



US Army Corps
of Engineers®
Jacksonville District

SAN JUAN METRO AREA, PUERTO RICO

COASTAL STORM RISK MANAGEMENT STUDY
DRAFT INTEGRATED FEASIBILITY STUDY
AND ENVIRONMENTAL ASSESSMENT

JULY 2020



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Using this Document

 **Report Reference Materials:** To ease navigation through the report, prompts are provided throughout the document, alerting the reader to reference additional sections or graphics, or to explain the purpose of an ensuing discussion. In this report, these prompts can be identified by this blue box format. In addition, an overall table of contents is provided, along with detailed tables of contents as well as an index at the end of the report.

Organization of this report meets the requirements provided in Appendix G of ER 1105-2-100 (30 June 2004), documenting the iterative U.S. Army Corps of Engineers (USACE) Plan Formulation Process. The planning process consists of six major steps:

- (1) Specification of problems and opportunities
- (2) Inventory, forecast, and analysis of existing conditions within the study area
- (3) Formulation of alternative plans
- (4) Evaluation of the effects of the alternative plans
- (5) Comparison of the alternative plans
- (6) Selection of the recommended plan based upon the comparison of the alternative plans.

Steps may be repeated as problems become better understood and new information becomes available.

Steps 1 and 2 are discussed in Chapters 1-2, and provide the foundation for developing alternative plans and selection of a recommended plan outlined in Chapter 3.

Each chapter and summary graphic, as well as the executive summary, describes plan development as it progresses through the four integrated environments that shape a coastal storm risk management (CSR) project: the built environment (upland development, etc.); the natural environment (species of concern and their habitat); the physical environment (currents, tides, sea level rise, etc.), and the economic environment (vulnerability of built environment to damages). Concerns relative to plan formulation and National Environmental Policy Act (NEPA) review are summarized and encapsulated in the discussions of these four main environments.

The recommended format of an Environmental Assessment (EA) is provided in 40 CFR 1502.10 and has been integrated into the Feasibility Report. The basic table of contents for the report outlines how the EA format has been integrated into the planning process to develop a recommended plan that meets the requirements of both USACE Plan Formulation Policy and NEPA.

Note that sections pertinent to the NEPA analysis are denoted with an asterisk.

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EXECUTIVE SUMMARY



Please refer to the Graphic Executive Summary throughout the report.

Introduction

Puerto Rico is significant to the nation with its rich cultural heritage, unique environmental resources, and tourism. Problems from storms and hurricanes have been increasingly evident over past years, with special attention on the storm season in 2017 which left destruction from multiple hurricanes, such as Hurricane Maria, Hurricane Irma, and winter storm Riley.

This U.S. Army Corps of Engineers (USACE) study is an interim response to the study authority to determine Federal interest in a plan to reduce damages to infrastructure as a result of coastal flooding from coastal storms and hurricanes in the San Juan Metropolitan (Metro) Area. More specifically, this study will assess coastal flooding risks due to storm surge, which includes wave contributions and tidal influences under the Coastal Storm Risk Management (CSRMM) mission. The effects of sea level change (SLC), which is expected to exacerbate coastal flooding, will also be assessed. The study develops and evaluates CSRMM alternatives for the San Juan Metro Area, which for this study includes the municipalities of San Juan, Cataño, Guaynabo, and Toa Baja. The alternatives described in this report are formulated to reduce risk to residents, industries, businesses and infrastructure that is critical to the nation's economy.

Purpose and Need

This study of the San Juan Metro Area began with the non-federal sponsor, the Department of Natural and Environmental Resources (DNER), bringing concerns about problems in the area to the U.S. Army Corps of Engineers (USACE). The year 2017 brought two back to back hurricanes, Irma and Maria, which caused widespread damages to homes and businesses. In response to these problems, USACE is pursuing this study, under Section 204 of the Flood Control Act of 1970, Public Law 91-611, with funds provided under the Bipartisan Budget Act (BBA) of 2018 Public Law 115-123.

The purpose of the San Juan Metro Area CSRMM study is to determine if there is Federal interest in a Federal plan to reduce damages to infrastructure as a result of coastal flooding from storm surge, tide and waves (rather than inland rainfall and stormwater runoff) during coastal storms and hurricanes along the back bay areas in the municipality of San Juan and adjacent municipality communities. The study team has produced this draft report and will produce a final report, which will be available for public review and comment. The report will consider all alternatives and their effects, under the National Environmental Policy Act (NEPA) of 1969.

This report is an interim response to the study authority. Section 204 of the Flood Control Act of 1970, Public Law 91-611, authorizes the Secretary of the Army, acting through the Chief of Engineers, to prepare plans for the development, utilization and conservation of water and related land resources of drainage basins and coastal areas in the Commonwealth of Puerto Rico. Study funds for this study were appropriated under Bipartisan Budget Act of 2018, Public Law 115-123.

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Study Area

Puerto Rico is the smallest of the Greater Antilles and is located in the Northeast of the Caribbean shield made up of the Greater Antilles and Minor Antilles. This position makes it extremely vulnerable to hurricanes due to the warmer temperatures of the waters in these zones.

Areas within this initially defined region were separated into 6 study reaches based on their respective watershed basins, and named accordingly: Reach 1 - West San Juan Bay, Reach 2 - East San Juan Bay, Reach 3 - Condado Lagoon, Reach 4 - Cano Martin Pena, Reach 5 - Los Corozos and San Jose Lagoon and Reach 6 -Torrecilla Lagoon. During further investigation, Reaches 1 and 3 were carried forward while Reaches 4-6 and Reach 2 were screened out from further analysis in this study, described further in Chapter 1, Section 1.5 of this report.

The study now focuses on the critical areas most likely to experience damages from coastal flooding within the San Juan Metro Area, which include Reach 1, West San Juan Bay (WSJB) reach and Reach 3, Condado Lagoon (CL) reach. The study area for Reaches 1 and 3 encompasses roughly 9.5 square miles of area and contains approximately 22 structures identified as critical infrastructure, in addition to approximately 14 schools, and major hurricane and tsunami evacuation routes.

The study area has approximately 20,000 structures¹ and vehicles, with a combined estimated value of approximately \$3.4 billion. Coastal flooding from storm surge, tide and wave contributions cause major damages to these structures and vehicles, and will continue to do so with increased risk from sea level change. Additionally, coastal flooding is hazardous to the community, and negatively impacts the economic development of stores, hotels and restaurants, and decrease property values.

The Tentatively Selected Plan

This study analyzed 32 measures, resulting in a focused array of 23 alternatives which were then evaluated and compared according to USACE planning principles. The TSP reasonably maximizes net benefits to contribute to national economic development (NED) and is consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements.

The TSP consists of a collection of key structural and natural and nature-based features in strategic locations designed to appropriate elevations which work together to reduce the risk of damages as a result of coastal flooding from storm surge, tide and waves during coastal storms and hurricanes along with the effect of SLC in the San Juan Metro Area.

The TSP includes levees (2 miles), a series of breakwaters over 0.7 miles along the Cataño shoreline, seawall/floodwalls (6.7 miles), elevated living shoreline (2.3 miles), a storm surge gate/sluice gate on the Malaria Canal, and associated inland hydrology features (to ensure that rainfall runoff is able to continue to outflow as it currently does, with the TSP features in place). The TSP also contributes to creation of habitat and incorporates recreational features. Although the TSP was formulated to avoid and minimize impacts to the extent practicable, impacts are expected to occur and would be addressed through mitigation, which is evaluated further in Chapter 5 and in the preliminary mitigation plan in Appendix G,

¹ Including critical infrastructure (hospitals, fire stations, police stations, etc.)

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Environmental, Attachment 4, and in Chapter 4. There is some uncertainty in terms of the quantity and siting of onsite compensatory mitigation which would be conducted during the PED Phase of the project when site-specific survey data is available. Upon final design, the functional lift provided from the construction of the TSP would be incorporated into the functional assessments and mitigation plan. The **graphic executive summary** shows the tentatively selected plan and key features in more needed.

Benefits of the Tentatively Selected Plan

This study concludes that there is Federal Interest in a comprehensive plan to reduce the risk of storm surge and associated damages to the San Juan Metro Area, summarized in **the graphic executive summary**. The TSP brings benefits to the nation in all of the four Principles and Guidelines² (P&G) accounts under National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). Additionally, the TSP meets the planning criteria of being complete, efficient, effective, and acceptable. Under the National Environmental Policy Act of 1969 (NEPA), the TSP has been evaluated for effects, which are described in Chapter 5 in the **Main Report**. The USACE environmental operating principles³ have been used throughout the planning process and identified and addressed specifically in Section 6.6.27 of the main report. The TSP provides average annual net benefits (AAEQ) of \$64M million each year over a 50-year period of analysis. The TSP is economically justified with a benefit to cost ratio of 5.2 (FY20 discount rate of 2.75%).

Sea Level Change (SLC)

Following procedures outlined in ER 1110-2-8162 and ET 1100-2-1, low, intermediate, and high sea level rise values were estimated over the life of the project using the official USACE sea level change calculator tool. Projections for sea level rise are based on a start date of 1992, which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001. In the future without-project conditions, sea level rise could be expected to increase by 0.58 (low), 1.26 (intermediate), and 3.39 feet (high) by year 2079 with respect to the above mentioned present local mean sea level tide datum. Sea level change will happen regardless of whether the tentatively selected plan is implemented or not. In addition to reducing impacts from storm surge, the TSP would also reduce the risk of damages and community impacts as a result of sustained flooding from sea level change.

Environmental Considerations

The environmental quality account considers non-monetary effects on ecological, cultural, and aesthetic resources. Under this account, the preferred plan should avoid or minimize environmental impacts and maximize environmental quality in the project area to the extent practicable considering other criteria

² The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, established by the U.S. Water Resources Council on March 10, 1983, have been developed to guide the formulation and evaluation studies of the major Federal water resources development agencies. These principles and guidelines are commonly referred to as the "P&G," and will be cited throughout the plan formulation sections of this report.

³ USACE has formalized its commitment to the environment by creating a set of "Environmental Operating Principles" applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation and preservation, and restoration are considered in all USACE activities.

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and planning objectives. More detailed descriptions of the analysis and impacts can be found in Section 5 of this report and in the Appendices. For the purposes of alternatives analysis, all action plans were compared to the future without-project condition (i.e., NEPA No Action), which factors in 50 years of sea level change (to 2079). Effects for each alternative were evaluated, and were carefully considered during plan formulation and for selection of the tentatively selected plan. The first step in mitigation planning involves employing efforts to avoid adverse impacts. After development of the focused array of alternatives, the PDT coordinated with resource agencies who participated during the PDT meetings. These meetings focused on the primary resources that could be impacted by the proposed alternatives.

Cost Estimate and Implementation

The project first cost is currently estimated to be \$331.6M (including an abbreviated risk-based contingency⁴), with a Federal cost of \$214M and a non-federal cost of \$117.6M, based on cost sharing percentages from the Water Resources Development Act (WRDA) of 1986 (Federal: 65%; non-federal: 35%). Project construction is assumed to begin in 2024 and take approximately 5 years, assuming concurrent construction crews in various locations.

Table ES-1-1. Tentatively Selected Plan Cost Summary (Project First Cost, FY20 Price Levels).

WBS Code	Item	Total Project First Cost (FY20)
10	Breakwaters & Seawalls	\$163,682,000
11	Levees & Floodwalls	\$13,262,000
13	Pumping Plant	\$40,320,000
14	Recreation Facilities	\$10,108,000
15	Floodway Control & Diversion Structures	\$8,375,000
06	Fish & Wildlife Facilities ⁵	\$7,791,000
01	Lands and Damages	\$34,192,000
30	PED	\$34,548,000
30	Real Estate Administration Cost (Fed)	\$195,000
30	Real Estate Administration Cost (non-fed)	\$ 455,000
31	Construction Management	\$18,674,000
	Project First Cost	\$331,600,000

Table ES-1-2. Summary of Project Cost Sharing (Project First Costs, FY20 Price Levels).

Item	Federal Share	Federal Cost	Non-federal Share	Non-federal Cost	Project First Cost
Project First Cost ⁶	65.0%	\$214,000,000	35.0%	\$117,600,000	\$331,600,000
LERRD Credit				\$ 34,600,000	
Non-federal Cash Contribution				\$83,000,000	

⁴ The contingency for construction, pre-construction engineering & design, and supervision & administration (S&A) is 40%; real estate contingency is 30%.

⁵ This item includes mitigation.

⁶ Project cost share is 65%-35%; however, recreation is cost shared at 50%-50% and has been factored into cost sharing totals

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Coordination with Agencies and the Public

Stakeholders include the communities in the municipalities of San Juan, Cataño, Guaynabo, and Toa Baja; Department of Natural and Environmental Resources (DNER), Puerto Rico Ports Authority (PRPA), Department of Public Works, San Juan Bay Estuary, as well as Federal environmental agencies, state and local agencies, and non-governmental organizations (NGO). The study team has met with communities during the studies, and has bi-weekly meetings with DNER, National Marine Fisheries Service (NMFS), and Fish and Wildlife Service (FWS). The team is in the process of coordinating a webinar meeting with representatives of the municipalities, DNER, PRPA, and the Department of Public Works to brief these entities on the TSP and understand perspectives and views of those agencies.

Residual Risk

The proposed project would greatly reduce, but not completely eliminate, future coastal storm risk and damages which result from coastal flooding within the project area. Coastal storm damages, caused primarily by coastal flooding, would be reduced by approximately 85% to 92% in the location of the project area over the 50 year period of analysis; therefore, the residual damages would be in the range of 8% to 15%. Periodically revisiting sea level rise trends described earlier be crucial for adaptive management to manage risk.

The tentatively selected plan is designed to maximize net NED benefits in accordance with ER 1105-2-100 rather than to achieve a specific level of protection. The FWOP damages modeled by G2CRM show that the vast majority of damages occur at or below the 1% annual exceedance coastal flood elevation, which is a storm that has a 1% chance of occurring in any given year.

Reaches West San Juan Bay 1A and East San Juan Bay were screened out from the study after the analysis showed that minimal damages are occurring in these areas. The cost to build a project in these reaches to reduce the damages would be higher than the benefit received. As a result, these areas are not economically feasible to pursue; along with additional considerations under planning criteria, these reaches were screened from further analysis. However, the low damages shown by the analysis indicates there is low risk of coastal flooding damages to the communities.

After further analysis of reaches 4 through 6, the study team determined that those reaches have multiple sources of coastal flooding influences and the uncertainty in the exchanges of flow between them is too high without performing more extensive hydrologic modeling. The problem in these reaches is a combination of precipitation with storm surge. This type of analysis to include both precipitation as well as understanding the complexity of storm surge from multiple points would necessitate the use of multiple models and complex model interfaces, increasing the scope of this study. The study team acknowledges there are flooding problems, resulting in potential risk to critical infrastructure and socially vulnerable communities from hydrologic induced flooding (precipitation) in addition to storm surge in reaches 4 through 6. These areas are recommended to be evaluated under a separate study in order to adequately address both storm surge and precipitation holistically, using the same study authority that is used for this study.

The risk of coastal flooding in the reaches described above is not affected by the proposed TSP.

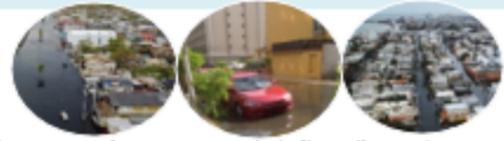
San Juan Metro Area Coastal Storm Risk Management (CSRM) Study - Background & Study Processes

INTRODUCTION

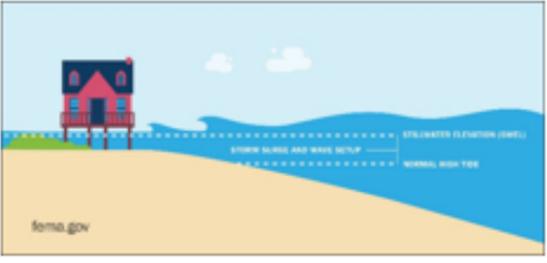
BACKGROUND

The study area has approximately 20,000 structures and vehicles, including critical infrastructure, with a combined estimated value of approximately \$3.4 billion. Flooded conditions from storm surge, tide and wave contributions cause major damages to these assets and will continue to do so with increased risk from sea level change.

PROBLEMS



1. Communities experience coastal flooding damages, which results from storm surge, tide, and wave contributions.
2. Community resilience is impacted before, during and after storms and hurricanes.
3. Future sea level rise conditions will exacerbate these problems.



STUDY AUTHORIZATION AND PROCESS

Authority for the San Juan Metro (back bay) Coastal Storm Risk Management (CSRM) study is granted under Section 204 of the Flood Control Act of 1970, Public Law 91-611. Study funds were appropriated under Bipartisan Budget Act of 2018 Public Law 115-123. Corps feasibility studies under this authorization are required to be completed in 3 years and with \$3M or less. The study schedule and milestones are shown on the next page. The study will examine alternative solutions, and will recommend one plan that meets Corps criteria to be the Tentatively Selected Plan. If the alternative is supported by Corps decision makers, it will receive an approved Chief's Report recommending it for authorization. The plan will then need to received appropriations for construction, which would be cost shared as appropriate between USACE and DNER.

PLAN FORMULATION

PRIMARY STUDY OBJECTIVE

Reduce risk of economic damages from coastal flooding to businesses, residents and infrastructure in the study area

STUDY OPPORTUNITIES

Maintain recreation, reduce tidal flooding, incidental improved effects to water quality, maintain aesthetics, maintain and enrich environmental resources

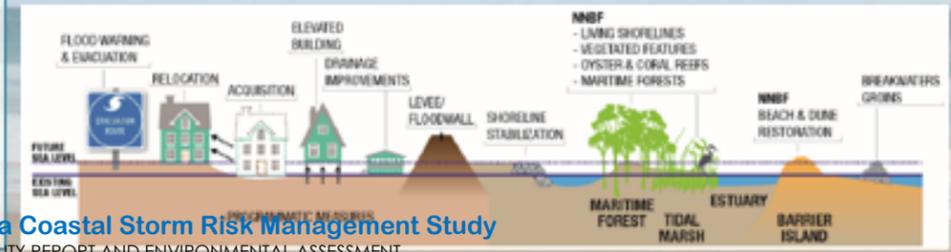
STUDY CONSTRAINTS

- Must be in compliance with all Federal laws, including avoid adverse impacts to existing environmental and cultural resources
- Avoid creating or exacerbating flooding with the project area or adjacent areas

Plan formulation is the process of developing alternative plans to address a given problem. The Corps uses a 6 step planning process:

- 1 Problem Identification
- 2 Inventory Existing Conditions and Forecast Future Conditions
- 3 Formulate Alternatives
- 4 Evaluate Alternatives
- 5 Compare Alternatives
- 6 Choose an Alternative

The first step in alternative formulation involves identifying all potential management measures for the given problems. A management measure is a structural or nonstructural action that can be implemented at a specific geographic site to address one or more planning objectives. Natural and nature-based measures are also encouraged under current policy. Measures are then screened against planning criteria, including objectives and constraints, and remaining measures are combined into alternative plans. Alternative plans are then screened and then modeled to determine benefits of each plan.



ECONOMICS – The National Economic Development Plan (NED)

The plan which the Corps will ultimately recommended for Federal participation is called the national economic development plan and should represent an alternative that achieves the greatest net benefits consistent with protecting the environment.

BENEFITS

Primary: Storm damage reduction

COSTS

- Cost of alternative over a 50 year period of Federal participation
- Associated costs

$$\frac{\text{BENEFITS}}{\text{COSTS}} > 1$$

In addition, plans must have a positive benefit to cost ratio.

$$\text{CSRM BENEFITS} = \text{ESTIMATED \$ DAMAGES WITHOUT PROJECT} - \text{ESTIMATED \$ DAMAGES WITH PROJECT}$$

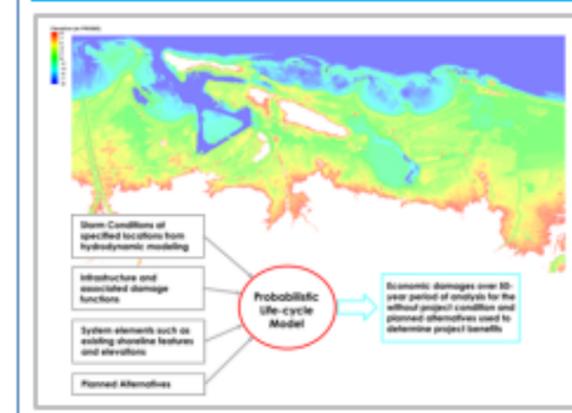
ENVIRONMENTAL & CULTURAL RESOURCES

The National Environmental Policy Act (NEPA) is a federal law enacted in 1969. As required by NEPA, the Corps will assess potential environmental effects of alternatives, to include cultural resources.



The findings will be explained in an NEPA document, which will be integrated into the Draft and Final Report. The NEPA document will be available for public review and comment before any decisions are made or actions are taken. Your input helps the Corps in identifying key environmental issues that may need to be evaluated.

ENGINEERING & MODELING



The engineering analysis for this study has considered the natural coastal processes, geological setting, existing protective features in the study area, as well as sea level rise scenarios. The team has leveraged data and local expertise from the sponsor (PR DNER) and other groups (PR Academia, stakeholders, Federal agencies, etc.) along with modeling to order to fully understand the problems and develop alternatives to reduce storm damages within the study area. The Corps certified model Generation II Coastal Storm Risk Model (G2CRM) was used for this study.

TENTATIVELY SELECTED PLAN & BENEFITS

The TSP reasonably maximizes net benefits to contribute to national economic development (NED) and is consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. The Corps uses four accounts to qualitatively or quantitatively describe other benefits of the plan. These are Environmental Quality (EQ), Other Social Effects (OSE), and Regional Economic Development (RED).

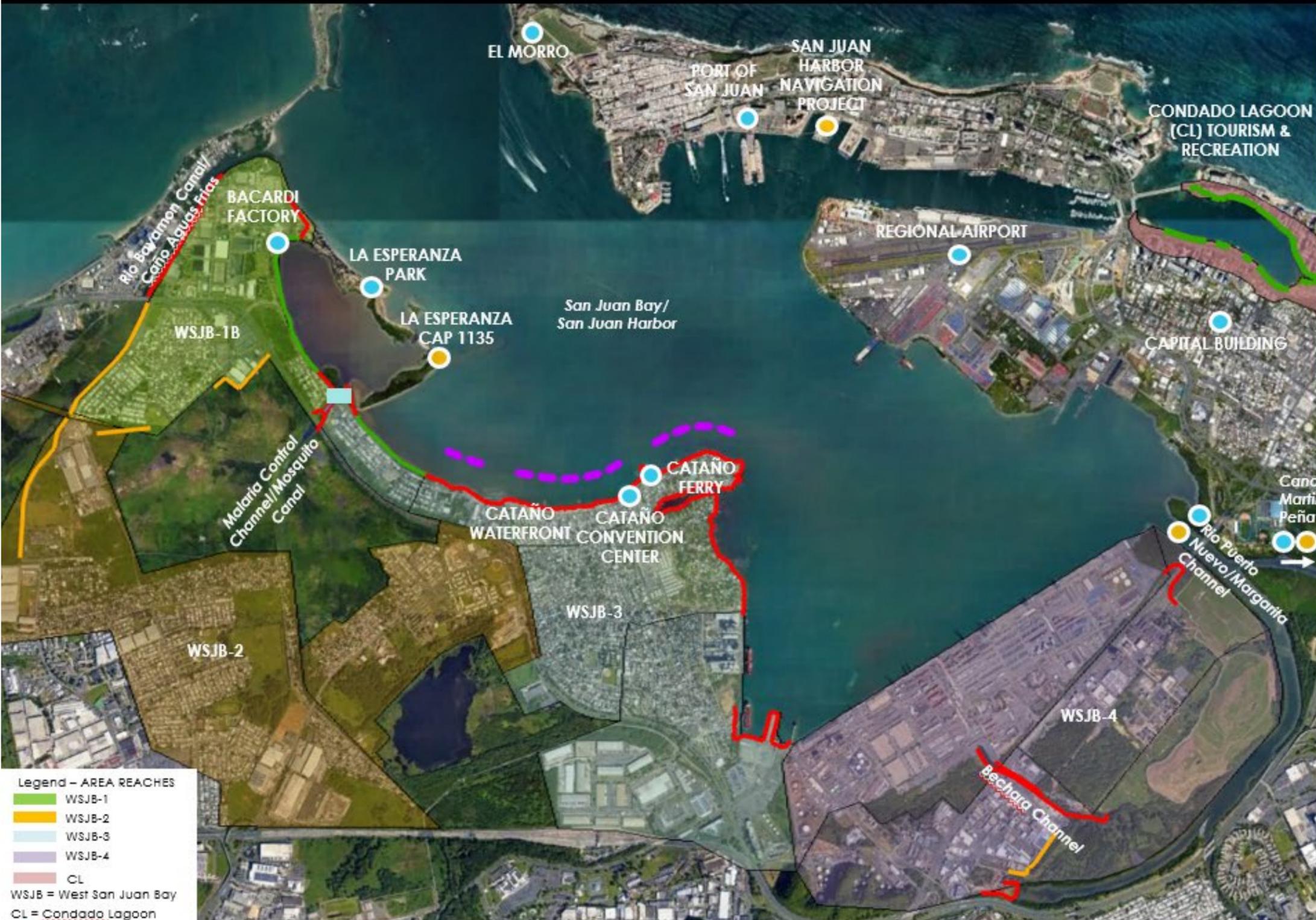
ESTIMATED STUDY SCHEDULE



*Contingent on authorization and appropriations



San Juan Metro Area Coastal Storm Risk Management (CSRM) Study THE TENTATIVELY SELECTED PLAN



Legend – AREA REACHES

- WSJB-1
- WSJB-2
- WSJB-3
- WSJB-4
- CL

WSJB = West San Juan Bay
CL = Condado Lagoon

VICINITY MAP



KEY FEATURES

- Structural
 - Levees = 2.0 miles
 - Seawall/floodwall = 6.7 miles
 - 1 small storm surge/sluice gate
 - Natural & Nature Based Features (NNBF)
 - Elevated living shoreline = 2.3 miles
 - Breakwater = 0.7 miles
- *It is also recommended that the non-federal sponsor pursues non-structural measures such as local outreach & evacuation plan/notification improvements

PROJECT FIRST COST: \$ 331.6M
 Federal Cost (65%): \$214M
 Non-Federal Cost (35%): \$117.6M

AAEQ NET BENEFITS: \$64M
 AAEQ Benefits: \$ 79.4M
 AAEQ Costs: \$ 15.4M
 BCR: 5.2 at 2.75%

Structural Measures	
	Seawall/Floodwall
	Levee (traditional)
	Storm Surge Gate - Small
Natural/Nature Based Features (NNBF)	
	Elevated living shoreline
	Breakwaters

- USACE Federal projects
- Significant Metro Area landmarks



1 Introduction

1 INTRODUCTION*

 Please refer to informational foldout Graphic Executive Summary Pages 1 and 2 as a reference throughout this report. Critical infrastructure is referred to throughout this report as a structure which serves a critical function to the community, and therefore may have increased risk of negatively impacting the community's resilience in terms of health and safety during and after a storm event. Critical infrastructure in this report are as follows: hospitals, care facilities, police stations, fire departments, airports, shelters, and hurricane/tsunami evacuation routes.

1.1 FEDERAL STUDY PURPOSE*

This U.S. Army Corps of Engineers (USACE) study is an interim response to the study authority to determine Federal interest in a plan to reduce damages to infrastructure as a result of coastal flooding from storms and hurricanes within the San Juan Metro Area. More specifically, this study will assess coastal flooding risks due to storm surge, which includes wave contributions and tidal influences under the Coastal Storm Risk Management (CSRM) mission. The effects of sea level change (SLC), which is expected to exacerbate coastal flooding, will also be assessed. The study develops and evaluates CSRM alternatives for the San Juan Metro Area, which for this study includes the municipalities of San Juan, Cataño, Guaynabo, and Toa Baja. The alternatives described in this report are formulated to reduce risk to residents, industries, businesses and infrastructures which are critical to the nation's economy.

1.2 STUDY SPONSOR

The non-federal sponsor for this study is the Puerto Rico Department of Natural and Environmental Resources (DNER).

1.3 STUDY AUTHORITY

This report is an interim response to the study authority. Authority for the San Juan Metro coastal storm risk management (CSRM) study is granted under Section 204 of the Flood Control Act of 1970, Public Law 91-611 which authorizes the Secretary of the Army, acting through the Chief of Engineers, to prepare plans for the development, utilization and conservation of water and related land resources of drainage basins and coastal areas in the Commonwealth of Puerto Rico. Study funds for this study were appropriated under Bipartisan Budget Act of 2018, Public Law 115-123.

1.4 LOCATION AND NEED*

Puerto Rico is the smallest of the Greater Antilles and is located in the Northeast of the Caribbean shield made up of the Greater Antilles and Minor Antilles. In addition, it is in the 18.5 ° N parallel of the Tropic of Cancer at latitude 65 ° W. This position makes it extremely vulnerable to hurricanes due to the warmer temperatures of the waters in these zones. The San Juan Metro Area is located in the northeastern portion of Puerto Rico, and for this study includes the municipalities of San Juan, Cataño, Guaynabo, and Toa Baja. The location and vicinity map is shown in the **graphic executive summary**.

Puerto Rico is significant to the nation with its rich cultural heritage, unique environmental resources, and as an international tourist destination. Problems from storms and hurricanes have been increasingly

evident over past years, with special attention on the storm season in 2017 which left destruction from multiple hurricanes, such as Hurricane Maria, Hurricane Irma, and winter storm Riley.

At least 16 major hurricanes have severely damaged infrastructure in the study area since late 1893, as described below in **Table 1-1**. The year 2017 brought two back to back hurricanes, Irma and Maria, which caused widespread damages to homes and businesses.

Although Irma's eye went to the north of Puerto Rico, the winds of tropical storm (64 knots) and heavy rain caused widespread power cuts and damages in homes and businesses. There was an almost total loss of electricity and water service during several days.

During Hurricane Maria, the center of the hurricane made its entrance by of the Municipality of Yabucoa and made landfall as a Category 4. The NOAA damage estimate in Puerto Rico and the U.S. Virgin Islands is \$90 billion dollars, making Hurricane Maria the third most expensive hurricane in US history.

Table 1-1. Hurricanes affecting the study area since 1893.

Month/Year	Name	Category
August 1893	San Roque	N/A
August 1899	San Ciriaco	N/A
September 1928	San Felipe II	Category 5
September 1931	San Nicolás	Category 1
September 1932	San Ciprián	Category 3
September 1956	Santa Clara	Category 1
September 1989	Hugo	Category 4
September 1995	Marilyn	Category 2
September 1996	Hortensia	Category 1
September 1998	Georges	Category 3
September 2004	Jeanne	Tropical Storm
August 2011	Irene	Tropical Storm
September 2011	Maria	Tropical Storm
August 2015	Erika	Tropical Storm
September 2017	Irma	Category 5
September 2017	Maria	Category 4

1.5 STUDY BACKGROUND AND SCOPING

Originally, the study was scoped to assess shoreline erosion along the coastline of the San Juan Metro Area. A NEPA scoping meeting was held in San Juan on November 8, 2018 where the study team presented the general study scope and requested feedback from communities. During that process, several communities expressed concerns of coastal flooding in the Cataño municipality, as well as the Condado Lagoon area within the San Juan municipality. As a result, the feasibility of addressing shoreline erosion as a Federal project along the coastline of the San Juan Metro area was incorporated into another ongoing USACE study, called the Puerto Rico Coastal Storm Risk Management (CSRМ) Study, to allow this study to focus solely on coastal flooding.

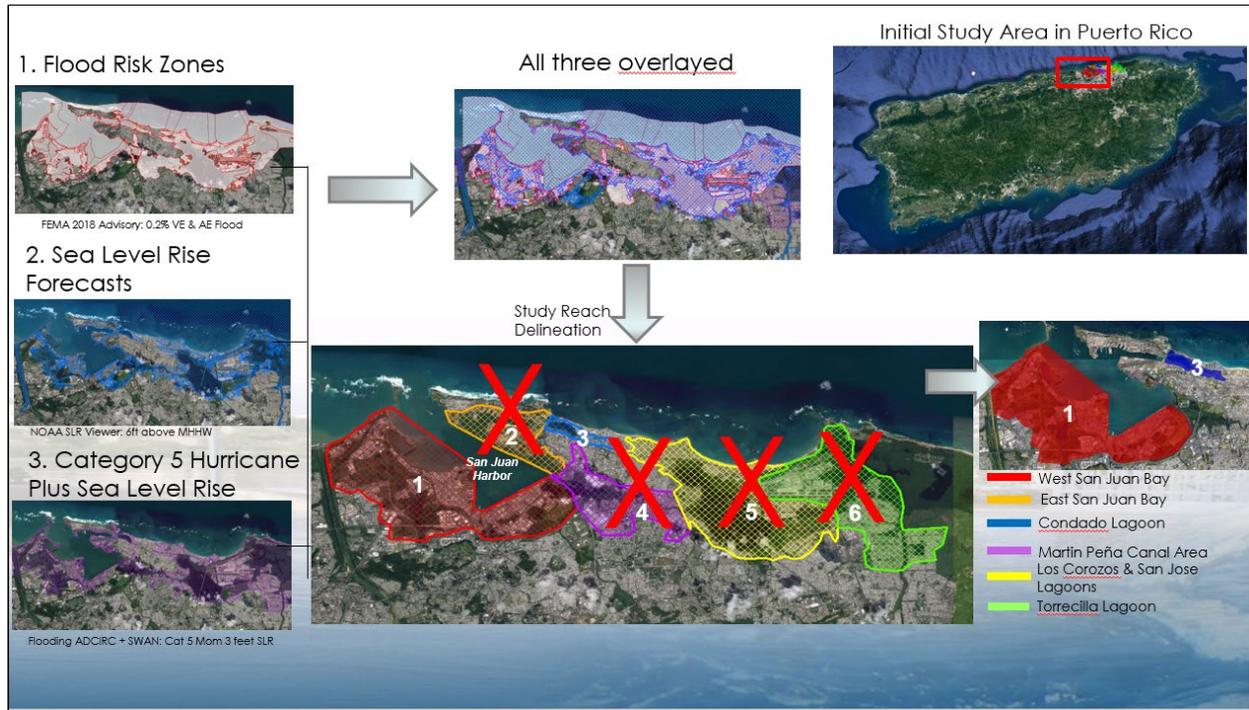
This study will assess coastal flooding risks to back bay areas, generally defined as areas connected to tidally influenced bays and estuaries which are hydraulically connected to the ocean. Throughout this report the term “coastal flooding” will be used to refer the flood levels generated by a storm event which includes contributions from storm surge, waves and astronomical tide. Sea level change will also be assessed as it is anticipated to exacerbate the impacts of coastal flooding.

Three data sets were overlaid in Geographic Information System (GIS) to determine the study area extent based on a high risk of storm surge and sea level rise. These three data sets are: 1) Flood Risk Zones (FEMA 2018 Advisory: 0.2% VE & AE Flood Zones⁷; 2) Sea Level Rise Forecasts (NOAA sea level viewer at 6 feet above MHHW); and 3) Flooding (ADCIRC + SWAN: Cat 5 Maximum of MEOW’s (Maximum Envelopes of Water⁸) plus 1 meter sea level rise) (**Figure 1-1**).

⁷ Represents flooding that could occur from a storm with a 2% chance of occurring, in VE and AE zones. VE and AE flood zones are defined by FEMA.

⁸ Flooding that could occur from a category 5 hurricane. MEOW is Maximum Envelope of Water, which is maximum storm surge footprint from each simulation is composited, retaining the maximum height of storm surge in a given basin grid cell, using ADCIRC and SWAN models. (double check this definition, refine as needed)

Figure 1-1. Initial Scoping for Storm Surge Study.



Areas within this initially defined region were separated into 6 study reaches based on their respective watershed basins, and named accordingly: Reach 1 - West San Juan Bay, Reach 2 - East San Juan Bay, Reach 3 - Condado Lagoon, Reach 4 - Cano Martin Pena, Reach 5 - Los Corozos and San Jose Lagoon and Reach 6 -Torrecilla Lagoon. During further investigation, Reaches 1 and 3 were carried forward while Reaches 4-6 and Reach 2 were screened out from further analysis in this study. The rationale for this descopeing of the study is described in the following discussions.

Reaches 1 through 3 have a single source of coastal flooding influence (Atlantic Ocean) and the flooding problem within these reaches is driven primarily by storm surge and are considered to be critical focus areas by the sponsor. These areas can be modeled within the existing economic model, Generation 2 Coastal Storm Risk Model (G2CRM), for a direct link to damages and benefits from storm surge versus design alternatives, and the study can be completed within three years.

After further analysis of reaches 4 through 6, the study team determined that those reaches have multiple sources of coastal flooding influences and the uncertainty in the exchanges of flow between them is too high without performing more extensive hydrologic modeling. The problem in these reaches is a combination of precipitation with storm surge. This type of analysis to include both precipitation as well as understanding the complexity of storm surge from multiple points would necessitate the use of multiple models and complex model interfaces. The study team acknowledges there are flooding problems, resulting in potential risk to critical infrastructure and socially vulnerable communities from hydrologic induced flooding (precipitation) in addition to storm surge in reaches 4 through 6. With sponsor support, these reaches were descopeed from this study and these areas are recommended to be evaluated under a separate study in order to adequately address both storm surge and precipitation holistically. The same study authority that is used for this study could be used.

approaching through the harbor. This reach contains approximately 16 structures identified as critical infrastructure, one of which is a major hurricane and Tsunami evacuation route (PR-165)⁹, in addition to 14 schools and 4 assembly points¹⁰ (Tsunami Program Map Tool, <http://prdst.uprm.edu/apps/prtmp/>).

This reach was further delineated into 5 planning reaches, based on geographic features and direction of storm surge. Throughout this report, they are called WSJB-1a, WSJB-1b, WSJB-2, WSJB-3, and WSJB-4 (See **Figure 1-3**). Each planning reach is separable from one another, meaning that any measure/alternative ultimately used for each area would not reduce storm surge risk in any of the other planning reaches.

REACH 3 – CONDADO LAGOON

This reach encompasses an area which is approximately .5 square miles, located to the East of San Juan Harbor and bordering the Condado Lagoon. This reach is within the San Juan municipality and suffers from storm surge and tidal influences from Condado Lagoon. There are 6 structures identified as critical infrastructure just outside of the study area. Frequent tidal flooding is reported by residents. This area also serves as a major throughway to communities evacuating from the west, and houses major Tsunami and Hurricane evacuation route PR-24. This reach is also at risk from sea level change. This reach remains as one planning reach, and is called CL-1 throughout this report.

⁹ GIS data is from FEMA Caribbean Division and was collected in 2016 & 2017.

¹⁰ Assembly points are a location for information updates from emergency responders.

Figure 1-3. Six Planning Reaches in the Study Area.



1.6 RISK INFORMED DECISION FRAMEWORK & STUDY TIMELINE

Planning has always been about solving problems and making decisions in light of uncertainty. The risk management framework is a decision making framework that allows USACE remain efficient and effective in making decisions given uncertainty with today’s complex challenges and limited resources.

Since the inception of “SMART Planning” in 2011, where feasibility studies are required to be completed in 3 years and with \$3M, USACE Planning has engaged in a significant transformation in the incorporation of risk-informed, decision-focused thinking into planning processes. The process emphasizes that study teams should use a reasonable level of detail to collect data and model alternatives to analyze and evaluate effectiveness in order to identify a USACE recommended plan.

Risk-informed planning embodies all the principles and tasks of the USACE risk management framework and the six-step planning process. This paradigm shift to explicitly assessing and managing risk is more important than ever in meeting the USACE Civil Works mission.

The study schedule and milestones are shown in **Figure 1-4**. Key Milestones during the Feasibility Phase are described as follows:

1. Alternatives Milestone Meeting (AMM): The Alternatives Milestone meeting marks the decision maker's agreement on a clear and logical formulation and evaluation rationale that indicates the study team is making appropriate risk-informed decisions and has a clear direction on next steps to complete the study. This milestone was achieved on December 13, 2018.
2. Tentatively Selected Plan Milestone (TSP): At this milestone, the study team has completed the evaluation and comparison of a focused array of distinctly different strategies for achieving the water resources objectives in the study area and identified a TSP to carry forward. This milestone was achieved on June 16, 2020. At this point in the study, the TSP has been characterized to a level of detail consistent with an approximately 10% level of design for structural and nonstructural measures. During feasibility level design, the designs, cost estimates, and benefit analysis will be refined for both structural and nonstructural measures included in the TSP. Risk and uncertainty will also be evaluated to determine ranges of economic benefits and costs and project performance in order to meet the requirements of ER 1105-2-101.
 - Release Draft Report for Public and Agency Review: This integrated draft feasibility report and EA documents the analysis that led to the selection of the TSP to a level of detail required for the release for concurrent public, technical, legal, and policy review and independent external peer review (IEPR).
3. Agency Decision Milestone: The study team has also identified additional analysis that is needed following the release of the draft report to develop sufficient cost and design information for the final feasibility-level analysis and feasibility report/EA. The Feasibility Level Design becomes the agency recommended plan after the Agency Decision Meeting. This phase of the study includes development of the Final Draft Report and additional design of the recommended plan, approximately 35%, to reduce risk and uncertainty with cost data, engineering effectiveness, environmental impacts, and economic benefits.
 - Final Report Release for State & Agency Review: This integrated final feasibility report and EA documents the analysis that led to the selection of the recommended plan and is released for public and agency final review and comment.
4. Chief's Report: If the recommended plan is supported by USACE decisions makers, it will receive an approved Chief's Report recommending it for Congressional authorization for construction.

The plan will then need to receive Congressional authorization appropriations for construction, and would be cost shared as appropriate between USACE and DNER. Upon receipt of these items, the project will continue to the preconstruction engineering and design (PED) phase where a more detailed analysis will be completed in order to develop plans and specifications needed to construct the project.

Figure 1-4. Feasibility Study Schedule and Milestones.



1.7 RELATED DOCUMENTS*

1.7.1 RELATED USACE AND NEPA STUDIES

- Puerto Rico Coastal Storm Risk Management Study: This USACE study is currently in progress and is studying the feasibility of a Federal plan to reduce risk from erosion and wave attack along the shoreline of San Juan and adjacent municipalities. This study is projected to complete the Chief’s Report by October 2021.
- South Atlantic Coastal Study (SACS): The SACS is underway and provides a risk management framework designed to help local communities better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. In particular, it encourages planning for resilient coastal communities that incorporates wherever possible sustainable coastal landscape systems that takes into account future sea level and climate change scenarios.
- Puerto Rico Vulnerability Study: This report was prepared by USACE, and finalized in October 2018, as the final report in a four phase series of reports to analyze evacuation behavior, shelters, hazards and vulnerability to hazards in Puerto Rico.

1.7.2 PRIOR NON-FEDERAL STUDIES

- Coastal Engineering Handbook, Puerto Rico: This handbook was produced by Tetra Tech for DNER as a means to provide best practices in coastal areas of Puerto Rico.

1.8 FEDERAL PROJECTS NEAR THE STUDY AREA

- Caño Martín Peña Ecosystem Restoration Project: The main purpose of the project is to clear vegetation in the Cano Martin Pena, and restore native vegetation along the fringes, allowing flow to be restored. Congress authorized the project in Section 5127 of the Water Resources Development Act (WRDA) of 2007, Public Law 110-114, with authorization contingent on the Assistant Secretary of the Army for Civil Works (ASA(CW)) reviewing a report prepared by the non-federal interest and determining that the report meets the evaluation and design standards of the Corps and that the project is feasible. The report included an Environmental Impact Statement (EIS). On May 16, 2016, the ASA(CW) approved the Caño Martín Peña Ecosystem Restoration Project as feasible and an environmentally sound project..
- Rio Puerto Nuevo Flood Control Project: This project reduces the risk of damages from flooding as a result of rapid upstream runoff, inadequate channel capacity, constriction at bridges, and elimination of the flood plain by urbanization in the Rio Puerto Nuevo channel. The project includes 6 segments that will be constructed through separate contracts through 2032. A Chief’s

Report was signed on April 25, 1986. It was authorized under Section 401 of the Water Resources Development Act of 1986 (Public Law 99-662), with funding from the Bipartisan Budget Act of 2018 to address damages from Hurricanes Harvey, Irma and Maria. NEPA documents are studies were completed in 1984, 1993, and 2002. USACE will prepare an additional NEPA documentation as appropriate during the PED phase.

- San Juan Harbor, Puerto Rico Project: This project incorporates improvements to the navigation channel to increase transportation cost savings and efficiencies in the harbor. The approved integrated report contained an environmental assessment (EA). A Chief's Report was signed on August 23, 2018, and the project was authorized under Section 1401 of WRDA 2018.
- San Juan Harbor Federal Navigation Project Under Section 1135 for Work at La Esperanza Peninsula: This project falls under the Continuing Authorities Program (CAP), for ecosystem restoration in the La Esperanza area.

1.9 OTHER NON-FEDERAL PROJECTS ADJACENT OR NEAR TO STUDY AREA

- La Concha Reefs near Condado: This project is under development and proposes to alter wave energy in critical locations along the seaward shoreline of Condado where high wave energy causes damage and life safety hazards.



