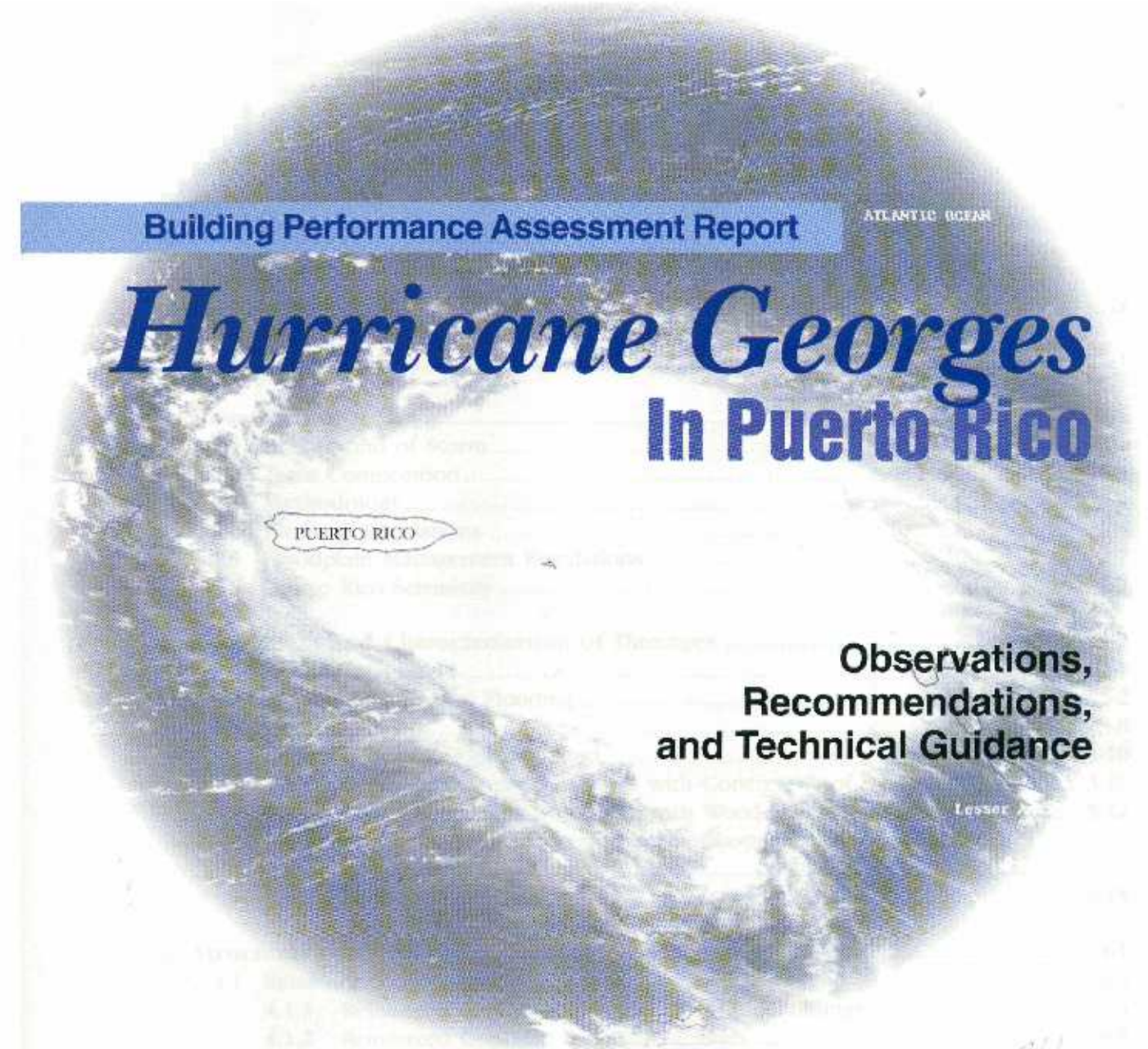
The Building Performance Assessment Process

In response to hurricanes, floods, earthquakes, and other disasters, the Federal Emergency Management Agency (FEMA) often deploys Building Performance Assessment Teams (BPATs) to conduct field investigations at disaster sites. The members of a BPAT include representatives of public and private sector entities who are experts in specific technical fields such as structural and civil engineering, building design and construction, and building code development and enforcement. BPATs inspect disaster-induced damages incurred by residential and commercial buildings and other manmade structures; evaluate local design practices, construction methods and materials, building codes, and building inspection and code enforcement processes; and make recommendations regarding design, construction, and code issues. With the goal of reducing the damage caused by future disasters, the BPAT process is an important part of FEMA's hazard mitigation activities. For more information about the BPAT program or if you are interested in becoming a member, please visit our website at www.fema.gov/mit/bpat.

