitation failures, and economic disruption.[1189]

The Superaqueduct plays a critical role in Puerto Rico's water security because it interconnects multiple reservoirs, Dos Bocas and Caonillas, and was designed to provide redundancy during droughts. However, its effectiveness is limited by sedimentation and operational mismanagement. If a dam failure occurred upstream or in this system, the Superaqueduct's ability to compensate would be severely compromised, especially during island-wide droughts when all reservoirs are overstressed. The 2020 ASCE report warns that sedimentation at diversion dams and tunnels has already reduced the Superaqueduct's firm yield from

[1187] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias: Lago Regulador de Isabela*. Unpublished internal report.
[1188] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* (White Paper). American Society of Civil Engineers, Puerto Rico Section. Retrieved from https://www.reservoirsedimentation.com.
[1189] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* (White Paper). American Society of Civil Engineers, Puerto Rico Section. https://www.reservoirsedimentation.com.

100 MGD to 78 MGD, and restoring this capacity requires urgent rehabilitation of upstream diversions. Without these measures, a catastrophic failure at Carraízo or La Plata would not only inundate downstream communities but also eliminate the primary water source for filtration plants like Sergio Cuevas, leaving hospitals, shelters, and emergency operations without potable water.[1190]

EAPs, such as the one for Cidra Dam, underscore the life-safety dimension of this lifeline. The plan anticipates scenarios in which uncontrolled releases or structural failure could force mass evacuations across municipalities like Cidra, Aguas Buenas, and Bayamón. These areas depend on interconnected water systems, meaning that a failure would disrupt both local supply and regional transmission.[1191] The EAP stresses coordination with municipal and federal agencies to mitigate cascading impacts, but even with robust protocols, the physical loss of reservoir capacity would overwhelm contingency measures. This illustrates why FEMA's lifeline concept is vital: water systems are not isolated. They underpin health, energy, and shelter lifelines. A dam failure would therefore trigger a systemic crisis, reinforcing the ASCE recommendation for conjunctive use operations, sediment management, and Superaqueduct rehabilitation as urgent priorities to safeguard Puerto Rico's resilience against both drought and structural hazards.

Changes in Development

Recent development trends and emergency planning practices reveal that insufficient coordination among agencies and limited public access to critical information significantly increase vulnerability to dam failure hazards. When EAPs, operational manuals, and inundation maps are not consistently shared or updated, it becomes more difficult to analyze and model different risk scenarios, particularly in areas experiencing urban expansion near flood-prone zones. This lack of integration between land use planning and dam safety measures undermines proactive mitigation efforts and delays decision-making during emergencies. Furthermore, gaps in public awareness reduce the effectiveness of evacuation protocols because communities might not understand the severity of potential impacts or the actions required during a dam-related incident. Strengthening interagency coordination and improving transparency in risk communication are therefore essential to reduce exposure and enhance resilience against catastrophic dam failures.

LAND USE AND BUILT ENVIRONMENT CHANGES

Recent development trends and emergency planning practices in Puerto Rico have significantly influenced the vulnerability to dam failure hazards. Comprehensive land use plans, regulated by the Puerto Rico Planning Board (PRPB) and individual municipalities, determine the types of present and future development permitted in urban and rural areas. These plans are shaped through public participation and approval by elected officials, aiming to reflect local values and priorities for growth and hazard mitigation.

[1190] Morris, G. L. (2020, December 15). *Solving persistent water supply problems in Puerto Rico: Critical problems and actions* (White Paper). American Society of Civil Engineers, Puerto Rico Section. https://www.reservoirsedimentation.com.

[1191] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de acción para emergencias de la Represa Cidra 2025: Manual de infraestructura*. San Juan, Puerto Rico: Autoridad de Acueductos y Alcantarillados.

Urban expansion has been pronounced, with 11% of Puerto Rico's land area classified as urban or built up, and nearly half of this development occurring outside traditional urban centers. A high degree of urban sprawl is present on approximately 40% of the island, with new residential and commercial construction often extending into flood-prone zones and riverbanks. This expansion increases exposure to dam-related flooding, especially in low-lying areas where existing levees may be overtopped during extreme weather events.

Land use planning and zoning ordinances vary substantially by municipality, and while the PRPB provides overarching guidance, local governments may adopt their own comprehensive plans. Developed areas are concentrated in coastal plains and valleys and along major highways, while undeveloped regions include steep slopes, agricultural lands, and substantial wetland ecosystems. Despite these protections, urban development continues to encroach on areas at risk of dam failure, often without adequate upgrades to dam infrastructure or integration of hazard mitigation measures.

Aging infrastructure and deferred maintenance further compound vulnerability. Many dams in Puerto Rico are over 50 years old, and funding for seismic and hydraulic studies remains limited. Sedimentation has reduced reservoir capacity in some cases by up to 60%, increasing the likelihood of overtopping during extreme rainfall events. Urban runoff associated with new development exacerbates this risk, as impervious surfaces accelerate stormwater flows into reservoirs and downstream communities.

Emergency preparedness gaps persist, particularly in rapidly growing urban areas. Although municipalities are responsible for updating emergency plans and evacuation routes, coordination between agencies and public access to critical information, such as inundation maps and operational manuals, remains inconsistent. This lack of integration between land use planning and dam safety measures undermines proactive mitigation efforts and delays decision-making during emergencies.

In summary, changes in Puerto Rico's built environment—driven by urban expansion, aging infrastructure, inadequate land use planning, sedimentation, and emergency preparedness gaps—have collectively increased vulnerability to dam failure. Strengthening interagency coordination, updating comprehensive land use plans, and improving transparency in risk communication are essential steps to reduce exposure and enhance resilience against catastrophic dam failures.[1192]

For example, the Represa Las Curías, located just four miles south of San Juan in a densely populated watershed, illustrates how urban expansion into flood-prone areas amplifies risk. The surrounding Río Piedras corridor is characterized by high traffic and residential density, meaning that any failure could cause severe downstream flooding and disrupt critical lifelines. Despite these vulnerabilities, the dam currently lacks an audible or visible emergency alert system for downstream populations, relying instead on manual notifications through the CIE and municipal agencies.[1193]

[1192] Finster, M., Hemphill, M., Marsh, K., Miles, P., & Freeman, C. (n.d.). *Dam Risks in Disasters: A Puerto Rico Case Study for Hurricane Fiona*. Argonne National Laboratory; Federal Emergency Management Agency; Freese and Nichols, Inc. https://www.weather.gov/sju/fiona2022.

[1193] Autoridad de Acueductos y Alcantarillados. (2025). *Plan de Acción para Emergencias de la Represa Las Curías*. San Juan, Puerto Rico: Autoridad de Acueductos y Alcantarillados.

PROJECTED FUTURE GROWTH AND REDEVELOPMENT

POPULATION CHANGES

The municipalities included in Table 170 were selected based on three criteria: (1) direct downstream location relative to a dam classified as High Hazard Potential by the U.S. Army Corps of Engineers (USACE); (2) significant population exposure in the area that would be affected in the event of dam failure or uncontrolled release; and (3) documented vulnerability to flood events based on historical records and local infrastructure conditions. Applying these criteria, five municipalities were identified—Orocovis, Manatí, Barceloneta, Utuado, and Bayamón. Table 170 summarizes each municipality's associated dam infrastructure, hazard classification, recent population trends, and primary vulnerability factors. Population trends were assessed using U.S. Census Bureau annual estimates for 2020–2024; municipalities with a consistent net population decrease are classified as "Declining," while those showing a marginal decrease are classified as "Slight decline."

Table 170: Dam Influence by Municipality[1]

Municipality	Associated Dam(s)	Hazard Classification[3,4]	Population Trend (2020–2024)	Key Vulnerability Factor
Utuado	Lago Caonillas, Lago Guajataca	High Hazard Potential	Declining	Steep mountainous terrain; limited evacuation routes; severe infrastructure damage from prior hurricane events[5,6]
Manatí	Río Grande de Manatí system	High Hazard Potential	Slight decline	Low-lying coastal plain; documented history of flash flooding; proximity to river delta increases inundation risk
Barceloneta	Río Grande de Manatí system	High Hazard Potential	Slight decline	Critical pharmaceutical and industrial infrastructure; low-lying terrain highly susceptible to flood inundation[7]
Orocovis	Lago de Matrullas	High Hazard Potential	Declining	High-elevation municipality with limited road access; elevated poverty rate reduces community recovery capacity
Bayamón	Lago Carraízo (Loíza Reservoir)	High Hazard Potential	Slight decline	Dense urban population; concentration of critical public services and infrastructure compounds flood impact

Mitigation Success Stories

EARLY WARNING SYSTEMS FOR HIGH-HAZARD DAMS

Puerto Rico has made significant progress in deploying EWSs for high-hazard dams, a priority that emerged after the devastating lessons of Hurricanes Maria and Fiona. These systems are designed to provide real-time monitoring and rapid alerts, ensuring that communities downstream have the time needed to respond during emergencies. The initiative includes installing automated sensors that track water levels, rainfall, and dam integrity and feeding data directly into municipal emergency management platforms. This integration allows authorities to issue timely alerts and initiate evacuations when thresholds are exceeded. Complementing these technological upgrades, EAPs have been developed for high-risk dams, such as Guajataca and Carraízo, outlining clear protocols for coordination and response.[1194]

The importance of EWSs cannot be overstated. By enabling continuous monitoring and automated notifications, these systems enhance community preparedness and significantly reduce response times during dam-related incidents. They also support data-driven decision making for emergency managers and dam operators, ensuring that actions are based on accurate, real-time information. Recent deployments have already demonstrated their value, improving situational awareness during extreme weather events and reinforcing Puerto Rico's resilience against future disasters.

PATILLAS DAM SEISMIC RESILIENCE PROJECT

Patillas Dam, built in 1913 and serving over 100,000 residents in southeastern Puerto Rico, is undergoing a major seismic resilience upgrade funded by FEMA's Hazard Mitigation Grant Program (HMGP).[1195]

Key Highlights:

- In 2021, FEMA allocated $2.6 million for the first phase, which includes engineering analysis, soil sampling, and topographic studies.
- The total project cost is estimated at $558 million, making it one of the largest dam mitigation investments in Puerto Rico's history.
- The project aims to mitigate structural vulnerabilities, restore reservoir capacity, and ensure continued water supply, agricultural irrigation, and power generation.
- PREPA and The Central Office for Reconstruction, Recovery and Resiliency (COR3) are leading the project in collaboration with FEMA.

[1194] Federal Emergency Management Agency. (2024). *FEMA approves construction funds for 17 Early Warning Systems*. Puerto Rico: FEMA.
[1195] Federal Emergency Management Agency. "FEMA Assigns Over $2.6 Million for the Patillas Dam." July 13, 2021. https://www.fema.gov/press-release/20210713/fema-assigns-over-26-million-patillas-dam.

LA PLATA RESERVOIR SAFETY ENHANCEMENT PROJECT

In May 2025, a major infrastructure and public safety initiative was launched to enhance the resilience of the La Plata Reservoir in Puerto Rico. Funded by FEMA's 404 Risk Mitigation Program, the project is designed to improve dam safety, emergency preparedness, and community protection in the face of extreme weather events. The total investment is estimated at $36 million, with additional support from the Community Development Block Grant Mitigation (CDBG-MIT) program.[1196]

Key Insights:

- Phased Implementation:
  - Phase 1 includes planning, design, and environmental assessments—fully funded by FEMA.
  - Phase 2 will focus on construction and equipment procurement, supported by CDBG-MIT.
- Early Warning System Deployment:
  - The project includes installation of structural monitoring instruments and community alert sirens for La Plata and other reservoirs.
  - These systems aim to detect dam integrity issues and provide real-time alerts to downstream populations.

[1196] Citizen Portal Inc. (2025, May 8). "*FEMA funds $36M project for La Plata reservoir safety enhancements in Puerto Rico*," https://citizenportal.ai/articles/6565832/international/puerto-rico/legislative/committees/house/house-of-representatives/article?q=FEMA%20funds%20%2436M%20project%20for%20La%20Plata%20reservoir%20safety%20enhancements%20in%20Puerto%20Rico.

Appendix C: Hazardous Materials

Appendix C: Hazardous Materials

The effective management of hazardous materials is critical to ensuring public safety, environmental protection, and operational continuity. To systematically assess and categorize potential threats, the ***CBRNE classification system—which stands for Chemical, Biological, Radiological, Nuclear, and Explosive***—provides a comprehensive framework for identifying and analyzing hazards. Each category represents distinct risks that require specialized detection, containment, and mitigation strategies. This analysis aims to evaluate the characteristics, potential impacts, and response considerations for materials classified under the CBRNE system. By understanding these classifications, organizations can develop robust emergency response plans, enhance situational awareness, and reduce the likelihood of catastrophic incidents.

Hazardous Materials Definition

Hazardous materials (often abbreviated as ***HazMat***) are substances that pose a risk to health, safety, property, or the environment due to their chemical, physical, or biological properties. These materials can be toxic, flammable, corrosive, reactive, radioactive, or infectious. They require special handling, storage, and disposal procedures to prevent harm during transportation, use, or accidental release.

CBRNE Hazard Definition

CBRNE is a classification system used to identify and categorize high-risk hazards that can result from intentional acts (such as terrorism) or accidental incidents. Each component represents a distinct type of threat.[1197]

[1197] National Science and Technology Council, Committee on Homeland and National Security, Subcommittee on Standards. (2011). A national strategy for CBRNE standards. Executive Office of the President. https://www.dhs.gov/sites/default/files/publications/chns_cbrne_standards_final_24_aug_11.pdf (or direct PDF URL used by DHS/National Science and Technology Council).

CBRNE HAZARD CLASSIFICATIONS[1198] [1199] [1200] [1201] [1202]

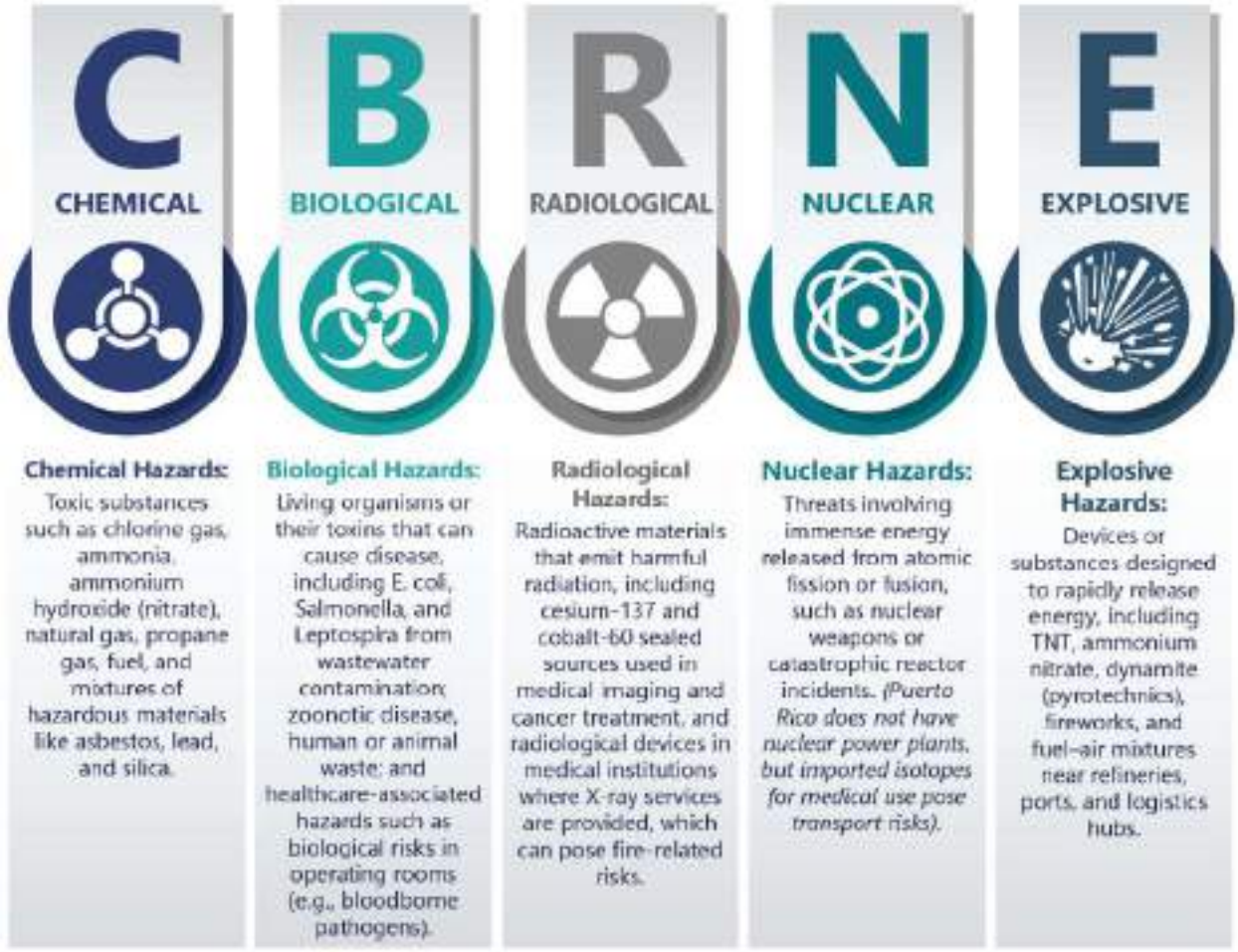


Figure 319: CBRNE Classifications

In Puerto Rico, these hazards arise from routine industrial operations, such as fuel storage, water and wastewater treatment, medical imaging, and industrial processing, as well as from natural disasters, such as hurricanes, flooding, and earthquakes, which can damage storage tanks, pipelines, ports, and medical

[1198] Puerto Rico Emergency Management Bureau. (2024). CBRNE hazard exposure and risk mapping summary. Government of Puerto Rico.
[1199] Centers for Disease Control and Prevention. (2018). Public Health Preparedness Capabilities: National Standards.
[1200] U.S. Nuclear Regulatory Commission. (2023). Radiological Material Licensing and Oversight for Medical Uses.
[1201] U.S. Nuclear Regulatory Commission. (2023). Radiological Material Licensing and Oversight for Medical Uses.
[1202] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). Explosives Incident and Fire Investigation Overview – Puerto Rico.

facilities, triggering secondary releases.[1203] [1204] [1205] Coastal industrial corridors, dense urban medical hubs, and seismic zones create conditions where a single incident can cascade across several Federal Emergency Management Agency (FEMA) Community Lifelines, such as Energy, Water Systems, Transportation, Health and Medical, and Safety and Security. This framework aligns with FEMA's Community Lifelines concept and national mitigation guidance.[1206] [1207] Figure 320 shows the primary risks in Puerto Rico.

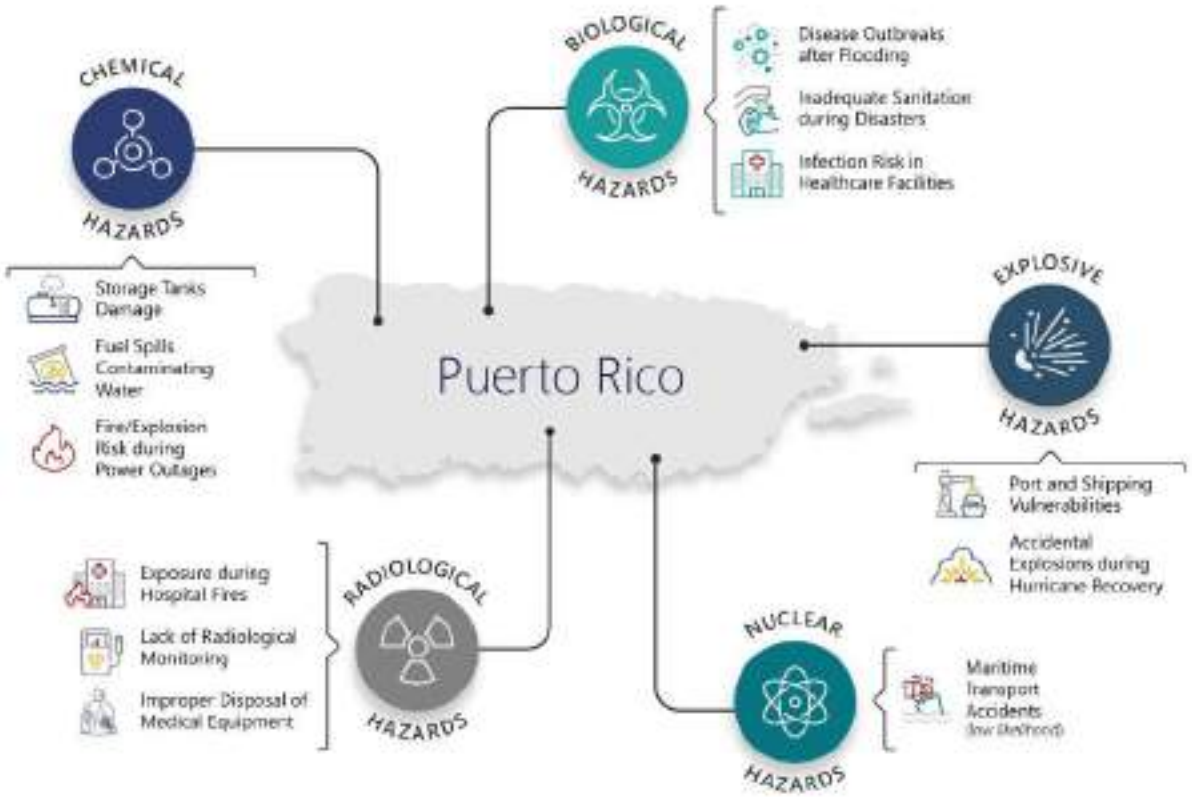


Figure 320: CBRNE Hazard Categories – Primary Risks in Puerto Rico

[1203] Puerto Rico Emergency Management Bureau. (2024). CBRNE preparedness and operations manual. Government of Puerto Rico.
[1204] Puerto Rico Emergency Management Bureau. (2021). Puerto Rico All-Hazards Plan: Base plan. Government of Puerto Rico.
[1205] U.S. Department of Energy, Office of Electricity. (2024). Energy infrastructure and industrial safety in Puerto Rico [Internal analytical summary]. U.S. Department of Energy.
[1206] Federal Emergency Management Agency. (2023). Community Lifelines Implementation Toolkit (Version 2.1). U.S. Department of Homeland Security.
[1207] Federal Emergency Management Agency. (2023). Hazard Mitigation Assistance Program and Policy Guide. U.S. Department of Homeland Security.

