Instructions for Using the Plan Review Crosswalk for Review of Local Mitigation Plans

Attached is a Plan Review Crosswalk based on the ***Multi-Hazard Mitigation Planning Guidance Under the Disaster Mitigation Act of 2000***, published by FEMA, dated March 2004. This Plan Review Crosswalk is consistent with the *Disaster Mitigation Act of 2000* (P.L. 106-390), enacted October 30, 2000 and *44 CFR Part 201 – Mitigation Planning, Interim Final Rule* (the Rule), published February 26, 2002.

SCORING SYSTEM

N – Needs Improvement: The plan does not meet the minimum for the requirement. Reviewer's comments must be provided.

S – Satisfactory: The plan meets the minimum for the requirement. Reviewer's comments are encouraged, but not required.

Each requirement includes separate elements. All elements of a requirement must be rated "Satisfactory" in order for the requirement to be fulfilled and receive a summary score of "Satisfactory." A "Needs Improvement" score on elements shaded in gray (recommended but not required) will not preclude the plan from passing.

When reviewing single jurisdiction plans, reviewers may want to put an N/A in the boxes for multi-jurisdictional plan requirements. When reviewing multi-jurisdictional plans, reviewers may want to put an N/A in the prerequisite box for single jurisdiction plans.

States that have additional requirements can add them in the appropriate sections of the *Multi-Hazard Mitigation Planning Guidance* or create a new section and modify this Plan Review Crosswalk to record the score for those requirements.

Optional matrices for assisting in the review of sections on profiling hazards, assessing vulnerability, and identifying and analyzing mitigation actions are found at the end of the Plan Review Crosswalk.

The example below illustrates how to fill in the Plan Review Crosswalk.

Example

Assessing Vulnerability: Overview

Requirement §201.6(c)(2)(ii): *[The risk assessment **shall** include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description **shall** include an overall summary of each hazard and its impact on the community.*

Element	Location in the Plan (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan include an **overall summary** description of the jurisdiction's **vulnerability** to each hazard?	Section II, pp. 4-10	The plan describes the types of assets that are located within geographically defined hazard areas as well as those that would be affected by winter storms.		✓
B. Does the plan address the **impact** of each hazard on the jurisdiction?	Section II, pp. 10-20	The plan does not address the impact of two of the five hazards addressed in the plan. **Required Revisions:** • Include a description of the impact of floods and earthquakes on the assets. **Recommended Revisions:** • This information can be presented in terms of dollar value or percentages of damage.	✓	
		SUMMARY SCORE	✓	

Local Mitigation Plan Review and Approval Status

Jurisdiction: Aguada	**Title of Plan:** Municipality of Aguada Hazard Mitigation Plan	**Date of Plan:** March 2005 – Revisions in November of 2005
Local Point of Contact: Hector Hernandez Rios	**Address:**	
Title: Director		
Agency: OMME		
Phone Number: **(787) 868-7000**	**E-Mail:**	

State Reviewer:	**Title:**	**Date:**

FEMA Reviewer:	**Title:**	**Date:**
Date Received in FEMA Region [Insert #]		
Plan Not Approved		
Plan Approved		
Date Approved		

Jurisdiction:	**NFIP Status***			
	Y	**N**	**N/A**	**CRS Class**
1.				
2.				
3.				
4.				
5. [ATTACH PAGE(S) WITH ADDITIONAL JURISDICTIONS]				

*** Notes:** **Y = Participating** **N = Not Participating** **N/A = Not Mapped**

LOCAL MITIGATION PLAN REVIEW SUMMARY

The plan cannot be approved if the plan has not been formally adopted.

Each requirement includes separate elements. All elements of the requirement must be rated "Satisfactory" in order for the requirement to be fulfilled and receive a score of "Satisfactory." Elements of each requirement are listed on the following pages of the Plan Review Crosswalk. A "Needs Improvement" score on elements shaded in gray (recommended but not required) will not preclude the plan from passing. Reviewer's comments must be provided for requirements receiving a **"Needs Improvement"** score.

SCORING SYSTEM

Please check one of the following for each requirement.

N – Needs Improvement: The plan does not meet the minimum for the requirement. Reviewer's comments must be provided.

S – Satisfactory: The plan meets the minimum for the requirement. Reviewer's comments are encouraged, but not required.

Prerequisite(s) (Check Applicable Box)	**NOT MET**	**MET**
Adoption by the Local Governing Body: §201.6(c)(5) **OR**		
Multi-Jurisdictional Plan Adoption: §201.6(c)(5) **AND** Multi-Jurisdictional Planning Participation: §201.6(a)(3)		

Planning Process	**N**	**S**
Documentation of the Planning Process: §201.6(b) and §201.6(c)(1)		

Risk Assessment	**N**	**S**
Identifying Hazards: §201.6(c)(2)(i)		
Profiling Hazards: §201.6(c)(2)(i)		
Assessing Vulnerability: Overview: §201.6(c)(2)(ii)		
Assessing Vulnerability: Identifying Structures: §201.6(c)(2)(ii)(A)		
Assessing Vulnerability: Estimating Potential Losses: §201.6(c)(2)(ii)(B)		
Assessing Vulnerability: Analyzing Development Trends: §201.6(c)(2)(ii)(C)		
Multi-Jurisdictional Risk Assessment: §201.6(c)(2)(iii)		

Mitigation Strategy	**N**	**S**
Local Hazard Mitigation Goals: §201.6(c)(3)(i)		
Identification and Analysis of Mitigation Actions: §201.6(c)(3)(ii)		
Implementation of Mitigation Actions: §201.6(c)(3)(iii)		
Multi-Jurisdictional Mitigation Actions: §201.6(c)(3)(iv)		

Plan Maintenance Process	**N**	**S**
Monitoring, Evaluating, and Updating the Plan: §201.6(c)(4)(i)		
Incorporation into Existing Planning Mechanisms: §201.6(c)(4)(ii)		
Continued Public Involvement: §201.6(c)(4)(iii)		

Additional State Requirements*	**N**	**S**
Insert State Requirement		
Insert State Requirement		
Insert State Requirement		

LOCAL MITIGATION PLAN APPROVAL STATUS

PLAN NOT APPROVED ☐

PLAN APPROVED ☐

*States that have additional requirements can add them in the appropriate sections of the *Multi-Hazard Mitigation Planning Guidance* or create a new section and modify this Plan Review Crosswalk to record the score for those requirements.

See Reviewer's Comments

PREREQUISITE(S)

Adoption by the Local Governing Body

Requirement §201.6(c)(5)*: *[The local hazard mitigation plan **shall** include] documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., City Council, County Commissioner, Tribal Council).

Element	**Location in the Plan** (section or annex and page #)	Reviewer's Comments	SCORE NOT MET	SCORE MET
A. Has the local governing body adopted the plan?	Section 1, p. 3, adoption resolution in Appendix A			
B. Is supporting documentation, such as a resolution, included?	Appendix A			
		SUMMARY SCORE		

Multi-Jurisdictional Plan Adoption

Requirement §201.6(c)(5)*: *For multi-jurisdictional plans, each jurisdiction requesting approval of the plan **must** document that it has been formally adopted.

Element	**Location in the Plan** (section or annex and page #)	Reviewer's Comments	SCORE NOT MET	SCORE MET
A. Does the plan indicate the specific jurisdictions represented in the plan?	N/A – this is not a multi-jurisdictional plan			
B. For each jurisdiction, has the local governing body adopted the plan?	N/A – this is not a multi-jurisdictional plan			
C. Is supporting documentation, such as a resolution, included for each participating jurisdiction?	N/A – this is not a multi-jurisdictional plan			
		SUMMARY SCORE		

Multi-Jurisdictional Planning Participation

Requirement §201.6(a)(3)*: *Multi-jurisdictional plans (e.g., watershed plans) may be accepted, as appropriate, as long as each jurisdiction has participated in the process … Statewide plans will not be accepted as multi-jurisdictional plans.

Element	**Location in the Plan** (section or annex and page #)	Reviewer's Comments	SCORE NOT MET	SCORE MET
A. Does the plan describe **how** each jurisdiction participated in the plan's development?	Section 3, throughout			

SUMMARY SCORE		

PLANNING PROCESS: *§201.6(b): An open public involvement process is essential to the development of an effective plan.*

Documentation of the Planning Process

Requirement §201.6(b): *In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process **shall** include:*
(1) An opportunity for the public to comment on the plan during the drafting stage and prior to plan approval;
(2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and
(3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.

Requirement §201.6(c)(1): *[The plan **shall** document] the planning process used to develop the plan, including how it was prepared, who was involved in the process, and how the public was involved.*

Element	**Location in the Plan** (section or annex and page #)	**Reviewer's Comments**	SCORE N	SCORE S
A. Does the plan provide a narrative description of the process followed to prepare the plan?	Section 3 throughout			
B. Does the plan indicate who was involved in the planning process? (For example, who led the development at the staff level and were there any external contributors such as contractors? Who participated on the plan committee, provided information, reviewed drafts, etc.?)	Section 3, pp. 1-3, Table 3.1			
C. Does the plan indicate how the public was involved? (Was the public provided an opportunity to comment on the plan during the drafting stage and prior to the plan approval?)	Section 3, pp. 3-10			
D. Was there an opportunity for neighboring communities, agencies, businesses, academia, nonprofits, and other interested parties to be involved in the planning process?	Section 3, pp. 8-10 – specifically on page 10.			
E. Does the planning process describe the review and incorporation, if appropriate, of existing plans, studies, reports, and technical information?	Section 3, pp. 11-12			
		SUMMARY SCORE		

RISK ASSESSMENT: *§201.6(c)(2): The plan shall include a risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.*

Identifying Hazards

Requirement §201.6(c)(2)(i): *[The risk assessment **shall** include a] description of the type … of all natural hazards that can affect the jurisdiction.*

Element	Location in the Plan (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan include **a description** of the types of **all natural hazards** that affect the jurisdiction? If the hazard identification omits (without explanation) any hazards commonly recognized as threats to the jurisdiction, this part of the plan cannot receive a Satisfactory score. Consult with the State Hazard Mitigation Officer to identify applicable hazards that may occur in the planning area.	Section 4 throughout			
		SUMMARY SCORE		

Profiling Hazards

Requirement §201.6(c)(2)(i): *[The risk assessment **shall** include a] description of the … location and extent of all natural hazards that can affect the jurisdiction. The plan **shall** include information on previous occurrences of hazard events and on the probability of future hazard events.*

Element	Location in the Plan (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the risk assessment identify the **location** (i.e., geographic area affected) of each natural hazard addressed in the plan?	Section 4 throughout			
B. Does the risk assessment identify the **extent** (i.e., magnitude or severity) of each hazard addressed in the plan?	Section 4 throughout	The intensity scales for the maps in this section are described on page 2 of Section 4.		
C. Does the plan provide information on **previous occurrences** of each hazard addressed in the plan?	Section 4 throughout	Presidential disaster declarations have been added on page 9. Table 4.1. Aguada-specific storm event information from the National Climatic Data Center's (NCDC) Storm Event Database has been added on pages 9-10.		
D. Does the plan include the **probability of future events** (i.e., chance of occurrence) for each hazard addressed in the plan?	Section 4 throughout			
		SUMMARY SCORE		

Assessing Vulnerability: Overview

Requirement §201.6(c)(2)(ii): *[The risk assessment **shall** include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description **shall** include an overall summary of each hazard and its impact on the community.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan include an **overall summary** description of the jurisdiction's **vulnerability** to each hazard?	Section 4 throughout, specifically on Table 4.32 on pages 59 and 60.			
B. Does the plan address the **impact** of each hazard on the jurisdiction?	Section 4 throughout			
		SUMMARY SCORE		

Assessing Vulnerability: Identifying Structures

Requirement §201.6(c)(2)(ii)(A): *The plan **should** describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard area … .*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan describe vulnerability in terms of the **types and numbers** of **existing** buildings, infrastructure, and critical facilities located in the identified hazard areas?	Section 4, pp. 12-	***Note: A "Needs Improvement" score on this requirement will not preclude the plan from passing.*** All hazards impact the municipality uniformly except for the landslide and flooding hazards. Specific properties and critical facilities that are impacted by these hazards are discussed on pages 16, 20, 23, 26, 31, 37, 41, 45 of Section 4 and pages 4, 5 and 6 of Section 3.		
B. Does the plan describe vulnerability in terms of the **types and numbers** of **future** buildings, infrastructure, and critical facilities located in the identified hazard areas?	Section 4, pp. 61-65	***Note: A "Needs Improvement" score on this requirement will not preclude the plan from passing.***		
		SUMMARY SCORE		

Assessing Vulnerability: Estimating Potential Losses

Requirement §201.6(c)(2)(ii)(B): *[The plan **should** describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) of this section and a description of the methodology used to prepare the estimate … .*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan estimate **potential dollar losses** to vulnerable structures?	Section 4, pp. 51-60	***Note: A "Needs Improvement" score on this requirement will not preclude the plan from passing.***		
B. Does the plan describe the **methodology** used to prepare the estimate?	Section 4, pp. 1-8	***Note: A "Needs Improvement" score on this requirement will not preclude the plan from passing.***		
		SUMMARY SCORE		

Assessing Vulnerability: Analyzing Development Trends

Requirement §201.6(c)(2)(ii)(C): *[The plan **should** describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan describe land uses and development trends?	Section 4, pp. 46-49 and 63-65	***Note: A "Needs Improvement" score on this requirement will not preclude the plan from passing.***		
		SUMMARY SCORE		

Multi-Jurisdictional Risk Assessment

Requirement §201.6(c)(2)(iii): *For multi-jurisdictional plans, the risk assessment **must** assess each jurisdiction's risks where they vary from the risks facing the entire planning area.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan include a risk assessment for each participating jurisdiction as needed to reflect unique or varied risks?	NA			
		SUMMARY SCORE		

MITIGATION STRATEGY: *§201.6(c)(3): The plan shall include a mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools.*

Local Hazard Mitigation Goals

Requirement §201.6(c)(3)(i): *[The hazard mitigation strategy **shall** include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to*

the identified hazards.

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A Does the plan include a description of mitigation **goals** to reduce or avoid long-term vulnerabilities to the identified hazards? (**GOALS** are long-term; represent what the community wants to achieve, such as "eliminate flood damage"; and are based on the risk assessment findings.)	Section 5, pp. 3			
		SUMMARY SCORE		

Identification and Analysis of Mitigation Actions

Requirement §201.6(c)(3)(ii): *[The mitigation strategy **shall** include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan identify and analyze a **comprehensive range** of specific mitigation actions and projects for each hazard?	Section 5, pp. 9-28			
B Do the identified actions and projects address reducing the effects of hazards on **new** buildings and infrastructure?	Section 5, pp. 9-28			
C. Do the identified actions and projects address reducing the effects of hazards on **existing** buildings and infrastructure?	Section 5, pp. 9-28			
		SUMMARY SCORE		

Implementation of Mitigation Actions

Requirement: §201.6(c)(3)(iii): *[The mitigation strategy section **shall** include] an action plan describing how the actions identified in section (c)(3)(ii) will be prioritized, implemented, and administered by the local jurisdiction. Prioritization **shall** include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the mitigation strategy include how the actions are **prioritized**? (For example, is there a discussion	Section 5, pp. 1-8, Section 3, p. 8			

of the process and criteria used?)				
B. Does the mitigation strategy address how the actions will be **implemented and administered**? (For example, does it identify the responsible department, existing and potential resources, and timeframe?)	Section 5, pp. 29			
C. Does the prioritization process include an emphasis on the use of a **cost-benefit review** (see page 3-36 of *Multi-Hazard Mitigation Planning Guidance*) to maximize benefits?	Section 5, pp. 2, 29-30			
		SUMMARY SCORE		

Multi-Jurisdictional Mitigation Actions

Requirement §201.6(c)(3)(iv): *For multi-jurisdictional plans, there **must** be identifiable action items specific to the jurisdiction requesting FEMA approval or credit of the plan.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A Does the plan include at least one identifiable **action item** for each jurisdiction requesting FEMA approval of the plan?	NA			
		SUMMARY SCORE		

PLAN MAINTENANCE PROCESS

Monitoring, Evaluating, and Updating the Plan

Requirement §201.6(c)(4)(i): *[The plan maintenance process **shall** include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.*

Element	Location in the **Plan** (section or annex and page #)	Reviewer's Comments	SCORE N	SCORE S
A. Does the plan describe the method and schedule for **monitoring** the plan? (For example, does it identify the party responsible for monitoring and include a schedule for reports, site visits, phone calls, and meetings?)	Section 6, pp. 1-2			
B. Does the plan describe the method and schedule for **evaluating** the plan? (For example, does it identify the party responsible for evaluating the plan and include	Section 6, pp. 2, 3			

the criteria used to evaluate the plan?)				
C. Does the plan describe the method and schedule for **updating** the plan within the five-year cycle?	Section 6, pp. 3-4			
		SUMMARY SCORE		

Incorporation into Existing Planning Mechanisms

Requirement §201.6(c)(4)(ii): *[The plan **shall** include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.*

Element	**Location in the Plan** (section or annex and page #)	**Reviewer's Comments**	**SCORE** N	S
A. Does the plan identify other local planning mechanisms available for incorporating the requirements of the mitigation plan?	Section 6, pp. 4			
B. Does the plan include a process by which the local government will incorporate the requirements in other plans, when appropriate?	Section 6, pp. 4			
		SUMMARY SCORE		

Continued Public Involvement

Requirement §201.6(c)(4)(iii): *[The plan maintenance process **shall** include a] discussion on how the community will continue public participation in the plan maintenance process.*

Element	**Location in the Plan** (section or annex and page #)	**Reviewer's Comments**	**SCORE** N	S
A. Does the plan explain how **continued public participation** will be obtained? (For example, will there be public notices, an on-going mitigation plan committee, or annual review meetings with stakeholders?)	Section 6, pp. 4			
		SUMMARY SCORE		

This section provides a general introduction to the Municipality of Aguada Hazard Mitigation Plan. This introduction is presented in the following four subsections:

- 1.1 Background
- 1.2 Purpose
- 1.3 Authority
- 1.4 Organization of the Plan

1.1 BACKGROUND

Natural hazards, such as hurricanes, floods and earthquakes are a part of the world around us. Their occurrence is natural and inevitable, and there is little we can do to control their force and intensity. It is when these naturally occurring events intersect with our built environment—where we live, work and play—that these hazards have the potential to become disasters.

The Municipality of Aguada is located on the western coast of Puerto Rico. It is surrounded by the municipalities of: Aguadilla, Añasco, Cabo Rojo, Guánica, Hormigueros, Isabela, Lajas, Mayagüez, Moca, Rincon, Sabana Grande and San Germán. (See Figure 1.1.)

The Municipality of Aguada is approximately 78 square kilometers in size and is located in an area of Puerto Rico that is vulnerable to a wide range of natural hazards, including flooding, hurricanes, earthquakes, and landslides.

These hazards threaten the life and safety of its residents and have the potential to damage or destroy both public and private property. While the threat from hazard events may never be fully eliminated, there is much we can do to lessen their potential impact. The concept and practice of reducing risks to people and property from known hazards is generally referred to as *hazard mitigation*. Techniques include both structural measures, such as strengthening or protecting buildings and infrastructure from the forces of hazards, and non-structural measures, such as the adoption of land use policies or the creation of public awareness programs. A comprehensive mitigation approach not only addresses hazard vulnerabilities that exist today but also addresses vulnerability associated with future development.

One of the best ways a community can implement a comprehensive approach to hazard mitigation is to develop, adopt and update as needed, a local hazard mitigation plan. A mitigation plan both establishes broad guiding principles and specific actions that can be implemented to reduce identified vulnerabilities. The Municipality of Aguada Hazard Mitigation Plan (referred to throughout the document as “Hazard Mitigation Plan” or “Plan”) is a logical first step toward incorporating hazard mitigation practices into the municipality’s daily activities, thereby lessening the vulnerability of the municipality.

FIGURE 1.1
LOCATION OF THE MUNICIPALITY OF AGUADA IN PUERTO RICO[1]

[1] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

1.2 PURPOSE

Recently, the United States Congress made the development of a hazard mitigation plan a specific eligibility requirement for any local government applying for federal mitigation grant funding through the Disaster Mitigation Act of 2000 (DMA 2000). Communities with an adopted and federally approved hazard mitigation plan will therefore become pre-positioned and more apt to receive available mitigation funds in both the pre- and post-disaster environments.

This Plan is designed to meet both the requirements of DMA 2000 and guidance from the applicable rules of the Puerto Rico State Emergency Management Agency (PRSEMA). The planning process followed was intended to lead to a hazard mitigation plan that:

- Protects life and property by reducing the potential for future damages and economic losses that result from natural hazards;
- Decreases the time required to recover and redevelop following future disaster events;
- Demonstrates a firm local commitment to hazard mitigation principles; and
- Complies with both state and federal legislative requirements for local hazard mitigation plans.

A key objective of this Plan is to ensure that proposed mitigation actions are coordinated at the local level and supported by appropriate central government agencies.

1.3 AUTHORITY

This Plan has been adopted and certified by the Municipality of Aguada under the authority defined under Law 81, August 30, 1991(Ley Núm. 81 del 30 de Agosto de 1991). The law was enacted to empower local municipalities. It established a framework for a more democratic and participatory form of government. This Plan was adopted and certified by the Mayor and the Municipal Assembly, a local representative group, which according to the Law 81, is given broad legislative powers to approve ordinances, resolutions and regulations on matters of municipal jurisdiction.

To adopt the Plan, the Mayor—the Honorable Miguel A. Ruiz—called an extraordinary session of the municipal assembly. This special session, called to order and held in accordance with procedures outlined in Law 81, "certified" the municipality's Hazard Mitigation Plan *(See Appendix A)*.

This Plan has been developed in accordance with current rules and regulations governing local hazard mitigation plans. The Plan shall be routinely monitored and updated to remain in compliance with the following legislation:

- The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by the Disaster Mitigation Act of 2000 (Public Law 106-390 – October 30, 2000).

1.4 ORGANIZATION OF THE PLAN

The following sections of the Plan present detailed information to support the purposes of the Plan. This section, Section One, introduces the Plan. Section Two provides a background of the municipality. Section Three describes the development of a Hazard Mitigation Committee and local community planning activities that were conducted for the development of this Plan. Section Four summarizes the results of the hazard identification and risk assessment, which estimates potential losses associated with identified hazards. Section Five describes goals and objectives of the Plan, along with a broad range of mitigation actions. Section Six presents the implementation strategy for the prioritized mitigation actions.

This section provides a brief overview of the Municipality of Aguada presented in the following subsections:

- 2.1 Administrative Divisions
- 2.2 Environment
- 2.3 Population and Demographics
- 2.4 Economy, Employment and Industry
- 2.5 Housing

2.1 ADMINISTRATIVE DIVISIONS

Aguada, like other municipalities in Puerto Rico, recognizes barrios and barrio-pueblos as the primary legal divisions of municipality. One barrio in each municipality is identified as the barrio-pueblo, the area that represented the seat of the government at the time Puerto Rico formalized the municipality and barrio boundaries in the late 1940s.

Aguada's 18 administrative barrios (illustrated in Figure 2.1) are:

- Asomante
- Atalaya
- Carrizal
- Cerro Gordo
- Cruces,
- Espinar
- Guanábano
- Guaniquilla
- Guayabo
- Jagüey
- Laguna
- Mal Paso
- Mamey
- Marías
- Naranjo
- Piedras Blancas
- Pueblo
- Río Grande

2.2 ENVIRONMENT

TOPOGRAPHY AND HYDROLOGY

Aguada consists of a mountainous interior that gradually transitions to a flat coastal plain. An extensive interior mountain range transects the eastern portion of the municipality and extends directly to the sea. This mountain range has alternating wide coastal plains: the Municipality of Anasco to the south and Municipality of Aguada to the north. Figure 2.2 shows the topography and hydrology of Aguada.

The coastal plain is relatively flat and is intersected by many rivers. The largest river is the Rio Culebrinas. It is approximately 40 kilometers long and makes its way to Aguada via the municipalities of San Sebastian and Moca. In Aguada, the Rio Culebrinas runs from east to west before finally dumping its sediments into the Atlantic Ocean.

FIGURE 2.1
ADMINISTRATIVE BOUNDARIES, MUNICIPALITY OF AGUADA[1]

[1] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

FIGURE 2.2
TOPOGRAPHY AND HYDROLOGY, MUNICIPALITY OF AGUADA[2]

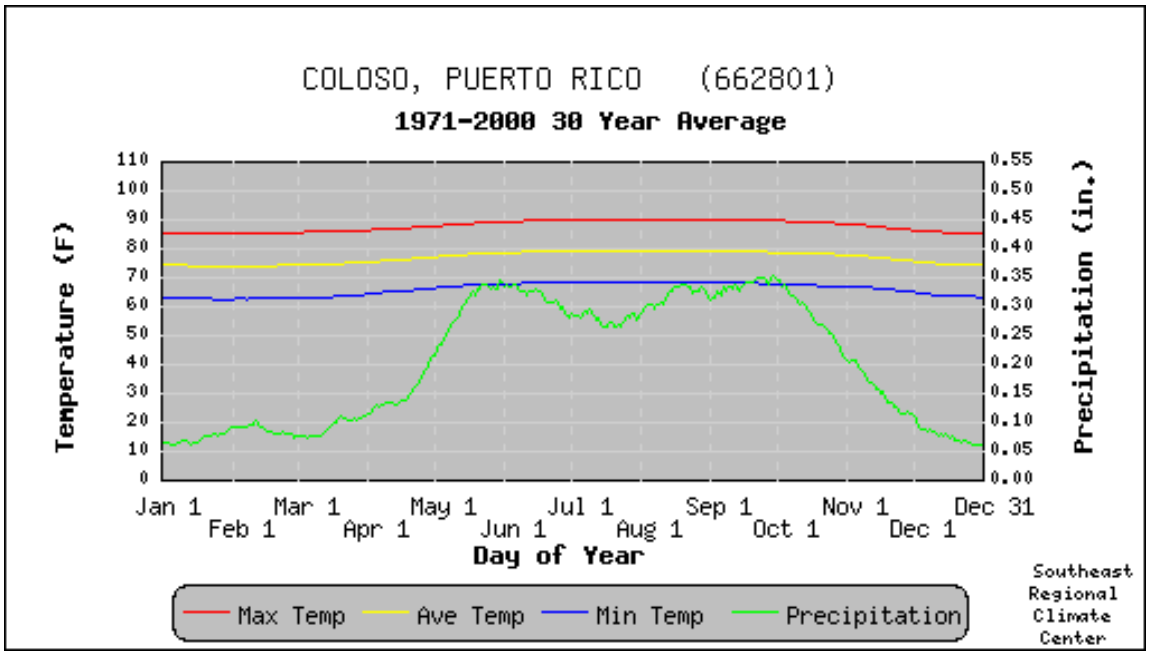
[2] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Aguada's coastal environment is comprised of beaches, wetlands, lagoons and mangrove swamps. Coastal areas in the Municipality are susceptible to strong marine forces (currents), waves, and thus erosion. Between 1950 and 1977, it is estimated that beaches in Aguada lost approximately 25 meters of shoreline due to coastal flooding and erosion. In fact, the coastal environment changed so drastically that its classification changed from a developed beach to a foreshore.

CLIMATE

The western coast of Puerto Rico receives the largest amount of rainfall in Puerto Rico---from 65 to 90 inches annually. The average temperature in this region is approximately 82 degrees Fahrenheit. In Aguada, like Puerto Rico, the seasons do not change very drastically. Figure 2.3 highlights the 30-year average temperatures and precipitation for Coloso, Puerto Rico.

FIGURE 2.3 ***Temperature and Precipitation 1971–2000***



Southeast Regional Climate Center, sercc@dnr.state.sc.us

2.3 POPULATION AND DEMOGRAPHICS

Over the later half of the 20th century, Aguada has experienced steady population growth. This growth is directly related to the capacity of the territory to retain its population (economy) and attract individuals from neighboring municipalities. In fact, Agauda bucked a trend of negative population growth for the western part of the island during the 1950s and experienced positive annual population growth of 1.14 percent in a period of relative decline.

The U.S. Census reported that 31,567 persons resided in Aguada in 1980. By 1990, this number had increased to 35,911, which represented a 13.7 percent increase in total population. In 2000, the U.S. Census reported 17 percent increase in the population to 42,042. This increase is almost double that of the overall average growth rate for Puerto Rico of 8.1 percent for the same period. Table 2.1 shows the latest demographic data for Aguada according to the 2000 U.S. Census.

TABLE 2.1 ***Population Data, Municipality of Aguada***

Subject	Number	Percent
Total Population	**42,042**	**100.0**
Male	20,608	49.0
Female	21,434	51.0
Under 5 years of age	3,234	7.7
5 to 9 years of age	3,442	8.2
10 to 14 years of age	3,632	8.6
15 to 19 years of age	3,729	8.9
20 to 24 years of age	3,418	8.1
25 to 34 years of age	5,902	14.0
35 to 44 years of age	6,451	15.3
45 to 54 years of age	5,127	12.2
55 to 59 years of age	1,886	4.5
60 to 64 years of age	1,569	3.7
65 to 74 years of age	2,161	5.1
75 to 84 years of age	1,127	2.7
85 years and over	364	0.9
Median age (years)	31.3	
18 years and over	29,513	70.2
21 years and over	27,250	64.8
62 years and over	4,562	10.9
65 years and over	3,652	8.7

General population growth in the municipality is due to aggressive municipal housing programs that have acquired vacant lands for low to moderate-income home construction.

2.4 ECONOMY, EMPLOYMENT AND INDUSTRY

Economically, the Municipality of Aguada is similar to other rural municipalities. The 2000 median family income for Aguada was $11,384, which is comparable to the municipalities of Moca, Patillas, and Arroyo (Table 2.2).

TABLE 2.2 ***Comparative Household Income Levels***
Municipality of Aguada and Other Rural Municipalities

Income in 1999	Aguada		Other Rural Municipalities					
			Moca		Patillas		Arroyo	
	Count	%	Count	%	Count	%	Count	%
Households 2000	**13,529**	**100**	**12,743**	**100**	**6,595**	**100**	**6,160**	**100**
Less than $10,000	6,013	44.4	5,649	44.3	2,823	42.8	2,753	44.7
$10,000 to $14,999	2,196	16.2	2,130	16.7	1,046	15.9	1,038	16.9
$15,000 to $24,999	2,611	19.3	2,472	19.4	1,272	19.3	1,123	18.2
$25,000 to $34,999	1,186	8.8	1,241	9.7	720	10.9	653	10.6
$35,000 to $49,999	878	6.5	757	5.9	475	7.2	394	6.4
$50,000 to $74,999	365	2.7	254	2.0	153	2.3	119	1.9
$75,000 to $99,999	144	1.1	126	1.0	48	0.7	23	0.4
$100,000 to $149,999	69	0.5	68	0.5	28	0.4	25	0.4
$150,000 to $199,999	13	0.1	7	0.1	0	0.0	17	0.3
$200,000 or more	54	0.4	39	0.3	30	0.5	15	0.2
Median HH Income	$11,384		$11,271		$12,021		11,484	
Per Capita Income	$6,100		$5,664		$5,950		$5,797	

In 2000, its median household income was slightly lower than the island's median household income of $14,412. According to the U.S. Census, 55.6 percent of the municipality's residents live below the poverty line. In the same period, 44.4 percent of the families had an income lower than $10,000; 16.2 percent had an income between $10,000 and $14,999; 19.3 percent had an income between $15,000 and $24,999; and only 20.1 percent had an income $25,000 or higher.