2

Existing & Future Without Project Conditions

2 EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

2.1 GENERAL SETTING*

This chapter describes conditions as they currently exist, and as they are projected to exist if a project is not implemented, within the San Juan Metro Area, Puerto Rico. Information gathered in this step helps to describe the problems and opportunities and forecast future conditions. The future without-project (FWOP) condition is the most likely condition of the study area without construction of a Federal The future without-project (FWOP) condition is also the no-action alternative for the purposes of National Environmental Policy Act (NEPA) and this report uses both terms interchangeably. The future without-project (FWOP) condition is also the no-action alternative for the purposes of National Environmental Policy Act (NEPA) and this report uses both terms interchangeably.

The San Juan Metro Area study area is approximately 9.5 square miles, spanning 6 reaches over 4 municipalities. The back bay portion of the San Juan Metro Area is influenced by tropical systems generally during the summer and fall and by northeasters during the late fall, winter, and spring. Although hurricanes typically generate larger waves and storm surge, northeasters can have a greater cumulative impact on the area due to longer storm duration and greater frequency of event occurrence. Periodic and unpredictable hurricanes and coastal storms, with their intense breaking waves and elevated water levels, can cause significant damage to the shoreline and back bay infrastructure. Low elevations make this area particularly at risk for elevated water levels from coastal flooding during hurricanes and storms, which are expected to be exacerbated by sea level rise. The natural environment includes submerged aquatic vegetation, freshwater wetlands, and mangroves as well as key species in those habitats. The area is highly urbanized with dense populations and infrastructure, generally built as concrete homes built at one level, with some high rises, and contains critical infrastructure including evacuation routes. The future without-project condition within the period of analysis (2029 to 2079) are identified as continued damages to structures, contents, vehicles, infrastructure, life safety and degraded access to emergency services prior to, during and after future storm events. This will result in continued maintenance and reconstruction of structures and infrastructure following storm events.

This chapter characterizes the setting in more detail, within four main environments: 1: Natural Environment, 2. Physical Environment; 3. Built Environment; and 4. Economic Environment. In addition to these descriptions, existing input into the USACE certified model is briefly discussed, which serves to verify the existing conditions and then estimates conditions projected out 50 years into the future. These conditions become the baseline of comparison for alternative evaluations for plan formulation (described in Chapter 3).

2.2 NATURAL ENVIRONMENT*

The San Juan Metro area is located on the North coast of Puerto Rico and has approximately 40 to 50 miles of heavily developed fronting shoreline. San Juan bay is directly connected to the Atlantic Ocean via the Boca del Morro which is the entrance to San Juan Harbor (Please refer to Figure X). Condado Lagoon lies to the east of San Juan bay and Cataño and La Esperanza lie on the west side of San Juan bay. La Esperanza Park contains an embayment with perimeter vegetation (generally mangroves and exotic

species) and sandy beaches approximately 30-50 feet wide with vegetation in some locations on the north side. Condado Lagoon's shoreline consists primarily of vegetation (red and black mangroves), concrete seawalls, and nearshore submerged aquatic vegetation including sea grass.

2.2.1 WATER QUALITY

EXISTING CONDITION

The San Juan Bay estuary system includes San Juan Bay, Condado Lagoon, San José Lagoon, Los Corozos Lagoon, La Torrecilla Lagoon, and the Piñones Lagoon, as well as the interconnecting Martín Peña and San Antonio Channels and the Suárez Canal. "San Juan Bay is the focal point for most of the past and present development within the San Juan metropolitan area, and the bay's drainage basin has been almost completely urbanized. The intensity and diversity of human activities taking place within the metropolitan area have influenced the water and sediment quality of the estuary in many ways, impairing in many instances its functions and values (SJBEP 2000)". However, San Juan Bay's direct connection to the Atlantic Ocean via the Boca del Morro results in relatively high average dissolved oxygen levels between 5.0-6.5 mg/L and oceanic salinities of 33-37 ppt just below the water's surface (-2-feet) within San Juan Harbor (Anamar 2013). The Rio Puerto Nuevo turning basin is located in the southeast portion of the harbor near the mouth of the Puerto Nuevo River which is a large source of sediment and fresh water into the harbor. The River connects to the low flowing Caño Martín Peña which connects to the San José Lagoon. The Caño Martín Peña and San José Lagoon are severely degraded from highly turbid, organic and bacteria-rich waters with low levels of dissolved oxygen.

2.2.1.1 REACH 1 – WEST SAN JUAN BAY

San Juan Bay is microtidal and the western bay is shallow. Water circulation in this area is driven by the wind and by tidal currents, but is generally poor. In areas of limited circulation, such as La Esperanza, sediments accumulate. The Malaria Control Canal (MCC) carries urban storm runoff from low-lying residential and industrial areas of Cataño and drains into the embayment at La Esperanza Park. The Cano Aguas Frias drains cooling water outflow from the Palo Seco Power Plant, just north of La Esperanza Park, into northwest San Juan bay. To the southeast, freshwater flows from the Puerto Nuevo River are driven by local rainfall which flushes untreated and treated stormwater runoff and wastewater from Caño Martín Peña and San José Lagoon into the harbor. Despite this, the Puerto Rico Environmental Quality Board (EQB), through the promulgation of the Puerto Rico Water Quality Standards Regulation, has designated the waters of the San Juan Bay as "Class SC", where "Class SC" are coastal waters intended for uses where the human body may come in direct contact with the water (such as fishing, boating, etc.) and for use in propagation and preservation of desirable species. The turbidity standard for Class SC waters in Puerto Rico is not to exceed 10 nephelometric turbidity units (NTU), except by natural phenomena (EQB 2020).

2.2.1.2 REACH 3 – CONDADO LAGOON

Urban storm water and runoff, entering the lagoon primarily from the east end, degrades water quality. In addition deep artificial depressions within the lagoon act as storage pools for organic matter and nutrients discharged into the lagoon. As a result, water quality is degraded and aquatic habitat, such as seagrasses, is negatively impacted.

FUTURE WITHOUT-PROJECT CONDITION

Shoreline erosion and inundation of structures would continue to cause chronic increases in turbidity and sedimentation along and adjacent to the shorelines and degraded water quality in San Juan bay and Condado lagoon.

2.2.2 WETLANDS AND SUBMERGED AQUATIC VEGETATION (SAV)

2.2.2.1 REACH 1 – WEST SAN JUAN BAY

EXISTING CONDITION

Wetlands

Centuries of development have severely altered the natural ecosystems of San Juan bay. Most of the shoreline is now hardened and developed. Despite this the San Juan Bay Estuary is the largest estuary in Puerto Rico, part of the National Estuary Program (NEP), and an estuary of national importance. Coastal mangrove wetland habitats occur throughout the estuary and within West San Juan bay along the Cano Aguas Frias, La Esperanza Park (a dredged material placement area for construction of the Federal navigation channel between 1963-1965) and the MCC and at the mouth of the Puerto Nuevo River. Mangrove species found in San Juan bay include: red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*). Like seagrasses (discussed below), mangroves are a highly productive habitat that "provide feeding, breeding, nesting, and roosting areas for birds, mammals, and reptiles, with the vegetative detritus of mangroves serving as the base of the food web for crabs, mollusks, shrimp, and fish, among others" (SJBEP, 2000). Mangroves are important for shoreline protection and stabilization. In addition, mangrove habitats provide many important ecological functions, including providing refugia for juvenile stages of managed fish species, and have been identified as significant resources for federally listed species. These systems also provide organic matter that forms the basis of a littoral-zone, marine food web. Sloughs (channels of slow-moving water) penetrate mangrove wetlands adjacent to channel areas. Some of these sloughs are natural, while some are man-made. These are extremely important areas that provide species with passageways for movement into and out of interior mangrove areas. They are also important for refuge and feeding areas for various fishes and invertebrates such as juvenile spiny lobster (*Panulirus argus*) and gray snapper (*Lutjanus griseus*).

In addition to mangroves, palustrine emergent freshwater wetlands occur along the MCC. These areas have been degraded through anthropogenic alterations in the watershed resulting in poor water quality and reduced habitat value.

SAV

Submerged aquatic vegetation (SAV) consisting of marine macro-algae and seagrass occurs at scattered locations and generally at depths less than -15ft (-4.6m). Both red and green macro-algae are prevalent throughout the bay. Seagrass species include shoal grass (*Halodule wrightii*), paddle grass (*Halophila decipiens*), manatee grass (*Syringodium filiforme*), and turtle grass (*Thalassia testudinum*). Scattered turtle and paddle grass beds have been found in San Juan Bay (NOAA 2016; USACE 2017). These include mono-specific beds of paddle grass, mixed red and green macro-algae with paddle grass, and sparse turtle grass as documented with underwater video during benthic surveys conducted by the NMFS and

the USACE from January through December 2016 (Reports available at: <http://www.saj.usace.army.mil/About/Divisions-Offices/Planning/Environmental-Branch/Environmental-Documents/>, Puerto Rico, San Juan Harbor Navigation Study, Appendix H1 & H2).

Seagrasses significantly modify the physical, chemical, and geological properties of coastal areas; they provide nutrients, primary energy, and habitats which sustain our coastal fisheries resources; and they provide foraging grounds for some endangered marine species (Vicente, 1990). Federally protected species such as green sea turtles (*Chelonia mydas*) and Antillean manatees (*Trichechus manatus manatus*) feed directly on seagrasses. Seagrass beds also serve as a substrate for epiphytes, such as filamentous algae and epiphytic diatoms, which in turn serve as food for invertebrates and fish.

FUTURE WITHOUT-PROJECT CONDITION

In the future without-project condition/No Action Alternative, existing unabated shoreline erosion and sedimentation would continue to negatively impact SAV, mangrove and palustrine emergent wetlands in the San Juan bay area. In addition, mangroves could out compete and replace palustrine emergent wetlands with future SLR.

2.2.2.2 REACH 3 – CONDADO LAGOON

EXISTING CONDITION

Wetlands

Through the years, mangroves have been cleared around the shoreline of the Condado Lagoon for various reasons such as dredging and filling. Some mangrove still exists along the shoreline fringe. However, the growth of mangroves around the lagoon is restricted due to the shoreline stabilization (riprap) placed along some of the shoreline. The mangrove species found around the Condado Lagoon are: red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*). In an attempt to increase the acres of mangroves around the shoreline of the Condado Lagoon, the San Juan Bay Estuary Program (SJBEP) has in place a program to plant mangroves, which consists of restoring a portion of the fringing mangrove wetland along the shoreline of the Lagoon. The mangrove restoration effort is listed in the SJBEP Comprehensive Conservation and Management Plan as Action HW-3.

SAV

SAV within the Condado Lagoon consists of seagrass and algae. Four species of seagrasses have been documented to occur in the Condado Lagoon (MRI, 2005). Reported types of seagrasses are shoal grass (*Halodule wrightii*), paddle grass (*Halophila decipiens*), manatee grass (*Syringodium filiforme*) and turtle grass (*Thalassia testudinum*). However, during surveys in 2008 and 2011 *S. filiforme* was not observed throughout the lagoon. Three seagrass species were observed during the 2011 benthic survey: *H. decipiens*, *T. testudinum*, and *H. wrightii*. *H. decipiens* was the dominant seagrass. No *H. decipiens* occurrences were recorded below 6 m (20 ft.) at any of the investigated sites. *H. decipiens* was most abundant in the mid depth range 2.7 to 5.8 m (9.0 to 19.0 ft.), but did not occur any deeper than 5.7m (19 ft.). *T. testudinum* had the second highest number of occurrences. No *T. testudinum* was found deeper than 6.7 m (22.0 ft.). The highest numbers of *T. testudinum* were recorded at shallow (1.8 to 2.4 m [6 to 8 ft.]) and mid-range depths (2.7 to 5.8 m [9 to 19ft]). *H. wrightii* was sighted in only one quadrat at a depth of 5.2 m (17.0 ft.).

A total of 13 different genera of macroalgae were observed during the 2011 benthic surveys. The different macroalgae genus observed were: *Acetabularia*, *Amphiroa*, *Batophora*, *Caulerpa*, *Dictyopteris*, *Dictyota*, *Gracilaria*, *Halimeda*, *Jania*, *Laurencia*, *Padina*, *Sargassum*, and *Udotea*. *Caulerpa spp.*, *Dictyota spp.*, *Acetabularia spp.*, and *Laurencia spp.* were the dominant genera. No macroalgae were recorded below 8 m (26 ft.).

FUTURE WITHOUT-PROJECT CONDITION

In the future without-project condition/No Action Alternative, existing unabated shoreline erosion and sedimentation would continue to negatively impact SAV and mangroves in San Juan bay.

2.2.3 HARBOTTOM HABITAT

2.2.3.1 REACH 1 – WEST SAN JUAN BAY

EXISTING CONDITION

In addition to the SAV, hardbottom habitat occurs within San Juan bay but primarily adjacent to Boca del Moro (narrow, discontinuous linear or fringing “reef” consisting of corals covering fossil sand dunes [i.e., eolianites], **Figure 2-1**; Caribbean Fisheries Management Council [CFMC] 2004), along the Catano shoreline (scattered rocks with macro-algae, **Figure**), and elsewhere on hard substrates (rocks, pilings, docks, bulkheads). Encrusting zoanthids, octocorals (*Leptogorgia*, *Briareum*), sponges, polychaetes, and sea stars have been documented. Hard corals (including seven (7) species listed as threatened under the ESA) are found on the fringing reefs along the northern coastline out of the action area.

Hardbottom habitat provides valuable structure for benthic (occurring at the bottom of a body of water) fauna and flora, as well as fish habitat. Hardbottom refers to a classification of coral communities that occur in temperate, subtropical, and tropical regions that lack the diversity, density, and reef development of other types of coral communities (SAFMC 1998). For the purposes of this investigation, hardbottom habitat is defined as exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota (the plant and animal life of a region). Hardbottom provides habitat and foraging grounds for a diverse array of invertebrate and fish species. These communities support habitat-structuring sessile (non-mobile) epifauna (organisms living on the sea floor) such as sponges, corals, bryozoans, and ascidians (Burgess et al. 2011).

The Catano area is subject to substantial turbidity and sedimentation as well as a lack of hard substrate to support a thriving coral community (NMFS EFH consultation from Appendix C of USACE 2016).

FUTURE WITHOUT-PROJECT CONDITION

Unabated shoreline erosion and sedimentation could negatively affect nearshore hardbottom under the FWOP condition.

Figure 2-1. Limestone substrate adjacent harbor entrance channel (SOURCE: NOAA 2016).

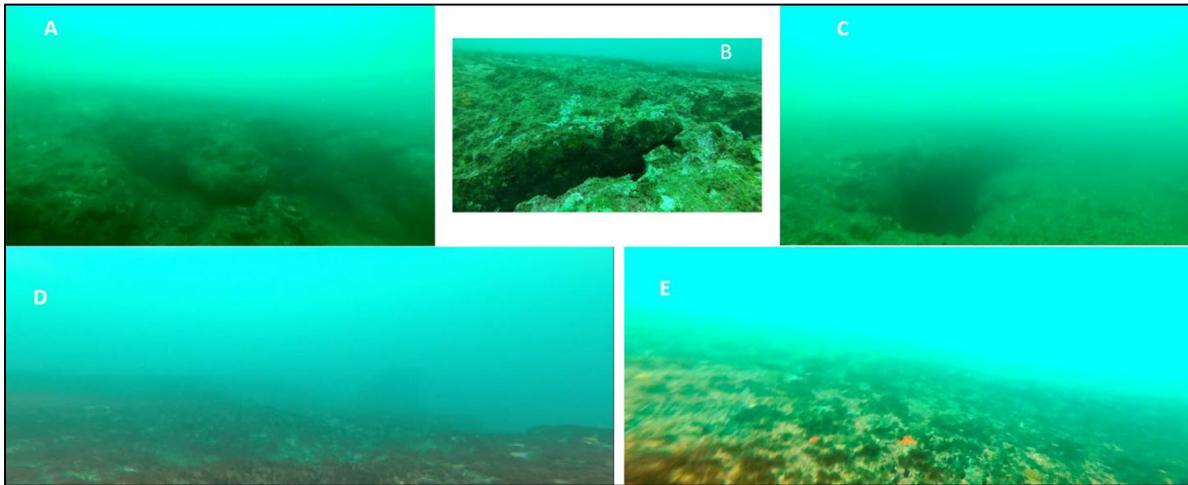
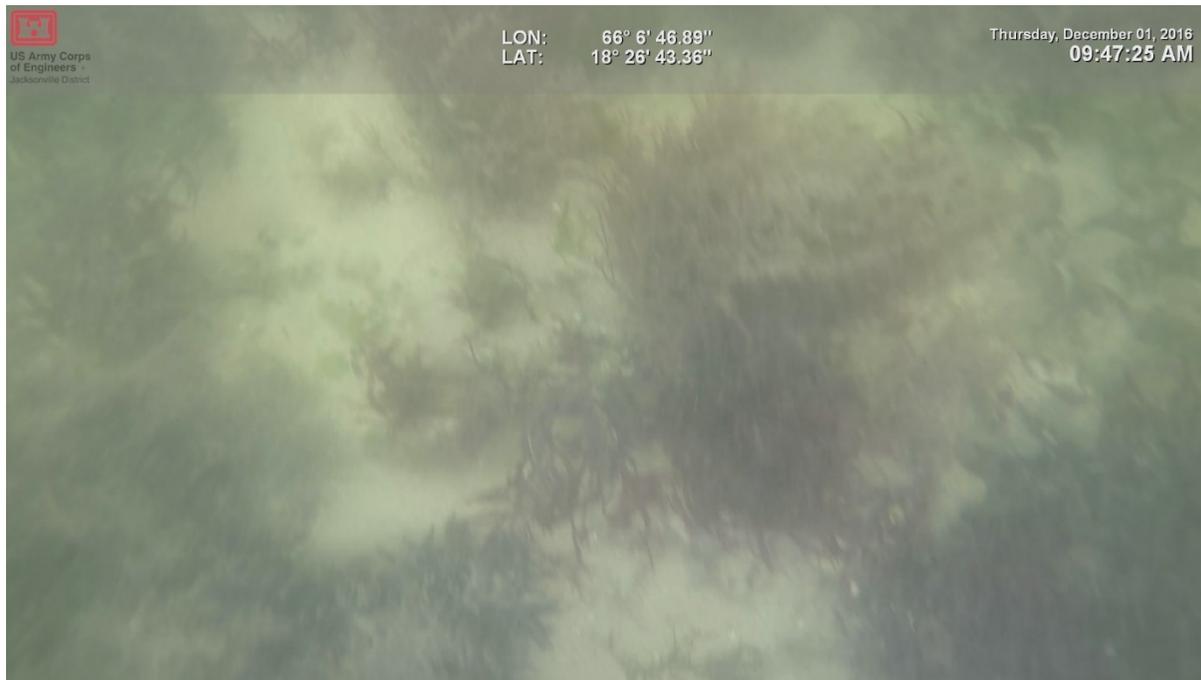


Figure 2-2. Catano hardbottom with macro-algae.



2.2.3.2 REACH 3 – CONDADO LAGOON

EXISTING CONDITION

The northwestern portion of Condado Lagoon is more exposed to the Ocean and contains hard substrate that supports various coral species. However, the portion of Condado Lagoon south of the Ashford Avenue Bridge is more protected from wave action and has limited hard substrate to support corals. Habitat characterization sampling conducted by MRI (2005) revealed hard bottom and coral communities within

the Condado Lagoon, exclusively on the north side near the El Boqueron inlet. No hard coral communities have been reported south of Dos Hermanos Bridge in the lagoon basin itself. The existence of hard coral communities is less likely to occur in the basin area due in part to high turbidity and poor water quality conditions.

FUTURE WITHOUT-PROJECT CONDITION

Unabated shoreline erosion and sedimentation could affect nearshore hardbottom under the FWOP condition.

2.2.4 ESSENTIAL FISH HABITAT

EXISTING CONDITION

The Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Act are intended to protect those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity. If a proposed action potentially affects EFH, then consultation with NMFS is required. The EFH consultation ensures the potential action considers the effects on important habitats and supports the management of sustainable marine fisheries.

In the Caribbean waters under the jurisdiction of the U.S., EFH is identified and described based on areas where the life stages of 17 managed species of fish and marine invertebrates occur. Fourteen of the 17 managed species, which have been documented in the study area, are listed in **Table 2-1** below.

Since all of these species occur in all habitats within the Caribbean waters under U.S. jurisdiction, EFH includes all waters and substrates, including coral habitats, submerged vegetation, and adjacent intertidal vegetation, including wetlands and mangroves that are necessary for the reproduction, growth, and feeding of marine species.

2.2.4.1 REACH 1 & 3 – WEST SAN JUAN BAY AND CONDADO LAGOON

All of San Juan Bay is tidally influenced, so it and adjacent wetlands are considered EFH. Therefore, EFH within the project area includes estuarine and marine submerged and emergent vegetation, tidal freshwater wetlands, tidal creeks, water column, intertidal and subtidal mudflats (unconsolidated bottom), coastal inlets, coral and artificial reefs, and hardbottom. Many of these habitats foster growth and provide food and protection from predators and are integral to producing healthy populations of commercially and recreationally important species. Species that may occur in the project area habitats are noted in **Table 2-1**.

Table 2-1. Managed species documented in the study area.

Species	Common Name	SPAG*	FMP
<i>Chaetodon striatus</i>	Banded Butterflyfish		Reef Fish - aquarium trade
<i>Epinephelus guttatus</i>	Red Hind	X	Reef Fish
<i>Cephalopholis fulvus</i>	Coney	X	Reef Fish
<i>Lutjanus analis</i>	Mutton Snapper		Reef Fish
<i>Lutjanus apodus</i>	Schoolmaster		Reef Fish
<i>Lutjanus griseus</i>	Gray Snapper	X	Reef Fish

<i>Ocyurus chrysurus</i>	Yellowtail Snapper	X	Reef Fish
<i>Haemulon plumieri</i>	White Grunt		Reef Fish
<i>Balistes vetula</i>	Queen Triggerfish		Reef Fish
<i>Sparisoma chrysopterygum</i>	Redtail Parrotfish		Reef Fish
<i>Holocentrus ascensionis</i>	Squirrelfish		Reef Fish
<i>Malacanthus plumieri</i>	Sand Tile Fish		Reef Fish
<i>Panulirus argus</i>	Spiny Lobster		Spiny Lobster
<i>Strombus gigas</i>	Queen Conch		Queen Conch

Source: Rivera, 2015; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011.
 *SPAG: Potential Spawning Aggregation site in San Juan Bay (Ojeda et. al. 2007).

Per the Fishery Management Plan (FMP) for each of the four groups below, EFH is defined as (CFMC and NOAA 2004):

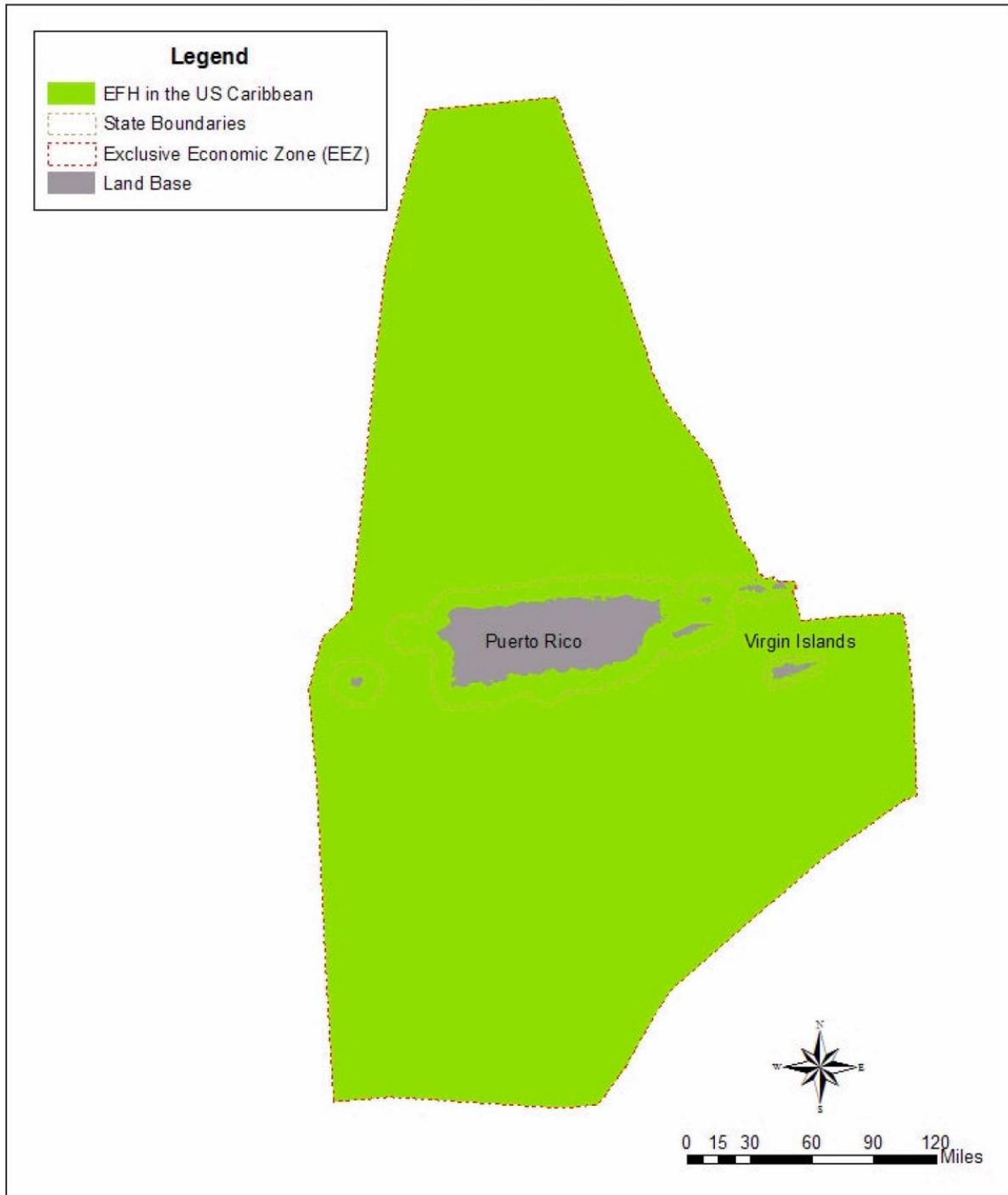
Spiny Lobster FMP: EFH in the U.S. Caribbean consists of all waters from MHW to the outer boundary of the EEZ- habitats used by phyllosoma larvae and seagrass, benthic algae, mangrove, coral, and live/hard bottom substrates from MHW to 100 fathoms depth used by other life stages.

Queen Conch FMP: EFH in the U.S. Caribbean consists of all waters from MHW to the outer boundary of the EEZ – habitats used by eggs and larvae and seagrass, benthic algae, coral, live/hard bottom and sand/shell substrates from MHW to 100 fathoms depth used by other life stages.

Reef Fish FMP: EFH in the U.S. Caribbean consists of all waters from MHW to the outer boundary of the EEZ – habitats used by eggs and larvae and all substrates from MHW to 100 fathoms depth used by other life stages.

Coral FMP: EFH in the U.S. Caribbean consists of all waters from mean low water (MLW) to the outer boundary of the EEZ – habitats used by larvae and coral and hard bottom substrates from MLW to 100 fathoms depth – used by other life stages.

Figure 2-3. Composite EFH for species and life stages of the Spiny Lobster, Queen Conch, Reef Fish, and Coral.



FUTURE WITHOUT-PROJECT CONDITION

Unabated shoreline erosion could cause increased turbidity and potentially loss of sea grasses. In addition, mangrove habitat could be impacted by these coastal processes as well. Therefore, the FWOP condition could have a negative effect to EFH.

2.2.5 PROTECTED SPECIES

2.2.5.1 REACH 1 & 3 – WEST SAN JUAN BAY AND CONDADO LAGOON

The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) have responsibilities under the Endangered Species Act of 1973 (ESA) to protect certain species. There are many threatened and endangered (T&E) species known to occur near San Juan bay. However, not all of them would be affected by a proposed action. Accordingly, the USACE is working with USFWS Field Office in Boqueron, Puerto Rico, as well as the NMFS Southeast Regional Office in St. Petersburg, Florida to focus on the species listed in **Table 2-2**. This list includes the federally-listed T&E species that could be present in the area based upon their geographic range. However, the actual occurrence of a species in the area would depend upon the availability of suitable habitat, the season of the year relative to a species' temperature tolerance, migratory habits, and other factors. The following sections summarize species-specific information relevant to the Study area.

Table 2-2. Selected federally-threatened and endangered species potentially present in the vicinity of San Juan Harbor, Puerto Rico.

Common Name	Scientific Name	Status	Year Listed
Marine Mammals			
Antillean Manatee	<i>Trichechus manatus</i>	T	2017
Marine Turtles			
Leatherback turtle	<i>Dermochelys coriacea</i>	E	1970
Hawksbill turtle	<i>Eretmochelys imbricata</i>	E	1970
Green turtle	<i>Chelonia mydas</i>	Northwest Atlantic DPS; T	2016
Fish			
Scalloped hammerhead shark	<i>Sphyrna lewini</i>	Central and Southwest Atlantic DPS; T	2014
Nassau grouper	<i>Epinephelus striatus</i>	T	2016
Giant manta ray	<i>Manta birostris/ M.</i>	T	2017
Corals			
Elkhorn coral	<i>Acropora palmata</i>	T	2006
Staghorn coral	<i>Acropora cervicornis</i>	T	2006
Pillar coral	<i>Dendrogyra cylindrus</i>	T	2014
Rough Cactus Coral	<i>Mycetophyllia ferox</i>	T	2014
Lobed Star Coral	<i>Orbicella annularis</i>	T	2014
Mountainous Star Coral	<i>Orbicella faveolata</i>	T	2014
Boulder Star Coral	<i>Orbicella franksi</i>	T	2014
Terrestrial Reptiles			
Puerto Rico Boa	<i>Epicrates inornatus</i>	E	1976

Common Name	Scientific Name	Status	Year Listed
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E – federally-endangered

T – federally-threatened

Endangered: A taxon "in danger of extinction throughout all or a significant portion of its range."

Threatened: A taxon "likely to become endangered within the foreseeable future throughout all or a significant portion of its range."

2.2.5.1.1 FISHES

EXISTING CONDITION

Of the three listed fish species, Nassau grouper are most likely to occur in the vicinity of the project. However, in the late 1980’s Nassau grouper reached commercial extinction and a fishery moratorium was implemented in the 1990s but commercial fishing continued in Florida and the U.S. Atlantic (including Puerto Rico) despite initial moratoriums (Frias-Torres, 2008). The giant manta ray is considered to be a migratory species that is commonly found offshore in the open ocean and on the outer continental shelf.

Scalloped Hammerhead Shark. The hammerhead sharks are recognized by their laterally expanded head that resembles a hammer. The scalloped hammerhead shark (*Sphyrna lewini*) is distinguished by a marked central indentation on the anterior margin of the head, along with two more indentations on each side of this central indentation, giving the head a “scalloped” appearance. The body is fusiform, with a large first dorsal fin and low second dorsal and pelvic fins. Coloration is generally uniform gray, grayish brown, bronze, or olive on top of the body that shades to white on the underside with dusky or black pectoral fin tips. This shark is a high trophic level predator and opportunistic feeder with a diet that includes a wide variety of teleosts, cephalopods, crustaceans, and rays. The northwest Atlantic Ocean DPS was listed under the ESA as threatened on September 2, 2014.

Estuaries and coastal embayments have been identified as particularly important nursery areas, while offshore waters contain important spawning and feeding areas. Adult habitat consists of continental shelf areas further offshore, with adult aggregations common over seamounts and near islands. The scalloped hammerhead shark can be found in coastal warm temperate and tropical seas worldwide. In the western Atlantic Ocean, the species range extends from the northeast coast of the United States (from New Jersey to Florida) to Brazil, including the Gulf of Mexico and Caribbean Sea. The species could occur along the north coast of Puerto Rico outside the area of influence of the proposed action.

Nassau Grouper. The Nassau grouper (*Epinephelus striatus*) is a long-lived (29 years max), moderate sized Serranid fish with large eyes and a robust body. The range of color is wide, but ground color is generally buff, with five dark brown vertical bars and a large black saddle blotch on top of caudal peduncle and a row of black spots below and behind its eye. There is also a distinctive dark tuning-fork mark beginning at the front of the upper jaw, extending dorsally (on top) along the interorbital region, and then dividing into two branches on top of the head behind the eyes; another dark band from the tip of the snout through the eye and then curving upward to meet its fellow just before the dorsal-fin origin. Juveniles exhibit a color pattern similar to adults. On 29 June 2016, NMFS issued a final rule (81 FR 42268) listing the Nassau Grouper as a threatened species under the ESA.

The Nassau grouper is primarily a shallow-water, insular fish species that has long been valued as a major fishery resource throughout the wider Caribbean, South Florida, Bermuda and the Bahamas. The Nassau grouper is considered a reef fish, but it transitions through a series of developmental shifts in habitat. The larvae are planktonic and after 35-40 days recruit from an oceanic environment into demersal habitats hiding in macroalgae, coral, and seagrass beds.

The Nassau grouper's confirmed distribution currently includes Bermuda, Florida, throughout the Bahamas and Caribbean Sea. The species does occur along the north coast of Puerto Rico outside the area of influence of the proposed action.

Giant Manta Ray. On January 12, 2017, NMFS published a proposed rule in the Federal Register (82 FR 3694) to list the giant manta ray (*Manta birostris*/*M. alfredi*) as threatened species under the ESA. The distribution of the giant manta ray is worldwide in tropical and temperate ocean waters. On the U.S. Atlantic Coast, the giant manta ray has been documented as far north as New Jersey. The giant manta ray is commonly encountered on shallow reefs or sighted feeding offshore at the surface. The giant manta ray is occasionally observed in sandy bottom areas and seagrass beds. Regional sub-populations appear to be small and generally contain less than 1,000 adult individuals and are generally declining except for those areas where they are specifically protected (Hawaii, Maldives, Yap, Palau). The primary threats to *Manta* species are targeted fishing and fishery bycatch. This species is anticipated to occur outside the area of influence of the proposed action.

FUTURE WITHOUT-PROJECT CONDITION

No effects to these overfished and oceanic species are anticipated in the FWOP. They are not expected to occur in San Juan bay and therefore would not be affected by unabated shoreline erosion and sedimentation in the FWOP condition.

2.2.5.1.2 SEA TURTLES

EXISTING CONDITION

Four different sea turtles species could occur in the study area, Loggerhead, Leatherback, Hawksbill, and Green. Of the four species, the hawksbill and green are the most common in San Juan bay. Although sandy beach habitat occurs within San Juan bay along La Esperanza and in Condado Lagoon, DNER has not documented nesting there (Carlos Diez, Puerto Rico Department of Natural and Environmental Resources, San Juan, Puerto Rico, personal communication, July 12, 2016). Sea turtle nesting is limited to the sandy beaches along the north coast of Puerto Rico adjacent to San Juan bay.

Leatherback. Leatherback sea turtles (*Dermochelys coriacea*) are widely distributed throughout the oceans of the world, and are found in waters of the Atlantic, Pacific, and Indian oceans (Ernst and Barbour, 1972). Leatherback turtles are the largest living turtles and have a larger migration range than any other sea turtle species. The leatherback is the most pelagic (open ocean) of the sea turtles and is often seen near the edge of the continental shelf; however, they are also observed just offshore of the surf line. They enter coastal waters on a seasonal basis to feed in areas where jellyfish are concentrated.

Zug and Parham (1996) pointed out that the main threat to leatherback populations in the Atlantic is the combination of fishery-related mortality (especially entanglement in gear and drowning in trawls) and the intense egg harvesting on the main nesting beaches. Boat strikes are also a threat and source of mortality

for leatherbacks in Puerto Rico. There is potential for leatherbacks to be present off the north coast during migration and leatherback nesting has been documented on the sandy beach north of the Avenida Ashford (Dos Hermanos) Bridge (USFWS, 2005 – Harberer 2005). No critical habitat has been designated for leatherback turtles in the project area.

Loggerhead. The loggerhead (*Caretta caretta*) is characterized by a large head with blunt jaws. The carapace and flippers are a reddish-brown color; the plastron is yellow. Adults grow to an average weight of about 200 pounds. The USFWS and the NMFS listed the Northwest Atlantic Ocean distinct population segment (DPS) of the loggerhead sea turtle as threatened on September 22, 2011 (76 FR 58868).

No loggerhead sea turtle nesting has ever been documented in Puerto Rico (Carlos Diez, Puerto Rico Department of Natural and Environmental Resources, San Juan, Puerto Rico, personal communication, July 12, 2016). The species feeds on mollusks, crustaceans, fish, and other marine animals. The loggerhead sea turtle can be found throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans. It may be found hundreds of miles out to sea, as well as in inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Coral reefs, rocky places, and ship wrecks are often used as feeding areas. This species could occur offshore San Juan Harbor. No critical habitat has been designated for loggerhead turtles in the project area.

Hawksbill. The hawksbill turtle (*Eretmochelys imbricata*) is small to medium-sized compared to other sea turtle species. Hawksbill turtles are unique among sea turtles in that they have two pairs of prefrontal scales on the top of the head and each of the flippers usually has two claws. This species was listed under the ESA as endangered in 1970.

Hawksbill turtles use different habitats at different stages of their life cycle, but are most commonly associated with healthy coral reefs. The ledges and caves of coral reefs provide shelter for resting hawksbills both during the day and at night. Hawksbills are known to inhabit the same resting spot night after night. Hawksbills are also found around rocky outcrops and high energy shoals. These areas are optimum sites for sponge growth, which certain species are the preferred food of hawksbills. They are also known to inhabit mangrove-fringed bays and estuaries, particularly along the eastern shore of continents where coral reefs are absent.

The nesting season varies with locality, nesting occurs all year long in Puerto Rico. Hawksbills nest at night and, on average, about 4.5 times per season at intervals of approximately 14 days. They nest under the vegetation on the high beach and nests have been observed having the last eggs of the clutch as close as 3 inches from the sand's surface. Hawksbill sea turtles have been reported in San Juan Bay and nesting has been documented on the sandy beach north of the Avenida Ashford (Dos Hermanos) Bridge (USFWS, 2005 – Harberer 2005). Designated Critical Habitat (DCH) for this species occurs approximately 50 miles east of the project area around Culebra Island.

Green. The nesting range of green sea turtles in the southeastern United States includes sandy beaches of mainland shores, barrier islands, coral islands, and volcanic islands between Texas and North Carolina, the U.S. Virgin Islands (USVI) and Puerto Rico (NMFS and USFWS, 1991). Green turtles (*Chelonia mydas*) are primarily herbivorous, feeding on algae and sea grasses, but also occasionally consume jellyfish and sponges. Green turtle foraging areas in the southeastern United States include any coastal shallow waters having macroalgae or sea grasses, including areas near mainland coastlines, islands, reefs, or shelves, and any open-ocean surface waters, especially where advection from wind and currents concentrates pelagic (open ocean) organisms (Hirth, 1997; NMFS and USFWS, 1991). Adults of both sexes are presumed to

migrate between nesting and foraging habitats along corridors adjacent to coastlines and reefs. DCH for this species occurs approximately 50 miles east of the project area around Culebra Island. The SAV habitat found in San Juan Harbor and Condado Lagoon are important grazing areas for the green sea turtle.

FUTURE WITHOUT-PROJECT CONDITION

Unabated shoreline erosion and sedimentation under the FWOP condition could negatively affect foraging sea turtles from loss of SAV habitat in San Juan bay. According to DNER, no records of sea turtle nesting have been documented in San Juan bay and DCH does not occur near the project area.

2.2.5.1.3 ANTILLEAN MANATEES

EXISTING CONDITION

Antillean manatees (*Trichechus manatus manatus*) have large, seal-shaped bodies with paired flippers and a round, paddle-shaped tail. They are typically grey (color can range from black to light brown) and are occasionally spotted with barnacles attached to them or colored by patches of green or red algae. Average adult manatees are about nine feet long and weigh about 1,000 pounds (<https://www.fws.gov/southeast/wildlife/mammals/manatee/>).

The Antillean manatee inhabits the coastal waters of Puerto Rico, and has been documented both feeding and traveling in West San Juan Bay and Condado Lagoon area. Seagrass beds in the bay and lagoon provide suitable foraging habitat. USFWS has jurisdiction for protection of the manatee under the ESA and the MMPA. On April 5, 2017, the USFWS published a final rule reclassifying the West Indian manatee and its two recognized subspecies (Florida and Antillean) from endangered to threatened (82 FR 16680). This species is also protected by Law Number 241 (Wildlife Law of the Commonwealth of Puerto Rico) and Regulation Number 6766, which regulates the management of threatened and endangered species in Puerto Rico. No DCH has been designated for this species in the project area. USFWS has jurisdiction for protection of the manatee under the ESA and the MMPA. On April 5, 2017, the USFWS published a final rule reclassifying the West Indian manatee and its two recognized subspecies (Florida and Antillean) from endangered to threatened (82 FR 16680). This species is also protected by Law Number 241 (Wildlife Law of the Commonwealth of Puerto Rico) and Regulation Number 6766, which regulates the management of threatened and endangered species in Puerto Rico. No DCH has been designated for this species in the project area.

FUTURE WITHOUT-PROJECT CONDITION

Unabated shoreline erosion and sedimentation under the FWOP condition could affect foraging manatees through loss of SAV habitat.

2.2.5.1.4 CORALS

EXISTING CONDITION

West San Juan Bay and Condado Lagoon

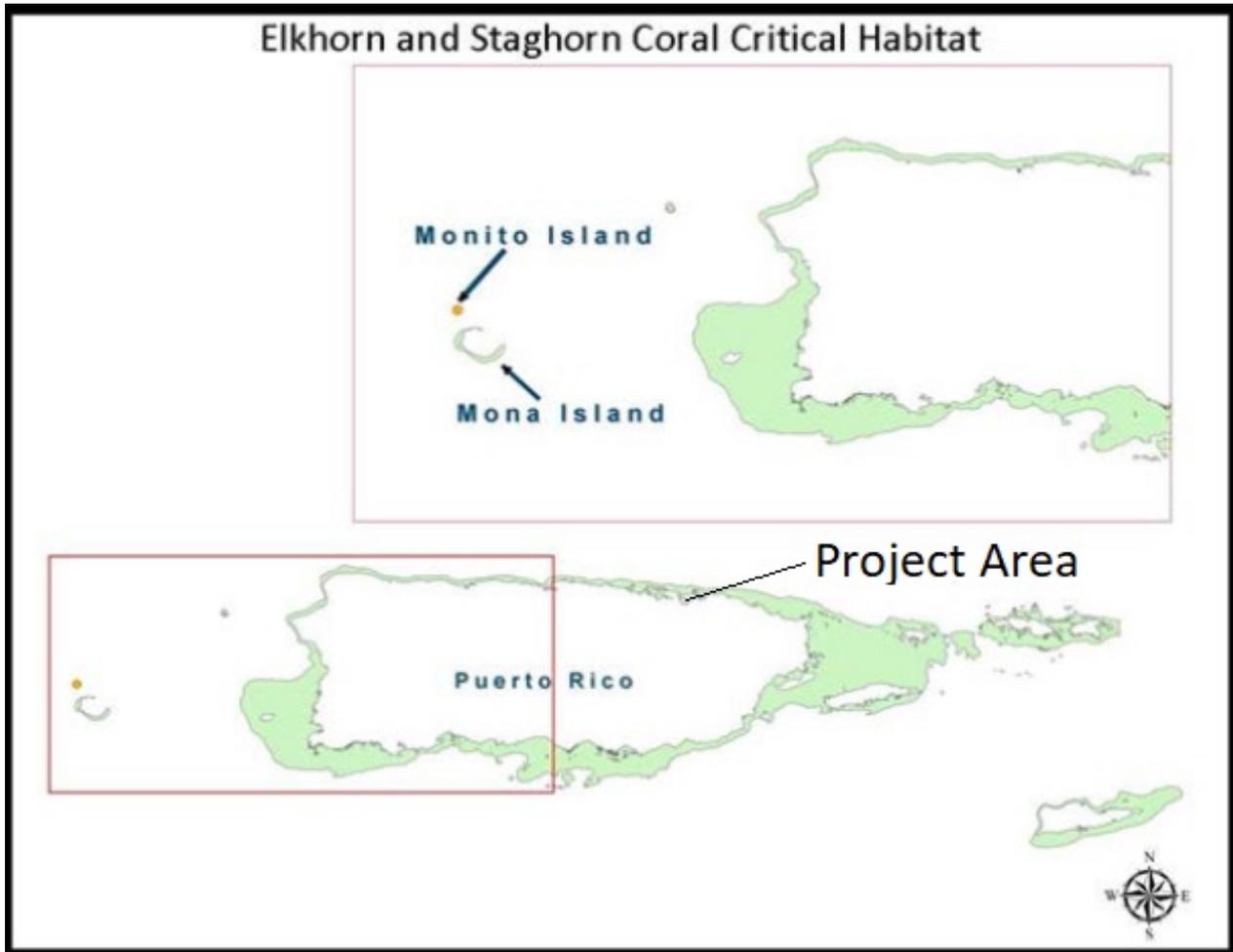
The following ESA listed corals could occur at the mouth of the bay adjacent Boca del Moro and north of Dos Hermanos Bridge at the mouth of the Condado lagoon.