Throughout Puerto Rico, the BPAT visited communities where people had lost their life's belongings and literally did not have a roof over their heads. The team was struck by the dignity of those individuals who had suffered great losses and appreciated the courtesy and hospitality that was extended to them. The team also appreciated their patience with the BPAT's questions. This report is dedicated to these individuals, their families, and their friends. Their remarkable spirit is summarized by the saying "*al mal tiempo, buena cara*", which translates as "hard times, strong faces".



Building Performance Assessment Report

Hurricane Georges
In Puerto Rico

Observations, Recommendations, and Technical Guidance

Federal Emergency Management Agency
Mitigation Directorate
Washington, DC
Region II, New York, NY
and the Caribbean Area Office

TABLE OF CONTENTS

Table of Contents

List of Figures and Tables

List of Acronyms

A-Zone	Special Flood Hazard Areas, excluding V-Zones
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ARPE	Administración de Reglamentos y Permisos (Regulations and Permits Administration)
ASCE 7-95	American Society of Civil Engineers Standard 7-95 *Minimum Design Loads for Buildings and Other Structures*
ASD	Allowable Stress Design
ASOS	Automatic Surface Observing System
ASTM	American Society for Testing and Materials
BFE	Base Flood Elevation
BOCA	Building Officials and Code Administrators
BPAT	Building Performance Assessment Team
CAV	Community Assessment Visit
CIAPR	Colegio de Ingenieros y Agrimensores (College of Engineers and Surveyors)
CMU	Concrete Masonry Unit
EIFS	Exterior Insulating Finishing System
EO12699	Executive Order 12699
EO11988	Executive Order 11988
EPS	Expanded Polystyrene System
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
HVAC	Heating, Ventilation, and Air Conditioning
IBC	International Building Code
ICBO	International Conference of Building Officials
in	inch
LRFD	Load and Resistance Factor Design
mb	millibars
mph	miles per hour
NEHRP	National Earthquake Hazards Reduction Program

NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
psf	pounds per square foot
SBC	Standard Building Code
SBCCI	Southern Building Code Congress International
SFHA	Special Flood Hazard Area
UBC	Uniform Building Code
V-Zone	An area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources

1 Executive Summary

On the evening of September 21, 1998, Hurricane Georges made landfall on Puerto Rico's east coast as a strong Category 2 hurricane. It traveled directly over the interior of the island, mainly in an east-west direction, and passed off Puerto Rico's west coast on September 22. Puerto Rico had not experienced a hurricane of this magnitude since Hurricane Hugo, a devastating Category 3 hurricane that passed over the northeast corner of Puerto Rico in a southeast to northwest direction in September 1989.

On September 30, the Federal Emergency Management Agency's (FEMA) Mitigation Directorate deployed a Building Performance Assessment Team (BPAT) to Puerto Rico to assess damages caused by Hurricane Georges. The team included architects, engineers, planners, insurance specialists, and floodplain management specialists. The BPAT's mission was to assess the performance of buildings and other structures throughout Puerto Rico and make recommendations for improving building performance in future events.

After an aerial assessment of the island, the BPAT conducted field investigations in selected areas affected by the storm. The field investigations of significantly damaged areas centered on the performance of single-family residential home construction. Isolated examples of success and failure in commercial buildings (primarily building envelope issues in high-rise buildings) and several essential facilities observed during field investigations were also documented. Commercial buildings were not investigated for compliance with current structural seismic guidelines. One- and two-family residential buildings, however, were investigated for their ability to sustain a seismic event. Seismic resistance of nonstructural elements was also observed.

It is important to note that wind speeds experienced on the island were not of the strength to test the design of Puerto Rico's buildings. A more significant wind event striking Puerto Rico would likely have resulted in even more failures than were observed.

A large number of residential buildings in Puerto Rico experienced structural damage from the high winds of Hurricane Georges. This can be attributed to a lack of a continuous load path from the roof structure to the foundation that the BPAT observed in most of the damaged buildings. In addition, a large number of residential buildings in identified Special Flood Hazard Areas (SFHAs) were damaged from floodwaters.