Employment in the municipality is distributed among 13 industrial classifications. The U.S. Census indicates that there were a total of 12,521 individuals 16 years old and over in the labor force. A total of 9,755 individuals are employed in 13 industries highlighted in Table 2.3.

TABLE 2.3 ***Workforce by Industry (2000), Municipality of Aguada***

Employed Civilian Population- Age 16 years and over		
Industry	**Number**	**%**
Agriculture, forestry, fishing and hunting, and mining	160	1.6
Construction	1,018	10.4
Manufacturing	2,442	25
Wholesale trade	257	2.6
Retail trade	1,183	12.1
Transportation and warehousing, and utilities	253	2.6
Information	96	1
Finance, insurance, real estate, and rental and leasing	297	3
Professional, scientific, management, administrative, and waste management services	432	4.4
Educational, health and social services	1,556	16
Arts, entertainment, recreation, accommodation and food services	679	7
Other services (except public administration)	455	4.7
Public administration	927	9.5
TOTAL	**9,755**	**99.9**

In 2000, 22.1 percent or 2,766 individuals 16 years and over were listed as unemployed. This unemployment rate is high in comparison to Puerto Rico, which reported an unemployment rate of 19 percent for the same period.

2.5 HOUSING

The U.S. Census indicates that there are 15,590 housing units in the Municipality of Aguada. Table 2.4 illustrates housing trends in Aguada over the period of 1900—2000. These figures indicate that the residential growth in Aguada outstrips that of the commonwealth.

TABLE 2.4 ***Number of Housing Units, Municipality of Aguada***

Number of Housing Units			
Location	**1990**	**2000**	**Percent Change**
Aguada	10,270	15,590	51%
Puerto Rico	205,508	268,476	21%

The predominant housing type is a single-family detached dwelling. It accounts for the majority of housing types throughout the community (Table 2.5). The housing density is approximately 504 housing units per square mile. This is a higher density than the average density for the entire island.

TABLE 2.5 ***Types of Housing Units, Municipality of Aguada***

Units in Housing Structure		
Housing Type	**Number**	**Percent**
1-unit, detached	12,399	79.5
1-unit, attached	2,170	13.9
2 units	407	2.6
3 or 4 units	258	1.7
5 to 9 units	154	1.0
10 to 19 units	30	0.2
20 or more units	96	0.6
Mobile home	76	0.5

Table 2.6 indicates that, according to the 2000 U.S. Census, more than 80 percent of the municipality's housing stock is owner-occupied, while renters occupy approximately 19.4 percent of households.

TABLE 2.6 ***Tenure of Housing, Municipality of Aguada***

Tenure	Number	%
Owner-occupied housing units	10,901	80.6
Renter-occupied housing units	2,619	19.4
Total	**13,520**	**100.0**

This section includes a description of the hazard mitigation planning approach utilized for the development of the Plan. It also describes the organization of community resources (i.e., formation of a hazard mitigation planning committee), outcomes of public informational meetings, and important documents/legislation reviewed during the development of the Plan. The section is presented in the following five subsections:

- 3.1 Description of the Hazard Mitigation Planning Process
- 3.2 Formation of a Hazard Mitigation Committee
- 3.3 Public Participation and Community Workshops
- 3.4 Plan Outreach
- 3.5 Review of Existing Legislation, Plans and Reports

3.1 DESCRIPTION OF THE HAZARD MITIGATION PLANNING PROCESS

The planning process was initiated by the Puerto Rico State Emergency Management Agency (PRSEMA), the Municipality of Aguada Office of Emergency Management, the Municipality of Aguada Federal Programs Office, and PBS&J, a consulting firm selected to support the preparation of the Plan. The Hazard Mitigation Committee, introduced later in this section, along with project consultant PBS&J led the development of the Plan over a 12-month period that included the steps listed below:

- Background research and field assessment;
- Community-based planning process;
- Hazard identification and risk assessment;
- Community-based mitigation strategy; and
- Strategy for plan implementation and maintenance.

The findings of the background research conducted by the study contractor are found in Section Two, titled *Community Profile.* Section Two describes the makeup of the community, including the prevalent environmental, demographic and economic characteristics. During this phase, an analysis of the community's built environment and critical facilities was conducted. This baseline information, which provides a snapshot of the community's exposure (i.e., economic assets), is located in the *Hazard Identification and Risk Assessment* (Section Four) and is essential to the vulnerability analysis conducted for the municipality.

The hazard mitigation planning process, which is highlighted in this section, was launched by the creation of a Hazard Mitigation Planning Committee. This committee provided oversight to the plan development process and worked to engage the public through three (3) public informational workshops. A fundamental component of this planning process involves public participation and input. In this phase of the Plan, the study contractor conducted a review of appropriate plans, studies and reports.

The next important phase of the planning process involved the *Hazard Identification and Risk Assessment* (Section Four). An analysis was conducted to ***identify*** and describe the type of hazards that can affect the municipality. This analysis included a ***hazard profile*** that presents a description of the location and extent of each identified hazard (delineate areas at risk), describes ***previous occurrences*** of hazard events (history), and provides an understanding of the ***frequency*** (probability) of each hazard event. To be consistent with DMA 2000, further analysis was conducted that ***assesses vulnerability*** to hazards by providing a summary of the overall impact to community assets (types and numbers of buildings, infrastructure and critical facilities), and projects ***future vulnerability*** (potential losses) in Aguada so that mitigation options can be reasonably assessed.

Based on citizen input gathered from community workshops, an assessment of the baseline information and the findings of the *Hazard Identification and Risk Assessment*, the community formulated a comprehensive *Mitigation Strategy* (Section Five). This involved the development of broad mitigation goals and objectives and the identification and prioritization of mitigation measures or actions. Following the completion of its *Mitigation Strategy*, the municipality concentrated on designing measures to ensure the Plan's ultimate implementation located in *Plan Implementation* (Section Six). In this section, an implementation framework is provided to ensure that mitigation actions, outlined in the Plan, are implemented, evaluated and routinely updated.

3.2 FORMATION OF A HAZARD MITIGATION COMMITTEE

The planning process began on **March 31, 2003** with an executive-level meeting, which led to the creation of a small select Hazard Mitigation Planning Committee. The role of the Committee is to provide oversight to the plan development process, participate in project progress meetings, facilitate public informational meetings, and provide leadership for the identification, prioritization and implementation of mitigation measures.

During the above referenced project kick-off meeting, the municipality focused on identifying persons that would be committed to being part of the planning process. The Hazard Mitigation Planning Committee is comprised of individuals from relevant municipal departments, Community Board members,[1] and community organizations. The persons listed in Table 3.1 all made a firm commitment to be part of Aguada's Hazard Mitigation Planning Committee.

[1] The Community Board is a formal board that is formed by the municipality to oversee the development of the comprehensive development plan.

TABLE 3.1 ***Hazard Mitigation Planning Committee***

Name	Department/Community Function
Martin Concepcion	Director, Office of Emergency Management, Municipality of Aguada
Alberto Perez	Office of Emergency Management, Municipality of Aguada
Isabel Cardona	Lions Club, Community Board Member
Francisco Carrero	Citizen, Community Board Member
Geraldo Hernandez	Aguadenos para Conservacion de los Ambeinte, Community Board Member
Miquel Valle	Federal Funding Department, Municipality of Aguada
Manuel Gonzalez	Igelias Pentecostal de Aguada

3.3 PUBLIC PARTICIPATION AND COMMUNITY WORKSHOPS

The Hazard Mitigation Planning Committee held three (3) meetings; two meetings were structured public informational meetings to facilitate the public involvement and the third meeting focused on developing a comprehensive mitigation strategy for the community.

COMMUNITY WORKSHOP 1: IDENTIFYING HAZARDS AND UNDERSTANDING COMMUNITY CONCERNS

An initial public information meeting/workshop was held on **May 14, 2003**. Discussions at the meeting focused on the overall project approach, in which emphasis was placed on the steps necessary to meet the requirements of the Disaster Mitigation Act of 2000. A description of the proposed hazard mitigation planning process was presented, explaining each step and the type of data that would be required. Information was identified which the municipality must provide regarding hazard information, capability assessment, existing policies and ordinances, and area land uses.

Twelve (12) persons attended this meeting including representatives from the municipality emergency management agency, concerned citizens, and the study contractor. To open discussion and initiate the hazard identification process, the study contractor provided the community with a list of hazards that were relevant to Puerto Rico. The Municipality of Aguada identified a preliminary list of hazards of concern specifically for Aguada. Table 3.2 summarizes this hazard identification and selection process, showing all potential hazards which could impact the municipality as well as those hazards determined to be applicable to the municipality and thus worthy of further study based on group discussion.

TABLE 3.2 ***Identification of Applicable Hazards***

Potential Hazards	Applicable Hazards	Hazard
☑	☑	Coastal Flooding
☑		Drought
☑	☑	Earthquake (Ground Shaking)
☑	☑	Earthquake (Liquefaction)
☑	☑	Earthquake-Induced Landslide
☑	☑	High Wind (including hurricane and tropical storm)
☑	☑	Rainfall-Induced Landslide
☑	☑	Riverine Flooding
☑	☑	Tsunami
☑		Urban Fire
☑		Wildfire

From the list of 11 hazards, eight (8) were selected as applicable hazards of interest for the municipality for the Hazard Mitigation Plan. These eight hazards include *earthquake (ground shaking, liquefaction, earthquake-induced landslide, tsunami), flooding (riverine and coastal), rainfall-induced landslide, and high wind (including hurricanes and tropical storms).* These hazards are described in greater detail in *Hazard Identification and Risk Assessment (Section 4).*

Once hazards were identified, PBS&J facilitated a "cardstorming" exercise – an interactive brainstorming session for workshop attendees to identify concerns and recommendations for mitigating applicable hazards in Aguada. The cardstorming technique required input from every workshop participant and resulted in both broad and very specific input for inclusion in the Plan. The results of this strategic planning exercise, and consequently the first community workshop, are summarized below by hazard:

Flooding

Flooding is by far the most pressing hazard of concern within the municipality. Individuals expressed concerns about two types of flooding: urban flash flooding and rural riverine flooding. Concerns noted about flooding hazards include:

- Community members pointed out that new construction occurs without consideration of hazards or existing hydrology. Continued commercial development along Carr. 411 (Desvio Sur) is of particular concern.
- New construction in environmentally sensitive areas (wetlands and flood zones) has increased the frequency of flood-related damages. In Barrio Mamey and Asumante, it has also increased the need for emergency evacuation services.
- There are repetitive flood damages to homes in Barrio Espinar. Floodwaters of the Rio Culebrinas cause damages to homes and frequently block P.R. Carr. 442 and 115.

- Citizens have pointed out that new construction along Rio Ingenio has increased surface run-off. Increased sedimentation in the river has impeded its natural flow and caused localized urban flooding (i.e., traffic disruption on Car. 414).
- Inadequate stormwater drainage infrastructure in Barrio Rio Grande and Guayabo has caused localized urban flooding and frequent transportation disruptions on Carr. 115 (South).
- Increased surface run-off and inadequate stormwater infrastructure has increased susceptibility to flooding in low-lying areas such as Las Casonas.

Landslides

Landslides occur during intense heavy rainfall and result from general failure of land due to improper cut and fill, and loss of vegetation. Landslides damage streets, pilings of houses, and limit vehicular access to some areas. The major concern identified by the community with regard to landslide hazards is:

- Citizens indicated that most of the landslides occur in mountainous areas of the municipality. They also indicated that they tend to occur along roads administered by the central government such as P.R. Car. 411, 403, 417, 416, and 419.

Earthquake-Related Hazards

The major concerns identified by the community about earthquake-related hazards include:

- Individuals expressed concern about seismic hazards, especially tsunamis. The Office of Emergency Management pointed out that tsunamis have the potential to produce extensive damages, particularly on the western coast of Puerto Rico. Municipal officials pointed out that a tsunami evacuation plan has been developed.
- Citizens expressed concern about increased construction in the coastal areas, especially tourist development and vacation homes.

High Wind

The major concerns identified by the community about the high wind hazard include:

- Hurricane winds are a concern for most citizens; nevertheless, most concerns focused on associated flooding.
- Citizens indicated that homes continue to be constructed without the proper permits and/or wind resistant techniques. Many citizens mentioned that informal construction occurs because of cost associated with formal construction (plans, etc.) and the perception that the formal permit and review process at ARPE favor larger developers.

Environment

The major environmental and planning concerns identified by the community include:

- The environmental impacts of large subdivisions, particularly developments in mountainous areas, have decreased natural habitat and forests, increased erosion, and stormwater run-off.

- Citizens also expressed concern about the destruction of "mogotes." These large limestone deposits are being mined and the landscape has been scarred as a result.
- The clandestine extraction of sand from beaches has decreased natural vegetation of the littoral environment. Reduction of sandy areas also reduces natural barriers that protect against storm surge. Coastal erosion and flooding is becoming a bigger problem, especially along sections of P.R. Car. 442, 441, and 115.
- Citizens mentioned that strip mall developments are transforming the landscape and increasing susceptibility to flood hazards (i.e., Devisio Sur).

Education

The major education concerns identified by the community include:

- Citizens urged the municipality to pursue education programs. They mentioned that specific programs should focus on helping citizens understand the potential impacts of hazards, the importance of preparedness, and mitigation.
- Citizens recommended that the Office of Emergency Management use the hazard maps that have been developed as part of this Plan to educate the community about hazard-prone areas. Maps are important tools for risk communication and can help develop neighborhood response and recovery strategies.
- Citizens also suggested that the municipal government form community-based volunteer groups to increase awareness of risk and mitigation.

Government Coordination

Concerns regarding government coordination include:

- Individuals recommended that the other municipal agencies/departments should become involved in the mitigation planning process. The Office of Emergency Management was encouraged to explore how to develop linkages with other municipal offices.
- Citizens expressed concern that the municipality should develop linkages with the central government as it relates to disaster services, especially during response and initial recovery.

The concerns and recommendations described above were noted and considered by the Hazard Mitigation Committee in later discussions regarding the development of mitigation goals, objectives, and actions.

COMMUNITY WORKSHOP 2: UNDERSTANDING RISKS AND BUILDING A VISION FOR MITIGATION

A second public informational meeting was held on **August 28, 2003**. This workshop consisted of a presentation of the findings of the risk assessment and the development of an overarching framework for the community's mitigation strategy.

Ten (10) persons attended this meeting including committee members, government representatives and community leaders. The overall purpose of this workshop was to present the findings of the risk assessment in order to provide a factual basis for the development of a mitigation strategy. The mitigation strategy is to provide a framework to guide the identification of different mitigation actions (projects and policies) to reduce future risk.

During this meeting, a series of large hazard maps were presented and used to identify areas of potential hazard concern. Quantitative loss estimates were also presented to provide community members with an understanding of the overall impact of the identified hazards.

The study contractor facilitated a strategic planning session to develop an overarching framework for the municipality's mitigation strategy. Community members were engaged to develop a long-term vision for hazard mitigation:

> *Ensure that the residents, visitors and businesses in Aguada are safe and secure from natural hazards. This program will lead to the development of specific actions that reduce the risk and vulnerability before events happen and will be based on the principles of community cooperation, public education and partnerships.*

After the development of the mission statement, the Hazard Mitigation Planning Committee reconvened to identify a series of overarching goals for Aguada. Study contractors explained that overarching ***goals*** should be accompanied by specific ***objectives*** or strategies that are intended to support, correspond and define a path to attain the desired goals. After considering local capability, the results of the risk assessment as well as the suggestions received during the first community workshop, the outcome was a list of four (4) goals and six (6) objectives listed below:

Goal #1 **Implement programs and policies to reduce the impact of natural disasters on population, property and infrastructure.**

- Objective 1.1. Protect existing development from future disaster events.
- Objective 1.2. Protect future development by implementing sound land use and development policies.

Goal #2 **Increase municipality capabilities to implement and maintain mitigation programs.**

- Objective 2.1. Identify and development policies, programs and regulations to support effective hazard mitigation programming throughout the municipality.

Goal #3 **Implement programs that increase awareness and understanding of hazards and hazard mitigation.**

- Objective 3.1. Develop outreach programs focused on increasing public awareness of hazards and their associated risks.

Goal #4 **Increase municipal emergency preparedness, response and recovery capabilities.**

- Objective 4.1. Enhance the local government capability to support emergency response and recovery operations.
- Objective 4.2. Maximize governmental coordination and communication between municipality, central government and federal agencies in emergency situations.

HAZARD MITIGATION PLANNING COMMITTEE WORKSHOP: DEVELOPING A MITIGATION STRATEGY

A third meeting was held on **October 21, 2003**. This workshop consisted of presentation of the draft report,[2] which was provided to the Office of Emergency Management for public distribution. The Committee was asked to provide feedback on each goal and objective identified during the previous public informational meeting.

The study contractor led a strategic planning process to develop a hazard mitigation strategy that consisted of developing a series of actions designed to achieve the aforementioned goals and objectives. The outcome of this meeting was the identification of 39 actions.

For each action, specific implementation requirements were defined. These requirements included the identification of the lead department/agency designated for action implementation, an estimation of project costs (approximation until actual final dollar amounts can be determined), determination of funding method, determination of a project implementation timeframe; and a prioritization of each action.

Committee members subjectively prioritized each action. A simple ranking was utilized to rate the priority of each action as high, medium or low priority. Prioritization was based on the Committee's knowledge of the municipality's administrative, technical and financial capabilities. Each prioritized action was voted on with guidance provided by the study contractors. Details regarding the process used for the prioritization of mitigation actions are found in Section 5 of this Plan.

3.4 PLAN OUTREACH

A fundamental component of the municipality of Aguada's community-based mitigation planning process involves public participation. Individual citizen involvement provides the Hazard Mitigation Planning Committee with a greater understanding of local concerns and ensures a higher degree of mitigation success by developing community "buy-in" from those directly affected by the planning decisions of public officials. As citizens become more involved in decisions that affect their life and safety, they are more likely to gain a greater appreciation of the natural hazards present in their community and take personal steps to reduce their potential impact. Public awareness is a key

[2] Please note that the draft report was made available to the public through the Office of Emergency Management. At the same time, it was submitted to FEMA and PRSEMA for consideration.

component of an overall mitigation strategy aimed at making a home, neighborhood, school, or business safer from the potential effects of natural hazards.

A range of stakeholders were invited to comment during the development of the Hazard Mitigation Plan, such as agencies, businesses, academia, nonprofits, or other interested parties. Community workshops were advertised by various means, including the posting of a meeting notice at municipal offices, phone calls, and word of mouth.

With regard to providing the public with an opportunity to comment on the Plan during the drafting stages and prior to the Plan's ultimate adoption, copies of the draft Plan were delivered to the Federal Programs Office and the Emergency Management Office. Public notice of the availability of the draft plan was given during the final public workshop. During this time of availability, the draft document was open for review and comment by interested parties and stakeholders in the hazard mitigation planning process.

Invited participants were made aware of the need for public participation and the community workshops via public notice letters that were sent to select stakeholders[3]. The Office of Emergency Management also worked to engage different community groups in the planning process. This was done informally and these groups were notified of the availability of the draft Plan on a person-to-person basis. Again, the draft Plan was made available at the final community meeting and was held at the Office of Emergency Management for review and comment by the public.

With low public attendance during workshops, the Hazard Mitigation Planning Committee sought to develop other mechanisms for community outreach, such as identifying and working with select agencies, organizations and community groups. Plan outreach meetings sought to provide these groups with an overview of the hazard mitigation planning process, help them understand concerns about hazards, and encourage them to participate in the development of the Plan. The central theme of these outreach activities was to go to the community as opposed to waiting for the community to "come to you." The Committee determined that community-based organizations would be one effective way to disseminate information about the planning process throughout the community. The outreach efforts have been community-wide and have not attempted to make contact with neighboring communities or central government agencies.

Between August and September 2003, the Office of Emergency Management led the community outreach effort by establishing a series of meetings[4] with the following community groups, non-profits, and business leaders:

[3] A copy of this public notice letter is available in the packet of supplemental documentation accompanying this Plan. Also available are the workshop agendas. All meeting minutes and notes were incorporated as appropriate directly into the writing of the Plan. Due to a change in local administration, copies of other pertaining documents may not be available from municipality officials.

[4] Exact dates for these meetings were not provided by the municipality.

- Lions Club (Club de Leones)—Isabela Cardona, a member of Mitigation Committee, made a presentation to the club members about the mitigation planning process in Aguada.
- Rotary Club (Club Rotario)—Pedro Bosques, Presidente of the Aguada Rotary Club, was present during both planning workshops. He has facilitated a presentation by Office of Emergency Management personnel at a Rotary luncheon.
- Aguadeons para Conservacion de los Ambeinte—Geraldo Hernandez, Presidente, has participated in all planning workshops and has disseminated information to his association. Aguadeons para Conservacion de los Ambeinte is very interested in helping the community implement identified mitigation actions, especially those related to the protection of the environment.
- Groupo Programa Apoyo Enlace Comunitario (PAEC)—The Office of Emergency Management has provided this group with information about the planning effort. Although this group focuses on helping citizens with drug problems, it is very interested in facilitating community education programs.
- Club Amigos Unidos—The Office of Emergency Management has provided this group with information about the planning effort. This group is very interested in the mitigation planning project as it has facilitated residential reconstruction following disasters. It also helps citizens organize to improve infrastructure and performs small mitigation projects (i.e., stabilization of soils for landslides).
- Consejo de Seguridad Vecinal, The Offfice of Emergency Management has provided this group with information about the planning effort. Consejo de Seguridad Vecinal provides support to police officers and helps special needs populations (elderly, sick, etc.).
- Altrusas de Puerto Rico, Aguada. The Office of Emergency Management has provided this group with information about the planning effort. Altrusas de Puerto Rico is organized to help women and families with social needs (affordable housing, medical care, etc.).

In order to meet the FEMA requirement that neighboring jurisdictions be notified of plan development, municipal officials from Aguada sent a letter to the municipalities of Aguadilla, Rincon, Anasco, and Moca. The letter informed officials from those municipalities of the hazard mitigation plan developed for Aguada and instructed anyone interested to contact the municipality for more information. General comments on the Plan were also solicited from these municipalities; however, no comments were received from these neighboring municipalities. A copy of the letter that was submitted to the neighboring jurisdictions can be obtained by contacting the Municipality of Aguada.

Future updates of the Plan will extend this effort to include increased participation from state and federal agencies, as well as neighboring jurisdictions, businesses, academia, non-profits and other parties that are interested in participating in the planning process over time.

3.5 REVIEW OF EXISTING LEGISLATION, PLANS AND REPORTS

The review of existing plans, studies, reports, and ordinances was an important aspect of the planning process. The review focused on important studies and legislation that would have an impact on the municipality's ability to implement and manage a hazard mitigation initiative. This information assisted in identifying opportunities to address existing gaps, weaknesses or conflicts with other initiatives in addition to integrating the implementation of this Plan with existing planning mechanisms, where appropriate. Information gained through the review of these documents was considered during the creation of goals, objectives, and mitigation actions included in this Plan. The subsection below provides a summary of major documents/legislation that were reviewed and considered by the Hazard Mitigation Planning Committee during the development of the Mitigation Strategy.

LEGISLATION

A review of several central government regulations provided an understanding of the established norms and procedures for land use and development in Puerto Rico. An understanding of each of these is useful for future planning focused on reducing vulnerability and impact to natural hazards.

- **Regulation No. 4** was the principal document that established guidelines for the control of urban and rural lands in Puerto Rico and defined planning criteria for new developments to follow.
- **Regulation No. 3** established guidelines and controls for the subdivision of land for residential development, as well as for the development of infrastructure (i.e., aqueducts, sewer systems, electric energy, telephone, etc.) to allow access to new facilities, new subdivisions, or urbanized areas. Regulation No. 3 also contains guidelines to lessen impacts to surrounding areas (instability of the slopes, special natural resources, etc.).
- **Regulation No. 7** adopted building standards to regulate building construction on the island. It was updated after Hurricane Georges by the adoption of the "Emergency Regulation to Repeal Building Regulation." This emergency action adopted the 1997 edition of the Uniform Building Code™ (UBC) and the American Society of Civil Engineers (ASCE), ASCE 7-95 for wind load provision in lieu of the provision in the 1997 UBC.
- **Regulation No. 12** established the "certification process" in ARPE. This process was implemented to streamline development review procedures. It allows the engineering and architectural community to certify if a construction or development project is in conformance with all regulations.
- **Regulation No. 13***: Reglamento Sobre Zonas Susceptibles a Inundaciones* (Regulation No. 13 – Flood Zones). Adopted in 1971 to restrict development in flood zones, this regulation was adopted under the protection of Law No. 3 of September 27, 1961, which is known as the *Ley para el Control de Edificaciones en Zonas*

Susceptibles a Inundaciones (Law to Control Construction in Flood Zones). Regulation No. 13 was amended in 1978, when the Central Government joined the National Flood Insurance Program (NFIP). These amendments were necessary to conform to federal legislation regulating construction in the Special Flood Hazard Areas (SFHAs) as identified in the Flood Insurance Rate Maps (FIRMs). FEMA published the FIRMs for Puerto Rico in August 1978.

COMPREHENSIVE PLAN: LAND USE AND ZONING

A review of the *Plan Territorial*, or comprehensive plan, provided critical baseline information (history, demographic profile, etc.). It also provided an understanding of the municipality's development objectives. It is also the main instrument for strategic and integrated land use planning for the municipal territory.

This document outlined goals and strategies based on a complete analysis of the municipality's population, its potential for growth, and the general needs that may arise from this growth. It also described the public policies that would guide the implementation of recommendations outlined in the Plan.

The development of Aguada's *Plan Territorial* has been stalled. Because of this, many of the data and findings outlined in the plan are outdated. The changing land use patterns and expectations of citizens have thereby jeopardized the adequacy of the plan itself.

This section presents the results of the risk assessment conducted for the Municipality of Aguada. The risk assessment was prepared to satisfy the requirements of DMA 2000, FEMA Region II, and to meet the PRSEMA guidance for the development of local hazard mitigation plans. More importantly, it provides a foundation for the community's decision makers to evaluate mitigation measures that can help reduce the impacts of a natural hazard event, when one occurs.

This section is organized around the risk assessment process shown in Figure 4.1 and includes the following six subsections:

- 4.1 Introduction and Methodology
- 4.2 Identification of Hazards
- 4.3 Profile of Hazards
- 4.4 Inventory of Assets
- 4.5 Loss Estimates
- 4.6 Understanding Future Losses In Aguada

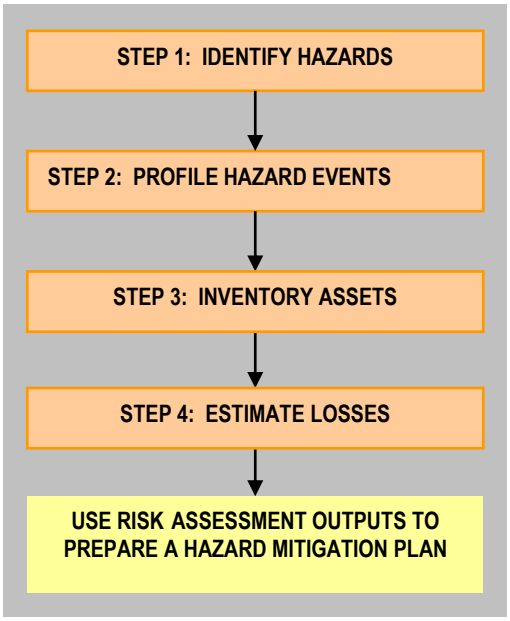
4.1 INTRODUCTION AND METHODOLOGY

The risk assessment process used for this project is consistent with the process and steps presented in FEMA Publication 386-2, "State and Local Mitigation Planning How-To Guide, Understanding Your Risks—Identifying Hazards and Estimating Losses" (FEMA 2001). Figure 4.1 shows the steps that comprise the risk assessment process. Details regarding how HAZUS®MH can be used to conduct a DMA 2000 risk assessment are provided in FEMA 463, "How-To Guide for Using HAZUSMH for Risk Assessment" (FEMA 2004).

The methodology used to assess potential exposure and losses associated with priority hazards for this is consistent with the ***HAZUSMH risk assessment methodology***. The HAZUSMH methodology is parametric, in that distinct hazard parameters (for example, ground motion for earthquake and discharge depth of flood) and inventory parameters (for example, building types) are modeled to determine the potential impact (damages and losses) on humans, buildings, and other assets. For this risk assessment, the HAZUSMH risk assessment methodology was modified because the software and inventory data was not available for Puerto Rico.

To develop model parameters consistent with HAZUSMH, the project team relied on data from

Figure 4.1 ***Risk Assessment Process***



several sources. These included ***hazard*** data gathered from a FEMA HMGP-funded project titled, "Integrated Hazard Assessment for Puerto Rico." The above referenced study provided baseline hazard information.

To gain an understanding of ***inventory***, or the "built environment," a field assessment was conducted to identify building types, building replacement costs (dollars per square foot) for various building types, and "occupancy classes" (residential and commercial).

To **assess vulnerability**, population characteristics were determined to be the most prominent indicator of social vulnerability. In general, GIS queries were performed to indicate where the people reside within the municipality relative to hazard levels. In addition, the analysis was further broken down to identify the number of people less than 18 years of age and the number of people over 65 years of age. These two demographic subgroups help refine the social vulnerability analysis as these two population groups are the most likely to need assistance during a hazard event. General vulnerability of the municipality is described in qualitative terms. Future Plan updates hope to provide a more quantitative assessment of vulnerability for each hazard.

To ***estimate losses***, building type distributions (**general building stock**) identified during the field assessment were related to specific damage and loss characteristic parameters for each hazard. These damage and loss characteristics were modified from the results of the study carried out by the University of Puerto Rico under contract from the Puerto Rico Planning Board titled, "Verification of HAZUS Fragility Curves of Concrete and Steel Buildings for Puerto Rico."

The loss estimation methodology for **critical facilities** is undertaken in a similar fashion. The exposure value of critical facilities types were collected from a FEMA HMGP-funded HAZUS study conducted by the Puerto Rico planning board following Hurricane Hortense. Exposure values were modified based on field observations. The risk level for all relevant hazards (earthquake, flood, wind, etc.) was determined for each building type, classifying them into five separate levels (Very Low, Low, Medium, High, and Very High). The risk level for each hazard varies and the five levels of damage were interpolated, where applicable, using the following criteria:

- Ground shaking - PGA levels - .10 - .50 – broken into 5 hazard levels
- Liquefaction – based on probability of ground shaking hazard level, soil type
- Earthquake Landslide - based on probability of ground shaking hazard level, soil type and slope
- Tsunami – no hazard magnitude or intensity level was provided
- Wind – 90-122 mph
- Rain-induced landslide – The hazard map (Figure 4.9) identifies susceptibility
- River Flood Depths range from 1- 3.9 meters
- Coastal Flood Depths range from 1- 2.5 meters

The damage ratios for facilities were based on modified standard damage ratios obtained from HAZUS^{MH} and ACT (Applied Technology Council). The product of the resulting damage ratios and the exposure are the expected aggregated losses for each facility class.

Ground Shaking Hazard Assessment: Data Sources, Ground Shaking Hazard Model Assumptions, and Limitations for Aguada

The hazard assessment was developed using the Seismic Hazard Map of 1994 (Earth Science Consultants, 1994), which provides ground shaking intensity (expressed in terms of Peak Ground Acceleration (PGA) for 50-, 100-, 250-, 1,000-year return periods).