Elkhorn Coral. Elkhorn coral (*Acropora palmata*) belong to the most abundant group of corals in the world (Acropora genus) and once represented the most dominant reef building species throughout Florida and the Caribbean. Elkhorn coral is a large, branching coral with thick and sturdy antler-like branches and is found in shallow reefs, typically in water depths from 0-35 feet, as these corals prefer areas where wave action causes constant water movement. Colonies are fast growing: branches increase in length by 2-4 inches (5-10 cm) per year, with colonies reaching their maximum size in approximately 10-12 years. Over the last 10,000 years, elkhorn coral has been one of the three most important Caribbean corals contributing to reef growth and development and providing essential fish habitat. This species was listed under the ESA as threatened on May 9, 2006.

Elkhorn coral was formerly the dominant species in shallow water (3-16 ft. [1-5 m] deep) throughout the Caribbean and on the Florida Reef Tract, forming extensive, densely aggregated thickets (stands) in areas of heavy surf. Coral colonies prefer exposed reef crest and fore reef environments in depths of less than 20 feet (6 m), although isolated corals may occur to 65 feet (20 m).

NMFS has designated critical habitat for elkhorn and staghorn corals in four areas: Florida, Puerto Rico, St. John/St. Thomas, and St. Croix. Figure 2-9 shows the designated areas for Puerto Rico, which includes all areas surrounding the islands of the Commonwealth of Puerto Rico, 98 ft. (30 m) in depth and shallower, seaward of the U.S. Coast Guard Convention on the International Regulations for Preventing Collisions at Sea (COLREGS demarcation line). Per NOAA chart 25670, the COLREGS demarcation line transects outer bar channel Cut-2 in San Juan Harbor. In addition, a 4(d) rule (50 CFR Part 223) establishing “take” prohibitions for elkhorn and staghorn corals went into effect on November 28, 2008 for these areas. Take includes collecting, bothering, harming, harassment, damage to, death, or other actions that affect health and survival of listed species. This species has been documented in the study area on the narrow, discontinuous linear or fringing “reef” consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). DCH for this species occurs in outer Bar Channel Cuts 1 and 2 at the entrance to San Juan Harbor.

Figure 2-4. Elkhorn and Staghorn Corals Designated Critical Habitat (DCH).



Staghorn Coral. Staghorn coral (*Acropora cervicornis*) is a branching coral with cylindrical branches ranging from a few centimeters to over 6.5 feet (2 m) in length. This coral exhibits the fastest growth of all known western Atlantic corals, with branches increasing in length by 4-8 inches (10-20 cm) per year. This species was listed under the ESA as threatened on May 9, 2006.

Staghorn coral occurs in back reef and fore reef environments from 0-98 feet (0 to 30 m) deep. In addition to growing on reefs, staghorn corals often form colonies on bare sand. The upper limit is defined by wave forces, and the lower limit is controlled by suspended sediments and light availability. Fore reef zones at intermediate depths of 15-80 feet (5-25 m) were formerly dominated by extensive single species stands of staghorn coral until the mid-1980s.

Staghorn coral is found in the Atlantic Ocean, Caribbean Sea, and western Gulf of Mexico. Specifically, staghorn coral is found throughout the Florida Keys, the Bahamas, the Caribbean islands, and Venezuela. The northern limit of staghorn coral is around Boca Raton, Florida. The dominant mode of reproduction for staghorn coral is asexual fragmentation, with new colonies forming when branches break off a colony and reattach to the substrate. Sexual reproduction occurs via broadcast spawning of gametes into the water column once each year in August or September. Individual colonies are both male and female

(simultaneous hermaphrodites) and will release millions of "gametes." The coral larvae (planula) live in the plankton for several days until finding a suitable area to settle, but very few larvae survive to settle and metamorphose into new colonies. The preponderance of asexual reproduction in this species raises the possibility that genetic diversity is very low in the remnant populations. This species has been documented in the study area on the narrow, discontinuous linear or fringing "reef" consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). DCH for this species occurs in outer Bar Channel cuts 1 and 2 at the entrance to San Juan Harbor.

Pillar Coral. Pillar coral (*Dendrogyra cylindrus*) colonies form numerous, heavy, cylindrical spires, that grow upwards from an encrusting base mass. The colonies can attain a height of 10 feet (3 m), with a pillar diameter of more than 4 inches (10 cm). Polyps are normally extended during the day, giving the colony a fuzzy appearance. This species was listed under the ESA as threatened on 10 October 2014. Colonies are typically found on flat gently sloping back reef and fore reef environment in depths of 3-82 feet (1-25 m). The species does not occur in extremely exposed locations. This species occurs in the Caribbean, the southern Gulf of Mexico, Florida, and the Bahamas. In addition, it has been documented in the study area on the narrow, discontinuous linear or fringing "reef" consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). NMFS has not yet proposed DCH for this species.

Rough Cactus Coral. Rough cactus coral (*Mycetophyllia ferox*) colonies consist of flat plates with radiating valleys. It is a widely recognized valid species with colonies comprised of thin, weakly attached plates with interconnecting, slightly sinuous, narrow valleys. Tentacles are generally absent and corallite centers tend to form single rows. The walls of the valleys commonly join to form closed valleys, a feature not seen in other members of *Mycetophyllia*. The ridges are usually small and square, with a groove on top. The ridges, or walls between valleys, are commonly quite thin, and are irregular, and valleys are narrower. This species was listed under the ESA as threatened on 10 October 2014.

This species is most common in fore reef environments from 5-30 meters (but is more abundant from 10-20 meters), but also occurs at low abundance in certain deeper back reef habitats and deep lagoons. This species occurs in the Caribbean, southern Gulf of Mexico, Florida, and the Bahamas. In addition, it has been documented in the study area on the narrow, discontinuous linear or fringing "reef" consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). NMFS has not yet proposed DCH for this species.

Lobed Star Coral. Lobed star coral (*Orbicella annularis*) colonies grow in several morphotypes that were originally described as separate species. The species occurs as long, thick columns with enlarged, dome-like tops; large, massive mounds; sheets with skirt-like edges; irregularly bumpy mounds and plates or as smooth plates. Colonies grow up to 10 feet (3 m) in diameter. The surface is covered with distinctive, often somewhat raised, corallites. This species was listed under the ESA as threatened on 10 October 2014.

Lobed star coral inhabits most reef environments and is often the predominant coral between 22-82 ft. (7-25 m). The flattened plates are most common at deeper reefs, down to 165 ft. (50 m). Common to Florida, Bahamas and Caribbean. In addition, it has been documented in the study area on the narrow, discontinuous linear or fringing “reef” consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). NMFS has not yet proposed DCH for this species.

Mountainous Star Coral. This species has been called the “dominant reef-building coral of the Atlantic” (Brainard et al 2011). *Orbicella faveolata* buds extratentacularly to form head or sheet colonies with corallites that are uniformly distributed and closely packed, but sometimes unevenly exsert. Septa are highly exsert, with septocostae arranged in a variably conspicuous fan system, and the skeleton is generally far less dense than those of its sibling species. Active growth is typically found at the edges of colonies, forming a smooth outline with many small polyps. This species was listed under the ESA as threatened on 10 October 2014.

Orbicella faveolata is found from 3-100 feet (1-30 m) in back-reef and fore-reef habitats, and is often the most abundant coral between 30-65 feet (10-20 m) in fore-reef environments. This species occurs in the Caribbean, the Gulf of Mexico, Florida, and the Bahamas. May also be present in Bermuda, but this requires confirmation. In addition, it has been documented in the study area on the narrow, discontinuous linear or fringing “reef” consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). NMFS has not yet proposed DCH for this species.

Boulder Star Coral. This species (*Orbicella franksi*) builds massive, encrusting plate or subcolumnar colonies via extratentacular budding. The characteristically bumpy appearance of this species is caused by relatively large, unevenly exsert, and irregularly distributed corallites. Boulder Star Coral is distinguished from its sibling *Orbicella* species by this irregular or bumpy appearance; a relatively dense, heavy, and hard skeleton (corallum); thicker septo-costae with a conspicuous septocostal midline row of lacerate teeth; and a greater degree of interspecies aggression. This species was listed under the ESA as threatened on 10 October 2014.

This species mostly grows in the open like other species of this genus but smaller, encrusting colonies are common in shaded overhangs. It is uncommon in very shallow water, but becomes common deeper. This species occurs in the Caribbean, the Gulf of Mexico, Florida, and the Bahamas. In addition, it has been documented in the study area on the narrow, discontinuous linear or fringing “reef” consisting of corals covering fossil sand dunes (i.e., eolianites) trending in an east-west direction and extending, in some sites, up to 0.9 miles off shore (CFMC, 2004; CSA Architects & Engineers, 2014; ERM, 2013; Glauco A. Rivera & Associates, 2011; Coll Rivera Environmental, 2005). NMFS has not yet proposed DCH for this species.

FUTURE WITHOUT-PROJECT CONDITION

In the future without-project condition, unabated shoreline storm erosion and sedimentation would continue to result in degraded water quality and effects to listed corals.

2.2.5.1.5 Puerto Rican Boa

EXISTING CONDITION

The Puerto Rican boa was listed as endangered in 1970 (35 FR 13519). It is the largest snake in Puerto Rico, averaging a length of 6 ½ feet. The color can be variable but typically ranges dark browns, grays, and blacks with a series of spots or black bars and a blackish belly. This boa is unique to Puerto Rico and is widespread in its distribution across the island. The species is abundant in protected and inaccessible areas. It can be found in a variety of habitats and is arboreal and terrestrial. Sub-adults and adults' diet consists of birds, small mammals, and lizards. The Puerto Rican boa is non-poisonous and generally harmless unless provoked. No DCH has been identified for the Puerto Rican boa. The Puerto Rican boa appears to be widely distributed throughout Puerto Rico and utilizes a wide variety of habitats, ranging from mature forest to plantations and disturbed areas (USFWS 2011). Gould et al. (2008) stated that the PR boa predicted habitat model includes the following land cover types: moist and wet forest, woodland and shrubland, mangrove, Pterocarpus, mature dry forest, and dry forest near water bodies, at or below 1,000 m of elevation. This species is more likely to occur in WSJB than Condado lagoon.

FUTURE WITHOUT-PROJECT CONDITION

In the FWOP/No Action Alternative, significant effects to Puerto Rican boa are not anticipated. While unabated shoreline erosion could negatively affect mangrove habitat, this resource could also increase in coverage under future SLR possibly increasing habitat for the boa.

2.2.6 BIRDS

EXISTING CONDITION

REACH 1 & 3 – WEST SAN JUAN BAY and CONDADO LAGOON

Various areas within West San Juan Bay and Condado lagoon are utilized by many species of birds for nesting and feeding. According to the Puerto Rico Breeding Bird Atlas (<http://www.aosbirds.org/prbba/Puerto%20Rico%20Status.html>), about 58 species of birds are found within the San Juan Bay area, 44 of which are sea birds, waterfowl or wading birds that utilize the shallows, wetlands and open water of San Juan Bay. The brown pelican (*Pelecanus occidentalis*) is a permanent resident in the bay. Pelicans feed throughout the bay but prefer the calm waters behind the Esperanza peninsula and mangrove lined shores. Numerous gulls, terns, and frigate birds also use the Esperanza peninsula and sheltered waters behind it for roosting and feeding (USFWS 2017).

FUTURE WITHOUT-PROJECT CONDITION

Without the proposed CSR measures adverse impacts to bird habitat from unabated shoreline erosion and sedimentation could occur. Mangroves could out compete and replace existing WSJB palustrine emergent wetlands with future SLR. This could affect bird assemblages in the area due to loss of habitat.

2.2.7 INVASIVE SPECIES

EXISTING CONDITION

REACH 1 & 3 – WEST SAN JUAN BAY and CONDADO LAGOON

Invasive species can adversely impact native plant and animal populations by disrupting natural ecosystem functions. Islands have long been considered to be particularly vulnerable to biotic invasions. The 1,032 species of alien plants reported for Puerto Rico and Virgin Islands (PRVI) represent about a third of total plant diversity on these islands (DRNA 2015). Some aquatic invasive species that may occur in the project area or in the area of influence include:

- Freshwater Plants
 - *Phragmites australis* (Common reed)
 - *Melaleuca quinquenervia* (Bottlebrush tree)
- Freshwater Animals
 - *Iguana iguana* (Green iguana)
 - *Cherax quadricarinatus* (Australian red claw crawfish)
- Marine/Estuarine Animals
 - *Pterois volitans* (Red lionfish)
 - *Oreochromis aureus* (Blue tilapia)
 - *Petrolisthes armatus* (Green porcelain crab)
 - *Perna viridis* (Asian green mussel)
 - *Phyllorhiza punctata* (Australian spotted jellyfish)
- Marine/Estuarine Plants
 - *Halophila stipulacea* (Mediterranean seagrass)

Species can be introduced by a variety of different mechanisms; however, most estuarine and marine species introductions are associated with shipping (Ruiz et al. 2000). Commercial shipping is the only direct mechanism related to this project. Presently, the largest single source of shipping-related introductions is ballast water (Carlton 1985, Lavoie et al. 1999). Ballast water is pumped into the hull of a vessel to stabilize the vessel and keep it upright while carrying cargo. This water can be discharged at the receiving port as the cargo is loaded or unloaded. Each vessel may take on and discharge millions of gallons of water. Ballast water taken on in foreign ports may include an abundance of aquatic plants, animals, and pathogens not native to Puerto Rico. If discharged into state waters, these foreign species may become problematic.

In addition to ballast water discharge, another important source for the introduction of nonindigenous organisms is the fouling community that grows on the hull, rudder, propellers, anchor, anchor chain, or any other submerged structure of vessels that are not properly cleaned or maintained. Historically, such fouling communities were composed of massive layers of a variety of organisms, both attached and merely entrained in or living on that growth. Although such extensive growth is not as common on seagoing vessels in recent times, it still provides an opportunity for worldwide transport of fouling organisms, particularly on towed barges and other structures like mothballed ships and exploratory drilling platforms.

FUTURE WITHOUT-PROJECT CONDITION

In the future without-project condition, the potential will continue to exist for introduction of invasive species. Recent Federal regulations require the shipping industry to implement better controls to prevent the introduction of invasive species through the ballasts of vessels (USCG 2012). These regulations should decrease the rate at which invasive species are introduced to the study area. The USCG will continue to monitor, enforce, and revise regulations related to the discharge of ballast water while vessels are in port according to the USCG Ballast Water Management Final Rule Published 23 March 2012.

2.2.8 AIR QUALITY

EXISTING CONDITION

REACH 1 & 3 – WEST SAN JUAN BAY and CONDADO LAGOON

Puerto Rico is a United States territory with commonwealth status. The USEPA, Region 2 and the Puerto Rico EQB regulate air quality in Puerto Rico. The Clean Air Act (CAA) gives USEPA the responsibility to establish the primary and secondary National Ambient Air Quality Standards (NAAQS) that set acceptable concentration levels for seven criteria pollutants: particulate matter, fine particulate matter, sulfur dioxide, carbon monoxide, nitrous oxides, ozone, and lead. Short-term standards (1, 8, and 24-hour periods) have been established for pollutants contributing to acute health effects, while long-term standards (annual averages) have been established for pollutants contributing to chronic health effects. On the basis of the severity of the pollution problem, nonattainment areas are categorized as marginal, moderate, serious, severe, or extreme. Each state has the authority to adopt stricter standards; however Puerto Rico has accepted the United States Federal Standards. USEPA regulations designate Air-Quality Control Regions (AQCRs) in violation of the NAAQS as nonattainment areas. USEPA regulations designate AQCRs with levels below the NAAQS as attainment areas. Maintenance AQCRs are areas previously designated nonattainment areas that have subsequently been designated attainment areas for a probationary period through implementation of maintenance plans.

West San Juan Bay and Condado Lagoon are located within the Puerto Rico AQCR which is comprised of the entire Commonwealth of Puerto Rico, including Vieques, Culebra, and surrounding islands (40CFR§81.77). Puerto Rico has adopted the NAAQS established by the USEPA and has developed a State Implementation Plan under the CAA that incorporates permitting and regulatory requirements for stationary and mobile sources of air pollution. All areas within the AQCR are in attainment or unclassifiable (due to lack of data) for NAAQS for the following criteria pollutants: ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{2.5}, and lead (USEPA 2008).

Due to their locations, West San Juan Bay and Condado Lagoon experience nearly constant on-shore trade winds and sea breezes. These areas are surrounded by the municipalities of San Juan, Guaynabo, and Cataño. Non-compliance was due to pollution from power plants, industrial facilities, motor vehicles, and major San Juan emitters. In 2010 the municipality of Guaynabo became compliant air quality standards. In 2011 USEPA provided a grant to the Polytechnic University of Puerto Rico in the amount of \$886,095 to install pollution-reduction technology on 72 heavy-duty trucks and replace 10 old heavy-duty trucks with 2010 or newer lower emissions diesel trucks in the Port of San Juan. These upgrades reduced the air emissions of fine particles (particulate matter, (PM)), nitrogen oxides (NO_x), and carbon monoxide from

diesel engines operating in the port. The municipality of Guaynabo is identified as being in moderate non-attainment of the NAAQS for particulate matter with a diameter of 10 micrometers or less (USEPA 2008).

The PREPA owns and operates two power plants in the vicinity. The San Juan Power Plant located in the area of the bay and the Palo Seco Power Plant located in Cataño just outside the entrance of the Bay. In order to comply with upcoming Mercury and Air Toxics Standards (MATS) administered by the USEPA and to reduce cost of electricity production in Puerto Rico, PREPA is preparing to convert a number of the power generation units at its San Juan and Palo Seco Power Plants to burn natural gas as the primary fuel instead of Bunker C and Diesel (No. 6 and No. 2 type) fuel oil.

FUTURE WITHOUT-PROJECT CONDITION

If no-action were taken, no change to the existing air quality would be expected. Ambient air quality conditions in San Juan bay would more than likely remain the same.

2.2.9 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

EXISTING CONDITION

REACH 1&3 – WEST SAN JUAN BAY and CONDADO LAGOON

West San Juan Bay and Condado Lagoon are highly developed. All of the major port storage facilities have confinement areas sufficient to contain any spills and no hazardous or toxic materials or waste have been identified within the project footprint. No hazardous, toxic, or radioactive waste has been encountered or released in the project area. Sediments from the bay typically have traces of heavy metals, Polychlorinated biphenyls (PCBs), pesticides, Polycyclic Aromatic Hydrocarbons (PAHs), and petroleum products, at low levels that do not affect the sediment quality or the water quality of the bay.

FUTURE WITHOUT-PROJECT CONDITION

No significant effects to or from hazardous and toxic materials are anticipated from the FWOP condition.

2.2.10 NOISE

EXISTING CONDITION

REACH 1 & 3 – WEST SAN JUAN BAY and CONDADO LAGOON

Noise is often defined as any sound that is undesirable because it interferes with communication, is intense enough to damage hearing, diminishes the quality of the environment, or is otherwise annoying. Response to noise varies by the type and characteristics of the noise source; distance from the source; receptor sensitivity, and time of day. Noise can be intermittent or continuous, steady or impulsive, and it may be generated by stationary or mobile sources. Noise is described by a weighted sound intensity (or level), which represents sound heard by the human ear and is measured in units called decibels (dB). The potential impacts of underwater sounds associated with dredging operations have come under increasing scrutiny by regulatory agencies.

San Juan bay has functioned as an international harbor since pre-colonial times. Over the last 300 years, San Juan Harbor has evolved to accommodate the growing shipping industry as larger vessels continued to arrive. At the same time, recreational and other commercial boat traffic and industrial noise has continued to increase. Several sources of ambient noise are present in San Juan bay. The ambient noise level of an area includes sounds from both natural (wind waves, fish, tidal currents, mammals) and artificial (commercial and recreational vessels, dredging, pile driving, etc.) sources. Tidal currents produce hydrodynamic sounds, which are most significant at very low frequencies (< 100 Hz). Vessel traffic, including vessels passing the immediate study area, generate sounds that can travel considerable distances, in frequencies ranging from 10 to 1000Hz. Sea state (surface condition of the water characterized by wave height, period, and power) also produces ambient sounds above 500 Hz. As a commercial and industrial area, San Juan bay experiences a wide range of noise from a variety of industrial activities. Biological sounds associated with mammals, fishes, and invertebrates can also generate broadband noise in the frequency of 1 to 10 kHz with intensities as high as 60 to 90 dB.

San Juan Harbor has the typical noise characteristics of a busy harbor including recreational and commercial vessel traffic, dredging vessels and dock side facilities. Noise sources for vessels include cranes, whistles and various motors for propulsion. Dockside noise sources include cranes, trucks, cars, and loading and unloading equipment. In addition to the noise in the water/marine environment, noise can impact the human environment. Background noise exposures change during the course of the day in a gradual manner, which reflects the addition and subtraction of distant noise sources. Ambient noise represents the combination of all sound within a given environment at a specified time. Humans hear sound from 0-140 dB. Sound above this level is associated with pain.

High intensity sounds can permanently damage fish hearing (Nightingale and Simenstad 2001). These sounds have been documented to be continuous and low frequencies (< 1000 Hz) and are within the audible range of listed species of both whales (7Hz–22 kHz) and sea turtles (100-1000Hz) (Clarke et al. 2002).

Noise has been documented to influence fish behavior. Fish detect and respond to sound by utilizing cues to hunt for prey, avoid predators, and for social interaction. Fish produce sound when swimming, mating, or fighting and also noise associated with swimming. Fish use a wide range of mechanisms for sound production, including scraping structures against one another, vibrating muscles, and a variety of other methods. Sounds produced by spawning fishes, such as sciaenids, are sufficiently loud and characteristic for them to be used by humans to locate spawning locations.

Relative to exposure to anthropogenic noise, NOAA guidelines define two levels of harassment for marine mammals: Level A based on a temporary threshold shift (190 dB for pinnipeds and 180 dB for cetaceans), and Level B harassment with the potential to disturb a marine mammal in the wild by causing disruption to behavioral patterns such as migration, breeding, feeding, and sheltering (160 dB for impulse noise such as pile driving and 120 dB for continuous noise such as vessel thrusters) (<http://www.nwr.noaa.gov/Marine-Mammals/MM-sound-thrshld.cfm>). According to Richardson et al. (1995) the following noise levels could be detrimental to marine mammals: Prolonged exposure of 140 dB re 1 μ Pa/m (continuous man-made noise), at 1 km can cause permanent hearing loss. Prolonged exposure of 195 to 225 dB re 1 μ Pa/m (intermittent noise), at a few meters or tens of meters, can cause immediate hearing damage.

At the time this document was prepared, NOAA had released a draft report that provides guidance for assessing the effects of anthropogenic sound on marine mammal species under the jurisdiction of NMFS (NOAA 2013). The guidance will replace the current thresholds used by NOAA and described above. NOAA compiled, interpreted, and synthesized best available science to update the threshold levels for temporary and permanent hearing threshold shifts. Different target species for protection have widely divergent tolerance levels for sounds (owing to different hearing sensitivities, hearing integration times, etc.). Due to the complexity and variability of marine mammal behavioral responses, NOAA will continue to work over the next years on developing additional guidance regarding the effects of anthropogenic sound on marine mammal behavior (<http://www.nmfs.noaa.gov/pr/acoustics/guidelines.htm>).

FUTURE WITHOUT-PROJECT CONDITION

San Juan bay is within an urban setting and noises related to recreational and commercial vessel traffic, dredging vessels, and dock side facilities would continue similar to the existing conditions.

2.2.11 COASTAL BARRIER RESOURCES

EXISTING CONDITION

REACH 1 & 3 – WEST SAN JUAN BAY and CONDADO LAGOON

The Coastal Barrier Resources Act (CBRA) was enacted by Congress in 1982. The CBRA was implemented to prevent development of coastal barriers that provide quality habitat for migratory birds and other wildlife and spawning, nursery, nesting, and feeding grounds for a variety of commercially and recreationally important species of finfish and shellfish. As a deterrent to development, Federal insurance is not available for property within designated high-hazard areas. These high-hazard areas are called Coastal Barrier Resources System (CBRS) units.

CBRS units are areas of fragile, high-risk, and ecologically sensitive coastal barriers. Development conducted in these areas is ineligible for both direct and indirect Federal expenditures and financial assistance. Along with CBRS units are otherwise protected areas (OPAs). OPAs are national, state, or local areas that include coastal barriers that are held for conservation or recreation. The only Federal funding prohibition within OPAs is Federal flood insurance.

There are three CBRS units located near San Juan bay, PR-87 Punta Vacía Talega and PR-87P Punta Vacía Talega OPA approximately 13-19 km east and PR-86P Punta Salinas OPA approximately 6 km west (Figure 2-10).

FUTURE WITHOUT-PROJECT CONDITION

The CBRS units and OPAs will continue to be protected from development without a project pending no changes in the current regulations.

Figure 2-5. West San Juan Bay and Condado Lagoon Vicinity Coastal Barrier Resource System Units.

2.2.12 CULTURAL AND HISTORIC RESOURCES

EXISTING CONDITION

Cultural resources are defined by the National Historic Preservation Act (54 U.S.C. §300101 *et. seq*) (NHPA) as prehistoric and historic sites, structures, districts, or any other physical evidence of human activity considered important to a culture, a subculture, or a community for scientific, traditional, religious, or any other reason. Several Federal laws and regulations protect these resources, including the NHPA of 1966, the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. §§469-469c), and the Archaeological Resources Protection Act of 1979 (16 U.S.C. §§470aa-470mm). Additionally, NEPA requires that Federal agencies consider the “unique characteristics of the geographic area such as proximity to historic or cultural resources” (40 CFR 1508.27(b)(3)) and “the degree to which the [proposed] action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places” (40 CFR 1508.27(b)(8)). Documentation of historic properties and cultural resources is important for this project, as San Juan is central to the history of not just Puerto Rico, but also the Caribbean and world events. The area is rich in precolonial and historic human activity, with the potential for significant resources from the last several thousand years.

The analysis of impacts to cultural resources relies on existing information primarily from documents prepared by the Puerto Rico State Historic Preservation Officer (SHPO), GIS data of resources from SHPO, and properties listed in the National Register of Historic Places. The Area of Potential Effects (APE) for cultural resources extends beyond the study area and is defined as the areas where structural measures are implemented and non-structural measures are applied to historic properties as defined in 36 C.F.R. §800.16(l). An effect is an alteration to the characteristics of a historic property qualifying it for inclusion in or eligibility for the NRHP (36 CFR 800.16(i)). Effects may be direct or indirect. Examples of effects include visual intrusions, alterations of setting, noise, vibrations, viewsheds, and physical impacts. Indirect effects may occur where the actions enable other effects, which may be later in time or removed by distance. These may include increased development or changes in landuse that may reasonably be associated with an action.

Section 106 of the NHPA and its implementing regulations, 36 CFR Part 800, requires an assessment of the potential impact of an undertaking on historic properties that are within the proposed project's area of potential effect (APE), which is defined as the geographic area(s) "within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist" (36 CFR 800.16(d)). The APE for the direct impacts for the proposed project includes the areas where ground disturbing activities would occur, including construction and staging areas. Direct impacts associated with the proposed project includes locations where the broader character or use of an areas could be impacted by the proposed project features, such as by changing viewsheds or access points.

The proposed project reaches surround San Juan Harbor and Condado Lagoon, and are historically linked to San Juan. San Juan has been a significant port dating back to the end of the fifteenth century and the European exploration and settlement of the New World. Christopher Columbus landed on the west coast of Puerto Rico at Boquerón Bay in 1493, naming the area San Juan Bautista. At this time, the indigenous population measured approximately 60,000 people, a group modern archaeologists refer to as Taíno. Spanish colonization of the island did not occur until 1508 when Juan Ponce de León established a permanent settlement with the permission of the Taíno chiefdom of Guainía (Jiméz de Wagenheim 1998). The first settlement, Caparra, is located in Guaynabo, south of the reaches of the proposed project. The port serving Caparra is thought to be located within the reaches of the proposed project, beneath the current port facilities.

Ponce de León also explored the northern coast of the island and established *Puerto Rico* (Rich Port) at present day San Juan to export the island's gold. The Spanish subjection and maltreatment of the indigenous population led to a Taíno revolt in 1511. However, due to military subjugation, disease, and abuse from the Spanish, the native population was reduced by 75 percent in 1515. In order to replace the native workforce of the island's gold mines, the Spanish began importing enslaved Africans and indigenous people from nearby islands (Jiméz de Wagenheim 1998).

By 1521, the islet adjacent to *Puerto Rico* became the central Spanish settlement of San Juan and the island itself had come to be called Puerto Rico. Through the second half of the sixteenth century, San Juan became increasingly strategic for the export of sugarcane and ginger, and as a military outpost for Spain's colonial empire. In order to reinforce the military defenses of Puerto Rico, the Santa Catalina fortress (present-day *La Fortaleza*) was built and construction began on *El Morro* Castle. The city was fortified well enough to rebuke the attack of Sir Francis Drake in 1595. George Clifford, 3rd Earl of Cumberland, attacked and took the city in 1598; however, Spanish forces arrived shortly to rescue the island from the British. In 1625 Dutch forces attacked the city of San Juan, but the Spanish repelled the forces from *El Morro*. After this attack, the Spanish began improving their waterside fortifications, including the initial construction of the City Wall in 1634 (Krivor 2017).

During the eighteenth century, the ruling Bourbon court introduced trade and administrative reforms that stimulated agricultural development, military improvements, and population growth (Jiméz de Wagenheim 1998). City fortifications, including walls and moats, were constructed between 1789 and 1798. *El Morro* was expanded and updated to defend San Juan against warships during this period, and was successfully utilized to resist a British naval invasion in 1797 (Giusti 2014).

During the beginning of the nineteenth century, Spain loosened its grip on Puerto Rico resulting in increased trade with foreign nations. Native Puerto Ricans (*Criollos*) sought political autonomy and gradually transformed the island to a sugarcane and coffee plantation-based economy (Jiméz de

Wagenheim 1998). As Puerto Rico engaged in the global economy, San Juan was the center of economic development. The growth was not universal, as the droughts and disease led to the dissolution of the historic Guaynabo municipality in 1875. During the nineteenth century, Cataño was established as a shipping hub. The village originally stretched along the shoreline, with transports connecting the south shore of the harbor with San Juan. The remainder of the shoreline remained primarily mangroves.

The Spanish American War led to changes in the area of the proposed project. The San Juan region experienced rapid development after the Spanish American War ended in July 1898 with the cession of Puerto Rico to the United States (Acosta 2014) and the subsequent collapse of the sugar industry. USACE and the San Juan Harbor Board engaged in multiple projects worked to improve the harbor, using dredged material to create land in the project reaches.

In 1940, the U.S. Army established a terminal along the southern shore of San Juan Harbor. The area to the east was then filled in the 1950s, creating Puerto Nuevo. During the twentieth century, much of the surrounding area of the proposed project saw considerable development. The southern shore of Condado Lagoon, long the location of a major transportation route, developed as a primary land route into San Juan. During the nineteenth and twentieth century this area was developed as San Juan grew, going from what was once the edge of the city into its current fully-urbanized form.

Previous efforts to identify cultural resources have documented archaeological sites, historic structures, and historic districts near the proposed project alternatives. The data for Cataño include few resources. The review of resources and investigations in the municipio conducted by the State Historic Preservation Office (SHPO) in 2016 found only four resources, but noted one is listed on the National Register of Historic Places (NRHP) (OECH 2016). All four of the recorded resources are located near alternatives considered in this study.

Two resources are located near the Caño Aguas Frias. The archaeological site Ruinas Hacienda Palmas (CN0100001) is the remains of a 1843 hacienda that produced sugar. This surrounding fields were used for sugar cane, and the hacienda had a mill and other related structures. No evidence of the archaeological site was seen during a field reconnaissance of the mapped location of this resource, with the area noted as being a highly disturbed transmission line corridor. Los Tendales de Hacienda Palmas (CN0100002) does not have a formal report on file, but is recorded as a historic archaeological site. Neither of these sites has been found eligible for listing in the NRHP.

Primera Iglesia Evangélica Luterana (CN0200002) is located in eastern Cataño, south of San Juan Harbor. This church was constructed in 1917, and was designated a historic landmark by the Puerto Rican legislature in 2004. The Distrito Destilería Bacardí (CN0200001) is a historic district listed in the NRHP (entry 10000524). These are the grounds of the Bacardi rum distillery, the largest rum distillery in the world. It has operated since 1947, with various supporting structures constructed during subsequent years. The significance of this resource comes from its association with Puerto Rican economic, cultural, and social development, with Streamline Moderne and Art Deco architecture.

In the portions of the project within Guaynabo, no previous resources have been documented. This may be attributed to the disturbed nature of much of area associated with fill events along the coast, though the evidence left behind by historic terraforming activities to create the port infrastructure may now be considered archaeological site, and may have buried archaeological sites.

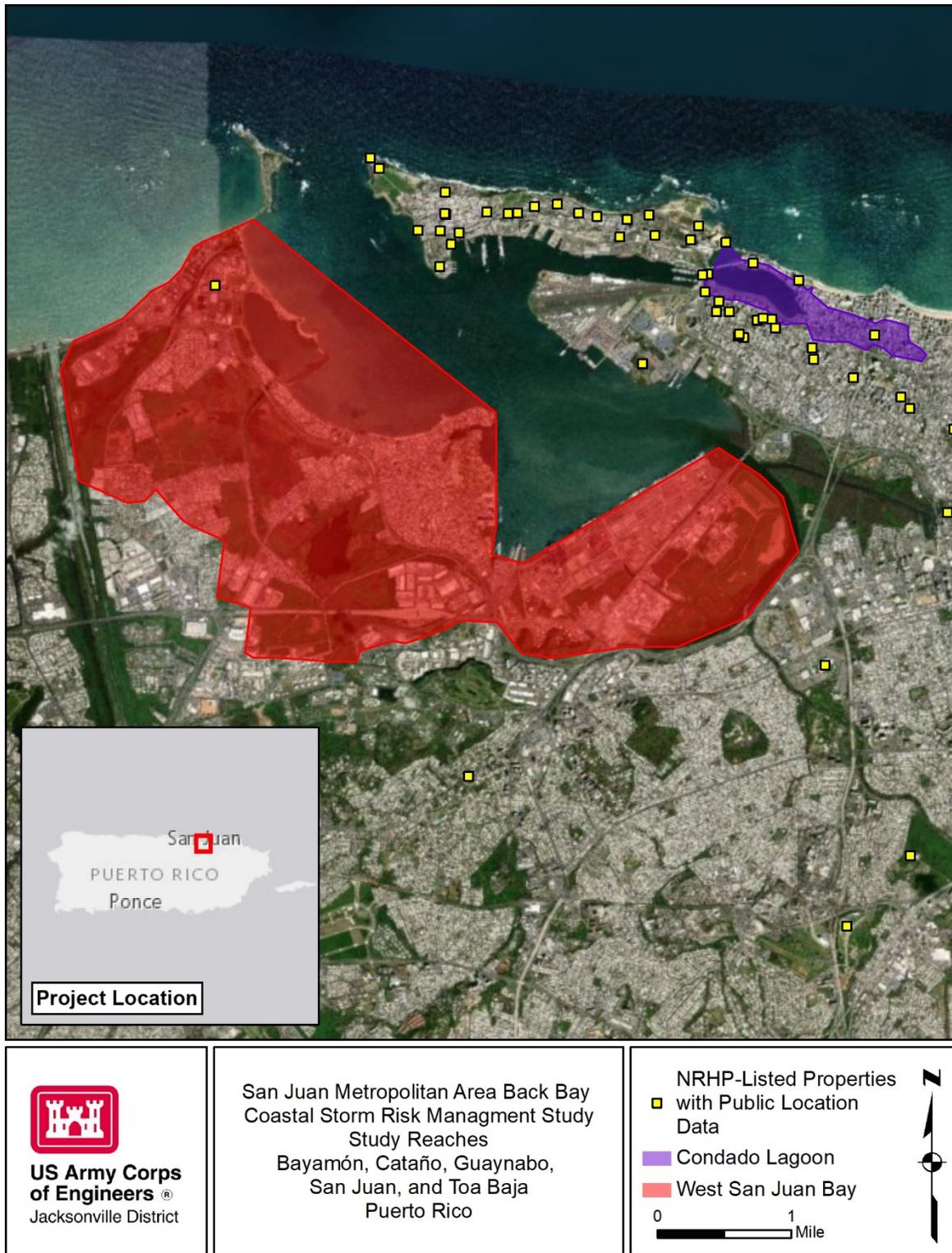
Within the portions of the project alternatives in San Juan Municipio, there are a number of resources buildings and structures located around the Condado Lagoon. At the western end of the lagoon, there are two recorded historic properties. These are a bridge across the Caño San Antonio and the terminus of the historic advanced defense line for San Juan. The NRHP-listed San Antonio Railroad Bridge is the former railroad bridge crossing from the mainland onto San Juan islet, later converted into a pedestrian bridge (entry 09000789). As part of the NRHP-listed Línea Avanzada (SJ0100013, NRHP entry 97001136), a remnant bridgehead is recorded east of the railroad bridge on the north side of the Caño, marking the end of fortifications. Both of these resources are over 200 meters from the proposed project. Near the southern terminus of the bridges from San Juan islet to Santurce, archaeological site SJ-5 (SJ0100005) has been recorded as a prehistoric shell midden.

Additional historic structures have been recorded in the Miramar area, though all well away from the southern coast where the project features are proposed. The closest, Asilo de Niñas de Miramar (NRHP entry 85002908) is located over 100 meters inland. The first row of structures facing the southern edge of lagoon have not been recorded in the databases reviewed by the USACE. Along the northern shore, there are two NRHP-listed structures. The Hotel Condado Vanderbilt (SJ0200057, NRHP entry 08001110) is a significant structure related to the development of the tourism industry in Puerto Rico constructed in 1919. The Edificio Miami (SJ0200038, NRHP entry 84003169) is an art deco building from 1936 that was the first private apartment building constructed in the Santurce area, and possibly the first apartment building constructed in Puerto Rico.

FUTURE WITHOUT-PROJECT CONDITION

Without a project the extensive cultural and historic resources of the San Juan metropolitan area would continue to be protected under several Federal laws and regulations similar to the existing conditions descriptions. Existing revetments and sea walls will continue to protect historic properties from erosional effects, though the vulnerabilities to coastal storms documented in this report may not be mitigated.

Figure 2-6. NRHP properties in the vicinity of the tentatively selected plan (archaeological sites not depicted due to the sensitivity of information).



2.2.13 AESTHETICS AND RECREATION

EXISTING CONDITION

Aesthetic resources are perhaps more difficult to define than aesthetics itself. USEPA (1973) stated the following:

“A. G. Alexander Baumgarten (1714-62) is credited with coining the word AESTHETIC, in his work *Aesthetica* (dated 1750), to denote "that branch of science which deals with beauty" (Klien, 1966). Like beauty, then, the word has no clear and agreed-on definition that is operative--it remains a term that designates a vague concept...”

In the context of large infrastructure projects, aesthetics generally involves personal and subjective evaluations of the acceptability of visual scenes. The subject is often approached in terms of a “viewshed”, which is the scene of the proposed project and consequences as viewed from various locations. Since the project involves a large landscape, this section will be addressed from a regional San Juan Harbor aspect. San Juan Harbor is a historic seaport, and has been associated with vessels of increasing size for hundreds of years. A scenic setting is provided by the harbor and river and the numerous vessels common to these waters, including commercial and recreational boats as well as vessels calling on the Port. The estuarine environment provides opportunities for boating and fishing, as well as an escape from the faster pace of land-based activities. Several boat ramps and marinas are located in San Juan bay. The project is situated in an urban/commercial setting.

FUTURE WITHOUT-PROJECT CONDITION

In the FWOP condition/No Action Alternative, one potential effect could be storm erosion and sedimentation around WSJB and CL which could continue to affect local aesthetics. These include roadways and railways, infrastructure, vehicular traffic, industrial complexes, residential structures and hotels/tourist district (Condado Lagoon).

2.2.14 EXISTING PROJECTS

EXISTING CONDITIONS

Refer to the graphic executive summary for the general location of these projects with respect to the study area. See Chapter 1 for descriptions of each project.

- Caño Martín Peña Ecosystem Restoration Project
- Rio Puerto Nuevo Flood Control Project
- San Juan Harbor, Puerto Rico Project
- San Juan Harbor Federal Navigation Project Under Section 1135 for Work at La Esperanza Peninsula

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

These projects will continue to function and operate as intended. However, increased sea level change could exacerbate coastal flooding in areas adjacent to these projects.

2.3 PHYSICAL ENVIRONMENT (CONDITIONS)

2.3.1 STORM SURGE INTERACTIONS WITHIN THE PHYSICAL ENVIRONMENT

This study assesses coastal flooding risks due to storm surge, which also includes wave contributions and tidal influences, as well as sea level change. The section below describe existing physical conditions and expected future conditions, in absence of a project. It is a general excerpt of the more detailed descriptions, which can be found in **Appendix A, Engineering**.

2.3.1.1 STORM EFFECTS

EXISTING CONDITIONS

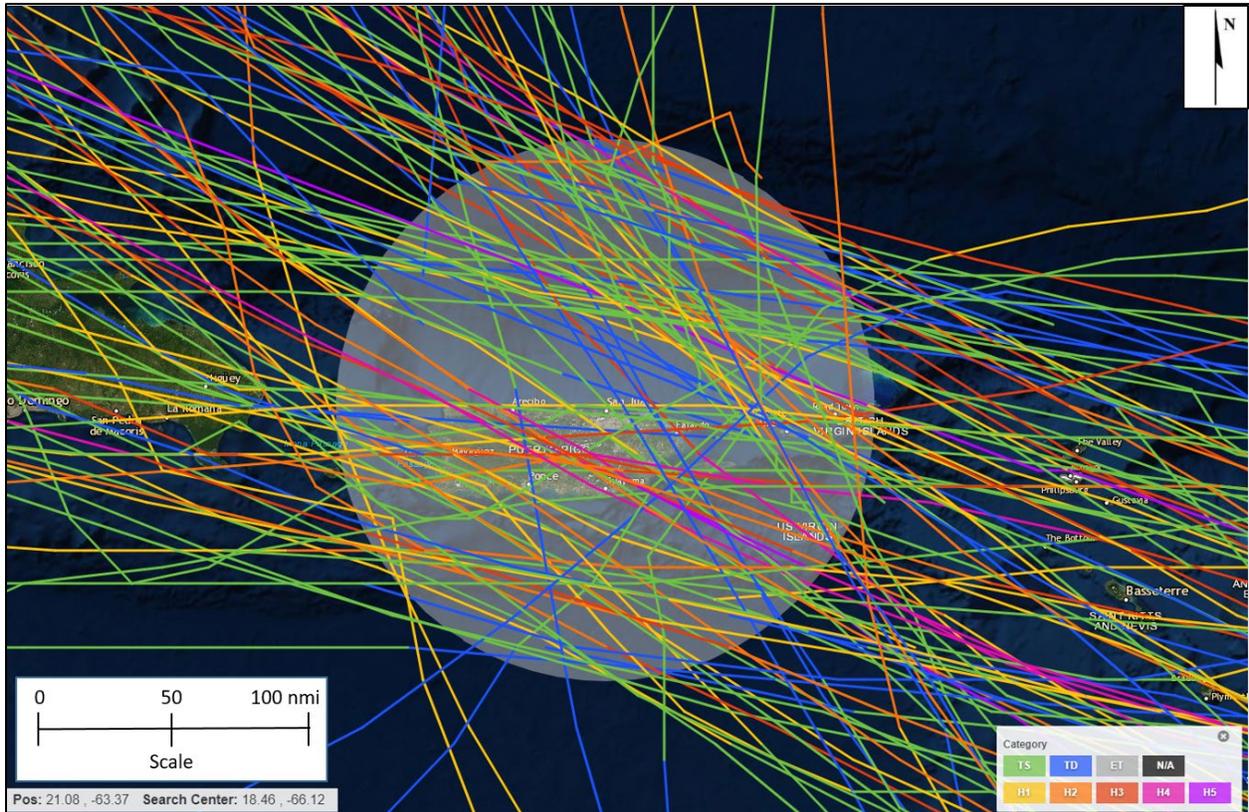
The backbay portion of the San Juan Metro Area is influenced by tropical systems generally during the summer and fall and by northeasters during the late fall, winter, and spring. Although hurricanes typically generate larger waves and storm surge, northeasters can have a greater cumulative impact on the area due to longer storm duration and greater frequency of event occurrence. Periodic and unpredictable hurricanes and coastal storms, with their intense breaking waves and elevated water levels, can cause significant damage to the shoreline and backbay infrastructure.