INTENT-AGNOSTIC PROTOCOLS

Puerto Rico's CBRNE protocols are intent-agnostic; they follow FEMA's National Incident Management System[1208] and National Response Framework,[1209] ensuring consistent command and coordination regardless of incident cause. They are designed to function the same way whether an incident is triggered by natural hazards, accidents, or intentional acts. These principles rely on a common, all-hazards framework so that incident command, communications, protective actions, and coordination mechanisms do not change based on motive.

At the territorial level, the Puerto Rico Emergency Management Bureau (PREMB) applies these principles through the Puerto Rico All-Hazards Plan and related emergency operations plans, which translate national doctrine into Puerto Rico's hazard environment and governance structure.[1210] [1211] For this hazard profile, the emphasis is on how those intent-agnostic principles support risk-informed planning and mitigation—for example, by standardizing hazard identification, protective action decision-making, and information sharing across agencies before an incident occurs—rather than on detailed response procedures.

PUERTO RICO HAZARD CONTEXT AND HIGH-RISK LOCATIONS

Puerto Rico's geography, coastal industrial corridors, and dense medical infrastructure create clusters of CBRNE-relevant hazards in specific regions of the island. Table 171 summarizes representative hazard types, common sources, potential impacts, and examples of high-risk locations based on PREMB's CBRNE hazard exposure summary,[1212] the Department of Energy's (DOE's) industrial safety analysis,[1213] and the Environmental Protection Agency's (EPA's) Risk Management Program (RMP) facility inventory.[1214] Figure 321 is a map of high-risk locations in Puerto Rico.

[1208] Federal Emergency Management Agency. (2017). National Incident Management System (3rd ed.). U.S. Department of Homeland Security.
[1209] Federal Emergency Management Agency. (2019). National Response Framework (4th ed.). U.S. Department of Homeland Security.
[1210] Puerto Rico Emergency Management Bureau. (2021). Puerto Rico All-Hazards Plan: Base plan. Government of Puerto Rico.
[1211] Puerto Rico Emergency Management Bureau. (2024). Puerto Rico All-Hazards Plan – Emergency Operations Plan (revised edition). Government of Puerto Rico.
[1212] Puerto Rico Emergency Management Bureau. (2024). CBRNE hazard exposure and risk mapping summary. Government of Puerto Rico.
[1213] U.S. Department of Energy, Office of Electricity. (2024). Energy infrastructure and industrial safety in Puerto Rico [Internal analytical summary]. U.S. Department of Energy.
[1214] Environmental Protection Agency. (2023). Risk Management Program (RMP) facility data – Puerto Rico [Data set]. U.S. Environmental Protection Agency.

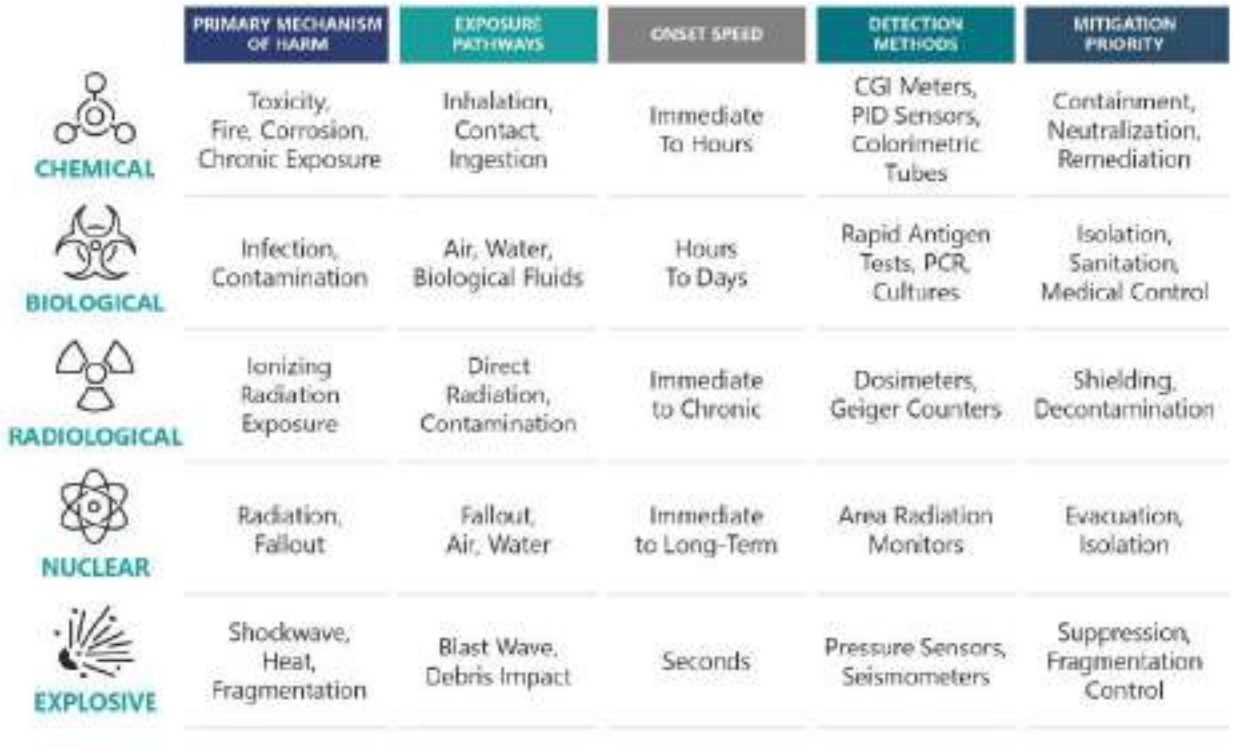
Table 171: Representative CBRNE Hazard Types, Sources, Potential Impacts, and High-Risk Locations

Hazard Category	Hazard Type	Common Sources	Potential Impacts	High-Risk Locations
Chemical	Natural Gas (Methane/ liquefied natural gas [LNG])	LNG terminals, pipelines, power plants	Fire, explosion, cryogenic burns	Peñuelas, San Juan, Guayanilla
Chemical	Ammonia (Anhydrous/Aqueous)	Refrigeration systems, wastewater plants	Toxic inhalation, vapor migration	San Juan, Bayamón, Arecibo
Chemical	Propane Gas	Residential/commercial tanks	Fire, explosion, asphyxiation	Island-wide, rural areas
Chemical	Fuel (Gasoline, Diesel, Jet)	Refineries, terminals, transport	Fire, explosion, contamination	Bayamón, Yabucoa, Guayanilla
Biological	Human/Animal Waste	Wastewater, floodwaters	Infectious disease, contamination	Flood-prone coastal regions
Biological	Biological (Hospitals)	Surgical suites, biomedical waste	Infection, cross-contamination	San Juan Metro, Mayagüez, Ponce
Explosive	Dynamite/Pyrotechnics	Construction, storage	Fire, detonation, debris impact	Vega Baja, Carolina, ports
Chemical	Chlorine/Ammonium Hydroxide	Water treatment, sanitation	Toxic vapor, corrosion	Puerto Rico Aqueduct and Sewer Authority (PRASA) sites, industrial zones
Chemical	Asbestos/Lead/Silica	Demolition, debris	Chronic respiratory illness	Urban redevelopment zones
Radiological	Radiological Devices (X-ray)	Hospitals, labs	Radiation exposure	San Juan, Ponce
Nuclear	Nuclear/Radiological Transport	Ports, airports	Contamination, exposure	San Juan, Mayagüez, Ponce ports

Figure 321: High-Risk Locations, Showing the Hazard Category and Hazard Type

CROSS-HAZARD COMPARISON CHART

The Cross-Hazard Comparison Chart (Figure 322) provides a standardized reference for comparing CBRNE hazards across key dimensions: primary mechanism of harm, exposure pathways, onset speed, detection methods, and mitigation priorities. Adapted from FEMA's hazardous materials, CBRNE response guidance,[1215] and the Occupational Safety and Health Administration's (OSHA's) Hazardous Waste Operations and Emergency Response (HAZWOPER) standard,[1216] it supports emergency planners, facility managers, and first responders—such as those in Puerto Rico—in prioritizing protective actions across multiple hazard types.



	PRIMARY MECHANISM OF HARM	EXPOSURE PATHWAYS	ONSET SPEED	DETECTION METHODS	MITIGATION PRIORITY
CHEMICAL	Toxicity, Fire, Corrosion, Chronic Exposure	Inhalation, Contact, Ingestion	Immediate To Hours	CGI Meters, PID Sensors, Colorimetric Tubes	Containment, Neutralization, Remediation
BIOLOGICAL	Infection, Contamination	Air, Water, Biological Fluids	Hours To Days	Rapid Antigen Tests, PCR, Cultures	Isolation, Sanitation, Medical Control
RADIOLOGICAL	Ionizing Radiation Exposure	Direct Radiation, Contamination	Immediate to Chronic	Dosimeters, Geiger Counters	Shielding, Decontamination
NUCLEAR	Radiation, Fallout	Fallout, Air, Water	Immediate to Long-Term	Area Radiation Monitors	Evacuation, Isolation
EXPLOSIVE	Shockwave, Heat, Fragmentation	Blast Wave, Debris Impact	Seconds	Pressure Sensors, Seismometers	Suppression, Fragmentation Control

Figure 322: Cross-Hazard Comparison of CBRNE Hazard Characteristics

PLACARDING AND LABELING REQUIREMENTS

Placarding and labeling requirements for CBRNE-related materials in Puerto Rico follow federal and national consensus standards for transportation, workplace hazard communication, and emergency response markings. Table 172 summarizes representative U.S. Department of Transportation (DOT) placards for selected hazardous materials commonly present in Puerto Rico, along with typical National Fire Protection Association (NFPA) 704 hazard ratings and placarding requirements that align with the Pipeline and

[1215] Federal Emergency Management Agency. (2013). *IS-5.A: An introduction to hazardous materials*. Emergency Management Institute.
[1216] Occupational Safety and Health Administration. (2024). *Hazard communication standard* (29 C.F.R. § 1910.1200). U.S. Department of Labor.

Hazardous Materials Safety Administration's (PHMSA's) Hazardous Materials Regulations (49 CFR Part 172, 2023), OSHA's Hazard Communication Standard (29 CFR §1910.1200, 2024), and NFPA 704 (2022).

Table 172: Representative DOT Placards, NFPA 704 Ratings, and Labeling Requirements for Selected Hazardous Materials

Hazard Type	DOT Placard/ Marking	NFPA 704 Diamond (Typical Ratings)*	Labeling Requirement Reference
LNG (UN1972)	Division 2.1 – Flammable Gas placard	Health 1/ Flammability 4/ Reactivity 0	49 CFR 172.532 (Flammable Gas placard)
Ammonia, anhydrous (UN1005)	Division 2.2 – Non-flammable Gas with Inhalation Hazard marking	Health 3/ Flammability 1/ Reactivity 0	49 CFR 172.528, 49 CFR 172.540 (Inhalation hazard/poison gas markings)
Propane/Liquefied Petroleum Gas (LPG) (UN1978)	Division 2.1 – Flammable Gas placard	Health 1/ Flammability 4/ Reactivity 0	49 CFR 172.532 (Flammable Gas placard)
Diesel/Fuel Oil (NA1993/UN1202)	Class 3 – Combustible Liquid (Combustible placard)	Health 2/ Flammability 3/ Reactivity 0	49 CFR 172.544 (Combustible placard)
Infectious Substances (UN2814/2900/3373/3291)	Class 6.2 – Infectious Substance label/mark	Health 3/ Flammability 0/ Reactivity 0	49 CFR 172.432 (Infectious Substance label); CDC *Biosafety in Microbiological and Biomedical Laboratories (BMBL)*
Chlorine (UN1017)	Division 2.3 – Poison Gas (with Inhalation Hazard marking)	Health 4/ Flammability 0/ Reactivity 1	49 CFR 172.540 (Poison Gas/Inhalation Hazard)
Explosives (Dynamite, Fireworks)	Class 1.1–1.4 Explosives placards (e.g., 1.1D, 1.3G, 1.4G)	Typically, very high flammability and reactivity (e.g., Flammability 4/ Reactivity 3–4; Health rating varies)	49 CFR 172.522–172.525 (Explosives placards); ATF 27 CFR Part 555; NFPA 495
Radiological Materials	Class 7 – RADIOACTIVE placard (trefoil symbol)	Varies by chemical form; NFPA 704 indicates chemical hazard, while radiological hazard is indicated by the trefoil symbol	49 CFR Part 172, Subpart F and Appendix B; Nuclear Regulatory Commission (NRC) posting requirements 10 CFR 20.1902, 20.1904

Hazard Type	DOT Placard/ Marking	NFPA 704 Diamond (Typical Ratings)*	Labeling Requirement Reference
Asbestos/Lead/Silica	Generally, no DOT placard for most in-place materials (regulated substances)	Health 2–3/ Flammability 0/ Reactivity 0 (chronic health hazard)	OSHA 29 CFR 1910.1001 (Asbestos); 29 CFR 1926.62 (Lead); related OSHA standards

RESPONSIBLE AND REGULATORY AGENCIES

CBRNE risk management in Puerto Rico relies on Puerto Rico agencies with primary operational authority, supported by federal regulators and technical partners. The agencies listed below have key roles in planning, regulating, and coordinating mitigation, preparedness, response, and recovery for CBRNE-related hazards. This list focuses on CBRNE-relevant responsibilities and is not exhaustive.

PUERTO RICO AGENCIES

- ***Puerto Rico Emergency Management Bureau (PREMB):*** Leads territorial coordination for CBRNE incidents and all-hazards emergency management, including implementation of the Puerto Rico All-Hazards Plan and Emergency Operations Plan.[1217]
- ***Puerto Rico Department of Health (DOH):*** Oversees public health preparedness, epidemiology, and medical system readiness for biological, radiological, and other health-related emergencies; operates public health alerting and coordination platforms.[1218]
- ***Puerto Rico Aqueduct and Sewer Authority (PRASA):*** Manages public drinking water and wastewater systems, including treatment, disinfection, and chemical handling that can influence CBRNE-related water and wastewater risks.[1219]
- ***Department of Natural and Environmental Resources (DNER/DRNA):*** Protects and manages natural and environmental resources, including oversight of contamination, remediation, and environmental impacts associated with hazardous substances.[1220]

[1217] Puerto Rico Emergency Management Bureau. (2021). *Puerto Rico All-Hazards Plan: Base plan*. Government of Puerto Rico.
[1218] Puerto Rico Department of Health. (2025). *Puerto Rico Health Alert Network and emergency preparedness activities*. Puerto Rico Department of Health.
[1219] Puerto Rico Aqueduct and Sewer Authority. (2025). *Drinking water and wastewater services in Puerto Rico: Regulatory and operational overview*. Puerto Rico Aqueduct and Sewer Authority.
[1220] Puerto Rico Department of Natural and Environmental Resources. (2025). *Mission and functions of the Department of Natural and Environmental Resources*. Government of Puerto Rico.

FEDERAL PARTNERS

- ***FEMA Region 2:*** Coordinates federal emergency management support for Puerto Rico, including hazard mitigation, recovery, and technical assistance for CBRNE-related planning and projects.[1221]
- ***Environmental Protection Agency (EPA):*** Provides authority and technical support for hazardous substance releases and contaminated sites through programs such as Superfund and CBRNE emergency response guidance.[1222]
- ***Occupational Safety and Health Administration (OSHA):*** Establishes worker protection standards and guidance for hazardous materials, including CBRNE-related personal protective equipment and emergency response operations.[1223]
- ***Pipeline and Hazardous Materials Safety Administration (PHMSA):*** Regulates the safe transportation of hazardous materials and pipelines, supporting prevention and preparedness for chemical and fuel incidents affecting Puerto Rico.[1224]
- ***U.S. Department of Energy (DOE):*** Supports energy system reliability and emergency actions for the electric grid and fuel supply, including emergency orders and technical assistance relevant to CBRNE-related energy infrastructure risks.[1225]
- ***U.S. Coast Guard (USCG):*** Leads federal marine environmental response for oil and hazardous substance spills in navigable waters, coordinating preparedness and response for maritime CBRNE incidents.[1226]
- ***Centers for Disease Control and Prevention (CDC/*National Institute for Occupational Safety and Health*):*** Provides public health emergency preparedness and occupational safety guidance for chemical, biological, radiological, and natural disasters that affect response and recovery workers and the public.[1227]
- ***Nuclear Regulatory Commission (NRC):*** Licenses and regulates civilian uses of radioactive materials, including medical and industrial sources relevant to radiological and nuclear hazards in Puerto Rico.[1228]

[1221] Federal Emergency Management Agency. (2025). FEMA Region 2 overview: New Jersey, New York, Puerto Rico, and the U.S. Virgin Islands. U.S. Department of Homeland Security.
[1222] Environmental Protection Agency. (2023). Risk Management Program (RMP) facility data – Puerto Rico [Data set]. U.S. Environmental Protection Agency.
[1223] Occupational Safety and Health Administration. (2024). *Hazard communication standard* (29 C.F.R. § 1910.1200). U.S. Department of Labor.
[1224] Pipeline and Hazardous Materials Safety Administration. (2025). *Office of Hazardous Materials Safety: Hazardous materials transportation safety program*. U.S. Department of Transportation.
[1225] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1226] U.S. Coast Guard. (2023). *Marine Environmental Response and Preparedness Manual*. U.S. Department of Homeland Security.
[1227] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.
[1228] U.S. Nuclear Regulatory Commission. (2023). *Radiological material licensing and facility oversight report – Puerto Rico*. U.S. Nuclear Regulatory Commission.

- ***Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF):*** Regulates lawful commerce, storage, and investigation of explosives and related materials, supporting safety and security for explosive hazards.[1229]

These agencies work together—through formal plans, regulatory frameworks, and operational agreements—to provide the governance backbone for the CBRNE hazard mitigation strategies described in this hazard profile.

Location

This section identifies locations in Puerto Rico where CBRNE-related hazards are most likely to occur, based on historical incidents, facility inventories, and multi-hazard GIS data. The analysis draws on FEMA's National Risk Index and flood hazard datasets, PREMB all-hazards and industrial hazard planning data, and EPA RMP facility records for regulated sites in Puerto Rico.

High-priority CBRNE locations typically involve industrial or medical facilities situated within floodplains, coastal storm surge zones, or seismic corridors—particularly along Puerto Rico's coastal industrial belts and dense urban corridors.

GEOGRAPHIC HAZARD ZONES

Puerto Rico's geography creates distinct CBRNE hazard zones relevant to mitigation planning:

- Industrial Coastal Corridors (North and South)

  Refineries, fuel import terminals, power plants, and bulk chemical storage facilities—such as those in Figure 323—are concentrated along Peñuelas, Guayanilla, Yabucoa, Bayamón, Toa Baja, and other coastal municipios. These areas face elevated risk of chemical and explosive releases during extreme events due to exposure to storm surge and riverine flooding.[1230]

- Mountainous Central Interior

  Steep slopes and heavy rainfall increase landslide and runoff potential, which can mobilize wastewater, agricultural waste, and other contaminants—raising biological hazard risks for downstream communities and water systems.[1231]

[1229] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). *Explosives hazard management and site risk data – Puerto Rico*. U.S. Department of Justice.
[1230] Puerto Rico Emergency Management Bureau. (2024). *Puerto Rico all-hazards and industrial hazard planning atlas*. Government of Puerto Rico.
[1231] Puerto Rico Emergency Management Bureau. (2024). *Puerto Rico all-hazards and industrial hazard planning atlas*. Government of Puerto Rico.

Figure 323: Puerto Rico's Coastal Industrial Corridor[1232]

- Urban Metropolitan Areas

  The San Juan–Bayamón–Carolina corridor and other hubs (e.g., Ponce, Mayagüez) combine high population density, major transportation nodes, and clusters of hospitals and laboratories (see Figure 324). These factors concentrate biological and radiological risks and amplify the consequences of CBRNE incidents that disrupt energy, water, and transportation lifelines.[1233] [1234] [1235]

[1232] The photo shows large fuel storage tanks and refinery infrastructure located adjacent to residential communities and near transportation routes along the shoreline.
[1233] Federal Emergency Management Agency. (2025). *National Risk Index – Puerto Rico data and documentation*. U.S. Department of Homeland Security.
[1234] Puerto Rico Emergency Management Bureau. (2024). *Puerto Rico all-hazards and industrial hazard planning atlas*. Government of Puerto Rico.
[1235] U.S. Nuclear Regulatory Commission. (2023). Radiological material licensing and oversight for medical uses (U.S. Nuclear Regulatory Commission Regulation series guidance).

Figure 324: Aerial Photo of the San Juan Metropolitan Area[1236]

These hazard zones align with FEMA's National Risk Index characterization of Puerto Rico's coastal and urban vulnerabilities and PREMB's all-hazards and industrial hazard mapping.[1237] National Oceanic and Atmospheric Administration (NOAA) coastal flood and storm surge products and U.S. Geological Survey (USGS) seismic hazard data provide additional context for where CBRNE facilities and lifelines intersect with flood- and earthquake-prone areas.[1238] [1239]

[1236] The photo shows dense urban development, major highways, and port facilities along the coastline. A large public building (likely a hospital or medical center) is visible in the foreground, supporting the text about metro areas concentrating population, hospitals, labs, and transport hubs.
[1237] Federal Emergency Management Agency. (2025). *National Risk Index – Puerto Rico data and documentation*. U.S. Department of Homeland Security.
[1238] National Oceanic and Atmospheric Administration. (2024). *Coastal flood and storm surge hazard tools for Puerto Rico*. National Ocean Service.
[1239] U.S. Geological Survey. (2024). *Puerto Rico seismic hazard and design ground motion resources*. U.S. Geological Survey.