- The 100-year ground shaking map was generated using an acceleration variability (σ) of 0.6 at a set of sites across a uniformly spaced two-dimensional grid.
- Ground shaking susceptibility was based on local soil conditions and the surficial geology based on the *Hydrogeologic Map of Puerto Rico and Adjacent Islands* (1965).
- Local site geology was classified using NEHRP[1] provisions to define localized site amplification classification.
- To compute the damage potential (estimate losses), the baseline hazard frequency, intensity and susceptibility values (PGA) were computed against damage functions developed for a series of building types identified during field surveys.

Liquefaction Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The potential damage from liquefaction is conditional on the ground shaking amplitude (i.e., PGA), ground shaking duration, and groundwater depth.

- Conditional probability of liquefaction as a function of Peak Ground Acceleration (PGA) was utilized from Integrated Hazard Assessment Report, 2001. Probabilities were consistent with the HAZUS methodology (FEMA, 1999).
- The relative liquefaction susceptibility of a region was characterized by evaluating its soil/geologic conditions and groundwater depth. Susceptibility rating ranging from very low to very high was assigned using the Youd and Perkins (1978) classification system.
- To compute the damage potential (estimate losses), the baseline hazard frequency, intensity and susceptibility values (PGA) were computed against damage functions developed for a series of building types identified during field surveys.
- The damage functions for liquefaction were developed using an approach similar to the one provided in the HAZUS Technical Manuals (FEMA, 1999).

[1] NEHRP is the National Earthquake Hazards Reduction Program. This program's congressional mandate is "to reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program."

Earthquake-Induced Landslide Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The potential damage from an earthquake-induced landslide is significantly influenced by ground shaking amplitude (i.e., PGA) and the landslide susceptibility category.

- Conditional probability of earthquake-induced landslides is a function of Peak Ground Acceleration (PGA). The probability categories used to classify hazard susceptibility are consistent with the HAZUS methodology (FEMA, 1999).
- The relative earthquake-induced landslide susceptibility was classified using a soil association map developed by the National Cooperative Soil Survey that broke a broad-based inventory of soils and non-soil areas into five distinct physiographic regimes.
- For each physiographic regime susceptibility categories were assigned as a function of geologic group and slope angle.
- To compute the damage potential (estimate losses), the baseline hazard intensity—permanent ground deformation values (PGD)—was computed against damage functions developed for a series of building types identified during field surveys.

Tsunami Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The tsunami hazard maps used in this study were developed as part of a study titled, "Tsunami Coastal Flood Mapping for Puerto Rico and Adjacent Islands" (Mercado, 2003).

- There were 340 potential faults identified under the methodology mentioned above. A simulation was made of each one of them using the Japanese non-linear shallow water tsunami TIME model.
- Three nested grids were used, starting with the outer grid with a cell size of 27 arc seconds, followed by the intermediate grid with cell size of 9 arc seconds, and the inner grid with a resolution of 3 arc seconds.
- The induced sea bottom deformation was determined for each one of the potential faults using the Mansinha and Smylie (1971) method.
- Recently acquired SHOALS bathymetry was used to determine nearshore ocean elevations. To determine the depth of deeper waters, NOS data and Sandwell and Smith (ETOPO-2) bathymetry were utilized.
- The USGS Digital Elevation Model was utilized to determine land elevations.
- The tsunami model and the data have been shown to provide good estimates of the observed runup due to the 1918 Puerto Rico tsunami (Mercado and McCann, 1998).
- The tsunami map was developed using a deterministic approach and is irrespective of the time of occurrence. Therefore, the inland flood extent for a 100-year recurrence timeframe cannot be determined.

High Wind Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The development of the high wind hazard map included two distinct sets of data: one derived from a simulation model and the other from a wind hazard model.

- The wind hazard methodology was based on numerical modeling of hurricane motion and procedures developed by the American Society of Civil Engineers (ASCE, 2000) for calculating wind loads. It takes into account basic wind speeds, surface roughness and topography.
- Hurricane wind speeds are based on the hurricane simulation model described in Vickery et al. (2000). The simulation uses the hurricane database HURDAT[2] to generate synthetic storms and predicts 100-year peak gust wind speed in a flat terrain model from 120 mph to 130 mph (Applied Research Associates, Raleigh, North Carolina (2001)).
- Wind speeds are affected by surface roughness due to vegetation, terrain features, and buildings (Vickery, 2001). The roughness effect is taken into account for "Exposure B" according to ASCE 2000 and is assumed for the entire island.

Automated GIS procedures were used to develop a map that depicts ASCE topographic speed-up effects in which local terrain features were taken into consideration.[3] These factors account for the slow down experienced as the hurricane moves inland and for when it speeds up as the wind runs up hill slopes.

Riverine Flooding Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The magnitude of riverine flood damages is increasing in Aguada. Flood events continue to have an impact on greater numbers of buildings. The assessment of damages was limited to the FEMA 100-year floodplain data.

- The assessment utilizes the FEMA 100-year flood as an indicator of the overall hazard.
- Flood elevations for the 100-year floodplain were derived from FEMA Q3 Flood Data.

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[2] HURDAT is the National Hurricane Center's (NHC's) North Atlantic hurricane database. The original database of six-hourly positions and intensities was put together in the 1960s in support of the Apollo space program to help provide statistical track forecast guidance for tropical storms and hurricanes (Jarvinen et al., 1984).

[3] ASCE topographic speed-up effects composite factor utilized

$$K_{zt} = 1 + K_1 K_2 K_3$$

The three factors are calculated using the following procedures:

K_1 is a factor to account for the shape of topographic feature and is calculated from the ratio of H/L_h. H is the height of the hill and L_h is a horizontal distance used for scaling purposes and is explained below.

K_2 is a factor to account for distance upwind (or downwind) of the crest and is calculated from the ratio of x/L_h, where x is the upwind/downwind distance.

K_3 is a factor to account for reduction in speed-up with height above ground and the ratio of z/L_h, where z is the height above local ground.

- Because of significant inconsistencies between the digital Base Flood Elevations (BFEs) and the terrain model, the 100-year floodplain polygons were used to infer flood elevations.
- The resulting GIS layer was used to generate an estimate of flood surface elevations to understand damages and losses.

Coastal Flooding Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The coastal flood damages are increasing in Aguada, particularly as development increases in coastal areas. The risk assessment in this study was limited to the VE zones from the FEMA Q3 maps.

- A 100-year flood probability was assumed for these areas.
- Flood elevations for the coastal high hazard areas were derived from an interpretation of both FEMA Q3 maps and digital USGS 1:20,000 topographic data.
- GIS overlay techniques were used to determine the flood depth of the Coastal High Hazard Area.[4]
- Flood damage functions were developed using various published reports, expert opinion, and FEMA Flood Insurance Administration (FIA) damage curves. Flood damage functions relate depth of flooding (in meters) to the damage ratio.
- The risk assessment allowed the project team to estimate the amount of property in the VE zones, as well as the type and value of structures present.

Rainfall-Induced Landslide Hazard Assessment: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

To identify the rain-induced landslide hazard in Aguada, a series of geospatial attributes were combined to create a hazard susceptibility map. This included the use of a:

- **Slope Map**: Larsen and Torres-Sanchez (1998) evaluated the frequency of landslide events in nine slope classes. Based on their empirical data, they chose 12° (21 percent slope) as the boundary value between high and low susceptibility.
- **Elevation Model**: Larsen and Torres-Sanchez (1998) based their subdivision of elevation categories on the increased incidence of landslides above 300 m in elevation. Elevation was used as a surrogate for soil moisture rather than rainfall.
- **Aspect Map**: Slope aspect can be divided into three categories, according to whether the slope faces, is in lee of, or is normal to the prevailing wind.
- **Geology Map**: Monroe's (1979) classification of Puerto Rico into four susceptibility categories was primarily based upon the underlying bedrock and surficial geology.

[4] The error inherent in the terrain model suggests that flooding depths do not have great accuracy; however, they are suitable to distinguish between flooding depths of 1m, 2m, and 3m or greater.

- **Land Use Map**: Land use refers to current land use and includes modification of the natural topography. Larsen and Torres-Sanchez (1998) simplified land-use categories to include forest, pasture, and cropland, and developed areas such as roads and structures.

The physiographic and climatic characteristics were extrapolated to understand the relative contribution of the geospatial characteristics (slope, elevation, and slope aspect). Based on empirical data published by Larsen and Torres-Sanchez (1998), the results were normalized to create an island-wide susceptibility map. The landslide susceptibility map was divided into five categories: Very Low, Low, Moderate, High, and Very High. Based on data presented by Larsen and Torres-Sanchez (1996) for the 10-year period, the probability of a rainfall-induced landslide event occurring within a one square kilometer grid cell was calculated for Aguada. It was determined by allocating a proportion of landslide events to each susceptibility category. This was used to develop an estimated number and size of landslides over a 100- year period throughout the island[5].

Infrastructure and Critical Facilities: Data Sources, Hazard Model Assumptions, and Limitations for Aguada

The loss estimation methodology for critical facilities is undertaken in a similar fashion to the loss estimation procedure for regular building inventory, adjusted to reflect limitations in the available data and to account for differences in the resolution level of the data. The limitations include the following:

- Use of standardized exposure values, as specific information for each facility type was not available.
- Limited attribute information for detailed structure classification.
- Use of a methodology sensitive to exposure values.
- The methodology is adequate for determining approximate expected losses for use in comparison between structures, and not for structural evaluation of individual structures.
- No available data to conduct an analysis on lifelines (i.e., transportation, water and electric networks).

It should be noted that the use of damage curves does not evaluate the structural integrity of critical facilities, but only determines expected losses from several hazards for comparison purposes for the infrastructure in a given region. The evaluation and expected behavior of a particular structure to any hazard should be undertaken with the services of a licensed and experienced structural engineer retained for that specific service.

[5] The average size landslide in the two more developed basins was 363 m^2. The average area affected by landslides was 0.0012 km^2 per square kilometer per decade, which essentially is 0.12 percent of one square kilometer grid cell. Over the 100-year design return period considered in this Integrated Hazard Assessment, 0.12 km^2 or 1.2 percent of the cell is likely to be affected.

Maps

All maps referenced within this section are 11-inch x 17-inch map inserts. These maps are available electronically in PDF (Portable Document Format) viewable with Adobe Acrobat Reader.

Limitations and Uncertainties

With regard to hazard history data, several requests were made for historical information at varying levels of government and from national data centers (local, state, and federal government agencies). Some information was provided by state and national sources, and this information is included in this risk assessment. Local data is extremely limited, and limited time and resources are available to conduct in-depth surveys and person-to-person interviews, etc. The public (through workshops and plan outreach meetings) provided some information on historical hazard problems and problem areas, however this type of data in general is not readily available and it is difficult to build an accurate history of hazards from these limited efforts.

For this risk assessment, the loss estimates and exposure calculations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from (1) approximations and simplifications that are necessary to conduct such a study, (2) incomplete or outdated data on inventory, demographic, or economic parameters, (3) the unique nature and severity of each hazard when it occurs, and (4) the amount of advance notice that the residents have to prepare for the event. These factors result in a range of uncertainty in loss estimates, possibly by a factor of two or more. As a result, potential exposure and loss estimates are approximate. These results do not predict precise results and should be used to understand relative risk.

4.2 IDENTIFICATION OF HAZARDS

The Municipality of Aguada has suffered significant loss of lives and property damage from natural hazards. The Municipality has received 6 presidential disaster declarations since 1975. Table 4.1 lists these disasters.

Table 4.1 ***Presidential Disaster Declarations in Aguada, 1975-2005***

Year	Date	Declaration / Disaster Type
1975	09/19	Tropical Storm Elioise
1979	09/12	Hurricane David
1986	07/11	Heavy Rains, Flooding and Mudslides
1996	09/18	Hurricane Hortense
1998	09/24	Hurricane Georges
2004	10/19	Tropical Storm Jeanne and Associated Landslides and Mudslides

NATIONAL CLIMATIC DATA CENTER STORM EVENT DATABASE

The following table (Table 4.2) provides information on weather events reported in Aguada as recorded in the National Oceanic and Atmospheric Administration's (NOAA), National Climatic Data Center (NCDC) database. NCDC receives Storm Data from the National Weather Service who, in turn, receives their information from a variety of sources, including, but not limited to: county, state and federal emergency management officials, local law enforcement officials, skywarn spotters, NWS damage surveys, newspaper clipping services, the insurance industry and the general public. Information on hazard events not recorded in this database (earthquakes, hurricanes, etc.) are discussed in each of the following hazard subsections.

TABLE 4.2 ***National Climatic Data Center Storm Event Data for Aguada***

Date	Time	Type of Event	Magnitude	Property Damage	Description
4/3/1997	9:18 AM	High Swells	NA		A reporter from Rincon indicated that some moored boats in Aguada were pushed up onto a nearby road at the time of high tide.
6/3/1999	7:00 PM	Flood	NA		Heavy rains during the afternoon hours across the northwest Puerto Rico caused that Rio Culebrinas to overflow its banks over Espinosa sector in Aguada affecting agricultural sectors.
8/7/1999	2:30 PM	Thunderstorm Winds	NA	$2,000	A kp4 rainfall reporter indicated that strong gusty winds in Aguadilla associated with a thunderstorm damaged some zinc roofs and knocked down some tv antennas and trees. In Anasco a Weather Service Employee indicated small hail.

Date	Time	Type of Event	Magnitude	Property Damage	Description
5/26/1999	11:00 PM	Flood	NA		Civil Defense indicated that river Culebrinas went out of its banks flooding Palmar sector in Aguadilla, Tablonar sector in Aguada and road 115.
5/28/1999	11:00 PM	Flood	NA		Civil Defense indicated that Culebrinas river went out of its banks flooding Palmar sector in Aguadilla, Tablonar sector in Aguada and road 115.

This subsection describes the process used to identify those hazards that would be addressed in detail in this risk assessment. This process included identifying an initial list of hazards and then selecting hazards of interest specifically relevant to the planning area. It also describes the type of hazards that can affect the municipality.

As described in *Planning Process*, the Municipality of Aguada identified a preliminary list of hazards of concern during the first community workshop. Following a discussion of potential hazards, participants determined which of the potential hazards are applicable to the municipality and should be studied further. Table 4.3 summarizes the hazard identification and selection process, showing potential hazards in alphabetical order as well as applicable hazards which are detailed in this risk assessment.

TABLE 4.3 ***Identification of Hazards of Interest***

Potential Hazards	Applicable Hazards
Coastal Flooding	☑
Drought	
Earthquake (Ground Shaking)	☑
Earthquake (Liquefaction)	☑
Earthquake-Induced Landslide	☑
High Wind (including Hurricane and Tropical Storm)	☑
Rainfall-Induced Landslide	☑
Riverine Flooding	☑
Tsunami	☑
Urban Fire	
Wildfire	

From the list of 11 potential hazards, eight (8) were selected as hazards of interest for the municipality. These eight hazards include (in the order in which they are discussed in this section) *earthquake (ground shaking, liquefaction, earthquake-induced landslide and tsunami), high wind (including hurricane and tropical storm), flooding (riverine and coastal),* and *rainfall-induced landslide.* These hazards were chosen due to the higher level of risk for these hazards compared to other hazards which affect Aguada. It is important to note that this risk assessment is based on best available data and represents a base-level assessment for the planning area. Additional work

will be done on an ongoing basis to enhance, expand and further improve the accuracy of the baseline established here.

Table 4.4 summarizes the eight hazards of interest selected for further analysis. It also shows historical event data for Puerto Rico as a whole and sources identified and used for the project.

TABLE 4.4 ***Summary of Hazards of Interest for Municipality of Aguada (Impacts across Puerto Rico)***

Hazard	Years	No. Of Events	Potential /Significant Impacts	Available Data Sources and Maps
Earthquake (including Ground Shaking, Liquefaction, Earthquake-Induced Landslide, and Tsunami)	1918 to Present	11 major	Light to significant damages reported with these events. Note that in 2002, 967 earthquakes were reported in the Puerto Rico zone.	University of Puerto Rico Seismic Network, Integrated Hazard Assessment for Puerto Rico
High Wind (including Hurricanes and Tropical Storms)	1981 to 2001	19	Hurricanes have produced significant damages throughout Puerto Rico. In 1998, FEMA expenditures exceeded $2 billion.	National Weather Service (www.srh.noaa.gov/)
Riverine Flooding	1899 to 2002	25 major	1948 (31.6 feet above flood stage level) 1996 (30.2 feet)—5 deaths, 100s of homes damaged, over $1 billion loss.	National Climate Data Center, United States Geological Survey
Coastal Flooding	1994 to 2002	26	History of coastal flood events in Puerto Rico is not specific to individual municipalities; therefore this number represents flooding for all of Puerto Rico.	National Climate Data Center, United States Geological Survey
Rainfall-Induced Landslide	1985	1 major	The worst landslide disaster in Puerto Rico's history—the Mameyes landslide of October 1985.	A database of rainfall-induced landslide events has not been maintained for the Municipality of Aguada.
Notes: Modified from FEMA 386-2, Worksheet No. 1 (FEMA 2001).				

4.3 PROFILE OF HAZARDS

This subsection includes data and information used to profile priority hazards in the Municipality of Aguada. This information is presented in terms of a description of each type of hazard; the location, extent and distribution of each hazard; known history of hazard occurrences[6]; frequency of the hazard as it relates to the analysis performed for this risk assessment and the idea of determining the probability of future events; and a baseline assessment of vulnerability consisting of such factors as social vulnerability and the vulnerability of critical facilities.[7]

HAZARD PROFILE: EARTHQUAKE GROUND SHAKING

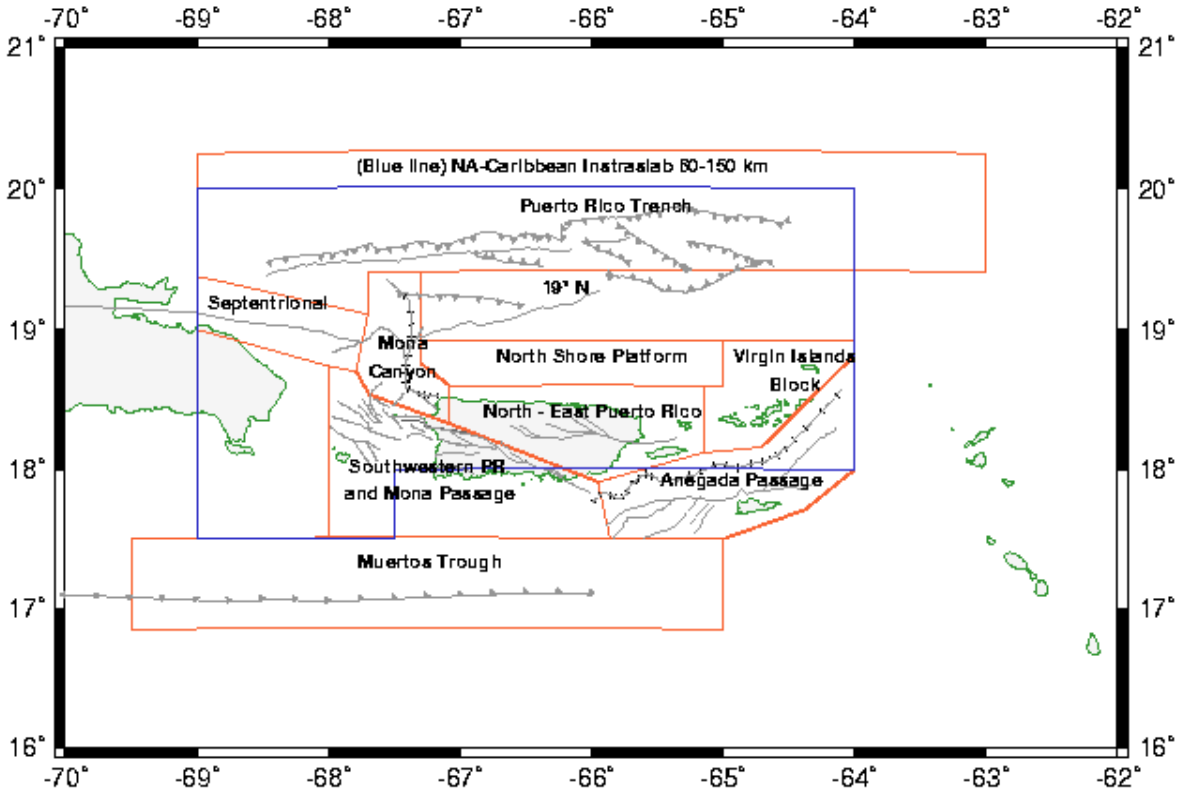
Earthquake Ground Shaking: Hazard Description

Puerto Rico is located in the limit between the plates of North America and the Caribbean, an area of oblique subduction and lateral displacement between the two plates. The seismic activity is concentrated in eight zones: the Puerto Rico Trench; slope faults at north and south of Puerto Rico; northeast of "Zona del Sombrero"; to the west, at the Mona Canyon; Mona Passage; to the east, in the depressions of the Virgin Islands and Anegada; the Muertos Depression to the south; and southeast of Puerto Rico. Aguada is located in the Mona Canyon Zone, an area of relatively frequent seismic activity. (See diagram on following page.)

Earthquakes represent a particularly severe threat because of the irregular time intervals between events, the lack of adequate forecasting, and the catastrophic damage that can occur from a major event. An earthquake is caused by the release of energy accumulated within or along the edge of the earth's tectonic plates. It is characterized by sudden **ground shaking**. The severity of an earthquake depends on the location and amount of energy released. As it occurs, the seismic waves radiate away from the earthquake location causing the ground to shake. The severity of the shaking increases with the amount of energy released and decreases with distance from the location of the earthquake. The ground shaking from the earthquake may be felt hundreds of miles from where it occurred. The intensity of the ground shaking is the result of several factors including the magnitude and type of earthquake, distance from the earthquake, soil conditions of the area, and the orientation of the site relative to the earthquake occurrence.

[6] Complete hazard history data specific to Aguada is extremely limited for certain hazards, such as the earthquake ground shaking and high wind hazards. Therefore, hazard history data for the whole of Puerto Rico was used where appropriate and local data was included where available.

[7] For the purposes of this risk assessment, critical facilities in Aguada are generally defined as police, fire, emergency response, medical clinics and care facilities, alcaldia, and schools.



Earthquake Ground Shaking: Hazard Location, Extent and Distribution

The ground shaking hazard generally occurs in areas of deep, unconsolidated alluvial sediments. These areas are susceptible to amplification of peak ground acceleration (PGA) during an earthquake. Figure 4.2 illustrates the varying susceptibility of geological materials in Aguada to ground shaking. This map ranks ground shaking in five hazard intensity levels.

The extent and distribution of the ground shaking hazard in Aguada is varied because:

- The high hazard areas exist in areas of deep, unconsolidated alluvial sediments. These areas are susceptible to amplification of peak ground acceleration (PGA) during an earthquake.
- The communities of Espinar, Carrizal, Guayabo, and parts of Guaniquilla, Barrio Pueblo, Asomante and Rio Grande fall within the very high hazard area.
- There have been new developments, particularly urbanizations, in areas of softer soil. These developments have tended to move artificial fill over soft clay and alluvium creating greater potential for amplification of strong ground motions.
- Many segments of the built environment are susceptible to damage from earthquakes, especially non-reinforced concrete buildings and older masonry commercial buildings in the downtown area.

FIGURE 4.2
GROUND SHAKING HAZARD MAP[8]

[8] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Earthquake Ground Shaking: Hazard History

As depicted above, Aguada falls into a relatively active zone. During 2002, the Puerto Rico Seismic Network located 967 earthquakes in Puerto Rico. This activity was equal to the amount of earthquakes in the previous year. Listed below is an abbreviated list of significant earthquakes in the Puerto Rico zone.[9] Detailed information regarding property damage, cost of recovery, lives lost, duration of event, etc. is extremely limited at the local, state and national/federal levels for local jurisdictions in Puerto Rico—any available data for Aguada is included below. Future Plan updates will seek to more fully document hazard occurrences in the future.

- **October 11, 1918, 10:15 a.m.**: The strongest earthquake officially recorded in Puerto Rico to date, termed the "Devil's Scream", measured approximately 7.7 on the Richter Scale. The epicenter was located in the Mona Canyon, just northwest of Aguadilla. Thousands of houses and many churches, factories, sugar refineries, public buildings, chimneys, bridges and other structures in Puerto Rico suffered severe damage that totaled over $4 million dollars. The ground shaking was also very intense (MM VII-VIII) in surrounding cities of Isabela, Aguada, Añasco and Mayagüez. In those places where the intensity reached or surpassed VI (MM) almost all the brick chimneys of the sugar mills collapsed or were seriously damaged. The quake severed many of the underwater telegraph cables providing communication to areas outside of the island. A tsunami developed as a result of the earthquake, sending a wave twenty feet high crashing into the western coast at Mayagüez. Damage was reported on the entire Island and Vieques. Besides Mayagüez, the quakes and tsunamis caused damage in the towns of Rincón, Aguadilla, Moca, Arecibo, Añasco, San Sebastian, Isabela and Humacao. The death toll in Puerto Rico was estimated at 116 (includes quake and tsunami-related deaths).
- **October 24, 1918, 11:43 p.m.**: Aftershock of the earthquake of the 11 of October. Maximum intensity in the island was VII (RF).
- **November 12, 1918, 5:45 p.m.**: Another aftershock of the earthquake of the 11 of October. Maximum intensity in the island was VI (RF, RT).
- **February 10, 1920, 6:07 p.m.**: Earthquake felt in all Puerto Rico. Maximum intensity was VI (DH), M=6.5.
- **December 18, 1922, 8:35 a.m.**: Earthquake felt in all Puerto Rico. Maximum intensity in the island was VI (DH), M=6.3.
- **June 12, 1939, 12:05 a.m.**: Earthquake felt in the entire island. Maximum intensity of VI (DH).
- **July 28, 1943, 11:02 p.m.**: Earthquake occurred to the northwest of Puerto Rico. Its magnitude was of 7.5 (PS). Many people around Puerto Rico felt the event but it did not cause damages.

[9] All times are local. *M* is the magnitude that reflects the energy released by the earthquake. If it is not specified that the intensity is RF (Rossi Forell), it is MM (Modified Mercalli). Data compiled by **University of Puerto Rico, Puerto Rico Seismic Network**.

- **August 4, 1946, 1:51 p.m.**: This earthquake of magnitude 7.8 (PS) happened outside the northeastern coast of the Dominican Republic. Ample damages and tsunami waves were reported in Haiti and the Dominican Republic. This earthquake was felt with an intensity of up to VI in the Mona Island and the western coast of Puerto Rico. In the rest of the island an intensity of V was reported. A tsunami of 2 feet was observed in the western and north coast of the island (PRWRA). Smaller damages in all Puerto Rico were reported (DH).
- **August 8, 1946, 9:28 a.m.**: Earthquake in Dominican Republic (M=7.4, PS). Small tsunami in Mayagüez and Aguadilla.
- **March 23, 1979, 3:33 p.m.**: Strong earthquake felt in all the Caribbean area; in Puerto Rico it was felt with an intensity of VI. It was reported in Haiti, Colombia, Venezuela and Dominican Republic (DH). Epicenter located in the south of the Dominican Republic, 17.89N, 68.97W, and 73 km of depth, M=6.1 (USGS).
- **August 24, 1981, 5:50 a.m.**: Strong earthquake felt in all Puerto Rico, M=5.7. Epicenter in the Mona Passage. There were only light damages in Guayanilla (DH).
- **May 30, 1987, 1:55 p.m.**: Strong earthquake felt in the southwest of the island, M=4.6, intensity VI. There were light damages reported near the epicenter near Boquerón.
- **July 31, 1997, 10:35 a.m.**: The earthquake had an intensity of IV on the Mercalli Modified Scale and was located just north of Arecibo.
- **September 22, 2003, 12:45 a.m.:** This tremor was felt throughout the entire Dominican Republic and in Puerto Rico. It was located approximately 410 kilometers northeast of Mayaguez. The maximum intensity was at V in Puerto Rico (PR).

Earthquake Ground Shaking: Hazard Frequency

The frequency of the ground shaking hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Earthquake Ground Shaking: Assessing Vulnerability

As shown in Figure 4.2 presented previously, all of Aguada has at least moderate vulnerability and are expected to experience PGA levels of 0.10 to 0.50 in an earthquake event (Areas shown as "very high" would most likely experience PGA of 0.5 while moderate areas would experience lower PGA levels). All existing and future structures, critical facilities, and infrastructure are vulnerable to ground shaking. Structures situated in high hazard areas may experience higher damage levels than those structures located farther from high hazard areas. Also, vulnerability of structures depends on the soundness of construction—the stronger the building, the more likely that potential impacts will be lessened in smaller earthquake events.

To assess the social vulnerability to the ground shaking hazard, Table 4.5 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to

describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age are also broken out by hazard level areas.

TABLE 4.5 ***Ground Shaking Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	47.97	24,432	7,820	1950
Low	20.96	10,697	3,420	850
Moderate	10.7	6,665	2,130	530
High	0	0	0	0
Very High	0	0	0	0

HAZARD PROFILE: LIQUEFACTION

Liquefaction: Hazard Description

Liquefaction is a phenomenon that causes unconsolidated soils to lose strength and act like viscous fluid when subjected to earthquake ground shaking. The frequency and intensity of liquefaction that can occur during an earthquake is based on several factors, including the geologic conditions of the area, groundwater depth, ground shaking intensity, and the magnitude of the earthquake.

Liquefaction: Hazard Location, Extent and Distribution

The liquefaction hazard generally occurs in areas of deep, unconsolidated alluvial sediments. These areas are usually found in areas with high water tables (i.e., coastal areas). In Aguada, these are confined mostly to coastal areas. Figure 4.3 illustrates the varying susceptibility of geological materials in Aguada to liquefaction. This map ranks liquefaction into five hazard intensity levels.

The extent and distribution of the liquefaction hazard in Aguada is varied because:

- There are large areas of unconsolidated alluvial deposits in the municipality. These areas are associated with a high water table (i.e., deep alluvial valleys, coastal and floodplains, marshes, swamps, and lagoons).
- The communities of Espinar and Carrizal, and parts of Guayabo, Guaniquilla, Barrio Pueblo, Asomante and Rio Grande fall within the very high hazard area.
- Liquefaction occurs in association with an earthquake; therefore, the buildings are subject to ground shaking as well.
- Liquefaction incrementally increases the damage (in addition to the ground shaking damage) to buildings due to the ground deformation.
- Liquefaction also may cause damage to infrastructure such as roads or bridges.

FIGURE 4.3
LIQUEFACTION HAZARD MAP[10]

[10] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Liquefaction: Hazard History

Historical details of liquefaction impacts in Aguada is extremely limited. One known instance of liquefaction impact occurred during the 1918 earthquake, when fountains of sands of up to 10 - 12 feet and cracks in the low lying grounds were reported in western Puerto Rico. Future Plan updates will seek to more fully document hazard occurrences in the future.

Liquefaction: Hazard Frequency

The frequency of the liquefaction hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Liquefaction: Assessing Vulnerability

As shown on the previous hazard map (Figure 4.3) which is based on the probability of ground shaking hazard level and soil type, northern coastal areas as well as the northwestern interior of the municipality are especially vulnerable to liquefaction. All existing and future structures, critical facilities, and infrastructure located in these areas are vulnerable to impact due to liquefaction. Structures situated in high hazard areas may experience higher damage levels than those structures located farther from high hazard areas.

To assess the social vulnerability to the liquefaction hazard, Table 4.6 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.6 ***Liquefaction Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	58.64	31,029	9,900	2,400
Low	5.342	4,503	1,440	360
Moderate	0.128	96	30	8
High	0.035	15	5	1
Very High	15.4	6,028	1,920	480

HAZARD PROFILE: EARTHQUAKE-INDUCED LANDSLIDE

Earthquake-Induced Landslide: Hazard Description

Landslides are abrupt movements of materials that become detached from slopes or cliffs; they move by free-fall, sliding, or rolling. Earthquake-induced landslides can occur in natural slopes, cut slopes in soil or weathered rock, or fill slopes. They are common where steep cut slopes are present in relatively shallow soils over unweathered or fractured rock. The frequency and intensity of landslides that can occur during an earthquake is the result of several factors, including the geologic materials of the area, the slope, the water content of the slide material, the earthquake ground shaking, and the magnitude of the earthquake.