A limited number of mid- and high-rise buildings were inspected by the BPAT. Damage observed at these buildings was to nonstructural elements, including damage to glazing, curtain walls, interior walls, and damages to finishes from windborne rain. Building envelope damage resulted from loads on the components and windborne debris that broke glazing.

The BPAT concluded that while not all of the damage caused by Hurricane Georges could have been prevented, a significant amount could have been avoided if more buildings had been constructed to Puerto Rico's existing Planning Regulation 7 (building code).

Furthermore, a lack of compliance with and enforcement of Planning Regulation 13 (floodplain management) contributed to the damages. Additional damage could have been avoided if more buildings had been designed and constructed to current codes and regulations that address flood, wind, and seismic loads. Although the BPAT observed several examples of successful mitigation implementation, many buildings unfortunately received too little attention to mitigation. If effective mitigation efforts had been implemented more extensively in the design and construction of buildings, the widespread devastation of the hurricane would have been substantially reduced.

Puerto Rico's Regulations and Permitting Administration (Administración de Regalmentos y Permisos [ARPE]) has taken several important steps following Hurricane Georges to increase public safety and reduce property damage from natural hazards. These steps include:

- At ARPE's request, the International Conference of Building Officials (ICBO) conducted and completed a peer review of ARPE in January 1999. This peer review evaluated the new needs created by Hurricane Georges as well as the re-engineering effort currently underway.
- The Government of Puerto Rico, including ARPE, passed emergency regulation in December 1998 that repealed Planning Regulation 7 and adopted the 1997 Uniform Building Code (UBC) as the building code for Puerto Rico.
- ARPE is positioned to make recommendations concerning building regulations to the new Certification and Building Board of Puerto Rico that is expected to be created in March 1999 under proposed legislation submitted by the Governor to the Puerto Rico Legislature.
- ARPE and FEMA are implementing a strategic plan to provide the necessary training to make the transition to these new building regulations.

The ICBO's peer review of ARPE assessed how ARPE administers and enforces planning regulations related to building design and construction. The review evaluated ARPE's current needs—and identified unmet needs—to respond effectively to the massive amount of reconstruction necessary following Hurricane Georges as well as future construction. The peer review resulted in recommendations in the areas of policies, procedures, practices, training and education, facilities, salaries, benefits, promotion, and office automation. Since the completion of the peer review, FEMA, ICBO, and ARPE have been working closely together to develop a plan that meets the identified unmet needs.

In addition to the recommendations outlined above, the BPAT recommends the following:

- The Government of Puerto Rico should continue supporting positive mitigation education efforts undertaken by the Puerto Rico Civil Defense, Colegio de Ingenieros y Agrimensores (CIAPR), Colegio de Arquitectos, and the University of Puerto Rico College of Engineering in Mayagüez.
- ARPE and the Puerto Rico Planning Board should use information gathered by the Community Assistance Visit (CAV) in May 1998 and from the damage of Hurricane Georges to continue to educate homeowners on the risks involved in building in floodprone areas. A renewed effort in enforcement of Planning Regulation 13 during the rebuilding stages, specifically in the permitting process, should result in a significant reduction in property loss from future hurricane events.
- The BPAT agrees with the Government of Puerto Rico's decision to adopt the 1997 UBC as an interim step toward adopting the International Building Code

(IBC) when it becomes available. Furthermore, the BPAT recommends several local amendments be adopted.

- Essential facilities should be evaluated for their vulnerability to natural hazard events.
- The Government of Puerto Rico should perform a study on its electrical power distribution system

2 Introduction

This report presents FEMA's Building Performance Assessment Team's (BPAT) observations on the success and failure of buildings in Puerto Rico to withstand the wind and flood forces generated by Hurricane Georges. In addition, the seismic resistance of some of the buildings observed was assessed. In this report, "buildings" refer to single- and multi-family homes, residential buildings, and commercial and industrial buildings. Recommendations to improve building performance in future natural disasters in Puerto Rico are included. During this building performance assessment, additional consideration was given to mitigation success stories, particularly when mitigation successfully reduced damages In the context of this document, mitigation is defined as actions taken to prevent building damage and/or minimize the extent and impact of building damage if it occurs.