CBRNE HAZARD LOCATION PROFILES

This subsection summarizes locations where each CBRNE hazard type is most likely to occur in Puerto Rico, based on facility databases, recent incident history, and PREMB's CBRNE hazard mapping.[1240] [1241] Profiles emphasize locations where industrial, medical, and energy facilities intersect with flood, storm surge, and seismic exposure.[1242] [1243] [1244]

CHEMICAL HAZARDS

Primary Locations

- Southern Coastal Corridor – Peñuelas, Guayanilla, Yauco

  Cluster of LNG storage, petrochemical refineries, and ammonia distribution terminals in low-lying coastal zones with recurring flood and storm surge exposure.[1245] [1246]

- Northern Industrial Corridor – Bayamón, Toa Baja, Arecibo

  High concentration of industrial plants and wastewater facilities handling chlorine and other corrosive substances, many within FEMA 100-year flood zones.[1247] [1248]

- Eastern Energy and Port Corridor – Yabucoa, Fajardo

  Fuel import terminals and port facilities handling hazardous materials along exposed shoreline and estuarine areas.[1249] [1250]

[1240] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1241] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1242] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1243] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1244] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1245] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1246] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1247] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1248] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1249] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1250] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.

Chemical hazard clusters closely track EPA RMP facility locations and DOE industrial hazard assessments. Many sites overlie FEMA flood zones or storm surge areas, elevating the risk of flood-triggered spills and plume releases (see Figure 325).[1251] [1252] [1253]

[1251] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1252] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1253] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.

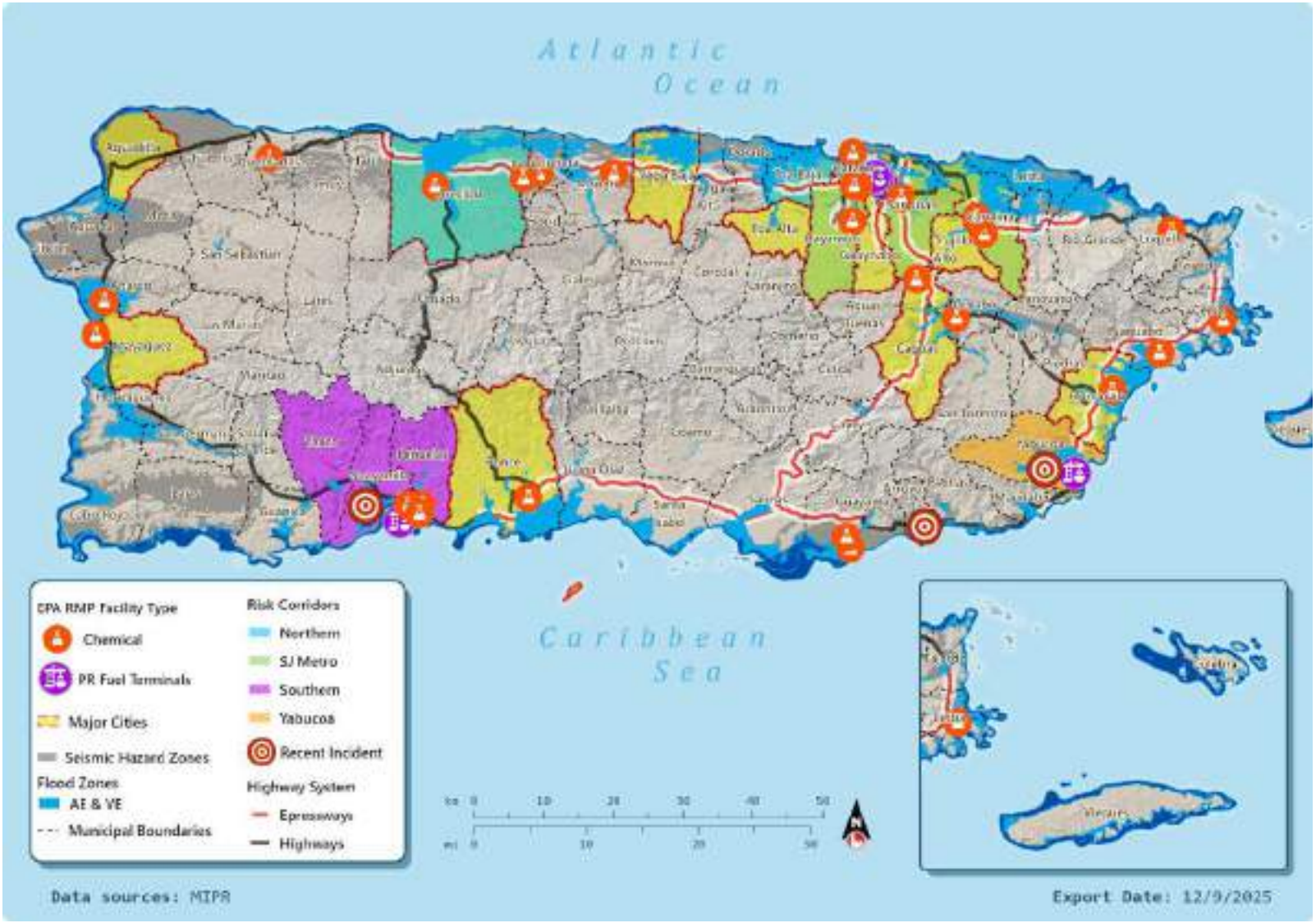


Figure 325: Density and Flood Exposure of Hazardous Chemical Facilities

Chemical hazard clusters closely track EPA RMP facility locations and DOE industrial hazard assessments. Many sites overlie FEMA flood zones or storm surge areas, elevating the risk of flood-triggered spills and plume releases.[1254] [1255] [1256]

BIOLOGICAL HAZARDS

Primary Locations

- Urban Medical Hubs – San Juan, Carolina, Bayamón

  Regional clusters of hospitals, laboratories, and biomedical waste streams requiring controlled handling and disposal.[1257] [1258]

- Coastal and Flood-Prone Zones – Ponce, Mayagüez, Arecibo

  Areas with documented wastewater overflows, animal waste contamination, and combined sewer/stormwater issues during hurricanes and flood events.[1259] [1260]

- Agricultural Basins – Lajas Valley, Adjuntas

  Agricultural regions with potential for zoonotic disease and agricultural waste runoff affecting downstream water quality. [1261] [1262]

Biological hazards are strongly linked to wastewater infrastructure, health facilities, and low-lying floodplains, where recurring storms and aging systems increase the probability of sewage releases and contamination of drinking water or recreation areas (see Figure 326). [1263] [1264]

[1254] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1255] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1256] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1257] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1258] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.
[1259] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1260] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.
[1261] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1262] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.
[1263] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1264] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.

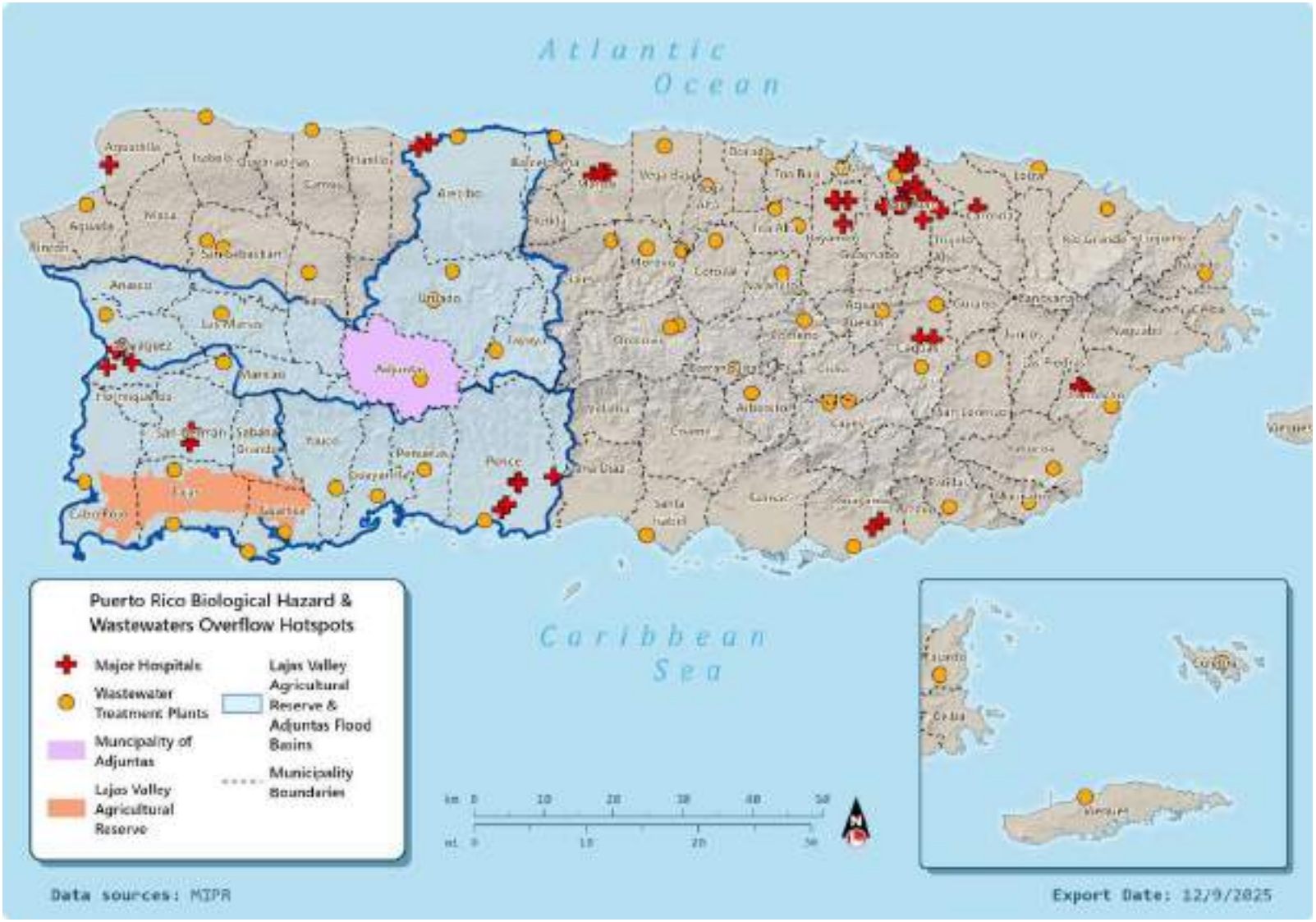


Figure 326: Map of Biological Hazards in Puerto Rico

Biological hazards are strongly linked to wastewater infrastructure, health facilities, and low-lying floodplains, where recurring storms and aging systems increase the probability of sewage releases and contamination of drinking water or recreation areas. [1265] [1266]

RADIOLOGICAL AND NUCLEAR HAZARDS

Primary Locations

- San Juan Metropolitan Area

  Diagnostic imaging departments, cancer treatment centers, and other medical facilities using sealed radiological sources represent the island's primary radiological exposure potential.[1267]

- Bayamón

  Storage and handling of medical isotopes and other radiological materials used for imaging and therapy.[9]

Radiological risk is localized and predominantly associated with medical use and transport of sealed sources, rather than power generation (see Figure 327. Routine NRC oversight and DOH radiological health programs set licensing and safety requirements, but facility density in San Juan–Bayamón increases the consequences of an incident.[1268]

[1265] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1266] Centers for Disease Control and Prevention. (2023). *Public health and sanitation hazard mapping – Puerto Rico*. U.S. Department of Health and Human Services.
[1267] U.S. Nuclear Regulatory Commission. (2023). *Radiological material licensing and facility oversight report – Puerto Rico*. U.S. Nuclear Regulatory Commission.
[1268] U.S. Nuclear Regulatory Commission. (2023). *Radiological material licensing and facility oversight report – Puerto Rico*. U.S. Nuclear Regulatory Commission.

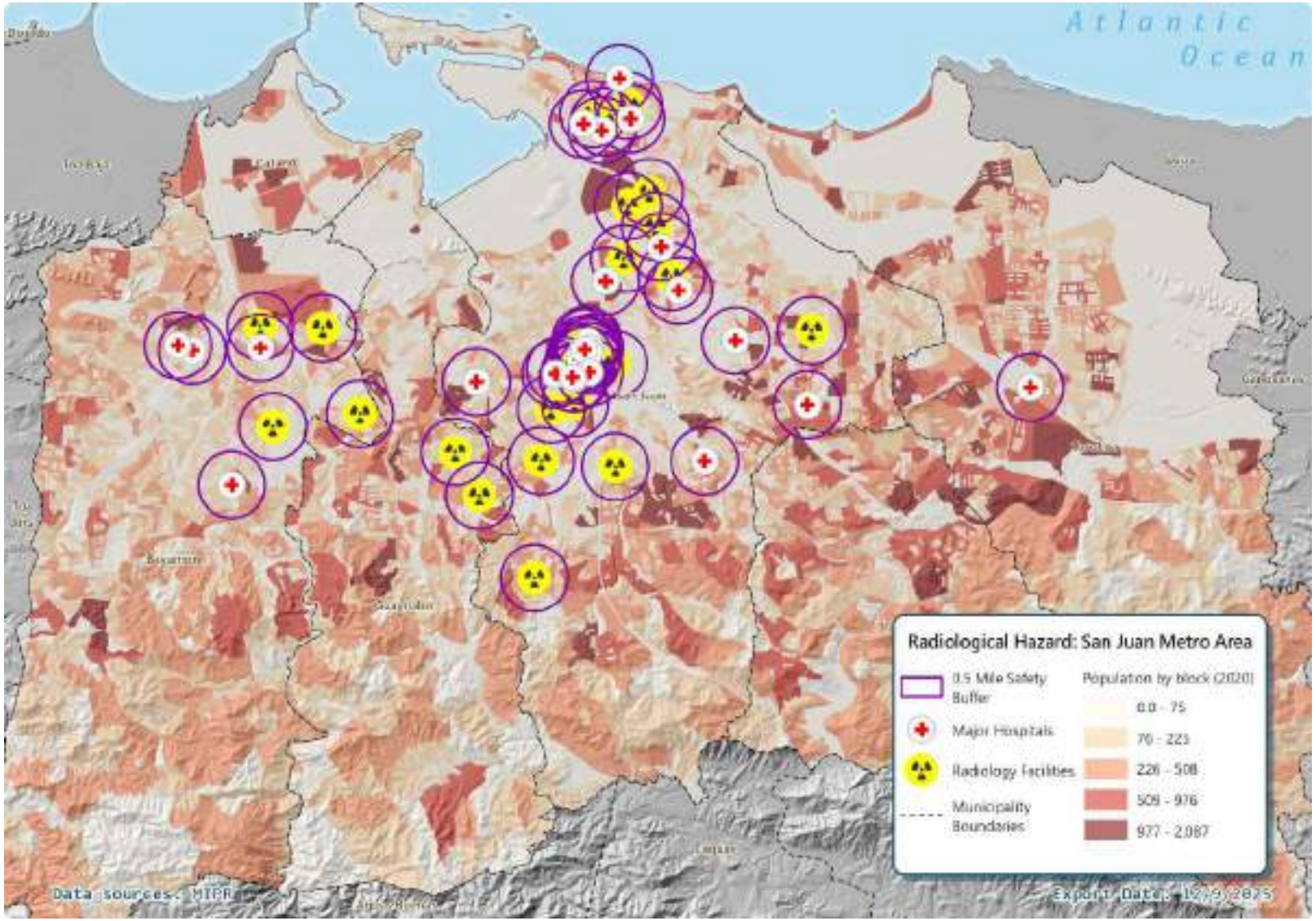


Figure 327: Radiological Source Density and Safety Zones in Puerto Rico

EXPLOSIVE HAZARDS

Primary Locations

- Vega Baja

  Pyrotechnics storage and manufacturing sites associated with localized blast and fire risk.[1269]

- Guayanilla

  Petroleum storage and industrial gas manufacturing facilities that pose combined explosion and fire hazards, including earthquake-triggered events.[1270] [1271]

- Yabucoa

  Coastal fuel terminal and associated infrastructure with explosive and flammable material risks in a storm- and flood-exposed setting.[1272] [1273]

Explosive hazards are less frequent but of high consequence, and they are driven by pyrotechnics, fuel-air mixtures, and industrial operations. Many explosive-risk sites are co-located with chemical storage in coastal and seismic zones (see Figure 328).[1274] [1275]

[1269] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). *Explosives hazard management and site risk data – Puerto Rico*. U.S. Department of Justice.
[1270] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1271] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). *Explosives hazard management and site risk data – Puerto Rico*. U.S. Department of Justice.
[1272] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1273] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). *Explosives hazard management and site risk data – Puerto Rico*. U.S. Department of Justice.
[1274] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1275] Bureau of Alcohol, Tobacco, Firearms and Explosives. (2023). *Explosives hazard management and site risk data – Puerto Rico*. U.S. Department of Justice.

Figure 328: Explosive Hazard Buffer Zones

MIXED CBRNE HAZARDS

Primary Locations

- **Bayamón–San Juan Corridor**

  Overlap of industrial facilities, ports, major hospitals with radiological equipment, and dense population centers produces a multi-hazard CBRNE convergence zone with potential for chemical, biological, radiological, and explosive impacts during flood, hurricane, or earthquake events.[1276] [1277] [1278]

- **Southern Industrial Complex – Guayanilla–Peñuelas**

  Co-located fuel terminals, petrochemical facilities, ammonia distribution, and energy infrastructure in flood- and seismic-exposed areas support scenarios where chemical, explosive, and secondary biological hazards occur in a single event.[1279] [1280] [1281]

These mixed-hazard zones correspond to areas where multiple CBRNE facility types intersect with high natural-hazard exposure and where previous incidents have demonstrated cascading effects on energy, water, and public health systems (See Figure 329).[1282] [1283]

[1276] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1277] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1278] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1279] Environmental Protection Agency. (2023). *Risk Management Program (RMP) facility data – Puerto Rico [Data set]*. U.S. Environmental Protection Agency.
[1280] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1281] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.
[1282] Puerto Rico Emergency Management Bureau. (2024). *CBRNE hazard exposure and risk mapping summary*. Government of Puerto Rico.
[1283] U.S. Department of Energy, Office of Electricity. (2024). *Industrial hazard assessment and response coordination report – Puerto Rico*. U.S. Department of Energy.

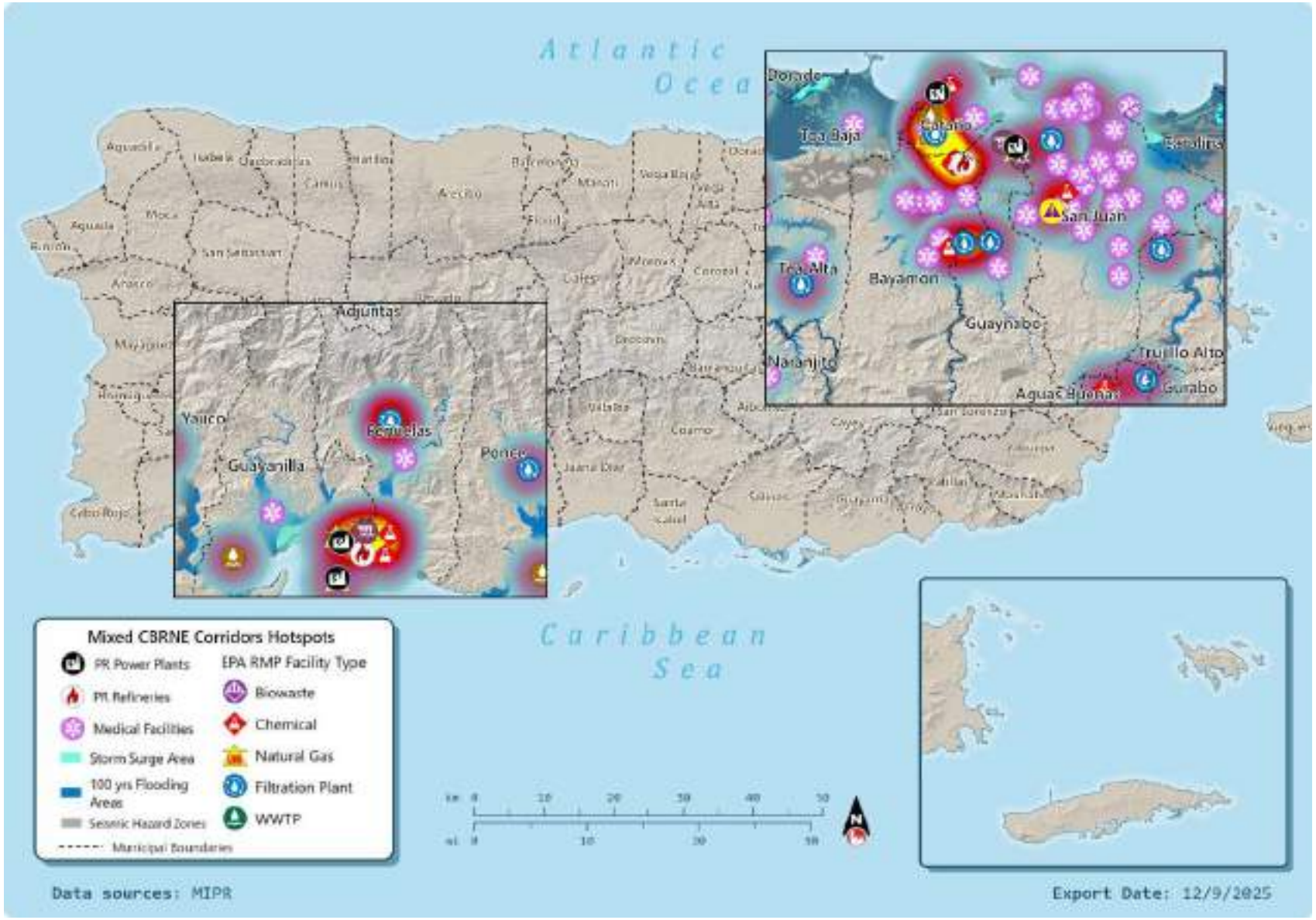


Figure 329: Mixed CBRNE Corridor Hotspots

GEOGRAPHIC SUMMARY TABLE

Table 173 summarizes where each CBRNE hazard is most concentrated in Puerto Rico, the key infrastructure involved, the surrounding environmental context, and the relative risk classification.