Earthquake-Induced Landslide: Hazard Location, Extent and Distribution

In Aguada, moderate to high earthquake-induced landslide hazard intensity areas coincide with ground shaking and liquefaction hazard areas. This is due to the predominance of soft soils in relatively flat coastal areas. However, potential damages related to this hazard are more likely to occur in mountainous areas that coincide with moderate ground shaking hazard levels. Figure 4.4 illustrates the varying susceptibility of geological materials in Aguada to earthquake-induced landslides. This map ranks earthquake-induced landslides into five hazard intensity levels. The extent and distribution of earthquake-induced landslides is varied because:

- There are areas that are prone to an earthquake hazard (ground shaking).
- The moderate to high hazard intensity levels in low-lying areas is due to high ground shaking amplification in softer soils.
- Mountainous areas of the municipality are susceptible to slope failure due to earthquake ground shaking. These areas include the rural communities of Cerro Gordo, Atalaya, Laguna, Naranjo and Marias.
- Earthquake-induced landslides can threaten residential structures and infrastructure lifelines such as water, power, telecommunication and transportation networks.

FIGURE 4.4
EARTHQUAKE-INDUCED LANDSLIDE HAZARD MAP[11]

[11] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Earthquake-Induced Landslide: Hazard History

No information regarding historical impacts of earthquake-induced landslide in Aguada could be identified. Therefore, information regarding property damage, cost of recovery, lives lost, duration of event, etc. is not available for this hazard. Future Plan updates will seek to more fully document hazard occurrences in the future.

Earthquake-Induced Landslide: Hazard Frequency

The frequency of the earthquake-induced landslide hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Earthquake-Induced Landslide: Assessing Vulnerability

As shown on the previous hazard intensity map (Figure 4.4), most of northern Aguada is moderately or highly vulnerable to earthquake-induced landslide, especially in coastal areas (based on the probability of the ground shaking hazard level, soil type and slope of terrain, areas of "Very High" intensity are likely more vulnerable to this hazard than those of lower intensity categories.). All existing and future structures, critical facilities, and infrastructure located in areas with steep slopes or loose soils may be vulnerable to landslide resulting from seismic activity.

To assess the social vulnerability to the earthquake-induced landslide hazard, Table 4.7 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.7 ***Earthquake-Induced Landslide Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	13.44	5,897	1,880	470
Low	0.22	128	40	10
Moderate	66.45	36,017	11,500	2,880
High	0	0	0	0
Very High	0	0	0	0

Aguada officials identified the following highways and barrios as being particularly vulnerable to the landslide hazard:

- Carretera 411 barrios Jaguey and Atalaya
- Carretera 403 barrio Lagunas
- Carretera 417 barrios Marias and Cerro Gordo
- Carretera 416 barrios Piedras Blancas and Lagunas

HAZARD PROFILE: TSUNAMI

Tsunami: Hazard Description

Earthquakes can generate tsunamis—large waves generated in the ocean by a sudden displacement of a large volume of water. After a major offshore earthquake, a tsunami can reach the shore in just minutes. Tsunamis can also travel over great distances and with longer advance warning, and can still have enough energy to cause significant damages on a distant coast.

Tsunami: Hazard Location, Extent and Distribution

Tsunami hazard areas are all low lying, relatively flat coastal areas. Inland flood areas in Aguada are depicted in Figure 4.5.

The extent and distribution of the tsunami hazard is confined to coastal areas:

- The presence of these large, active fault zones located just off shore of the island creates a substantial tsunami threat for the coast of Puerto Rico.
- Although a tsunami advances much slower as it approaches land, its momentum is powerful enough to flatten houses, buildings and trees, and carry ships far inland.
- Parts of the communities of Guaniquilla, Espinar, Carrizal, Guayabo, and Rio Grande fall within the inland flood area.
- Tsunamis cause extensive environmental damage as they may strip beaches of sand that may have taken years to accumulate, uproot trees and other coastal vegetation, and cause large-scale flooding.
- Tsunamis can devastate development along coastlines, causing widespread property damage and loss of life.
- Tsunamis can devastate infrastructure lifelines such as water, power, telecommunication, and transportation networks.

FIGURE 4.5
TSUNAMI HAZARD MAP[12]

[12] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Tsunami: Hazard History

On the northwestern coast of Puerto Rico, the most noted tsunami was spawned by the large earthquake in October 1918, impacting Mayaguez (located south of Aguada) with wave heights over 19 feet which caused extensive damage and killed more than 40 people. Details regarding impacts of this tsunami in Aguada are not currently available.

Detailed hazard history data specific to Aguada does not exist for some hazards identified in this section, including the tsunami hazard. Therefore, information regarding property damage, cost of recovery, lives lost, duration of event, etc. is not available for this hazard. Future Plan updates will seek to more fully document hazard occurrences in the future.

Tsunami: Hazard Frequency

The frequency of the tsunami hazard event cannot be determined. The tsunami map was developed using a deterministic approach and is irrespective of the time of occurrence. Therefore, the inland flood extent for a 100-year recurrence timeframe cannot be determined nor can the probability of future events be calculated.

Tsunami: Assessing Vulnerability

Coastal areas of Aguada are vulnerable to the tsunami hazard because of their proximity to the ocean. Existing and future buildings, critical facilities and infrastructure in low lying coastal areas are vulnerable to the impact of a tsunami event.

To assess the social vulnerability to the tsunami hazard, Table 4.8 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.8 ***Tsunami Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Inland Flood Area	9.97	4,845	1,550	388

Aguada officials identified the following barrios as being particularly vulnerable to the tsunami hazard:

- Barrio Espinal
- Barrio Guaniquillas
- Barrio Rio Grande
- Barrio Guayabo

HAZARD PROFILE: HIGH WIND

High Wind: Hazard Description

Hurricanes and tropical storms are the most frequently experienced high wind hazard in Puerto Rico, resulting in widespread damage and numerous casualties. Hurricanes are intense tropical weather systems with maximum sustained winds greater than 74 mph. They develop over warm water and are caused by the atmospheric instability created by the collision of warm and cool air. Hurricanes are particularly dangerous because of their destructive potential, large zone of influence, spontaneous generation, and erratic movement. Damage to buildings and infrastructure can be caused either by the force of high winds or from wind-borne debris that acts as wind-driven missiles. Hurricanes are often accompanied by high tides, storm surges, and heavy rainfall that can cause landslides, storm surge, and flooding. The official Atlantic hurricane season extends from June 1 through November 30, with August and September as the peak months for hurricanes in Puerto Rico.

The magnitude of hurricanes is measured on the Saffir-Simpson scale, shown in Table 4.9, which categorizes hurricane magnitude by wind speeds and storm surge above normal sea levels. However, hurricanes are often associated with torrential rains that can lead to extensive inland flooding.

TABLE 4.9 ***Saffir-Simpson Hurricane Scale***

Category	Wind Speed	Storm Surge (feet above normal sea level)	Expected Damage
1	74–95 mph	4–5 feet	**Minimal**: Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, no real damage is done to structures.
2	96–110 mph	6–8 feet	**Moderate**: Some trees are toppled, some roof coverings are damaged, major damage is done to mobile homes.
3	111–130 mph	9–12 feet	**Extensive**: Large trees are toppled, some structural damage is done to roofs, mobile homes are destroyed, structural damage is done to small homes and utility buildings.
4	131–155 mph	13–18 feet	**Extreme**: Extensive damage is done to roofs, windows, and doors, roof systems on small buildings completely fail, some curtain walls fail.
5	> 155 mph	> 18 feet	**Catastrophic**: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures and entire buildings could fail.

Source: Understanding Your Risks: Identifying Hazards and Estimating Losses. FEMA. 2001.

High Wind: Hazard Location, Extent and Distribution

The moderate to very high wind hazard intensity levels occurs in mountainous regions of the municipality. Although wind speeds are expected to be higher in coastal areas, this takes into account wind speed decay as a storm moves inland. Figure 4.6 illustrates the varying susceptibility of high winds. This map ranks high wind hazard intensity in five hazard intensity levels.

The extent and distribution of the high wind hazard is varied because:

- Aguada, like any other municipality in Puerto Rico, is susceptible to hurricanes, tropical storms and strong tropical depressions.
- Strong winds have caused extensive property damage throughout the municipality. Intense winds can cause damage to residential structures and lifeline services—water, power, telecommunication and transportation networks.
- Mountainous areas are susceptible to wind speed-up factors as the wind moves over hilly terrain (localized gusts). The communities of Cerro Gordo, Atalya, Cruces, Jaguey and Naranjo are susceptible to such wind speed-up factors.
- Riverine and coastal flooding are associated hazards.

FIGURE 4.6
HIGH WIND HAZARD MAP[13]

[13] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

High Wind: Hazard History

The list below highlights the hurricanes that passed within seventy miles of Aguada between 1851 and 2003 (data from National Oceanic and Atmospheric Administration, Tropical Prediction Center/National Hurricane Center). During this period within this same area, there were also five tropical depressions and 21 tropical storms. Detailed information regarding property damage, cost of recovery, lives lost, etc. due to high winds is extremely limited for Aguada—any available data is provided below. Future Plan updates will seek to more fully document hazard occurrences in the future.

- **August 18, 1851** • A Category 2 hurricane had winds of 105 mph.
- **September 5, 1852** • A Category 1 hurricane had winds of 80 mph
- **September 24, 1852** • A Category 2 hurricane had winds of 105 mph
- **October 29-30, 1867** • An unnamed storm fluctuated from a Category 3 to a Category 1 storm, with winds ranging from 80-115 mph.
- **September 13, 1876** • An unnamed storm fluctuated from a Category 2 to a Category 1 storm, with winds ranging from 80-105 mph.
- **August 20, 1891** • A Category 2 hurricane had winds ranging from 100-110 mph.
- **August 17, 1893** • An unnamed storm fluctuated from a Category 3 to a Category 2 storm, with winds ranging from 105-115 mph.
- **September 1, 1896** • An unnamed storm fluctuated from a Category 2 to a Category 1 storm, with winds ranging from 85-100 mph.
- **August 8, 1899** • An unnamed storm fluctuated from a Category 4 to a Category 3 storm, with winds ranging from 120-145 mph.
- **August 22, 1909** • A Category 2 hurricane brought winds of 90 mph.
- **September 7, 1910** • A Category 2 hurricane brought winds of 100 mph.
- **August 22, 1916** • A Category 1 storm with winds 75-90 mph impacted western Puerto Rico.
- **July 23-24, 1926** • A Category 1 storm brought 75-80 mph winds.
- **September 13-14, 1928** • This hurricane began as a Category 5 with 160 mph winds before weakening to Category 4 strength with winds of 155 mph. Category 2 to a Category 1 storm, with winds ranging from 80-105 mph.
- **September 2-3, 1930** • This unnamed storm fluctuated between Category 3 and Category 4 storm status, with winds ranging from 155-135 mph.
- **September 11, 1931** • This Category 1 storm brought 80-90 mph winds.
- **September 27, 1932** • A Category 2 hurricane impacted Puerto Rico with 100-110 mph winds.
- **October 4, 1943** • A Category 1 hurricane impacted the island with 90 mph winds.

- **August 12, 1956** • Hurricane Betsy, a Category 1 hurricane, impacted the island with winds of 90 mph.
- **September 26-27, 1963** • A Category 1 storm, Hurricane Edith had a central pressure of 1000 millibars and winds of 75 mph.
- **September 9-10, 1996** • Hurricane Hortense, a Category 1 storm, passed over the southwest corner of Puerto Rico in a SE to NW direction. Winds at 80 mph, a four foot storm surge, up to 20 inches of rain and barometric pressure at 989 millibars were reported. Power was lost over 85% of the island. Nineteen people died. The southwestern tip of Puerto Rico bore the brunt of the storm's hurricane-force winds and torrential rains. Property and casualty insurance claims from Hurricane Hortense are estimated to exceed $70 million.
- **September 21-22, 1998** • Hurricane Georges, a Category 2 storm with winds 105-110 mph, passed over St Croix in the U.S. Virgin Islands and then entered Puerto Rico near Humacao and traveled through the interior of the island exiting just south of Mayaguez in Cabo Rojo. The hurricane traveled mainly in an E to W direction, causing an estimated $100 million in damage across Puerto Rico, destroying crops and causing flooding. The entire island lost power for a time. Aguada reported approximately 5-10 inches of rain during the storm.
- **August 21-23, 2000** • Hurricane Debby, a Category 1 storm with 75 mph winds, passed just north of St. Thomas and within 1º latitude to the northeast of Puerto Rico in an E-SE to W-NW direction. In Puerto Rico, the main impact came from heavy rainfall. There were reports of mud slides and damaged or collapsed bridges. Over 400 homes were reportedly "affected" by flood waters. Five homes suffered moderate to severe structural damage. Total damage is estimated at $500,000 dollars.
- **October 24, 2003** • A strong wind event downed trees and power lines at Barrio Guaniquilla and Barrio Jaguey in Aguada.

High Wind: Hazard Frequency

The frequency of the high wind hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events. Winds associated with a probable 100-year event range form 90 to 122 mph, thus a Category 2 storm could be considered to be a 100-year storm event using this methodology.

High Wind: Assessing Vulnerability

As shown in the previous hazard map (Figure 4.6), all of Aguada, including all existing and future structures, critical facilities, and infrastructure, is vulnerable to high winds, especially due to hurricanes and tropical storms. The central portion of Aguada is likely to experience less intense high wind occurrences than the more interior areas and coastal areas, based on the probability of winds ranging from 90-122 mph occurring in the area. Small portions of Aguada along the southern border are believed to be high intensity areas for high wind occurrence, or “High”

intensity, and would be more likely to experience higher wind impacts than areas of lower intensity categories. Also, vulnerability of structures depends on the soundness of construction as well as mitigation measures employed (e.g. shutters). Though high wind associated with hurricanes and tropical storms can cause damages, heavy rainfall may also be associated with such events, thus structures and infrastructure located in flood zones or landslide areas may also be vulnerable to associated hazards.

To assess the social vulnerability to the high wind hazard, Table 4.10 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.10 ***High Wind Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	9.96	4,342	1,380	340
Low	24.15	13,235	4,230	1,050
Moderate	46.01	24,465	7,820	1,950
High	0	0	0	0

HAZARD PROFILE: RIVERINE FLOODING

Riverine Flooding: Hazard Description

Flooding is defined as the accumulation of water within a water body and the overflow of excess water onto adjacent floodplain lands. Riverine flooding occurs when the volume of water exceeds that capacity of stream channel. Water overflows banks and causes flooding.

In Aguada, the many stream valleys are narrow, relatively short and steep. This makes the larger rivers (Rio Culebrinas) susceptible to flooding. The Rio Culebrinas has a high-flow channel and relatively wide valleys; however, accumulated waters from upstream tributaries often overwhelm capacity creating ideal conditions for rapid flooding throughout the municipality.

Flooding events have had substantial impact on Aguada. Flooding has caused extensive property damage, blocked roads, disrupted economic activities by shutting down critical facilities, and have caused repetitive damages to residential areas.

Riverine Flooding: Hazard Location, Extent and Distribution

Riverine flooding generally occurs along the Rio Culebrinas and in low-lying coastal areas. Smaller tributaries are also susceptible to flooding from large meteorological systems, especially tropical storms. The flow-accumulated waters in upstream tributaries into lower elevations create conditions that are ideal for rapid flooding. Figure 4.7 illustrates the varying susceptibility to riverine flooding. This map ranks flooding hazard intensity in five hazard intensity levels.

The extent and distribution of riverine flooding hazard is varied because:

- It is susceptible to heavy rainfall from hurricanes, tropical storms and depressions.
- It has a large river system—the Rio Culebrinas. This river has many upstream tributaries that drain into it from upland areas.
- It has large low-lying floodplains near sea level that are prone to run-off from upland areas. This creates an environment that is ideal for rapid flooding throughout the municipality, especially in the communities of Rio Grande, Guayabo, Guanaquilla, Espinar, and Guanabano.
- Flooding is more likely to occur when there is continuous rainfall and soils are already saturated.
- New development within the floodplain has increased flood related damages and caused evacuation problems for emergency managers.
- Rainfall is likely the cause of the frequent flooding of creeks, small streams, roadside culverts and low-lying areas with inadequate stormwater infrastructure.

FIGURE 4.7
RIVERINE FLOODING HAZARD MAP[14]

[14] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Riverine Flooding: Hazard History

According to the United States Geological Survey (USGS), 25 major flood events occurred in Puerto Rico from 1899-1995. Using data from USGS, the National Weather Service, and the National Climatic Data Center, major flood events which are believed to possibly have impacted Aguada in some way are shown in Table 4.11. The events highlight a seasonal pattern to flooding that follows a distinct rainy season that occurs usually between June and November (which coincidentally is also hurricane season). Detailed information regarding property damage, cost of recovery, lives lost, duration of event, etc. is extremely limited at the Aguada—any available data is provided below. Future Plan updates will seek to more fully document hazard occurrences in the future.

TABLE 4.11 ***Chronology of Major Floods Affecting Northwestern Puerto Rico, 1899 to 2004***

Date	Area Affected and Known Impacts	Recurrence Interval[15]
August 8, 1899	Island-wide flooding was associated with the passing of a strong hurricane (Category 3-4).	Undetermined
September 13, 1928	Island-wide flooding was associated with the passing of a Category 5 hurricane.	100
September 26, 1932	Island-wide flooding preceded the passing of a Category 2 hurricane across the island on September 27.	Undetermined
December 9–11, 1965	Interior and North Coast areas were flooded.	2 to 25 years
September 16, 1975	Hurricane Eloise produced 24-hour rainfall totals as high as 23 inches in some areas in southwestern Puerto Rico. Thousands of residents had to evacuate their homes as a result of the flooding and landslides. It is estimated that damages exceeded $125 million and 34 deaths were reported.	25 to 100 years
August 29–31, 1979	Eastern, southern, and Northern Puerto Rico were impacted by floods.	2 to 25 years
September 4, 1979	Northern and Eastern Puerto Rico experienced flooding due to rains from Tropical Storm Frederic.	2 to 10 years
October 6–7, 1985	Southern and western Puerto Rico was affected by intense flooding as a result of a nearly stationary tropical storm that caused intense rains. Many rivers produced discharges that exceeded the 100-year recurrence interval. Across Puerto Rico, 170 deaths and $125 million in damages were reported.	>100 years
January 5–6, 1992	Northern and Eastern Puerto Rico experienced flooding.	10 to 100 years
September 23, 1994	The Culebrillas River went out of its banks during a series of days at road 418.	Undetermined
September 9–10, 1996	Parts of Puerto Rico experienced flooding due to Hurricane Hortense.	Undetermined

[15] Recurrence interval is the average interval of time within which the streamflow will be greater than a particular value for floods. These values were calculated by the United States Geological Survey.

Date	Area Affected and Known Impacts	Recurrence Interval[15]
October 12–13, 1997	Island-wide flooding was reported.	Undetermined
October 19–22, 1998	Island-wide flooding was reported.	Undetermined
May 26, 1999	It was reported that Rio Culebrinas overflowed its banks, flooding the Tablonar sector in Aguada as well as road 115.	Undetermined
November 11, 1999	Northern Portion of Puerto Rico experienced flooding.	Undetermined
May 6–8, 2001	Puerto Rico received torrential rainfall, resulting in widespread flooding of streams, rivers and roads, and also landslides in many municipalities. The heaviest rainfall (7-12 inches in a 24-hour period) occurred in the municipalities of Western, Southwestern, Southern, and the Western Interior of Puerto Rico, causing an estimated $146 million dollars in property damage. The government of Puerto Rico requested that 22 municipalities be declared Federal Disaster Areas.	Undetermined
October 28, 2001	Heavy rains caused Rio Culebrinas and its tributaries to overflow their banks in Aguada. Several houses in Aguada lost all their household goods due to the flash flooding. Property damage in northwestern Puerto Rico was estimated at $50,000.	Undetermined
November 7, 2001	Across the island, especially In Aguada, Aguadilla, and Moca, numerous rivers experienced extensive flooding. Authorities reported that floodwaters swept away bridges, damaged hundreds of homes and forced more than 250 people to stay in emergency shelters. Damage to banana, coffee and other crops was estimated at $17 million.	Undetermined
November 13-14, 2002	Rio Culebrinas overflowed its banks following torrential rains, affecting several roads, low lying areas, and several residences in Aguada. Damages in northwestern Puerto Rico were estimated at $125,000.	Undetermined
May 18, 2003	Rio Culibrinas was reportedly overflowed its banks along roads 115 and 418 in Aguada. Several houses were reported flooded, with $10,000 in damage.	Undetermined
September 12, 2003	A 50 year old female died when she attempted to make a low water crossing in her vehicle during the initial flood crest at the Chuco Ramos Sector of Barrio Piedras Blancas. Approximately $7,000 in damage was reported.	Undetermined
October 26, 2003	Rio Culebrinas nearly overflowed its banks in the Coloso Valley in Aguada.	Undetermined

Riverine Flooding: Hazard Frequency

The frequency of the riverine flooding hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Riverine Flooding: Assessing Vulnerability

Most areas of Aguada are located outside of the flood prone areas. However, northern Aguada has several areas more vulnerable to riverine flooding (approximately 1 to 3.9 meters in depth), as shown on the previous hazard map (Figure 4.7). Areas labeled as "High" intensity are more likely to experience riverine flooding of greater depths than areas of lower intensity classification. Areas along roads 418, 115, and 441 are particularly vulnerable and are more likely to experience flooding than other areas of the municipality. Any existing and future structures, critical facilities, and infrastructure located in low-lying areas near water bodies, particularly in known Special Flood Hazard Areas, are vulnerable to riverine flooding.

To assess the social vulnerability to the riverine flooding hazard, Table 4.12 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.12 ***Riverine Flooding Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	2.18	1,113	350	90
Low	2.95	1,030	330	80
Moderate	2.61	879	280	70
High	2.08	801	250	64
Very High	5.74	1,421	460	100

Aguada officials identified the following barrios and roads as being particularly vulnerable to the riverine and urban flooding hazards:

- Barrio Espinal
- Barrio Guanabanos
- Barrio Guayabo
- Bario Asomante
- Avenida Nativo Alers (desvio sur)
- Carretera 115 intercesion Nativo Alers

Hazard Profile: Coastal Flooding

Coastal Flooding: Hazard Description

Coastal flooding is strongly associated with the term storm surge, which is the rising of the sea level due to the low pressure, high winds, and high waves associated with a hurricane as it makes landfall. Storm surge can cause significant flooding and cost people their lives if they are caught unexpected.

Coastal flooding in Puerto Rico is common and associated with low-pressure systems, including tropical storms and hurricanes. The coastal plain also is vulnerable to flooding by large coastal sea swells generated by winter storms over the Atlantic Ocean. Storm surges occur with a rise in sea water level associated with intense low-pressure cells and ocean storms. Rising flood or water levels is a function of wind, atmospheric pressure, tide, waves, and/or swell. Coastal topography and immediate offshore bathymetry also may affect the level of flooding.

Coastal Flooding: Hazard Location, Extent and Distribution

The distribution of coastal hazard intensity levels is confined to coastal areas with gradually sloping lands. In the past, there have been several areas that have been affected by coastal storm surges. Figure 4.8 illustrates the varying susceptibility to coastal flooding. This map ranks flooding hazard intensity in five hazard intensity levels.

The extent and distribution of the coastal flooding hazard is varied because:

- Aguada, like any other municipality in Puerto Rico, is susceptible to hurricanes, tropical storms and strong depressions.
- In coastal areas, high waves frequently disrupt infrastructure, particularly roads.
- Flooding problems have been exacerbated by increased coastal development. The natural character of the coastal environment has been degraded, thus decreasing a natural barrier for high wave action.
- All significant coastal flooding events also have potential to threaten human life and safety, especially in low-lying coastal communities and settlements of Rio Grande, Guayabo, Guanaquilla, and Espinar.

FIGURE 4.8
COASTAL FLOODING HAZARD MAP[16]

[16] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Coastal Flooding: Hazard History

The National Climatic Data Center (NCDC) Storm Event Database reported 26 coastal flood events for the island of Puerto Rico from 1994 to 2002. Detailed information regarding property damage, cost of recovery, lives lost, duration of event, etc. is extremely limited at the Aguada—any available information for two known coastal floods is provided below. Future Plan updates will seek to more fully document hazard occurrences in the future.

One significant coastal flood event occurred in March 2001, when a strong low pressure system north of the island caused large northwest swells to move across the coastal waters. The most affected areas were the west and north coasts of the island where various coastal roads were inundated, especially at times of high tide. The heavy surf with water, sand and debris directly affected various roads in the neighboring municipalities of Aguadilla and Mayaguez. Another significant coastal flooding event occurred on February 1, 1999, when large north swells arrived along the north coast of Puerto Rico. Swells were estimated between 15 to 17 feet over exposed areas. Several coastal roads in Aguada were closed due to water, sand and debris on the road. Approximately $40,000 in damages resulted form this flooding.

Coastal Flooding: Hazard Frequency

The frequency of the coastal flooding hazard event is based on a 100-year return period—the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Coastal Flooding: Assessing Vulnerability

Coastal areas, including existing and future structures, critical facilities, and infrastructure, are vulnerable to coastal flooding (approximately 1 to 2.5 meters in depth), as shown on the previous hazard map (Figure 4.8). Areas labeled as higher intensity are more likely to experience coastal flooding of greater depths than areas of lower intensity classification.

To assess the social vulnerability to the coastal flooding hazard, Table 4.13 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and the number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.13 ***Coastal Flooding Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	0.05	0	0	0
Low	0	7	2	1
Moderate	0.08	103	33	8
High	0.32	161	52	13
Very High	0	0	0	0

Aguada officials identified the following barrios as being particularly vulnerable to coastal flooding:

- Barrio Espinal
- Barrio GUaniquillas
- Barrio Guayabo
- Barrio Rio Grande

HAZARD PROFILE: RAINFALL-INDUCED LANDSLIDES

Rainfall-Induced Landslides: Hazard Description

Landslides in Puerto Rico are caused by rock formations that have been weathered over time into increasingly weak materials. Puerto Rico's steep topography and shallow, fine-grained soils over bedrock make it highly susceptible to landslides. Many landslides occur along road cuts or fills, and vary in size from a few cubic yards of soil or rock to entire hillsides hundreds of feet long. As stated in the Building Performance Assessment Report prepared in the aftermath of Hurricane Georges, "Landslides will become a greater problem in the future as more developments and houses are constructed in regions prone to such risks" (FEMA, March 1999).

Most landslides occur as rain saturates soils, causing the shallow subsoil to lose structure and fall, usually at the contact with the bedrock. There are many types of mass movements, including:

- **Creep**: the slow, steady down slope movement of soil or rock, often indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences.
- **Debris flow**: a rapid mass movement in which loose soils, rocks and organic matter combine with entrained air and water to form a slurry that then flows down slope, usually associated with steep gullies.
- **Debris avalanche**: a variety of very rapid to extremely rapid debris flow.
- **Mudflow**: a rapidly flowing mass of wet material containing at least 50 percent sand-, silt-, and clay-sized particles.

Rainfall-Induced Landslides: Hazard Location, Extent and Distribution

Softer, granular soil regions found in sloping lands primarily define the distribution of rainfall-induced landslide hazard areas. The areas occur where slope grades are high and exposed to predominant weather patterns (prevailing winds). Figure 4.9 illustrates the varying susceptibility of soils in Aguada to rainfall-induced landslides. This map ranks rainfall-induced landslides into three hazard intensity levels.

The extent and distribution of rainfall-induced landslide hazard is varied because:

- Aguada is susceptible to heavy rainfall.
- It has areas of steep topography and shallow, fine-grained soils are highly susceptible to landslides.
- The moderate-to-very-high hazard levels are found throughout the mountainous areas of the municipality. Specific areas that are susceptible to this hazard include the communities of Cerro Gordo, Atalaya, Laguna, Naranjo, Jaguey, Cruces and Marias.
- Most landslides in Aguada have been minor and have moved debris into roads and highways causing damage or traffic disruptions.
- Landslides can cause significant structural damage and/or personal injury.

FIGURE 4.9
RAINFALL-INDUCED LANDSLIDE HAZARD MAP[17]

[17] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

Rainfall-Induced Landslides: Hazard History

Detailed information regarding property damage, cost of recovery, lives lost, duration of event, etc. is extremely limited for Aguada. An historical record of landslide occurrences unique to the Municipality of Aguada has not been maintained and therefore is not available for use in this analysis. Future Plan updates will seek to more fully document hazard occurrences in the future.

The worst landslide disaster in Puerto Rico's history (and North America) has been the Mameyes landslide of October 1985—an event that claimed the lives of at least 129 people and possibly as many as 300. Over 100 homes were destroyed and many more were considered uninhabitable.

Rainfall-Induced Landslides: Hazard Frequency

The frequency of the rainfall-induced landslide hazard event is based on a 100-year return period; the municipality has a 1 percent annual probability of observing the losses shown in the loss estimates subsection of this risk assessment. This is the best available determination with regard to the probability of future hazard events.

Rainfall-Induced Landslides: Assessing Vulnerability

Most of Aguada lies in areas with very low landslide susceptibility. There are small pockets of land with moderate susceptibility to landslide occurrence, as seen on the previous hazard map (Figure 4.9). There are few areas of very high probability of occurrence which are all located in the southernmost portion of Aguada. All existing and future structures, critical facilities, and infrastructure located in areas with steep slopes or loose soils may be impacted by landslide resulting from rainfall.

To assess the social vulnerability to the rainfall-induced landslide hazard, Table 4.14 provides an estimate of area (in square kilometers) and affected population for each level of hazard intensity in order to describe social vulnerability in the planning area. The identification of special needs communities such as the number of people less than 18 years of age and number of people over 65 years of age is also broken out by hazard level areas.

TABLE 4.14 ***Rainfall-Induced Landslide Hazard Intensity Levels, Population and Special Needs Groups***

Hazard Intensity Level	Area (sq km)	Population	< Age 18	>Age 65
Very Low	13.44	5,897	1,887	472
Low	0.22	128	41	10
Moderate	66.45	36,017	11,525	2,881
High	0	0	0	0
Very high	0	0	0	0

Aguada officials identified the following highways and barrios as being particularly vulnerable to the landslide hazard:

- Carretera 411 barrios Jaguey and Atalaya
- Carretera 403 barrio Lagunas
- Carretera 417 barrios Marias and Cerro Gordo
- Carretera 416 barrios Piedras Blancas and Lagunas

4.4 INVENTORY OF ASSETS

An important component of this Hazard Mitigation Plan is the identification of the general built environment. An understanding of the built environment provides an idea of the municipality's exposure (type of buildings and estimated value). As most buildings in most municipalities are typically used for residential uses, Figure 4.10 illustrates the distribution of housing units.

Based on U.S. Census data, a building inventory profile was developed to estimate the distribution of commercial buildings. A rapid field survey was used to categorize number and types of buildings for select land use districts on the island. The following land use designations, illustrated in Figure 4.11 were identified during a rapid field survey. They are:

- Urban Center (CU)
- Urban Peripheral (UP)
- Urbanization (UB)
- Rural Communities (RC)
- Rural/Mountain (RM)

The **Urban Center (CU)** classification is comprised of areas of intensive use. This category refers to the traditional urban center, which is comprised mostly of commercial structures. Structure types vary from older historic un-reinforced concrete buildings to modern steel-frame buildings.