A separate team has prepared a BPAT report on the effects of Hurricane Georges in the Gulf Coast of the United States. A copy of the Gulf Coast BPAT report is available from FEMA by contacting FEMA's Publication Distribution Center at (800) 480-2520, and requesting FEMA Publication #338, or it may be downloaded from the World Wide Web at www.fema.gov

2.1 Background of Storm

Historical data indicate that the island of Puerto Rico has been struck or otherwise affected by 10 hurricanes since 1893 [Defensa Civil Estatal de Puerto Rico and FEMA 1996]. Their intense rain and devastating wind speeds have caused extensive damage to the island. Figure 2-1 shows the path of these hurricanes. Hurricane category designators in Figure 2-1 (e.g., CAT 2) are based on the Saffir-Simpson scale.[1] Central pressure of the hurricane (measured in millibars) and wind speed (measured in mph as 1-minute sustained) ranges for hurricane categories of the Saffir-Simpson scale are shown in Table 2-1.

Hurricane Georges formed 400 miles south-southwest of the Cape Verde Islands and moved across the Atlantic into the Caribbean on September 16, 1998. It made landfalls in the West Indies; Virgin Islands; Puerto Rico; Hispanola, Cuba; the Florida Keys, the Chandeleur Islands of Louisiana, and coastal Mississippi. Hurricane Georges was upgraded September 17 to a Category 4 hurricane as it moved west through the Caribbean packing 150-mph winds over open water. The storm was downgraded to a Category 2 once it moved through the Leeward, U.S. and British Virgin Islands on September 21. The storm was categorized as a tropical storm late afternoon on September 28. Wind speeds are further discussed in Section 3.1.

[1] The Saffir-Simpson hurricane scale ranks hurricanes by categories (CAT) These categories are based on the central pressure of the hurricane and wind speed (measured as 1-minute sustained)