Table 173: Concentrations of CBRNE Hazards in Puerto Rico

Hazard Type	Primary Municipalities/ Corridors	Key Infrastructure	Environmental Context	Relative Risk Classification
Chemical	Peñuelas, Guayanilla, Yabucoa, Bayamón, Toa Baja, Arecibo, Fajardo	LNG and fuel terminals, refineries, bulk chemical storage, ammonia distribution, wastewater treatment plants	Coastal industrial corridors in FEMA AE/VE flood zones; storm surge and riverine flooding; some seismic exposure	**High**
Biological	San Juan, Bayamón, Carolina, Ponce, Mayagüez, Arecibo, Lajas, Adjuntas	Hospitals and laboratories, wastewater treatment plants, pump stations, agricultural operations	Urban medical hubs and flood-prone drainage basins with recurring sewer overflows; agricultural runoff in valley regions	**Moderate–High**
Radiological	San Juan (metro corridor), Bayamón	Hospitals and cancer centers with sealed sources; diagnostic imaging and isotope storage facilities	Dense urban built environment; co-location of radiological facilities with major transportation and energy corridors	**Low–Moderate**
Explosive	Vega Baja, Guayanilla, Yabucoa	Pyrotechnics manufacturing and storage, fuel terminals, industrial gas facilities	Industrial zones with fuel-air explosion potential; coastal and seismic exposure; proximity to transport corridors	**Moderate–High**
Multi-Hazard (CBRNE)	Bayamón–San Juan corridor; Guayanilla–Peñuelas industrial complex	Co-located industrial, medical, energy, and wastewater facilities; major ports and transport hubs	Convergence of chemical, biological, radiological, and explosive sources within high-exposure flood, storm surge, and seismic zones	**Very High**

Previous Occurrences

This chapter summarizes major disasters and significant hazard events in Puerto Rico from 2015 to 2025, focusing on interactions between natural hazards and technological systems that produced CBRNE-relevant conditions, such as hazardous material releases, wastewater contamination, and public health emergencies. Information is drawn from FEMA disaster declarations, the NOAA National Centers for Environmental Information (NCEI) Storm Events Database, and PREMB archives. These examples are illustrative rather than exhaustive; they highlight cascading impacts that inform CBRNE risk assessment and mitigation strategies.

FEDERAL DECLARATIONS AND CBRNE IMPACTS

2017 – DR-4339-PR – HURRICANE MARIA

Hurricane Maria caused catastrophic infrastructure failure across Puerto Rico. The collapse of the electrical grid led to prolonged power outages, forcing hospitals and critical care facilities to rely on backup generators, many of which failed, resulting in life-threatening medical emergencies. Wastewater treatment plants were inoperable for weeks, discharging untreated sewage into waterways and creating severe public health hazards. Flooding also impacted industrial zones, where chemical storage sites were compromised, increasing the risk of hazardous material spills and environmental contamination.[1284] [1285] **FEMA Link:** DR-4339[1286]

2020 – DR-4473-PR – PUERTO RICO EARTHQUAKES

A series of strong earthquakes damaged critical infrastructure, including hospitals and pharmaceutical manufacturing facilities, disrupting medical services and supply chains. Industrial sites storing chemicals and fuel tanks sustained structural damage, raising the potential for leaks and fires. Emergency shelters faced overcrowding and sanitation challenges, heightening the risk of infectious disease outbreaks. These cascading effects illustrate how seismic events can trigger technological failures with significant CBRNE implications.[1287] [1288] **FEMA Link:** DR-4473[1289]

[1284] Federal Emergency Management Agency (FEMA). (2017–2024). *Disaster declarations for Puerto Rico*. Retrieved from https://www.fema.gov.
[1285] National Centers for Environmental Information (NCEI). (2017–2024). Storm Events Database. NOAA. Retrieved from https://www.ncei.noaa.gov.
[1286] Federal Emergency Management Agency, "DR-4339-Puerto Rico Hurricane Maria," 2017, https://www.fema.gov/disaster/4339.
[1287] Federal Emergency Management Agency. (2024). *Puerto Rico disaster declarations summary* (DR-4339-PR, DR-4473-PR, DR-4671-PR, DR-4805-PR). U.S. Department of Homeland Security.
[1288] Puerto Rico Emergency Management Bureau. (2024). *Hazardous materials and flood event archive – Puerto Rico*. Government of Puerto Rico.
[1289] Federal Emergency Management Agency, "DR-4473-Puerto Rico Earthquakes," 2020, https://www.fema.gov/disaster/4473.

2022 – DR-4649-PR – SEVERE STORMS, FLOODING, AND LANDSLIDES

Intense rainfall and flooding overwhelmed wastewater systems, causing untreated sewage to contaminate rivers and coastal areas. Landslides blocked major transportation routes, delaying hazardous material transport and emergency response operations. Small industrial facilities reported localized chemical spills due to flood damage, posing environmental and health risks. These conditions highlight the vulnerability of water and transportation infrastructure to cascading failures during severe weather events.[1290] [1291] **FEMA Link:** DR-4649[1292]

2022 – DR-4671-PR – HURRICANE FIONA

Hurricane Fiona triggered widespread power outages that disrupted water treatment plants and dialysis centers, creating acute medical emergencies. Fuel shortages compounded response challenges, limiting generator use and emergency transport. Floodwaters infiltrated potable water systems, increasing the risk of waterborne diseases. The event underscores how energy and water system failures during hurricanes can escalate into public health crises with CBRNE relevance.[1293] [1294] **FEMA Link:** DR-4671[1295]

2024 – DR-4805-PR – SEVERE STORMS, FLOODING, LANDSLIDES, AND MUDSLIDES

This disaster caused extensive road damage, hindering the movement of hazardous materials and emergency supplies. Wastewater treatment failures led to raw sewage discharge into communities, creating significant health hazards. Emergency shelters reported sanitation breakdowns and disease control issues, amplifying public health risks. The event demonstrates how transportation and sanitation system disruptions can compound CBRNE vulnerabilities during prolonged storm events.[1296] [1297] **FEMA Link:** DR-4805[1298]

2024 – DR-4850-PR – TROPICAL STORM ERNESTO

Tropical Storm Ernesto resulted in widespread power outages, forcing reliance on generators and increasing carbon monoxide poisoning incidents. Flooding damaged chemical storage facilities, leading to localized

[1290] Puerto Rico Emergency Management Bureau (PREMB). (2017–2024). Incident archives. Retrieved from https://www.manejodeemergencias.pr.gov.
[1291] National Centers for Environmental Information. (2024). *Storm Events Database: Puerto Rico hazard records (2015–2025)*. National Oceanic and Atmospheric Administration.
[1292] Puerto Rico Severe Storm, Flooding, and Landslides DR-4649-PR. 4649 | FEMA.gov.
[1293] Federal Emergency Management Agency, "DR-4671-Puerto Rico Hurricane Fiona," 2022, https://www.fema.gov/disaster/4671.
[1294] National Centers for Environmental Information. (2024). *Storm Events Database: Puerto Rico hazard records (2015–2025)*. National Oceanic and Atmospheric Administration.
[1295] Puerto Rico Severe Storm, Flooding, and Landslides DR-4649-PR. 4649 | FEMA.gov.
[1296] Federal Emergency Management Agency. (2024). *Puerto Rico disaster declarations summary* (DR-4339-PR, DR-4473-PR, DR-4671-PR, DR-4805-PR). U.S. Department of Homeland Security.
[1297] Puerto Rico Emergency Management Bureau. (2024). *Hazardous materials and flood event archive – Puerto Rico*. Government of Puerto Rico.
[1298] Federal Emergency Management Agency, "DR-4805-Puerto Rico Severe Storms, Flooding, Landslides and Mudslides," 2024, https://www.fema.gov/disaster/4805.

hazardous material spills. Drinking water sources were contaminated by floodwaters, raising the risk of gastrointestinal illnesses. This event illustrates how even moderate storms can produce cascading effects that intersect with CBRNE concerns.[1299] **FEMA Link:** DR-4850[1300]

STATE-ONLY EMERGENCY DECLARATIONS AND CBRNE IMPACTS

This section summarizes significant Puerto Rico state-level emergency declarations that were not federally declared disasters, focusing on CBRNE-relevant impacts, such as hazardous material risks, wastewater contamination, and public health emergencies. Information is drawn from PREMB archives and official executive orders.

2017 – HURRICANE IRMA (PRE-MARIA)

Prior to Hurricane Maria, Puerto Rico declared a state of emergency for Hurricane Irma impacts. While less severe than Maria, Irma caused localized power outages that disrupted medical services and refrigeration for pharmaceuticals. Flooding led to minor wastewater system failures and chemical runoff in coastal areas, posing environmental and health risks.[1301]

2019 – DROUGHT EMERGENCY

A prolonged drought prompted a state emergency declaration due to critical water shortages. Hospitals and rural communities faced sanitation challenges, and concentrated wastewater and chemical residues in reservoirs increased contamination risks. These conditions highlighted vulnerabilities in water infrastructure and public health systems.[1302]

2021 – COVID-19 PUBLIC HEALTH EMERGENCY

Puerto Rico extended its public health emergency under executive orders during the COVID-19 pandemic. Medical surge capacity strained hospital systems and hazardous waste disposal, including personal protective equipment (PPE) and biohazard materials. Increased use of chemical disinfectants raised storage and handling risks, creating secondary CBRNE concerns. [1303]

[1299] Puerto Rico Emergency Management Bureau. (2024). *Hazardous materials and flood event archive – Puerto Rico*. Government of Puerto Rico.
[1300] Federal Emergency Management Agency, "DR-4850- Puerto Rico Tropical Storm Ernesto," 2024, https://www.fema.gov/disaster/4850.
[1301] Puerto Rico Emergency Management Bureau (PREMB). (2017–2025). Emergency declarations and incident archives. Retrieved from https://www.preps.pr.gov.
[1302] Central Office for Recovery, Reconstruction and Resiliency (COR3). (2017–2025). Disaster recovery transparency portal. Retrieved from https://recovery.pr.gov.
[1303] Puerto Rico Emergency Management Bureau (PREMB). (2017–2025). Emergency declarations and incident archives. Retrieved from https://www.preps.pr.gov.

2023 – HEATWAVE AND POWER GRID STRESS

Extreme heat and grid instability led to an emergency declaration. Widespread generator use increased carbon monoxide poisoning incidents, while cooling system failures in hospitals and pharmaceutical facilities risked spoilage of temperature-sensitive medications. These cascading effects illustrate how climate-related events can intersect with technological vulnerabilities.[1304]

SIGNIFICANT EVENTS

The NCEI Storm Events Database provides a record of major storms, floods, and other hazard events in Puerto Rico.[1305] For this hazard profile, a subset of high-impact events with clear or likely CBRNE dimensions—such as widespread wastewater overflows, hazardous materials concerns, or industrial damage—is summarized in Table 174. These examples are illustrative and based on NCEI records, FEMA disaster declarations, and PREMB incident reporting; they do not represent an exhaustive catalog of all relevant events.[1306] [1307] [1308]

Table 174: NCEI Data Summary for Major CBRNE-Related Events

Date (Month/Year)	Primary Hazard Event	NCEI/FEMA Reference	Primary CBRNE-Relevant Impacts	Approximate Geographic Extent
Sep 2017	Major hurricane causing catastrophic wind and flood damage	Hurricane Maria (FEMA DR-4339-PR)	Widespread power outages; wastewater and drinking water system failures; hazardous materials and sewage releases into rivers and coastal waters	Island-wide
Jan 2020	Southwest Puerto Rico earthquake sequence	NCEI Earthquake Records; FEMA DR-4473-PR	Structural damage to energy and industrial facilities; emergency inspections of tanks and fuel storage; localized hazardous materials concerns	Southwestern coastal corridor

[1304] Central Office for Recovery, Reconstruction and Resiliency (COR3). (2017–2025). Disaster recovery transparency portal. Retrieved from https://recovery.pr.gov.
[1305] NOAA National Centers for Environmental Information (NCEI). Billion-Dollar Weather and Climate Disasters Dataset. Retrieved from https://www.ncei.noaa.gov/access/billions/state-summary/PR.
[1306] NOAA National Centers for Environmental Information (NCEI). Billion-Dollar Weather and Climate Disasters Dataset. Retrieved from https://www.ncei.noaa.gov/access/billions/state-summary/PR.
[1307] NOAA National Centers for Environmental Information (NCEI) Storm Events Database. Retrieved from https://www.climate.gov/maps-data/dataset/severe-storms-and-extreme-events-data-table.
[1308] PREMB Emergency Portal. Retrieved from https://www.preps.pr.gov. Hurricane Maria's devastation of Puerto Rico | https://www.climate.gov/news-features/understanding-climate/hurricane-marias-devastation-puerto-rico.

Date (Month/Year)	Primary Hazard Event	NCEI/FEMA Reference	Primary CBRNE-Relevant Impacts	Approximate Geographic Extent
Sep 2022	Hurricane producing intense rainfall and flooding	Hurricane Fiona (FEMA DR-4671-PR)	Wastewater treatment plant overflows; pump station failures; sewage discharges and contamination of surface waters	Multiple coastal and riverine municipios

These events show that major storms and earthquakes in Puerto Rico often produce CBRNE-relevant conditions, including hazardous materials releases, large wastewater overflows, and infrastructure damage that affects energy, water, and public health.[1309] [1310] [1311]

EVENT NARRATIVES

2015 – Extreme Drought and Tropical Storm Erika

Puerto Rico experienced one of its driest years on record, with rainfall 13.55 inches below normal. Severe drought conditions put stress on water systems, reducing sanitation capacity and increasing contamination risks. Later in the year, Tropical Storm Erika brought heavy rains but failed to alleviate drought impacts. These conditions created vulnerabilities in water supply and wastewater management, raising public health concerns.[1312]

2017 – Hurricane Maria

Hurricane Maria was a Category 4 storm that devastated Puerto Rico, causing widespread power grid failure, hospital generator outages, and wastewater treatment plant shutdowns. These cascading failures led to raw sewage discharge, hazardous material spill risks, and severe medical emergencies. Maria remains the most impactful disaster in Puerto Rico's modern history.[1313]

[1309] NOAA National Centers for Environmental Information (NCEI). Billion-Dollar Weather and Climate Disasters Dataset. Retrieved from https://www.ncei.noaa.gov/access/billions/state-summary/PR.
[1310] NOAA National Centers for Environmental Information (NCEI) Storm Events Database. Retrieved from https://www.climate.gov/maps-data/dataset/severe-storms-and-extreme-events-data-table.
[1311] PREMB Emergency Portal. Retrieved from https://www.preps.pr.gov. Hurricane Maria's devastation of Puerto Rico | NOAA Climate.gov.
[1312] National Weather Service San Juan. (2016). 2015 annual climate summary for Puerto Rico and the U.S. Virgin Islands. NOAA/NWS. https://www.weather.gov/media/sju/climo/monthly_reports/2015/2015Summary.pdf.
[1313] Scott, M. (2018, August 1). Hurricane Maria's devastation of Puerto Rico. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/hurricane-marias-devastation-puerto-rico.

2019 – Drought Emergency

A prolonged drought led to state-level emergency declarations, stressing water infrastructure and sanitation systems. Concentrated chemical residues in reservoirs increased contamination risks, while hospitals faced operational challenges due to water scarcity.[1314]

2020 – Puerto Rico Earthquakes

A series of earthquakes damaged hospitals, pharmaceutical facilities, and industrial sites storing chemicals and fuel. Structural failures raised hazardous material spill risks, while emergency shelters faced sanitation breakdowns, increasing infectious disease potential. [1315]

2022 – Hurricane Fiona

Hurricane Fiona caused island-wide power outages, disrupting water treatment plants and dialysis centers. Fuel shortages limited generator use, and floodwaters contaminated potable water systems, creating acute public health risks. [1316]

2024 – Tropical Storm Ernesto and Hurricane Beryl

Tropical Storm Ernesto caused localized flooding, wastewater system failures, and chemical storage damage. Hurricane Beryl, though not making direct landfall, brought extreme winds and storm surge, stressing coastal infrastructure and increasing hazardous material exposure risks. **Reference:** [worlddata.info]

Various Years – Industrial Fires and Explosions in Coastal Corridors

Industrial fires and localized explosions at coastal fuel terminals and chemical facilities in Puerto Rico over the past two decades underscore the significant risk posed by chemical and explosive hazards. Notably, the 2009 Caribbean Petroleum Corporation (CAPECO) explosion in Bayamón released millions of gallons of petroleum products, generated a vapor cloud spanning over 70 acres, and caused severe environmental damage and structural impacts across nearby communities.[1317] [1318] [1319] These events, while geographically concentrated within industrial zones, demonstrate the potential for high-consequence CBRNE incidents.

The implications are clear: robust secondary containment measures, adequate blast standoff distances, and well-defined emergency planning zones are critical for facilities situated in areas vulnerable to flooding, severe storms, or seismic activity. Puerto Rico regulations, such as Regulation 8785, mandate secondary containment systems and spill prevention plans for hazardous materials, while federal guidance emphasizes

[1314] NOAA National Centers for Environmental Information. (2022). Puerto Rico and the U.S. Virgin Islands: State climate summary. In State Climate Summaries 2022. NCICS. https://statesummaries.ncics.org/chapter/pr/.
[1315] NOAA National Centers for Environmental Information. (2022). Puerto Rico and the U.S. Virgin Islands: State climate summary. In State Climate Summaries 2022. NCICS. https://statesummaries.ncics.org/chapter/pr/.
[1316] NOAA National Centers for Environmental Information. (2022). Puerto Rico and the U.S. Virgin Islands: State climate summary. In State Climate Summaries 2022. NCICS. https://statesummaries.ncics.org/chapter/pr/.
[1317] U.S. Chemical Safety Board. (2010). Investigation Report: Caribbean Petroleum Tank Explosion. Washington, DC.
[1318] Environmental Protection Agency. (2010). CAPECO Explosion Incident Report. Washington, DC: EPA.
[1319] Federal Emergency Management Agency. (2011). Puerto Rico Hazard Mitigation Plan. Washington, DC: FEMA.

blast-resistant design and minimum standoff distances to mitigate explosion impacts.[1320] Additionally, FEMA and Department of Homeland Security (DHS) planning frameworks highlight the need for integrated emergency operations and risk assessments to protect surrounding communities from cascading effects of industrial accidents.[1321] [1322]

ANALYTICAL SUMMARY

Review of NCEI records,[1323] FEMA declarations,[1324] and PREMB incident reports[1325] [1326] indicate that multiple major disasters since 2015 have had documented CBRNE dimensions, rather than CBRNE incidents being rare or isolated. As shown in Figure 330, several patterns are evident.

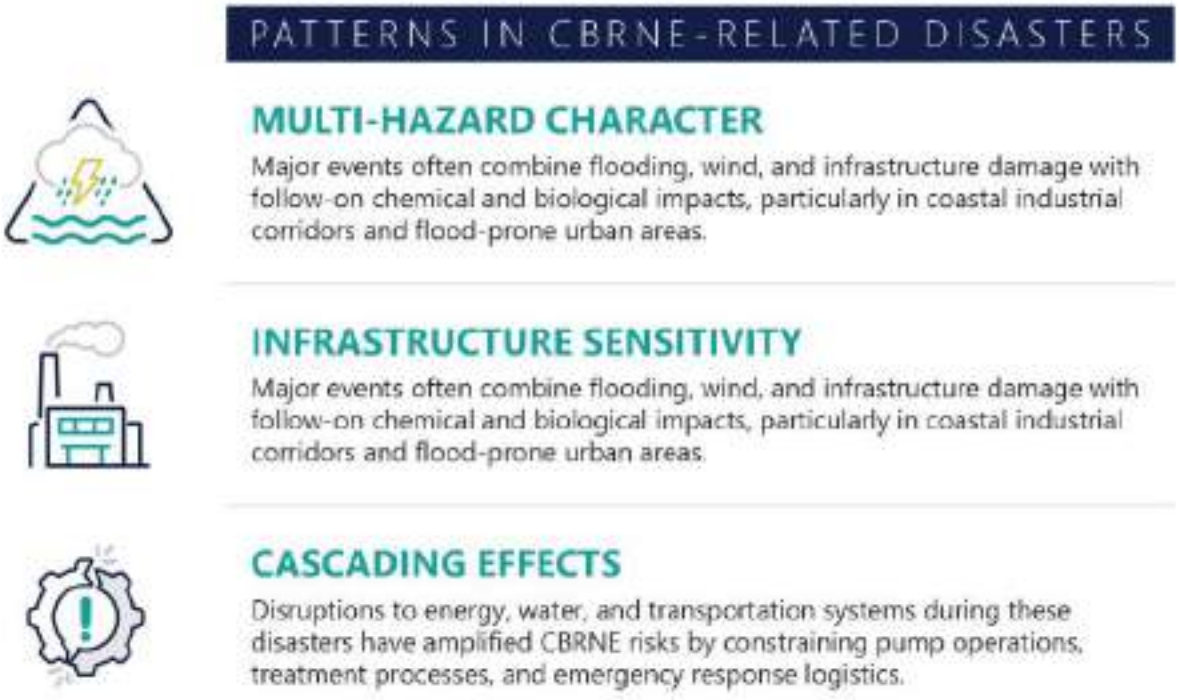


Figure 330: Patterns in CBRNE-Related Disasters

Instead of assigning a precise annual frequency or percentage of events with CBRNE components, this section emphasizes that CBRNE-relevant consequences have been a recurring feature of recent major

[1320] Department of Homeland Security. (2019). Chemical Facility Safety and Security Guidelines. Washington, DC: DHS.
[1321] Federal Emergency Management Agency. (2020). Emergency Planning for Hazardous Materials Facilities. Washington, DC: FEMA.
[1322] Department of Homeland Security. (2019). Chemical Facility Safety and Security Guidelines. Washington, DC: DHS.
[1323] NOAA National Centers for Environmental Information (NCEI) Storm Events Database: https://www.ncei.noaa.gov.
[1324] FEMA Disaster Declarations: https://www.fema.gov/disasters.
[1325] PREMB Emergency Portal: https://www.preps.pr.gov.
[1326] Central Office for Recovery, Reconstruction and Resiliency (COR3) Recovery Portal: https://recovery.pr.gov.

disasters, underscoring the need to integrate CBRNE considerations into multi-hazard mitigation projects and lifeline resilience planning.[1327]

Potential Severity of CBRNE Events

The potential severity of CBRNE events in Puerto Rico is assessed by examining both the physical magnitude of each hazard and its anticipated impacts on human populations, critical infrastructure, and the natural environment.[1328] Severity for each hazard type is quantified using established scientific and engineering metrics—such as sieverts for radiological exposure, overpressure for explosive events, the Modified Mercalli Intensity (MMI) scale for earthquakes, and the Saffir–Simpson Hurricane Wind Scale for tropical cyclones.[1329] [1330] These measurements are then contextualized within Puerto Rico's unique geographic characteristics, infrastructure resilience, and patterns of urban development to provide a realistic estimate of potential consequences.[1331]

CHEMICAL EVENTS

MEASUREMENT AND SEVERITY FACTORS[1332]

- Release quantity and rate
- Toxic concentration and duration of exposure (relative to Acute Exposure Guideline Levels)
- Area and population within the potential dispersion plume

EPA and industry-standard dispersion models estimate health impacts and environmental contamination.