Emanating from traditional urban center, along main business thoroughfares, is the **Urban Peripheral (UP)** land use classification. This classification is mixed-use and consists of residential, retail establishments, businesses, financial, professional and repair services. Structure types vary from one and two story concrete structures to large steel frame concrete structures.

Suburban developments are found near to the urban periphery. **Urbanization (UB)** or suburban residential subdivisions tend to consist of homogeneous house types: 1 story concrete structures.

The **Rural Community (RC)** is the most predominant land use classification found in the municipality. Over the years, rural lands have been developed as a result of Law 26 (Ley 26)[18], which sought to use unproductive agricultural lands for residential development. These lands, known as "parcelas," usually occur in areas that are adjacent to transportation routes. They are rural in character and typically consist of single and two family dwellings. Structure types vary from simple wood frame dwellings to one and two story concrete structures.

The **Rural/Mountain (RM)** land use classification has occurred in newly opened mountainous areas. It consists of a disorganized pattern of land use. Structure types vary from informal wooden frame structures to multi-family concrete structures.

[18] Program developed under a Department of Housing (Vivienda), Adminstration of Social Programs.

FIGURE 4.10
DISTRIBUTION OF HOUSING UNITS[19]

[19] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

FIGURE 4.11
LAND USE DESIGNATIONS[20]

[20] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

The field investigation identified six (6) sample proto-typical representative building types in the municipality (includes residential and commercial buildings). For each land use classification, a "structural distribution ratio" was assigned to identify the percentage of different building types and uses (i.e., occupancy classes—residential and commercial). Building distribution and occupancy information collected during field surveys was integrated into a database to determine the number of representative building types across the municipality. The compilation of this data provided project planners with the ability to differentiate between building types with substantially different damage and loss characteristics. It also provided critical information to assess the values of the general building stock across the municipality. Table 4.15 below lists the estimated value for general occupancy classes used for this risk assessment.

TABLE 4.15 ***Aggregated Building Stock Values, Municipality of Aguada***

Occupancy Class	Exposure
Residential	$1,083,917,000
Commercial	$446,041,000
Total	**$1,529,958,000**

Exposure estimates are based on aggregated building replacement costs (dollars per square foot). Exposure estimates were based on structure descriptions gathered during field assessments and verified using regional cost modifiers.[21] Future Plan updates will include estimated building counts for each occupancy class.

Critical Facilities and Infrastructure

Community members identified several critical facilities. Critical facilities are defined as those facilities that provide essential services and functions. Table 4.16 lists the number of facilities identified during this study effort and the average estimated exposure value for each facility class. Figure 4.12 provides a map of critical facility locations throughout the municipality.

TABLE 4.16 ***Municipality of Aguada, Critical Facilities by Class***

Facility Class	Number of Facilities	Average Estimated Facility Replacement Cost
Emergency Operations Centers	1	$575,000
Medical Clinic & Care Facilities	1	$2,700,000
Police Stations (Law Enforcement Offices)	2	$125,000
Fire Stations	1	$675,000
City Hall	1	$2,875,000
Schools	25	$330,000
Total	**31**	

[21] Structure characteristics and values were reviewed by the Puerto Rico College of Architects.

FIGURE 4.12
CRITICAL FACILITIES[22]

[22] The above referenced figure is an 11-inch x 17-inch map insert located on the following page. This figure is also available electronically in PDF (Portable Document Format), viewable with Adobe Acrobat Reader 5.0.

4.5 LOSS ESTIMATES

Using the methodology described in Section 4.1, loss estimates were calculated for each hazard of interest, as presented in this section.

LOSS ESTIMATES: EARTHQUAKE GROUND SHAKING

Estimated property damages and losses for the ground shaking hazard were aggregated across occupancy classes. The property damages from a 100-year ground shaking event are estimated to be $129,074,000 (approximately 8% of the aggregated building stock value in Aguada) and are summarized in Table 4.17. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.17 ***Estimated Damages/Losses for Ground Shaking***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	1,512	$93,600,000
Commercial	392	$35,474,000
Total	**1,904**	**$129,074,000**

The critical facilities identified in this study were located in very low to high hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.18. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.18 ***Qualitative Damage States and Estimated Losses for Ground Shaking, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire			1			$202,500
Emergency Response			1			$207,000
Medical Clinic & Care Facilities			1			$972,000
Alcaldia			1			$1,242,000
Schools	18	2	2	3		$858,000

LOSS ESTIMATES: EARTHQUAKE LIQUEFACTION

Estimated property damages and losses for liquefaction were aggregated across occupancy classes. The property damages from a 100-year liquefaction event are estimated to be $390,000 and are summarized in Table 4.19. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.19 ***Estimated Damages/Losses for the Liquefaction Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	5	$300,000
Commercial	1	$90,000
Total	**6**	**$390,000**

The critical facilities identified in this study were located in very low to very high hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.20 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.20 ***Qualitative Damage States and Estimated Losses for Earthquake Liquefaction, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire		1				$8,100
Emergency Response			1			$25,200
Medical Clinic & Care Facilities	1	1				$40,000
Alcaldia		1				$51,600
Schools	20	2			3	$103,950

LOSS ESTIMATES: EARTHQUAKE-INDUCED LANDSLIDE

Estimated property damages and losses for earthquake-induced landslides were aggregated across occupancy classes. The property damages from a 100-year earthquake-induced landslide event are estimated to be $6,243,000 and are summarized in Table 4.21. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.21 ***Estimated Damages/Losses for the Earthquake-Induced Landslides Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	60	$5,122,000
Commercial	16	$1,121,000
Total	**76**	**$6,243,000**

The critical facilities identified in this study were located in very low to high hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.22 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.22 ***Qualitative Damage States and Estimated Losses for Earthquake-Induced Landslides, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire			1			$32,800
Emergency Response			1			$29,700
Medical Clinic & Care Facilities			1			$141,100
Alcaldia			1			$159,750
Schools	18	2	2	3		$115,000

LOSS ESTIMATES: TSUNAMI

Estimated property damages and losses for tsunami were aggregated across occupancy classes. The estimated property damages from a worse case scenario tsunami event are estimated to be $42,063,000 and are summarized in Table 4.23.

TABLE 4.23 ***Estimated Damages/Losses for the Tsunami Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for Worst Case Scenario Event
Residential	195	$12,723,000
Commercial	140	$29,340,000
Total	**335**	**$42,063,000**

The critical facilities identified in this study were located in very low to high hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.24 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.24 ***Qualitative Damage States and Estimated Losses for Tsunami, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire	1					Negligible
Emergency Response	1					Negligible
Medical Clinic & Care Facilities	1					Negligible
Alcaldia	1					Negligible
Schools	22				3	$643,500

LOSS ESTIMATES: HIGH WIND

Estimated property damages and losses for high wind hazard were aggregated across occupancy classes. The property damages from a 100-year high wind hazard event are estimated to be $35,482,000 and are summarized in Table 4.25. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.25 ***Estimated Damages/Losses for the Wind Storm Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	474	$27,506,000
Commercial	87	$7,976,000
Total	**561**	**$35,482,000**

The critical facilities identified in this study were located in very low to moderate hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.26 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.26 ***Qualitative Damage States and Estimated Losses for High Wind, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police		2				$22,500
Fire		1				$81,000
Emergency Response		1				$51,750
Medical Clinic & Care Facilities		1				$243,000
Alcaldia		1				$250,000
Schools	6	17	2			$1,003,200

LOSS ESTIMATES: RIVERINE FLOODING

Estimated property damages and losses for riverine flooding hazard were aggregated across occupancy classes. The estimated property damages from a 100-year riverine flooding event are estimated to be $350,000 and are summarized in Table 4.27. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.27 ***Estimated Damages/Losses for the Riverine Flood Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	155	$11,059,000
Commercial	162	$7,593,000
Total	**217**	**$18,653,000**

The critical facilities identified in this study were located in very low to high hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.28 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.28 ***Qualitative Damage States and Estimated Losses for Riverine Flooding, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire	1					Negligible
Emergency Response	1					Negligible
Medical Clinic & Care Facilities	1					Negligible
Alcaldia	1					Negligible
Schools	21	2	1	2		$313,500

LOSS ESTIMATES: COASTAL FLOODING

Estimated property damages and losses for coastal flooding hazard were aggregated across occupancy classes. The estimated property damages from a 100-year coastal flooding event are estimated to be $1,131,000 and are summarized in Table 4.29. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.29 ***Estimated Damages/Losses for the Coastal Flood Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	4	$302,000
Commercial	7	$829,000
Total	**11**	**$1,131,000**

No critical and infrastructure facilities are located in the coastal flood hazard areas, therefore, coastal damage states are assumed to be negligible.

LOSS ESTIMATES: RAINFALL-INDUCED LANDSLIDES

Estimated property damages and losses for rainfall-induced landslide hazard were aggregated across occupancy classes. The estimated property damages from a 100-year rainfall-induced landslide event are estimated to be $5,796,000 and are summarized in Table 4.30. Future Plan updates will attempt to estimate potential losses for additional event frequencies, including 50-year and 500-year events.

TABLE 4.30 ***Estimated Damages/Losses for the Rain-Induced Landslide Hazard***

Occupancy Classes	Estimated Structures Potentially Impacted	Potential Losses for 100-year Event
Residential	65	$4,098,000
Commercial	14	$1,698,000
Total	**78**	**$5,796,000**

The critical facilities identified in this study were located in very low to moderate hazard intensity level areas. Critical facility damage states and estimated losses are highlighted in Table 4.31 below. Future Plan updates will attempt to provide loss estimates for infrastructure located in Aguada.

TABLE 4.31 ***Qualitative Damage States and Estimated Losses for Rainfall-Induced Landslides, by Critical Facility Type***

Facility Type	Very Low	Low	Moderate	High	Very High	Estimated Losses
Police	2					Negligible
Fire	1					Negligible
Emergency Response	1					Negligible
Medical Clinic & Care Facilities	1					Negligible
Alcaldia	1					$22,800
Schools	23		2			Negligible

LOSS ESTIMATES: SUMMARY

Table 4.32 summarizes the expected losses at a 100-year level event (except tsunami which is a worst case scenario event) for each hazard for the Municipality of Aguada, which are a culmination of the quantitative assessment. The top three hazards identified through this process are earthquake ground shaking hazard, the tsunami hazard, and the high wind including (hurricane and tropical storm) hazard.

TABLE 4.32 ***Summary of Vulnerability and Estimated Losses by Hazard***

Hazard	Potential Losses to Structures	Potential Losses to Critical Facilities	Total Potential Losses
Earthquake: Ground Shaking	$129,074,000	$3,481,500	**$132,555,500**
Summary of Vulnerability to the Earthquake: Ground Shaking Hazard If a large earthquake were to occur with an epicenter close to Aguada, there would be extensive damage to many of the buildings in the municipality. More common are the smaller earthquakes that cause only minor damage.			
Tsunami	$42,063,000	$643,500	**$42,706,500**
Summary of Vulnerability to the Tsunami Hazard Portions of the municipality of Aguada are vulnerable to tsunami hazard. These specific areas are discussed earlier in this section.			
High Wind (including Hurricane and Tropical Storm)	$35,482,000	$1,651,450	**$37,133,450**
Summary of Vulnerability to the High Wind (including Hurricane and Tropical Storm) Hazard Aguada is vulnerable to hurricanes and tropical storms on an annual basis and all properties are at risk with those structures located closer to the coast being slightly more vulnerable.			
Riverine Flooding	$18,652,000	$313,500	**$18,965,500**
Summary of Vulnerability to the Riverine Flooding Hazard Aguada frequently experiences heavy rainfall from thunderstorms, passing tropical storms and hurricanes. Several areas of the municipality are vulnerable to flooding caused by these events. Specific neighborhoods, structures and roads that are especially vulnerable are listed in detail earlier in this section.			
Earthquake-Induced Landslide	$6,243,000	$478,350	**$6,721,350**
Summary of Vulnerability to the Earthquake-Induced Landslide Hazard Because of the possibility of earthquakes in Aguada, the possibility of earthquake-induced landslides is a risk that Aguada also faces. All areas potentially at risk to rainfall-induced landslides would be at risk to earthquake-induced landslides as well. These vulnerable areas have been discussed earlier in this section.			
Rainfall-Induced Landslide	$5,796,000	$22,800	**$5,818,800**

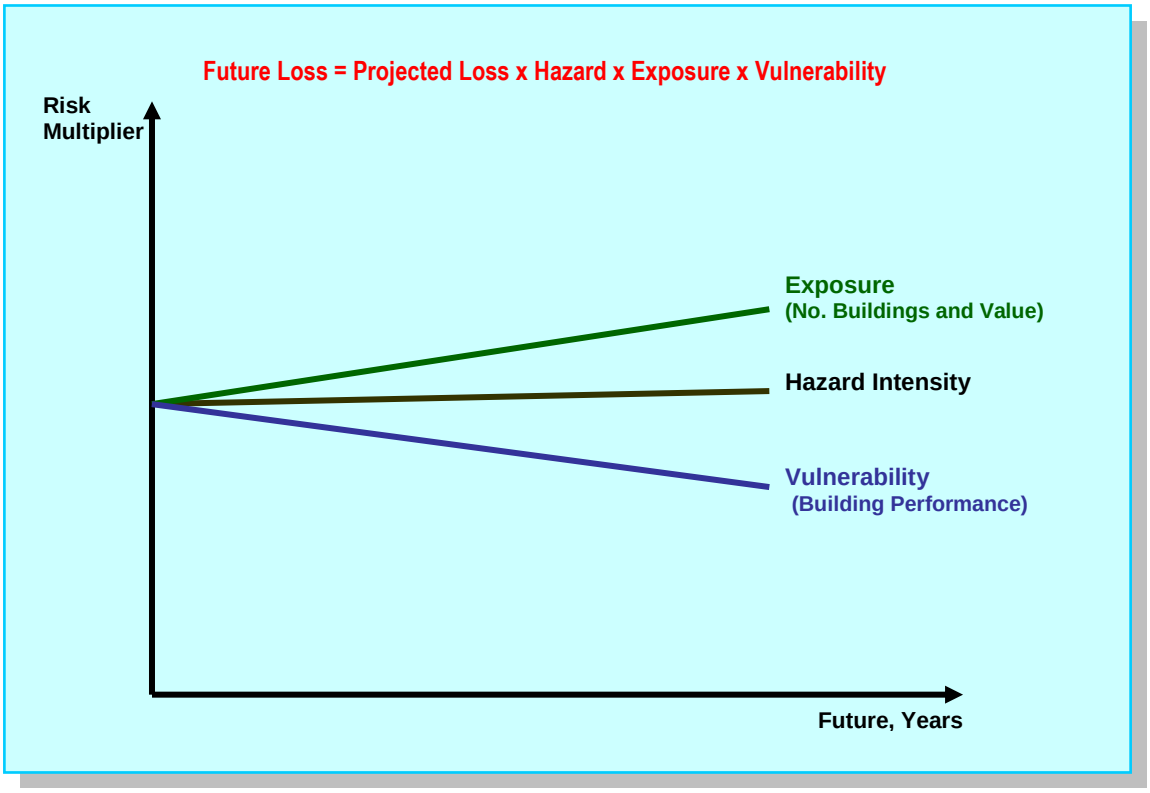
Hazard	Potential Losses to Structures	Potential Losses to Critical Facilities	Total Potential Losses
Summary of Vulnerability to the Rainfall-Induced Landslide Hazard Because of the heavy rainfalls that are typical to Aguada and because of the sloping terrain throughout the municipality, rainfall-induced landslides are common. Specific neighborhoods, structures and roads that are especially vulnerable are listed in detail earlier in this section.			
Coastal Flooding	$1,131,000	negligible	**$1,131,000**
Summary of Vulnerability to the Coastal Flooding Hazard Portions of the municipality of Aguada are vulnerable to coastal flooding caused by hurricanes and tropical storms. Specific areas of concern are discussed earlier in this section.			
Earthquake: Liquefaction	$390,000	$228,850	**$618,850**
Summary of Vulnerability to the Earthquake: Liquefaction Hazard Aguada is at risk to liquefaction caused by earthquakes. Specific areas of vulnerability are discussed earlier in this section.			

4.6 UNDERSTANDING FUTURE LOSSES IN AGUADA

In order to understand the future vulnerability (potential losses) in Aguada so that mitigation options can be reasonably assessed, it is necessary to compare expected future losses throughout the municipality. A comparative assessment of future risk may provide a basis to understand how future development may increase vulnerability to each hazard. This subsection presents a brief methodology that was used to compare future risk, projects losses for 10, 20 and 30-years from today, and proposes a land use map that provides the basis for policy makers to assess ways to reduce vulnerability in years to come.

The risk projection model presented in Figure 4.13 consists of three different components: (1) hazard intensity that is defined for a 100-year return period for each identified hazard, (2) exposure which is defined as the number of buildings (inventory) and value, and (3) the vulnerability or damageability of the building stock over time.

FIGURE 4.13 ***Components of Risk Projection Model***



These components were systematically combined in a risk projection model to understand the potential future losses for each hazard. This methodology facilitates an understanding of how the following components of the risk assessment changed over time. A description of these components is provided below:

Hazard—The hazard intensity/frequency relationship was assumed to remain constant throughout the 10, 20, and 30 year periods. This means that the hazard intensity, which is based on 100-year return period, is not expected to change dramatically over time (i.e., the timeframe window chosen for the analysis).

Vulnerability—The general characteristics of the built environment are expected to change over time due to: a) regular code improvements and updates, b) degree and level of code enforcement, and c) improvements in the construction material and practices. A vulnerability multiplier was used to update/modify the building performance from the present to that of years 2010, 2020, and 2030.

- *Building Code*—Puerto Rico's building codes have recently been updated to the 1997 edition of the Uniform Building Code (UBC) with the exception of the wind load provision, which is based on the American Society of Civil Engineers (ASCE 7-95). Through the change in building codes, it is assumed that, compared to today's buildings, future buildings will have enhanced performance. A building code multiplier was used to approximate improvements in the built environment.
- *Code Enforcement*—Although formal building codes have been adopted by the central government in Puerto Rico, code enforcement continues to be poorly implemented in rural municipalities. The lack of regulatory control in rural municipalities is directly related to the comprehensive planning process in which municipalities must first complete and adopt a *Plan Territorial* in order to obtain regulatory responsibilities. Once adopted, it is expected that code enforcement will gradually improve throughout the municipality. A code enforcement multiplier was used to approximate improvements in the built environment.
- *Construction Practices*—It is assumed that construction practices, in terms of workmanship and materials, will improve over time. A construction multiplier was used to approximate improvements in the built environment.

Therefore, the risk projection model holds that vulnerability in the municipality will decrease over time (i.e., building performance for a given hazard type and intensity will improve over time).

Exposure—U.S. Census data is used to predict future exposure (number of buildings and value) across the municipality. The U.S. Census population growth rate of 8 percent per annum was used to estimate future exposure values. The values were estimated based on a linear regression analysis for each land use classification defined during the field assessment. Therefore, the model assumes that exposure values will increase proportional to population growth and will be uniform across different land use categories in the municipality.

To provide a mechanism for community officials to understand expected future losses, the effects of mitigation actions are not included in the projection of future losses shown in Table 4.33.

TABLE 4.33 ***Estimated Aggregated Future Losses, Municipality of Aguada***

	2010		2020		2030	
Hazard	Buildings Impacted	Total Potential Future Loss	Buildings Impacted	Total Potential Future Loss	Buildings Impacted	Total Potential Future Loss
Earthquake Ground Shaking	3,847	$220,752,170	6,704	$280,110,019	7,980	$261,916,718
Earthquake Liquefaction	13	$713,864	22	$971,938	33	$975,153
Earthquake-Induced Landslide	154	$11,228,931	268	$14,984,454	402	$14,735,144
Tsunami	285	$44,778,756	496	$44,041,616	744	$43,326,897
High Wind	1,134	$59,168,887.07	1976	$73,204,227	2,961	$66,740,558
Riverine Flood	439	$32,225,488	764	$41,305,488	1,145	$39,014,580
Coastal Flood	22	$1,901,362	39	$2,371,507	58	$2,179,692
Rainfall-Induced Landslide	158	$2,529,640	276	$3,308,437	414	$3,188,585

AGUADA DEVELOPMENT TRENDS

The rate of population change in the Municipality of Aguada between 1990 and 2000 was 17 percent, which is more than double that of the overall average growth rate for Puerto Rico of 8.1 percent for the same period. One specific aspect of this growth is the expansion of commerce in the western part of Puerto Rico, which has precipitated the expansion of residential development.

The following description of commercial and residential development trends is based on field observations and a series of interviews conducted with key municipal staff. This section discusses several important future land development trends and potential impacts on the municipality's vulnerability to a series of natural hazards.

Residential Development

In Aguada, recent residential developments have been suburban in nature and have consisted of homogeneous house types (i.e., 1-story concrete structures). This trend currently leads the municipal housing market and is anticipated to increase in the future. These large-scale developments are attracting young families, an important factor for the municipality's economic viability.

Continued subdivision development will require a balance between economic benefits (i.e., tax revenues, employment, etc.) and the environmental impacts (i.e., surface run-off, vehicular

congestion, etc.). Future development will need to consider the physical characteristics of the site (i.e., topography, soils, etc.), vehicular access, and routing or capacity of existing basic infrastructure in order to achieve a balance between development and sustainability.

Commercial Development

The predominant trend in commercial development in Aguada consists of retail shopping centers on major road corridors outside of the traditional urban center boundaries. The development of shopping centers tend to be comprised of closely packed groups of structures that contain a large amount of floor space and a variety of commercial and service establishments. Commercial development along Desvio Sur has complimented new residential developments; however, it has also created problems. Developments have been constructed in environmentally sensitive areas, along natural drainage corridors, and have increased surface water run-off. Continued commercial development, without modification of existing stormwater drainage infrastructure, will increase localized flooding on this major thoroughfare. Increased flooding will damage infrastructure (streets) as well as adjacent commercial and residential developments beyond the area being developed.

Another trend in commercial development includes the development of walk-up condominiums and hotels. Development in this category varies in size from single multi-story structures to 20 or more structures. This type of development has been expanding tremendously during the last couple of decades. Some of the contributing factors of this expansion include convenient freeway access from the San Juan metropolitan area, changing social attitudes toward recreation and the municipality's conscious effort to strike a balance between residential and non-residential development.

Tourist development is scattered along the coastal barrios of Rio Grande, Guaynabo, Guaniquilla, Carrizal and Espinar. Development continues to occur in sensitive coastal environments and has caused problems, most notably destruction of the littoral environment and beach erosion. Coastal development has also increased the municipality's exposure to a variety of hazards including tsunami and coastal flooding. In efforts to strike a balance between the economy and the environment, the municipality should encourage intense commercial uses in areas that have the least impact.

Future Development Projects

At the time of this writing, current and proposed development projects were available as an indicator of future development within the municipality. Table 4.34 provides a listing of these improvements along with such relevant details as location, description of project, and proposed schedule (i.e., fiscal years).

TABLE 4.34 ***General Development Projects and Improvements, 2005–2010***

Location	Description	Proposed Schedule
Bo. Piedras Blancas	Urbanization Villa Sotomayor 50 single family dwellings	2005
Bo. Guayabo	Urbanization Las Casonas 20 single family dwellings	2005
Bo. Asomante	Urbanization Villa Asomante 125 low-moderate income single family dwellings	2005—2006
Bo. Guayabo	Urbanization Parkview 131 single family dwellings	2006
Bo. Pueblo	Aguada Town Center 20 commercial/retail spaces	2004—2005
Bo. Pueblo (Carr. 115)	Entrada Desvio Sur Professional Office Complex	2005
Bo. Guaynabano	Centerplex Mixed Use Commercial Complex Professional Offices and Retail	2004—2005
Bo. Espinar	Discovery Bay Marina 5 Condominiums with 300 Units Golf Course, 150 Slip Marina	2006—2010

Planned development projects may be less vulnerable to future hazard impact due to the use of more current construction practices which help mitigate new buildings where possible.

This section of the Hazard Mitigation Plan for the Municipality of Aguada identifies goals, objectives and actions of the Plan. This represents a framework for reducing the community's vulnerability to the effects of natural hazards. These mitigation strategies are based on community input, the risk assessment, and an assessment of technical and administrative capabilities. Section Five is divided into the following four subsections:

- 5.1 Mitigation Strategy
- 5.2 Mitigation Action Plan
- 5.3 Administration of Actions
- 5.4 Assessing Cost Effectiveness of Mitigation Actions

5.1 MITIGATION STRATEGY

The intent of the *Mitigation Strategy* is to provide the Municipality of Aguada with the goals that will serve as the guiding principles for future mitigation policy and project administration, along with a listing of proposed actions deemed necessary to meet those goals and reduce the impact of natural hazards. It is designed to be comprehensive and strategic in nature.

In being comprehensive, the development of the strategy included a thorough review of all natural hazards and identifies far-reaching policies and projects intended to not only reduce the future impacts of hazards, but also to assist the municipality to achieve compatible economic, environmental and social goals. In being strategic, the development of the strategy ensures that all policies and projects are linked to established priorities and assigned to specific departments or individuals responsible for their implementation with target completion deadlines. When necessary, funding sources are identified that can be used to assist in project implementation.

The first step in designing the *Mitigation Strategy* includes the identification of *Goals* and *Objectives*. Goals represent broad statements that are achieved through the implementation of a range of more specific objectives. Goals are usually expressed as broad policy statements and provide the framework for achieving the desired results over the long-term planning horizon (five to 10 years). *Goals* were developed in response to known hazard vulnerabilities and the municipality's capability to address them, and these goals represent broad statements that are achieved through the implementation of more specific, action-oriented objectives listed in the Mitigation Action Plan. These actions include both hazard mitigation policies (such as the regulation of land in known hazard areas through a local ordinance), and hazard mitigation projects that seek to address specifically targeted hazard risks (such as the acquisition and relocation of a repetitive loss structure). Objectives describe strategies that would lead to implementation of the identified goals. They are intended to support, correspond and define a path on how to attain the desired goals.

The second step involves the identification, consideration and analysis of available mitigation measures to help achieve the identified mitigation goals. This is a long-term, continuous process sustained through the development and maintenance of this Plan, beginning with the cardstorming exercise for Hazard Mitigation Planning Committee members and the public during a Community

Workshop. Alternative mitigation measures will continue to be considered as future mitigation opportunities become identified, as data and technology improve, as mitigation funding becomes available, and as this Plan is maintained over time.

The third and last step in designing the *Mitigation Strategy* is the creation of the local *Mitigation Action Plan (MAP)*. The MAP represents an unambiguous plan for action, and is considered to be the most essential outcome of the mitigation planning process. It includes a prioritized listing of proposed hazard mitigation actions (policies and projects) for Aguada along with accompanying information such as those agencies or individuals assigned responsibility for their implementation, potential funding sources and an estimated target date for completion. The MAP provides those individuals or agencies responsible for implementing mitigation actions with a clear roadmap that also serves as an important tool for monitoring progress over time. The cohesive collection of actions listed in the MAP also can serve as an easily understood menu of mitigation policies and projects for local decision makers. A range of mitigation techniques was identified to reduce hazard vulnerability and achieve established community goals and objectives. Mitigation techniques include prevention, property protection, natural resource protection, structural projects, emergency services, and public information and awareness activities. The Mitigation Action Plan presents the short-term, specific actions to be undertaken in order to achieve identified objectives. For each action, the Mitigation Action Plan identifies the objective(s) it is intended to achieve, provides general background information to justify the proposed action, and provides measures to ensure successful and timely implementation, including task assignments and appropriate funding sources, if applicable.

In preparing the Mitigation Actions Plan, Aguada considered their overall hazard risk and capability to mitigate natural hazards through the risk and capability assessment process and public comment, in addition to meeting the adopted mitigation goals and the unique needs of their community. A process for prioritization of identified hazard mitigation strategies was performed after the review of the draft Plan. In order to rank actions in high, medium, and low priority, the Hazard Mitigation Planning Committee used the following criteria for prioritization of hazard mitigation strategies:

1) cost-benefit review[1]
2) results of Hazard Identification and Analysis
3) results of Vulnerability Assessment
4) review of local capability (administrative, technical, etc.)
5) effectiveness in meeting hazard mitigation goals and comprehensive plan goals

Cost-benefit review was given special emphasis, in light of its possible use in environmental reviews for HMGP, FMA and other federal hazard mitigation projects. Other factors for prioritization included: (1) effect on overall risk to life and property; (2); ease of implementation; (3) political and community support; and (4) funding availability.

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[1] Only a general economic cost/benefit review was considered through the process of selecting and prioritizing mitigation actions for each jurisdiction. Mitigation actions with "high" priority were determined to be the most cost effective and most compatible with each jurisdiction's unique needs. A more detailed cost/benefit analysis will be applied to particular projects prior to the application for or obligation of funding, as appropriate.

GOALS AND OBJECTIVES

The following goals and objectives represent a comprehensive approach taken by the Municipality of Aguada to reduce the impacts of natural hazards. Each goal, objective and action was selected and prioritized by the Hazard Mitigation Committee and was based on public input gathered during a series of public information meetings. The following section is intended to guide both the day-to-day operations and the long-term approach taken by the Municipality of Aguada to reduce potential losses from future hazard events. It lists four (4) broad based goals, six (6) objectives and 39 actions.

Goal #1 **Implement programs and policies to reduce the impact of natural disasters on population, property and infrastructure.**

- Objective 1.1 Protect existing development from future disaster events.
- Objective 1.2 Protect future development by implementing sound land use and development policies.

Goal #2 **Increase municipality capabilities to implement and maintain mitigation programs.**

- Objective 2.1 Identify and develop policies, programs and regulations to support effective hazard mitigation programming throughout the municipality.

Goal #3 **Implement programs that increase awareness and understanding of hazards and hazard mitigation.**

- Objective 3.1 Develop outreach programs focused on increasing public awareness of hazards and their associated risks.

Goal #4 **Increase municipal emergency preparedness, response and recovery capabilities.**

- Objective 4.1 Enhance the local government capability to support emergency response and recovery operations.
- Objective 4.2 Maximize governmental coordination and communication between municipality, central government and federal agencies in emergency situations.

MITIGATION TECHNIQUES

A range of techniques, chosen from those listed below, was used in this Plan. Techniques may be added or subtracted as this Plan evolves, taking into account the effectiveness of chosen actions, their completion, or in response to the changing vulnerabilities found in Aguada.