San Juan Metro is located in an area of significant storm activity. **Figure 2-7** shows historic tracks of hurricanes and tropical storms from 1851 to 2019 as recorded by the National Hurricane Center (NHC). These hurricane data are available from NOAA (<https://oceanservice.noaa.gov/news/historical-hurricanes/>). The shaded circle in the center of this figure indicates a 100-nautical mile radius drawn from the center of the study area (San Juan). Based on NHC records, 119 tropical storms have passed within this 100-mile radius over the 169-year period of record. The 100-mile radius was chosen for display purposes because a tropical disturbance passing within this distance would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.). The shaded circle in the center of this figure indicates a 100-nautical mile radius drawn from the center of the study area (San Juan). Based on NHC records, 119 tropical storms have passed within this 100-mile radius over the 169-year period of record. The 100-mile radius was chosen for display purposes because a tropical disturbance passing within this distance would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.). The shaded circle in the center of this figure indicates a 100-nautical mile radius drawn from the center of the study area (San Juan). Based on NHC records, 119 tropical storms have passed within this 100-mile radius over the 169-year period of record. The 100-mile radius was chosen for display purposes because a tropical disturbance passing within this distance would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.). The shaded circle in the center of this figure indicates a 100-nautical mile radius drawn from the center of the study area (San Juan). Based on NHC records, 119 tropical storms have passed within this 100-mile radius over the 169-year period of record. The 100-mile radius was chosen for display purposes because a tropical disturbance passing within this distance would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.).

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In recent years, a number of named storms have significantly impacted the study area including Hugo (1989), Georges (1998), Maria (2017), Irma (2017), and extra-tropical storm Riley (2018). Damages from these storms, as well as from more distant storms causing indirect impacts, included damage from winds, waves, and elevated water levels.

Figure 2-7. Historic Tropical Storm Tracks (1851-2019, 100-mile radius).



FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

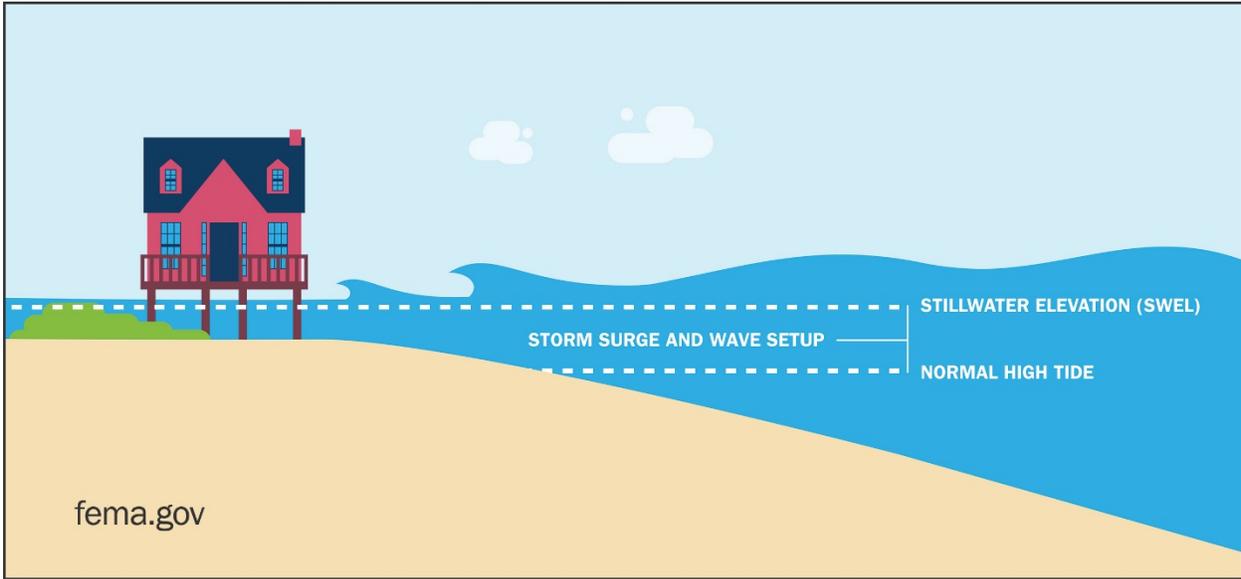
Storms would be expected to generally continue similar patterns as in the existing conditions. Storm surge, as a result of hurricanes and storms, would continue to cause damages in the San Juan Metro Area.

2.3.1.2 STORM SURGE EFFECTS

EXISTING CONDITIONS

Storm surge is defined as the rise of the ocean surface above its astronomical tide level due to storm forces. Surges occur primarily as a result of atmospheric pressure gradients and surface stresses created by wind blowing over a water surface. Strong onshore winds pile up water near the shoreline, resulting in super-elevated water levels along the coastal region and inland waterways. In addition, the lower atmospheric pressure which accompanies storms also contributes to a rise in water surface elevation. Extremely high wind velocities coupled with low barometric pressures (such as those experienced in tropical storms, hurricanes, and very strong northeasters) can produce very high, damaging water levels. In addition to wind speed, direction, and duration storm surge is also influenced by water depth, length of fetch (distance over water), wave setup, and frictional characteristics of the nearshore sea bottom. An increase in water depth may increase the potential for coastal flooding and allow larger storm waves to attack the shore. **Figure 2-8** shows a general graphic depicting storm surge.

Figure 2-8. Generalized graphic showing storm surge influences.



The annual exceedance probability (AEP) is the probability of occurrence of an event within any given year. The AEP for storm surge events can provide insight into the vulnerabilities of a given location through the comparison of flooding caused by the event with the existing topography of an area. **Table 2-3** provides the peak storm surge heights of standard AEP events for the San Juan Metro area, and include the effects of astronomical high tide and wave setup. The table displays AEP events from FEMA, which illustrates significantly larger elevations, for events equal to or greater than the 2% AEP, compared to the same NOAA events. The NOAA gauge at San Juan, PR (9755371) shows lower elevations for events equal to or

above a 2% AEP event because the period of record (approximately 42 years) is too small; indicating additional recorded data is needed to accurately represent the larger events.

Table 2-3. FEMA and NOAA Peak Storm Tide Elevations.

Annual Exceedance Probability (AEP)	NOAA Peak Storm Surge Height (ft-PRVD02)*	FEMA Peak Storm Surge Height (ft-PRVD02)
0.200	1.79	0.85
0.100	1.90	1.87
0.020	2.29	3.94
0.010	2.49	4.92
0.004	-	6.43
0.002	-	7.71

*AEP developed from 1983 to 2001

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

It could be possible that the historical NOAA water levels from the past will occur in the future, although this may underestimate the risk. In order to account for this uncertainty, stronger storms that may not have occurred on record in the study area but could plausibly occur in the future were generated synthetically using FEMA data, and are included in the storm suite used to model FWOP damages.

2.3.1.3 WAVES

EXISTING CONDITIONS

The wave energy dissipation that occurs as waves break onto coastal structures can be a principal cause of infrastructure damage. Wave height, period, and direction, in combination with tides and storm surge, are the most important factors influencing the behavior of the shoreline. The San Juan Metro study area is exposed predominantly to short period wind-waves with periodic exposure to longer period storm swells within certain portions of the study area. However, the majority of the back bay study area is protected by Isla de Cabras and Old San Juan land masses fronting the Atlantic Ocean, which dissipate most of the ocean-driven waves. The remaining wind-driven waves within the San Juan Bay and ocean-driven waves, through the San Juan Bay Inlet, are generally depth limited as they approach the shoreline, thus limiting the size and associated period of the waves.

In the Cataño area, the wind-driven waves within the San Juan Bay and ocean-driven waves through the San Juan Bay Inlet are generally depth limited as they approach the shoreline, limiting the wave height waves. Periodic damage to upland development, within specific portions of the backbay shoreline, is partially attributable to large storm waves produced primarily by northeasters during the late fall, winter, and early spring months and tropical disturbances, including hurricanes, during the summer months. Storm passage (northeasters and tropical storms) is frequent for the study area; even without landfall, a storm system passing within several hundred miles may cause increased waves that can impact the area.

Wave data for this report were obtained from the USACE Wave information Studies (WIS) hindcast database for the Atlantic Ocean, WIS station 61019. Given the deep depth at this station (11,733 feet), wave conditions at 61019 are considered to be representative of the general study area but do not accurately represent nearshore wave conditions within the San Juan Bay.

Average wave heights range from 5.9 feet to 9.6 feet (based on WIS Station #61019 from 1980-2014), indicating a moderate wave climate year round. Wave directions are generally from the east and northeast quadrants. A seasonal breakdown of wave heights shows that higher wave heights are more frequent in the late fall, winter, and early spring months (March through November) and tend to originate from the northeast and east quadrant equally. These larger wave heights can be attributed to the northeasters occurring along the east coast of North America inherently driving larger waves southeast towards the study area. Late spring, summer, and early fall waves (April through October), are smaller and originate predominantly from the east.

Long period, storm-generated swells are common throughout the year. The late fall, winter, and spring months (November to April) have slightly larger periods indicating the influence of Northeasters throughout this time period.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Waves would be expected to generally continue similar patterns as in the existing conditions. The Cataño shoreline in particular would continue to experience damages from waves, and wave contributions to storm surge would continue to cause damages in the San Juan Metro Area.

2.3.1.4 ASTRONOMICAL TIDES & CURRENTS

EXISTING CONDITIONS

Astronomical tides are created by the gravitational pull of the moon and sun and are well understood and predictable in magnitude and timing. The National Oceanic and Atmospheric Administration (NOAA) regularly publishes tide tables for selected locations along the coastlines of the United States and selected locations around the world. These tables provide times of high and low tides, as well as predicted tidal amplitudes.

Tides in San Juan, Puerto Rico are affected by mixed semidiurnal tidal fluctuations of the Atlantic Ocean, meaning two high and low tides at different elevations occur per tidal day. The study obtained tidal datums for San Juan, La Puntilla from NOAA tide station 9755371 San Juan Bay, Puerto Rico. The NOAA gauge contains data from 11/29/1977 to present (12/31/2019). Tidal datums are summarized in **Table 2-4** and are referenced to the Puerto Rico Vertical Datum of 2002 (PRVD02) and Mean Sea Level (MSL), and based on a tidal analysis periods of 01/01/1983 to 12/31/1987 and 01/01/1990 to 12/31/2001. The PRVD02 vertical datum is the official vertical datum of Puerto Rico and is referenced to the MSL of NOAA tide station at San Juan (9755371). The mean tide range, the difference between Mean High Water (MHW) and Mean Low Water (MLW), equals 1.11 ft and the spring tide range, the difference between Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) is 1.58 ft.

Table 2-4. Tidal Datums for San Juan, La Puntilla (9755371).

Tidal Datum	Elevation (ft-PRVD02)
Mean Higher-High Water (MHHW)	0.81
Mean High Water (MHW)	0.54
Puerto Rico Vertical Datum of 2002 (PRVD02)	0.00
Mean Sea Level (MSL)	0.00
Mean Low Water (MLW)	-0.56
Mean Lower-Low Water (MLLW)	-0.77

Along the Atlantic and Caribbean coasts of Puerto Rico, the currents are greatly influenced by the trade winds. In general, there is a west drift caused by prevailing east trade winds; the velocity averages about 0.23 miles per hour and is said to be strongest near the island. With variable winds or light trade winds it is probable that tidal currents are felt at times along the Atlantic and Caribbean coasts of Puerto Rico (NOAA, 2019).

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Tides would be expected to generally continue similar patterns as in the existing conditions. Storm surge, with tide contributions, would continue to cause damages in the San Juan Metro Area. Frequent tidal flooding would be expected to continue to cause damages and negative effects to the community and environment in the Condado Lagoon area.

2.3.1.5 WINDS

EXISTING CONDITIONS

Local winds can contribute to storm surge and the generation of small-amplitude, short period, waves that are important contributors to infrastructure damage throughout the back bay region. The study area lies within the tropical trade wind zone, resulting in moderate winds from easterly directions most of the time. Easterly winds range from 13.2 mph to 16.7 mph through the year based on WIS station #61019 from 1980-2014. Elevated wind speeds from the north-northeast quadrant in winter months occur during passage of northeasters which can cause extensive storm surge and shorefront damage. Occasionally the area is impacted by the passage of tropical storms that can generate devastating winds, waves, and storm surge, which can cause direct damage to coastal structures and infrastructure.

Wind conditions in Puerto Rico are seasonal. During winter and spring months (December through May) frontal weather patterns driven by cold Arctic air masses can extend as far south as Puerto Rico; these events are referred to as “Northeasters”. While Northeasters often result in wave conditions that cause extensive erosion and increased wave setup on the north coast of Puerto Rico, the south coast of Puerto Rico experiences little impact from these events.

During summer and fall months (June through November) tropical waves often develop into tropical storms and hurricanes, which can generate devastating winds, waves, and storm surge.

In the vicinity of San Juan winds are predominantly from the east throughout all months, although throughout the winter and spring months the secondary wind direction is generally from the northeast and throughout the summer and fall months the secondary wind direction generally is from the southeast. Additionally, daily breezes onshore and offshore result from differential heating of land and water masses. These diurnal winds typically blow perpendicular to the shoreline and have less magnitude than the trade winds and northeasters. While these breezes play a significant role in local weather patterns, they are not an appreciable cause of nearshore damage and erosion.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Winds would be expected to generally continue similar patterns as in the existing conditions. Storm surge, with contributions from wind, would continue to cause damages in the San Juan Metro Area.

2.3.1.6 TOPOGRAPHY AND FLOOD ZONES

EXISTING CONDITIONS

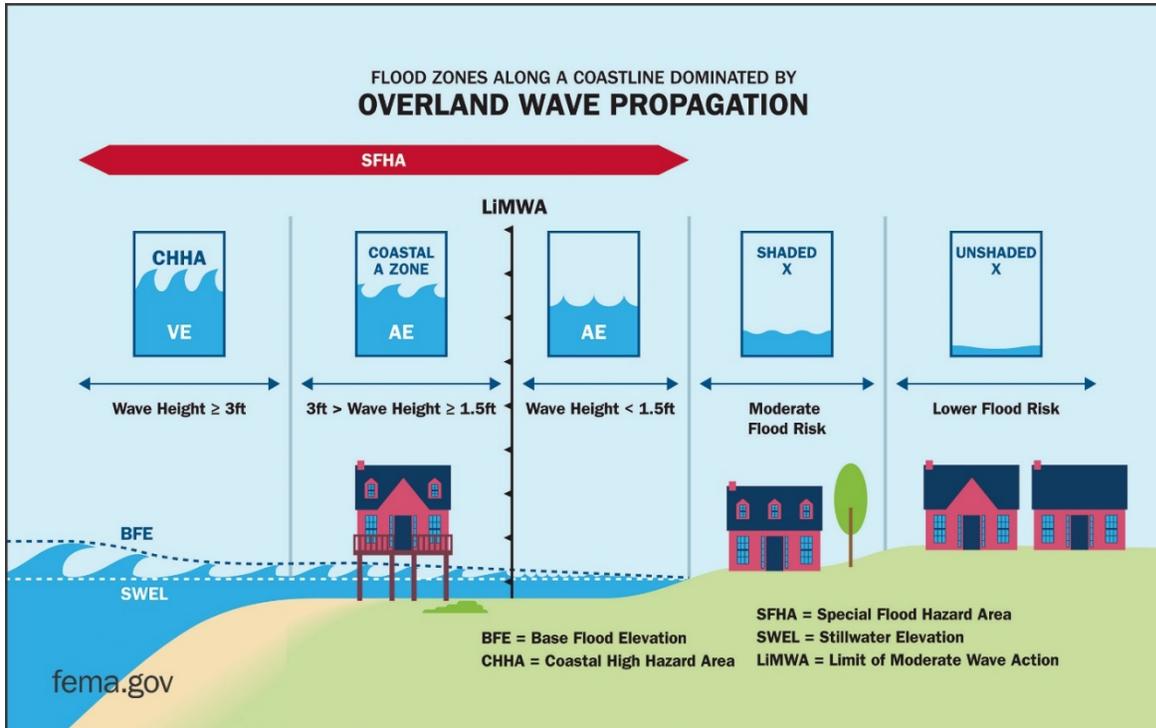
A Digital Elevation Model (DEM) consists of arrays of regularly spaced land surface elevation values referenced to a horizontal reference datum. The DEM (FEMA, 2018) in **Figure 2-9** shows low surface elevations in the study area, which makes the surrounding areas vulnerable to damages from storm surge and sea level change.

The FEMA Base Flood Elevation (BFE), defined as the 1% Annual Exceedance Probability (AEP) Flood, is the regulatory requirement for the elevation or floodproofing of structures. The BFE varies along the perimeter of San Juan Bay with a maximum BFE at Cataño of 4.0 m (13.12 ft). Flood zones and their meanings are depicted in **Figure 2-10**.

Figure 2-9. DEM showing low surface elevations and FEMA flood zones AE and VE.



Figure 2-10. Flood Zones in Coastal Areas.



FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Topography is expected to generally remain as it is in existing conditions. Flood zones may be altered over time, if conditions warrant. In general in the future, it is likely that both topography and flood zones will continue to play a part in how storm surge affects communities.

2.3.2 SEA LEVEL CHANGE

To incorporate the direct and indirect physical effects of projected future sea level change on design, construction, operation, and maintenance of projects, the U.S. Army Corps of Engineers (USACE) has provided guidance in the form of Engineering Regulation, ER 1100-2-8162 and Engineering Technical Pamphlet (EP) 1100-2-1. Three scenarios are required by Engineering Regulation (ER) 1100-2-8162: a Baseline (or “Low”) scenario, which is based on historic sea level rise and represents the minimum expected sea level change; an Intermediate scenario; and a High scenario representing the maximum expected sea level change.

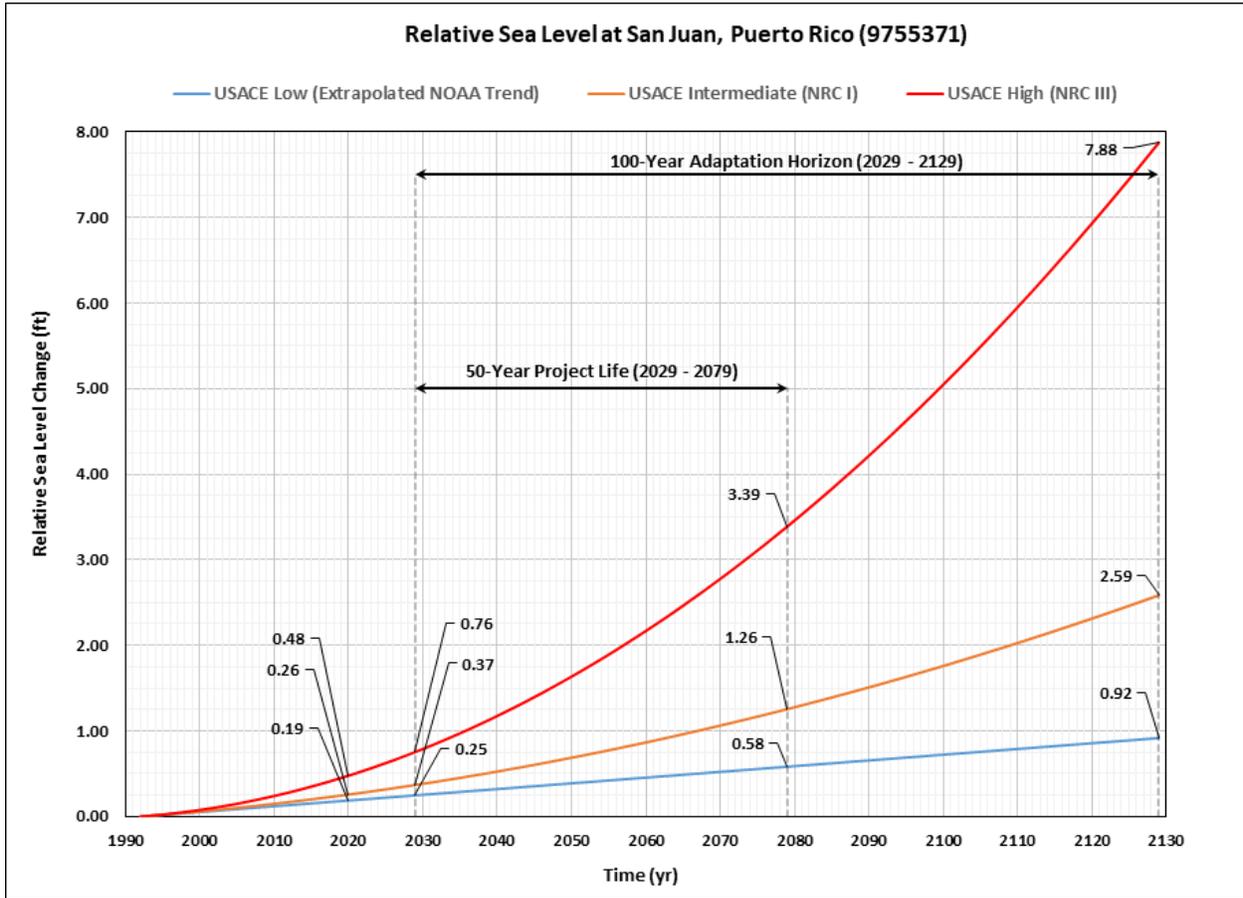
EXISTING CONDITIONS

Based on historical sea level measurements taken from NOS gauge 9755371 San Juan Bay, PR, the historic sea level change rate was determined using the updated published SLC from <http://www.corpsclimate.us/ccaceslcurves.cfm>. At San Juan Bay, PR gauge 9755371, the MSL trend updated for 2018 is 2.04 mm/year (0.0066929 feet/year) with a 95% confidence interval of +/- 0.39 mm/year (0.0012795 feet/year) based on monthly MSL data from 1962 to 2018 which is equivalent to a change of 0.67 ft in 100 years. The SLC value of 0.0066929 feet/yr was applied to the low, intermediate, and high SLC curves.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Following procedures outlined in ER 1110-2-8162 and ET 1100-2-1, low, intermediate, and high sea level rise values were estimated over the life of the project using the official USACE sea level change calculator tool. Projections for sea level rise are based on a start date of 1992, which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001. In the future, sea level rise could be expected to increase by 0.58 (low), 1.26 (intermediate), and 3.39 feet (high) by year 2079 with respect to the above mentioned present local mean sea level tide datum. Future SLC is expected to exacerbate the impacts of coastal flooding and wave attack as those forces would be occurring at a higher starting water level in the future as sea level rises.

Figure 2-11. Relative Sea Level Change for San Juan, Puerto Rico.



2.3.3 VERTICAL LAND MOVEMENT

EXISTING CONDITIONS

Vertical land movement (VLM) is the change of a land surface in reference to a vertical datum over time. Positive trends in VLM indicate that the land is rising and negative trends in VLM indicate that the land is subsiding (Zervas et al., 2013). Zervas et al (2013) found the VLM at NOAA tide station 9755371, San Juan Bay, to be 0.0008 in/yr (0.02 mm/yr). Indicating the study area does not generally experience VLM.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

It is likely that the VLM will continue at the same rate as described above.

2.3.4 GEOLOGY

EXISTING CONDITIONS

The study area is located within the shallow marine shelf that surrounds the Commonwealth of Puerto Rico. Sediments of Holocene to and Pleistocene overlie limestone of Tertiary age. The limestone is found at depths varying from 25 feet to more than 100 feet in depth. Periods of fluctuating sea levels occurred

during the glacial periods at the end of the Neogene period exposing the limestone allowing for weathering and erosion to occur. Shallow lagoons formed in depressions along the coast and sediments including silt and clay were deposited on the bottom of the Bahía de San Juan and Condado Lagoon. To date, fine grained carbonate and siliclastic sediments are transported from upland areas by streams and are deposited into the Lagoons.

Existing boring information shows that for the most part the soil profile consists of soft clay over clays of varying stiffness, underlain by limestone of varying depths. Some of the borings encountered silty and clayey sands with intermittent limestone layers, or layers of soft sand. One of the borings closest to Condado lagoon is located in shallow water and encountered a peat layer from 14.6 to 27.1 feet MLW. More detailed information can be found in **Appendix D, Geotechnical**.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

It is likely that the geological conditions will remain as they are in the future.

2.4 BUILT ENVIRONMENT

2.4.1 EXISTING INFRASTRUCTURE

The San Juan Metro Area is located on the northeast coast of Puerto Rico, with approximately 40 to 50 miles of fronting shoreline and is heavily developed with homes, businesses, condominiums. Cataño and La Esperanza lie on the west side of San Juan Harbor. The Condado Lagoon lies to the east of San Juan Harbor.

2.4.1.1 REACH 1 – WEST SAN JUAN BAY

EXISTING CONDITIONS

This reach describes an area which is approximately 9 square miles, and which is located to the West and South of San Juan Harbor. This reach contains portions of the municipalities of Cataño, Guaynabo, and San Juan. This area experiences not only coastal flooding but it has also experienced wave attack from waves approaching through the harbor (in the Cataño area, WSJB). This reach contains approximately 16 structures identified as critical infrastructure, one of which is a major hurricane and Tsunami evacuation route (PR-165)¹¹, in addition to 14 schools and 4 assembly points (Tsunami Program Map Tool, <http://prddst.uprm.edu/apps/prtmp/>).

West San Juan Bay 1 – La Esperanza and Caño Aguas Frias:

This discussion refers to the shorelines immediately north and south of La Esperanza Park and at the Caño Aguas Frias entrance. The natural channel opening on the southern side of La Esperanza Park was completely plugged with sediment during the site visit when the waterline was approximately 0.03 ft-MSL. The gates controlling runoff into La Esperanza from the Malaria Canal were noted to be closed as the water on the west side of the gate was stagnant and green with what seemed to be algae on top of

¹¹ GIS data is from FEMA Caribbean Division and was collected in 2016 & 2017.

the water. La Esperanza's embayment contains perimeter vegetation (generally mangroves varying in width from 30-70 ft). The north side of La Esperanza contains sandy beaches approximately 30-50 feet wide with vegetation in some locations.

West San Juan Bay 3 – Cataño:

The Cataño shoreline is primarily protected by structures such as rock revetments, concrete seawalls, and sheet-pile seawalls. The eastern side of Cataño (from the eastern point to the end of Calle Las Nereidas) generally contains 2-4 foot (ft) riprap. From the end of Calle Las Nereidas Interior to Calle Wilson, the shoreline is generally protected by seawalls and toe riprap. The seawalls generally protrude approximately 3-5 ft above the waterline and the riprap rock diameter ranged from 1-3 ft. The central portion of Cataño, from Calle Wilson to Calle Pilar, generally consist of sheet pile seawalls with a concrete cap 3-5 ft above the waterline. Riprap 1-3 ft in diameter generally protects the seawall toe. Rainwater runoff pipes located within portions of the seawall may be susceptible to surge and wave attack inundation since some pipes do not contain backflow preventers.

Seawall protection is lower in crest elevation traversing west from Calle Pilar to the beginning of the existing breakwater in front of the marina (Centro Agropecuario Cataño). The sheet pile seawall contains a concrete cap approximately 3 ft above the waterline. The seawall toe is protected by 1-2 ft riprap, which is smaller than the riprap protection noted along Cataño's eastern shoreline.

The marina at Centro Agropecuario Cataño is protected by a 400 ft long by 40 ft wide emergent breakwater 200 ft offshore and gabion with small rock at the shoreline. The breakwater contains rock approximately 2-4 ft in diameter, and a portion of gabion protects the shoreline. Rock revetment is approximately 3 ft above the waterline, with 2-4 ft rock, protects the shoreline east of La Esperanza Park to the marina at Centro Agropecuario Cataño.

The beach just north of the Cano Aguas Frias near the mouth of the canal, depicted in Figure 18, is approximately 50 ft wide with some vegetation. The canal itself spans roughly 50 ft wide at the mouth and was actively flowing into the San Juan Bay during the site visit. PR 870 immediately north of the Cano Aguas Frias entrance is protected with 2-4 ft riprap.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

The conditions described above would be expected to continue, and become exacerbated with sea level rise.

2.4.1.2 REACH 3 – CONDADO LAGOON

This reach encompasses an area which is approximately .5 square miles, located to the East of San Juan Harbor and bordering the Condado Lagoon. This reach is within the San Juan municipality and suffers from storm surge and tidal influences from Condado Lagoon. This area serves as a major thoroughway to communities evacuating from the west, and contains a Tsunami and Hurricane evacuation route, PR-24, identified as critical infrastructure. There is one shelter located within the immediate area of risk and 5 just outside of the area of risk. Roads and vehicles are largely impacted by frequent tidal flooding (“sunny day flooding”), as reported by residents. This reach is also at risk from sea level change.

EXISTING CONDITIONS

Condado Lagoon’s shoreline consists primarily of vegetation (red and black mangroves), concrete seawalls, and nearshore sea grasses. The seawall on the east side of the lagoon is generally 3 feet above the waterline with noted rainwater runoff openings in the seawall. The rainwater runoff openings are less than 1 foot above the waterline (-0.12 ft-MSL, NOAA Station 9755371) at the time of the site visit (July 2019). The MHHW at NOAA Station 9755371 is 0.81 ft-MSL indicating that tidal flooding could be entering through the rainwater runoff openings. Additionally, there is a partially failed seawall at the end of Calle Joffre. The under-designed seawall is approximately 1 foot above the waterline and has partially failed. There are signs of consistent wetting and drying behind the seawall.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

The conditions described above would be expected to continue, and become exacerbated with sea level rise.

2.4.2 HURRICANE EVACUATION ROUTES AND ZONES

2.4.2.1 REACH 1 – WEST SAN JUAN BAY

EXISTING CONDITIONS

This reach contains evacuation zones A and B, as defined in the Puerto Rico Hurricane Evacuation Study, October 2018. PR-165 is both a Tsunami and Hurricane evacuation route for the area. There are 6 shelters within the study reach.

2.4.2.2 REACH 3 – CONDADO LAGOON

EXISTING CONDITIONS

This reach contains evacuation zone A. This area serves as a major throughway to communities evacuating from the west, and contains a Tsunami and Hurricane evacuation route, PR-24. There is one shelter within the study reach, and 3 more shelters just outside of the study reach.

FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

The Puerto Rico Hurricane Evacuation Study, Behavioral Study, Final Report March 2014 offers insight as to evacuation practices from survey questions asked. When asked, "Have you or your household ever evacuated for a hurricane?" only 15% said yes. When asked what storm was responsible for their evacuation, most often mentioned was Hurricane Georges (made landfall in Puerto Rico in 1998 as Category 3 hurricane), followed by Hurricane Hugo (Category 3 in 1989) and Hurricane Hortense (Category 1 in 1996). Most (85%) with evacuation experience had stayed at the home of a relative or friend within their municipality and about 10% reported going to a public shelter. Only one left Puerto Rico.

When asked, "If you had to evacuate, where would you most likely go? Would you go to the home of a relative or friend, another property you own, a public shelter, a hotel, or someplace else?" answers indicate that 66% of the San Juan Metro Area residents would evacuate to the home of a friend or relative and 20% would evacuate to a public shelter, with 3% evacuating to a hotel, 1% to a church, and 9% were reported as "other" or "did not know". In the same survey for the San Juan Metro Area, 55% of those surveyed reported they were very likely to evacuate for a Category 1 or 2 hurricane with no official recommendation and 70% reported they were very likely to evacuate for a Category 3 or higher hurricane if they were ordered to leave. The same survey concluded the most important source of hurricane information are as follows: local radio 41%, cable TV 24%, local TV 20%, internet 6% and miscellaneous 9%.

2.5 SOCIO-ECONOMIC ENVIRONMENT

EXISTING CONDITIONS

The parameters used to describe the demographic and socioeconomic environments include trends in population, employment, and income distribution for the Commonwealth of Puerto Rico and the forty municipalities that make up the San Juan-Carolina-Caguas Metropolitan Statistical Area (MSA). Additional details may be found in the Economics Appendix.

Historical Population and Population Projections

The U.S. Census data indicates that the population of Puerto Rico increased from 1950 to 2000, a net increase of 1,597,907. This constitutes an average annual increase of 1.5 percent, or 31,958 per year during that period. The 2010 census shows a population of 3,725,789, a net loss of 82,821 or a 2.2% decline from the 2000 census. According to the statistics presented by the Puerto Rico Statistics Institute regarding U.S. Community Survey estimates, the population of Puerto Rico is expected to continue its downward trend in the period from 2010 to 2050. The decline in population is projected to reach 737,000 or 19.8% over the 40 year period. This constitutes an average annual decline of 0.5 percent, or 18,423

people per year. A surge in the out-migration of its citizens explains much of this decline, with nearly one-third of those born in Puerto Rico live on the U.S. mainland in 2013.¹²

San Juan-Carolina-Caguas MSA

In all, there are 78 municipalities of the Commonwealth of Puerto Rico. The largest MSA is the San Juan-Carolina-Caguas MSA with a total population of 2,350,126 in 2010, approximately 63.0% of the total population of Puerto Rico. Approximately two out of every three people in Puerto Rico live within the San Juan-Carolina-Caguas MSA. In 2015 the population of the municipality of San Juan was 355,074, the most populous municipality in Puerto Rico.

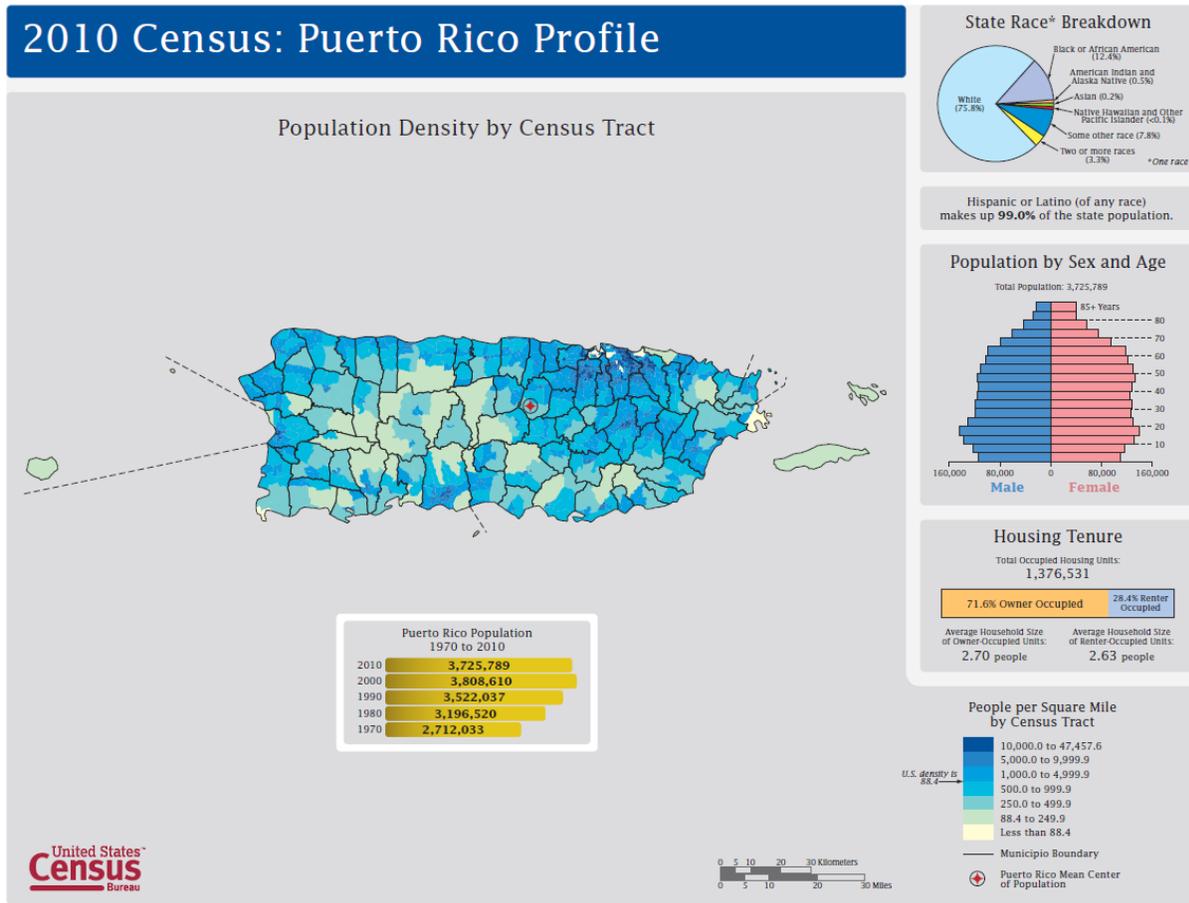
Population Density

Puerto Rico is 10 times more densely populated than the United States as a whole. Based on the 2015 population estimate, population density in Puerto Rico is 988 people per square mile or 362 people per square kilometer. This makes Puerto Rico the fourth most densely populated state or territory in the United States. It is behind only Washington, District of Columbia (10,589 people per square mile); New Jersey (1,210 people per square mile); and Rhode Island (1,006 people per square mile).

Figure 2-12 presents, at a glance, the 2010 Census Profile for the U.S. Territory of Puerto Rico including population distribution by race, population distribution by sex and age, population density, and the decennial population from 1970 to 2010.

¹² Based on 2013 data from the United Nations and U.S. Census Bureau as reported by the Pew Research Center in the August 11, 2014 article entitled “Puerto Rican Population Declines on Island, Grows on U.S. Mainland” by D’Vera Cohn, Eileen Patten and Mark Hugo Lopez.

Figure 2-12. Commonwealth of Puerto Rico 2010 Demographic Profile (Source: United States Census Bureau, 2010 Decennial Census).



Employment and Income

The economy of Puerto Rico is relatively concentrated in (1) educational services, healthcare and social assistance services, and (2) retail trade. According to the U.S. Census 2011-2015 American Community Survey (ACS) 5-Year Estimates, Puerto Rico employment totaled 1,063,350 on average with over 37% of jobs attributable to these two sectors combined.

The San Juan-Carolina-Caguas MSA industry sectors yield employment distributions similar to those in Puerto Rico overall. Also of note, the arts, entertainment, and recreation, and accommodation and food services sector ranks fourth in terms of the percentage of people employed in the San Juan-Carolina-Caguas MSA, which is consistent with San Juan Harbor’s prominence as a Caribbean cruise port and with the importance of tourism on the island.

According to the U.S. Census Bureau’s 2010-2014 ACS, the median household income in 2010-2014 for Puerto Rico was on average \$19,686. Of the three municipalities directly adjacent to San Juan Harbor, both San Juan (\$22,266) and Guaynabo (\$34,450) had median household incomes greater than that of Puerto Rico overall, while the median household income in Cataño (\$18,625) was less than that of Puerto Rico overall.

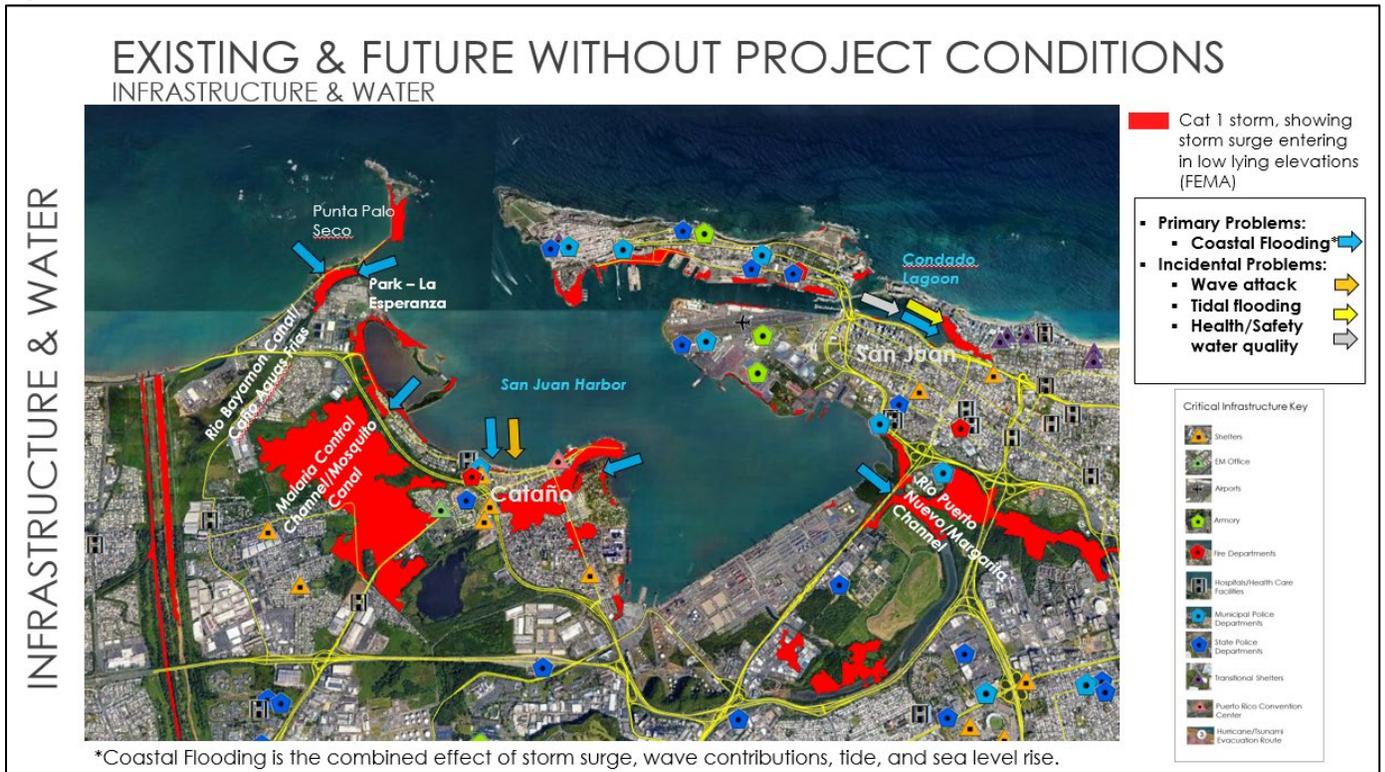
FUTURE WITHOUT-PROJECT CONDITIONS (NO-ACTION ALTERNATIVE)

Current trends would be expected to continue in the future without-project conditions.

2.6 OVERVIEW OF INTERACTIONS OF THE FOUR ENVIRONMENTS (ENVIRONMENTAL, PHYSICAL, BUILT, & ECONOMIC)

This section describes how the interactions of the four environments described in the above sections create problems and necessitate the study of solutions, and this discussion is directly linked to locations of measures/structures which are described in Chapter 3. **Figure 2-13** can be used as a reference during this section for descriptions of coastal flooding in each reach.

Figure 2-13. INTERACTIONS OF THE FOUR ENVIRONMENTS.



2.6.1 CONDADO LAGOON

The sources of flooding into Condado Lagoon are from the Atlantic Ocean. The area will initially flood through the northeastern side, and as the surge increases, the flooding will propagate further east as well as towards the north side of the model area. The south side of Condado Lagoon will flood during the higher surge events.

There is a high density of structures in this area, as well as the presence of high rises (many of which are hotels), and evacuation routes. This area supports recreation and tourism. One key problem in this area is frequent tidal flooding which is a nuisance to residents in the area/road inaccessibility and vehicle

damages. Flooding from lagoon into urban areas lifts debris and other contaminants, and brings them back to the lagoon, affecting water quality. There have been reports of standing water after storms, causing health problems in the community. Key environmental resources in the lagoon include seagrasses and mangroves.

2.6.2 WEST SAN JUAN BAY 1A

WSJB-1A contains two sources of potential flooding: through the Caño Aguas Frias along the south side of WSJB-1A and from the Atlantic Ocean into the north side of the model area. Flooding will first occur on the south side of WSJB-1A through the Caño Aguas Frias and eventually propagate into the north side of the area from the Atlantic Ocean. This area contains lower density infrastructure in the area and also houses the Palo Seco power plants. In discussions with the power plants, problems with storm surge has not been experienced in past storms. Key environmental resources in the area include mangroves.

2.6.3 WEST SAN JUAN BAY 1B

WSJB-1B contains three sources of potential flooding: through the Caño Aguas Frias along the north side of WSJB-1B, through La Esperanza Park on the east side of the model area, and through Malaria Canal just south of the area. Flooding will first occur on the east side of WSJB-1B and higher surge events will flood into the north side of the model area through the Caño Aguas Frias and the south side of WSJB-1B through the Malaria Canal. Key environmental resources in the area include seagrasses, freshwater wetlands, and mangroves.

2.6.4 WEST SAN JUAN BAY 2

The flooding sources into WSJB-2 are through the Malaria Canal and the Caño Aguas Frias. At the entrance of the Malaria Canal, an existing sluice gate remains closed with an approximate top elevation of 2 ft-PRVD02. Storm surge propagates into the area following the overtopping of the existing sluice gate. Flooding will occur along the east and west sides of the Malaria Canal and propagate into the area as the surge increases. Larger storm surge events can also flood through the Caño Aguas Frias and into the northwest side of WSJB-2. This reach contains higher density of Infrastructure in the area, as well as evacuation routes. There are also expansive wetlands in the area. Key environmental resources in the area include freshwater wetlands and mangroves.

2.6.5 WEST SAN JUAN BAY 3

Storm surge along with the influence of waves will cause flooding into WSJB-3 through the San Juan Harbor. Flooding will initially occur through the San Fernando Canal, which is located behind Cataño and within the northeast region of the area. As the surge increases, the flooding will propagate further into WSJB-3 through the north and southeast sides of the area. Storm generated waves will pass through the San Juan Harbor Inlet causing increases in flooding due to wave setup and wave runup. There is higher density of Infrastructure in the area, as well as evacuation routes. The waterfront area houses important community infrastructure, including pedestrian Blvd (“malecon”), convention center, ferry. Key environmental resources in the area include mangroves and seagrasses.