TYPICAL SEVERITY RANGE IN PUERTO RICO[1333] [1334]

Localized spills and leaks at industrial sites or along transportation corridors are most common. However, large fuel and chemical storage facilities in Peñuelas, Guayanilla, Yabucoa, Bayamón, and Toa Baja pose significant risk for high-severity events if containment systems fail during hurricanes, floods, or earthquakes.

ANTICIPATED IMPACTS[1335] [1336]

- Acute respiratory and dermal health effects

[1327] Environmental Protection Agency, & U.S. Department of Energy. (2024). *Multi-hazard interaction and mitigation analysis for Puerto Rico*. Joint analytical summary.
[1328] U.S. Department of Homeland Security. *CBRNE Consequence Assessment Guidelines*.
[1329] U.S. Department of Homeland Security. *CBRNE Consequence Assessment Guidelines*.
[1330] Puerto Rico Planning Board. *Hazard Mitigation Plan: Risk and Vulnerability Analysis*.
[1331] Puerto Rico Planning Board. *Hazard Mitigation Plan: Risk and Vulnerability Analysis*.
[1332] Puerto Rico Planning Board. *Hazard Mitigation Plan*.
[1333] Puerto Rico Planning Board. *Hazard Mitigation Plan*.
[1334] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1335] Puerto Rico Planning Board. *Hazard Mitigation Plan*.
[1336] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.

- Soil and water contamination
- Temporary closure of industrial and port facilities
- Downstream impacts on drinking water sources and ecosystems

EARTHQUAKE-INDUCED EVENTS[1337] [1338]

- Severity described using the MMI scale and extent of damage to tanks, pipelines, and containment systems.
- Southern Puerto Rico has experienced MMI VI–VIII shaking (2020 earthquake sequence), which can damage tanks and pipelines, especially older facilities.
- Anticipated impacts: Pipeline ruptures, tank failures, fires, and hazardous material releases in industrial corridors, with secondary effects on transportation and ports.

HURRICANE AND FLOOD-INDUCED EVENTS[1339] [1340] [1341]

- Characterized using Saffir–Simpson Hurricane Wind Scale and flood severity indices.
- Category 3–5 storms have inundated coastal industrial areas and wastewater systems.
- Anticipated impacts: Flood-triggered chemical spills, wastewater bypasses, contamination of surface waters, and impaired access/power amplifying severity.

BIOLOGICAL EVENTS

MEASUREMENT AND SEVERITY FACTORS[1342]

Biological hazards are assessed using frameworks such as the CDC pathogen severity classifications and the World Health Organization (WHO) Pandemic Severity Index, which consider transmissibility, clinical severity, and disruption to health and essential services.

TYPICAL SEVERITY RANGE IN PUERTO RICO[1343] [1344]

Biological hazards of concern include:

[1337] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1338] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*.
[1339] National Oceanic and Atmospheric Administration (NOAA). *Hurricane and Flood Risk Guidance*.
[1340] Puerto Rico Planning Board. *Hazard Mitigation Plan*.
[1341] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1342] Centers for Disease Control and Prevention (CDC). *Pandemic Severity Assessment Framework*; World Health Organization (WHO). *Pandemic Influenza Risk Management Guidance*.
[1343] Centers for Disease Control and Prevention (CDC). *Pandemic Severity Assessment Framework*; World Health Organization (WHO). *Pandemic Influenza Risk Management Guidance*.
[1344] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.

- Localized contamination events (e.g., sewage overflows and wastewater bypasses during storms)
- Broader outbreaks associated with waterborne or vector-borne diseases and respiratory illnesses

Flooding and wastewater failures significantly increase exposure risk, particularly in areas with urban medical hubs, flood-prone drainage basins with recurring sewer overflows, and agricultural runoff in valley regions. These conditions can amplify contamination and disease transmission, especially where wastewater treatment plants, pump stations, and laboratories are compromised during hurricanes or earthquakes. [1345] [1346]

CRITICAL INFRASTRUCTURE AND VULNERABLE SYSTEMS [1347] [1348]

- Hospitals and laboratories
- Wastewater treatment plants and pump stations
- Agricultural operations
- Urban medical hubs
- Flood-prone drainage basins
- Valley regions with agricultural runoff

ANTICIPATED IMPACTS [1349] [1350] [1351]

- Short- and medium-term increases in waterborne and vector-borne diseases (e.g., leptospirosis, gastrointestinal illness)
- Stress on healthcare systems due to surge in cases
- Localized restrictions on recreational or drinking water use

EARTHQUAKE-INDUCED EVENTS [1352] [1353]

- Sewer line ruptures and wastewater bypasses leading to contamination of rivers and coastal waters
- Increased risk of waterborne disease outbreaks (e.g., leptospirosis, cholera)

[1345] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1346] NOAA. *Hurricane and Flood Risk Guidance*; WHO. *Water, Sanitation and Health in Emergencies*.
[1347] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1348] NOAA. *Hurricane and Flood Risk Guidance*; WHO. *Water, Sanitation and Health in Emergencies*.
[1349] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1350] Centers for Disease Control and Prevention (CDC). *Pandemic Severity Assessment Framework*; World Health Organization (WHO). *Pandemic Influenza Risk Management Guidance*.
[1351] NOAA. *Hurricane and Flood Risk Guidance*; WHO. *Water, Sanitation and Health in Emergencies*.
[1352] Centers for Disease Control and Prevention (CDC). *Pandemic Severity Assessment Framework*; World Health Organization (WHO). *Pandemic Influenza Risk Management Guidance*.
[1353] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*; CDC. *Earthquake Safety and Public Health Guidance*.

- Disruption of hospitals and laboratories, reducing infection control and diagnostic capacity
- Agricultural contamination from damaged animal waste containment systems
- Vector habitat changes from earthquake-triggered flooding, increasing mosquito-borne disease risk.

HURRICANE AND FLOOD-INDUCED EVENTS[1354] [1355]

- Sewage overflows and contamination in low-lying industrial and agricultural areas
- Elevated leptospirosis and gastrointestinal illness risks; healthcare strain; contamination of surface and coastal waters

RADIOLOGICAL EVENTS

MEASUREMENT AND SEVERITY FACTORS[1356] [1357]

- Absorbed dose (Sv or mSv/hr.)
- Size/duration of contaminated area
- Tools like Residual Radiation (RESRAD) estimate exposure

TYPICAL SEVERITY RANGE IN PUERTO RICO[1358] [1359]

Risk tied to sealed sources and medical isotopes in San Juan and Bayamón. Expected exposures <1–10 mSv/hr., leading mainly to localized evacuations.

ANTICIPATED IMPACTS[1360]

Access restrictions, localized decontamination, and monitoring for exposed individuals.

EARTHQUAKE-INDUCED EVENTS[1361] [1362] [1363]

- MMI shaking can damage isotope storage or shielding.
- MMI VI–VIII could compromise containment in older facilities.

[1354] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data and Chemical Safety Reports*.
[1355] NOAA. *Hurricane and Flood Risk Guidance*; WHO. *Water, Sanitation and Health in Emergencies*.
[1356] U.S. Nuclear Regulatory Commission (NRC). *Radiological Emergency Preparedness Program Guidance.*
[1357] U.S. Department of Energy (DOE). *RESRAD Family of Codes for Radiation Risk Assessment*.
[1358] U.S. Nuclear Regulatory Commission (NRC). *Radiological Emergency Preparedness Program Guidance*.
[1359] U.S. Department of Energy (DOE). *RESRAD Family of Codes for Radiation Risk Assessment*.
[1360] U.S. Nuclear Regulatory Commission (NRC). *Radiological Emergency Preparedness Program Guidance*.
[1361] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Reports*.
[1362] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*; CDC. *Earthquake Safety and Public Health Guidance*.
[1363] U.S. Department of Energy (DOE). *RESRAD Family of Codes for Radiation Risk Assessment*.

- Anticipated impacts: Monitoring would increase, and medical facilities might require evacuation.

HURRICANE AND FLOOD-INDUCED EVENTS[1364]

Flooding may affect isotope storage areas, which could lead to contamination and require decontamination.

NUCLEAR EVENTS

MEASUREMENT AND SEVERITY FACTORS[1365]

- Yield (kilotons/megaton)
- Blast effects (overpressure, thermal radiation)
- Fallout extent – Modeled using the Hazard Prediction and Assessment Capability (HPAC) and modeling tools from the National Atmospheric Release Advisory Center (NARAC)

TYPICAL SEVERITY RANGE IN PUERTO RICO[1366]

Puerto Rico lacks nuclear plants or weapons facilities, so the risk is extremely low. The main concern is fallout from distant events.

ANTICIPATED IMPACTS[1367]

Radiation monitoring, advisories, and protective measures (e.g., potassium iodide).

EARTHQUAKE-INDUCED EVENTS[1368] [1369]

Could disrupt emergency response systems and monitoring infrastructure.

Anticipated impacts: Delays in fallout monitoring and protective measure distribution.

[1364] U.S. Department of Homeland Security. *CBRNE Consequence Assessment Guidelines*.
[1365] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; Lawrence Livermore National Laboratory (LLNL). *NARAC Modeling Tools for Nuclear and Radiological Incidents*.
[1366] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; Lawrence Livermore National Laboratory (LLNL). *NARAC Modeling Tools for Nuclear and Radiological Incidents*.
[1367] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; Lawrence Livermore National Laboratory (LLNL). *NARAC Modeling Tools for Nuclear and Radiological Incidents*.
[1368] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; Lawrence Livermore National Laboratory (LLNL). *NARAC Modeling Tools for Nuclear and Radiological Incidents*.
[1369] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Reports*.

HURRICANE AND FLOOD-INDUCED EVENTS[1370] [1371]

Flooding could impair communication and logistics for nuclear emergency preparedness.

EXPLOSIVE EVENTS

MEASUREMENT AND SEVERITY FACTORS[1372]

- TNT-equivalent yield
- Overpressure (psi) and fragmentation radius
- Overpressures ≥2 psi cause window breakage/light structural damage.

TYPICAL SEVERITY RANGE IN PUERTO RICO[1373] [1374]

Hazards are associated with pyrotechnics, fuel terminals, and industrial sites in Vega Baja and Guayanilla. Worst-case events could cause localized blast and fire damage within a few hundred meters.

ANTICIPATED IMPACTS[1375] [1376]

Structural damage, fires, fragmentation injuries, localized power/transport disruption, and short-term evacuation.

EARTHQUAKE-INDUCED EVENTS[1377] [1378]

MMI VI–VIII shaking can trigger explosions by damaging storage tanks or ignition systems.

Anticipated impacts: Secondary fires and blast hazards in industrial corridors.

[1370] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; Lawrence Livermore National Laboratory (LLNL). *NARAC Modeling Tools for Nuclear and Radiological Incidents*.
[1371] NOAA. *Hurricane Flood Guidance*.
[1372] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; ATF. *Explosives Industry Safety Standards*.
[1373] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1374] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; ATF. *Explosives Industry Safety Standards*.
[1375] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1376] U.S. Department of Defense (DoD). *Hazard Prediction and Assessment Capability (HPAC) User Guide*; ATF. *Explosives Industry Safety Standards*.
[1377] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1378] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Reports*.

HURRICANE AND FLOOD-INDUCED EVENTS[1379] [1380]

Flooding can compromise explosive storage integrity, increasing the risk of accidental detonation and fire spread.

MULTI-HAZARD CASCADING EVENTS

OVERVIEW

Multi-hazard cascading events occur when one hazard triggers or amplifies another, creating complex and compounded impacts. In Puerto Rico, the interaction between earthquakes, hurricanes, floods, and CBRNE hazards can significantly increase both severity and response complexity.

COMMON CASCADING SCENARIOS

- Earthquake → Chemical Release → Fire/Explosion

  Strong ground shaking (MMI VI–VIII) can rupture pipelines and tanks, leading to hazardous material spills and secondary fires or explosions.[1381] [1382]

- Hurricane/Flood → Biological Contamination → Public Health Crisis

  Category 3–5 hurricanes cause widespread flooding, which overwhelms wastewater systems and spreads pathogens. This can lead to outbreaks of leptospirosis, gastrointestinal illness, and vector-borne diseases. [1383] [1384]

- Earthquake → Radiological Incident → Healthcare Disruption

  Damage to medical isotope storage in hospitals during earthquakes could cause localized radiological contamination, compounded by simultaneous hospital infrastructure failures. [1385] [1386]

- Flood → Explosive Hazard → Industrial Corridor Shutdown

  Floodwaters infiltrating pyrotechnics or fuel storage facilities could trigger accidental detonations, fires, and cascading impacts on transportation and power systems.[1387] [1388]

- Combined Hurricane + Earthquake Sequence → Multi-sector Failure

[1379] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1380] NOAA. *Hurricane Flood Guidance*.
[1381] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1382] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*.
[1383] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1384] NOAA. *Hurricane and Flood Risk Guidance*.
[1385] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*.
[1386] U.S. Nuclear Regulatory Commission (NRC). *Radiological Emergency Preparedness Guidance*.
[1387] U.S. Environmental Protection Agency (EPA). *Risk Management Program Facility Data*.
[1388] U.S. Geological Survey (USGS). *Puerto Rico Earthquake Sequence Reports*.

Sequential hazards (such as a hurricane followed by an earthquake) could overwhelm emergency response, disrupt supply chains, and amplify CBRNE severity by limiting containment and recovery capacity [1], [2].

ANTICIPATED IMPACTS

- **Infrastructure Overload:** Simultaneous failures in power, water, and transportation systems
- **Public Health Strain:** Concurrent chemical exposure and disease outbreaks
- **Extended Recovery Times:** Multi-sector damage complicating restoration and resource allocation
- **Emergency Response Challenges:** Limited access and communication during cascading events

SEVERITY CLASSIFICATION TABLE

The severity of CBRNE events in Puerto Rico is assessed based on hazard magnitude and anticipated impacts on people, infrastructure, and the environment. Severity is quantified using scientific scales (e.g., sieverts for radiation, overpressure for explosions, Modified Mercalli Intensity for earthquakes, and Saffir–Simpson categories for hurricanes) and contextualized for Puerto Rico's geography, infrastructure, and development patterns [1], [2].

Table 175: Severity Classification Table

Hazard Type	Representative Severity Scale(s)	Typical Severity Range in Puerto Rico	Relative Severity Rating	Key Consequences
Chemical	Release quantity; toxic concentration vs. health thresholds; plume extent	Localized spills and high-consequence releases at coastal industrial facilities	**High**	Acute health effects; soil and water contamination; industrial and port disruption
Biological	CDC pathogen severity; WHO Pandemic Severity Index	Localized sewage/wastewater incidents and larger flood-related contamination events	**Moderate–High**	Increased disease risk; stress on healthcare systems; recreational and drinking water impacts
Radiological	Absorbed dose (Sv/mSv); size of controlled area	Localized low-level exposure around medical facilities (less than 1–10 mSv/hr.)	**Low–Moderate**	Precautionary evacuations; localized decontamination; facility shutdowns
Nuclear	Yield (kilotons/ megaton); fallout extent	No local facilities; the risk is limited to distant fallout scenarios	**Low**	Radiation monitoring; protective measures; minimal

Hazard Type	Representative Severity Scale(s)	Typical Severity Range in Puerto Rico	Relative Severity Rating	Key Consequences
				infrastructure disruption
Explosive	TNT-equivalent yield; blast overpressure (psi)	Localized industrial or pyrotechnic explosions with overpressure (greater than or equal to 2 psi)	**Moderate–High**	Structural damage, injuries, fires; short-term power/transport disruption
Earthquake-Induced	Modified Mercalli Intensity (MMI); damaged containment systems	MMI VI–VIII shaking in southern coastal industrial areas	**High**	Pipeline and tank failures; hazardous releases; fire and secondary infrastructure impacts
Hurricane/Flood-Induced	Saffir–Simpson category; flood depth/extent	Major coastal and riverine flooding during Category 3–5 storms	**Very High**	Industrial inundation; chemical and sewage releases; widespread environmental and health impacts
Multi-Hazard Cascading	Combination of scales above; multi-lifeline effects	Concurrent natural and technological failures in key industrial/urban corridors	**Very High**	Cross-sector lifeline disruption; complex, prolonged recovery

RISK MATRIX

The matrix in Figure 331 provides a color-coded representation of hazard severity levels in Puerto Rico.

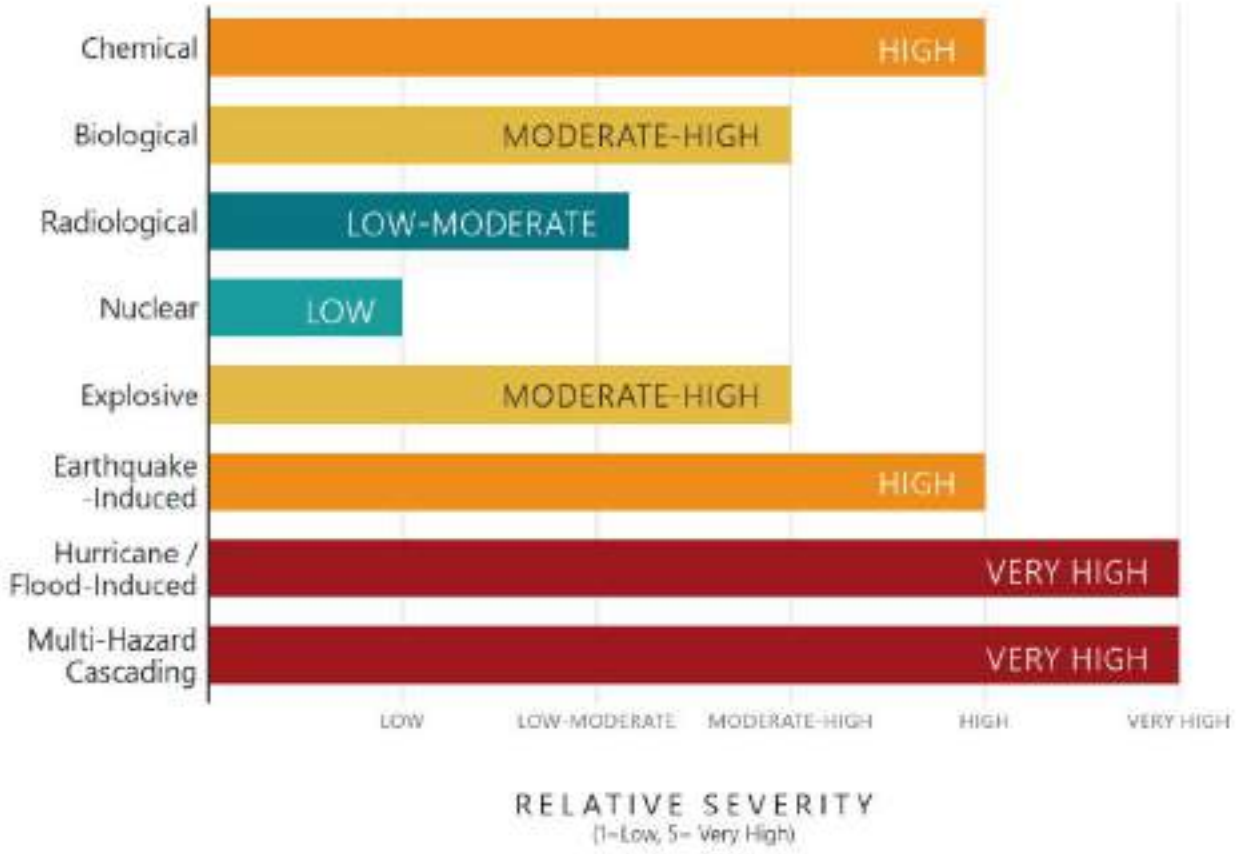


Figure 331: CBRNE Hazard Severity Risk Matrix for Puerto Rico

KEY RISK SUMMARY

Figure 332: Key CBRNE Risks for Puerto Rico

Probability of Future Hazard Events

The likelihood of future CBRNE incidents in Puerto Rico is assessed using recent incident history (2015–2025), facility and infrastructure exposure, and projected changes in natural hazards such as hurricanes, floods, and earthquakes (FEMA, 2023). Rather than estimating precise annual frequencies or percentage increases, this analysis classifies the probability of different CBRNE hazard types as high, moderate, or low based on observed patterns and exposure conditions. This approach aligns with the qualitative risk methodology outlined in the Puerto Rico State Hazard Mitigation Plan (FEMA, 2025).