Available Mitigation Techniques for Natural Hazards

Prevention

Preventative activities are intended to keep hazard-related problems from getting worse. They are particularly effective in reducing a community's vulnerability in areas where development has not occurred or capital improvements have not been substantial. Examples of preventative activities include:

- Planning and zoning
- Open space preservation
- Stormwater management
- Drainage system maintenance
- Capital improvements programming
- Coastal and riverine setbacks

Property Protection

Property protection measures either enable existing structures to better withstand hazardous events, remove structures from hazardous locations, or provide insurance to cover potential losses. Examples include:

- Acquisition
- Relocation
- Building elevation
- Critical facilities protection or "hardening"
- Retrofitting (i.e., windproofing, floodproofing, seismic design standards, etc.)
- Insurance
- Safe room construction

Natural Resource Protection

Natural resource protection activities reduce the impact of hazards by preserving or restoring the function of environmental systems. Examples include floodplains, wetlands and certain steep sloped areas. In many cases, environmentally sensitive areas are also high hazard areas. Thus, natural resource protection measures can serve the dual purpose of protecting lives and property while enhancing environmental goals such as improved water quality or enhancing recreational

opportunities. Parks, recreation or conservation agencies and organizations often implement these measures. Examples include:

- Floodplain protection
- Riparian buffers
- Fire resistant landscaping
- Erosion and sediment control
- Wetland preservation and restoration
- Habitat preservation
- Slope stabilization

Structural Projects

Structural mitigation projects are intended to lessen the impact of a hazard by physically modifying the environment. They are usually designed by engineers and managed or maintained by public works staff. Examples include:

- Reservoirs
- Levees/dikes/floodwalls
- Diversions/detention/retention
- Channel modification
- Storm sewers

Emergency Services

Although not typically considered a "mitigation technique," emergency services minimize the impact of a hazard event on people and property. These actions are typically taken immediately prior to, during, or in response to a hazard event. Examples include:

- Search and rescue
- Evacuation planning and management
- Flood "fighting" methods (i.e., sandbagging, use of temporary flood walls, etc.)
- Warning systems

Public Information and Awareness

Public information and awareness activities are used to advise residents, business owners, potential property buyers and visitors about hazards, hazardous areas and mitigation techniques they can use to protect themselves and their property. Examples of measures to educate and inform the public include:

- Outreach
- Speaker series/demonstration events

- Hazard map information
- Real estate disclosure
- Education
- Training

Mitigation Techniques for the Municipality of Aguada

In considering the appropriate mitigation techniques for the municipality of Aguada, the Hazard Mitigation Committee reviewed the findings of the *Hazard Identification and Risk Assessment.* The following matrix summarizes the mitigation techniques adopted:

Mitigation Technique	Ground Shaking	Liquefaction	Earthquake Landslide	Riverine Flooding	Coastal Flooding	Hurricane	Rainfall Landslide	Tsunami
Prevention	◆	◆	◆	◆	◆		◆	◆
Property Protection	◆			◆	◆	◆		◆
Natural Resource Protection	◆	◆		◆	◆			
Structural Projects				◆	◆	◆		
Emergency Services				◆	◆	◆		◆
Public Information/Awareness	◆	◆	◆	◆	◆	◆	◆	◆

5.2 MITIGATION ACTION PLAN

The mitigation actions listed on the pages that follow have been designed to achieve the goals and objectives identified in the Hazard Mitigation Plan. Each proposed action includes:

- The categorization of the mitigation technique;
- The hazard it is designed to mitigate;
- The objective(s) it is intended to achieve;
- General background information;
- An assigned level of priority (high, moderate or low);
- Funding sources, if applicable;
- The department or person assigned responsibility for carrying out the action; and
- A target completion date.

The mitigation actions are short-term, specific measures to be undertaken by the Municipality of Aguada and will be used as the primary measure of the Plan's progress over time. This approach is intended to facilitate the quick review and update of the Plan as described in Section Six, *Plan Implementation*.

While a capability assessment is not required as part of the Disaster Mitigation Act of 2000 planning requirements, the project consultant team reviewed current plans and legislation as part of the planning process. These plans provided important background information on the demographic profile of the municipality, proposed capital improvement projects and land use, and administrative capabilities. This information was used to assess the municipality's general capability to implement hazard mitigation policies and programs.

This analysis provided important information for developing an effective and practical hazard mitigation strategy. Specifically, it allowed the project consultant team to determine what actions are practical or are likely to be implemented over time given the administrative, technical, fiscal, legal and political makeup of the municipality.

An additional part of the evaluation involves the assessment of existing policies, programs and projects currently in place that impact the municipality's vulnerability to natural hazards. For example, future vulnerability may be reduced as hazard maps are used in the permit and development review process, now being implemented in the planning office. Hazard maps can be used to make decisions on where to place public infrastructure.

A description of the instructions given to participants for creating mitigation actions and the general process subsequently utilized through these instructions is provided below:

a. Mitigation Action: Identify specific actions that, if accomplished, will reduce vulnerability and risk in the impact area. Actions should match mitigation goals and objectives.

b. Objectives Addressed: Identify which Objective(s) is/are addressed by the defined action.

c. Category: Of the mitigation techniques available to the municipality (as outlined above), select the category(s) that best fit(s) the defined action.

d. Hazard: The hazard(s) the action attempts to mitigate against.

e. Background: Provide a brief description of the problem and any other pertinent narrative facts associated with the defined action.

f. Priority: Indicate whether the action is a 1) High priority—short term immediate—reducing overall risk to life an property; 2) Moderate priority—an action that should be implemented in the near future due to political or community support or ease of implementation; 3) Low priority—an action that should be implemented over the long term that may depend on the availability of funds.

g. Potential Funding Sources: If applicable, indicate how the cost to complete the action will be funded. For example, funds may be provided from existing operating budgets, from a previously established contingency fund, or a cost sharing federal or state grant, etc.

h. Hazard Mitigation Committee Leader: Identify which Hazard Mitigation Committee Leader will be responsible, or most responsible, for monitoring the progress of the defined action.

i. Department Responsibility: Identify the local agency, department or organization that is best suited to accomplish the defined action.

j. Estimated Timeframe: Indicate when the action will begin, and when the action is expected to be completed. Remember that some actions will require only a minimum amount of time, while others may require a long-term continuing effort.

Each of the proposed actions was discussed at the workshop (which included public participation) and prioritized as low, medium or high by the group. A vote was not conducted to prioritize actions in 1, 2, 3 order.[2]

[2] STAPLEE criterion was not available at the time that these actions were developed. Additional information on cost effectiveness is provided in 5.4 Assessing Cost Effectiveness of Mitigation Actions, located at the end of this section.

Mitigation Action 1	**Implement stream cleaning and drainage programs in Barrio Guayabo, Sector Casualidad, Des Vio Sur.**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in and around streams in the municipality. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 2	**Implement stream cleaning and drainage programs in Barrio Guayabo Carr. P.R. 115 (Desde Putusa hasta punte de pico pierdra).**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in island streams. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 3	**Implement stream cleaning and drainage programs in Barrio Rio Grande, Sector Tres Tiendas, Parcelas (Nieves).**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in and around streams in the municipality. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 4	**Implement stream cleaning and drainage programs in Barrio Guanaquilla, Parcelas Noboa.**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in and around streams in the municipality. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 5	**Implement stream cleaning and drainage programs in Barrio Asomante, Comunidad de Flores (Carr. P.R. 441).**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in and around streams in the municipality. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 6	**Implement stream cleaning and drainage programs in Barrio Asomante, Sector Tablonal, Carr. P.R. 439.**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stream cleaning is an important action to address flood problems in urban areas. Throughout the municipality there is natural debris (trees, limbs, etc.) as well as trash (garbage, washing machines) in and around streams in the municipality. Cleaning streams would facilitate natural flow and reduce blockages.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 7	**Prepare and adopt a municipality-wide stormwater management plan.**
Objectives Addressed:	Objective 1.1
Category:	Prevention
Hazard:	Flood
Background:	Stormwater maintenance is an important tool to address flood problems throughout the municipality. New development, especially roads and bridges, can affect drainage patterns and have an impact on stormwater run-off and flooding in surrounding areas.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 8	**Replacement and upgrade of culverts, drainage structures, and bridges that produce localized flooding in Barrio Piedras Blancas, Sector Chuco Ramos.**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	In developed areas, the alteration of existing structures such as bridges and road culverts is often necessary. This strategy represents an action that will reduce flooding impact on residential structures.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 9	**Replacement and upgrade of culverts, drainage structures, and bridges that produce localized flooding in Barrio Guanababo, Carr. P.R. 417 (Km. 3.6).**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	In developed areas, the alteration of existing structures such as bridges and road culverts is often necessary. This strategy represents an action that will reduce flooding impact on residential structures.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Public Works
Estimated Timeframe:	8 months

Mitigation Action 10	**Implement stream restoration and channelization to ensure adequate drainage and diversion in Barrio Guayabo, Sector Casualidad, Des Vio Sur.**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	Modifying existing streams, culverts or development of channel drainage systems that may alleviate nuisance flooding or minor flood events. It will also help to improve the conveyance of floodwaters downstream. This can be an effective strategy if flood-prone properties are removed downstream.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Geraldo Hernandez
Department Responsibility:	Public Works
Estimated Timeframe:	12 months

Mitigation Action 11	**Implement stream restoration and channelization to ensure adequate drainage and diversion in Barrio Guanaquilla, Parcelas Noboa.**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	Modifying existing streams, culverts or development of channel drainage systems that may alleviate nuisance flooding or minor flood events. It will also help to improve the conveyance of floodwaters downstream. This can be an effective strategy if flood-prone properties are removed downstream.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Geraldo Hernandez
Department Responsibility:	Public Works
Estimated Timeframe:	12 months

Mitigation Action 12	**Implement stream restoration and channelization to ensure adequate drainage and diversion in Barrio Asomante, Comunidad las Flores (Carr. P.R. 441).**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	Modifying existing streams, culverts or development of channel drainage systems that may alleviate nuisance flooding or minor flood events. It will also help to improve the conveyance of floodwaters downstream. This can be an effective strategy if flood-prone properties are removed downstream.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Geraldo Hernandez
Department Responsibility:	Public Works
Estimated Timeframe:	12 months

Mitigation Action 13	**Implement stream restoration and channelization to ensure adequate drainage and diversion in Barrio Asomante, Sector Tablonal, Carr. P.R. 439.**
Objectives Addressed:	Objective 1.1
Category:	Structural Projects
Hazard:	Flood
Background:	Modifying existing streams, culverts or development of channel drainage systems that may alleviate nuisance flooding or minor flood events. It will also help to improve the conveyance of floodwaters downstream. This can be an effective strategy if flood-prone properties are removed downstream.
Priority:	
Potential Funding Sources:	
Hazard Mitigation Committee Leader:	
Department Responsibility:	
Estimated Timeframe:	

Mitigation Action 14	**Identify and estimate the cost of flood-prone structures in Barrio Mamey, Sector Juan 23, Carr. P.R. 4417 (14 homes).**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Flood
Background:	Identification and acquisition of flood-prone properties would reduce future flood losses. It also provides additional open space that can be used for recreational purposes and increases the storage capacity of the watershed.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Isabela Cardona
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	12 months

Mitigation Action 15	**Identify and estimate the cost of flood-prone structures in Barrio Cruces, Sector Lopez (abajo), Carr. P.R. 414.**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Flood
Background:	Identification and acquisition of flood-prone properties would reduce future flood losses. It also provides additional open space that can be used for recreational purposes and increases the storage capacity of the watershed.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Isabela Cardona
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	12 months

Mitigation Action 16	**Identify and estimate the cost of flood-prone structures in Barrio Guanabano,Parcelas Luyando.**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Flood
Background:	Identification and acquisition of flood-prone properties would reduce future flood losses. It also provides additional open space that can be used for recreational purposes and increases the storage capacity of the watershed.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Isabela Cardona
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	12 months

Mitigation Action 17	**Identify and estimate the cost of flood-prone structures in Barrio Guanabano y Asomante, Cummunidad Coloso.**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Flood
Background:	Identification and acquisition of flood-prone properties would reduce future flood losses. It also provides additional open space that can be used for recreational purposes and increases the storage capacity of the watershed.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Isabela Cardona
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	12 months

Mitigation Action 18	**Identify and estimate the cost of flood-prone structures in Barrio Espinar, Carr. P.R. 4439 (road repeatedly floods).**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Flood
Background:	Identification and acquisition of flood-prone properties would reduce future flood losses. It also provides additional open space that can be used for recreational purposes and increases the storage capacity of the watershed.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Isabela Cardona
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	12 months

Mitigation Action 19	**Regulate and enforce development in areas identified as landslide hazard areas by implementing soil stabilizing vegetation and appropriate barriers.**
Objectives Addressed:	Objective 1.1
Category:	Natural Resource Protection, Property Protection
Hazard:	Landslides
Background:	The likelihood of landslides is increased when steep sloped areas are disturbed due to construction or the removal of existing vegetation. If the alteration of sloped areas is necessary, it is important to take steps to minimize the likelihood of future instability. Grading, re-planting of vegetation, or the construction of retaining walls or other structures may be necessary.
Priority:	Medium
Potential Funding Sources:	Internal Funding
Hazard Mitigation Committee Leader:	Gerald Hernandez
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	1 year, 6 months

Mitigation Action 20	**Regulate and enforce development in coastal areas to ensure that the appropriate retention buffers are used during construction.**
Objectives Addressed:	Objective 1.1
Category:	Natural Resource Protection
Hazard:	Coastal hazards, Landslides
Background:	The likelihood of coastal hazards is increased when existing vegetation is removed. If the alteration of natural vegetation is necessary, it is important to take steps to minimize the likelihood of future instability. Natural vegetation buffers should be used instead of structures such as retaining walls, etc.
Priority:	Medium
Potential Funding Sources:	Internal Funding
Hazard Mitigation Committee Leader:	Gerald Hernandez
Department Responsibility:	Oficina de Alcalde, Francisco Mercado
Estimated Timeframe:	1 year, 6 months

Mitigation Action 21	**Encourage architects, engineers and contractors working in the municipality to be knowledgeable of the newly adopted building codes and provisions for making structures more resistant to high winds.**
Objectives Addressed:	Objective 1.1
Category:	Property Protection
Hazard:	Wind
Background:	Wind storms can cause significant damage to residential structures—particularly roof systems. The dissemination of information to island developers may encourage better residential and commercial construction on the island.
Priority:	High
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	12 months

Mitigation Action 22	**Revise the Plan Ordainmento Territorial to incorporate the findings of the Municipality's Hazard Mitigation Plan.**
Objectives Addressed:	Objective 1.2
Category:	Prevention
Hazard:	All Hazards
Background:	By incorporating the findings of the Hazard Mitigation Plan into the comprehensive land use plan, the municipality makes the best use of natural hazards assessments. The community can include natural hazard mitigation measures into current capital improvement and other investment projects in a less costly fashion.
Priority:	Medium
Potential Funding Sources:	Internal Funding and OCAM
Hazard Mitigation Committee Leader:	Miguel Valle
Department Responsibility:	Programas Federales
Estimated Timeframe:	1 year, 6 months

Mitigation Action 23	**Establish a Municipal Development Review Board that works directly with the PR Planning Board, ARPE and Department of Natural Resources for consideration of new construction permits on the island.**
Objectives Addressed:	Objective 1.2
Category:	Prevention
Hazard:	All Hazards
Background:	A Development Review Board can provide an important function for the municipality by working in a participatory manner to uphold and interpret the municipal-level land use plans, zoning districts and ordinances. It can play an important intermediary role between the local government and central government agencies.
Priority:	Medium
Potential Funding Sources:	Internal Funding and OCAM
Hazard Mitigation Committee Leader:	Miguel Valle
Department Responsibility:	Oficina de Alcalde
Estimated Timeframe:	2 years

Mitigation Action 24	**Development linkage with the ARPE for consideration of hazard maps during the permit review process.**
Objectives Addressed:	Objective 1.2
Category:	Prevention
Hazard:	All Hazards
Background:	By developing a linkage or pursuing a memorandum of understanding with the ARPE, the municipality can ensure that the findings of the hazard assessment are being considered during the review of large residential and commercial projects.
Priority:	Medium
Potential Funding Sources:	Internal Funding and OCAM
Hazard Mitigation Committee Leader:	Miguel Valle
Department Responsibility:	Oficina de Alcalde
Estimated Timeframe:	2 years

Mitigation Action 25	**Modify Municipal Ordinance No. 3 to incorporate findings of the Hazard Mitigation Plan to limit or prohibit development in high hazard areas.**
Objectives Addressed:	Objective 2.1
Category:	Prevention
Hazard:	All hazards
Background:	Municipal Ordinance No. 3 is an ordinance that provides authority to the Emergency Management Office (OME) to respond to and assist in the recovery from natural disasters. It specifically states that the OME has the right to prohibit construction in hazard-prone areas. By incorporating the findings of the hazard assessment, it provides an important tool that can be utilized to limit development in high-risk areas and reduce future vulnerability.
Priority:	Medium
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias, Assemble Municipal
Estimated Timeframe:	12 months

Mitigation Action 26	**Conduct an engineering study to develop new Flood Insurance Rate Maps (FIRMs) that reflect "real" flooding areas in the municipality.**
Objectives Addressed:	Objective 2.1
Category:	Prevention
Hazard:	Flood
Background:	A complete flood study would entail the development of new flood maps that establish new or revised base flood elevations (BFEs). One of the starting points is the National Flood Insurance Program (NFIP). The community can apply through the regional FEMA office or the Hazards Study Branch of the Federal Insurance and Mitigation Administration.
Priority:	Moderate
Potential Funding Sources:	External Funding Sources (i.e. FEMA)
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	12 months

Mitigation Action 27	**Establish grant writing department in the municipality to identify central and federal funding sources that could support hazard mitigation initiatives.**
Objectives Addressed:	Objective 2.1
Category:	Prevention, Emergency Services
Hazard:	All Hazards
Background:	The vitality of the hazard mitigation program in the municipality will depend on the establishment of a grant writing department. To increase the amount of municipal grant money, the municipality will need to increase its grant writing and grant submittals to federal, central government, and private foundations.
Priority:	Medium
Potential Funding Sources:	Internal Funding
Hazard Mitigation Committee Leader:	Miguel Valle
Department Responsibility:	Oficina de Alcalde
Estimated Timeframe:	2 years

Mitigation Action 28	**Participate in federal and central government programs that provide technical assistance.**
Objectives Addressed:	Objective 2.1
Category:	Prevention, Emergency Services
Hazard:	All Hazards
Background:	There are several federal and central government programs that provide technical assistance and support to local communities. FEMA mitigation staff support many of these initiatives, including support through: the Hazard Mitigation Technical Assistance Program, the National Earthquake Technical Assistance Program, and the Wind and Water Technical Assistance Program. Technical assistance is also available through the Puerto Rico State Emergency Management Agency.
Priority:	Medium
Potential Funding Sources:	External Funding (i.e., FEMA and PRSEMA)
Hazard Mitigation Committee Leader:	Miguel Valle
Department Responsibility:	Oficina de Alcalde
Estimated Timeframe:	2 years

Mitigation Action 29	**Provide hazard mitigation educational information to local businesses.**
Objectives Addressed:	Objective 3.1
Category:	All Hazards
Hazard:	Public Information
Background:	The Institute for Business and Home Safety (IBHS) is a not-for-profit organization that emphasizes actions that businesses and homeowners can take to reduce the impact of natural hazards. For more information, visit www.ibhs.org.
Priority:	Medium/ Low
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Albert Perez
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	6 months

Mitigation Action 30	**Provide hazard mitigation educational information to neighborhood residents.**
Objectives Addressed:	Objective 3.1
Category:	All Hazards
Hazard:	Public Information
Background:	Hazard information should be provided to citizens, especially residents for special communities. Providing educational materials to the public is an excellent way to further institutionalize a local mitigation ethic throughout the community. The municipality should explore many different avenues to inform the public (i.e., radio, printed media, door-to-door, community workshops, etc.). By maintaining an ongoing dialogue, the media is more likely to assist the city in disseminating important information prior to or following an emergency or disaster.
Priority:	Medium/Low
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Albert Perez
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	6 months

Mitigation Action 31	**Establish, maintain and publicize a library section on hazard mitigation.**
Objectives Addressed:	Objective 3.1
Category:	All Hazards
Hazard:	Public Information
Background:	Citizens have a major stake in the development of a more sustainable community. A centrally-located repository for hazard information that describes hazards, hazard mitigation and policies, responsibilities, and procedures required before, during, and after an emergency situation can go a long way in educating the community and helping communities prepare and respond to specific hazard events.
Priority:	Medium/ Low
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Albert Perez
Department Responsibility:	Sistema de Información
Estimated Timeframe:	6 months

Mitigation Action 32	**Publish, distribute and disseminate hazard information brochures to municipal government departments.**
Objectives Addressed:	Objective 3.1
Category:	All Hazards
Hazard:	Public Information
Background:	Educating municipal employees is an excellent way to further institutionalize a local mitigation ethic. Because many employees interact with the public, they can help spread the mitigation message to the entire community. In addition, ongoing seminars may result in the identification of additional mitigation actions that can be incorporated into the Plan.
Priority:	Medium/Low
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Albert Perez
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	6 months

Mitigation Action 33	**Conduct needs assessment and implement municipality-wide flood warning system.**
Objectives Addressed:	Objective 4.1
Category:	Emergency Services
Hazard:	Flood
Background:	Determining the most effective type of flood warning system is a complicated issue. The type of system used will depend on the familiarity and comfort of municipal officials with the technological options. The municipality should consult with technical experts (i.e., USGS San Juan) and should solicit several proposals in order to choose a system. Quite often, the choices will be between manual systems and automated systems.
Priority:	Medium
Potential Funding Sources:	External Grant
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	1 year

Mitigation Action 34	**Implement a flood advisory board and program that indicates areas of frequent flooding and provides residents with information for evacuation during flood events.**
Objectives Addressed:	Objective 4.1
Category:	Emergency Services
Hazard:	Flood
Background:	The establishment of a flood advisory board comprised of community representatives, technical experts and emergency management officials, should be developed to oversee all flood-related projects such as stream cleaning, canalization, etc. This board should also pursue programs that heighten awareness of flood-prone areas in the community and encourage sensible and sustainable development.
Priority:	Medium
Potential Funding Sources:	Internal Funding Source
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias, Oficina de Alcalde
Estimated Timeframe:	18 months

Mitigation Action 35	**Develop and train Community Emergency Response Teams (CERTs) in communities.**
Objectives Addressed:	Objective 4.1
Category:	Emergency Services
Hazard:	All Hazards
Background:	The establishment of Community Emergency Response Teams (CERT) and program in the municipality will help train people to be better prepared to respond to emergency situations in their communities. When emergencies occur, CERT members can give critical support to first responders, provide immediate assistance to victims, and organize spontaneous volunteers at a disaster site.
Priority:	Medium
Potential Funding Sources:	External FEMA grant
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	1 year

Mitigation Action 36	**Upgrade municipal radio communication to facilitate more efficient communication between emergency responders, including OME, police, and fire department by implementing interoperable communication systems.**
Objectives Addressed:	Objective 4.1
Category:	Emergency Services
Hazard:	All Hazards
Background:	It is a common misconception that public safety responders (law enforcement, fire fighters, emergency personnel, etc.) can communicate efficiently and effectively in times of crisis. Local officials often communicate with each other by shuffling messages back and forth between agencies or—worse still—agencies using commercial cellular phones. Interoperable communication would make for a more efficient emergency response.
Priority:	Medium
Potential Funding Sources:	External Grant
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias, Policia y Bomberos
Estimated Timeframe:	18 months

Mitigation Action 37	**Conduct a needs assessment for emergency operations equipment and training needs.**
Objectives Addressed:	Objective 4.1
Category:	Emergency Services
Hazard:	All hazards
Background:	Determining the most effective type of equipment is an arduous task. The type of equipment will depend on day-to-day needs as well as those during response and recovery missions. A needs assessment should also consider training for emergency management staff.
Priority:	Medium
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	1 year

Mitigation Action 38	**Provide hazard mitigation information to municipal employees to familiarize other municipal departments with hazards, hazard mitigation and FEMA programs.**
Objectives Addressed:	Objective 4.2
Category:	Public Information and Awareness
Hazard:	All hazards
Background:	Hazard mitigation information should be provided to municipal employees. Providing educational materials to the municipal staff is an excellent way to further institutionalize a local mitigation ethic in local government.
Priority:	Medium
Potential Funding Sources:	External Grant
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	1 year

Mitigation Action 39	**Develop a formal inter-department mutual aid agreement between municipality and central governments for disaster response and recovery.**
Objectives Addressed:	Objective 4.2
Category:	Emergency Services, Public Information and Awareness
Hazard:	All hazards
Background:	Developing linkages with central government agencies is critical during emergency response and recovery missions. By establishing points of contact with each government agency (i.e., public works, transportation, PREPA, PRASA, etc.) the municipality can facilitate central government operations in the municipality, particularly around established mitigation goals.
Priority:	Medium
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	18 months

Mitigation Action 40	**Develop a database for each hazard to include hazard type, date of occurrence, area affected, severity and intensity, damage and economic impact.**
Objectives Addressed:	Objectives 1.1, 1.2 and 2.1
Category:	Emergency Services, Public Information and Awareness
Hazard:	All hazards
Background:	The Office of Emergency Management will seek to develop a simple database in Microsoft® Excel® for each hazard to include, at a minimum, hazard type, date of occurrence, area affected, severity and intensity, damage and economic impact. Because Aguada's EM office has limited computer equipment and staff, this will be a relatively challenging action to pursue. (A more practical alternative may be for the State EM Headquarters in San Juan to offer this service through their regional offices for the municipalities under their jurisdiction.)
Priority:	Medium
Potential Funding Sources:	Internal Funding Sources
Hazard Mitigation Committee Leader:	Martin Concepcion
Department Responsibility:	Oficina de Manejo de Emergencias
Estimated Timeframe:	18 months to establish; ongoing data collection and updating

5.3 ADMINISTRATION OF ACTIONS

The Hazard Mitigation Committee (identified in Section Three) will be in charge and responsible for the administration and implementation of the actions defined above. Specific actions are assigned to specific individuals, municipal departments, and/or organizations.

The initial leadership of the Committee, which will be elected every year, would come from the Office of Emergency Management, headed by Mr. Martin Concepcion. Mr. Concepcion possesses an entrepreneurial spirit and has shown the capability to oversee and follow through on Committee initiatives throughout the entire planning process.

The Hazard Mitigation Committee will be responsible for overseeing the progress made on the implementation of action items and updating the Plan, as needed, to reflect changing conditions. It will also be responsible for identifying opportunities to integrate findings of the Hazard Mitigation Plan into existing municipal plans and programs.

5.4 ASSESSING COST EFFECTIVENESS OF MITIGATION ACTIONS

As described in Section 5.1, the Hazard Mitigation Committee considered cost effectiveness during the development and prioritization of the mitigation actions presented in this section. Although a formal Benefit-Cost Analysis was not performed for the submission of this Plan, actions were identified based on administrative, technical and financial capabilities of the municipality. Cost-benefit review was given special emphasis, in light of its possible use in environmental reviews for HMGP, FMA and other federal hazard mitigation projects. Other factors for prioritization included: (1) effect on overall risk to life and property; (2); ease of implementation; (3) political and community support; and (4) funding availability.

Actions identified in this Plan are pragmatic in that they are consistent with the administrative, technical and financial capabilities of the municipality. For example, actions such as the identification and estimation of costs of flood-prone structures represent the first stage of a flood acquisition project. Therefore, it was agreed upon that a detailed Benefit-Cost Analysis would be performed at a future date for any projects sent forward for funding consideration under state and federal programs such as the Hazard Mitigation Grant Program (HMGP) or the Pre-Disaster Mitigation (PDM) program.

A qualitative assessment was used based on the criteria introduced and defined on page 6 of this section. Given relatively low administrative capabilities, this was a kind of subjective process in which the Hazard Mitigation Committee was guided through the process of selecting items that would offer a large impact for little expenditure. In most cases, specific attention was given to those items that can be implemented in the short-term with existing political support. For example, there is a need for acquisition of residential repetitive loss structures. A logical first step would be to identify each structure in an identified repetitive loss area and quantify the costs for acquisition.

The next step would then be to identify lands for redevelopment and so on. Therefore, no formal cost effectiveness criteria was used in the selection and/or prioritization of the mitigation actions, but rather was discussed to facilitate community decision-making. As stated previously in this section, STAPLEE criterion was not available at the time that these actions were developed.

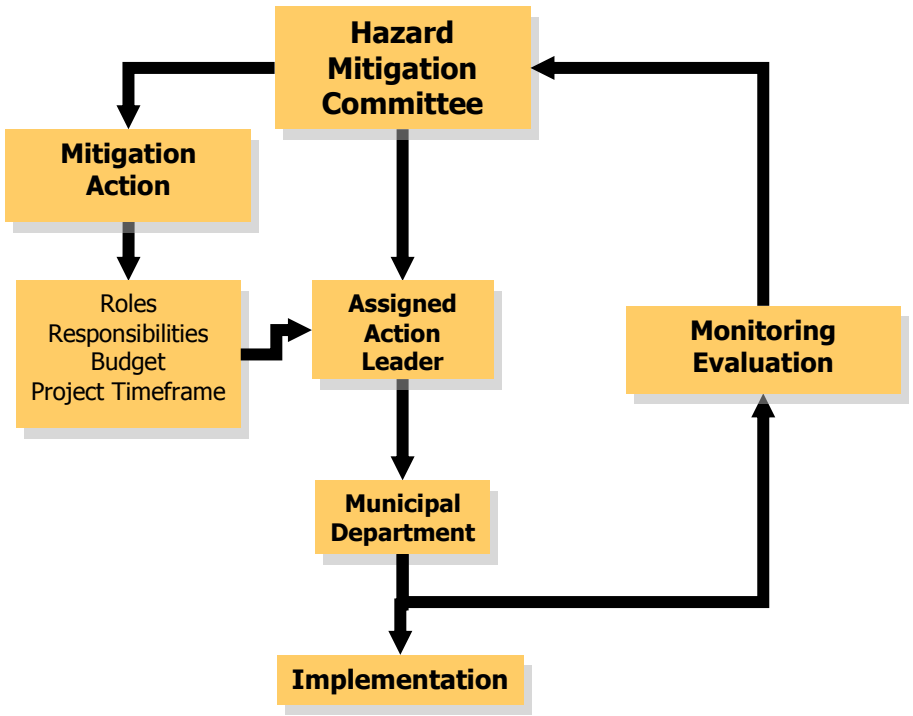
This section of the Plan provides a framework for implementation, monitoring, evaluation, and updating of the Plan in accordance with the requirements of the Disaster Mitigation Act of 2000. It provides a framework based on the same level of participation of all involved in the development of the Plan, but with specific roles and responsibilities clearly defined for action implementation. Section Six consists of the following seven subsections:

- 6.1 Responsibilities
- 6.2 Monitoring
- 6.3 Plan Evaluation and Reporting
- 6.4 Plan Review
- 6.5 Revisions and Updates
- 6.6 Public Involvement
- 6.7 Implementation Through Existing Planning Mechanisms

6.1 RESPONSIBILITIES

This Hazard Mitigation Committee will be in charge and responsible for the implementation of the actions defined in Section Five. The Committee has assigned specific actions to individuals, municipal departments, and/or organizations. Figure 6.1 provides a conceptual framework for the administration and implementation of mitigation actions.

FIGURE 6.1 ***Implementation Framework***



The Hazard Mitigation Committee will be in charge of assigning action/project responsibilities to different Committee members or municipality staff. Once actions/projects have been assigned, the Hazard Mitigation Committee will be responsible for monitoring progress and ensuring that goals and objectives of the Hazard mitigation Plan are obtained.

Mitigation Committee Action Leaders

The Hazard Mitigation Committee will therefore need to have capable officers—called Action Leaders—to undertake the following responsibilities. Action Leaders will:

- Facilitate the formulation of actions/projects; and
- Provide reports to the Hazard Mitigation Committee on success or shortfalls of project/action implementation.

An Action Leader will be in charge of working with each respective municipal department or organization that has been identified for implementation of the different actions.

6.2 MONITORING

As indicated above, the Hazard Mitigation Committee will have the task of monitoring the implementation through a designated Action Leader. Successful implementation of the Hazard Mitigation Plan requires continuous monitoring of all defined actions.

- Ensure that appropriate resources (technical, financial, political and legal) are assigned to the action/project;
- Monitor the implementation of each action item; and
- Conduct status meetings, site visits and phone calls with implementing municipal department.