2.6.6 WEST SAN JUAN BAY 4

The sources of flooding into WSJB-4 are from the Bechara, the San Juan Harbor, and the Margarita Canal. The area will initially flood through the Bechara, which is a tidally influenced channel that goes through the center of the model area from the San Juan Harbor on the north side, underneath the port, and out the south side of the area. As the surge increases, the flooding will propagate further into the interior of WSJB-4A and WSJB-4B through the Bechara. The San Juan Harbor will produce flooding into the northeast region into WSJB-4B and the Margarita Canal will flood the southside of the area into WSJB-4A and WSJB-4B. This area contains port infrastructure on north side and industrial/ residential infrastructure on south part. Key environmental resources in the area include seagrasses and mangroves.

2.7 MODELING OF THE FUTURE WITHOUT-PROJECT CONDITIONS WITH G2CRM

This study takes an inventory of existing physical conditions as described above and uses various models and analyses to verify existing conditions and then projects it out over 50 years in the USACE certified economic model Generation 2 Coastal Risk Model (G2CRM) to determine a probable future condition, in the absence of a project. This section describes an overview of the process.

G2CRM is a computer model that implements an object-oriented Probabilistic Life Cycle Analysis (PLCA) model using event-driven Monte Carlo Simulation (MCS). The model is based on driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas of different types that may interact hydraulically and may be protected by coastal defense measures that serve to shield the areas and the assets they contain from storm damage (USACE, 2018b). To determine the damages for a specific event and time G2CRM compares the total water level (sum of the storm surge, SLC, tide, and potential wave inputs) to asset first floor elevations within FWOP or Protective System Element (PSE) elevations and then first floor elevations within future with-project (FWP). The model integrates engineering and economic interactions of the elements below as storms occur during the 50 year life cycle.

Within the specific terminology of G2CRM, the important modeled components are:

- **Driving forces** - storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE;
- **Modeled areas (MAs)** - areas of various types (coastal upland, unprotected area) that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area.
- **Protective system elements (PSEs)** - the infrastructure that defines the coastal boundary be it a coastal defense system that protects the modeled areas from flooding (levees, pumps, closure structures, etc.), or a locally developed coastal boundary comprised of bulkheads and/or hardened shoreline.
- **Assets** – spatially located entities that can be affected by storms. Damage to structure and contents is determined using damage functions. For structures, population data at individual structures allows for characterization of loss of life for storm events.

2.7.1 MODEL ASSUMPTIONS

Key model assumptions are shown below in **Table 2-5**.

Table 2-5. Key Model Assumptions.

Input Field	Assumption / Model Input
Storm Suite	ADCIRC/STWAVE ¹³ storm suite chosen from South Atlantic Comprehensive Study (SACS) modeled events at Cataño. G2CRM contains 12 tropical storms from ADCIRC/STWAVE and 3 extra-tropical storms.
Storms per Season	Analyzed wave data from Wave Information Study (WIS) station 61019 and classified a storm as the average of the entire dataset plus two standard deviations.
Tide	National Oceanographic and Atmospheric Administration (NOAA) tide station 9755371. (San Juan Bay, PR)
Relative Storm Probability	Relative storm probability is based off the Federal Emergency Management Administration (FEMA) annual exceedance probabilities (AEP) event elevations.
Sea Level Rise	USACE intermediate curve is used for plan formulation based on 5-yr and 19-yr mean sea level moving average trends. The analyses will run the low and high sea level change (SLC) curves within G2CRM to compare damages to the proposed design for the evaluation of risk and potential adaptation of project features. The SLC rate was determined from NOAA gauge 9755371. G2CRM follows SLC guidance for ER 100-2-8162 and EP 1100-2-1.
Reaches	
Reach Specification	Reaches were determined using the extent of the FEMA 2018 0.2% annual exceedance value, NOAA sea level rise (SLR) viewer (6' above mean higher high water (MHHW)), and the ADCIRC/SWAN Cat 5 MOM w/ 1m SLR.
Development of Model Areas	Reaches were divided into Model Areas based on the separability from possible sources of coastal flooding for input into G2CRM. The engineering team used the digital elevation model (DEM) and the NOAA SLR Viewer to determine model separability based on the location of various flood sources.
Protective System Elements (PSE)	
PSE	PSEs were delineated at model area extents to protect portions of the model area subject to low elevations. For FWOP the top elevation is the lowest ground elevation of the PSE, for future with-project (FWP) the top elevation will change depending on the alternative.
Damage Elements	The damage element inventory contains 19,675 damageable structures
Foundation Type	Foundations generally concrete stem-wall.
Construction Type	Assumed mostly masonry construction types.
Structure Rebuild Times	

¹³ ADCIRC/STWAVE is an advanced model for waves and tides.

Number of Rebuild Times	Unlimited rebuild times assumed.
Rebuild assumptions	Assume not built to higher elevation.
Structure Values	Developed by real estate team to determine depreciated values of a sample of the population.
Content Values	Developed by real estate team to determine depreciated values of a sample of the population.
Structure Elevation Data	Developed using geospatial information system (GIS) using DEM and asset locations.
Damage Functions	North Atlantic Comprehensive Coastal Study (NACCS) – structure (residential, multi-story, high rise)
Vehicle Damages	Vehicle damages will be included in damage assessment.
First Floor Elevation	Assumed between 0-6" off the ground.
Structure Raising	Assumed no structure raising at this time.
Other Benefits	
Life Loss Prevention	Prevention of life loss will be evaluated.
Modeling Simulations	
Number of Iterations	5-iterations for initial plan formulation; 50-iterations for refined benefits. This was selected to provide stable simulation with negligible variability in output.
Discount Rate	2.75% (FY2020 discount rate)
Start Year	2020
Base Year	2029
End of 50 year period of analysis	2079
Life Cycle Duration	60 years.

2.7.2 G2CRM MODEL INPUT OVERVIEW - ENGINEERING HYDRODYNAMIC

More detailed information regarding the discussions below can be found in **Appendix A, Engineering**.

2.7.2.1 DRIVING FORCES

Within the G2CRM model, the still water depth is comprised of three water level components: storm surge; sea level change contribution; astronomical tide contribution less the relevant ground elevation (water-side ground elevation at protective system element, or representative unprotected model area ground elevation).

Meteorological driving forces are storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE (USACE, 2018). Additionally the number of storms per year and relative storm probability are incorporated into G2CRM and further described below.

STORM HYDROGRAPHS

To develop tropical storm hydrographs, the Engineer Research and Development Center (ERDC) coupled ADCIRC and STWAVE. ADCIRC is a two-dimensional hydrodynamic model that conducts short- and longterm simulations of tide and storm surge elevations and velocities in deep-ocean, continental shelves, coastal seas, and small-scale estuarine systems. STWAVE is a steady-state, finite difference, spectral model based on the wave action balance equation.

The study team selected 19 tropical storms from the South Atlantic Coastal Study (SACS) storm suite, using on the water level based AEP events from FEMA. Of the 19 tropical events ran in ADCIRC/STWAVE the team selected 12 to represent the storm suite for G2CRM input. These 12 selected tropical events ranged from 33.3% to 0.2% AEP events in relation to the FEMA AEP events.

To represent higher frequency and longer duration extra-tropical (ET) events, the team selected two events from Ocean Weather Inc.’s (OWI) operational (historical) storms from 1979 through 2017. Since the operational storms from OWI did not include events after 2017, the team added an additional ET storm (Riley) to the storm suite.

STORMS PER SEASON

To determine the storm event generation G2CRM first selects the tropical and extra-tropical events to occur through each season within the year. This study implemented three storm seasons within each year; January through May as an extra-tropical season, June through November as a tropical season, and lastly December as an extra-tropical season. G2CRM then uses the Poisson distribution to randomly select the number of storms to occur within each season based on the average number of storms in a season input. To determine the number of tropical and extra-tropical storm occurrences this study analyzed wave data from WIS station 61019. The study used wave heights instead of distance from the study area to more accurately define what is classified as a storm impacting the study area; to ensure all events impacting the study area, no matter how far away, are accounted for. The analysis classified a “storm” as the average of the entire dataset plus two standard deviations (10.6 ft). The analysis applied a decluster time of five days to eliminate any duplicate events and then applied a peak-over-threshold of the wave height classified as a “storm” (10.6 ft). To determine what events were tropical or extra-tropical the analysis used the NOAA Historical Hurricane Tracks (North Atlantic Basin) and filtered through the data. **Table 2-6** displays the storm occurrences per year for extra-tropical and tropical events.

Table 2-6. Storms per Season.

Extra-Tropical Storm Season (JAN to MAY)	Tropical Storm Season (JUN to NOV)	Extra-Tropical Storm Season (DEC)
6.8	1.6	0.6

RELATIVE STORM PROBABILITY

Following G2CRM’s storms per season selection it then chooses the storms that occur within each season by randomly selecting storms out of the available storm suite using bootstrap sampling with replacement (higher probability storms are chosen more often). To determine the relative storm probability based on surge the study analyzed water level data from the NOAA gauge (9755371) at San Juan and compared to

the FEMA 2009 return period curve. It could be argued that the historical NOAA water levels from the past will occur in the future, although this may underestimate the risk. The FEMA results provide an opportunity to evaluate impacts of stronger synthetic storms that may not have occurred on record, but could occur in the future. Therefore a decision was made to use the FEMA return period elevations since they accurately represent the larger events.

ASTRONOMICAL TIDES & SEA LEVEL CHANGE

The tide contribution to total water level is calculated internally within G2CRM based on an astronomical tide calculation using standard harmonic methods to determine tide at a given tide station on a given date/time.

G2CRM takes into account the water level contribution associated with sea level change (SLC). Sea level change is calculated per Corps policy and guidance. Each model run can make use of one of the three Corps-defined sea level change scenario curves: low, intermediate, high. User input is required for the base sea level change rate.

2.7.2.2 MODELED AREAS (MAS)

Model areas (MAS) are areas that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area (USACE, 2018). After the screening of study reaches 4-6 the engineering team divided the remaining reaches into MAs based on the separability from various flood sources for input into G2CRM. The engineering team used the DEM and the NOAA SLR Viewer to determine model separability based on the location of various flood sources. Figure A - 13 displayed below details the location of the eight MAs developed. The engineering team originally designated the MAs titled WSJB-1A and WSJB-1B as one MA, WSJB-1. The engineering team later separated WSJB-1 into two MAs due the separability of the two areas from the Aguas Frias Canal.

2.7.2.3 PROTECTIVE SYSTEM ELEMENTS (PSES)

The engineering team originally developed the PSEs to encompass the entire MA extent adjacent to the flood source, based on the DEM and NOAA SLR Viewer. The engineering team established this assumption as a worst case scenario. The study team later refined the exact locations and PSE lengths to remove high elevation areas following the development of the design elevations and completion of FWOP.

2.7.3 G2CRM MODEL INPUT OVERVIEW – ECONOMIC

More detailed information regarding the discussions below can be found in **Appendix C, Economic Analysis**.

2.7.3.1 STRUCTURE INVENTORY & DAMAGE FUNCTIONS

The structure inventory was developed using several data sources.¹⁴ The building polygons were horizontally projected and aligned base on the DSM and aerial images. The dataset was not complete meaning that some of the polygons were manually digitized. The DTM was subtracted from the DSM in order to obtain the heights. The Zonal Statistics tool was then implemented to determine the number of floors based on a conditional if statement. A sample of 30 polygons per area of interest were randomly selected to compare the statement value and the real value using Google Maps Aerial Image. In addition, Google Maps was used in order to assign the occupancy type descriptions for each polygon. The building square footage was determined using the building polygons and a sample of 30 polygons were randomly selected in order to determine the error in the estimate. The DTM was also used along with the building footprints to determine the building grade elevation. The final products were developed with the following information in the attribute table: Description, Occupancy Type, Floor Numbers, Area in Sq.Ft., and Grade Elevation. The damage element inventory contains 19,675 damageable structures.

Damages functions were used from the North Atlantic Coast Comprehensive Study (NACCS) and adapted for the local study area.

2.7.4 FUTURE WITHOUT-PROJECT MODEL RESULTS

The G2CRM model results verified that areas identified as vulnerable to experience storm surge damages would likely experience damages over a 50-year period. As mentioned earlier in the report, East San Juan Bay, Reach 2, was screened out during this phase. It is included in the discussion below for the purposes of showing results of the analysis and why it was not carried into further analysis in the study.

2.7.4.1 FUTURE WITHOUT-PROJECT DAMAGES BY OCCUPANCY

G2CRM was used to estimate damages and costs for the following categories:

- **Structure Damage:** Economic losses resulting from the structures situated within a low-lying area prone to flooding from coastal storms and hurricanes. Structure damages account for approximately 61.7% of the total FWOP damages
- **Content Damage:** The material items housed within the structures that are potentially subject to damage. Content damages make up approximately 38.3% of the total FWOP damages.

West San Juan Bay consists of 17,973 separable damage elements with an overall estimated value of \$3.14B, with structure and content valuations of \$2.21B and \$933M respectively. East San Juan Bay consists of 480 separable damage elements with an overall estimated value of \$476M, with structure and content valuations of \$342M and \$134M respectively. Condado Lagoon consists of 1,222 separable

¹⁴ Data sources: Puerto Rico US Geological Survey (USGS) 2015 1m x 1m LiDAR Digital Elevation Model (DEM) and Digital Surface Model (DSM) & Humanitarian OpenStreetMap Team (HOTOSM) Puerto Rico Buildings (OpenStreetMap Export)

damage elements with an overall estimated value of \$208M, with structure and content valuations of \$169M and \$39M respectively.

Table 2-7 provides greater detail on the composition of the average FWOP damages by category and damage element type based on the *AssetDamageDetail.csv* model output files.

Table 2-7. Distribution of FWOP Damages by Category and Type.

Damage Element Type	Average PV Structure Loss	Average PV Contents Loss	Total Loss PV	Percent of Total Loss
AUTOMOBILE	\$71,199,545	\$0	\$71,199,545	0.56%
COMMERCIAL	\$798,441,189	\$373,655,901	\$1,172,097,177	9.14%
COMMUNITY	\$30,245,163	\$3,521,071	\$33,766,215	0.26%
GOVERNMENT	\$715,964,605	\$305,209,998	\$1,021,174,586	7.96%
HOSPITAL	\$2,058,973	\$246,596	\$2,305,570	0.02%
MULTI-FAMILY RESIDENCES	\$66,542,224	\$20,937,050	\$87,479,261	0.68%
OTHER	\$7,157,974	\$0	\$7,157,974	0.06%
SINGLE FAMILY RESIDENCES	\$6,221,273,566	\$4,204,746,869	\$10,426,020,514	81.32%
Total	\$7,912,883,239	\$4,908,317,485	\$12,821,200,842	100.00%

2.7.4.1.1 SINGLE FAMILY RESIDENCES (SFR)

Single family residences consist of 1-3 story structures of varying construction type and value. This category accounts for the majority of the damage elements in the study area. 81.23% of the total FWOP damages are associated with the direct damages to these structures and their contents. This damage element type is well distributed across the study area, but has a high concentration in West San Juan Bay.

2.7.4.1.2 MULTI-FAMILY RESIDENCES (MFR)

Multi-family residences consist of multi-story structures of varying construction type and value. This category accounts for 0.68% of the total FWOP damages. There is a high concentration of this damage element type in Condado Lagoon as well as West San Juan Bay sub-reach 2.

2.7.4.1.3 COMMERCIAL (COM)

Damages associated with commercial structures and their contents make up 9.14% of the overall FWOP damages. Types of structures associated with this damage element include retail, banks, entertainment, parking and recreation. This damage element type is well distributed across the study area.

2.7.4.1.4 GOVERNMENT (GOV)

Damages associated with Government buildings and their contents make up 7.96% of the overall FWOP damages

2.7.4.1.5 HOSPITAL (HOSP)

Damages associated with hospitals and their contents make up only 0.02% of the overall FWOP damages. There were 5 structures within this category.

2.7.4.1.6 OTHER DAMAGE ELEMENTS

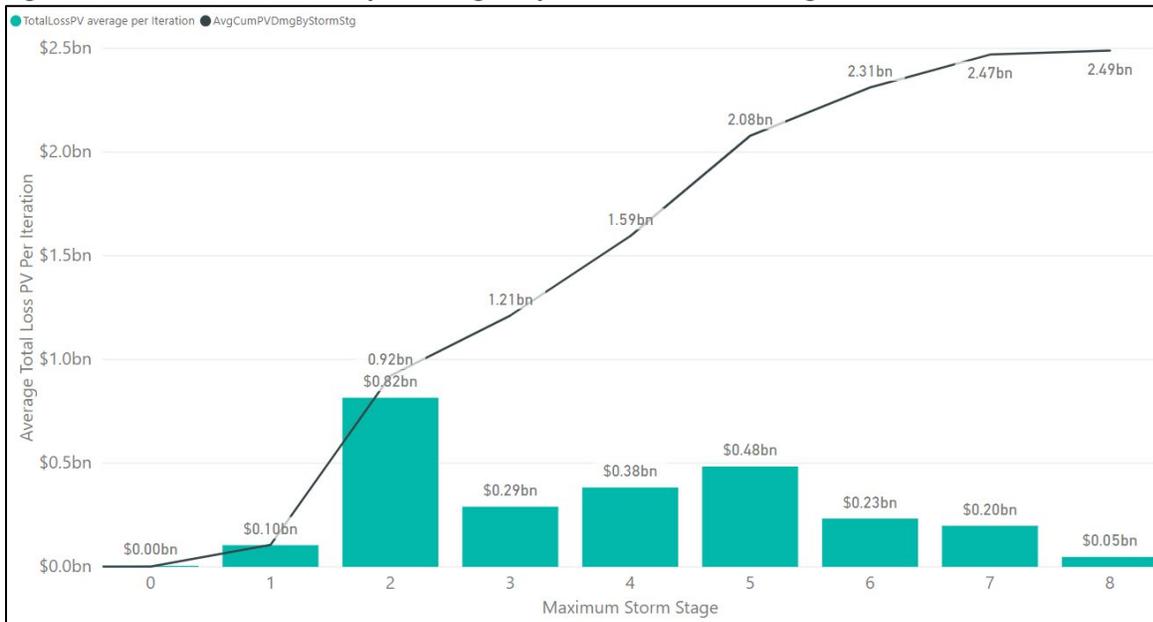
The remaining structures include AUTO, COMM and OTHER damage element types. The damages associated with these structures and their contents make up a combined 0.88% of the overall FWOP damages

2.7.4.2 FUTURE WITHOUT-PROJECT DAMAGES OVER REACHES BY FLOOD WATER LEVEL

2.7.4.2.1 REACH 1 WEST SAN JUAN BAY

The figure below shows the maximum storm stages, with both incremental damages (green bars) and cumulative damages (black line) caused at different stages. The majority of damages are caused by stages of 2 feet (\$820M), with cumulative damages occurring up to 8 feet.

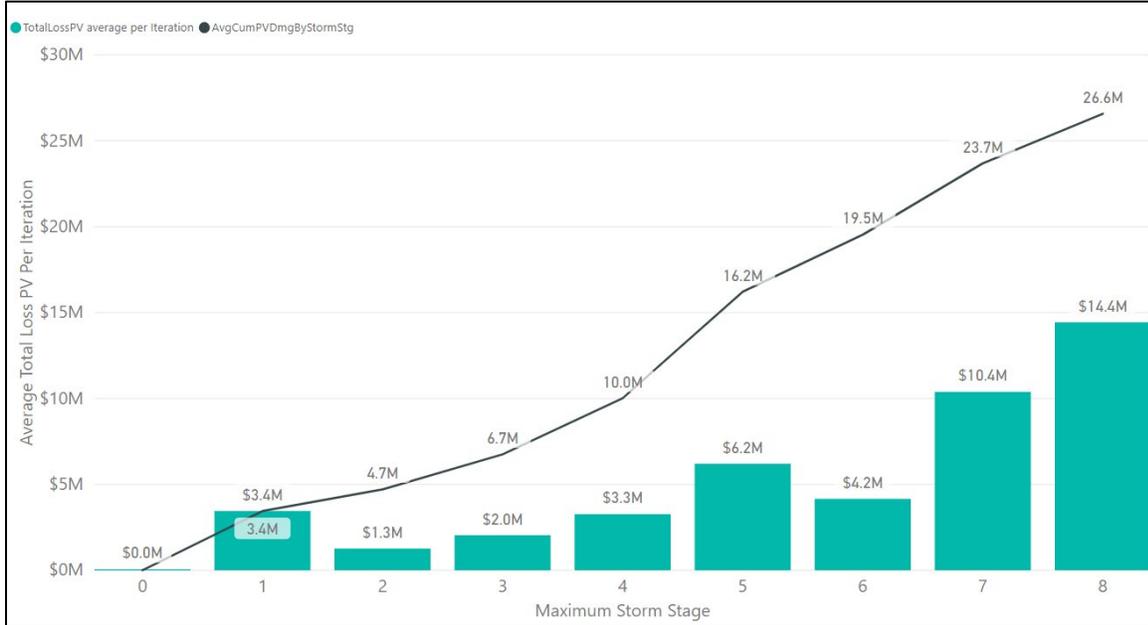
Figure 2-14. West San Juan Bay - Damages by Maximum Storm Stage.



2.7.4.2.2 REACH 2 EAST SAN JUAN BAY

The figure below shows the maximum storm stages, with both incremental damages (green bars) and cumulative damages (black line) caused at different stages. Damages begin to occur at a stage of 1 foot, with cumulative damages occurring up to 8 feet. The majority of damages in this area are caused by stages of 8 feet (\$14.4M).

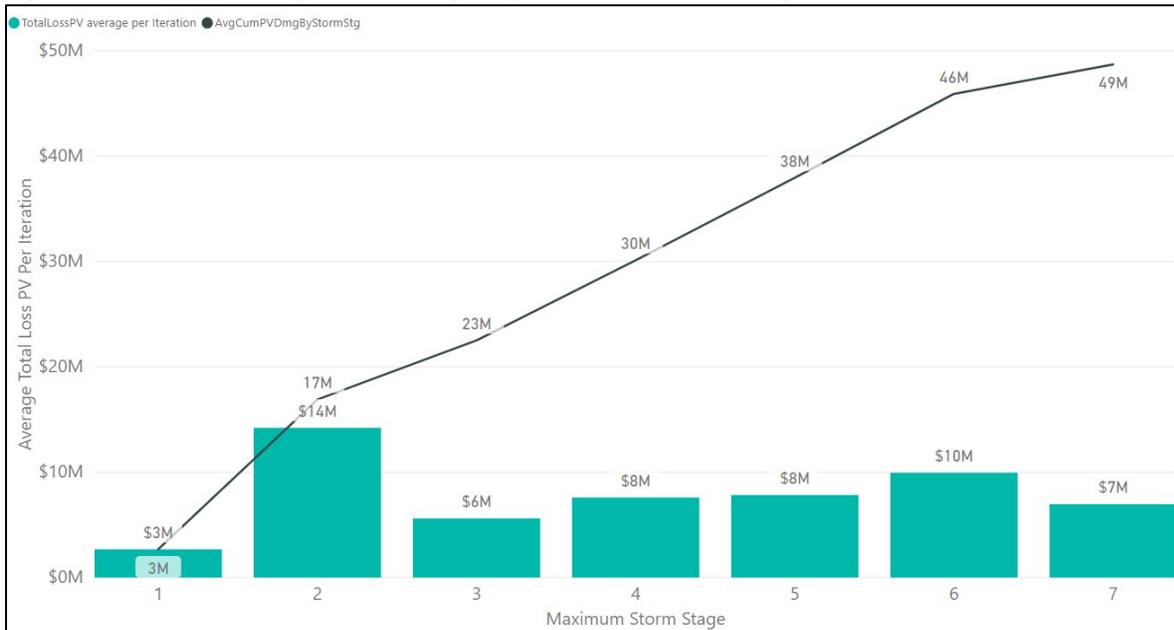
Figure 2-15. East San Juan Bay - Damages by Maximum Storm Stage.



2.7.4.2.3 REACH 3 CONDADO LAGOON

The figure below shows the maximum storm stages, with both incremental damages (green bars) and cumulative damages (black line) caused at different stages. The majority of damages are caused by stages of 2 feet (\$14.2M), with cumulative damages occurring up to 8 feet.

Figure 2-16. Condado Lagoon - Damages by Maximum Storm Stage.



The damages for each reach, reported in dollars for in present value (PV) and in average annual equivalent dollars (AAEQ), are shown below in **Table 2-8**. As the table shows, PV and AAEQ damages for most reaches is generally high, and if it assumed an implemented project could reduce most or all of the damages, it could be assumed that the benefit to cost ratio would be greater than 1. However, the exception is in the East San Juan Bay Reach 2. Here, present value damages are approximately \$26.6M. Very rough costs of potential projects for implementation were approximately \$80M. With coordination with the non-federal sponsor and key facilities in the area, a decision was made to not carry this reach forward for further analysis, as the cost of a project would be magnitudes higher than the benefits that could be obtained. It should be noted that critical infrastructure in this area is generally set back and at a higher elevation than other reaches.

The remaining reaches of Condado Lagoon and West San Juan Bay 1-4 were carried forward for further analysis. Using the initial inventory and forecast of information within this chapter as baseline conditions, Chapter 3 explores possible solutions using the USACE plan formulation process.

Table 2-8. Damages for Each Planning Reach, in the future without a project condition¹⁵.

Planning Reach	# Assets	Estimated Value	PV Damages	AAEQ Damages
CL	1222	\$208.6M	\$48.7M	\$1.8M
WSJB-1	2201	\$538.8M	\$120.6M	\$4.5M
WSJB-2	6623	\$966.4M	\$373.9M	\$13.8M
WSJB-3	8726	\$1.4B	\$1.9B	\$70.8M
WSJB-4	429	\$273.2M	\$84.7M	\$3.1M
ESJB	480	\$476.8M	\$26.6M	\$984.4K

¹⁵ Results are based on 5-iteration model runs in G2CRM, and are a good representation of damages for plan formulation. 50-iteration model runs in G2CRM are used for refined benefits in Chapter 4.



3 Plan Formulation

3 PLAN FORMULATION

3.1 PLAN FORMULATION RATIONALE



Please refer to informational foldouts REF-2 and REF-3 for Chapter 3.

The purpose of this feasibility study is to develop an implementable and acceptable plan to change the future condition and address specific problems and opportunities¹⁶ in the study area.

Using the initial inventory and forecast of information within Chapter 2 as baseline conditions, this chapter explores possible solutions using the USACE plan formulation process.

The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, established by the U.S. Water Resources Council on March 10, 1983, have been developed to guide the formulation and evaluation studies of the major Federal water resources development agencies. These principles and guidelines are commonly referred to as the “P&G,” and will be cited throughout the plan formulation sections of this report.

Four accounts (P&G 1983) facilitate the evaluation of management measures and display the effects of alternative plans.

1. **National Economic Development (NED) account:** Includes consideration of a measure’s potential to meet the planning objective to reduce storm damages, as well as decrease costs of emergency services, lower flood insurance premiums, and considers project costs. Costs and benefits used to fully evaluate the NED objective are not calculated at this stage; however, estimates can be made to gauge the overall cost-effectiveness of a measure for this initial screening. Effects of sea-level change and a measure’s adaptability to such change were considered under the National Economic Development (NED) account.
2. **Environmental Quality (EQ) account:** Considers ecosystem restoration, water circulation, noise level changes, public facilities and services, aesthetic values, natural resources, air and water quality, cultural and historic preservation, and other factors covered by the National Environmental Policy Act (NEPA).
3. **Other Social Effects (OSE) account:** Includes considerations for the preservation of life, health, and public safety; community cohesion and growth; tax and property values; and, the displacement of businesses and public facilities. For evaluation purposes, the OSE account is inclusive of the planning objectives to maintain recreation and maintain a safe evacuation route, and the planning constraint to avoid conflict with legal requirements.
4. **Regional Economic Development (RED) account:** Considers the potential impacts on the local economy including employment, income, and sales volume.

¹⁶ A problem is an existing undesirable condition to be changed. An opportunity is a chance to create a future condition that is desirable.

The P&G require the NED plan to be selected as the tentatively selected plan, unless an exception is granted. The NED plan must also be evaluated in consideration of the P&G criteria of completeness, effectiveness, efficiency, and acceptability. Each alternative plan is formulated in consideration of these four criteria:

1. **Completeness:** Extent to which the plan provides and accounts for all necessary investments or actions to ensure realization of the planning objectives
2. **Effectiveness:** Extent to which the plan contributes to achieving the planning objectives
3. **Efficiency:** Extent to which the plan is the most cost-effective means of addressing the specified problems and realizing the specified opportunities, consistent with protecting the nation's environment
4. **Acceptability:** Workability and viability of the alternative plan with respect to acceptance by Federal and non-federal entities and the public, and compatibility with existing laws, regulations, and public policies.

3.2 SCOPING*

3.2.1 STUDY SCOPING PROCESS

The National Environmental Policy Act (NEPA) scoping period for the study was initiated by letter dated October 16, 2018. Public and interagency meetings were then held November 8, 2018 in San Juan. Comments and feedback received were primarily concerning sea turtles, manatees, coral reefs/benthic resources, fish habitat, public safety, recreation and tourism. Pertinent correspondence associated with this NEPA scoping process is included in Appendix H. For additional information on the NEPA scoping process please refer to Section 6.1.

As described in Section 1.4, this study was re-scoped to address coastal flooding in the San Juan Metro Area. Out of the 6 reaches identified, 2 reaches were ultimately carried forward for further analysis.

The reduced study area includes Reach 1, known throughout this report as the West San Juan Bay (WSJB) reach, and Reach 3, known throughout this report as Condado Lagoon (CL) reach. The combined study area encompasses roughly 9.5 square miles of area and contains approximately 22 structures identified as critical infrastructure, in addition to approximately 14 schools, and major hurricane and tsunami evacuation routes.

After this re-scoping two additional public meetings were held on June 20, 2019 in Cataño and San Juan.

REACH 1 – WEST SAN JUAN BAY

This reach is comprised of an area approximately 9 square miles, which is located to the West and South of San Juan Harbor. This reach contains portions of the municipalities of Cataño, Guaynabo, and San Juan. This area experiences not only coastal flooding from storm surge, as well as being at risk for sea level change, but the Cataño shoreline in particular experiences wave attack from waves approaching through the harbor. This reach contains approximately 16 structures identified as critical infrastructure, one of

which is a major hurricane and Tsunami evacuation route (PR-165)¹⁷, in addition to 14 schools and 4 assembly points (Tsunami Program Map Tool, <http://prddst.uprm.edu/apps/prtmp/>).

This reach was further delineated into 5 planning reaches, based on geographic features and source/direction of storm surge. Throughout this report, they are called WSJB-1a, WSJB-1b, WSJB-2, WSJB-3, and WSJB-4 (**Figure 3-1**

REACH 3 – CONDADO LAGOON

This reach encompasses an area which is approximately .5 square miles, located to the east of San Juan Harbor and bordering the Condado Lagoon. This reach is within the San Juan municipality and suffers from storm surge and tidal influences from Condado Lagoon. Frequent tidal flooding is reported by residents. This area is also serves as a major thoroughway to communities evacuating from the west, and houses major Tsunami and Hurricane evacuation route PR-24. This reach is also at risk from sea level change. This reach remains as one planning reach, and is called CL-1 throughout this report.

¹⁷ GIS data is from FEMA Caribbean Division and was collected in 2016 & 2017.

Figure 3-1. Six Planning Reaches in the Study Area.



3.3 PROBLEMS AND OPPORTUNITIES*

Problems and opportunities have been identified by the Project Delivery Team (PDT) in several ways, including coordination with the sponsor (Department of Natural and Environmental Resources - DNER), municipalities, as well as scoping letter comments received from local residents and stakeholders, GIS data, reports from other agencies, and other USACE reports.

3.3.1 PROBLEMS AND OPPORTUNITIES

3.3.1.1 PROBLEMS

The problems in the study area are explained in more detail in Section 2.6. They include key problems related to coastal flooding, and are listed below.

- Coastal flooding from hurricanes and storms causes damage to structures, vehicles, and critical infrastructure, including Tsunami and Hurricane evacuation route, PR-165 and PR-24
- Coastal flooding from hurricanes and storms results in inaccessibility to critical infrastructure, including evacuation routes before, during and after storm events.

- Wave attack during hurricanes and storms causes damages to waterfront structures and infrastructure in Cataño, in the WSJB-3 planning reach.
- Sea level rise will cause increased risk of coastal flooding.
- Coastal flooding from hurricanes and storms can cause standing water and results in public safety risks, including health risks from waterborne diseases.
- Frequent tidal flooding events (Condado Lagoon) results in damages, public safety concerns, health risks, and accessibility concerns.
- Note that different sources of coastal flooding create the problems described above. For Condado Lagoon, the source of inundation is from the Condado Lagoon. For West San Juan Bay, the source of flooding is San Juan Bay.

3.3.1.2 OPPORTUNITIES

Opportunities are positive conditions in the study area that may result from implementation of a Federal project and are listed as follows:

- Reduce risk to life-safety and public health.
- Maintain or improve existing natural resources.
- Maintain or improve recreational opportunities.
- Reduce tidal flooding.
- Incidental improvement in water quality.
- Maintain or improve the aesthetic qualities.
- Use or re-purpose material for beneficial purposes.

3.4 OBJECTIVES

3.4.1 FEDERAL OBJECTIVES

The Federal objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net economic benefits that accrue in the study area and the rest of the nation.

The Federal objective is to maximize net benefits to the nation, and as such, it does not seek to identify specific targets within objectives. The planning process includes formulation of alternative plans to maximize benefits relative to costs.

3.4.2 PLANNING OBJECTIVES

The overarching goal of this study is to formulate alternatives for coastal study risk management to determine if Federal participation in reduction of the damage to infrastructure caused by storm surge within the study area is warranted and economically justified.

The overarching strategy is to identify the NED/TSP plan for each planning reach, in line with the Federal objectives described above, and recommend an overarching TSP comprised of each reach's NED/TSP plan,

showing incremental justification, to allow for comprehensive storm surge risk reduction within the San Juan Metro Area.

Although the key objectives are generally the same in each planning reach, it is important to note that the planning reaches represent unique communities within the San Juan Metro Area. While each planning reach has been defined as a separate unit, the goal is to provide a comprehensive storm risk reduction plan for the communities at risk of storm surge within the San Juan Metro Area.

Specific study objectives have been developed to provide a means of determining whether individual management measures are capable of solving the study area’s problems while taking advantage of the opportunities identified and avoiding the constraints. The following study objectives have been developed based on the problems, opportunities, goals, and Federal...

1. Reduce risk of damages to infrastructure as a result of coastal flooding combined with sea level rise (intermediate scenario) over the next 50 years.
 - 1a. Reduce risk of damages to infrastructure from wave attack during hurricanes and storms.
2. Increase community resilience in the area over the next 50 years.

A summary of problems, objectives, and opportunities are shown for each reach in **Figure 3-2**.

Figure 3-2. Summary of Problems, Objectives, and Opportunities for the Planning Reaches.

	WEST SAN JUAN BAY WSJB-1a,1b,2, 3, 4 WSJB-3		CONDADO LAGOON CL-1
PRIMARY PROBLEMS: DAMAGES TO INFRASTRUCTURE FROM –	Coastal Flooding 	+ Wave attack 	Coastal Flooding 
OTHER PROBLEMS: Inaccessibility to critical infrastructure, public health & safety risk, sea level rise	✓	✓	✓
OBJECTIVES			
1. Reduce risk of damages to infrastructure as a result of coastal flooding combined with sea level rise (intermediate scenario) over the next 50 years.	✓	✓	✓
1a. Reduce risk of damages to infrastructure from wave attack during hurricanes and storms.	N/A	✓	N/A
2. Increase community resilience in the area over the next 50 years.	✓	✓	✓
OPPORTUNITIES			
1. Reduce risk to life-safety and public health.	✓	✓	✓
2. Maintain or improve existing natural resources.	✓	✓	✓
3. Maintain or improve recreational opportunities.	✓	✓	✓
4. Reduce tidal flooding.	N/A	N/A	✓
5. Incidental improved effects to water quality.	N/A	N/A	✓
6. Maintain or increase aesthetics of community.	✓	✓	✓
7. Use or re-purpose material beneficially.	✓	✓	✓

3.4.3 USACE RESILIENCE INITIATIVE

The second objective of this study speaks to resilience. In EP 1100-1-2 USACE Resilience Initiative Roadmap 16 Oct 17, USACE has identified four key principles of resilience from the many definitions of

resilience that exist. These principles – Prepare, Absorb, Recover, and Adapt – exemplify the temporal aspects and actions that are inherent to the process of building community resilience capacity.

Prepare: The study will communicate the results of analyses, which will help communities anticipate future coastal flooding elevations with sea level rise. By identifying what those future coastal flooding with sea level rise elevations could be, the study will focus on identifying measures and alternatives which increase preparedness of the community before hurricanes and storms.

Absorb: This study focuses on solutions that will reduce damages to communities, meaning less damages for the communities to absorb.

Recover: This study strives to find a solution which not only reduces damages, but also will reduce the risk to health and safety of the communities during coastal flooding events, and allowing quicker recovery before, during and after storms.

Adapt: This study will offer recommendations for monitoring to inform when adaptations to solutions may need to occur and to what extent.

3.4.3.1 FEDERAL ENVIRONMENTAL OBJECTIVES

USACE strives to balance the environmental and development needs of the nation in full compliance with the National Environmental Policy Act (NEPA) and other authorities provided by Congress and the Executive Branch. Public participation is encouraged early in the planning process to help define problems and environmental concerns relative to the study. Therefore, significant environmental resources and values that would likely be impacted, favorably as well as adversely, by an alternative under consideration are identified early in the planning process. All plans are formulated to avoid to the fullest extent practicable any adverse impact on significant resources. Significant adverse impacts that cannot be avoided are mitigated as required by Section 906(d) of WRDA 1986.

This report is an integrated feasibility study and environmental document. As with a separate NEPA document, it discusses and documents the environmental effects of the recommended plan and summarizes compliance with Federal statutes and regulations.

3.4.3.2 ENVIRONMENTAL OPERATING PRINCIPLES

Consistent with the NEPA, USACE has formalized its commitment to the environment by creating a set of “Environmental Operating Principles” applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation and preservation, and restoration are considered in all USACE activities. Section 6.6.26 includes a discussion of the USACE Environmental Operating Principles and how the study addresses them.

3.4.3.3 CAMPAIGN PLAN OF THE U.S. ARMY CORPS OF ENGINEERS (USACE)

The USACE Campaign Plan (UCP) is USACE’s strategic change decision document. It is fully nested with the Army Campaign Plan (ACP) and National Goals and Objectives. As such, it drives and aligns strategic change; anticipates and shapes our future operating and fiscal environments; unites all of USACE with a common vision, purpose, and direction; and responsively adapts to mission and “battle space” changes. USACE Campaign Plan goals and objectives are listed in the FY18-22 USACE Campaign Plan (UCP). The four campaign plan goals and their associated objectives also build on prior strategic planning efforts.

The four goals of the Campaign Plan are:

- **Goal 1:** Support National Security
- **Goal 2:** Deliver Integrated Water Resource Solutions
- **Goal 3:** Reduce Disaster Risk
- **Goal 4:** Prepare for Tomorrow

3.4.4 STATE AND LOCAL OBJECTIVES

The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible for the administration of Puerto Rico's coastal trust lands, the maritime terrestrial zone, territorial waters and submerged lands thereunder through PR Law 23, Art.5(h). DNER also serves as the lead agency for the implementation of the Puerto Rico Coastal Zone Management Program (PRCZMP). The PRCZMP was adopted in 1978 as the coastal element of the Island-wide Land Use Plan. This plan is a partnership between the United States Federal Government through the National Oceanic and Atmospheric Administration (NOAA) and the Government of Puerto Rico (DNER and PR Planning Board). The principles of the PRCZMP include developing guidance for public and private development within the coastal zone, active management of coastal and marine resources, promoting scientific research, education and public participation, as well as coordinating state and federal actions. The Coastal Zone Management Act requires that each Federal agency conducting, supporting, or undertaking development activities that are in, or directly affect, the coastal zone of a state shall insure that the project is, to the maximum extent practicable, consistent with approved state management plans.

3.4.4.1 LOCAL COMPREHENSIVE PLANNING

The comprehensive planning approach provided in the US Navy's Climate Change Planning Handbook (2017) was adapted in the Coastal Engineering Handbook written for Puerto Rico by Tetra Tech, Inc. It follows a four stage process to establish scope, identify and screen alternatives, calculate benefits and cost of action alternatives, and assembling a portfolio of action items.

3.5 CONSTRAINTS

3.5.1 PLANNING CONSTRAINTS

A constraint is a restriction that limits the extent of the planning process; it is a statement of effects that alternative plans should avoid. Constraints are designed to avoid undesirable changes between without and with-project future conditions. There are no specific planning constraints for this study area. All studies must avoid conflict with Federal regulations, as stated in Federal law, USACE regulations, and executive orders.

3.5.2 LOCAL CONSTRAINTS

Local and state laws do not constrain NED formulation. However, they may be considered in the selection of a Locally Preferred Plan (LPP).

3.6 SUMMARY OF MANAGEMENT MEASURES

The following sections represent an excerpt of the plan formulation process for a brief overview. However, **Appendix F, Plan Formulation** should be referenced for those wishing to read the full plan formulation analysis.

Plan formulation is the process of developing alternative plans to address a given problem. The first step in plan formulation involves identifying all potential management measures for the given problems. A management measure is an action that can be implemented at a specific geographic site to address one or more planning objectives.

An alternative plan includes one or more management measures to address the problem. Alternative plans can differ by types of measures, or how measures are combined or defined, including dimensions, quantities, materials, locations or implementation time frames.

Coastal storm risk management measures consist of three basic types: structural, nonstructural, and natural or nature-based features. The plan formulation process will result in an array of feasible coastal storm risk management alternatives that may consist of a variety of structural, nonstructural, and natural/nature-based measures.

3.6.1 IDENTIFICATION OF MANAGEMENT MEASURES

Management measures were selected to accomplish at least one of the planning objectives for this study, which were formulated based on the problems. All possible measures were considered, including those beyond the authority of USACE to implement. The following is a summary of the management measures considered.

Structural coastal storm risk management measures are man-made, constructed measures that counteract a flood event in order to reduce the hazard or to influence the course or probability of occurrence of the event. This includes gates, levees, and seawalls that are implemented to reduce risk of damage to infrastructure and to reduce risk to public safety.

Nonstructural coastal storm risk management measures are permanent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding. Nonstructural measures differ from structural measures in that they focus on reducing the consequences of flooding instead of focusing on reducing the probability of flooding. Relocation, floodproofing (wet and dry), home elevation, and flood warning systems are examples of nonstructural measures.

Natural and nature-based coastal storm risk management measures work with or restore natural processes with the aim of wave attenuation and storm surge reduction. Examples are submerged breakwaters that can also act as an artificial reef, elevated living shorelines and addition of vegetation for redundancy of coastal risk reduction functions.

The following measures are identified and considered for all 6 planning reaches (WSJB-1a, WSJB-1b, WSJB-2, WSJB-3, WSJB-4, and CL-1). As detailed analysis continues in this report, measures are then screened out or carried forward for sub-reaches delineated by direction of the water flow hazard within each reach. Objectives for both reaches include reduction of risk to infrastructure due to flooding from storm surge

combined with sea level rise. In WSJB-3, an additional objective is to reduce risk to infrastructure due to wave attack during hurricanes and storms. Measures appropriate to address these objectives are outlined in the discussions below.

MEASURES – TO REDUCE STORM SURGE (SS) RISK (WSJB-1, 2, 3, 4, CL-1)

STRUCTURAL

These measures serve the purpose of raising up the elevation of existing strategic low points, to reduce the risk of flooding from a respective water elevation as a result of storm surge combined with sea level rise.

S-1 (SS): No-action: The no-action plan represents future conditions without the implementation of a project. Although this measure does not address any specific problems, it provides a comparison for all other measures. Information to describe this measure was collected during the inventory of existing conditions. The storm surge frequencies would be expected to continue over the 50-year period of analysis. Present structures and replacement costs will be used into the future. The No Action alternative would see no additional federal involvement in storm damage reduction as outlined within this study.

S-2 (SS): Seawall/Floodwall: Seawalls and floodwalls are interchangeable at this phase of the study in terms of the function they provide, and will generally be referred to as seawalls in order to be conservative in costs and real estate footprint assumptions. Seawalls and floodwalls will be delineated further in the final report in terms of design footprint (i.e.: Seawalls use a slightly wider footprint than floodwalls). Seawalls could be constructed at a position seaward of the structures which they are designed to protect. These structures in general have a smaller bottom width footprint and could be beneficial in areas which do not have a large footprint of available real estate, such as in urban settings which are developed. It is assumed that seawall structures in the study area would be constructed seaward of existing seawalls, to protect historic value as well as to avoid disruption of engineering structural integrity of the existing seawall function. Seawalls could be designed as walls or with broader tops allowing for recreation on top of the wall. Both options are considered with this measure. COMBINEABILITY: This measure would need to be combined with S-7¹⁸ and could combined with other measures.