CHEMICAL HAZARDS

PROBABILITY: HIGH (OCCURRING AT LEAST ONCE A YEAR)

Chemical incidents—such as fuel leaks, gas releases, and industrial spills—are expected to occur regularly in Puerto Rico, particularly in coastal industrial corridors and along major transportation routes (EPA, 2022). Historical data and recent hurricane-related flooding events indicate recurring chemical releases, including minor spills and occasional major incidents (EPA, 2025).

Key drivers include aging infrastructure, exposure of industrial facilities and pipelines to floods and storm surge, and seismic risk in southern coastal areas. Unless significant upgrades and protective measures are implemented, chemical incidents are projected to remain a high-probability hazard over the next several decades (EPA, 2025).

BIOLOGICAL HAZARDS

PROBABILITY: MODERATE (OCCURRING AT LEAST ONCE EVERY FIVE YEARS)

Biological hazards in Puerto Rico primarily stem from wastewater overflows, sewage contamination, and post-disaster public health conditions rather than large-scale bioterrorism events (FEMA, 2023). Major hurricanes and flood events have repeatedly caused sewage releases and water quality concerns, increasing the risk of waterborne and vector-borne diseases during and after storms (FEMA, 2023).

Given the frequency of heavy rainfall and coastal storms, biological hazards are expected to occur multiple times within a 10- to 15-year period, though not annually. Overall, these hazards present a moderate probability of significant public health and environmental impacts during the planning horizon (FEMA, 2023).

RADIOLOGICAL HAZARDS

PROBABILITY: LOW (OCCURRING LESS THAN ONCE EVERY FIVE YEARS)

Radiological hazards in Puerto Rico are primarily associated with medical uses of sealed sources and radiopharmaceuticals in hospitals and diagnostic centers (NRC, 2025). Historical reports indicate only

isolated minor events over the past decade, typically involving equipment issues or transport anomalies (NRC, 2022).

Existing licensing, inspection, and reporting requirements managed by the Nuclear Regulatory Commission and territorial health authorities provide multiple layers of control. Under current conditions, the likelihood of a significant radiological incident affecting the public is assessed as low for the planning period (NRC, 2025).

NUCLEAR HAZARDS

PROBABILITY: VERY LOW (OCCURRING LESS THAN ONCE EVERY DECADE)

Puerto Rico does not host nuclear power plants or large-scale nuclear facilities, which significantly reduces the risk of nuclear incidents (DOE, n.d.-a). Potential nuclear hazards are limited to the transport of small quantities of nuclear material for research or medical purposes, and these are subject to strict federal and territorial regulations (DOE, n.d.-b; NRC, 2025).

Given the absence of nuclear energy infrastructure and the robust regulatory framework, the probability of a nuclear event with public health or environmental consequences is considered very low for the planning horizon (DOE, n.d.-a).

EXPLOSIVE HAZARDS

PROBABILITY: MODERATE (OCCURRING AT LEAST ONCE EVERY FIVE YEARS)

Explosive hazards in Puerto Rico are linked to pyrotechnics manufacturing and storage, industrial operations involving flammable gases and liquids, and fuel terminals in municipios such as Vega Baja, Guayanilla, and Yabucoa (OSHA, n.d.-a). Historical records document a small number of significant explosions and major fires per decade, along with minor incidents (OSHA, n.d.-b).

Given the presence of explosive and flammable materials in coastal industrial zones and urban areas—and the potential for mechanical failures, human error, or seismic triggers—explosive events with community-level consequences are considered moderately likely over the planning horizon (OSHA, n.d.-a).

INTEGRATED MULTI-HAZARD

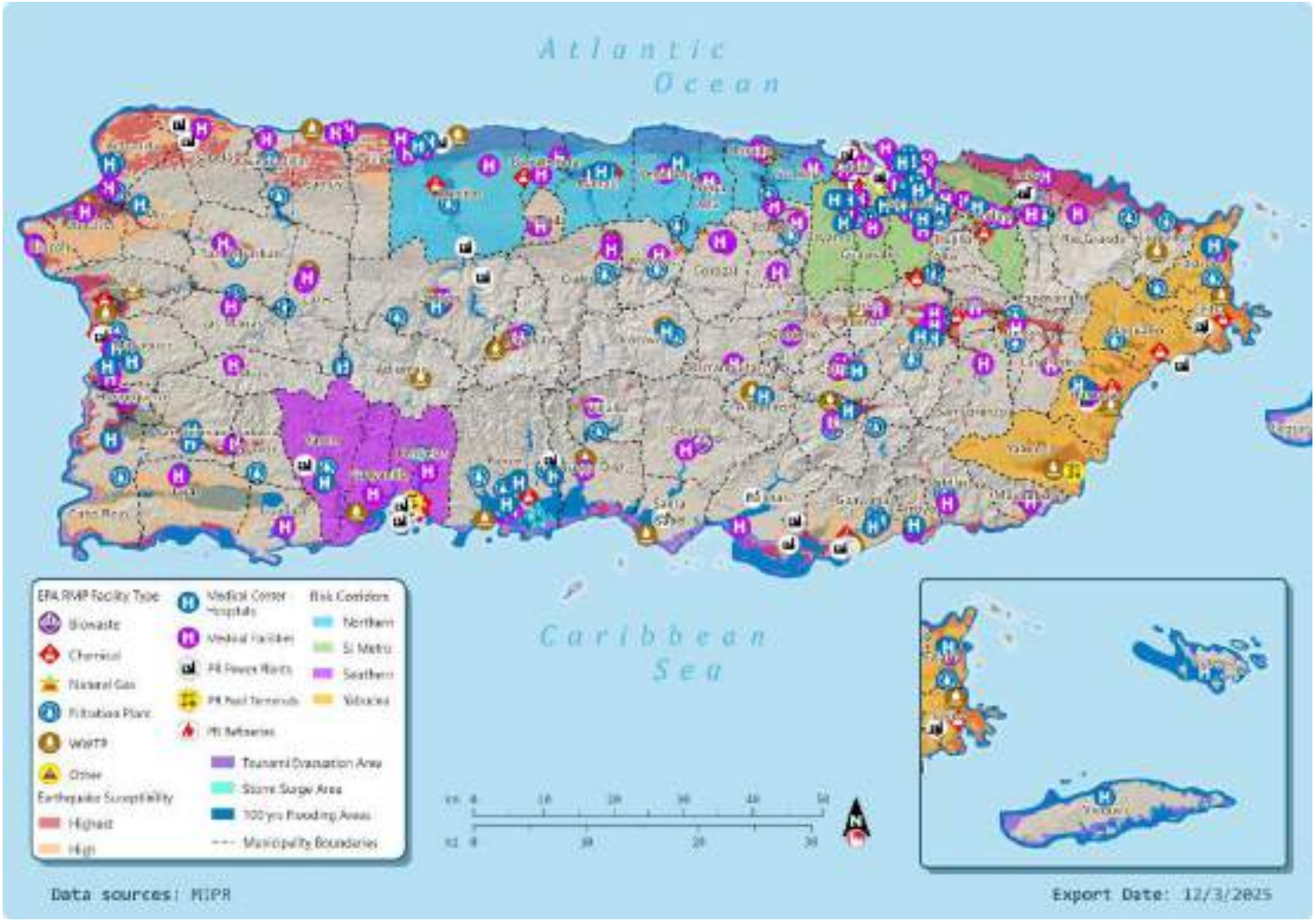


Figure 333: Multi-Hazard CBRNE Probability Map

PROBABILITY: MODERATE–HIGH (MULTI-HAZARD EVENTS IN MULTIPLE MAJOR DISASTERS PER DECADE)

Puerto Rico faces its greatest CBRNE risk from multi-hazard events, where natural hazards intersect with technological systems. These scenarios often involve cascading impacts, such as flooding at industrial sites, hurricanes disrupting wastewater and energy systems, or earthquakes damaging tanks and pipelines (FEMA, 2023; EPA, 2022; NRC, 2022). Recent hurricanes and the 2020 earthquake sequence illustrate how major disasters frequently include CBRNE components, such as hazardous material releases, sewage overflows, and secondary public health impacts (FEMA, 2023; EPA, 2025; OSHA, n.d.-a). Considering the frequency of hurricanes and heavy rainfall, the vulnerability of industrial and wastewater facilities in coastal and flood-prone zones, and documented past disasters with CBRNE dimensions, Puerto Rico is likely to experience multiple multi-hazard events with CBRNE implications within each 10 to 20 year period. These risks are particularly concentrated in the San Juan–Bayamón–Carolina and Guayanilla–Peñuelas industrial corridors (FEMA, 2023; EPA, 2022; OSHA, n.d.-a). Based on these factors, integrated multi-hazard CBRNE scenarios are assessed as having a moderate to high probability over the planning horizon (FEMA, 2025; EPA, 2025).

PROBABILITY CLASSIFICATION TABLE

Table 176 summarizes the qualitative probability ratings for each CBRNE hazard type in Puerto Rico, based on the State Hazard Mitigation Plan's standard likelihood scale (Low, Moderate, High, Very High). These ratings reflect observed patterns, historical incident data, and exposure conditions rather than precise annual frequencies. Each hazard type is classified according to its expected recurrence within the planning horizon and the primary drivers influencing its likelihood. This table provides a quick reference for planners and decision-makers to understand relative risk levels and prioritize mitigation strategies for CBRNE and integrated multi-hazard scenarios.

Table 176: Probability Classification for CBRNE Hazards in Puerto Rico

Hazard Type	Qualitative Probability	Approximate Recurrence (Planning Horizon)	Primary Drivers
Chemical	High	Incidents expected in multiple years within each decade	Aging industrial infrastructure; hurricane and flood exposure; storm surge impacts; seismic sensitivity; hazardous waste sites in Peñuelas and Guayama.
Biological	Moderate	Significant events expected at least once every 5–10 years	Flood-related wastewater overflows; sewage contamination during hurricanes; post-disaster public health conditions; vector-borne disease risk.
Radiological	Low	Isolated minor events in a decade; major events unlikely	Medical isotope use (Cesium-137, Ir-192); transport and handling controls; NRC oversight; no nuclear reactors present.

Hazard Type	Qualitative Probability	Approximate Recurrence (Planning Horizon)	Primary Drivers
Nuclear	Very Low	No major events expected; only transport-related risks	No nuclear power plants; legacy decommissioned BONUS reactor site; DOE oversight; strict federal transportation regulations.
Explosive	Moderate	A small number of significant incidents per decade	Pyrotechnics manufacturing; fuel terminals; industrial operations; seismic triggers; OSHA explosive material standards.
Multi-Hazard (CBRNE + natural)	Moderate–High	Multiple major disasters with CBRNE components per 10–20 years	Hurricanes, floods, and earthquakes affecting industrial and wastewater systems; cascading failures in energy and chemical facilities.

Vulnerability Assessment

Puerto Rico faces significant vulnerability to CBRNE incidents, compounded by recurrent natural hazards such as hurricanes, flooding, earthquakes, and tsunamis. Coastal industrial corridors, aging infrastructure, and concentrated lifelines amplify cascading impacts during multi-hazard events. This assessment evaluates locations, populations, critical facilities, infrastructure, and community lifelines; identifies primary issues; and provides actionable recommendations for mitigation and preparedness.

Puerto Rico's geographic and socio-economic characteristics create a complex risk environment for CBRNE incidents. Industrial hubs, energy facilities, and transportation corridors are concentrated in hazard-prone areas, increasing exposure to cascading failures during natural disasters. This assessment uses FEMA's Community Lifelines framework and jurisdiction-specific hazard analysis to identify vulnerabilities and recommend mitigation strategies.

LOCATIONS

HIGH-LEVEL OVERVIEW

Puerto Rico's vulnerability to CBRNE incidents is compounded by multi-hazard risks. Coastal regions concentrate industrial and energy infrastructure, while southern seismic zones intersect chemical storage and transport corridors. Northern and western coasts face tsunami hazards, and urban centers combine dense populations with hazardous material handling.

JURISDICTIONS MOST THREATENED

- **Southwestern Region – Peñuelas, Guayanilla, Ponce, Yauco**

- Hazards:

  Earthquakes (Lajas Valley fault), hurricanes (storm surge), chemical hazards (LNG, ammonia, petrochemical storage).

- Expanded Context:
  - Peñuelas and Guayanilla host major energy infrastructure, including liquefied natural gas (LNG) terminals and petrochemical facilities, making them highly vulnerable to seismic and flood events.
  - Ponce, the largest city in the south, is a critical transportation hub with a major port and industrial zones, increasing exposure to hazardous material transport disruptions.
  - Yauco lies near seismic fault lines and serves as a key connector for southern supply routes, which could be blocked during earthquakes or chemical spills.
- Multi-Hazard Impact:

  Earthquakes can rupture pipelines and tanks, hurricanes can flood industrial sites, and combined outages delay containment.

- **Northern Metro Area – San Juan, Bayamón, Carolina**
  - Hazards:

    Hurricanes (storm surge up to 6–9 ft), urban flooding, hazardous material transport, radiological facilities.

  - Expanded Context:
    - San Juan, Puerto Rico's capital and largest metro area, concentrates government, healthcare, and port operations, making it critical for emergency response and supply chain continuity.
    - Bayamón is a major industrial corridor with chemical processing and manufacturing facilities, increasing CBRNE exposure during floods or power outages.
    - Carolina, near the main international airport, is essential for evacuation and logistics but highly vulnerable to storm surge and flooding.
  - Multi-Hazard Impact:

    Flooding can disable radiological containment systems, power outages disrupt isotope cooling, and dense population amplifies exposure.

- **Northwest/ Coastal Lowlands – Arecibo, Aguadilla, Barceloneta**
  - Hazards:

    Tsunami (rapid inundation), earthquakes (Puerto Rico Trench), hurricane flooding, chemical hazards near pharmaceutical sites.

- Expanded Context:
  - Arecibo is home to industrial zones and coastal communities exposed to tsunami and hurricane flooding.
  - Aguadilla hosts a major airport and port facilities critical for disaster logistics, but these assets are highly vulnerable to tsunami and storm surge.
  - Barceloneta is a pharmaceutical manufacturing hub, where chemical storage and production facilities face flood and seismic risks.
- Multi-Hazard Impact:

  Tsunamis can overwhelm chemical safety systems, earthquakes compromise structural integrity, and hurricanes add contamination risks.

- **Southeastern Corridor – Yabucoa, Guayama**
  - Hazards:

    Hurricanes (storm surge), petrochemical complexes, fuel terminals, moderate seismic risk.
  - Expanded Context:
    - Yabucoa, historically impacted by Hurricane Maria, is a key entry point for fuel imports and energy distribution, making it critical for lifeline continuity.
    - Guayama hosts large petrochemical and energy facilities that supply power and industrial chemicals across the island, creating high exposure to surge and seismic hazards.
  - Multi-Hazard Impact:

    Storm surge can inundate fuel terminals, causing spills and fire hazards. Earthquakes can damage containment systems, triggering secondary explosions.

KEY PROBLEM STATEMENTS

- Industrial and energy hubs in southwestern and southeastern corridors lie within high-risk flood and storm surge zones, increasing spill and contamination potential.
- Earthquake-prone regions in the south and west overlap with hazardous material storage and transport networks, raising the risk of seismic-triggered chemical releases.
- Tsunami-prone northern and western coasts lack sufficient CBRNE-aware evacuation routes and vertical sheltering options.
- San Juan, Bayamón, and other urban centers combine dense population, critical lifelines, and hazardous material handling, amplifying cascading impacts during multi-hazard events.

POPULATIONS

HIGH-LEVEL OVERVIEW

Population vulnerability mirrors hazard exposure patterns. Coastal and industrial corridors—particularly in San Juan Metro, Southwest (Ponce, Guayanilla, Peñuelas), and Northwest (Arecibo, Aguadilla)—host large populations near hazardous material sites and flood-prone zones. Mountainous regions (central and western interior) face longer response times and limited access to specialized medical care.

EXPANDED CONTEXT BY REGION

- San Juan Metro: Densely populated urban core with high concentrations of hospitals, ports, and industrial corridors; evacuation complexity and high exposure to storm surge amplify risk.
- Southwest: Ponce and surrounding municipalities combine industrial hubs with residential areas near seismic fault lines and petrochemical facilities.
- Northwest: Arecibo and Aguadilla have coastal communities vulnerable to tsunami and hurricane flooding, with limited vertical evacuation options.
- Southeast: Yabucoa and Guayama have smaller populations but high exposure due to proximity to petrochemical complexes and fuel terminals.

KEY PROBLEM STATEMENTS

- Vulnerable populations (elderly, medically dependent, low-income, those with Access and Functional Needs) face disproportionate exposure and delayed evacuation in coastal and industrial zones.
- Public awareness of CBRNE hazards remains low outside metro areas, increasing risk during multi-hazard events.
- Rural and remote communities lack access to specialized healthcare, decontamination, and emergency transport during CBRNE-linked disasters.

STRUCTURES INCLUDING CRITICAL FACILITIES

HIGH-LEVEL OVERVIEW

Critical facilities—including hospitals, energy plants, wastewater systems, ports, and industrial complexes—are concentrated in high-risk coastal zones and urban corridors. Many predate modern hazard-resistant codes and remain within FEMA floodplains, storm surge zones, and mapped seismic areas.

EXPANDED CONTEXT BY REGION

- San Juan Metro: Major hospitals with radiological departments, San Juan Bay port, and energy substations are vulnerable to surge and flooding.
- Southwest: LNG terminals, petrochemical plants, and Ponce port facilities are exposed to seismic shaking and hurricane surge.
- Northwest: Pharmaceutical manufacturing sites and Aguadilla airport are at risk from tsunami and hurricane flooding.
- Southeast: Petrochemical complexes and fuel terminals in Guayama and Yabucoa are highly exposed to surge and seismic hazards.

KEY PROBLEM STATEMENTS

- Hospitals and water treatment plants in flood zones risk losing service and experiencing contamination during storms.
- Industrial sites lack redundant containment and backup power systems for safe shutdown during multi-hazard events.
- Aging structures and limited seismic retrofitting increase vulnerability to earthquakes and explosion shockwaves.
- Radiological healthcare facilities require upgraded containment and fire suppression systems.

INFRASTRUCTURE AND COMMUNITY LIFELINES

HIGH-LEVEL OVERVIEW

Using FEMA's Community Lifelines framework, Puerto Rico's vulnerability is best understood through its interdependent systems: Safety and Security; Food, Hydration, Shelter; Health and Medical; Energy; Communications; Transportation; Hazardous Materials; and Water Systems. Disruption in one lifeline can rapidly degrade others, particularly during hurricanes, earthquakes, and floods that can concurrently trigger CBRNE incidents.

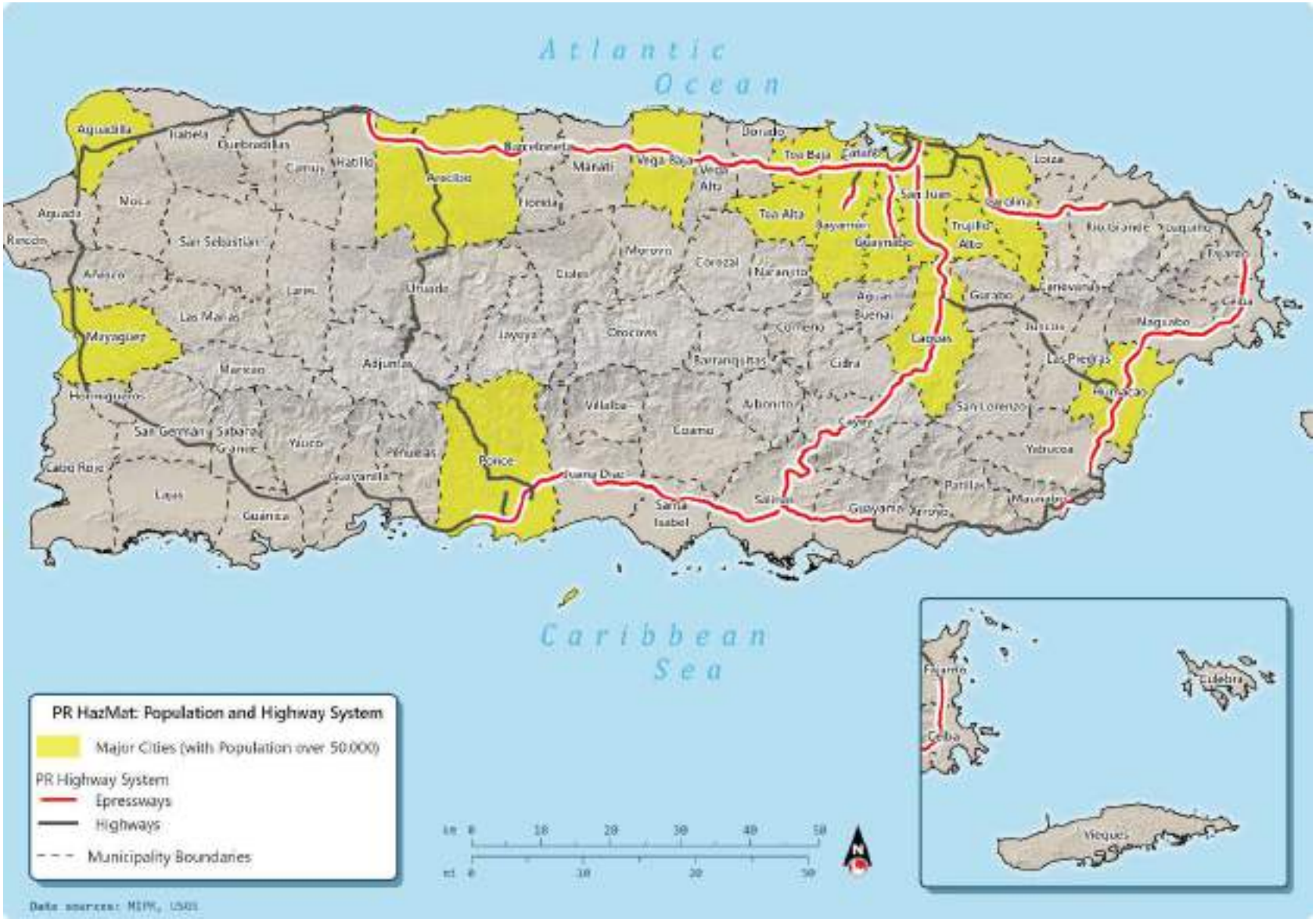


Figure 334: CBRNE Vulnerability Hotspots Map

REGIONAL HIGHLIGHTS

- Southwest: Energy lifeline highly exposed; seismic-triggered outages cascade into hazardous material containment failures.
- San Juan Metro: Communications and Transportation lifelines are critical for evacuation and logistics but are vulnerable to surge and flooding.
- Northwest: Transportation chokepoints and limited HazMat capacity hinder tsunami response.
- Southeast: Energy and hazardous materials lifelines dominate the risk profile; failure impacts fuel supply throughout the island.