The Hazard Mitigation Committee will meet as necessary based on changing events or circumstances. This will help ensure that the Plan is continuously updated to reflect changing conditions within each jurisdiction. Criteria for evaluating the Plan include, but are not limited to: assessing how the goals and objectives address current and expected conditions, assessing any changes in the magnitude or nature of risks, assessing current resources available for implanting the Plan, noting any implementation problems and identifying outcomes. The Action Leader, along with the implementing department, submit an **annual** report that provides adequate information to assess the status of each action.

6.3 PLAN EVALUATION AND REPORTING

As part of the formal project/action evaluation, the Hazard Mitigation Committee has required each Action Leader, assigned an action/project, to submit a written progress report. Formal

action/project status report is required at the annual meeting. Evaluation of each action should include:

- Description of the project;
- Percentage complete (per project task);
- Problems encountered during implementation; and
- Estimated completion date.

Based on this report, the Hazard Mitigation Committee will assess the degree of effectiveness and relevancy of each action's progress against the Plan's stated goals and objectives.

6.4 PLAN REVIEW

The Hazard Mitigation Committee shall review the Hazard Mitigation Plan on an annual basis. All meetings should be recorded and all recommendations noted. The Hazard Mitigation Committee should also evaluate if actions need to be discontinued, modified and/or if additional actions should be added to the Plan. Based on the results of the review, the Hazard Mitigation Committee shall develop a formal progress report and submit the report to the Mayor, Municipal Assembly, and the Puerto Rico Emergency Management Agency.

6.5 REVISIONS AND UPDATES

The Plan will be reviewed (at a minimum) every five years by the Hazard Mitigation Committee to determine whether there have been any significant changes in the area that may, in turn, necessitate changes in the types of mitigation actions proposed. Plan reviews may also be triggered by disaster events, significant changes in the built or natural environment, or based on legitimate concerns presented by members of the public. New development in identified hazard areas, an increased exposure to hazards, the increase or decrease in capability to address hazards, and changes to federal or state legislation are specific examples of factors that may affect the content of the Plan. Periodic reviews also provide local officials with the opportunity to evaluate those actions that have been successful and to explore the possibility of documenting potential losses avoided due to the implementation of specific mitigation measures. The Director of the Office of Emergency Management, Mr. Martin Conception, will have ultimate responsibility for Plan update and revision process and is responsible for reporting any review findings to interested parties. Following each five-year review, the updated Plan will be submitted for state and federal review, per the published federal regulations.

Following a disaster declaration, the Plan will be revised as necessary to reflect lessons learned, or to address specific circumstances arising from the event.

6.6 PUBLIC INVOLVEMENT

The Hazard Mitigation Committee shall notify the public and involve the public during the evaluation and update of the Mitigation Plan. This may be done through several mechanisms including: public education projects, surveys, public workshops, and hearings. The public would also have access to information via newsletters, mailings, and the different municipal departments.

6.7 IMPLEMENTATION THROUGH EXISTING PLANNING MECHANISMS

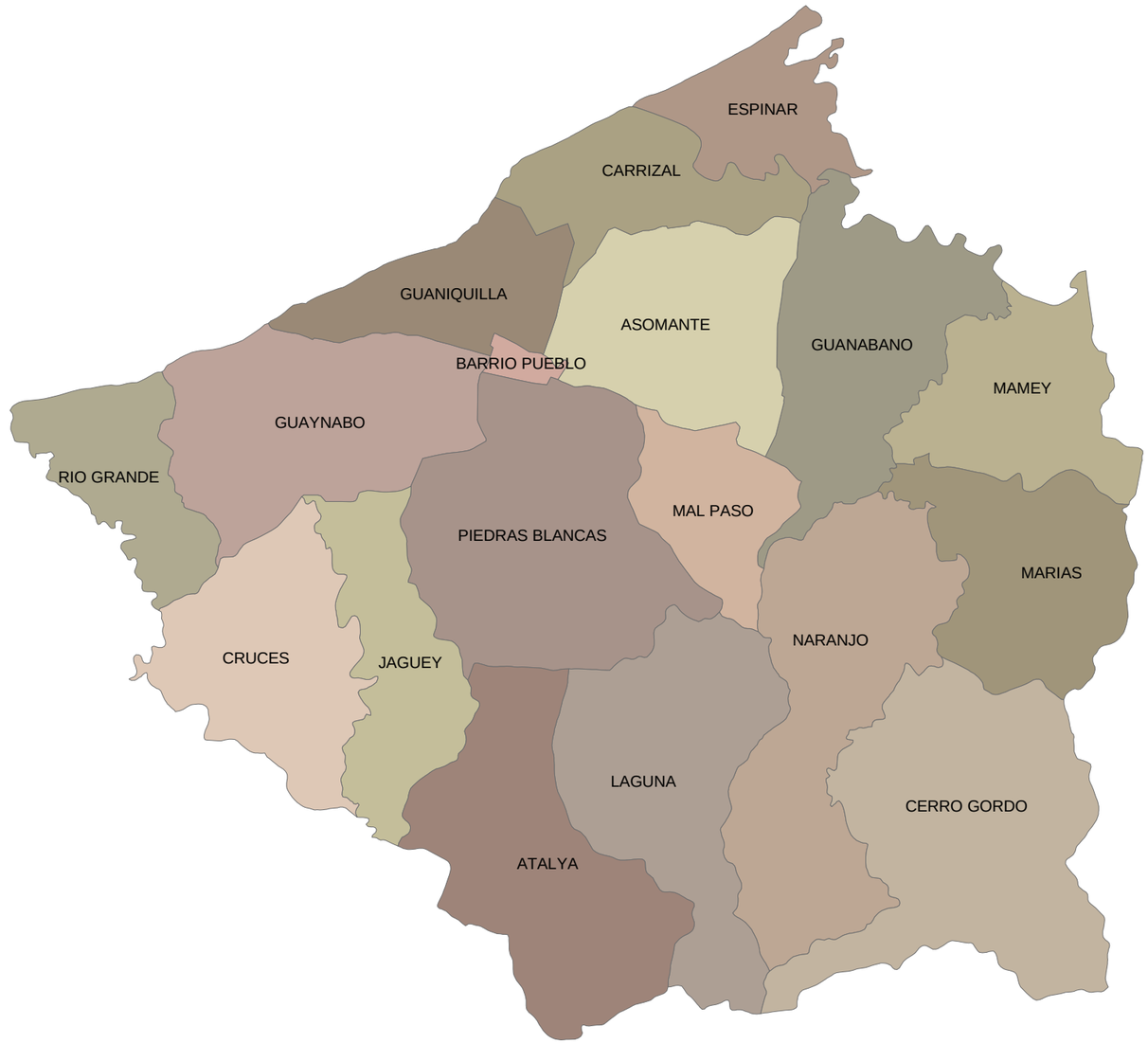
It will also be the responsibility of the Committee to integrate the requirements of the Hazard Mitigation Plan into other local planning documents, processes or mechanisms as opportunities may arise. Such opportunities to integrate the requirements of this Plan into other local planning mechanisms will be identified through future meetings of the Hazard Mitigation Committee and through the review process described herein.

This plan highlights several key planning principles that offer a foundation that may guide public policies and avoid a cycle of disaster-reconstruction-disaster:

- The Municipality of Aguada should limit intensive development in hazard-prone areas;
- The Municipality of Aguada should promote information about hazards and sustainable ways of coping with them;
- The Municipality of Aguada must develop the political will and capacity to effectively manage the land development process and encourage sustainable development practices;
- The Municipality of Aguada must do a better of job of coordinating activities with the central government agencies that sometimes counteract the purpose of existing land use outlined in the Plan Territorial;
- The Municipality of Aguada should foster innovation and change in land use development practices;
- The Municipality of Aguada should integrate findings into the Plan Territorial by modifying its Programa, Memorial and Land Use Regulations (Reglamentacion).

The implementation framework outlined in the sections above provide a framework for the Hazard Mitigation Committee to develop a "voice" within the community and work directly with policymakers and planners to help them understand the costs of risk reduction, assumption, or elimination. The Municipality of Aguada views the development and maintenance of this stand-alone Hazard Mitigation Plan as an effective tool to incorporate hazard mitigation into larger development processes and understands that its implementation will require some fundamental changes in the way the municipality plans for and regulates new development.

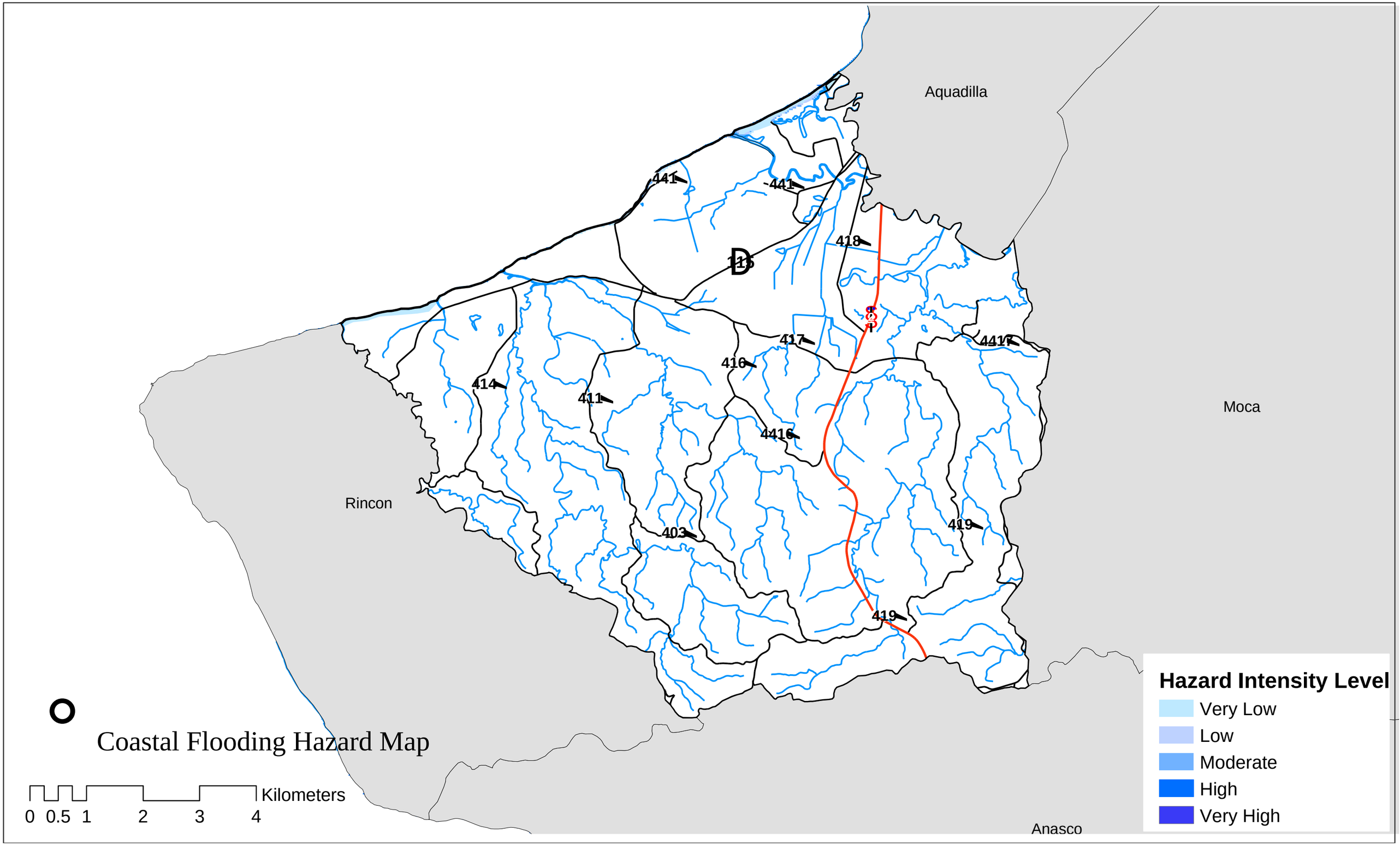
MUNICIPIO DE AGUADA



Municipality Barrios

0 0.5 1 2 3 4 Kilometers

MUNICIPIO DE AGUADA



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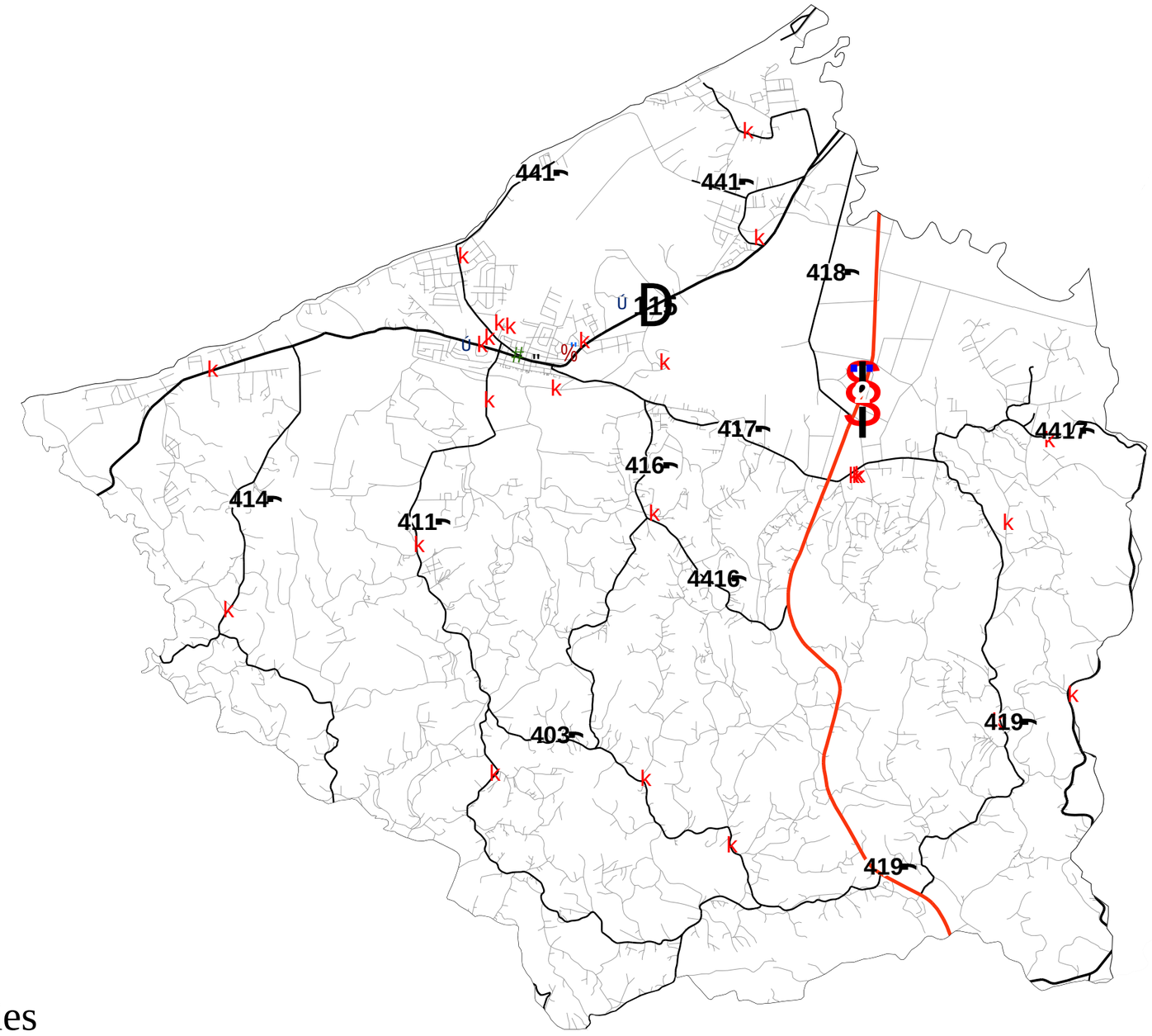


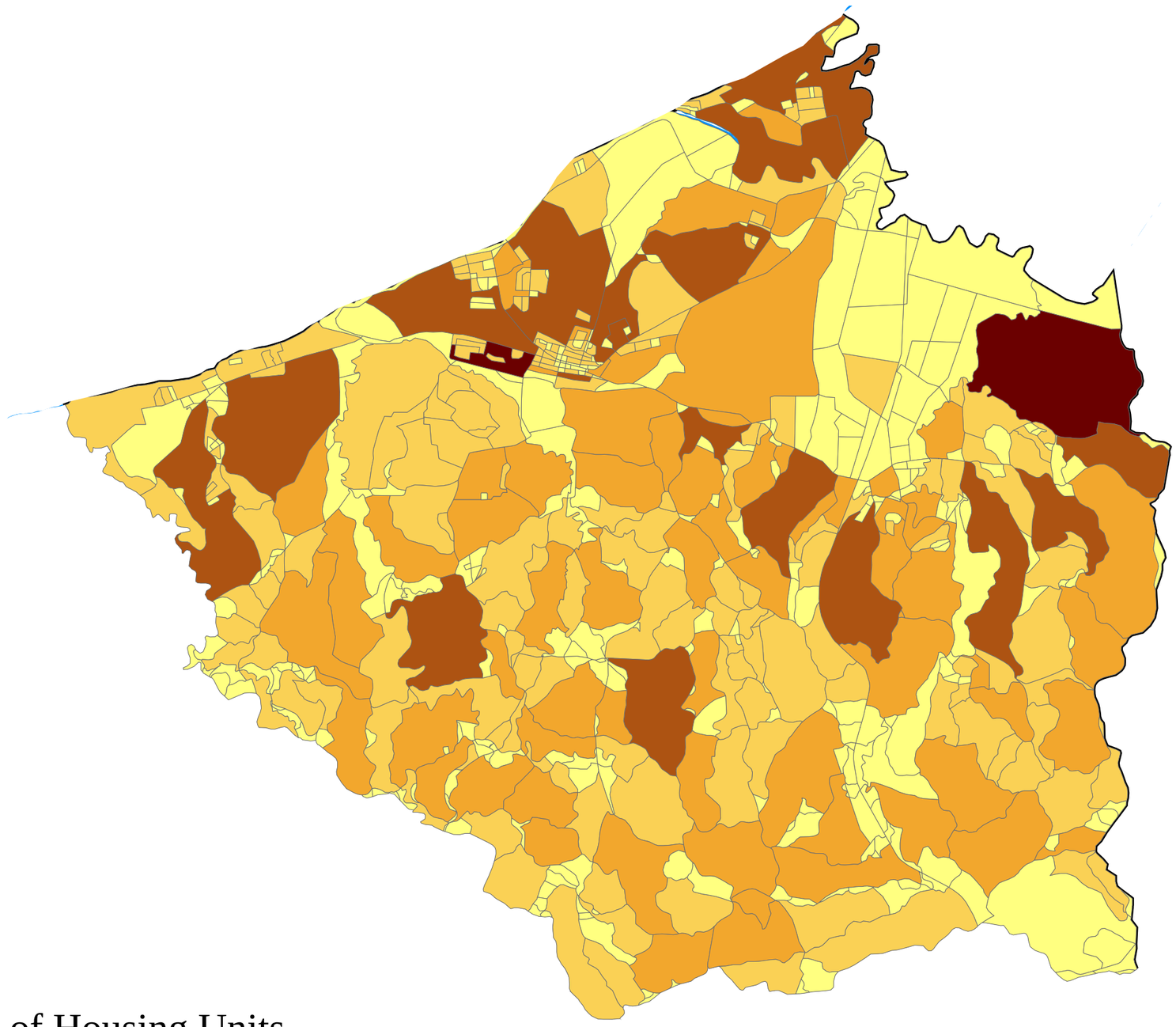
Critical Facilities

0 0.5 1 2 3 4 Kilometers

Critical Facilities

" Alcaldia
EOC
% Fire
" Hospital
Ú Police
k School

MUNICIPIO DE AGUADA



Distribution of Housing Units

0 0.45 0.9 1.8 2.7 3.6
Kilometers

US Census, Housing Units

- 0 - 16
- 17 - 51
- 52 - 110
- 111 - 232
- 233 - 360

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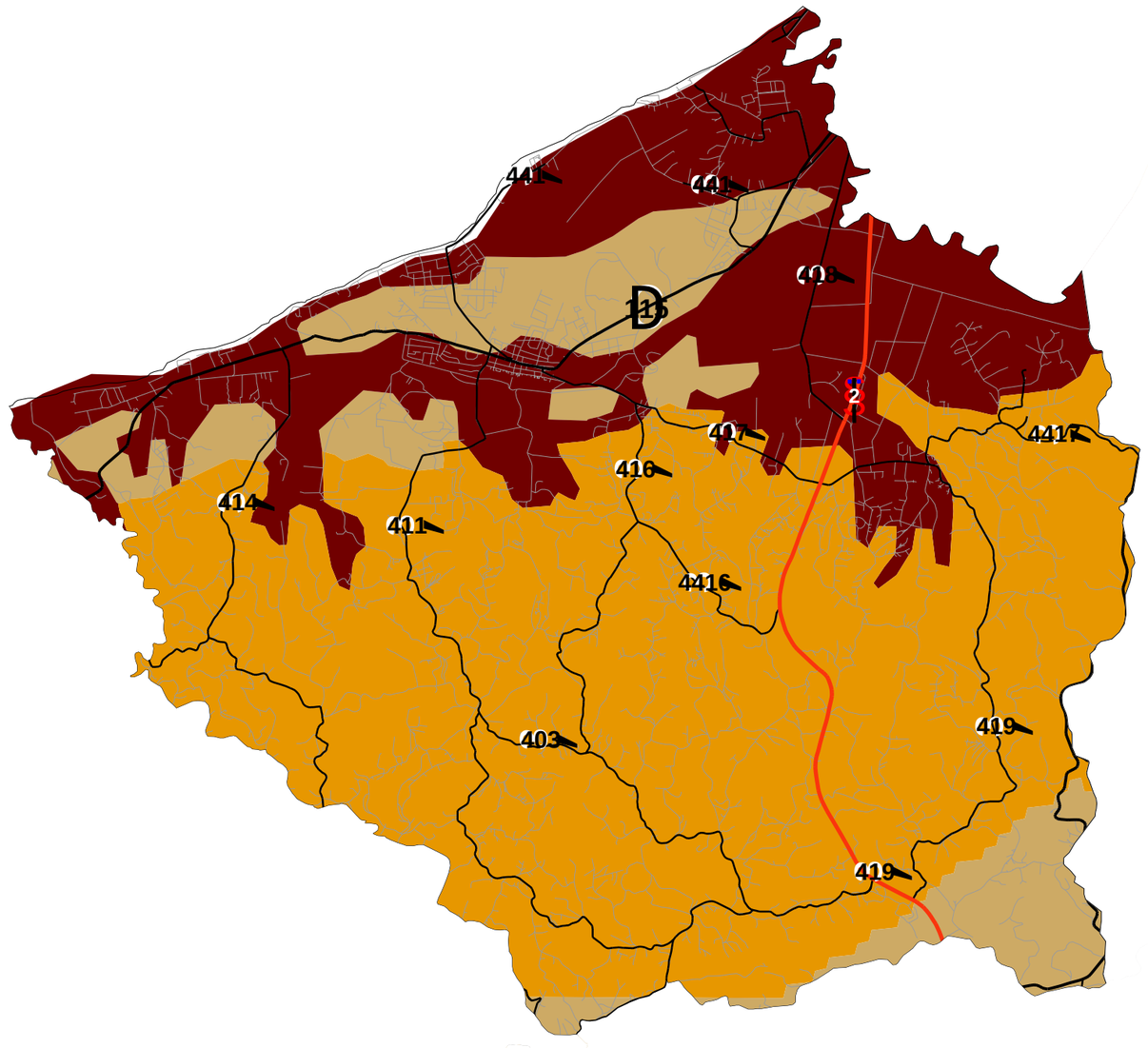

Ground Shaking Hazard Map

0 0.5 1 2 3 4 Kilometers

Hazard Intensity Level

- Very Low
- Low
- Moderate
- High
- Very High

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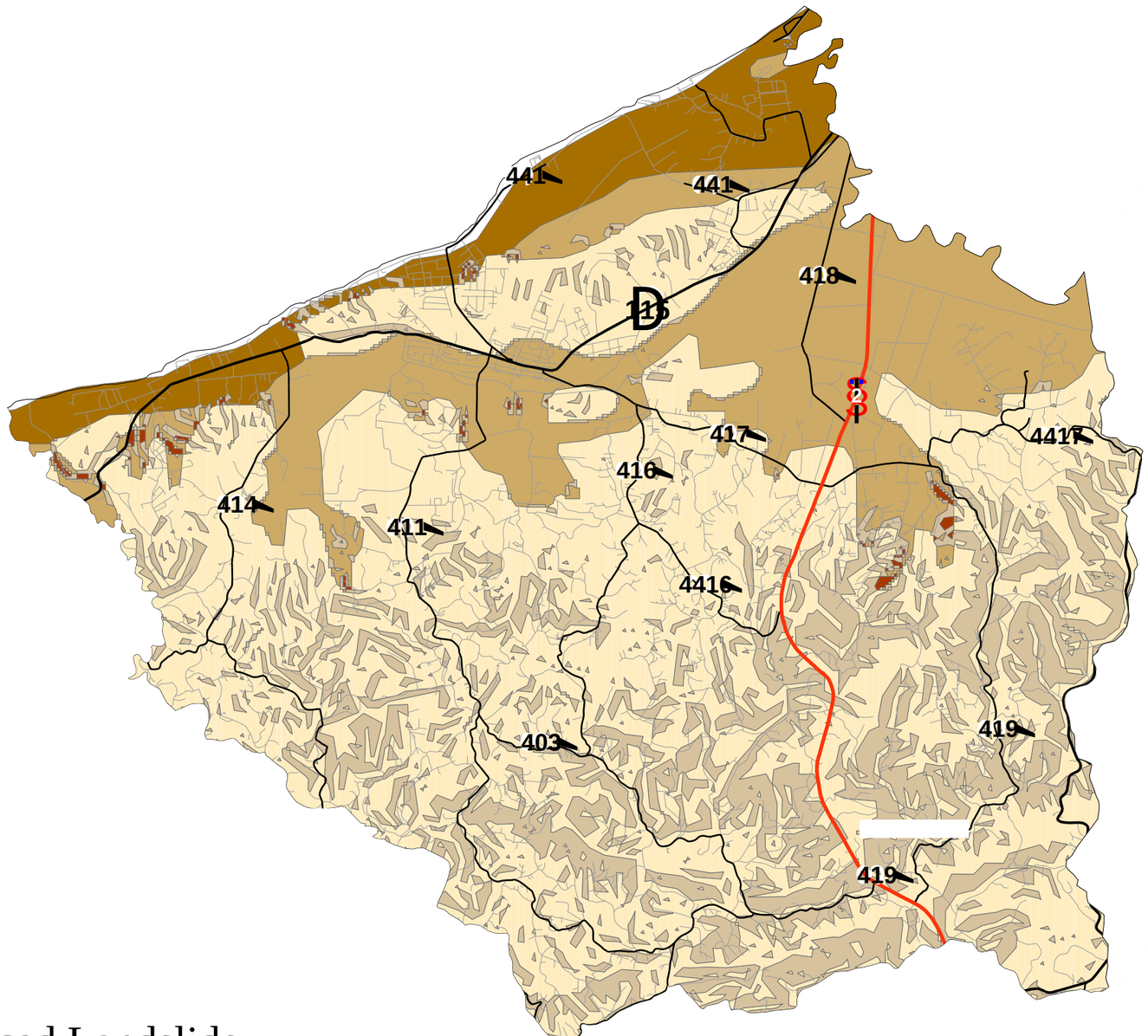