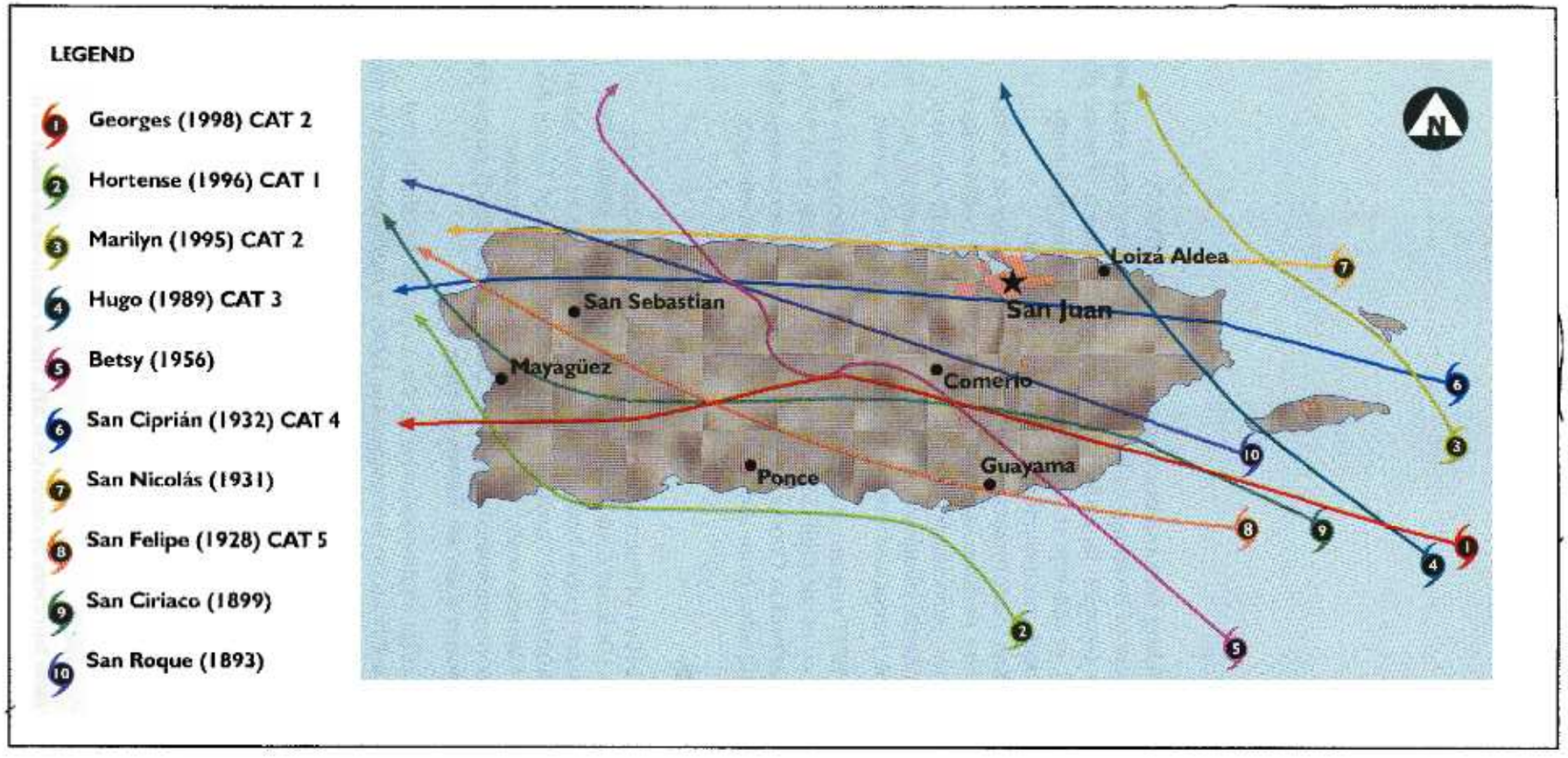


FIGURE 2-1 History of hurricanes in Puerto Rico.
Source: Huracanes en Puerto Rico: Guía de Mitigación de Danõs.

TABLE 2-1 Pressure and wind ranges for hurricane categories of the Saffir-Simpson Scale.

Category (CAT)	Central Pressure	Wind Speed (1-min. sust.)
1	>980 mb	74 mph - 95 mph
2	965 - 980 mb	96 mph - 110 mph
3	945 - 965 mb	111 mph - 130 mph
4	920 - 945 mb	131 mph - 155 mph
5	<920 mb	>155 mph

On the evening of September 21, 1998 Hurricane Georges made landfall on Puerto Rico's east coast as a strong Category 2 hurricane. The storm passed off the west coast of the island September 22, most probably as a weak Category 2 hurricane. It traveled directly over the island, mainly in an east-west direction. Puerto Rico had not experienced a hurricane of this magnitude since Hurricane Hugo, a devastating Category 3 hurricane that passed over the northeast corner of Puerto Rico in a southeast to northwest direction in September 1989 The only Category 4 and 5 hurricanes to strike the island this century were San Ciprían (Category 4, September 1932) and San Felipe (Category 5, September 1928). Prior to Hurricane Georges, the last hurricane to hit Puerto Rico was Hortense, which was a Category 1 hurricane when it passed over the southwest corner of the island in September 1996.

Rainfall from Hurricane Georges exceeded 18 inches at the center of Puerto Rico at Jayuya. The highest recorded level was east of Jayuya at Comerío, which received almost 26 inches of rain during the two-day period of the storm. Three deaths were directly attributed to Hurricane Georges in Puerto Rico and nine others occurred from medical complications [National Oceanic and Atmospheric Administration (NOAA) 1998].

Hurricane Georges caused extensive damage in Puerto Rico. It was the costliest disaster ever for the American Red Cross, which has spent $104 million for recovery in the Caribbean and United States combined [*New York Times* 1998]. Approximately 80 percent of Puerto Rico's 3.8 million people were without power and water at some point during the storm. Over 30,000 homes were destroyed and 50,000 more experienced major or minor damage. Hurricane Georges destroyed 75 percent of the country's coffee crop, 95 percent of Puerto Rico's plantains, and 65 percent of its chickens [NOAA 1998].

2.2 Team Composition

On September 30, the FEMA Mitigation Directorate deployed the BPAT to Puerto Rico to assess damages caused by Hurricane Georges. The team included architects engineers, planners, floodplain management specialists, and insurance specialists. See Appendix A.

The BPAT's mission was to assess the performance of buildings throughout Puerto Rico and make recommendations for improving building performance in future events. The BPAT process is intended to provide the government of Puerto Rico, local governments, and other interested parties guidance for post-hurricane reconstruction with the goal of enhancing the performance of buildings exposed to future natural hazards.

Aerial and ground site investigations were conducted to observe building conditions in selected areas affected by the storm. The mission did not include recording the number of buildings damaged by Hurricane Georges, determining the frequency of specific types of damage, or collecting data that could serve as the basis of statistical analysis. Collectively, the team has invested more than 1,000 hours to date conducting site investigations, inspecting damages, and preparing documentation. Documentation included field notes and photographs.