KEY PROBLEM STATEMENTS

- Limited HazMat teams and redundant communications undermine incident command during multi-site events.
- Flooding and contamination disrupt water systems and shelter operations.
- Specialized healthcare concentrated in metro areas leaves rural regions under-served.
- Energy infrastructure failures cascade across all lifelines, creating prolonged outages and secondary hazards.

MULTI-HAZARD CONSIDERATIONS

- Multi-hazard interactions amplify CBRNE risks:
  - **Hurricanes and Flooding:** Trigger chemical releases, fuel spills, and biological contamination from inundated industrial and wastewater sites.
  - **Earthquakes:** Compromise pipelines, storage tanks, and containment systems, generating chemical spills and explosive atmospheres.
  - **Tsunamis:** Rapid inundation of coastal industrial areas overwhelms safety systems before shutdown procedures can be completed.
- These interactions create complex emergencies that strain territorial and municipal response capacity.

SUMMARY OF PRIMARY ISSUES AND CONCERNS

- **Coastal Industrial Exposure:** Fuel terminals, LNG facilities, and chemical plants are concentrated in surge zones.
- **Seismic Vulnerability:** Southern and western fault zones intersect hazardous material networks.
- **Tsunami Evacuation Gaps:** Northern and western coasts lack vertical sheltering and rapid evacuation routes.

- **Urban Density & Lifeline Fragility:** Metro areas combine population density with hazardous material handling and aging infrastructure.
- **Limited Regional HazMat Capacity:** Western and southern municipalities lack rapid containment resources.
- **Healthcare Surge Constraints:** Specialized CBRNE treatment is concentrated in metro areas; rural regions are under-served.
- **Multi-Hazard Overlap:** Hurricanes, earthquakes, and tsunamis can simultaneously impact chemical storage, energy systems, and transportation corridors.

ACTION RECOMMENDATIONS

- **Planning & Preparedness**
  - Develop jurisdiction-specific multi-hazard evacuation plans for tsunami and flood-prone regions.
  - Conduct CBRNE-focused drills in high-risk industrial corridors.
  - Expand public awareness campaigns targeting vulnerable populations.
- **Infrastructure Hardening**
  - Retrofit critical facilities for seismic and flood resilience.
  - Install redundant containment systems and backup power at chemical storage sites.
  - Upgrade radiological healthcare facilities with modern fire suppression and isotope containment systems.
- **Lifeline Resilience**
  - Establish regional HazMat teams and pre-position CBRNE response assets.
  - Enhance communications redundancy for emergency services.
  - Harden energy infrastructure against surge and seismic hazards; prioritize microgrids.
  - Improve water system protection with backup power and contamination monitoring.
- **Monitoring & Early Warning**
  - Deploy real-time sensors at hazardous material sites.
  - Integrate CBRNE alerts into the Integrated Public Alert and Warning System (IPAWS) or the Emergency Alert System (EAS) for rapid public notification.
  - Expand GIS-based hazard mapping to identify overlapping risks.[1389]
- **Healthcare Surge Capacity**
  - Develop regional decontamination and triage centers outside metro areas.

[1389] Environmental Protection Agency. (2025). EnviroAtlas: Pollution sources and impacts data for Puerto Rico.

- Stockpile CBRNE-specific medical countermeasures and PPE in rural health facilities.
- Train healthcare staff in radiological and biological incident protocols.

Impact Assessment

This Impact Assessment summarizes how CBRNE incidents in Puerto Rico can disrupt public health, critical infrastructure, the economy, the environment, and FEMA Community Lifelines.[1390] These events often compound hurricanes, floods, and earthquake impacts, creating cascading failures.

CBRNE hazards pose serious health risks, including chemical burns, respiratory distress, infectious disease outbreaks, and mental health impacts. They can damage hospitals, water systems, power plants, and shelters, many of which are located in flood-prone areas, leading to prolonged outages and service interruptions.

Economic losses include facility damage, cleanup costs, and business disruption, while environmental impacts range from chemical contamination of water sources to ecosystem degradation. At the state level, emergency operations centers and major utilities remain vulnerable despite mitigation efforts. At the local level, limited resources and aging infrastructure increase recovery times and severity of impacts.

Understanding these vulnerabilities is critical for planning and resilience-building to protect lives, essential services, and economic stability.[13911392]

STATE ASSETS

CBRNE incidents can significantly affect state-level assets in Puerto Rico, which are critical for island-wide coordination, energy supply, and water service delivery. These include emergency management facilities, major energy infrastructure, large water and wastewater systems, and state-owned facilities such as government buildings, correctional institutions, and public universities (FEMA, 2021; Pharmaceutical Research and Manufacturers Association [PREMA], 2022).

EMERGENCY MANAGEMENT AND COORDINATION

- **Damage to Emergency Operations Centers (EOCs):** Physical damage or contamination of central and regional EOCs can severely limit command and control capabilities during multi-hazard events (FEMA, 2021).
- **Power and Communications Outages:** Prolonged outages disrupt incident management systems, slowing resource allocation and mutual aid coordination (PREMA, 2022).

[1390] Federal Emergency Management Agency (FEMA). (2021). Community Lifelines Toolkit, https://www.fema.gov/emergency-managers/practitioners/lifelines-toolkit.
[1391] AtkinsRéalis. (2025). *Puerto Rico local hazard mitigation planning: Island-wide risk assessment summary (project overview)*.
[1392] Federal Emergency Management Agency. (2023). Puerto Rico Community Mapping Collaboration Project: Case study.

- **Reduced Operational Capacity:** Even temporary closures force reliance on backup facilities that may lack full functionality.

ENERGY INFRASTRUCTURE

- **Vulnerability of Coastal Facilities:** Power plants, substations, and fuel import terminals located in flood-prone areas face risks of hazardous releases, fires, and prolonged outages during hurricanes or earthquakes (Puerto Rico Electric Power Authority [PREPA], 2021; DOE, 2021).
- **Fuel Supply Chain Disruptions:** Damage to terminals can interrupt fuel deliveries for emergency generators at hospitals and water plants, compounding cascading failures.
- **Extended Recovery Times:** Contaminated components require specialized cleaning or replacement, delaying restoration for weeks or months.

WATER AND WASTEWATER SYSTEMS

- **Structural Damage and Contamination:** State-regulated treatment plants may suffer pump failures or chemical intrusion during major events, leading to boil-water advisories and service interruptions (EPA, 2020; USGS, 2021).
- **Geographic Exposure:** Large plants serving metropolitan areas often sit near rivers or coastlines, making them highly exposed to flooding and hazardous material spills.
- **Complex Restoration Needs:** Recovery requires flushing, disinfection, and infrastructure repairs, often delayed by limited hazardous waste disposal capacity.

STATE-OWNED FACILITIES

- **Government Buildings:** Administrative offices, courthouses, and legislative facilities may be contaminated or damaged, disrupting governance and essential public services (FEMA, 2021).
- **Correctional Institutions:** Prisons and detention centers face unique challenges during CBRNE incidents, including evacuation logistics, contamination control, and maintaining security (DHS, 2020).
- **Public Universities and Research Centers:** Laboratories and campuses may store hazardous chemicals or radiological materials, increasing risk during disasters. Damage can halt academic operations and research critical to recovery (EPA, 2020; Puerto Rico Department of Education, 2021).
- **Transportation Hubs Owned by the State:** State-managed ports and airports are vulnerable to contamination and explosive hazards, delaying emergency aid and economic recovery (NOAA, 2021).

INTERDEPENDENCIES AND CASCADING RISKS

State-level assets depend on energy, water, communications, and transportation lifelines. A failure in one system—such as a power outage at a water treatment plant—can cascade into public health emergencies, economic losses, and operational delays across multiple sectors (FEMA, 2021; DHS, 2020).

LOCAL ASSETS

At the local level, CBRNE incidents can degrade municipal facilities, emergency services, and community resources, especially in areas with limited healthcare access, fewer local responders, or aging infrastructure (CDC, 2022; FEMA, 2021).

LOCAL EMERGENCY SERVICES

- **Fire, Rescue, and Police Stations:** Many are located in flood-prone or coastal areas, making them vulnerable to flooding, contamination, and structural damage. When these facilities are compromised, response times increase and mutual aid from neighboring jurisdictions becomes essential (FEMA, 2021).
- **Operational Challenges:** Contamination zones and hazardous debris can restrict vehicle movement, and decontamination requirements slow deployment and reduce available personnel (DHS, 2020).

COMMUNITY SHELTERS AND PUBLIC FACILITIES

- **Shelter Unsuitability:** Schools, community centers, and other designated shelters often lack adequate filtration systems, contamination control measures, or backup power. During chemical, biological, or radiological incidents, these deficiencies can make shelters unsafe for occupancy (CDC, 2022).
- **Secondary Impacts:** Shelters frequently serve as distribution points for food and water. If contamination occurs, it can disrupt multiple lifelines simultaneously and increase strain on emergency feeding and housing programs.

LOCAL HEALTH CLINICS AND HOSPITALS

- **Limited Capacity for Specialized Care:**[1393] Smaller clinics and hospitals often lack decontamination facilities and specialized CBRNE treatment capabilities. They may also face shortages of PPE and trained staff during large-scale incidents (Puerto Rico Department of Health, 2021).
- **Infrastructure Vulnerabilities:** Power loss, flood damage, and aging mechanical systems can force closures or limit services, especially in rural municipios where alternative care options are scarce (CDC, 2022).
- **Extended Recovery Times:** Restoration of services may require structural repairs, equipment replacement, and hazardous waste disposal, which can delay community recovery.

LOCAL-OWNED FACILITIES

- **Municipal Buildings:** Town halls, local government offices, and public works facilities may be contaminated or damaged, which can disrupt essential administrative functions and delay recovery operations (FEMA, 2021).

[1393] Puerto Rico Department of Health. "Threat, Vulnerability and Risk Analysis," 2025, https://www.salud.pr.gov/CMS/597.

- **Public Schools:** Schools often serve as shelters and community hubs. Damage or contamination can halt education and eliminate critical shelter capacity during disasters (Puerto Rico Department of Education, 2021).
- **Community Centers and Libraries:** These facilities often act as resource distribution points and emergency communication hubs. Their loss reduces community resilience and access to vital information (CDC, 2022).
- **Local Water and Wastewater Facilities:** Smaller treatment plants and pump stations owned by municipalities are highly vulnerable to flooding and chemical intrusion and often lack redundancy or backup power (EPA, 2020; USGS, 2021).

COMPOUNDING FACTORS

- **Geographic Isolation:** Rural and mountainous areas may experience delayed assistance due to transportation disruptions and limited local resources.
- **Socioeconomic Vulnerabilities:** Communities with fewer financial resources face greater challenges in accessing private recovery options, which increases reliance on state and federal aid.

COMMUNITY LIFELINES

CBRNE incidents in Puerto Rico can disrupt multiple lifelines simultaneously and create cascading failures across essential services (FEMA, 2021). Below is an expanded view of impacts aligned with FEMA's seven lifelines:

SAFETY AND SECURITY

- **Restricted Access for Emergency Services:** Hazardous releases, contamination zones, and explosive debris fields can severely limit the ability of police, fire, and EMS to reach affected areas. This delay in response can result in prolonged exposure to residents and increased mortality rates during emergencies (DHS, 2020).
- **Damage to Emergency Facilities and Equipment:** Explosions and fires can destroy fire stations, police precincts, and emergency vehicles, reducing operational capacity and forcing reliance on distant backup resources.[1394]
- **Operational Slowdowns Due to Decontamination:** Responders must use specialized PPE and undergo decontamination procedures before and after entering contaminated zones, which significantly slows response times and reduces coverage in unaffected areas (FEMA, 2021).
- **Evacuation Challenges:** Hazardous spills on major roads can block evacuation routes, forcing detours that increase travel time and complicate sheltering operations.

[1394] DHS. (2020). Explosives Threat Assessment. https://www.dhs.gov/science-and-technology/explosives-threat-assessment.

FOOD, HYDRATION, AND SHELTER

- **Drinking Water Contamination:** Chemical spills and sewage overflows can infiltrate water treatment plants and distribution systems, leading to boil-water advisories and service interruptions. Communities may become dependent on bottled water and tanker deliveries for extended periods (EPA, 2020; CDC, 2022).
- **Shelter Unsuitability:** Flood-associated sewage spills and airborne contaminants can render designated shelters unsafe without extensive sanitation measures, which reduces available shelter capacity during disasters.
- **Food Supply Chain Disruptions:** Port closures and hazardous material spills on highways can interrupt food deliveries and create shortages in grocery stores and emergency feeding programs. This disruption can last weeks if contamination affects major transportation hubs (NOAA, 2021).
- **Increased Reliance on Emergency Feeding Operations:** With local food systems compromised, emergency feeding programs must scale up rapidly, straining logistics and resources.

HEALTH AND MEDICAL

For Puerto Rico, public health impacts are often secondary to major disasters but can cause both acute and long-term health effects.

- **Acute Health Effects:** Chemical exposures can cause severe respiratory distress, burns, and neurological symptoms, which require specialized treatment and intensive care (Agency for Toxic Substances and Disease Registry [ATSDR], 2021; EPA, 2020).[13951396]
- **Disease Outbreaks:** Biological contamination from sewage overflows and stagnant floodwaters can lead to gastrointestinal illness and vector-borne diseases such as dengue and leptospirosis (CDC, 2022).[1397]
- **Radiological Risks:** Although typically localized, mishandled medical isotopes can expose patients, staff, and nearby residents to harmful radiation doses, necessitating specialized containment and treatment (NRC, 2021).[1398]
- **Traumatic Injuries and Mental Health Impacts:** Explosive events cause burns, lacerations, and blast injuries, and survivors often experience long-term psychological trauma, including post-traumatic stress disorder (PTSD) (DHS, 2020).

[1395] Agency for Toxic Substances and Disease Registry (ATSDR). (2021). Toxicological Profiles. https://www.atsdr.cdc.gov/toxicological-profiles/about/index.html.
[1396] Centers for Disease Control and Prevention. (2024). About chemical emergencies and associated chemical fact sheets (e.g., ammonia, benzene).
[1397] CDC. (2022). Waterborne Disease and Public Health Preparedness. https://www.cdc.gov/healthy-water-data/about/index.html.
[1398] U.S. Nuclear Regulatory Commission (NRC). (2021). Radiological Safety Guidelines. https://www.nrc.gov/about-nrc/radiation.

- **Hospital Surge and Capacity Reduction:** Hospitals may face overwhelming patient surges, staff exposures, and contamination of critical areas, which can reduce available beds and delay elective procedures (Puerto Rico Department of Health, 2021).

ENERGY (POWER AND FUEL)

In Puerto Rico, numerous critical facilities—such as power plants, substations, wastewater treatment plants, ports, and hospitals—are concentrated in coastal or flood-prone areas, which makes them highly vulnerable to hurricanes and intense rainfall (DOE, 2021; PREPA, 2021).

- **Storm-Driven Impacts:** Hurricanes and heavy rain can cause severe damage and contamination, leading to prolonged closures of hospitals, clinics, and dialysis centers; loss of functionality at pump stations, treatment plants, and industrial sites; and cumulative structural and mechanical deterioration that heightens vulnerability to future events.
- **Infrastructure Failures:** Explosions or contamination at fuel terminals and power plants may trigger shutdowns, resulting in widespread outages that disrupt homes, businesses, and critical facilities (PREPA, 2021; DOE, 2021).[1399]
- **Extended Recovery:** Specialized cleaning or component replacement is often required for contaminated or damaged systems, which can delay power restoration for weeks or even months (DOE, 2021).
- **Fuel Supply Chain Disruptions:** Damage to import terminals or hazardous spills along transport routes can interrupt fuel deliveries to generators at hospitals, shelters, and water treatment plants, compounding cascading failures.

COMMUNICATIONS

- **Network Disruptions:** Power loss and tower damage degrade cellular coverage, 911 service, and data networks, hindering emergency coordination and public alerts (FEMA, 2021).
- **Repair Delays:** Contamination zones restrict access for telecom crews, prolonging outages and reducing situational awareness during critical response periods.
- **Emergency Alert Failures:** Damage to infrastructure or delayed restoration of power can prevent timely dissemination of warnings, increasing risk to populations in affected areas.

TRANSPORTATION

- **Port Closures:** Hazardous spills or contamination at maritime terminals can halt cargo operations, delaying delivery of essential goods, medical supplies, and fuel (FEMA, 2021; NOAA, 2021).
- **Roadway Blockages:** Chemical or biological contamination on highways can impede evacuation and emergency response, forcing rerouting and increasing travel times.

[1399] Puerto Rico Electric Power Authority (PREPA). (2021). Energy Infrastructure Vulnerability Assessment. https://www.energy.gov/ceser/response-recovery.

- **Airport Disruptions:** Explosive hazards or contamination at airports can suspend flights and limit inbound aid and outbound evacuations during emergencies.

HAZARDOUS MATERIALS MANAGEMENT

- **Containment Challenges:** Large-scale spills and releases often exceed local containment capacity, requiring specialized teams, mutual aid, and federal support (EPA, 2020).[1400]
- **Long-Term Waste Disposal:** Contaminated soils, debris, and personal property require safe disposal, often necessitating off-island transport due to limited hazardous waste facilities.
- **Extended Recovery Timelines:** Waste management and remediation efforts can take months or years, delaying community recovery and increasing costs.

WATER SYSTEMS

- **Contamination of Drinking Water Sources:** Chemical spills, sewage overflows, and hazardous material releases can infiltrate surface water and groundwater, leading to unsafe drinking water and boil-water advisories (EPA, 2020; CDC, 2022).[1401]
- **Treatment Plant Vulnerabilities:** Water treatment facilities may experience structural damage, pump failures, or chemical intrusion during hurricanes, floods, or earthquakes. Power outages further disrupt treatment processes, reducing water quality and availability (DOE, 2021; FEMA, 2021).[1402]
- **Distribution System Disruptions:** Corrosive chemicals can damage pipes and valves, and biological contamination can require extensive flushing and disinfection before service restoration. These repairs often take weeks or months, delaying recovery (EPA, 2020).
- **Private Wells and Small Systems:** Rural communities relying on private wells or small water systems face heightened risks of contamination and often lack resources for testing and remediation (USGS, 2021).
- **Extended Recovery and Resource Strain:** Restoration efforts require specialized equipment, hazardous waste disposal, and coordination across multiple agencies. Limited hazardous waste facilities on the island exacerbate disposal challenges (EPA, 2020).[1403]

CROSS-CUTTING IMPACTS OF CBRNE IMPACTS

CBRNE incidents rarely affect a single sector in isolation. Instead, they create cascading failures across multiple lifelines and critical systems, amplifying the overall impact on communities, businesses, and government operations.

[1400] U.S. Environmental Protection Agency (EPA). (2020). Chemical Safety and Hazard Investigation Reports. https://www.csb.gov/.
[1401] U.S. Environmental Protection Agency (EPA). (2021). Occurrence of releases with the potential to impact sources of drinking water (EPA 817-R-21-001).
[1402] Environmental Protection Agency. (2025). Drinking water contaminants exposure and health risks research.
[1403] Environmental Protection Agency. (2025). Drinking water: Report on the environment – Contaminants and health.

BUILDINGS AND CRITICAL FACILITIES

- **Structural Damage and Contamination:** Corrosive chemicals can penetrate building materials, HVAC systems, and electrical components, requiring extensive remediation or full reconstruction (EPA, 2020; DHS, 2020), whereas explosions can cause catastrophic structural failure, rendering facilities inoperable for months.
- **Loss of Function in Essential Services:** Hospitals, emergency operations centers, water treatment plants, and power substations often share vulnerabilities such as coastal locations and aging infrastructure. When one facility fails, dependent services—like dialysis centers or wastewater treatment—also collapse (FEMA, 2021).
- **Compounded Recovery Challenges:** Facilities damaged by hurricanes or earthquakes may already be weakened, making them more susceptible to CBRNE contamination. This layered damage increases repair costs and prolongs downtime (NOAA, 2021).

ECONOMIC DISRUPTION

- **Direct Losses:** Include destruction of industrial assets, product spoilage, and costly cleanup operations (EPA, 2020). For example, chemical contamination in a pharmaceutical plant can halt production and require disposal of millions in inventory.
- **Indirect Losses:** Business interruption ripples through supply chains, affecting manufacturing, retail, and tourism. Port closures delay imports and exports, while contamination of beaches and marinas devastates tourism revenue (FEMA, 2021).
- **Long-Term Economic Impacts:** Persistent contamination can erode investor confidence, reduce property values, and increase insurance premiums, creating systemic financial strain (DHS, 2020).

ENVIRONMENTAL DEGRADATION

- **Water Resource Contamination:** Hazardous chemicals and sewage spills infiltrate rivers, aquifers, and coastal waters, threatening drinking water supplies and aquatic ecosystems (USGS, 2021; EPA, 2020). Cleanup may require dredging, chemical neutralization, and long-term monitoring.
- **Ecosystem Stress:** Contaminants disrupt food webs, reduce biodiversity, and impair fisheries critical to local economies. Combined with sea-level rise and other climate stressors, these impacts accelerate habitat loss (NOAA, 2021).[1404]
- **Persistent Pollutants:** Some chemicals, such as Polychlorinated biphenyls (PCBs) or heavy metals, remain in soils and sediments for decades, posing chronic health risks and complicating redevelopment efforts (ATSDR, 2021).