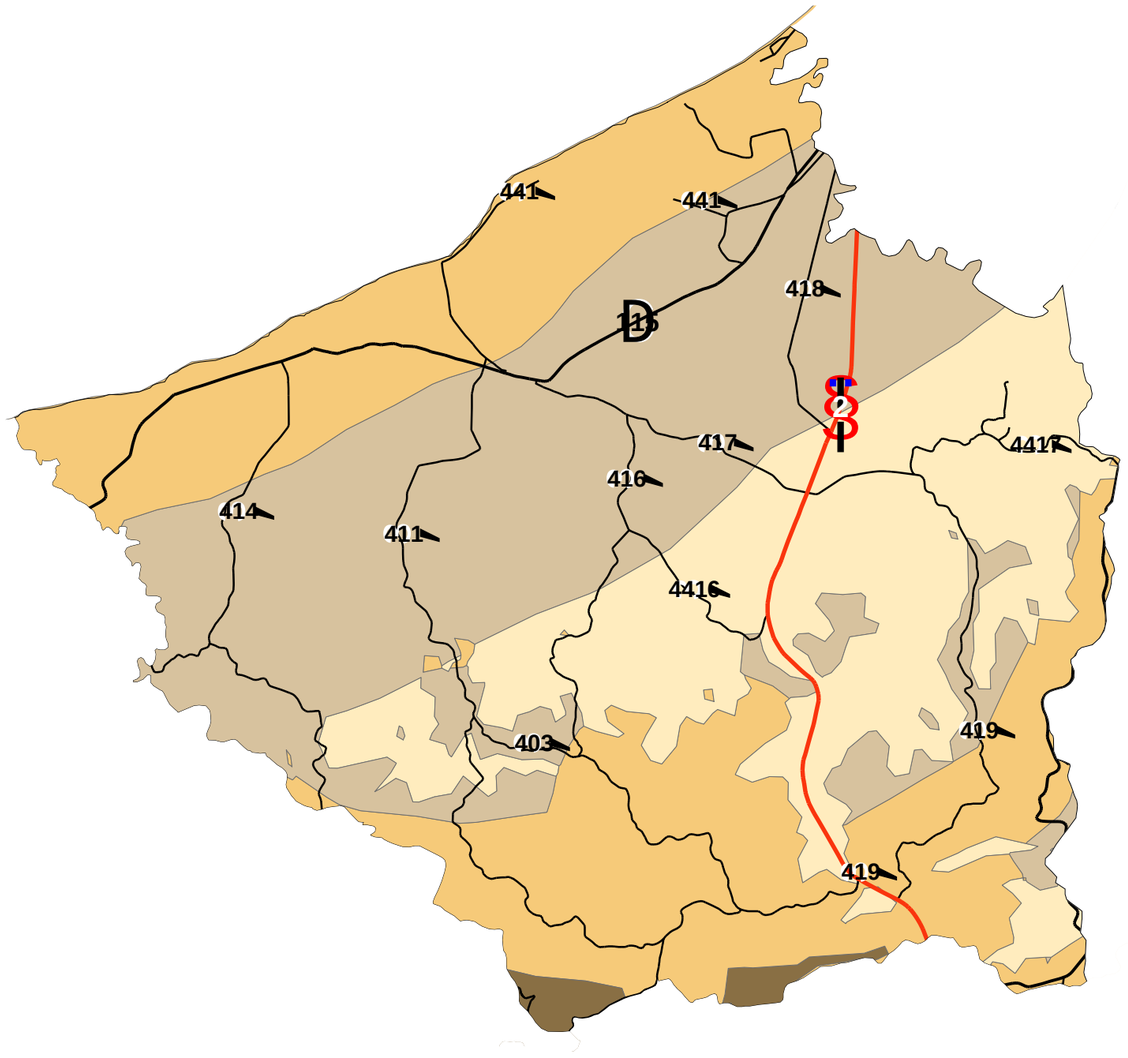
Earthquake-Induced Landslide Hazard Map

0 0.5 1 2 3 4 Kilometers

Hazard Intensity Level

- Very Low
- Low
- Moderate
- High
- Very High

MUNICIPIO DE AGUADA



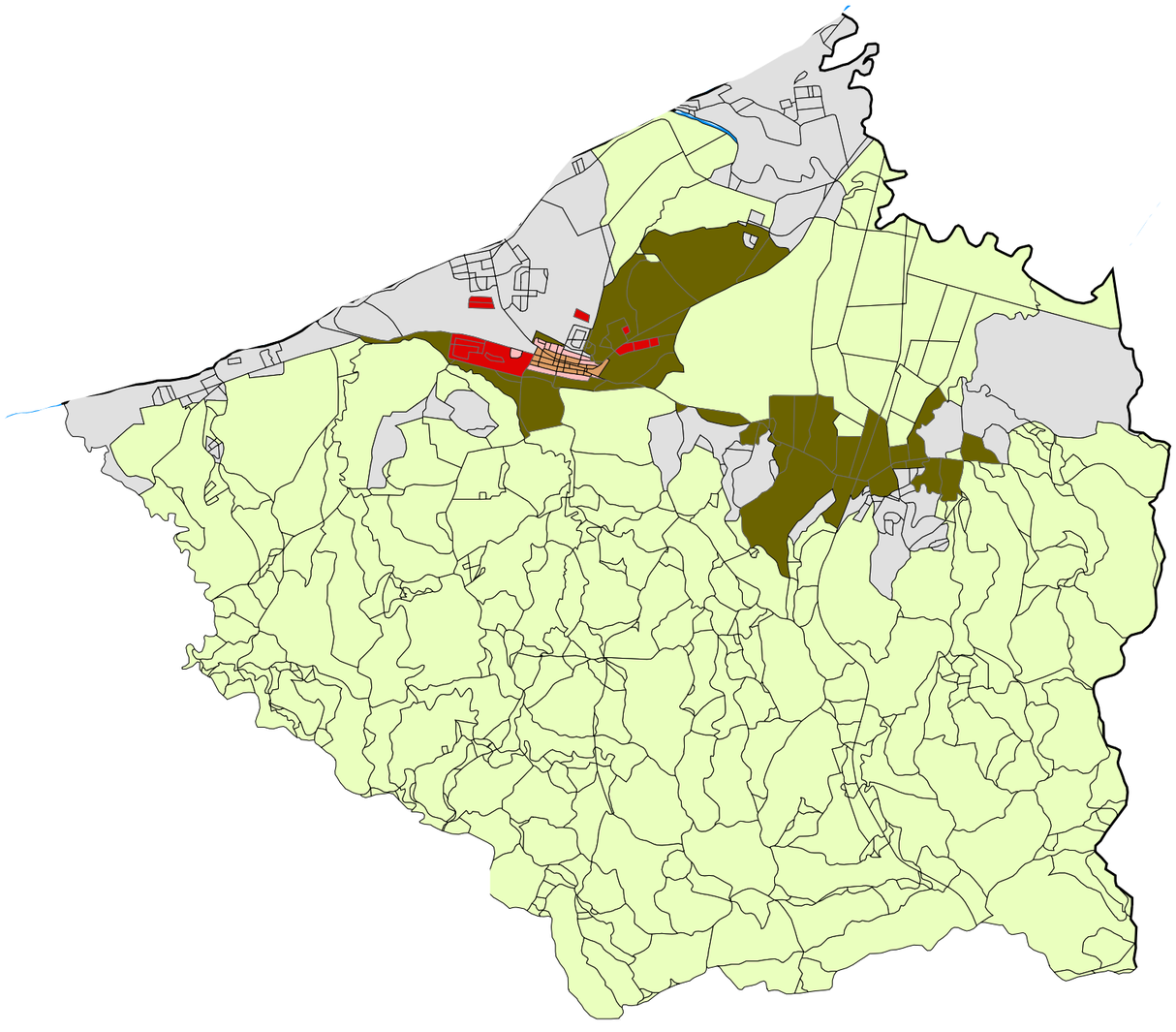
High Wind Hazard Map

0 0.5 1 2 3 4 Kilometers

Hazard Intensity Level

- Very Low
- Low
- Moderate
- High
- Very High

MUNICIPIO DE AGUADA



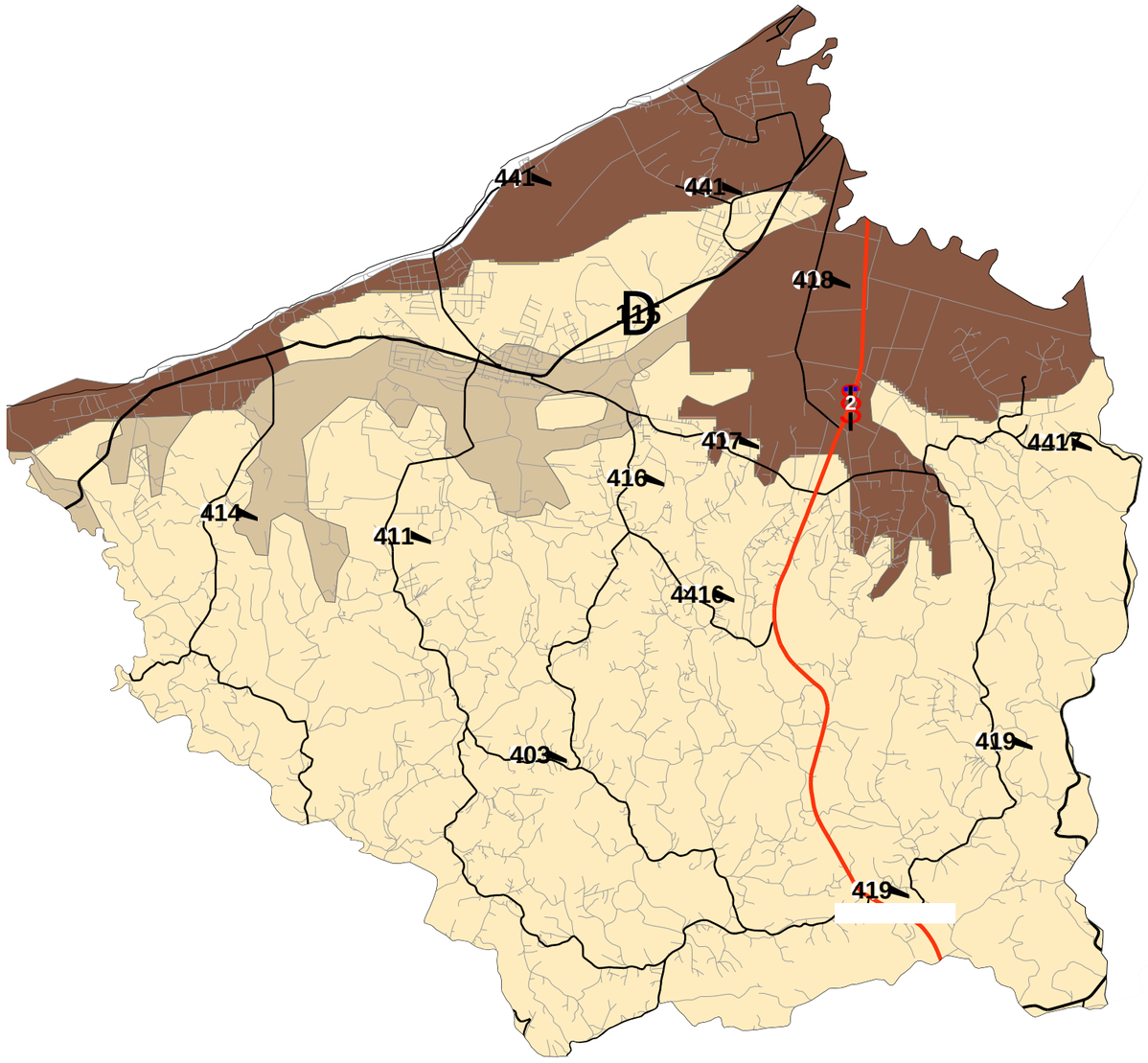
Land Use Classification

0 0.5 1 2 3 4 Kilometers

Land Use Categories

- Urban Center
- Urban Center Rural
- Rural Community
- Rural Mountain
- Suburban
- Urban Periphery

MUNICIPIO DE AGUADA



Liquefaction Hazard Map

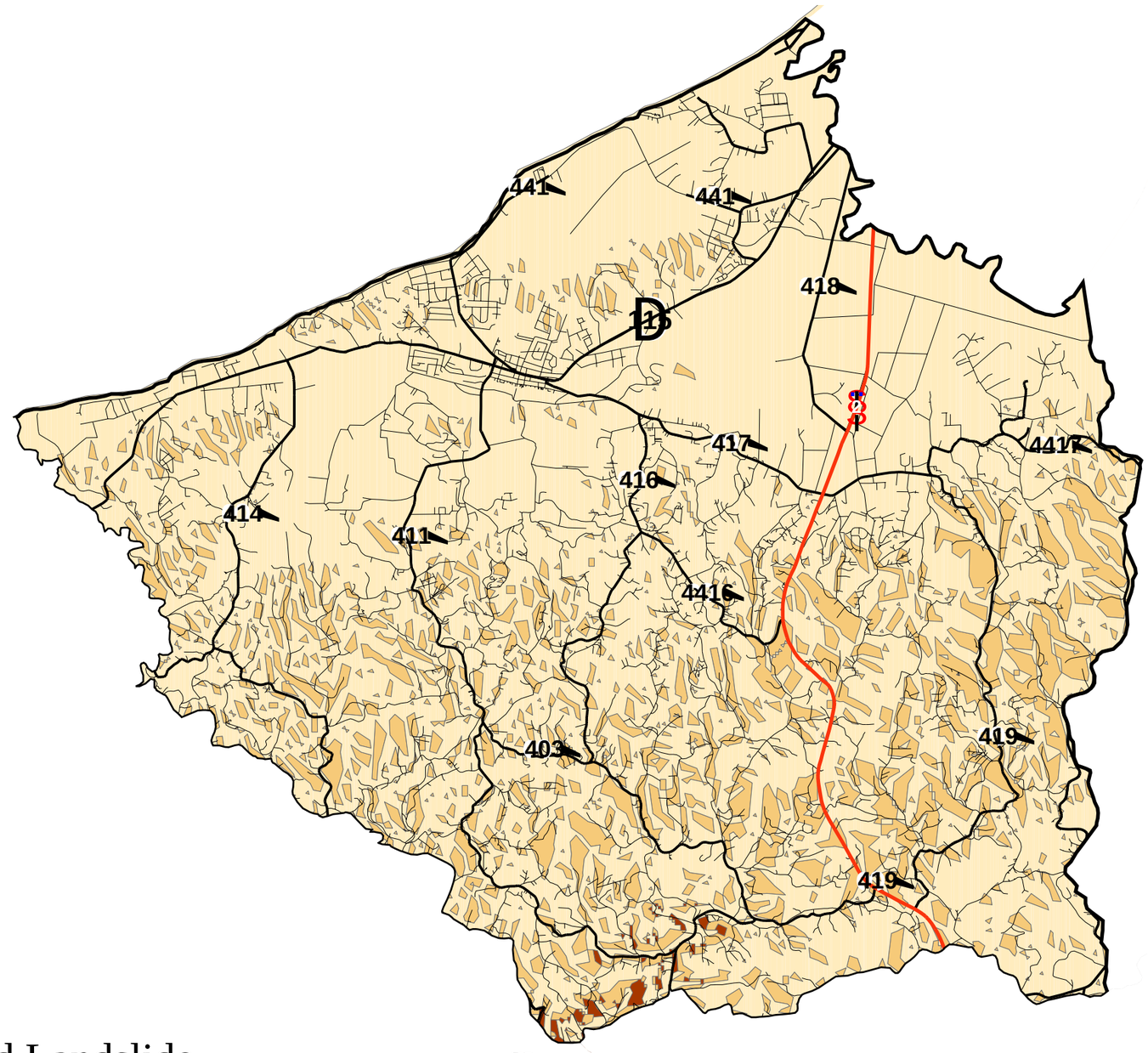
0 0.5 1 2 3 4 Kilometers

Hazard Intensity Level

- Very Low
- Low
- Moderate
- High
- Very High

Location of the Municipality of Aguada in Puerto Rico

MUNICIPIO DE AGUADA



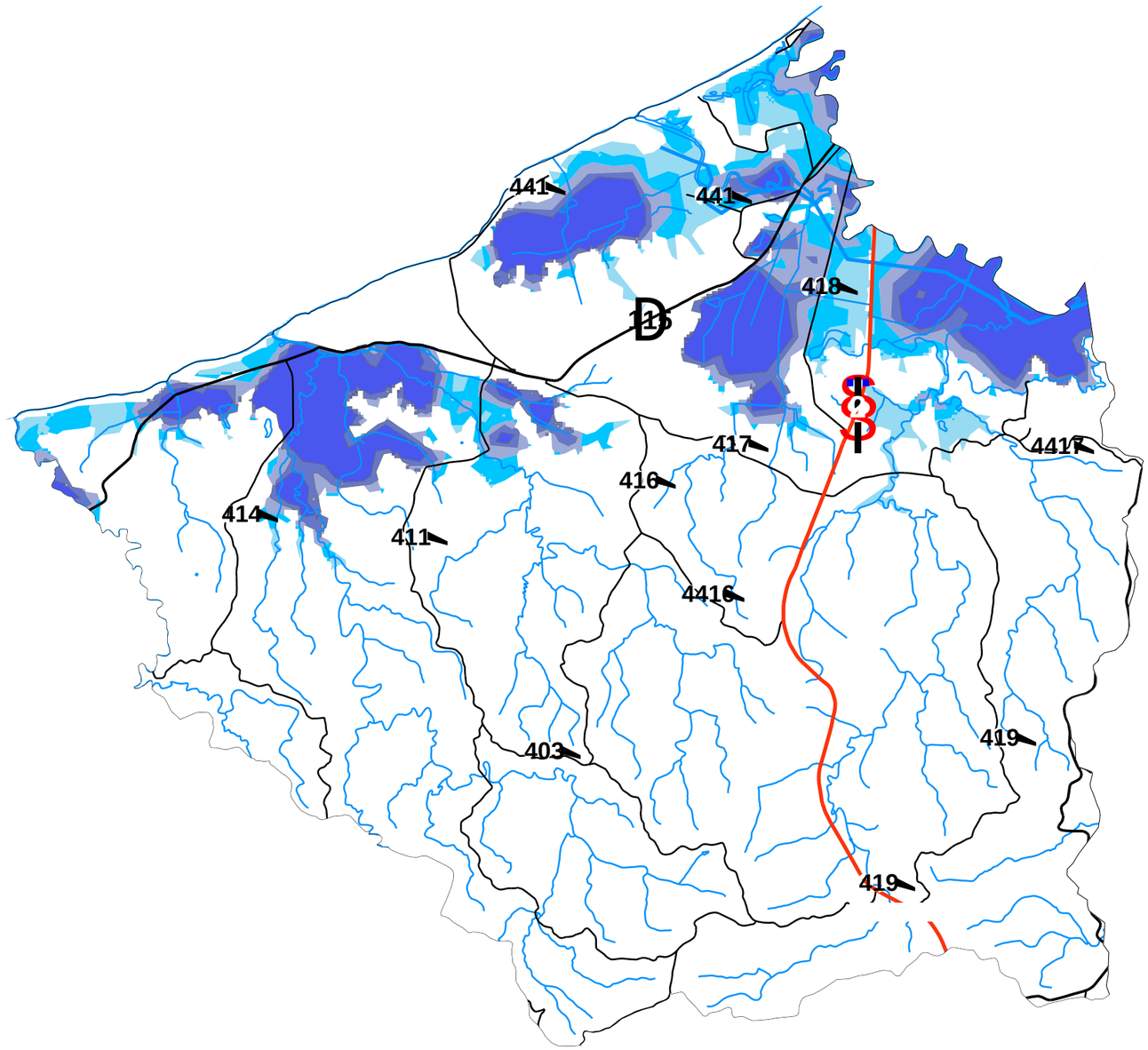
Rainfall-Induced Landslide Hazard Map

0 0.5 1 2 3 4 Kilometers

Hazard Intensity Level

- Very Low
- Moderate
- Very High

MUNICIPIO DE AGUADA



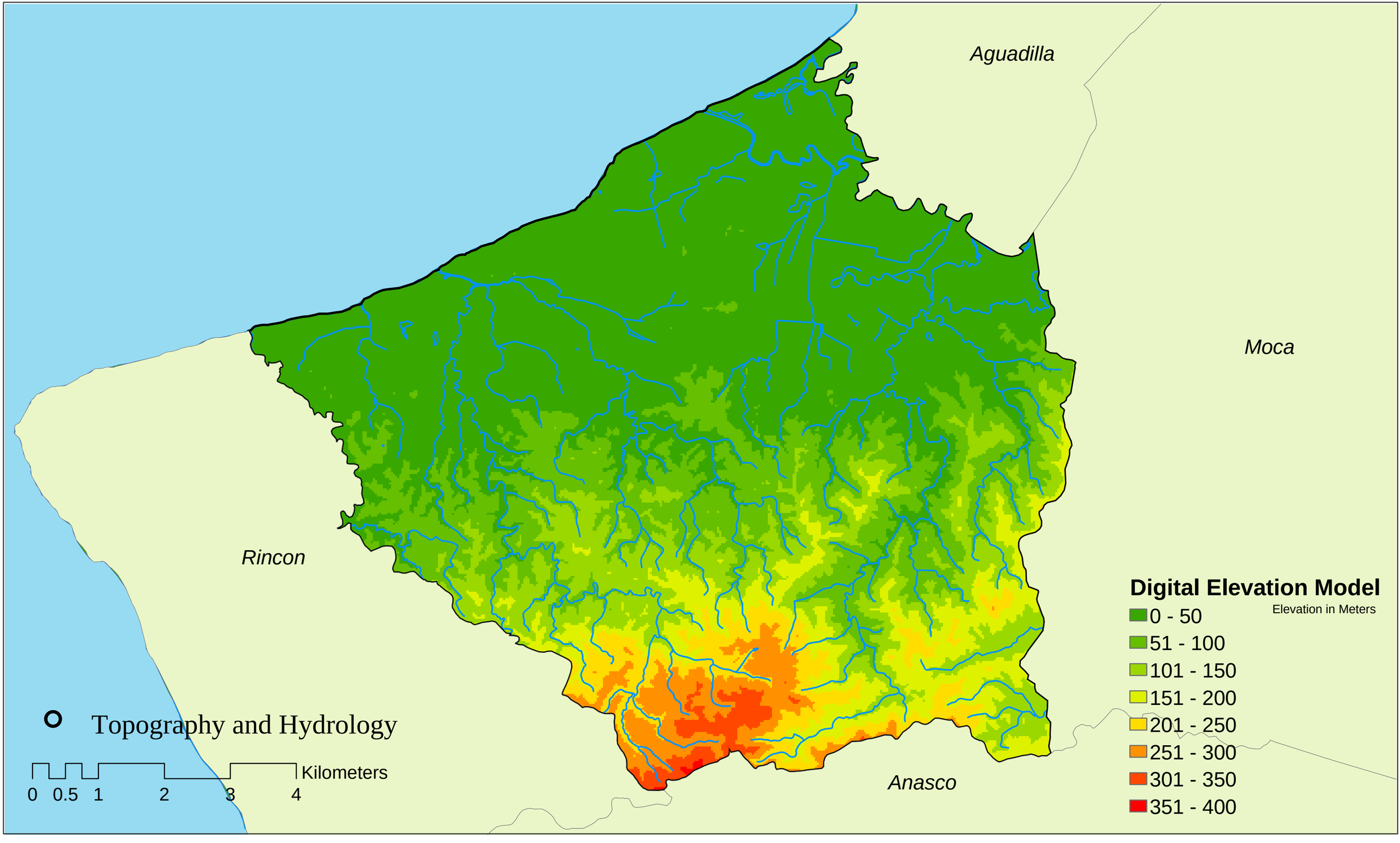
Riverine Flooding Hazard Map

0 0.5 1 2 3 4 Kilometers

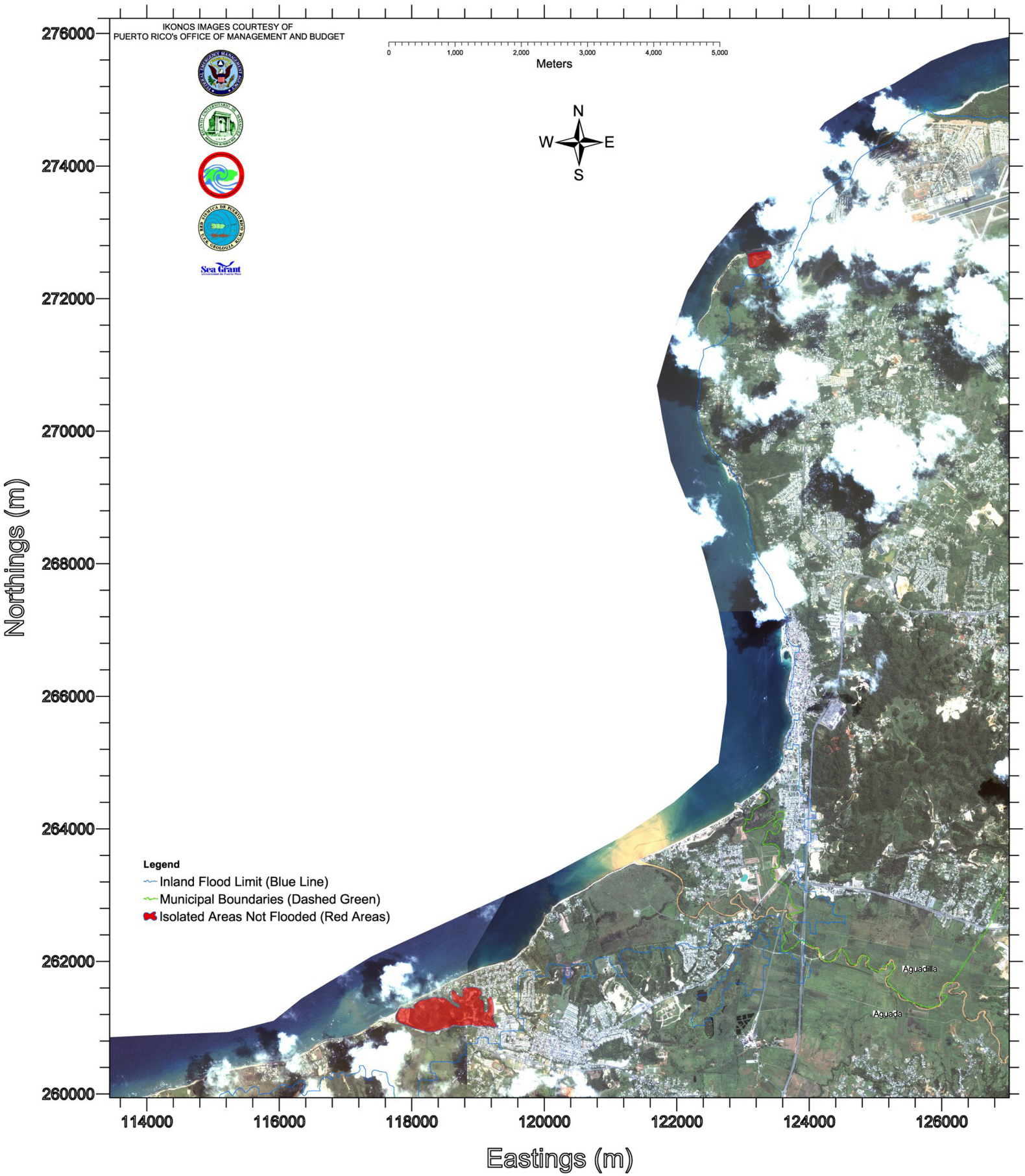
Hazard Intensity Level

- Very Low
- Low
- Moderate
- High
- Very High

MUNICIPIO DE AGUADA



AGUADILLA QUADRANGLE (PUERTO RICO STATE PLANE NAD83 METERS)
FEMA/UPR TSUNAMI FLOOD STUDY: INLAND LIMIT OF FLOODING
MAXIMUM RUNUP= 29.67m



U.S. Department of Homeland Security
Region II – Caribbean Division
P.O. Box 70105
San Juan, PR 00936-8105

FEMA

AGENDA

RE: PDM 2002 Local "Multi-Hazard" Mitigation Planning Meeting with FEMA,PRSEMA & CIPA

Topics to be discuss:

I. Planning Status of the municipalities of:

a. Corrections and additional information is required, as Crosswalk Worksheet provided to PRSEMA for the municipalities of Aguada, Moca, & Vieques. Pending plans resubmission by municipalities/PRSEMA.

II. Request for Extension:

a. Aguada – Date of Completion: **March 31, 2005**
b. Moca – Date of Completion: **March 31, 2005**
c. Vieques – Date of Completion: **March 31, 2005**
d. Requests for Extension – Justification/Documentation required:

(1) Justification for the extension (reason(s) for the delay).

(2) Demonstrate that work is in progress and that it will be completed within the requested extension period (including a description of necessary measures to complete the project, and a summary of remaining funds available for completion of these measures.

(3) A revised budget information form (regardless of whether or not there are changes to the budget).

(4) Copies of any contracts entered into effect between the Municipality and CIPA or any vendors/Consultants.

(5) Percentage of all work completed to-date.

(6) A description of all work completed to-date. Extensions may not be considered for projects that are behind schedule as a result of delays in project initiation and implementation, which would place Federal funding for that municipality in jeopardy.

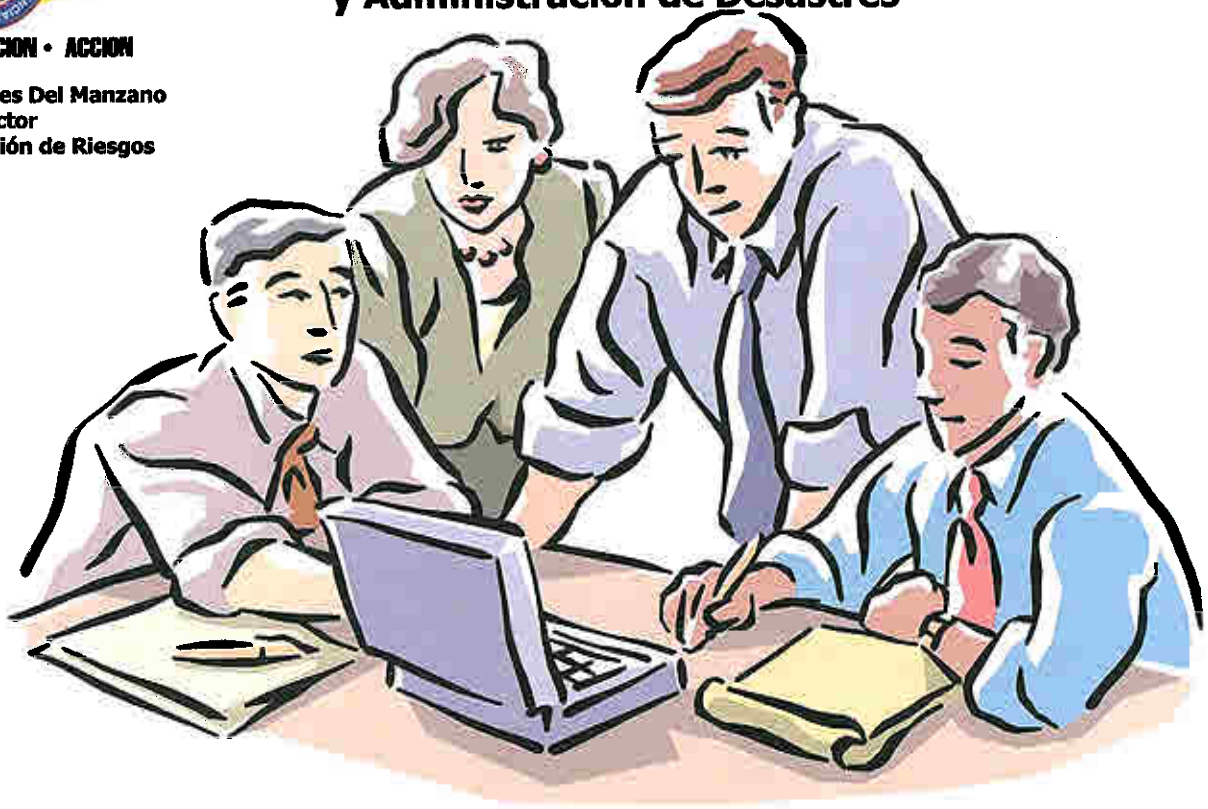
REQUEST FOR EXTENSION SHALL BE SUBMITED, NO LATER THAN OCTOBER 7, 2005

III. **Other issues/Meeting Adjourn**

Estado Libre Asociado de Puerto Rico
Agencia Estatal para el Manejo de Emergencias
y Administración de Desastres

APOYO • PROTECCION • ACCION

Sr. Ramón E. Vales Del Manzano
Director
Área de Mitigación de Riesgos



Área de Mitigación de Riesgos Naturales

Reunión: **PDM – Aguada, Moca & Vieques**
Representantes Municipales, Compañía PBS & J y FEMA
atraso entrega de los Planes de Mitigación Multi-Riesgos

23 de septiembre de 2005
10:00 am

Hoja de Asistencia

Nombre y Apellidos	Agencia y/o Institución	Núm. de Teléfono	Firma
Mariellie Ríos Rodríguez	Fun. Adm. I – Área de Mitigación	724-0124	
Ricardo Gracia Vázquez	Fun. Adm. I – Área de Mitigación	724-0124	
Alberto Pérez Santiago	Oficial de Planes, OMME - Aguada	868-7000	
Ing. Wilson J. Román	Director, Ofic. de Planificación - Moca	877-3011	
Fabián Martínez	Dir. Prog. Federales - Vieques	741-3192	
Héctor Hernandez	municipio de Aguada	868-7000	
Jaime Pabon	PBS&J Caribe Engineering	294-2010	
Nathan Naughton	PBS&J Raleigh	9197626808	
Adolfo Figueroa Gonzalez	Director OMME	877-5540	
Gary Blanchard	Area - Mitigation	296-3581	

Hon. Miguel A. Ruiz Hernández
Alcalde

Estado Libre Asociado de Puerto Rico
Gobierno Municipal de Aguada
Oficina Municipal para el Manejo de Emergencias
Aguada, Puerto Rico

28 de Augusto 2003

Municipio de Aguada
Taller de Mitigación

I.Repasó y Status de Plan

II.Presentación de Análisis de Resigos

a. **Mapas y Perdidas**

III.Desarrollo de Principios Guías

a. **Enunciación de la Misión y de las Metas del Plan**

b. **Sesión de Discusión y Reflexión: Preocupaciones de la Comunidad sobre los Desastres Naturales.**

IV.Desarrollo de Acciones

Dirección Postal: P. O. Box 517, Aguada, Puerto Rico 00602
Tel. 787-868-7000

Hon. Miguel A. Ruiz Hernández
Alcalde

Estado Libre Asociado de Puerto Rico
Gobierno Municipal de Aguada
Oficina Municipal para el Manejo de Emergencias
Aguada, Puerto Rico

14 de Mayo, 2003

Municipio de Aguada
Taller de Mitigación

Taller de Planificación de la Mitigación de Desastres

I. Introducción

Introducción a los Participantes del Taller
Discusión sobre el Estatuto de Mitigación de Desastres de 2000, Sección 322

II. Desarrollo de un Plan de Mitigación de Múltiples Peligros

Etapas e Itinerario del Proyecto

- **Adquisición de Datos**
- **Perfil Comunitario y Evolución**
- **Identificación de Peligros y Evaluación de Riesgos**
- **Desarrollo de Estrategia y Acción**

IV. Resumen y Próximos Pasos

Dirección Postal: P. O. Box 517, Aguada, Puerto Rico 00602
Tel. 787-868-7000