S-3 (SS): Levee: Levees are embankments constructed along a waterfront to reduce the risk of flooding in relatively large areas, with typical slopes ranging from 1V:2H to 1V:5H, depending on construction material. They are typically constructed by compacting soil into a large berm that is wide at the base and tapers toward the top. Grass or some other type of non-woody vegetation is usually planted on the levee to add stability to the structure. Levees may be constructed in urban areas; however, large tracts of real estate are usually required due to the levee width and required setbacks. COMBINEABILITY: This measure would need to be combined with S-7 and could combined with other measures.

S-4 (SS): Storm Surge Barrier, Large: In most cases, the barrier consists of a series of movable gates that stay open under normal conditions but are closed when storm surge is expected to exceed a certain predetermined level. Storm surge barriers are often chosen as a preferred alternative to closing off

¹⁸ Structural measures, such as seawalls and levees tend to trap rainfall runoff associated with storms on the landward side. S-7 represents culverts or pumps and would allow outflow of water from behind the landward side of the structure to carry the water to seaward sides, ensuring that functions to meet appropriate rainfall runoff needs are met.

waterways completely and may also reduce the required length of flood risk management measures adjacent to and/or behind the barriers. Storm surge barriers range in scale from small/local sluice gates reducing risk to a small coastal inlet to very large barrier systems that are designed to reduce risk to a large estuary or bay and consist of a series of coastal dikes, gates, and in some cases navigation locks. Storm surge barriers must be tied into high ground, whether it be existing high ground, a seawall, levee or other. Specifically, a storm surge barrier of this magnitude would be placed across San Juan Harbor and across the inlet of Condado Lagoon. COMBINEABILITY: This measure would need to be combined with S-2 or S-3 due to a requirement to tie into high ground, and assuming there will not be naturally existing high ground available.

S-5 (SS): Storm Surge Gate, Small: This measure refers to a smaller storm gate, or sluice gate, to close off risk of storm surge in smaller canals. Specifically, this type of gate could be used in the Mosquito Canal/Malaria Canal or Northern Canal. COMBINEABILITY: This measure would need to be combined with S-2 or S-3 due to a requirement to tie into high ground, and assuming there will not be naturally existing high ground available.

S-6 (SS): Pump Stations: Pump stations can be used to redirect water in low lying elevations to more appropriate locations. They generally have a sustained operation and maintenance commitment as well as associated costs. This measure represents larger pump stations that would be used to prevent storm surge, rather than smaller pumps that would be used in combination with structural measures to assist in outflow of runoff. COMBINEABILITY: This could be a stand-alone alternative, but would not be very effective given the large expanse of low lying elevations.

S-7 (SS): Inland Hydrology: Structural measures, such as seawalls and levees tend to trap rainfall runoff associated with storms on the landward side. Gravity outlets, such as culverts, in some cases can be installed along the length of the structure. In cases where significant runoff may be trapped behind the structure, ponding areas and pump stations may be required. This measure must be come combined with other structures such as levees and seawalls to allow outflow of water from behind the landward side of the structure to carry the water to seaward sides, ensuring that functions to meet appropriate rainfall runoff needs are met. While currently undefined, this measure will address the need for adequate rainfall runoff with other measures, and will be developed further and refined as needed for planning purposes. COMBINEABILITY: This measure is intended to be combined with S-2, S-3, S-8, NNBF-2 and NNBF-3.

S-8 (SS): Retention basin: This measure would involve land buyout to create a water retention basin in low areas to temporarily impound water and offset flooding impacts elsewhere. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

NON-STRUCTURAL

NS-1 (SS): Improved evacuation plan: The Puerto Rico Hurricane Evacuation Study was released in October 2018, and references evacuation zones. Conclusions from surveys conducted in the Puerto Rico Hurricane Evacuation Study, Behavioral Study, Final Report March 2014 generally indicated that residents would be more likely to evacuate out of the evacuation zone to higher ground if directed to do so. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected whether they evacuate or not; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-2 (SS): Improved public notification systems: Warning systems can limit damages of an event due to increased preparedness and ensure evacuation directives are messaged to the community. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected whether they receive the public notification or not; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-3 (SS): Improved public outreach about coastal flooding risk: Measures to convey storm surge risk to communities could help community better understand how it could affect them during a storm. An example used in other areas is storm surge posts, which visually show the storm surge stages which could be expected in various areas associated with category 1-5 storms. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected even if they are aware of the risks; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-4 (SS): Re-Zoning: Re-zoning could apply to phasing out development low lying areas over time. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding could still occur in areas which are not re-zoned; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-5 (SS): Floodproofing (Dry): Dry floodproofing involves making building and site modifications to prevent water from entering during a flooding event. Dry floodproofing methods would be to seal flood prone structures from water with door and window barriers, small scale rapid deployable floodwalls, or sealants. Dry floodproofing is generally feasible up to 3 feet and is prohibited in FEMA VE zones. COMBINEABILITY: Due to limited risk reduction (only up to 3 feet), this measure would need to be combined with other measures. This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-6 (SS): Floodproofing (Wet): Wet floodproofing involves making a series of modifications to a structure to allow an enclosed area below the base flood elevation to flood. The method of floodproofing reduces risk to the building but not to the contents of the building. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-7 (SS): Acquisition of land and structures (Buyout): This measure would allow storm surge to flood into low lying elevations. Structures within the area vulnerable to damage would be identified for acquisition. Structures on the acquired parcels would be demolished and natural areas restored. Such parcels would become public property and would reduce the number of structures vulnerable to storm damages. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-8 (SS): Elevate critical infrastructure: This measure, in combination with other measures, could reduce damages to critical infrastructure by building them to higher elevations. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many

communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-9 (SS): Elevate infrastructure: This measure, in combination with other measures, could reduce damages to infrastructure by building them to higher elevations. COMBINEABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-10 (SS): Relocation of Critical Infrastructure: This measure would allow the area to continue to flood from storm surge, while relocating critical infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study are would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective

NS-11 (SS): Relocation of critical evacuation route: This measure would allow the area to continue to flood from storm surge, while relocating infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study are would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-12 (SS): Elevate local roads: This measure, in combination with other measures, could reduce damages to roadways by building them to higher elevations. This measure would be especially applicable in the Condado Lagoon area, where tidal flooding impacts road access often. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NATURAL AND NATURE-BASED FEATURES

NNBF-1 (SS): Greenways: Use undeveloped land or purchase land which is susceptible to flooding to function as additional natural storage/retention during coastal storm and/or heavy rain events. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NNBF-2 (SS): Elevated Living Shoreline: This measure would be similar to a levee, however it would have two transitional berms at lower elevations. It would include placement of fill, stone, and vegetation, to reduce risk of storm surge flooding depths by providing a more natural raised elevation. It could provide additional benefits to create an effective buffer, provide valuable habitat and improve water quality. This measure is envisioned to be better suited for areas with less space and would be planted with vegetation suited for brackish/salt water habitats/environments. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

NNBF-3 (SS): Horizontal (“Tiered”) Levee: This measure would be similar to the elevated living shoreline, however it would have three transitional berms at lower elevations. It would include placement of fill,

stone, and vegetation, to reduce risk of storm surge flooding depths by providing a more natural raised elevation. It could provide additional benefits to create an effective buffer, provide valuable habitat and improve water quality. This measure is envisioned to be better suited for areas with more space and would be planted with vegetation suited for freshwater/marsh habitats/environments. COMBINEABILITY: This measure would need to be combined with S-7 to also address inland hydrologic needs for rainfall runoff.

MEASURES – TO REDUCE WAVE ATTACK (WA) RISK (PLANNING REACH WSJB-3)

STRUCTURAL

S-1: No-action: The no-action plan represents future conditions without the implementation of a project. Although this measure does not address any specific problems, it provides a comparison for all other measures. Information to describe this measure was collected during the inventory of existing conditions. The storm surge frequencies would be expected to continue over the 50-year period of analysis. Present structures and replacement costs will be used into the future. The No Action alternative would see no additional federal involvement in storm damage reduction as outlined within this study.

S-2: Seawall (WA): In addition to the function of a seawall for risk reduction as a result of storm surge, a seawall also can function for wave attack. Reference the description for seawall (SS). COMBINEABILITY: This measure would need to be combined with S-7 (SS) to address rainfall runoff. This is a duplicative measure that can cover both SS and WA.

S-3: Revetment (WA): This measure would involve placement of large rock, designed to withstand the wave environment, seaward of structures which are most vulnerable to storm damages which may result from shoreline erosion. The engineered structure would have a sloped profile designed to dissipate wave energy before it reaches the protected structures. The revetment could be covered by a dune or some degree of beach fill for additional protection and for aesthetic reasons. Construction would be from the beach, with intermittent access from roads. Impacts to the nearshore resources during construction would be avoided. COMBINEABILITY: This could be a stand-alone alternative.

NON-STRUCTURAL

NS-1 (WA): Acquisition of land and structures (Buyout): Structures within the area vulnerable to damage would be identified for acquisition. Structures on the acquired parcels would be demolished and natural areas restored. Such parcels would become public property and would reduce the number of structures vulnerable to storm damages. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-2 (WA): Relocation of Critical Infrastructure: This measure would allow the area experience wave attack while relocating infrastructure to a higher elevation to reduce risk of critical damage. Structures vulnerable to storm damage in the study area would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

NS-3 (WA): Improved public outreach: Measures to convey risk from the wave action risk to communities could help community better understand how it could affect them during a storm. Signs in the area could be a means to convey information. This would be a measure implemented by the non-federal sponsor. COMBINEABILITY: This measure alone would not meet the objective to reduce risk since coastal flooding would still occur and many communities would still be affected; it would need to be combined with other structural or NNBF measures that would reduce coastal flooding in order to be effective.

Natural and nature-based features

NATURAL AND NATURE-BASED FEATURES

NNBF-1 (WA): Submerged/Emergent Breakwaters: Offshore breakwaters reduce the amount of wave energy reaching the shoreline, and in this case, would reduce risk of damage to the storm surge measure. The breakwaters would be constructed of large rock with foundation materials to prevent subsidence. The breakwaters would be trapezoidal in profile and would be placed parallel to the shoreline in shallow water. The breakwater would be constructed in segments, separated from each other, to prevent infilling between the beach and the breakwater. The elevation and length of each breakwater segment and the distance between segments would be designed considering the local wave and sediment transport characteristics. This measure could benefit the environmental resources in the area, with the rock mimicking natural reefs adjacent to the study area, and potentially creating foraging habitat for benthic species. Mangroves could grow on top of the breakwaters as well for additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other storm surge measures to fulfill both the storm surge and wave attack reduction objectives.

NNBF-2 (WA): Emergent Island: This type of island would be elevated from the water and would act as a barrier island to the shoreline area. It would serve the same function as a breakwater, but it would be engineered with appropriate earthen materials. This measure could benefit the environmental resources in the area, with the rock on the outer face of the island potentially creating foraging habitat for benthic species. Mangroves and other plant species could grow on top of the islands as well for additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other storm surge measures to fulfill the storm surge and wave attack objectives.

NNBF-3 (WA): Mangrove/Vegetation Fringe: Mangroves have been shown to reduce wave action during coastal storm events, however, it is not measureable in terms of stand-alone benefits for the purposes of this analysis. Therefore, this measure would need to be combined with another measure which is measureable in terms of benefits, and would provide additional benefit/redundancy to that measure. Mangroves provide additional habitat and foraging opportunities for birds. COMBINEABILITY: This measure would need to be combined with other wave attack and storm surge measures to fulfill the storm surge and wave attack objectives.

3.7 SCREENING OF MANAGEMENT MEASURES

Screening is the ongoing process of eliminating measures which will no longer be considered, based on evaluation criteria.

3.7.1 PRELIMINARY SCREENING

Criteria to evaluate study measures was derived from the specific project objectives, ability to meet long term considerations, the four P&G accounts, as well as constraints. During this process, the interdependency, as well as the exclusivity of measures, is identified. This process serves to eliminate some measures from further consideration. Costs and benefits are not calculated at this stage.

In order to provide a metric for appraisal of the various management measures, a numeric score was applied by judging a measure's ability to meet planning objectives, meet long term considerations, avoid constraints, and to contribute to each of the four P&G accounts. The management measures were evaluated and rated in **Table 3-1** as follows: 0 = does not meet criteria, 1 = partially meets criteria, and 2 = fully meets criteria. If the total rating equals a number greater than 11, the measure partially meets, at least, over half of the objectives and constraints and is carried forward for further analysis. If the total rating is equal to or less than 11, the measure is not considered further. Planning criteria is shown in **Figure 3-3**. The results of the screening, are summarized in **Figure 3-4**, with measures with a dashed red line shown as screened out and the remaining measures being carried forward. More detail on the evaluation can be found in **Appendix F, Plan Formulation**.

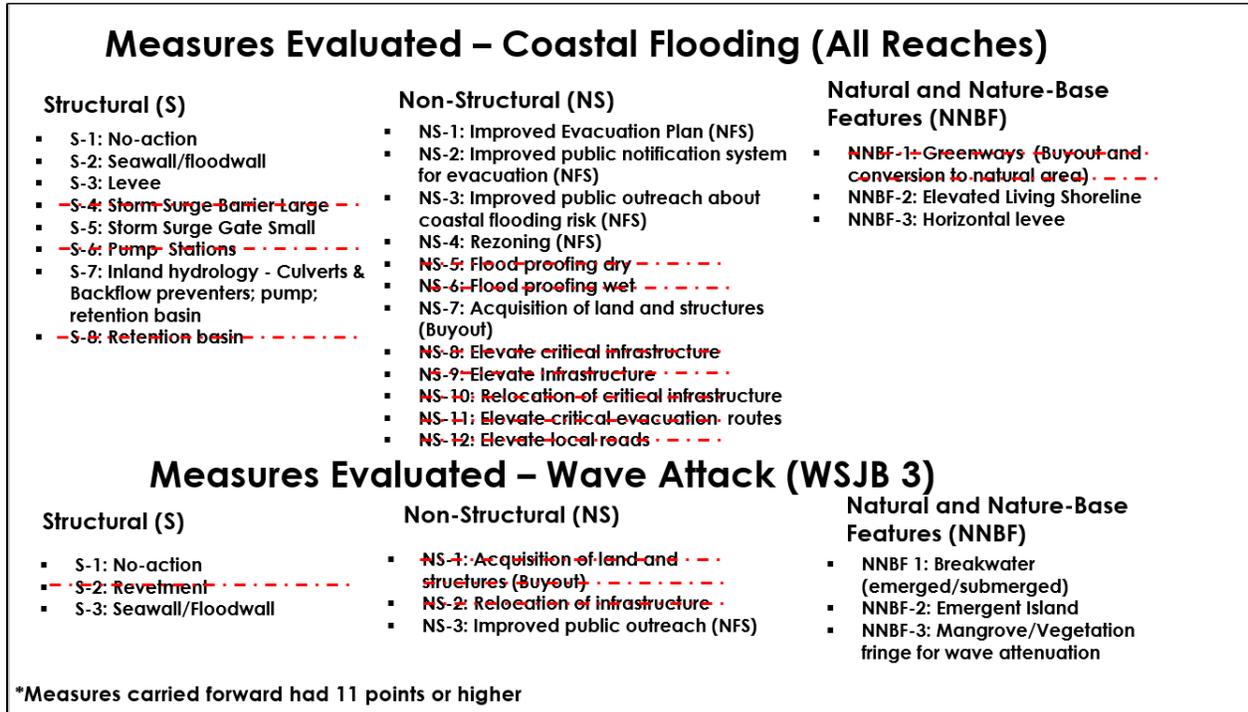
Figure 3-3. Planning Criteria for Screening of Measures.

Planning Criteria for Measures

- **Meet planning objectives**
 - Reduce flood damages (storm surge + SLR)
 - Reduce wave attack (only applies to WSJB3)
 - Improve community access/safety to critical infrastructure before, during, after storm (resilience) (storm surge + SLR)
- **Longterm Considerations**
 - Response/Ease of adaptability to sea level rise
 - Sustainability (ie: operation cost and maintenance responsibility)
- **Planning Constraints**
 - Cannot violate Federal regulations or laws
 - Cannot incur greater life safety risk compared to FWOP
- **Evaluate Planning & Guidance 4 Accounts**
 - National Economic Development (NED)
 - Environmental Quality (EQ)
 - Other Social Effects (OSE)
 - Regional Economic Development (RED)

*Each planning criteria is worth up to 2 points under evaluation. Any measures which violate either constraint are automatically ineligible to be carried forward. All measures must have 11 points or greater to be carried forward.

Figure 3-4. Measures Considered and Evaluated, with Screening Results (Coastal Flooding and Wave Attack).



3.7.2 FORMULATION STRATEGY

The overarching strategy is to identify the NED/TSP plan for each planning reach, and recommend an overarching TSP comprised of each reach’s NED/TSP plan, showing incrementally justification, to allow for comprehensive storm surge risk reduction within the San Juan Metro Area.

Planning reaches as described in this report were configured in ways such that they would be self-contained units of cost and benefits, or separable elements. This means that benefits accrued in each planning reach would be derived from alternatives only in that reach. Measures that met criteria to be carried forward were combined using the combinability thought process as described earlier, as well as refined geographical elevation information, existing site conditions, and professional engineering judgment as to the most feasible combinations per reach.

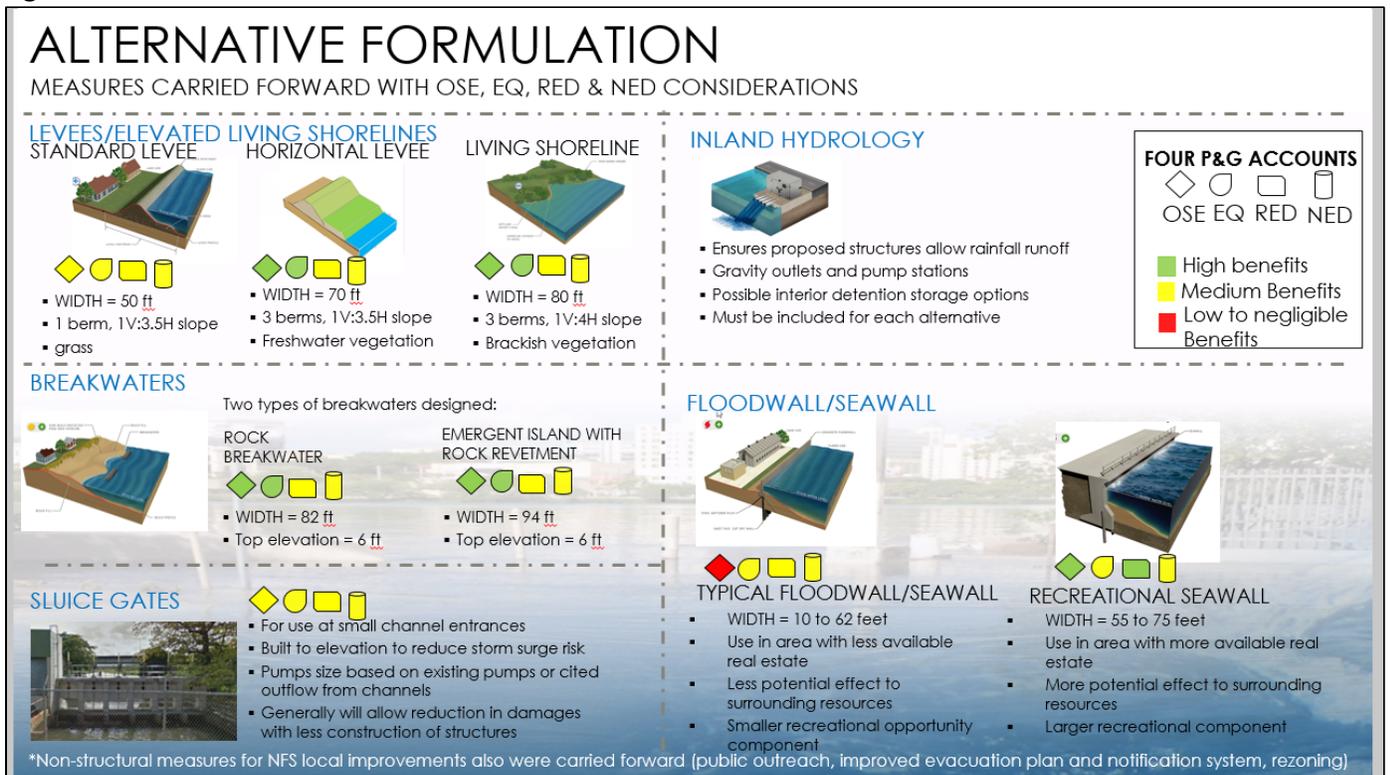
Design Elevations

To produce risk-based design elevations for the desired measures the study team followed ECB 2019-15 and ER 1105-2-101. ER 1105-2-101 states the assurance, also known as conditional non-exceedance probability, is based on the uncertainty in the flow and stages associated with a given exceedance probability event. This study utilized the 90% Confidence Intervals (CI) from Federal Emergency Management Administration (FEMA) to incorporate the total water level uncertainty. To represent the design elevation, the study used the 90% CI of the 1% AEP event with mean higher high water (MHHW) and the intermediate sea level Change (SLC) out to the end of the assumed federal participation (2079). The study team analyzed the stage-damage output from the future without-project (FWOP) G2CRM model runs to confirm that the design elevations would provide sufficient damage reduction to each

planning reach. The study team assumed the average design elevation between the planning reaches for a representative cost estimate; between the draft and final report, the study team will optimize design elevations. To incorporate sea level change, the intermediate curve (1.26 feet) was chosen for plan formulation, based on trends for 5-year and 19-year MSL moving average (Reference Section 2.3.2). Sensitivities for the high SLC curve were conducted after the TSP was determined (See Chapter 4).

The results of the evaluation that was performed in the screening matrixes for measures under the four P&G accounts (OSE, EQ, RED, and NED) are graphically expressed in **Figure 3-5**. Measures that scored highest rank of 2 are designated with green; measures that scored a mid-range of 1 are shown in yellow; and measures that scored zero are shown in red. The P&G accounts, combined with design assumptions, existing site conditions of the area, and environmental and real estate considerations, were considered for formulation of alternatives, are shown in **Figure 3-5**. In this figure, certain measures are grouped together which share common design characteristics and functions, for ease of reading and rationale of how and why measures were formulated into alternatives. In addition to the structural and natural and nature-based feature measures shown, the non-structural measure of acquisition of land and structures (buyout) in strategic areas which are flooded to certain elevations was also carried forward. Additionally, non-structural measures that the non-federal sponsor and local communities would carry out were also carried forward, such as improved public outreach about coastal flooding, improved evacuation plans and notification systems, and evaluations of re-zoning over time as needed. These were carried forward as recommendations to the non-federal sponsor and local communities only and would not be carried out as part of the federal project.

Figure 3-5. Consideration of Measures for Formulation of Alternatives.



3.8 COMPARISON & EVALUATION OF THE FOCUSED ARRAY OF ALTERNATIVES

Using the key information as described above in concert with ground elevations and key flooding sources leading to the highest risk of damages, the focused array of alternatives was formulated and is provided in **Table 3-1** and graphically below in **Figure 3-6** and **Figure 3-7**. All alternatives in the focused array include inland hydrology measures, to allow to outflow of rainfall runoff, and non-structural measures that the non-federal sponsor and local communities would carry out such as improved public outreach about coastal flooding, improved evacuation plans and notification systems, and evaluations of re-zoning over time as needed.

Although the key objectives are generally the same in each planning reach, it is important to note that the planning reaches represent unique communities within the San Juan Metro Area. While each planning reach has been defined as a separate unit, the goal is to provide a comprehensive storm risk reduction plan for the communities at risk of storm surge within the San Juan Metro Area.

Using the focused array of alternatives, first a quantitative economic evaluation must be made to identify which plan in the final array maximizes NED benefits. Additionally, the focused array of alternatives are also qualitatively compared and evaluated against criteria. An environmental analysis must also be conducted under NEPA to compare and evaluate the final array for a set of environmental factors, prior to determination of the NED Plan or Tentatively Selected Plan. Those three evaluations are found in the discussions below.

Table 3-1. Focused Array of Alternatives.

Alternative	Description
CONDADO LAGOON REACH (CL-1)	
CL1-Alt 1	Full Seawall
CL1-Alt 2	Full Recreational Seawall (this is a seawall with a greater width so that it can serve recreational purposes)
CL1-Alt 3	Full Recreational seawall with vegetation
CL1-Alt 4	Full Elevated Living Shoreline
CL1-Alt 5	Seawall north + Elevated Living Shoreline south
WEST SAN JUAN BAY (WSJB-1A)	
WSJB1A-Alt 1	Seawall + Levee
WEST SAN JUAN BAY (WSJB-1B)	
WSJB1B-Alt 1	Seawall + Levee + Elevated living shoreline
WSJB1B-Alt 2	Seawall + Levee
WEST SAN JUAN BAY (WSJB-1A + WSJB-1B)	
WSJB1A/B-Alt 1	Small Storm Gate + Seawall + Levee + Elevated living shoreline
WEST SAN JUAN BAY (WSJB-2)	
WSJB2-Alt 1	Levee + Seawall
WSJB2-Alt 2	Horizontal ("Tiered") levee + Seawall
WSJB2-Alt 3	Small Storm Surge Gate + Levee + Seawall
WSJB2-Alt 4	Small Storm Surge Gate + Horizontal ("Tiered") Levee + Seawall
WSJB2-Alt 5	Buyout in low lying elevations
WEST SAN JUAN BAY (WSJB-3)	
WSJB3-Alt 1	Seawall + Higher T-wall
WSJB3-Alt 2	Seawall + Breakwater
WSJB3-Alt 3	Seawall + Emergent Island
WSJB3-Alt 4	Seawall + Recreational Seawall + Breakwater
WSJB3-Alt 5	Seawall + Living Shoreline + Breakwater
WEST SAN JUAN BAY (WSJB-4)	
WSJB4-Alt 1	Seawall in low elevations
WSJB4-Alt 2	Seawall + Levee in low elevations

Figure 3-6. Focused Array of Alternatives for the San Juan Metro Area (CL, WSJB-1A, WSJB-1B).

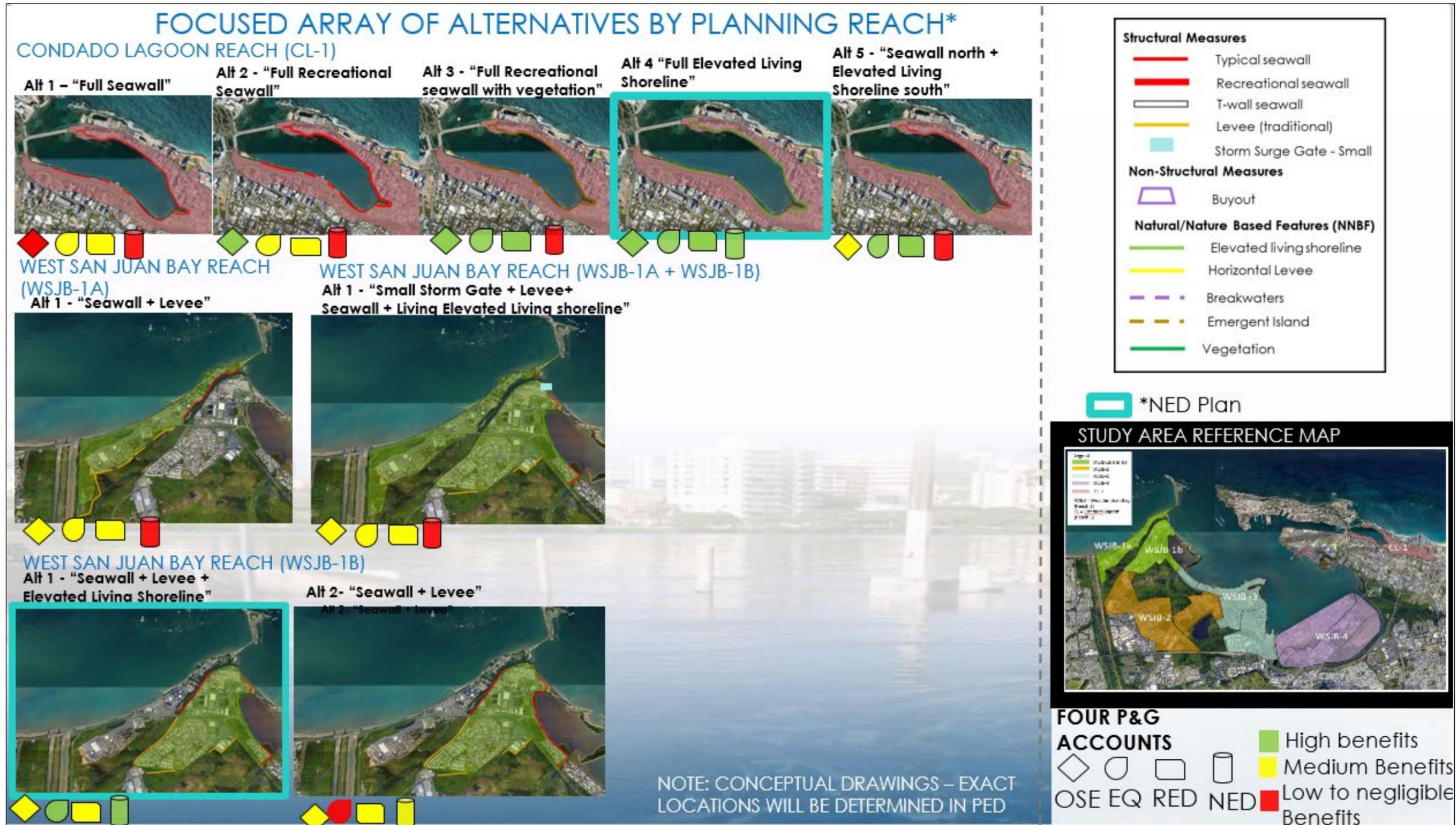
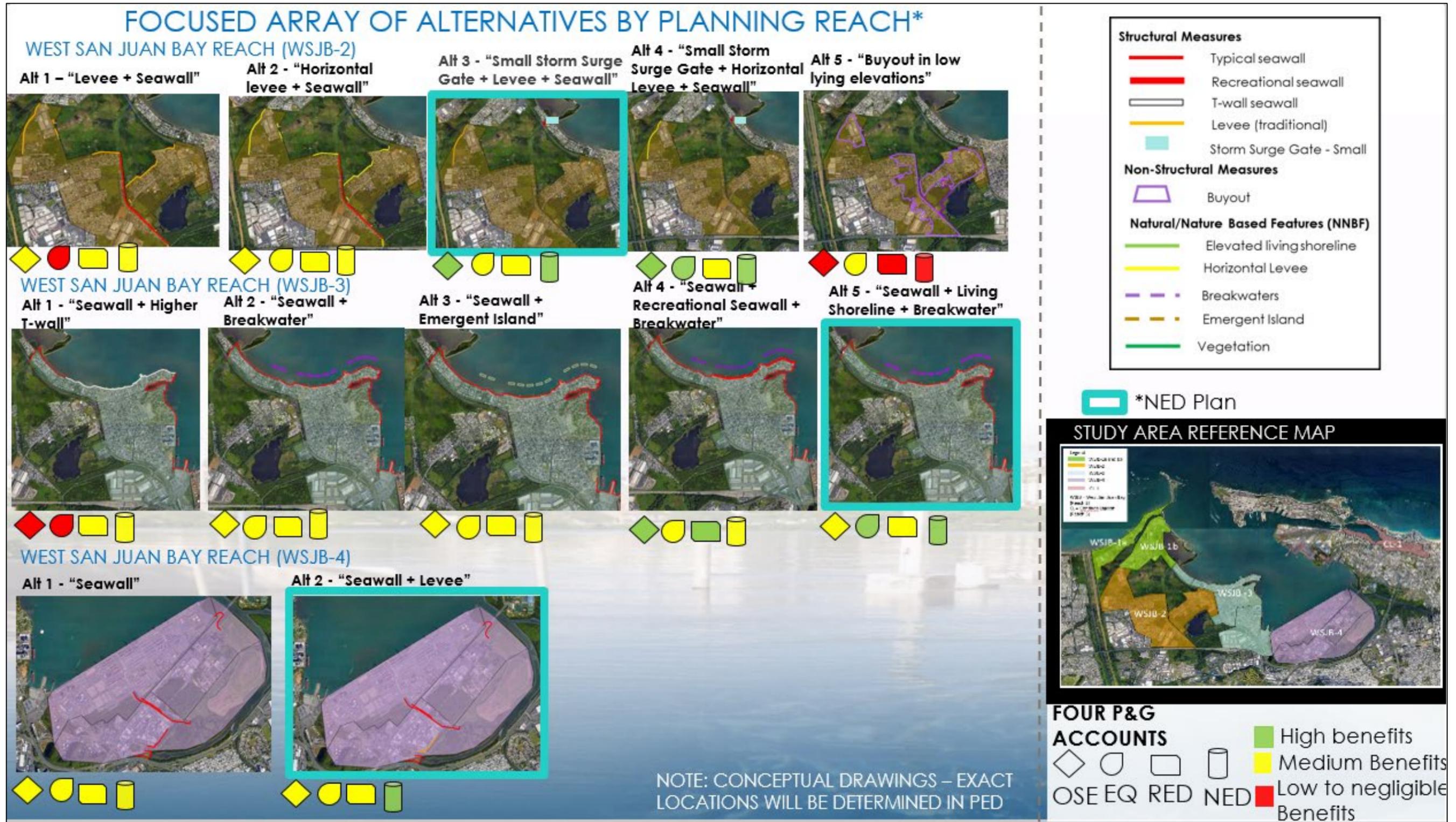


Figure 3-7. Focused Array of Alternatives for the San Juan Metro Area (WSJB-2,WSJB-3, WSJB-4).



3.8.1 ECONOMIC EVALUATION (COSTS & BENEFITS)

Each NED plan, shown below in **Table 3-3** and marked with blue highlight, is shown to have the highest net benefits within the reach compared to the other alternatives, and is also shown to be economically justified with a BCR greater than 1.0.

Several alternatives are shown to have negative net benefits and a benefit to cost ratio less than 1. These alternatives are: CL Alt 1-3; CL 5-6; WSJB-1A Alt 1a; WSJB-1A + 1B Alt 1(1a +1b).

Table 3-2. Highest Net benefits for each reach.¹⁹

Planning Reach	Alt	AAEQ NED Benefits	AAEQ NED Costs	AAEQ Net NED Benefits	BCR
CL	Alt 1	\$1,615,029	\$2,765,543	-\$1,150,513	0.58
	Alt 2	\$1,615,029	\$3,041,053	-\$1,426,024	0.53
	Alt 3	\$1,615,029	\$3,177,832	-\$1,562,803	0.51
	Alt 4	\$1,615,029	\$1,173,503	\$441,526	1.38
	Alt 5	\$1,615,029	\$2,213,702	-\$598,673	0.73
	Alt 6	\$1,615,029	\$2,381,342	-\$766,313	0.68
WSJB-1A	Alt 1a	\$845,901	\$1,366,053	-\$520,152	0.62
WSJB-1B	Alt 1b	\$2,489,862	\$1,551,049	\$938,813	1.61
	Alt 2b	\$2,489,862	\$1,776,316	\$713,546	1.40
WSJB-1A+1B	Alt 1(1a+1b)	\$3,520,179	\$3,961,721	-\$441,542	0.89
WSJB_2	Alt 1	\$10,560,200	\$1,418,998	\$9,141,202	7.44
	Alt 2	\$10,560,200	\$1,501,723	\$9,058,477	7.03
	Alt 3	\$12,722,287	\$929,641	\$11,792,646	13.69
	Alt 4	\$12,722,287	\$949,714	\$11,772,572	13.40
	Alt 5	\$13,532,392	\$9,053,628	\$4,478,764	1.49
WSJB_3	Alt 1	\$63,239,363	\$6,953,358	\$56,286,005	9.09
	Alt 2	\$63,826,013	\$6,033,587	\$57,792,426	10.58
	Alt 3	\$63,239,363	\$5,864,812	\$57,374,551	10.78
	Alt 4	\$63,826,013	\$6,118,909	\$57,707,103	10.43
	Alt 5	\$63,826,013	\$5,794,279	\$58,031,734	11.02
WSJB_4	Alt 1	\$2,667,710	\$1,545,697	\$1,122,014	1.73
	Alt 2	\$2,667,710	\$1,370,288	\$1,297,423	1.95

¹⁹ Results are based on 5-iteration model runs in G2CRM, and are a good representation of damages for plan formulation. 50-iteration model runs in G2CRM are used for refined benefits in Chapter 4.

3.8.2 PLANNING CRITERIA EVALUATION

Criteria to evaluate the study alternatives consisted of meeting specific project objectives, evaluations under the four P&G accounts, long term consideration, as well as avoiding constraints, and required evaluation criteria of completeness, efficiency, effectiveness and acceptability. The alternatives were evaluated and rated in as follows: 0 = does not meet criteria, 1 = partially meets criteria, and 2 = fully meets criteria. If the total rating equals a number greater than 14, the study alternative partially meets, at least, over half of the objectives and constraints and is carried forward for further analysis. If the total rating is less than 14, the study alternative is not considered further. All alternatives scored above 14. However, the NED account noted which alternatives had negative net benefits, as described in the above section. Screening matrixes showing the criteria and evaluations are shown in **Appendix F, Plan Formulation**.

3.8.3 ENVIRONMENTAL QUALITY

The environmental quality account considers non-monetary effects on ecological, cultural, and aesthetic resources. Under this account, the preferred plan should avoid or minimize environmental impacts and maximize environmental quality in the project area to the extent practicable considering other criteria and planning objectives. More detailed descriptions of the analysis and impacts can be found in Section 5 of this report and in the Appendices. For the purposes of alternatives analysis, all action plans were compared to the future without-project condition (i.e., NEPA No Action), which factors in 50 years of sea level change (to 2079). Effects for each alternative were evaluated below in **Table 3-3** and were carefully considered during plan formulation and for selection of the tentatively selected plan.

3.8.3.1 ENVIRONMENTAL MINIMIZATION AND AVOIDANCE MEASURES*

The first step in mitigation planning involves employing efforts to avoid adverse impacts. After development of the initial array of alternatives, the PDT coordinated with resource agencies who participated during the PDT meetings. These meetings focused on the primary resources (cultural resources, fish habitat, SAV, hardbottom, wetlands) that could be impacted by the proposed alternatives.

Cultural Resources. The USACE has conducted a review of recorded resources located near the proposed project features. The USACE will conduct surveys to refine the locations of resources as the features are designed to ensure avoidance and minimization of effects to cultural resources from the construction and implementation of the alternatives. If avoidance is not possible, USACE will develop mitigation measures with the Puerto Rico State Historic Preservation Officer (SHPO) with input from Instituto de Cultura Puertorriqueña and other interested parties. The terms detailing how USACE will ensure additional measures to protect cultural resources are in a Programmatic Agreement (PA) being developed by USACE and SHPO. As project designs are refined and optimized, impacts to cultural resources will continue to be minimized and avoided in some cases. Because the USACE cannot fully determine how the project may

affect historic properties prior to finalization of this feasibility study, a PA will be used to ensure compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA). Specifically, the scope and diversity of potential effects of the project and constraints of the USACE planning policy make a PA for compliance with Section 106 essential. The PA will allow the USACE to complete the necessary archaeological surveys during the follow on Preconstruction Engineer and Design (PED) phase of the project, and it will also allow any additional inventories and mitigation to be completed after measures have been clearly defined and sited. Consultation and coordination with all interested parties is ongoing and will be finalized prior to project implementation.

Fish Habitat, SAV, Hardbottom, Wetlands. The USACE will avoid and minimize effects to these resources by limiting CSRM measure construction within these areas to the minimum required to meet the project purpose. Many areas could be avoided and their extents would be determined during the PED Phase of the project when detailed, site-specific surveys would be conducted. Therefore, environmental impacts can be minimized by limiting CSRM measure footprints. In addition, construction adjacent the coral reefs at the entrance to San Juan bay and Condado lagoon would not occur. The reduction of impacts includes a minimized footprint and the potential for decreased indirect effects.

Table 3-3. Summary of Environmental Effects of the TSP and the No Action Alternative.

ALTERNATIVE ENVIRONMENTAL FACTOR	Condado Lagoon	WSJB-1B	WSJB 2	WSJB-3	WSJB-4	No-Action Plan
GENERAL ENVIRONMENTAL SETTING (refer to Sections 2.1 and 5.1.1)						
Wetlands	Construction of the elevated living shoreline could directly affect approximately 3.5 acres of existing mangroves.	Construction of the CSRSM measures could directly affect approximately 4.8 acres of existing mangroves and 2.7 acres of palustrine emergent wetlands.	Construction of the Sluice Gate could directly affect approximately 0.8 acres of existing mangroves and 0.8 acres of palustrine emergent wetlands.	Construction of the CSRSM measures could directly affect approximately 0.2 acres of existing mangroves.	Construction of the CSRSM measures could directly affect approximately 2.0 acres of existing mangroves and 0.01 acres of palustrine emergent wetlands.	In the future without-project (FWOP)/no-action alternative existing mangroves and palustrine emergent wetlands would continue to be affected by SLR and storm surge.
Water Quality	Elevated living shoreline construction in the water may result in direct but minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to avoid and minimize these impacts. Turbidity monitoring would be conducted during construction to maintain 10 NTU above background standard or temporarily shut down; No long-term impacts anticipated.	Construction of the CSRSM measures may result in direct but minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to avoid and minimize these impacts. Turbidity monitoring would be conducted during construction to maintain 10 NTU above background standard or temporarily shut down; No long-term impacts anticipated.	Construction of the Sluice Gate may result in direct but minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to avoid and minimize these impacts. Turbidity monitoring would be conducted during construction to maintain 10 NTU above background standard or temporarily shut down. No long-term impacts anticipated. Operation, including discharges from the Malaria Control Canal gate, would remain the responsibility of DNER in compliance with NPDES permit PRR040000/04000F and	Construction of the CSRSM measures may result in direct but minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to avoid and minimize these impacts. Turbidity monitoring would be conducted during construction to maintain 10 NTU above background standard or temporarily shut down; No long-term impacts anticipated.	Construction of the CSRSM measures may result in direct but minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to avoid and minimize these impacts. Turbidity monitoring would be conducted during construction to maintain 10 NTU above background standard or temporarily shut down; No long-term impacts anticipated.	In the FWOP/no-action alternative there could be degradation of water quality from erosion and sedimentation due to SLR and storm events. This could result to effects to listed corals adjacent the entrance to San Juan Bay and Condado lagoon and along the north coast.

			DA permit SAJ-2013-03237.			
Air Quality	Anticipated air quality impacts resulting from construction equipment emissions and other construction activities are expected to be minor and temporary.	Anticipated air quality impacts resulting from construction equipment emissions and other construction activities are expected to be minor and temporary.	The adverse impacts to air quality due to emissions from construction activities are anticipated to be minor and temporary.	The adverse impacts to air quality due to emissions from construction activities are anticipated to be minor and temporary.	The adverse impacts to air quality due to emissions from construction activities are anticipated to be minor and temporary, and are anticipated to be less than significant	The FWOP/no-action alternative would likely have no effect to air quality.
Threatened and Endangered Species	KEY for acronyms: NE=No Effect, MANLAA=May Affect, but is Not Likely to Adversely Affect, MALAA=May Affect, but it Likely to Adversely Affect					
Fish -Nassau Grouper -Scalloped Hammerhead Shark -Giant Manta Ray	Construction of the elevated living shoreline is expected to have no effect on these overfished and oceanic species.	Construction of the CSRSM measures is expected to have no effect on these species.	Construction of the Sluice Gate is expected to have no effect on these species.	Construction of the CSRSM measures is expected to have no effect on these species.	Construction of the CSRSM measures is expected to have no effect on these species.	The FWOP/no-action alternative would likely have no effect to Nassau grouper, scalloped hammerhead shark, or giant manta ray.
Swimming Sea Turtles -Loggerhead -Leatherback -Green -Hawksbill	Construction of the elevated living shoreline MANLAA these species. Monitoring and shutdown during construction required (See 5.1.6.3).	Construction of the CSRSM measures MANLAA these species. Monitoring and shutdown during construction required (See 5.1.6.3).	Construction of the Sluice Gate MANLAA these species. Monitoring and shutdown during construction required (See 5.1.6.3).	Construction of the CSRSM measures MANLAA these species. Monitoring and shutdown during construction required (See 5.1.6.3).	Construction of the CSRSM measures MANLAA these species. Monitoring and shutdown during construction required (See 5.1.6.3).	The FWOP/no-action alternative would likely have no effect to swimming sea turtles.
Antillean Manatee	Construction of the elevated living shoreline MANLAA this species. Standard construction conditions to be employed including monitoring and shutdown during construction (See 5.1.6.4).	Construction of the CSRSM measures MANLAA this species. Standard construction conditions to be employed including monitoring and shutdown during construction required (See 5.1.6.4).	Construction of the Sluice Gate MANLAA this species. Standard construction conditions to be employed including monitoring and shutdown during construction (See 5.1.6.4).	Construction of the CSRSM measures MANLAA this species. Standard construction conditions to be employed including monitoring and shutdown during construction (See 5.1.6.4).	Construction of the CSRSM measures MANLAA this species. Standard construction conditions to be employed including monitoring and shutdown during construction required (See 5.1.6.4).	The FWOP/no-action alternative would likely have no effect to Antillean manatees.
Listed Corals -Elkhorn -Staghorn -Pillar -Lobed Star -Mountainous Star	Construction of the elevated living shoreline would have NE on these species. Turbidity monitoring and shutdown during	Construction of the CSRSM measures would have NE on these species. Turbidity monitoring and shutdown during	Construction of the Sluice Gate would have NE on these species. Turbidity monitoring and shutdown during	Construction of the CSRSM measures would have NE on these species. Turbidity monitoring and shutdown during construction required (See 5.1.4 and 5.1.6.5).	Construction of the CSRSM measures would have NE on these species. Turbidity monitoring and shutdown during construction required (See 5.1.4 and 5.1.6.5).	In the FWOP/no-action alternative there could be degradation of water quality from erosion and sedimentation due to SLR and storm events. This could result to effects to listed corals adjacent the entrance to San Juan Bay and Condado lagoon and along the north coast.