[1404] National Fish and Wildlife Foundation. (2019). Puerto Rico Coastal Resilience Assessment.

INTERDEPENDENCIES AND CASCADING FAILURES

- **Energy-Water Nexus:** Power outages at water treatment plants halt potable water production, while contaminated water systems increase hospital strain (DOE, 2021; FEMA, 2021).
- **Transportation-Economy Link:** Road closures delay fuel deliveries, which in turn affect generator operations at hospitals and shelters (NOAA, 2021).
- **Communications-Emergency Response:** Telecom outages hinder coordination among responders, slowing hazardous material containment and evacuation efforts (FEMA, 2021).

Changes in Development

This section analyzes how development patterns, reconstruction efforts, demographic shifts, and changes in state and local assets since the 2017 hurricanes and 2020 earthquakes have altered Puerto Rico's exposure and vulnerability to CBRNE hazards. It addresses land use and the built environment, projected growth and redevelopment, population changes, and evolving vulnerabilities at state and local levels [1],[2].

LAND USE AND BUILT ENVIRONMENT CHANGES[1405]

Puerto Rico's 2015 Land Use Plan (*Plan de Uso de Terrenos*) continues to guide development and conservation decisions across the island, including coastal industrial zones and urban corridors where many CBRNE-relevant facilities are located [1]. Since 2017, federal recovery programs and private investment have driven extensive reconstruction and new construction, particularly in coastal communities and metropolitan areas [2],[3].[1406] [1407]

KEY PATTERNS AFFECTING CBRNE RISK[1408]

- **Rebuilding and expansion in coastal industrial corridors:** Refineries, fuel import terminals, and other industrial facilities remain concentrated in low-lying areas vulnerable to storm surge and riverine flooding [1],[2].
- **Urban densification near critical facilities:** Mixed-use and commercial redevelopment in the San Juan–Bayamón–Carolina corridor has increased the number of residents and businesses near

[1405] Puerto Rico Planning Board. Plan de Uso de Terrenos de Puerto Rico (Land Use Plan). Government of Puerto Rico. 2015. https://guaynabocity.gov.pr/en/oficina-de-planificacion-y-ordenacion-territorial/soil-zoning-map/.
[1406] Federal Emergency Management Agency, "FEMA Continues to Streamline Recovery in Puerto Rico, Enhances Resilient Outcomes and Equitable Solutions," 2024, https://www.fema.gov/print/pdf/node/676733.
[1407] Federal Emergency Management Agency (FEMA). Puerto Rico Recovery Progress Reports. FEMA, various years, https://www.fema.gov/print/pdf/node/676733.
[1408] Government of Puerto Rico, CDBG MIT Program. (2023). Mitigation and Adaptation Policy Support (MAPS) Program Guidelines.

hospitals, laboratories, ports, and major transportation hubs that handle hazardous materials [1],[4].[1409]

- **Targeted mitigation for infrastructure:** Billions of dollars in FEMA and other federal recovery funding have supported hazard mitigation measures at infrastructure projects, including elevation, flood protection, and hardening of critical facilities [2],[5].[1410]

While structural resilience at many facilities has improved, exposure of people and assets in coastal and urban hazard zones remains high—and in some locations has increased—as redevelopment intensified in already at-risk areas [1],[2],[5].

PROJECTED FUTURE GROWTH AND RE-DEVELOPMENT

Over the next decade, Puerto Rico's development trajectory will be shaped by continued recovery funding, Community Development Block Grant Disaster Recovery (CDBG-DR) and Community Development Block Grant–Mitigation (CDBG-MIT) investments, and energy system modernization [2],[3],[6].

KEY TRENDS WITH CBRNE IMPLICATIONS

- **Large-scale mitigation and infrastructure investments:** The U.S. Department of Housing and Urban Development (HUD) has allocated $8.285 billion in CDBG-MIT funds to Puerto Rico, and the Commonwealth's action plan emphasizes mitigation for housing, infrastructure, and planning [3],[6].[14111412]
- **Ongoing reconstruction of critical infrastructure:** FEMA and Commonwealth recovery reports highlight thousands of infrastructure projects—many incorporating hazard mitigation measures—across energy, water, transportation, and public facilities [2],[5].
- **Potential for renewed industrial and energy siting in hazard-prone areas:** Some planned or proposed projects under CDBG-DR/MIT and other programs may reinforce industrial and energy uses in flood-prone or coastal areas unless land use and siting decisions explicitly account for multi-hazard CBRNE risk [1],[3],[6].

If these investments are not paired with stronger land use controls, safe siting guidance, and enhanced CBRNE monitoring, redevelopment could increase the concentration of high-consequence facilities in

[1409] Puerto Rico Department of Transportation and Public Works. Urban Redevelopment and Transportation Corridor Studies. Government of Puerto Rico. 2020. https://caguas.gov.pr/wp-content/uploads/2025/03/TransportationSystemPlan2024.pdf.
[1410] FEMA Hazard Mitigation Grant Program (HMGP). Puerto Rico Hazard Mitigation Projects Summary. FEMA. 2018–2023. https://www.fema.gov/grants/mitigation/learn/hazard-mitigation.
[1411] U.S. Department of Housing and Urban Development (HUD). Community Development Block Grant Disaster Recovery (CDBG-DR) and Mitigation (CDBG-MIT) Action Plans for Puerto Rico. HUD, 2018–2023, https://www.hud.gov/hud-partners/community-cdbg-dr.
[1412] U.S. Department of Housing and Urban Development (HUD). CDBG-MIT Allocation and Mitigation Action Plan for Puerto Rico. HUD, 2020, https://www.hud.gov/sites/dfiles/CPD/documents/FR-6109-N-04-CDBG-MIT-Allocation-Puerto-Rico-Spanish.pdf.

hazard-exposed corridors—even as individual structures become more resistant to wind and water [1],[3],[6].

POPULATION CHANGES

Puerto Rico's population has continued to decline overall, but demographic and spatial changes since 2017 have important implications for CBRNE vulnerability [7],[8].

KEY DYNAMICS

- **Island-wide population decline with local concentration:**[1413] Census estimates show that the Commonwealth's total population has decreased since 2017, while some metropolitan municipios—particularly in the San Juan area—remain densely populated, including in coastal and industrial corridors [7],[8].
- **Aging population:** A growing share of residents age 65 and older increases sensitivity to chemical exposures, heat, infectious disease, and prolonged service disruptions during complex events [8].[1414]
- **Persistent health-system and workforce constraints:** Federal health assessments highlight long-standing shortages of health professionals and medically underserved municipalities, especially outside major urban centers, limiting local capacity to manage CBRNE-related health impacts and extended emergencies [9].[1415]

These trends mean that, even with fewer total residents, more socially vulnerable and medically fragile populations may be living in or near high-risk corridors, while rural communities may have less capacity to prepare for and respond to CBRNE incidents [8],[9].

VULNERABILITY OF STATE ASSETS CHANGES

State-level assets—such as central emergency management, major energy infrastructure, and large water systems—have been the focus of significant reconstruction and mitigation since the 2017 hurricanes and 2020 earthquakes [2],[5],[10].

Notable changes:

- **Increased investment in critical infrastructure resilience:** FEMA Public Assistance and hazard mitigation funding, along with other federal programs, have supported rebuilding and hardening of

[1413] U.S. Census Bureau. Puerto Rico Population Estimates and Demographic Trends. https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-puerto-rico-municipios.html.
[1414] Puerto Rico Institute of Statistics. Demographic and Aging Trends in Puerto Rico, https://estadisticas.pr/.
[1415] U.S. Department of Health and Human Services (HHS). Health Professional Shortage Areas and Medically Underserved Areas in Puerto Rico, https://aspe.hhs.gov/sites/default/files/private/pdf/255466/PuertoRico_Assessment.pdf.

power plants, substations, major water and wastewater facilities, hospitals, and other critical state-level assets [2],[5],[10].[1416]

- **Enhanced planning and policy capacity:** The CDBG-MIT Mitigation Action Plan and related programs include support for revising building codes, land use plans, and mitigation policies, which can reduce long-term exposure if fully implemented [3],[6],11].

However:

- **Centralization of leadership and facilities in the San Juan metropolitan area continues to create potential single points of failure** for emergency management, energy coordination, and other state functions during large or multi-hazard CBRNE events [2],[10].
- **Dependence on complex, interdependent lifelines means that damage to energy, water, or telecommunications** can still rapidly degrade performance of state assets, even when individual facilities are hardened [2],[5].

In summary, state assets are more robust structurally but remain vulnerable to cascading infrastructure failures and geographic concentration [2],[5],[10].

VULNERABILITY OF LOCAL ASSETS CHANGES

At the local level, development and recovery have produced uneven changes in vulnerability across municipalities. Larger urban areas have gained some capability, while many smaller or rural jurisdictions still face resource and personnel constraints [3],[9],[11].

KEY OBSERVATIONS

- **Local emergency services and HazMat capacity have improved in some metropolitan municipalities** that benefitted from recovery funding and have larger tax bases, but many smaller municipios still depend on regional or external support for hazardous materials incidents and specialized response functions [3],[11].[1417]
- **Health care access and local facilities remain limited in many communities:** Federal assessments identify most Puerto Rico municipios as medically underserved, which can slow detection, treatment, and public health response during CBRNE-related events [9].
- **Sheltering and local critical facilities—including schools, community centers, and small clinics**—often lack specialized capabilities such as enhanced filtration, contamination control zones, and robust backup power, even when designated as shelters or staging points [3],[11].

[1416] Puerto Rico Electric Power Authority (PREPA) and Puerto Rico Aqueduct and Sewer Authority (PRASA). Infrastructure Resilience and Recovery Reports. https://recovery.pr.gov/documents/Tenth%20Congressional%20Report%20%2812-1-23%29.pdf.
[1417] Puerto Rico Emergency Management Bureau (PREMB). Local Emergency Management Capacity Assessments and Hazardous Materials Response Plans, https://recovery.pr.gov/en/road-to-recovery/pa-faast/map.

As a result, local vulnerability has decreased modestly in some urban centers but remains elevated, or has worsened, in many rural or economically stressed communities, especially where population decline coincides with loss of services and workforce [3],[9],[11].

SUMMARY TABLE

Table 177: Development and Vulnerability Change Overview

Section	Development Trend	Effect on CBRNE Exposure/Vulnerability
Land Use & Built Environment	Continued coastal and urban redevelopment; facility hardening; hazard mitigation investments	Exposure in hazard zones remains high despite hardening; improved structural resilience but systemic risk persists
Future Growth & Redevelopment	Large recovery and mitigation investments; energy modernization; thousands of projects underway	Potential for safer facilities but greater concentration of high-consequence sites; hazard exposure may rise without land-use controls
Population Changes	Overall population decline; aging population; urban concentration; health system and workforce shortages	Fewer people overall but more vulnerable populations in risk corridors; limited rural capacity for CBRNE response
State Asset Vulnerability	Hardening of major infrastructure; policy updates; improved planning capacity; centralization in San Juan	Better individual facility resilience but systemic vulnerability to cascading failures and single points of failure remains
Local Asset Vulnerability	Uneven gains: metro areas improved HazMat capacity; persistent service gaps in rural areas; shelters lack specialized controls	Metro capacity improves but rural CBRNE readiness remains limited; uneven preparedness and limited contamination control

CBRNE Mitigation Success Stories

Puerto Rico faces unique challenges in managing CBRNE risks due to its geographic location, industrial footprint, and exposure to hurricanes, earthquakes, and flooding. These hazards can trigger cascading failures across critical lifelines, such as water, energy, transportation, and healthcare systems. To address these vulnerabilities, Puerto Rico has implemented a multi-layered mitigation strategy that combines infrastructure investments, regulatory compliance, and interagency coordination. This section provides an overview of these strategies and highlights success stories that demonstrate tangible progress in reducing CBRNE risks and improving resilience.

CBRNE MITIGATION STRATEGY OVERVIEW

Puerto Rico's approach to CBRNE mitigation is grounded in national standards and adapted to local hazard conditions. The strategy leverages federal funding, territorial planning frameworks, and technical expertise to create a comprehensive risk reduction program.[1418] Key components include:

- **FEMA Hazard Mitigation Assistance (HMA) Programs:** The Hazard Mitigation Grant Program (HMGP) and Building Resilient Infrastructure and Communities (BRIC) provide funding for projects that reduce long-term disaster risk. These programs prioritize lifeline protection and resilience against multi-hazard threats (FEMA, 2023).[1419]
- **Community Development Block Grant–Mitigation (CDBG-MIT):** Administered by HUD, this program supports large-scale infrastructure improvements and planning initiatives that enhance resilience in vulnerable communities (HUD, 2022).
- **Federal Regulatory Frameworks:** Agencies such as EPA, OSHA, PHMSA, and NRC establish standards for hazardous materials management, worker safety, and radiological controls. These regulations guide facility upgrades and operational protocols in Puerto Rico (EPA, 2023; OSHA, 2023).
- **Territorial Planning and Response Frameworks:** Local agencies, including PREMB, PRASA, and DOH, translate national standards into actionable plans tailored to Puerto Rico's hazard environment. These frameworks ensure coordination across sectors and levels of government.

STRATEGIC GOALS:

12. **Prevent Hazardous Releases:** Reduce the likelihood and consequences of chemical, biological, and radiological contamination at industrial, energy, health, and water facilities exposed to natural hazards.
13. **Protect Critical Lifelines:** Strengthen infrastructure to prevent cascading failures in essential services such as water, power, transportation, and healthcare.
14. **Enhance Preparedness and Coordination:** Improve monitoring, training, and interagency collaboration for multi-hazard CBRNE scenarios.

KEY MITIGATION APPROACHES

Puerto Rico employs a combination of structural, non-structural, and programmatic measures to reduce CBRNE risk:

- **Facility Hardening:** Industrial, energy, water, and healthcare facilities located in floodplains or seismic zones are being retrofitted with elevation measures, floodwalls, secondary containment systems, and

[1418] Federal Emergency Management Agency. (2023). Hazard Mitigation Assistance Program and Policy Guide (Version 1.1). U.S. Department of Homeland Security.
[1419] Puerto Rico Department of Housing. (2020). Community Development Block Grant Mitigation (CDBG-MIT) Action Plan for Puerto Rico.

seismic reinforcements. These upgrades reduce physical damage and prevent hazardous material releases during disasters.

- **Water and Wastewater System Modernization:** Treatment plants are being equipped with backup generators, improved disinfection systems, and upgraded chemical handling protocols. These measures ensure continuity of operations during power outages and floods, reducing contamination risks.
- **Hazardous Materials Management:** Facilities handling fuels, ammonia, chlorine, and other hazardous substances are implementing enhanced storage, monitoring, and emergency shutoff systems. These improvements align with EPA's Risk Management Program and PHMSA standards, reducing the probability of accidental releases.
- **Energy System Resilience:** Projects funded by FEMA, DOE, and CDBG-MIT focus on strengthening the electric grid and providing reliable backup power for hospitals, emergency operations centers, and water facilities. These efforts mitigate cascading risks associated with prolonged outages.
- **Planning, Training, and Exercises:** PREMB leads multi-hazard drills and integrates CBRNE considerations into municipal mitigation and emergency operations plans. These activities build capacity among local responders and improve coordination during emergencies.[14201421]
- **Public Awareness and Preparedness:** Outreach campaigns educate communities on hazard awareness, risk communication, and safe behaviors during chemical, biological, and radiological incidents. These efforts enhance community resilience and reduce exposure.

Mitigation Success Stories

HARDENING WATER AND WASTEWATER FACILITIES[1422]

Hazard Focus: Chemical and Biological

Lifelines: Food, Water, and Shelter; Health and Medical

Puerto Rico has prioritized upgrades to drinking water and wastewater treatment facilities through FEMA Public Assistance, HMGP, and other funding streams. Key improvements include elevating critical equipment above flood levels, installing backup generators, and modernizing chlorine and disinfection systems. These measures:

- Maintain treatment operations during outages and floods.

[1420] Occupational Safety and Health Administration. (2024). Hazardous waste operations and emergency response (29 C.F.R. § 1910.120). U.S. Department of Labor.
[1421] Puerto Rico Emergency Management Bureau. (2024). Hazard mitigation and emergency operations planning guidance – Puerto Rico. Government of Puerto Rico.
[1422] Puerto Rico Aqueduct and Sewer Authority. (2023). System improvements and mitigation projects for drinking water and wastewater facilities – Project summaries. Puerto Rico Aqueduct and Sewer Authority.

- Reduce the risk of sewage overflows and untreated discharges during storms.
- Improve safe handling and containment of chlorine, ammonia, and other chemicals.

By addressing vulnerabilities documented during past hurricanes and flood events, these projects significantly reduce contamination risks and protect public health (FEMA, 2023; PRASA, 2022).

ENERGY INFRASTRUCTURE RESILIENCE AND BACKUP POWER[14231424]

Hazard Focus: Chemical, Explosive, Multi-Hazard

Lifelines: Energy; Health and Medical; Water; Communications

Energy resilience is critical to prevent cascading failures during disasters. FEMA, DOE, and Commonwealth partners have implemented:[1425]

- Long-term recovery and mitigation plan for transmission and distribution systems.
- Reliable backup generation and fuel supplies for hospitals, emergency operations centers, water facilities, and communications sites.
- Integration of hazard mitigation measures into energy reconstruction projects to withstand hurricanes and earthquakes.

These investments reduce the likelihood that prolonged outages will compromise critical systems, such as pumps at industrial facilities or treatment capacity at water plants (DOE, 2023; FEMA, 2023).

COASTAL AND FLOOD RESILIENCE IN INDUSTRIAL CORRIDORS[1426]

Hazard Focus: Chemical, Explosive, Multi-Hazard

Lifelines: Energy; Transportation; Hazardous Materials

Coastal industrial areas face high exposure to storm surge and flooding. Federal and Commonwealth programs have supported projects that include drainage improvements, shoreline stabilization, and protective infrastructure. These efforts:

- Lower the probability of inundation at industrial sites and tank farms.
- Limit hazardous material spills into communities and ecosystems.

[1423] U.S. Department of Energy, Office of Electricity. (2024). Puerto Rico energy resilience and grid modernization initiatives. U.S. Department of Energy.
[1424] Federal Emergency Management Agency. (2024). Puerto Rico recovery and mitigation projects: Progress update fact sheet. U.S. Department of Homeland Security.
[1425] U.S. Department of Energy (DOE). (2021). Energy Sector Resilience Guidelines. https://www.energy.gov/eere/listings/energy-resilience.
[1426] U.S. Army Corps of Engineers. (2022). Coastal flood risk management and resilience initiatives in Puerto Rico. U.S. Army Corps of Engineers.

- Improve emergency access routes for hazardous materials teams during flood events.

Coordinated with land use and transportation planning, these projects enhance both physical protection and operational readiness in high-risk corridors (HUD, 2022; PREMB, 2023).

PUBLIC HEALTH PREPAREDNESS AND BIOLOGICAL RISK REDUCTION[1427] [1428]

Hazard Focus: Biological and Chemical

Lifelines: Health and Medical; Food, Water, and Shelter

Since the 2017 hurricanes and the COVID-19 pandemic, Puerto Rico has strengthened public health preparedness through:

- Enhanced disease surveillance and reporting systems for outbreaks and contamination events.
- Training and exercises on chemical and biological emergencies.
- Improved protocols for sheltering, sanitation, and infection prevention during disasters.
- Support for local health departments and hospitals in emergency planning for waterborne, vector-borne, and respiratory disease risks.

These initiatives improve detection, management, and mitigation of biological and chemical exposures during disasters, ensuring better coordination with PREMB and other response entities (CDC, 2023; Puerto Rico Department of Health [DOH-PR], 2023).

Mitigation Strategy Summary

Table 178: Integrated CBRNE Mitigation Strategy Summary for Puerto Rico

Strategy Type	Primary CBRNE Hazard(s) Addressed	Lifelines Affected	Expanded Example Actions in Puerto Rico
Facility Hardening and Flood/Seismic Protection	Chemical, Explosive, Multi-Hazard	Energy, Water, Transportation	Elevation of substations and pump stations; floodwalls and secondary containment at tank farms; seismic retrofits for critical facilities.

[1427] Centers for Disease Control and Prevention. (2018). Public health preparedness capabilities: National standards for state, local, tribal, and territorial public health. U.S. Department of Health and Human Services.
[1428] Centers for Disease Control and Prevention. (2024). Emergency preparedness and response: Chemical and biological emergencies [Program overview and guidance].

Strategy Type	Primary CBRNE Hazard(s) Addressed	Lifelines Affected	Expanded Example Actions in Puerto Rico
Water and Wastewater System Upgrades	Biological, Chemical	Food, Water, Shelter; Health & Medical	Backup generators for treatment plants; modernization of disinfection systems; improved chemical handling; reduced overflow risk during storms.
Hazardous Materials Management and Monitoring	Chemical, Explosive	Hazardous Materials; Safety & Security	Enhanced storage and containment for fuels, chlorine, and ammonia; emergency shutoff systems; compliance with EPA Risk Management Program (RMP) and PHMSA standards.[1429]
Energy Resilience and Backup Power	Multi-Hazard, Chemical, Explosive	Energy; Health & Medical; Communications	Grid modernization; resilient backup generation for hospitals, emergency operations centers, and water facilities; integration of hazard mitigation into energy reconstruction.
Planning, Training, and Exercises	All CBRNE Categories	Safety & Security; All Lifelines	PREMB-led multi-hazard drills; integration of CBRNE considerations into municipal mitigation and emergency operations plans; updates to local emergency plans; coordination with federal and local partners.
Public Health Preparedness	Biological, Chemical	Health & Medical; Food, Water, Shelter	Enhanced disease surveillance; chemical and biological emergency training; improved sheltering and sanitation protocols; infection prevention measures during disasters.

[1429] Hazardous materials safety program overview. 2023. U.S. Department of Transportation.