Field investigations of significantly damaged areas mainly focused on one- to two-story buildings (homes). However, some essential facilities and high-rise commercial and industrial buildings were also assessed and are included in this report.

2.3 Methodology

The BPAT conducted two aerial assessments of Puerto Rico. The first passed through Canóvanas, Humacao, Caguas, Jayuya, Adjuntas, Utuado, Aguadilla, Rincón, Mayagüez, Cabo Rojo, Ponce, and Toa Baja. A second flyover of east Puerto Rico included Fajardo and the two islands to the east: Vieques and Culebra (Figure 2-2).

Field investigations began on October 4 and lasted until October 9. Wind and flood damage and success stories were gathered and local residents were interviewed. Power poles, as well as other infrastructure items, were also inspected to determine the effects of the storm.

On October 6, the BPAT split into two groups, a wind investigation team (Wind Team) and flood investigation team (Flood Team). Ground investigations for both groups included visits to Jayuya, Adjuntas, and Utuado (Figure 2-3). On October 7, the Flood Team continued west investigating coastal and riverine flooding in Cabo Rojo, Rincón, Mayagüez, Aguadilla, and Arecibo. The Wind Team remained in the center of the island north of Ponce to observe wind damage and investigate reports of tornadic activity. On October 9, both teams flew to Culebra to inspect this newly designated FEMA Project Impact community.[2] The BPAT team completed its deployment on October 10.

2.4 Planning Regulations

Planning Regulation 7 (building code) was first adopted by the Government of Puerto Rico in 1968 and was later amended in 1987. The "provisions on the minimum loads for calculation of [loads acting on] structures were completely revised, taking into consideration the requirements of the 1982 Uniform Building Code (UBC) and recommendations of the study carried out by the Commission on Earthquakes of the Engineers and Surveyors Association of Puerto Rico," according to the amended regulations. As part of the 1987 Planning Regulation amendment, Puerto Rico was identified as a seismic zone 3, requiring all new construction—single-family houses included—to be seismic-resistant. A design wind speed of 110 mph (fastest-mile) was recommended. Puerto Rico's Regulations and Permitting Administration (Adminstración de Reglamentos y Permisos [ARPE]) regulates these provisions of Planning Regulation 7, which was in effect at the time Hurricane Georges struck

[2] FEMA's Project Impact Program helps communities protect themselves from the devastating effects of natural disasters by taking actions that dramatically reduce the potential for disruption and loss to buildings and property. FEMA provides expertise and technical assistance from the national and regional levels (including other federal and state agencies) to individual communities to mitigate against natural hazard events and provide funding for the administrative support of these initiatives.