-Boulder Star -Rough Cactus	construction required (See 5.1.4 and 5.1.6.5).	construction required (See 5.1.4 and 5.1.6.5).	construction required (See 5.1.4 and 5.1.6.5).			
Puerto Rican Boa	Construction of the elevated living shoreline MANLAA the Puerto Rican boa. Required implementation of USFWS standard conditions (See 5.1.6.6).	Construction of the CSRMM measures MANLAA this species. Required implementation of USFWS standard conditions (See 5.1.6.6).	Construction of the Sluice Gate MANLAA this species. Required implementation of USFWS standard conditions (See 5.1.6.6).	Construction of the CSRMM measures MANLAA this species. Required implementation of USFWS standard conditions (See 5.1.6.6).	Construction of the CSRMM measures MANLAA this species. Required implementation of USFWS standard conditions (See 5.1.6.6).	The FWOP/no-action alternative would likely have no effect to Puerto Rican boas.
Essential Fish Habitat	Construction could affect EFH including SAV, estuarine water column, and estuarine scrub shrub (mangroves) (See 5.1.3 and 5.1.5). Elevated living shoreline would provide habitat (See Appendix G).	Construction could affect EFH including SAV, estuarine water column, estuarine scrub shrub (mangroves), and palustrine emergent wetlands (See 5.1.3 and 5.1.5). CSRMM measures would provide habitat (See Appendix G).	Construction could affect EFH including estuarine water column, estuarine scrub shrub (mangroves), and palustrine emergent wetlands (See 5.1.3 and 5.1.5).	Construction could affect EFH including SAV, estuarine water column, estuarine scrub shrub (mangroves) (See 5.1.3 and 5.1.5). CSRMM measures would provide habitat (See Appendix G).	Construction could affect EFH including estuarine water column, estuarine scrub shrub (mangroves), and palustrine emergent wetlands (See 5.1.3 and 5.1.5).	In the FWOP/no-action alternative there could be degradation of water quality from erosion and sedimentation due to SLR and storm events. This could result to impacts to EFH.
Birds	Temporary disturbance during construction. Mangrove habitat potentially directly affected. Elevated living shoreline would provide habitat (See 5.1.7 and Appendix G).	Construction could affect birds and bird habitat including mangroves and palustrine emergent wetlands. CSRMM measures would provide habitat (See 5.1.7 and Appendix G).	Temporary disturbance during construction. Mangrove and palustrine emergent wetland habitat potentially directly affected.	Temporary disturbance during construction. Mangrove habitat potentially directly affected. CSRMM measures would provide habitat (See 5.1.7 and Appendix G).	Temporary disturbance during construction. Mangrove and palustrine emergent wetland habitat potentially directly affected.	In the FWOP/no-action alternative there could be erosion and loss of bird habitat due to SLR and storm events.
SAV	Construction could affect SAV (See 5.1.3 and 5.1.5). Elevated living shoreline would provide habitat (See Appendix G).	Construction could affect SAV (See 5.1.3 and 5.1.5). CSRMM measures would provide habitat (See Appendix G).	No effects anticipated.	Construction could affect SAV (See 5.1.3 and 5.1.5). CSRMM measures would provide habitat (See Appendix G).	No effects anticipated.	In the FWOP/no-action alternative there could be degradation of water quality from erosion and sedimentation due to SLR and storm events. This could result to impacts to SAV.
Hardbottom Habitat	No direct impacts anticipated. Impact estimates will be revised as necessary once updated field surveys can be conducted. BMPs including turbidity monitoring required during construction.	No direct impacts anticipated. Impact estimates will be revised as necessary once updated field surveys can be conducted.	No direct impacts anticipated. Impact estimates will be revised as necessary once updated field surveys can be conducted. BMPs including turbidity monitoring required during construction.	No direct impacts anticipated. Impact estimates will be revised as necessary once updated field surveys can be conducted. BMPs including turbidity monitoring required during construction.	No direct impacts anticipated. Impact estimates will be revised as necessary once updated field surveys can be conducted.	In the FWOP/no-action alternative there could be degradation of water quality from erosion and sedimentation due to SLR and storm events. This could result to impacts to hardbottom habitat.

Invasive Species	Construction of the elevated living shoreline would not cause additional threats from invasive species; BMPs required during construction to avoid the spread and help control invasive species.	Construction of the proposed CSRMM measures would not cause additional threats from invasive species; BMPs required during construction to avoid the spread and help control invasive species.	Construction of the Sluice Gate would not cause additional threats from invasive species; BMPs required during construction to avoid the spread and help control invasive species.	Construction of the proposed CSRMM measures would not cause additional threats from invasive species; BMPs required during construction to avoid the spread and help control invasive species.	Construction of the proposed CSRMM measures would not cause additional threats from invasive species; BMPs required during construction to avoid the spread and help control invasive species.	In the FWOP/no-action alternative control of invasive species would continue to be governed by regulation.
Environmental Justice	Construction of the proposed elevated living shoreline is not anticipated to have a disproportionately high and adverse impact on low income or minority communities or cause negative secondary effects. Beneficial effect to the overall area anticipated from sustainable storm damage reduction measures. Would benefit all populations in the area via reduction in damages as a result of back bay flooding.	Construction of the proposed elevated living shoreline is not anticipated to have a disproportionately high and adverse impact on low income or minority communities or cause negative secondary effects. Beneficial effect to the overall area anticipated from sustainable storm damage reduction measures. Would benefit all populations in the area via reduction in damages as a result of back bay flooding.	Construction of the proposed elevated living shoreline is not anticipated to have a disproportionately high and adverse impact on low income or minority communities or cause negative secondary effects. Beneficial effect to the overall area anticipated from sustainable storm damage reduction measures. Would benefit all populations in the area via reduction in damages as a result of back bay flooding.	Construction of the proposed elevated living shoreline is not anticipated to have a disproportionately high and adverse impact on low income or minority communities or cause negative secondary effects. Beneficial effect to the overall area anticipated from sustainable storm damage reduction measures. Would benefit all populations in the area via reduction in damages as a result of back bay flooding.	Construction of the proposed elevated living shoreline is not anticipated to have a disproportionately high and adverse impact on low income or minority communities or cause negative secondary effects. Beneficial effect to the overall area anticipated from sustainable storm damage reduction measures. Would benefit all populations in the area via reduction in damages as a result of back bay flooding.	In the FWOP/no-action alternative flooding from SLR and storm damage would continue to effect low income and minority communities around San Juan bay.
Noise	Minor adverse impacts to wildlife due to displacement from construction noise; Temporary and minor impact to human populations due to the construction activities.	Minor adverse impacts to wildlife due to displacement from construction noise; Temporary and minor impact to human populations due to the construction activities.	Minor adverse impacts to wildlife due to displacement from construction noise; Temporary and minor impact to human populations due to the construction activities.	Minor adverse impacts to wildlife due to displacement from construction noise; Temporary and minor impact to human populations due to the construction activities.	Minor adverse impacts to wildlife due to displacement from construction noise; Temporary and minor impact to human populations due to the construction activities.	In the FWOP/no-action alternative noise levels would continue to reflect that of an active harbor and large metropolitan area around San Juan bay.
HTRW	Construction of the elevated living shoreline would not cause additional threats from HTRW; Additional investigations could be required in PED. BMPs required during construction to avoid the spread and help control hazardous substances.	Construction of the proposed CSRMM measures would not cause additional threats from HTRW; Additional investigations could be required in PED. BMPs required during construction to avoid the spread and help control hazardous substances.	Construction of the proposed Sluice Gate would not cause additional threats from HTRW; Additional investigations could be required in PED. BMPs required during construction to avoid the spread and help control hazardous substances.	Construction of the proposed CSRMM measures would not cause additional threats from HTRW; Additional investigations could be required in PED. BMPs required during construction to avoid the spread and help control hazardous substances.	Construction of the proposed CSRMM measures would not cause additional threats from HTRW; Additional investigations could be required in PED. BMPs required during construction to avoid the spread and help control hazardous substances.	In the FWOP/no-action alternative control of HTRW would continue to be governed by regulation.

Aesthetics	Elevated living shorelines could benefit local area aesthetics; Not out of character for the San Juan area.	Nature-based CSRM measures could benefit local area aesthetics; Not out of character for the San Juan area.	No effect to area wide aesthetics; Not out of character for the San Juan area.	Nature-based CSRM measures could benefit local area aesthetics; Not out of character for the San Juan area.	Nature-based CSRM measures could benefit local area aesthetics; Not out of character for the San Juan area.	In the FWOP/no-action alternative local aesthetics would continue to reflect those of an active harbor and San Juan metropolitan area around San Juan bay.
Coastal Barrier Resources	No effect to CBRS units as they are too far away to be affected.	No effect to CBRS units as they are too far away to be affected.	No effect to CBRS units as they are too far away to be affected.	No effect to CBRS units as they are too far away to be affected.	No effect to CBRS units as they are too far away to be affected.	In the FWOP/no-action alternative CBRS units would continue to be governed by regulation.
Cultural and Historic Resources	The direct effects of construction may impact historic properties through disturbance of the ground and alterations of viewsheds. Additional investigations will be required in PED.	The direct effects of construction may impact historic properties through disturbance of the ground and alterations of viewsheds. Additional investigations will be required in PED.	The direct effects of construction may impact historic properties through disturbance of the ground and alterations of viewsheds. Additional investigations will be required in PED.	The direct effects of construction may impact historic properties through disturbance of the ground and alterations of viewsheds. Additional investigations will be required in PED.	The direct effects of construction may impact historic properties through disturbance of the ground and alterations of viewsheds. Additional investigations will be required in PED.	In the FWOP/no-action alternative impacts to historic properties are not anticipated.

3.9 SCREENING OF ALTERNATIVES

After the above analyses were completed, the economic analysis shows that several alternatives are shown to have negative net benefits and a benefit to cost ratio less than 1. These alternatives are: CL Alt 1-3; CL 5-6; WSJB-1A Alt 1a; WSJB-1A + 1B Alt 1(1a +1b). With consideration given to the planning criteria evaluation and the environmental evaluation, these alternatives are not carried forward for further analysis. Reach WSJB-1A does not have any alternatives which have a benefit to cost ratio equal to or greater than 1. The team consulted with staff at the Palo Seco Power Plants, which are the most significant critical infrastructure in this reach. Verbal communication indicated that the power plants have never had problems from storm surge, given past historical storms. The current analysis using planning criteria and environmental evaluations did not provide sufficient additional benefits or rationale to carry this reach forward in the analysis for inclusion in the TSP.

3.10 THE TENTATIVELY SELECTED PLAN

This analysis finds that there is Federal Interest in a comprehensive plan to reduce damages to the San Juan Metro Area. The P&G and ER 1105-2-100 state that the NED plan is the plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment. The NED Plan consists of the plan with the highest net benefits from each of the most vulnerable areas within the San Juan Metro Area, which is:

- CL Alt 4- Elevated Living Shoreline;
- WSBJ-1B: Alt 1 - Seawall + Levee + Elevated Living Shoreline;
- WSJB-2: Alt 3 – Small Storm Surge Gate + Levee + Seawall;
- WSJB-3: Alt 5 – Seawall + Living Shoreline + Breakwater;
- WSJB-4: Alt 2 – Levee + Seawall;

This NED plan uses key structural and natural and nature-based features in strategic locations designed to appropriate elevations which work together to reduce the risk of damages as a result of coastal flooding from storm surge, tide and waves during coastal storms and hurricanes in the San Juan Metro Area.

The NED plan brings benefits to the nation in all of the four P&G accounts (NED, EQ, RED, OSE), and meets the planning criteria of being complete, efficient, effective, and acceptable. Under NEPA, the NED plan has been evaluated for effects, which are described in Chapter 4. Consistent with the NEPA, USACE has formalized its commitment to the environment by creating a set of “Environmental Operating Principles” applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation and preservation, and restoration are considered in all USACE activities. These are identified and addressed specifically in Section 6.6.26 of this report. The NED provides average annual net benefits (AAEQ) of \$64M each year of a 50-year period of analysis. The NED plan is economically justified with a benefit to cost ratio of 5.2.

The TSP includes levees (2 miles), a series of breakwaters (0.7 miles) along the Cataño shoreline, seawalls (6.7 miles), elevated living shoreline (2.3 miles), a storm surge gate/sluice gate on the Malaria Canal, and associated inland hydrology features (to allow rainfall runoff with constructed features). Although the NED plan was formulated to avoid and minimize impacts to every extent possible, impacts are expected

to occur and would be addressed as mitigation, which is evaluated further in Chapter 5 under NEPA and in the mitigation plan in Appendix G, Environmental, Attachment 3, and in Chapter 4.

Typically, the NED plan becomes the Tentatively Selected Plan unless the non-federal sponsor chooses to pursue a Locally Preferred Plan (LPP) which differs from the NED plan. An LPP is subject to the requirements described in ER 1105-2-100. The option of selecting an LPP was coordinated with the non-federal sponsor, who does not wish to pursue an LPP at this time. The NED plan therefore is the tentatively selected plan.



4 The Tentatively Selected Plan

4 THE TENTATIVELY SELECTED PLAN

4.1 DESCRIPTION OF THE TENTATIVELY SELECTED PLAN

The Tentatively Selected plan consists of a collection of key structural, non-structural and natural and nature-based features in strategic locations designed to appropriate elevations which work together to reduce the risk of damages as a result of coastal flooding from storm surge, tide and waves during coastal storms and hurricanes in the San Juan Metro Area.

The TSP includes levees (2 miles), a series of breakwaters over 0.7 miles along the Cataño shoreline, seawalls (6.7 miles), elevated living shoreline (2.3 miles), a storm surge gate/sluice gate on the Malaria Canal, and associated inland hydrology feature (to allow continued rainfall runoff with the TSP constructed features). The TSP also contributes to creation of habitat and incorporates recreational features, which were added after selection of the plan, and discussed in this chapter. Although the TSP was formulated to avoid and minimize impacts to the extent practicable, impacts are expected to occur and would be addressed through mitigation, which is evaluated further in Chapter 5 and in the preliminary mitigation plan in Appendix G, Environmental, Attachment 4. These features and aspects of the TSP are discussed in this Chapter.

4.2 PROJECT DESIGN - CONCEPTUAL DETAILS OF THE TSP BY PLANNING REACH

Designs and assumptions described below are at a 10% level of design and are at a conceptual level only. The PED phase (which occurs after the feasibility phase is complete) would refine design to get to 100% level for construction.

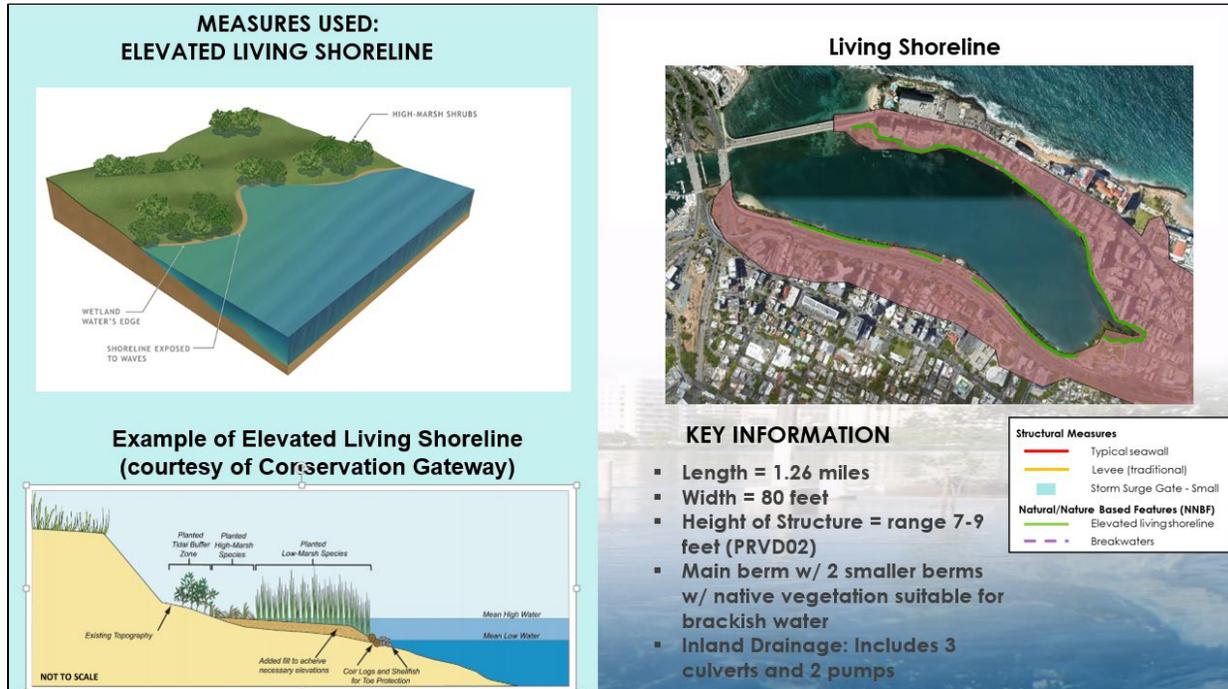
4.2.1 CONDADO LAGOON (CL-1)

In this reach, an elevated living shoreline will be constructed at the location shown in the graphic executive summary and in **Figure 4-1**. The elevated living shoreline will consist of three berms, with the first berm set to the specified design elevation and a top width of 5 ft and the slope will be kept at a 1V:4H on both the landward and seaward sides of the living shoreline. A concrete stem wall will be placed within the top berm and will extend from the top of the structure to 2-feet below existing grade. The second berm will be set to an elevation of 2 ft-PRVD02 and maintain a berm width of 1 foot to support various vegetative species like marsh grass. The third berm will be set to an elevation of -1 ft-PRVD02 and contain a berm width of 3 feet. Toe protection will encompass the entire bottom berm width of 3 ft and height of 3 ft with a D_{n50} of 1 ft with a unit weight of 147 lb/ft³. A 1-ft in diameter sediment tube surrounded by filter fabric will be placed within the center of the toe protection to support red mangrove plantings to help stabilize the toe of the berm.

The design elevation would be from 7- to 9-ft PRVD02, which will be further optimized throughout the feasibility phase and finalized during PED. This design accounts for inland drainage by using both culverts and pumps. The culverts will be placed in various locations throughout the model area and vary in width

depending on the measure type. Pumps will be placed within the eastern side of the model area to assist with the outflow of rainfall at the lowest elevation region within the model area. If necessary a retention basin could also be implemented to support the storage of rainfall runoff on the eastern side of Condado Lagoon.

Figure 4-1. Living Shoreline in Condado Lagoon.

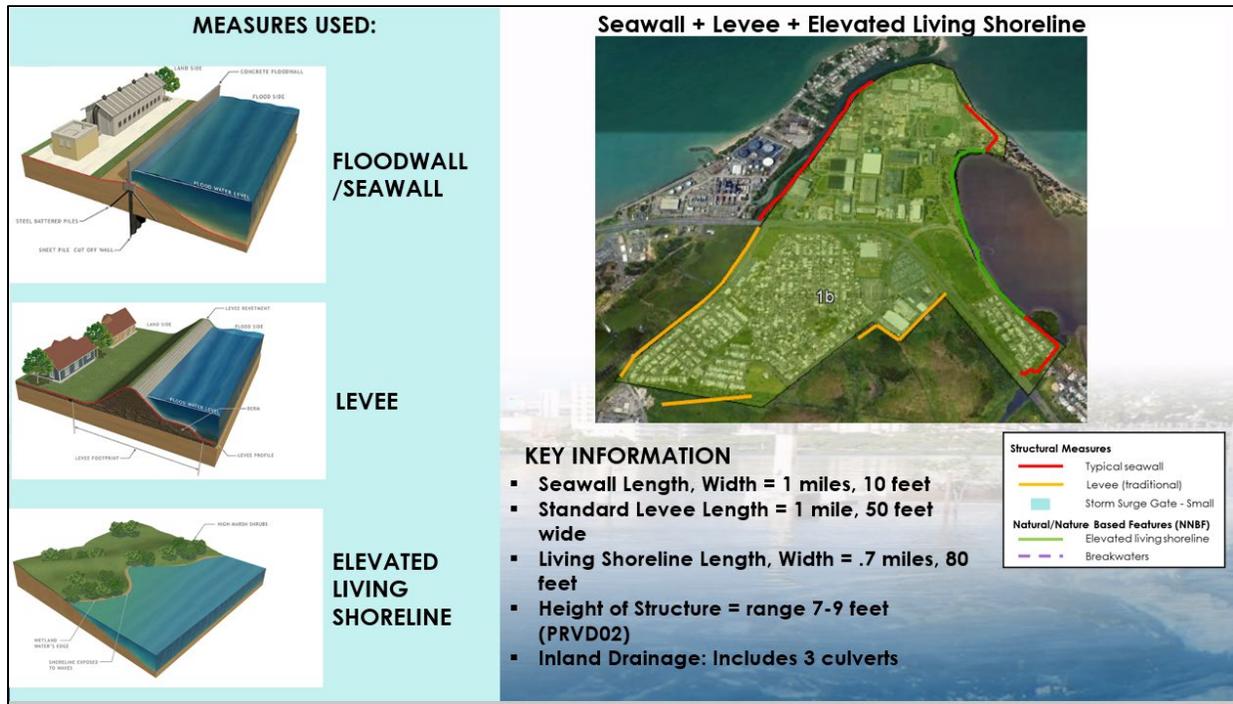


4.2.2 WEST SAN JUAN BAY 1B (WSJB-1B)

In this reach, a seawall would be constructed as well as a living shoreline as shown in the graphic executive summary and **Figure 4-2**. The seawall would be designed to be a steel cantilever sheetpile seawall although some locations of the seawall may transition into a floodwall although some locations of the seawall may transition into a floodwall depending on available real estate for the footprint. The sheetpiles will be driven approximately 25 ft deep and contain backfill up to the design elevation. The seawall will contain a 2-foot by 2-foot concrete cap and the team assumed no toe protection at the seawall location due to the limited wave action around WSJB-1B. Standard levees are proposed along the western and southern sides of the model area. The exact sediment type is unknown at the levee locations and therefore the engineering team assumed a slope of 1V:3.5H. Additionally, the study assumed a top width of 12-ft to maintain vehicle access to the levees. The elevated living shoreline located on the eastern side of the model area will consist of three berms, with the first berm set to the specified design elevation and a top width of 5 feet. The slope of the living shoreline will be kept at a 1V:4H on both the landward and seaward sides. A concrete stem wall will be placed within the top berm and will extend from the top of the structure to 2-feet below existing grade. The second berm will be set to an elevation of 2 ft-PRVD02 and maintain a berm width of 1 foot to support various vegetative species like marsh grass. The third berm will be set to an elevation of -1 ft-PRVD02 and contain a berm width of 3 feet. Toe protection will encompass the entire bottom berm width of and height of 3 feet with a D_{n50} of 1 ft with a unit weight of

147 lb/ft³. A 1-ft in diameter sediment tube surrounded by filter fabric will be placed within the center of the toe protection to support red mangrove plantings to help stabilize the toe of the berm.

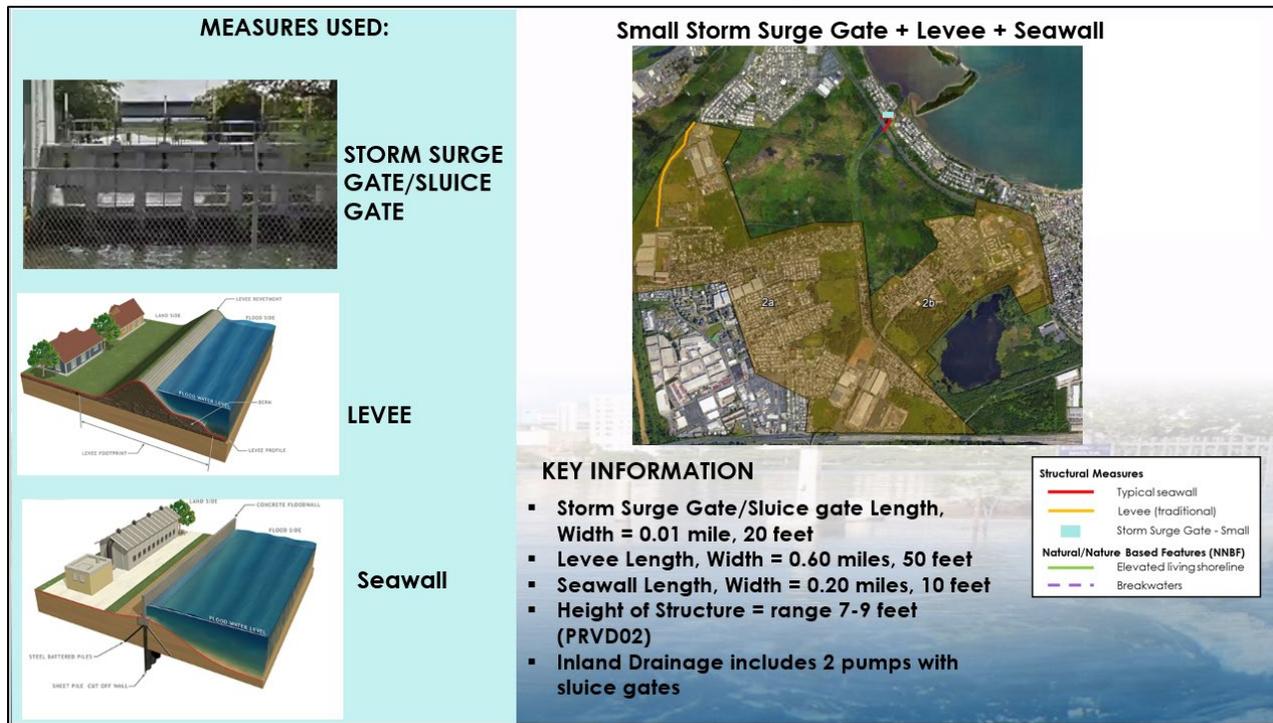
Figure 4-2. Seawall, Levee and Elevated Living Shoreline in West San Juan Bay 1b.



4.2.3 WEST SAN JUAN BAY 2 (WSJB-2)

In this reach, a storm surge gate/sluice gate would be constructed as shown in the graphic executive summary and **Figure 4-3** to extend approximately 50-ft across the Malaria Canal. Since the existing sluice gate remains closed pumps are currently installed to pump out the inland rainfall runoff. The engineering team assumed that the existing FEMA pumping capacity at Malaria Canal will have to be maintained, therefore the design includes three 50 CFS pumps and one 100 CFS pump. A seawall will tie into high elevations on either side of PR-165 from the sluice gate. The western side of the area will be protected by either a standard or horizontal (tiered) levee.

Figure 4-3. Storm Surge Gate, Levee, Seawall in West San Juan Bay 2.



4.2.4 WEST SAN JUAN BAY 3 (WJSB-3)

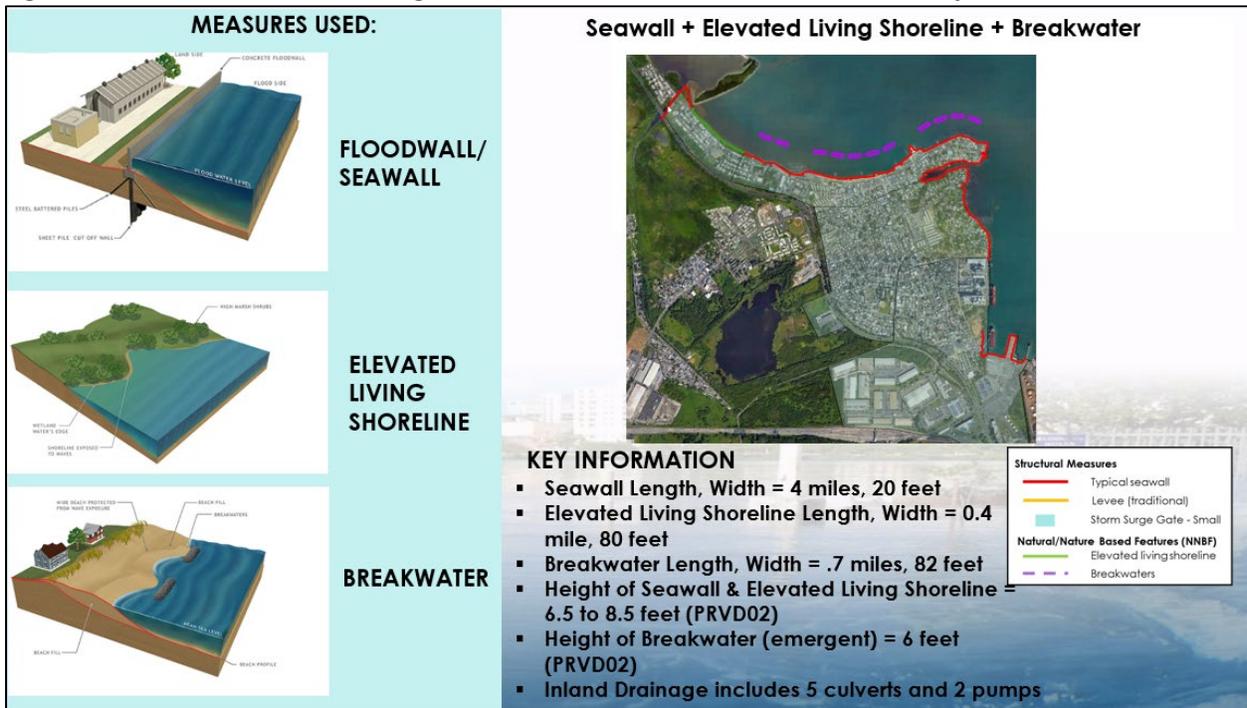
In this reach, the following would be constructed as shown in the graphic executive summary and **Figure 4-4**, which includes a rock breakwater, an elevated living shoreline, and a seawall. The living shoreline will be placed along the northeastern-facing shoreline of WSJB-3A. The elevated living shoreline will consist of three berms, with the first berm set to the specified design elevation and a top width of 5 ft and the slope will be kept at a 1V:4H on both the landward and seaward sides of the living shoreline. A concrete stem wall will be placed within the top berm and will extend from the top of the structure to 2-feet below existing grade. The second berm will be set to an elevation of 2 ft-PRVD02 and maintain a berm width of 1 foot to support various vegetative species like marsh grass. The third berm will be set to an elevation of -1 ft-PRVD02 and contain a berm width of 4 feet. Toe protection will encompass the entire bottom berm width of 4 ft and height of 3 ft with a D_{n50} of 2 ft with a unit weight of 147 lb/ft³. A 1-ft in diameter sediment tube surrounded by filter fabric will be placed within the center of the toe protection to support red mangrove plantings to help stabilize the toe of the berm.

The seawall is assumed to be a steel cantilever sheetpile seawall although some locations of the seawall may transition into a floodwall depending on available room within the canal. The sheetpiles will be driven approximately 25 to 40 feet deep to maintain a depth driven of twice the difference between the design elevation and the seaward elevation. The sheetpile will be driven from 24 feet deep to 40 feet deep, based on soil characteristics in different locations. The seawall will contain a 2-foot by 2-foot concrete cap with backfill up to the design elevation as well as toe protection with a D_{n50} of approximately 2-ft with a unit weight of 147 lb/ft³. The toe protection will have an approximate width of 8-ft and a height of 4-ft. If a floodwall is determined to be necessary due to a restriction of space, a T-Wall will be used. The T-Wall will

consist of two piles spaced approximately 7.5 ft along the centerline of the wall with a total pile length of approximately 55 feet. In addition to the seawall. The T-Wall will consist of two piles spaced approximately 5 ft along the centerline of the wall with a total pile length of approximately 55 feet. The T-Wall will contain backfill up to an elevation of 5 ft-PRVD02 as well as toe protection with a D_{n50} of approximately 2.6 feet with a unit weight of 147 lb/ft³. The toe protection will have an approximate width of 12 feet and a height of 5 feet.

The design elevation would be from 7- to 9-ft PRVD02, which will be further optimized throughout the feasibility phase and finalized during PED. This design accounts for inland drainage by using both culverts and pumps. The culverts will be placed in various locations throughout the model area and vary in width depending on the measure type. Pumps will be placed within the eastern side of the model area to assist with the outflow of rainfall at the lowest elevation region within the model area.

Figure 4-4. Seawall, Elevated Living Shoreline, Breakwater in West San Juan Bay 3.



4.2.5 WEST SAN JUAN BAY 4 (WSJB-4)

In this reach, a seawall would be constructed as shown in the graphic executive summary and figure below. The team designed the seawall to be a steel cantilever sheetpile seawall although some locations of the seawall may transition into a floodwall depending on available room within the canal. The sheetpiles will be driven approximately 25 deep to maintain a depth driven of twice the difference between the design elevation and the seaward elevation. The seawall will contain a 2-foot by 2-foot concrete cap and the team assumed no toe protection since there is no wave action along the model area. If a floodwall is determined to be necessary due to a restriction of space a T-Wall will be used. The T-Wall will consist of 2 piles spaced approximately 7.5 ft along the centerline of the wall with a total pile length

of approximately 60 feet. A levee would also be constructed in the location shows. The exact sediment type is unknown at the levee location, and therefore it is assumed at a slope of 1V:3.5H. Additionally, a top width of 12-ft is assumed to maintain vehicle access to the levee.

Figure 4-5. Seawall + Levee in West San Juan Bay 4.



4.2.6 RECREATION FEATURES

Recreation features have been incorporated into the TSP project features, and project first cost, and are eligible for cost sharing up to 10% of the Federal share per ER 1105-2-100. Elevated living shorelines and levees will incorporate recreation access steps at intervals and the crests of the levees and elevated living shorelines will include gravel trails, for hiking and walking in areas where communities would be able to take advantage of those features. Certain portions of seawalls in existing high-use recreational areas may include a wider top width for recreational use and access. These features will be refined through the Final Report and into the PED phase.

4.2.7 PROJECT CONSTRUCTION

Project construction is assumed to begin in 2024 and take approximately 5 years, assuming concurrent construction crews in various locations. Current assumptions are as follows:

1. Condado Lagoon: 2.6 years
2. WSJB 1B: 2.2 years
3. WSJB 2: 1.6 years
4. WSJB 3: Two separate contracts: Seawall/Living shoreline (4.6 years) and Breakwater (2.3 years)
5. WSJB 4: 1.2 years

4.2.8 PROJECT MITIGATION

Although the NED plan was formulated to avoid and minimize impacts to every extent possible, impacts are expected to occur and would be addressed as mitigation, which is evaluated further in Chapter 5 and in the preliminary mitigation plan in Appendix G, Environmental, Attachment 4. The siting of compensatory mitigation would be conducted during the PED Phase of the project when site-specific survey data is available to assess bottom conditions, hydrology, water quality, and presence of other protected species (to avoid potential impacts to other protected species). In addition, upon final design, the functional lift provided by the TSP would be incorporated into the functional assessment and mitigation plan. A bathymetric survey would be conducted prior to in-water work to assess water depths and bottom conditions in the project area. The limits of existing resources would be identified prior to implementation to ensure the estimated acreages and functional analysis are accurate. Wherever feasible, mitigation sites (if needed) would be within approximately five miles of the impact site to offset impacts as close as possible site. For instance, there is opportunity to enhance the degraded palustrine wetlands adjacent the MCC as discussed in section 2.3 above.

4.2.9 OPERATIONS AND MAINTENANCE CONSIDERATIONS

Operation and Maintenance (also known as Operation, Maintenance, Repair, Replacement, Rehabilitation, or OMRR&R) include all activities which are not related to the initial construction, and are borne 100% by the non-federal sponsor.

Operations and maintenance costs for determining the TSP were based on costs for similar existing structures for labor and materials to perform yearly inspections/tests of pump stations, floodwall street closures, storm surge barriers, small repairs, and potentially replacing gates or equipment during the 50-year period of analysis. Costs were then adjusted based on the length, type of measure, and additional labor/material costs as deemed necessary for different structural measures. After computation of the total costs, they were annualized using the FY2020 discount rate of 2.750% for a 50-year life cycle of the project. The annual average costs for OMRR&R are estimated to be \$2.3M per year.

4.3 PRE-CONSTRUCTION, ENGINEERING & DESIGN (PED) CONSIDERATIONS

During PED, design refinements will be conducted for all planned structural elements based on new field investigations and analyses. This chapter will discuss, not only what information and field investigations will be needed to achieve a final design, but also, how and what is proposed in this study that may be changed or adjusted.

4.3.1 UPDATED SURVEYS

It is recommended that topographic and/or bathymetric surveys be performed during PED in areas where structural measures are proposed. New surveys may determine an adjustment to the proposed height and/or length of structures is necessary. All elevations within the alternative designs are based off elevations from the digital elevation model (DEM), which is based off data from 2018 or older. A more

recent and comprehensive topographic and hydrographic survey will be required in order to develop plans and specifications.

4.3.2 SEAWALL DESIGN REFINEMENT

During the PED phase, subsurface explorations will be conducted along seawall alignments to supplement the existing information, reference the Geotechnical Appendix for additional details. Information from all subsurface explorations will be used to develop site-specific subsurface cross sections and refine the seawall designs, if necessary. These data will supplement additional design calculations, including but not limited to axial and lateral load capacity, settlement, footing uplift pressure, and depth driven of piles/sheetpiles. Findings from these analyses could result in changes to the assumed embedment depth of the piles (shorter or longer). Additionally, it is recommended to further analyze the wave conditions adjacent to each model area to potentially refine the rock size within alternatives that include toe protection and/or breakwaters. The apron width and height may be subject to change following this analysis as well. Additionally, locations along the proposed seawalls may need refinement where existing boat ramps and/or marinas are located to maintain public accessibility to the waterfront.

4.3.3 INLAND HYDROLOGY ANALYSIS REFINEMENT

During the PED phase, the team will refine the interior drainage analysis to more accurately design measures for interior drainage relief. The analysis would entail the use of the HEC-HMS (Hydrologic Engineering Center – Hydrologic Modelling System) software version 4.3 or the latest model available with the guidance of Engineering Manual 1110-2-1413. Rainfall frequencies ranging from the 2-year to 500-year 24-hour point rainfall from NOAA Atlas 14 will be used as the input.

4.3.4 ALIGNMENT & EASEMENTS

During the PED Phase, more information and data will be collected, including real estate information. The collection of new information and data may require adjustments to the proposed alignments, if easements cannot be acquired in certain areas. Real estate requirements for the study area consist of Flowage Easements (FE), Flood Protection Levee Easements (FPLE), Temporary Work Area Easement (TWAE), and Bank Protection Easement (BPE). These easements are necessary to provide adequate construction room to build proposed flood risk management features and secure lands needed for Operations and Maintenance (O&M). Additionally, the engineering team created preliminary staging areas, although additional refinement to the exact acreage and location will be refined in PED. More information on easements and real estate requirements can be found in the Real Estate Appendix in this study report.

4.4 SEA LEVEL CHANGE CONSIDERATIONS

The total regional sea level rise predicted by the three scenarios (low, intermediate, and high) will have a significant impact to the San Juan Metro area. Potential impacts of rising sea level include overtopping of waterside structures, increased shoreline erosion, and flooding of low-lying areas. SLC will further exacerbate the problem of inundation due to storm surge and tidal impacts to the study area for the Future Without-Project condition. As stated in **Section 3.6.2 of Appendix A, Engineering**, the intermediate

SLR scenario was selected as a basis for the feasibility level of design. Therefore, all proposed project features have currently been designed to account for 50 years of potential sea level rise (approximately

1.26 ft). This increase in water elevation due to sea level rise is reflected as an increase in the design elevation of hard structures such as levees, floodwall, and seawalls. Additionally, measures such as pump stations have been incorporated into the project to help facilitate the proper discharge of the hydrologic runoff during elevation sea levels due to storm surge and sea level rise.

The optimization of the design elevation for the project features is expected to continue during the feasibility phase. As this optimization occurs, the crest elevation, invert elevation, or other critical threshold elevations will be defined and compared against the sea level rise curves. This comparison will allow the appropriate design refinements to be recommended as well as proposition of potential methodologies that may trigger sea level change adaptations for project features. Additional analysis is forthcoming to determine the additional project modifications that would be needed for the federal project up to and beyond 50 year planning horizon necessary to provide the same level of protection.

4.5 BENEFITS OF THE RECOMMENDED PLAN

4.5.1 ECONOMIC SUMMARY

This analysis finds that there is Federal Interest in a comprehensive plan to reduce damages to the San Juan Metro Area. The TSP consists of the plan with the highest net benefits from each of the most vulnerable areas within the San Juan Metro Area, which is:

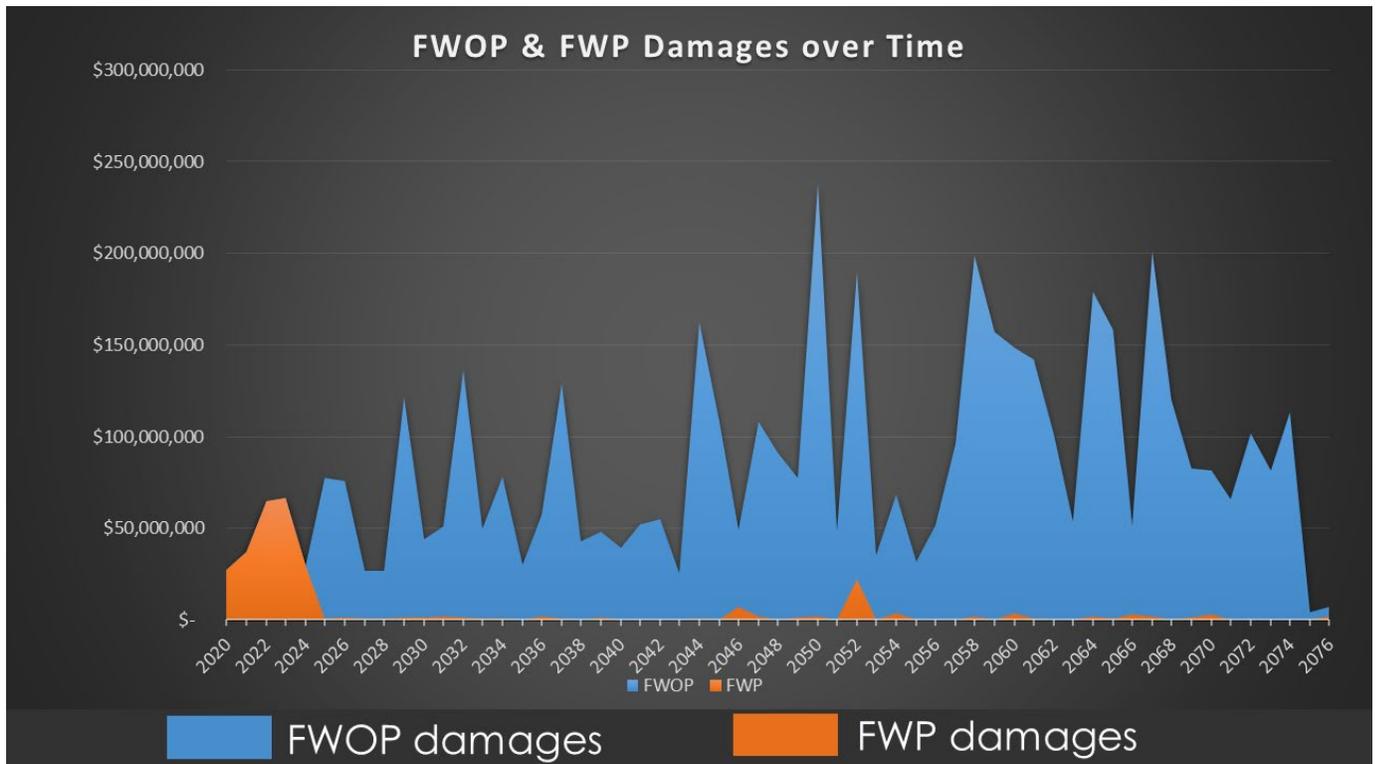
- CL Alt 4- Living Shoreline;
- WSBJ-1B: Alt 1 - Seawall + Levee + Elevated Living Shoreline;
- WSJB-2: Alt 3 – Small Storm Surge Gate + Levee + Seawall;
- WSJB-3: Alt 5 – Seawall + Living Shoreline + Breakwater;
- WSJB-4: Alt 2 – Levee + Seawall;

This TSP uses key structural, non-structural and natural and nature-based features in strategic locations designed to appropriate elevations which work together to effectively and efficiently reduce the risk of damages due to coastal flooding by 85% to 92% in the San Juan Metro Area. The TSP provides average annual net benefits (AAEQ) of \$64M each year of a 50-year period of analysis. The TSP is economically justified with a benefit to cost ratio of 5.2.