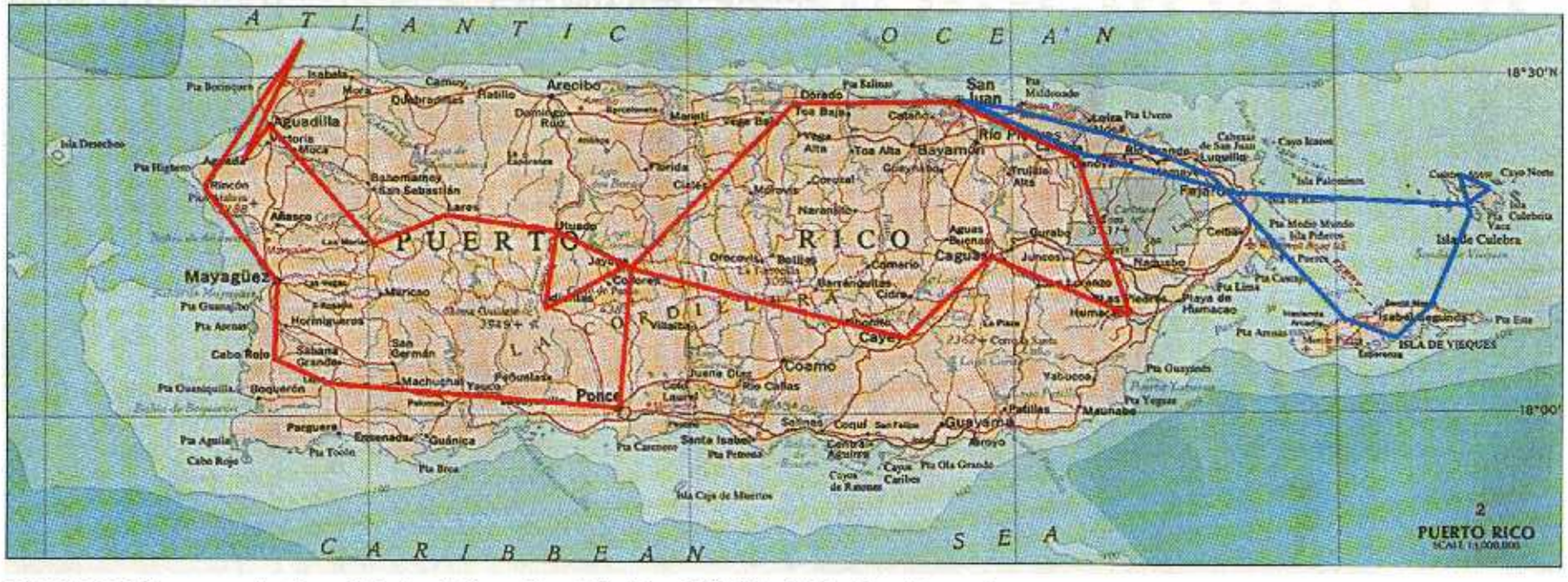


FIGURE 2-2 Flyover routes from October 2 (in red) and October 3 (in blue). Map is not to scale.
Source: The Perry Castañeda Library Map Collection.

FIGURE 2-3 Locations of ground investigation by the BPAT. Map is not to scale.

Puerto Rico In late December 1998, the government of Puerto Rico adopted emergency regulations to repeal Planning Regulation 7 and adopt the 1997 Uniform Building Code (UBC) as the building code of Puerto Rico.

2.5 Floodplain Management Regulations

In August 1978, the Government of Puerto Rico joined the National Flood Insurance Program (NFIP). The NFIP was created by an act of the U S. Congress to make flood insurance available to property owners in communities that agree to enact and administer floodplain management regulations meeting program requirements. Initial Flood Insurance Rate Maps (FIRMs) of Puerto Rico were issued in August 1978; the most recent updates were published in September 1996.

The Government of Puerto Rico adopted NFIP-compliant floodplain management provisions under Planning Regulation 13 to regulate construction in Special Flood Hazard Areas (SFHAs) identified as flood zones on FIRMs. In coastal areas, this means that buildings must be adequately elevated and protected from the effects of high-velocity flood flow. In V-Zones, buildings must be elevated on piling (or column) foundations and the lowest horizontal structural member of the lowest floor must be at or above the Base Flood Elevation (BFE). In addition, the area below the building must be free of obstructions or enclosed by non-supporting breakaway walls intended to collapse under wind and water loads without causing damage to the foundation or the elevated portion of the building.

In A-Zones, which are less likely to be affected by high-velocity flow, the top of the lowest floor of the building must be at or above the BFE and the areas below the BFE can be enclosed with non-breakaway walls. However, the area below the BFE can only be used for parking, access, and storage. These regulations require new and substantially improved buildings in floodprone areas to be built to reduce flood hazards. The Puerto Rico Planning Board and ARPE regulate Planning Regulation 13.

2.6 Puerto Rico Seismicity

Along with much of the Caribbean, Puerto Rico is subject to significant earthquake and tsunami risk. The written history of earthquake damage in Puerto Rico dates back to 1867 when the first earthquake was recorded, with an estimated magnitude of 7.3 on the Richter Scale occurring off southeast Puerto Rico. In 1918, the island was hit by a magnitude 7.3 earthquake approximately 9 miles off its northwest coast. The ensuing tsunami had wave heights approaching 19 feet and caused major damage. Reportedly, 116 people were killed, 40 as a direct result of the tsunami. A minor earthquake also hit the island in 1922 [Earth Scientific Consultants]. The American Society of Civil Engineers Standard 7-95 (ASCE 7-95), *Minimum Design Loads for Buildings and Other Structures*, as well as the National Earthquake Hazards Reduction Program (NEHRP) 1997 Recommended Provisions, require all structures in Puerto Rico, including single family homes, to be seismic resistant. These documents have stricter requirements for seismic construction in Puerto Rico than Planning Regulation 7 (building code) that was in place when Hurricane Georges struck Puerto Rico The recently adopted 1997 UBC is compliant with both the 1997 NEHRP and the seismic provisions of ASCE 7-95.