Table 4-1. Economic Summary in AAEQ of the Recommended Plan. (FY20 Price level and FY20 Water Resources Discount rate (2.75 %).

TSP ECONOMIC SUMMARY (FY20 price level, 50-year period of analysis, 2.75% discount rate)	
Total Average Annual Cost²⁰	\$15,404,000
Average Annual Total Benefits	\$79,426,000
Average Annual Net Benefits	\$64,022,000
Benefit Cost Ratio (BCR) (2.75 % discount rate)	5.2

Figure 4-6. FWP Reduction in damages compared to the FWOP project condition.



²⁰ Includes Interest During Construction (IDC) and OMRR&R

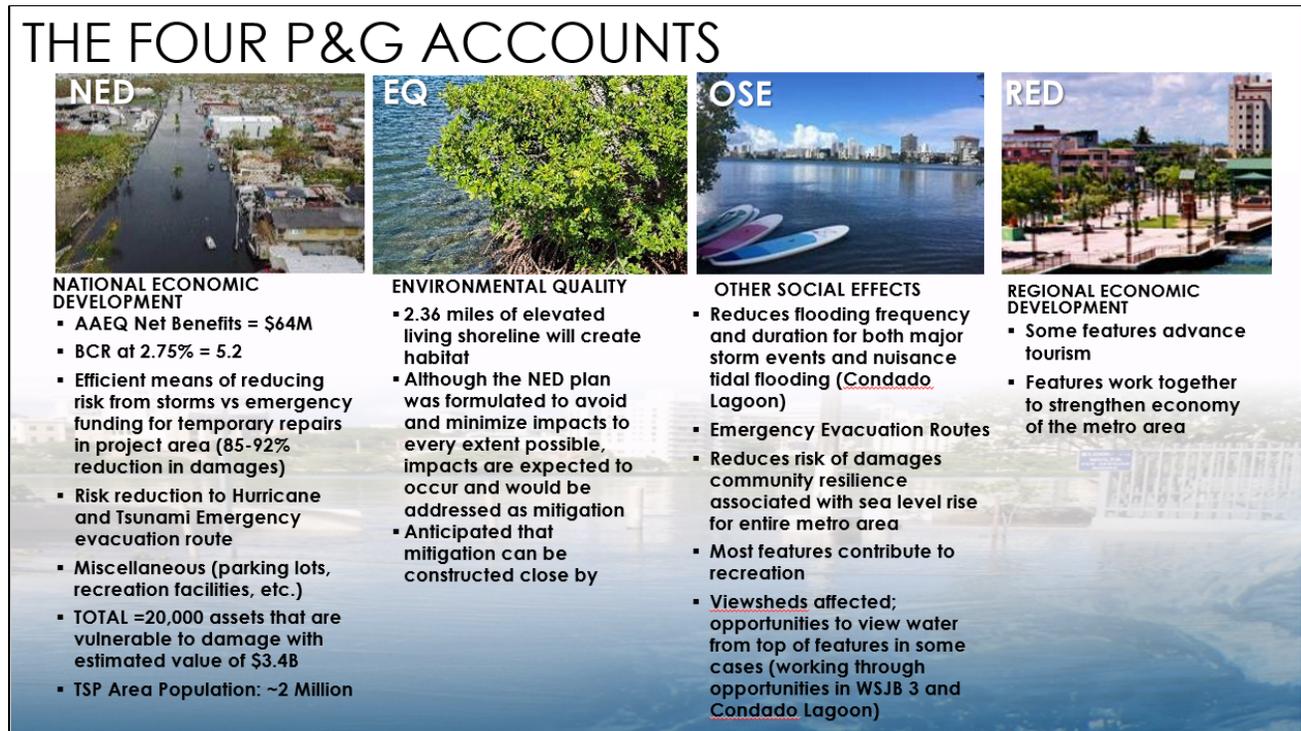
Table 4-2. Benefits and Reduction in Damages By Reach²¹.

Sub-Reach	NED Benefits	NED Costs	Net Benefits	BCR	% Damage Reduction
CL	\$1,478,799	\$1,460,817	\$17,982	1.01	90%
WSJB-1	\$2,532,702	\$1,970,059	\$562,643	1.29	90%
WSJB-2	\$10,029,970	\$1,381,679	\$8,648,291	7.26	92%
WSJB-3	\$62,965,473	\$9,133,218	\$53,832,254	6.89	90%
WSJB-4	\$2,418,761	\$1,458,226	\$960,535	1.66	85%
TSP Total	\$79,425,705	\$15,404,000	\$64,021,704	5.2	

4.5.2 BENEFITS WITH REGARD TO THE FOUR P&G ACCOUNTS AND P&G PLANNING CRITERIA

The NED plan brings benefits to the nation in all of the four P&G accounts (NED, EQ, RED, OSE), and meet the planning criteria of being complete, efficient, effective, and acceptable. Under NEPA, the NED plan has been evaluated for effects, which are described in Chapter 4. Consistent with the NEPA, USACE has formalized its commitment to the environment by creating a set of “Environmental Operating Principles” applicable to all its decision making and programs. These principles foster unity of purpose regarding environmental issues and ensure that environmental conservation and preservation, and restoration are considered in all USACE activities. These are identified and addressed specifically in Section 6.6.26 of this report.

Figure 4-7. Summary of Evaluations Under the Four P&G Accounts.



²¹ Results are based on 50-iteration model runs in G2CRM. Benefits reflect storm damage reduction benefits at this time; however, other benefits categories may be pursued for quantification prior to the final report.

4.5.3 RESILIENCY

The second objective of this study speaks to resilience. In EP 1100-1-2 USACE Resilience Initiative Roadmap 16 Oct 17, USACE has identified four key principles of resilience from the many definitions of resilience that exist. These principles – Prepare, Absorb, Recover, and Adapt – exemplify the temporal aspects and actions that are inherent to the process of building community resilience capacity.

Prepare: The study report communicates the results of analyses, which will help communities anticipate future coastal flooding elevations with sea level rise.

Absorb: the TSP offers solutions that will reduce damages to communities from 85%-92%, meaning less damages for the communities to absorb.

Recover: The TSP reduces damages, and also reduces the risk to health and safety of the communities during coastal flooding events through features that will reduce the risk of flooding in roads and health and safety problems that can arise from standing water, and allowing quicker recovery before, during and after storms.

Adapt: This report offer recommendations for monitoring to inform when adaptations to features in the TSP may need to occur and to what extent. The ability of the project to adapt into the future was assessed through the analysis of varying rates of sea level rise as well as an assessment of project performance out to 2129. The USACE Climate Change Adaptation Goal is to minimize impacts from climate change and maximize resiliency in the coastal landscape. The current 10% structural design of the San Juan Metro Area project takes into consideration the effects of sea level rise as part of the design (i.e., heights of walls). Although USACE designs Civil Works projects to have a 50 year design life, the designs should take into consideration how and if the design can adapt to the effects of sea level rise and climate change 100 years after the project is constructed and what adjustments can be made to the design to assure that the project can adapt into the future.

4.6 CONSISTENCY WITH SACS

The South Atlantic Coastal Study (SACS) is underway and provides a risk management framework designed to help local communities in the South Atlantic region of the United States better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. In particular, it encourages planning for resilient coastal communities that incorporates wherever possible sustainable coastal landscape systems that takes into account future sea level and climate change scenarios.

The San Juan Metro Area study echoes the principles of the SACS, considering the entire area as a system, and focuses on solutions in one of the high risk areas noted under SACS. The San Juan Metro Area CSRSM feasibility study team has been able to leverage information from SACS. The study used the SACS Tier 1 Risk Assessment Viewer to verify social vulnerability within high storm surge risk areas; additionally SACS data (ADCIRC/STWAVE) were used to generate hydrology data to identify storm surge risk. The San Juan Metro Area CSRSM developed parametric costs cost measures which were shared with SACS for future holistic parametric costs; the San Juan Metro Area CRSM tentatively selected plan will be referenced in SACS. SACS, and the feasibility studies which overlap it, including the San Juan Metro Area CSRSM study, will continue to share and leverage information from one another.

4.7 LANDS, EASEMENTS, RIGHTS OF WAY, RELOCATION AND DISPOSAL AREAS (LERRDS)

This section describes the lands, easements, rights of way, relocation, and disposal areas (LERRD) anticipated, identified or estimated at this time, that appear to be required for construction, operation and maintenance of the proposed project; including estimated acreage, estates, ownerships, and preliminarily and roughly estimated values and identified assumptions. The non-federal sponsor shall provide lands, easements, and rights-of-way.

The following Real estate requirements are necessary to provide adequate construction room to build the proposed coastal storm risk management features and secure lands needed for Operations and Maintenance (O&M):

- **Seawall:** Total area consists of 12.38 acres, within the Terrestrial Maritime Zone (TMZ). It is assumed that seawall structures in the study area would be constructed seaward of existing seawalls, to protect historic value as well as to avoid disruption of engineering structural integrity of the existing seawall function. The Puerto Rico Department of Natural and Environmental Resources (DNER) is responsible for the administration of Puerto Rico's coastal trust lands, the maritime terrestrial zone, territorial waters and submerged lands thereunder through PR Law 23, Art.5(h). Therefore, under PR Law 23, Art.5(h) and in concert with 48 U.S. Code § 74²², no lands would need to be acquired by the non-federal sponsor.
- **Levee:** Lands would need to be acquired as Flood Protection Levee Easement by the non-federal sponsor.
- **Storm Surge Gate, Small:** Lands would need to be acquired as Flood Protection Levee Easement by the non-federal sponsor.
- **Inland Hydrology/Outflow Structures:** Lands would need to be acquired in Fee by the non-federal sponsor.
- **Elevated Living Shoreline:** Lands would need to be acquired as Flood Protection Levee Easement by the non-federal sponsor.
- **Staging Areas:** Staging and storage areas have been identified for every reach of the project. Lands would need to be acquired as Temporary Work Area Easement by the non-federal sponsor.
- **Disposal:** Necessary disposal of ground or marsh material will be determined later during PED phase. Land would need to be acquired in Fee by the non-federal sponsor.

²² The harbor areas and navigable streams and bodies of water and submerged lands underlying the same in and around the island of Puerto Rico and the adjacent islands and waters, owned by the United States on March 2, 1917, and not reserved by the United States for public purposes, are placed under the control of the government of Puerto Rico, to be administered in the same manner and subject to the same limitations as the property enumerated in sections 747 and 748 of this title.

- **Recreation:** Recreational features included in this project are expected to be constructed within the project footprint. Therefore, no additional lands would need to be acquired by the non-federal sponsor.
- **Mitigation:** Mitigation areas are anticipated to be used as remediation for projects impacts. The actual location, acreage, and mitigation methodology will vary depending on the final development of the project and mitigation site designs that will occur during the PED Phase of the project. Lands would need to be acquired in Fee by the non-federal sponsor.
- **Road Access:** Road access would be over public roads and highways. No lands would be needed to be acquired by the non-federal sponsor.
- **Operation and Management:** After construction is completed, operation and management of the project features would be conducted within the public domain lands.

STANDARD ESTATES

If a property must be acquired for the project, the NFS will need to acquire all needed property rights and interest up to and including fee acquisitions. Most of the structural measures for the storm surge wall will require perpetual and temporary construction easements. Some properties would require fee acquisitions due to the amount of land and building remaining after the taking, leaving an uneconomic remnant. The NFS and Federal administrative costs associated with obtaining all real estate is included in the Administrative Review.

4.8 FEDERAL IMPLEMENTATION RESPONSIBILITIES

USACE is responsible for budgeting for the Federal share of future Federal construction projects. Federal funding is subject to budgetary constraints inherent in the formation of the national civil works budget in a given fiscal year. USACE would perform the necessary preconstruction engineering and design (PED) needed prior to construction. USACE would meet requirements for the use of Federal lands at the borrow area, obtain water quality certification, coordinate with the state as required by the Coastal Zone Management Act, and construct the project. Cost sharing of PED and initial construction will be in accordance with WRDA 1986, as amended, subject to the availability of appropriations.

4.9 NON-FEDERAL IMPLEMENTATION RESPONSIBILITIES

The non-federal sponsor for the CSRSM project will be DNER. A list of items of local cooperation are included in **Chapter 7, Recommendations**. The non-federal sponsor shall provide lands, easements, and rights-of-way and bear a portion of the administrative costs associated with land requirements. The non-federal project sponsor will be responsible for all costs of operation, maintenance, repair, rehabilitation, and replacement of project features. Section 402 of the 1986 Water Resources Development Act, as amended (33 USC 701b-12), states that "Before construction of any project for local flood protection or any project for hurricane or storm damage reduction, that involves Federal assistance from the Secretary, the non-federal interest shall agree to participate in and comply with applicable Federal floodplain management and flood insurance programs." The non-federal sponsor and communities must be enrolled in, and in compliance with, the National Flood Insurance Program (NFIP) to receive Federal funding for a recommended storm damage reduction project.

The PR Planning Board (PRPB) runs the National Flood Insurance Program in PR, and manages all PR riverine and coastal flood plains through PRPB Regulation 13. The non-federal sponsor and communities must be enrolled in, and in compliance with, the National Flood Insurance Program (NFIP) to receive Federal funding for a recommended storm damage reduction project. Under the PR Planning Board, DNER and communities are enrolled in the NFIP and are in compliance with this regulation.

4.10 TENTATIVELY SELECTED PLAN COST

The project first cost is currently estimated to be \$331.6M (including an overall average 28% abbreviated risk-based contingency), with a Federal cost of \$214M and a non-federal cost of \$117.6M. Project construction is assumed to begin in 2024 and take approximately 5 years, assuming concurrent construction crews in various locations. **Appendix B, Cost** provides additional detail.

Table 4-3. Tentatively Selected Plan Cost Summary (Project First Cost, FY20 Price Levels).

WBS Code	Item	Total Project First Cost (FY20)
10	Breakwaters & Seawalls	\$163,682,000
11	Levees & Floodwalls	\$13,262,000
13	Pumping Plant	\$40,320,000
14	Recreation Facilities	\$10,108,000
15	Floodway Control & Diversion Structures	\$8,375,000
06	Fish & Wildlife Facilities ²³	\$7,791,000
01	Lands and Damages	\$34,192,000
30	PED	\$34,548,000
30	Real Estate Administration Cost (Fed)	\$195,000
30	Real Estate Administration Cost (non-fed)	\$ 455,000
31	Construction Management	\$18,674,000
	Project First Cost	\$331,600,000

4.11 TENTATIVELY SELECTED PLAN COST SHARING

The project first cost is currently estimated to be \$331.6M, with a Federal cost of \$214M and a non-federal cost of \$117.6M, based on cost sharing percentages from the Water Resources Development Act (WRDA) of 1986 (Federal: 65%; non-federal: 35%).

²³ This item includes mitigation.

Table 4-4. Tentatively Selected Plan Cost Allocation (Project First Cost, FY20 Price Levels).

Item	Federal Cost Share	Federal Cost	Non-federal Cost Share	Non-federal Cost	Project First Cost
Project First Cost ²⁴	65.0%	\$214,000,000	35.0%	\$117,600,000	\$331,600,000
LERRD Credit				\$ 34,600,000	
Non-federal Cash Contribution				\$83,000,000	

4.12 FINANCIAL ANALYSIS OF NON-FEDERAL SPONSOR'S CAPABILITIES

A financial analysis used to be required for any plan being considered for USACE implementation that involves non-federal cost sharing. By memorandum dated April 24, 2007, the Assistant Secretary of the Army (Civil Works), granted approval of the self-certification of non-federal sponsors for their ability to pay the non-federal share of projects. The self-certification is required prior to submission of the final report.

4.13 VIEWS OF THE NON-FEDERAL SPONSOR

The Department of Natural and Environmental Resources (DNER) is the non-federal sponsor for the Tentatively Selected Plan. They have been an integral part of the study team throughout the feasibility study process. DNER supports the TSP.

4.14 RISK AND UNCERTAINTY

Risk and uncertainty is inherent within the feasibility phase during planning, and has been addressed and managed in several ways during the process.

Engineering: The study team will perform a Qualitative Risk Assessment (QRA) for any alternatives that include a levee (and potentially a floodwall or seawall), prior to the Final Feasibility Report. To address life safety and the qualification of the tolerable risk guidelines the engineering team will follow Planning Bulletin 2019-04, which states levee risk, which is sometimes considered as incremental risk, is used to describe the additional risk imposed by non-performance of the levee. The incremental risk may occur from one or more of four scenarios: 1) breach prior to overtopping, 2) overtopping with breach, 3) malfunction or improper operation of levee system components, and 4) levee overtopping without breach. Flood waters would inundate the community protected by the levee in the event of non-performance, posing a risk to life loss. The engineering team will also follow ECB 2019-15, which states a goal of the proposed levee is to achieve all four Tolerable Risk Guidelines: 1) Understanding the Risk, 2) Building Risk Awareness, 3) Fulfilling Daily Responsibilities, and 4) Actions to Reduce Risk. The team anticipates that during the QRA multiple data sources such as inundation maps, first floor elevations, and potential breach models may assist in understanding the flooding that could result in the failure of a project feature.

²⁴ Project cost share is 65%-35%; however, recreation is cost shared at 50%-50% and has been factored into cost sharing totals

During the PED phase, subsurface explorations will be conducted along seawall alignments to supplement the existing information, reference the Geotechnical Appendix for additional details. Information from all subsurface explorations will be used to develop site-specific subsurface cross sections and refine the seawall designs, if necessary. These data will supplement additional design calculations, including but not limited to axial and lateral load capacity, settlement, footing uplift pressure, and depth driven of piles/sheetpiles. Findings from these analyses could result in changes to the assumed embedment depth of the piles (shorter or longer). Additionally, it is recommended to further analyze the wave conditions adjacent to each model area to potentially refine the rock size within alternatives that include toe protection and/or breakwaters. The apron width and height may be subject to change following this analysis as well. The wave analysis will also be used to determine if additional rock revetment should be designed to reduce potential wave reflection towards other areas within San Juan Harbor. The engineering team will reevaluate the crest elevation of the system to consider the latest information on the total water level, waves, and SLC per the ER 1105-2-101 guidance on risk based design.

Interior drainage calculations were computed using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS). The U.S. Army Corps of Engineers HEC-HMS version 4.3 software was developed by the Hydrologic Engineering Center to simulate the hydrologic precipitation-runoff relationship in dendritic watersheds. HEC-HMS was used to simulate the upland watersheds of the San Juan Metro area to estimate runoff volumes and flow hydrographs for use in the feasibility level design of interior drainage structures. This analysis was performed to ensure that for each project alternative, appropriate interior drainage components were identified to handle residual flooding due to the proposed project features. The level of detail provided is commensurate with the study purpose and other technical elements as described in EM 1110-2-1413, Hydrologic Analysis of Interior Areas. The analysis here-in aided in identifying the type, size, and configuration of the components, as well as study measure locations and costs necessary for the economic and real estate evaluation. The engineering team is finalizing operational requirements but are expected to be complete by the final Feasibility Report.

Modeling: G2CRM incorporates risk and uncertainty to determine an optimized plan under many future scenarios. There is some uncertainty in the population data as the sources used to collect the information were not up to date. The structure inventory was compiled using virtual databases and Google Earth; data used may not be up to date to include new structures, vacant buildings and lots or correct occupancy types.

Mitigation: There is some uncertainty in terms of the quantity and siting of onsite compensatory mitigation which would be conducted during the PED Phase of the project when site-specific survey data is available. Upon final design, the functional lift provided from the construction of the TSP measures would be incorporated into the functional assessments and mitigation plan. It is anticipated that any mitigation sites would be located within approximately five miles to offset impacts as close as possible to the impact site. The mitigation cost has been accounted for in the cost estimate and includes a 40% contingency.

Cost: An abbreviated Cost Schedule Risk Analysis (CSRA) has been completed, which addresses risks to project implementation and construction. Based on the results of the analysis, a contingency value of \$94.5M has been added, which includes various contingency percentages for different items²⁵. This contingency includes risks related to costs for the effect of schedule delay on overall project cost. There

²⁵ The contingency for construction, pre-construction engineering & design, and supervision & administration (S&A) is 40%; real estate contingency is 30%.

are no high risks associated with this project and remaining risks are typical of civil works projects, such as those related to quantity estimates or unforeseen environmental risks. In the future, the risks will continue to be assessed and managed in during the remainder of the feasibility phase and into the design and construction phase of the project.

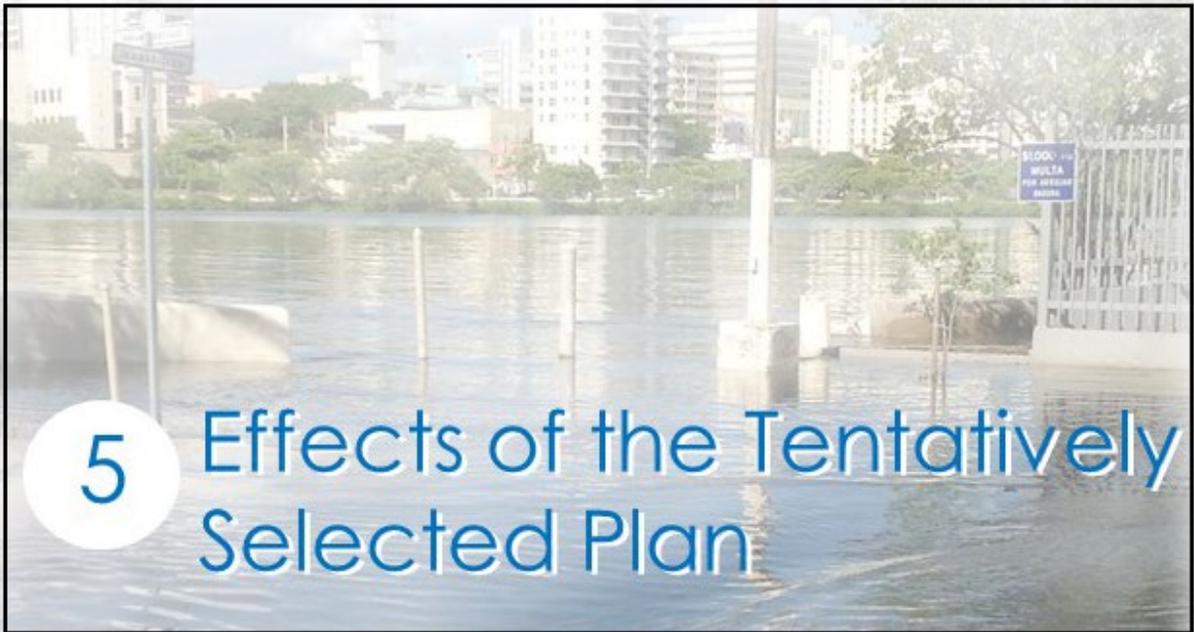
4.14.1 RESIDUAL RISK

The proposed project would greatly reduce, but not completely eliminate, future coastal storm risk and damages which result from coastal flooding. Coastal storm damages, caused primarily by coastal flooding, would be reduced by approximately 85% to 92% in the location of the project area over the 50 year period of analysis; therefore, the residual damages would be in the range of 8% to 15%. Periodically revisiting sea level rise trends described earlier be crucial for adaptive management to manage risk.

The tentatively selected plan will reduce damages but does not have a specific design level. In other words, the project is not designed to fully withstand a certain category of hurricane or a certain frequency storm event. During study scoping, it was determined that the vast majority of damages occur at the 90% assurance for the 1% exceedance probability event + MHHW + Intermediate Sea Level Change.

Reaches West San Juan Bay 1A and East San Juan Bay were screened out from the study after the analysis showed that minimal damages are occurring in these areas. The cost to build a project in these reaches to reduce the damages would be higher than the benefit received. As a result, these areas are not economically feasible to pursue; along with additional considerations under planning criteria, these reaches were screened from further analysis. However, the low damages shown by the analysis indicates there is low risk of coastal flooding damages to the communities. The risk of coastal flooding in these reaches is not affected by the proposed TSP.

After further analysis of reaches 4 through 6, the study team determined that those reaches have multiple sources of coastal flooding influences and the uncertainty in the exchanges of flow between them is too high without performing more extensive hydrologic modeling. The problem in these reaches is a combination of precipitation with storm surge. This type of analysis to include both precipitation as well as understanding the complexity of storm surge from multiple points would necessitate the use of multiple models and complex model interfaces, which would increase the scope of this study. The study team acknowledges there are flooding problems, resulting in potential risk to critical infrastructure and socially vulnerable communities from hydrologic induced flooding (precipitation) in addition to storm surge in reaches 4 through 6. These areas are recommended to be evaluated under a separate study in order to adequately address both storm surge and precipitation holistically. The same study authority that is used for this study could be used. The risk of coastal flooding in these reaches is not affected by the proposed TSP.



5

Effects of the Tentatively Selected Plan

5 EFFECTS OF THE TENTATIVELY SELECTED PLAN*

This section is the scientific and analytic evaluation of effects that would result from implementing the Recommended Plan. Chapter 2 of this report provides information on existing conditions as well as effects resulting from the “no-action alternative,” or the “Future Without-Project Conditions.” Table 3.4 provides a summary of direct and indirect effects of the TSP and the No Action Plan. The following section provides a more detailed analysis of anticipated changes to the existing environment including direct, indirect, and cumulative effects as a result of the Recommended Plan, or the “Future With-Project Conditions.”

5.1 NATURAL (GENERAL) ENVIRONMENT

5.1.1 SURFACE WATER QUALITY

Surface water quality can be affected by the proposed project directly or indirectly and temporarily. Direct, temporary effects on water quality may occur during project construction; increased turbidity is primary among these effects. Long term effects are not anticipated. A Water Quality Certification (WQC) in Accordance with Section 401 of the Clean Water Act, as amended, will be obtained and the conditions of this certification will be adhered to as a commitment of this project.

5.1.2 TURBIDITY AND SUSPENDED SOLIDS

Construction of CSRM measures is likely to have a temporary and minor impact to water quality. The proposed project would have construction in various areas of the bay for roughly 2 years.

The direct impacts to local waters during construction would be minor but adverse. Floodwall, living shoreline and possible breakwater construction in the water may result in direct impacts from construction activities. This would be a minor impact to local water quality. Sedimentation may increase in the local area due to the construction, although BMPs (best management practices) would be used to minimize these impacts.

5.1.3 WETLANDS AND SAV

The USACE has determined that construction of the proposed CSRM measures could directly affect existing mangrove and freshwater wetlands and SAV. In addition, temporary indirect effects from elevated turbidity levels during construction could occur. Best available information was used to generate preliminary impact estimates (See Appendix G Preliminary Mitigation Plan). These included the U.S. Fish and Wildlife Service National Wetland Inventory maps, NOAA National Ocean Service benthic atlas dataset for Puerto Rico and the USVI from 2000, and geophysical surveys conducted for the San Juan Harbor Navigation Project by USACE and NMFS HCD staff between 2016 and 2017. Preliminarily estimated acreages of direct impacts are:

- Approximately 11.3 acres of mangroves
- Approximately 3.5 acres of freshwater wetlands
- Approximately 11.8 acres of SAV

These are preliminary estimates of direct impact and the actual acreages are expected to change once updated field surveys can be conducted.

5.1.4 HARDBOTTOM HABITAT

As discussed in Section 2.2.3.1, hardbottom habitat is present adjacent the entrance to San Juan bay and along the north coast. The USACE anticipates that CSRMM measure construction would not directly affect existing hardbottom habitat. However, it is possible that some of the areas preliminarily delineated as SAV could contain hardbottom especially around the shoreline of Condado Lagoon (CL1-Alt 4) and the Catano nearshore where the breakwaters are proposed (WSJB3-Alt 5). Therefore the impact estimates will be revised as necessary once updated field surveys can be conducted.

Indirect impacts to hardbottom habitats would be due in large part to any turbidity resulting from the construction activities. Best Management Practices (BMPs) would be reemployed to minimize turbidity during in-water construction activities. Turbidity could result in sub-lethal effects (injury, decreased fecundity, etc.) on the macroinvertebrate community. Recent USACE consultations under Section 7 of the Endangered Species Act were conducted with the National Marine Fisheries Service for San Juan Harbor in 2016 and 2018 (Consultation Number SER-2013-10961 and SER-2017-18763). The 2018 BO concluded any effects to corals and critical habitat associated with transit and disposal of dredged materials within the Condado lagoon would be discountable. It is anticipated that construction of CSRMM measures around the shoreline of Condado lagoon (and at SWJB) would likewise have discountable effects to corals and Acroporid coral DCH, with use of BMPs during construction. The USACE will conduct turbidity monitoring in accordance with a monitoring plan that will be developed prior to construction to insure avoidance and minimization of effects to hardbottom habitat. Therefore, indirect impacts to hardbottoms and coral reefs from turbidity and sedimentation as a result of construction are not anticipated.

5.1.5 ESSENTIAL FISH HABITAT

Based on preliminary impact estimates the proposed project could affect EFH including hardbottom habitat (See Section 5.1.4), SAV, estuarine water column, estuarine scrub shrub (mangroves) and palustrine emergent wetlands (See Section 5.1.3). The preliminary impact estimates will be revised as necessary once updated field surveys can be conducted. In addition, the preliminary TSP is draft and could be refined to further avoid and minimize impacts. For example the final location of the WSJB3-Alt 5 breakwaters could be moved, and final design for the Condado living shoreline could be revised, to avoid resources should SAV or hardbottom be found there during updated field surveys. Considering this, the relatively small TSP footprint, and expected habitat enhancement benefits from construction of the nature-based CSRMM measures, the USACE has determined at this time and based on the preliminarily estimated impacts, the project is not anticipated to significantly affect EFH or federally managed fisheries in Puerto Rico.

Effects of the proposed action could include death and injury of fishes and forage during construction. Direct removal of SAV, hardbottom, mangrove and FW wetland habitats could occur as well as temporary changes in water quality. The below list summarizes potential effects of the proposed project on EFH and managed species.

1. Injury or mortality of individual fishes (adults, sub-adults, juveniles, larvae, and/or eggs, depending on species, time of year, location, etc.) due to construction. No one area would experience an extended duration of temporary effects during construction.

2. Indirectly affecting foraging behavior of individuals through production of turbidity at construction site (an effect temporary in duration).
3. Indirectly affecting movements of individuals around/away from construction equipment/area and related disturbed benthic habitats (an effect temporary in duration).
4. Directly affecting foraging and refuge habitats by removal of SAV, hardbottom, mangrove and FW wetland habitats.
5. Directly benefitting foraging and refuge habitat through construction of natural and nature-based CSR measures and additional habitat creation as needed.

These impacts would occur on a temporary scale. As noted, the affects would only be felt in the area of construction activity which would not be taking place at all locations at all times. Individually or in sum, the above are not anticipated to significantly adversely affect managed species or EFH. An EFH Assessment is incorporated into this integrated document in sections 2.2.2-2.2.4 and 5.1.3-5.1.4 and will be coordinated with NMFS concurrent with the public review of the Draft IFR/EA.

5.1.6 PROTECTED SPECIES

5.1.6.1 OVERVIEW

A summary of effect determinations for Threatened and Endangered Species as a result of the proposed project is in Table 5-3. The USACE determined that the proposed project, will have “no effect” (NE) on scalloped hammerhead shark, Nassau grouper, and giant manta ray, elkhorn, staghorn, pillar, rough cactus, lobed star, mountainous star and boulder star corals; “may affect, but is not likely to adversely affect” (MANLAA), loggerhead, hawksbill, leatherback and green sea turtles, Antillean manatee, and Puerto Rican boa; and will not adversely modify DCH for Acroporid corals. Project designs will be refined to minimize potential effects to the extent feasible. A biological assessment evaluating these determinations will be sent to the National Marine Fisheries Service and U.S. Fish and Wildlife Service initiating consultation under Section 7 of the ESA.

5.1.6.2 FISH (NASSAU GROUPE, SCALLOPED HAMMERHEAD SHARK, AND GIANT MANTA RAY)

Considering the overlaps of various life stages in distribution within the proposed project area and subsequent risk of take relative to construction operations, this section considers the impacts of the proposed project to scalloped hammerhead shark (SHS), Nassau grouper (NG), and giant manta ray (GMR) together. Potential direct and indirect impacts associated with in-water construction that may adversely impact these species could include entrainment and/or capture of adults, juveniles, larvae, and eggs, short-term impacts to foraging and refuge habitat, water quality, and disruption of migratory pathways. However, given the mobility of these species, the anticipated small area of active construction and anticipated lack of occurrence of these species in the action area, the likelihood of proposed construction activities to incidentally take SHS, NG and GMR is discountable. Therefore, the no effect determination for these species is based on the anticipated low abundance within the project area and the mandatory buffer distances between construction activities and coral reef/hardbottom habitat.

Table 5-3. Summary of Effect Determination for Threatened and Endangered Species. (Details can be found in Appendix G.)

2020 SAN JUAN METRO BACKBAY CSRM STUDY ESA TABLE			
Common Name	Scientific Name	Status	Determination
Marine Mammals			
Antillean manatee	<i>Trichechus manatus</i>	T	MANLAA
Sea Turtles			
Loggerhead sea turtle NW Atlantic DPS	<i>Caretta caretta</i>	T	MANLAA
Hawksbill sea turtle	<i>Eretmochelys imbricata</i>	E	MANLAA
Leatherback sea turtle	<i>Dermochelys coriacea</i>	E	MANLAA
Green sea turtle South Atlantic DPS	<i>Chelonia mydas</i>	T	MANLAA
Fish			
Nassau grouper	<i>Epinephelus striatus</i>	T	NE
Scalloped hammerhead shark	<i>Sphyrna lewini</i>	E	NE
Giant manta ray	<i>Manta birostris</i>	T	NE
Invertebrates			
Elkhorn coral	<i>Acropora palmata</i>	T	NE
Staghorn coral	<i>Acropora cervicornis</i>	T	NE
<i>Acroporid Coral Designated Critical Habitat</i>			NLAM
Pillar coral	<i>Dendrogyra cylindrus</i>	T	NE
Lobed star coral	<i>Orbicella annularis</i>	T	NE
Mountainous star coral	<i>Orbicella faveolata</i>	T	NE
Boulder star coral	<i>Orbicella franksi</i>	T	NE
Rough cactus coral	<i>Mycetophyllia ferox</i>	T	NE
Terrestrial Reptiles			
Puerto Rican Boa	<i>Epicrates inornatus</i>	E	MANLAA

5.1.6.3 SEA TURTLES

Overall impacts to sea turtles from construction activities are not anticipated. Current conservation measures implemented by the USACE to reduce impacts to sea turtles during in-water construction are discussed in Section 6 of this report (Environmental Compliance). The USACE will use the following measures outlined below during the construction of the proposed project (described in detail in Appendix G):

- a. Protected species observers during in-water work.
- b. Shut-down of construction activities and monitoring should a turtle come with 50-feet until the animal leaves the area of its own volition.

5.1.6.4 ANTILLEAN MANATEE

The proposed project may affect, but is not likely to adversely affect the manatee. The contractor would adhere to the standard manatee conditions during construction in order to avoid impacts. The Contractor may be held responsible for any manatee harmed, harassed, or killed as a result of vessel collisions or

construction activities. Failure of the Contractor to follow these specifications is a violation of the Endangered Species Act and could result in prosecution of the Contractor under the Endangered Species Act or the Marine Mammals Protection Act. The standard manatee conditions apply year-round in Puerto Rico. The Contractor will be instructed to take the necessary precautions to avoid contact with manatees. If manatees are sighted within 100 yards of the dredging activity, all appropriate precautions would be implemented to insure protection of the manatee. The Contractor would stop, alter course, or maneuver as necessary to avoid operating moving equipment (including watercraft) any closer than 100 yards of the manatee. Operation of equipment closer than 50-feet to a manatee shall necessitate immediate shutdown of that equipment.

5.1.6.5 CORALS

As stated in Section 2.2.5.1.4, none of the seven Caribbean listed threatened coral species have been documented within the construction footprint or within the 150m indirect impact zone and Acroporid DCH is also 250m from the closest construction area.

Recent USACE consultations under Section 7 of the Endangered Species Act were conducted with the National Marine Fisheries Service for San Juan Harbor in 2016 and 2018 (Consultation Number SER-2013-10961 and SER-2017-18763). The 2018 BO concluded any effects to corals and critical habitat associated with transit and disposal of dredged materials within the Condado lagoon would be discountable. It is anticipated that construction of CSRM measures around the shoreline of Condado lagoon (and at WSJB) would likewise have discountable effects to corals and DCH, with use of BMPs during construction. The USACE will conduct turbidity monitoring in accordance with a monitoring plan that will be developed prior to construction to insure avoidance and minimization of effects to hardbottom habitat. Therefore, indirect impacts to hardbottoms and listed corals from turbidity and sedimentation as a result of construction are not anticipated.

5.1.6.6 PUERTO RICAN BOA

Although CSRM construction activities in WSJB would occur in an area where the Puerto Rican boa could be present the USACE determined by utilizing the USFWS standard construction conditions (including monitoring and relocation), potential effects to the snake can be minimized. The USACE determined that the Project may affect, but is not likely to adversely affect the Puerto Rican boa.

5.1.7 BIRDS

The USACE does not anticipate that avian species, including shorebirds, seabirds, and migratory birds, would be adversely (directly or indirectly) affected by the proposed project. The proposed project would cause only temporary impacts to the bird community as individuals avoid active construction areas due to noise and general activity. Construction in WSJB would occur in mangroves and wetlands but impacts to the bird community are expected to be temporary and last for the duration of construction.

Shorelines used by birds within the bay are expected to stabilize in the future-with-project condition (proposed project). Beneficial effects to important nesting, foraging, and loafing/roosting habitats for migratory birds should result from the habitat benefits of the nature-based CSRM features. USACE is committed to monitoring the assumptions of the project to ensure that additional impacts to natural resources in the San Juan bay area are not incurred including monitoring for nesting birds during construction.

5.1.8 INVASIVE SPECIES

The proposed project would include measures to clean construction equipment before and between use which should reduce the potential for the introduction and spread of invasive species.

5.1.9 AIR QUALITY

Construction equipment is typically powered by diesel engines. Depending on the size, type, age, and condition of the equipment, various emissions can be expected for the duration of the operation. The project area is compliant with Puerto Rico air quality standards. The proposed construction would occur in a bay that experiences nearly constant trade winds and sea breezes.

The proposed project has been analyzed for conformity applicability pursuant to regulations implementing Section 176(c) of the Clean Air Act. It has been determined that the activities proposed under this proposed project would not exceed de minimis (a level of risk too small to be concerned with) levels of direct or indirect emissions of a criteria pollutant or its precursors and are exempted by 40 CFR Part 93.153. For these reasons a conformity determination is not required for this proposed project.

5.1.10 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE

Using an EPA web mapper (<https://www.epa.gov/superfund/search-superfund-sites-where-you-live>), the proposed project is not expected to encounter HTRW. No HTRW would be released in the project area during or after construction. The project should not impact existing sediment conditions. None of the construction areas would be affected by HTRW. The proposed project would not change or affect the ability for Federal regulations, U.S. Customs, and Port Security to continue to address the transportation of any HTRW. It is anticipated additional investigations would be conducted in PED prior to construction to insure no HTRW exists within the project area.

5.1.11 NOISE

5.1.11.1 IMPACTS OF CONSTRUCTION NOISE ON MARINE LIFE

NMFS is currently developing guidelines for determining sound pressure level thresholds for fish and marine mammals, based on existing studies, the NMFS current thresholds for determining impacts to marine mammals is between 180 and 190 dB re 1 uPa for potential injury to cetaceans and pinnipeds respectively, and 160 dB re 1 uPa for behavioral disturbance/harassment from an impulsive noise source, and 120 dB re 1 uPa from a continuous source. Reine et al (2012) found that the 120 dB re 1uPa proposed threshold was exceeded by ambient noises in their study area. It is unlikely that underwater sound from conventional construction operations can cause physical injury to marine mammals and fish species. Some temporary loss of hearing could occur if the animal remains in the immediate vicinity of construction for lengthy durations, although the risk of this outcome is low. Fish and marine mammals would likely respond to construction by using avoidance techniques. Avoidance is defined as an effect that causes the animal to not occupy an area that is periodically or infrequently occupied. Construction is likely to cause avoidance due to noise (and increased turbidity and other temporary water quality changes). Therefore, construction activities would likely cause the temporary displacement of fish and marine mammals as a response to the noise.

5.1.11.2 IMPACT OF CONSTRUCTION NOISE ON THE HUMAN ENVIRONMENT

There would be a temporary increase in the ambient noise level during the construction phase of the project. The construction would be within 150m of sensitive receptors. However, since construction should not occur in one position for any extended period of time, there will be no disproportionate adverse impact on any communities. Noise generated by this project would not be substantially different from other ambient noise levels of an active harbor and metropolitan area.

5.1.12 COASTAL BARRIER RESOURCES

The proposed project would not affect the three CBRS Units located in the vicinity of San Juan bay, PR-87 Punta Vacía Talega and PR-87P Punta Vacía Talega OPA approximately 13-19 km east and PR-86P Punta Salinas OPA approximately 6 km west (Figure 2-30). These resources are geographically distant from the project area and no features are to be constructed within the CBRS Units."

5.1.13 CULTURAL AND HISTORIC RESOURCES

Analysis of potential impacts to historic and cultural resources considered both direct and indirect effects (see Section 2.1.17). Direct effects may result from physically altering, damaging, or destroying all or part of a historic or cultural property, or changing the character of physical features within the property's setting that contribute to its historic significance. An effects analysis focuses on the characteristics of a historic property that qualify it for inclusion in the National Register, and assesses the potential to alter historically significant characteristics and diminish the integrity of a historic property. There may also be cultural resources of value which are not eligible for inclusion in the National Register. The APE for direct effects was defined as being within and adjacent to the proposed alternatives, as well as staging and work areas. Indirect effects are reasonably foreseeable effects caused by an undertaking that may occur later in time, be farther removed in distance or be cumulative. In the case of the alternatives, these may include increased development associated with the protection afforded by the alternatives and increased pedestrian traffic along the seawalls.

While background research revealed numerous cultural resources and historic properties within the APE, a full inventory has not yet been conducted. Each of the alternatives has the potential to affect cultural resources. The direct footprint of levee construction may disturb archaeological sites, be a visual intrusion in historic districts, or alter the appreciation of historic structures. Two archaeological sites have been documented near this footprint, and others may be associated with the historic hacienda or prehistoric occupation of this area. The design of the seawalls will need to consider the effects on the Distrito Destilería Bacardí and other resources identified in the future, as well as how the seawalls may alter the accessibility to the water or other characteristics which may be contributing to the significance of historic districts or landscapes. The construction of inland water-control infrastructure, to alter the direction of runoff, may change the hydrology of an area and affect archaeological sites over time. The construction of the elevated living shoreline may directly affect archaeological sites within the footprint, as well as alter the viewshed of historic structures or character of historic districts. The footprint of the breakwaters may overlap historic shipwrecks or even submerged prehistoric archaeological sites. The conceptual nature of the plans and planning timeline prevent a full accounting of effects to cultural resources.

As project designs are refined and optimized, impacts to cultural resources be minimized and avoided where possible. Consultation with SHPO and coordination with the Instituto de Cultura Puertorriqueña

is ongoing, including review of the Areas of Potential Effect prior to TSP and SHPO concurrence on the use of a programmatic agreement (PA). Due to the lack of detailed project designs during the current feasibility stage, it will not be possible to conduct fieldwork to identify and evaluate cultural resources or to determine the effects of the TSP on historic properties. In consultation with SHPO, pursuant to 54 USC 306108, § 800.4(b)(2), and 36 CFR 800.14(b)(1)(ii), USACE is deferring final identification and evaluation of historic properties until after project approval, when additional funding and design details are available. Because the USACE cannot fully determine how the project may affect historic properties prior to finalization of this feasibility study, a PA will be used to ensure compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA). Specifically, the scope and diversity of potential effects of the project and constraints of the USACE planning policy make a PA for compliance with Section 106 essential. The PA will allow the USACE to complete the necessary archaeological surveys during the follow on Preconstruction Engineer and Design (PED) phase of the project, and it will also allow for the identification of historic properties, assessment of effects, and inclusion of measures to avoid, minimize, and mitigate effects to historic properties to be completed after project features have been clearly defined and sited. A draft PA is included as an appendix to this report and was previously sent to the SHPO and the Instituto de Cultura Puertorriqueña for review. The PA will be completed prior to the issuance of a FONSI.

5.1.14 AESTHETICS AND RECREATION

The proposed project, CSRM measure construction, could alter the aesthetic resources of San Juan bay and increase recreational opportunities. Although the definition of aesthetics is fluid (see Section 2.2.18), for the purposes of the present evaluation, the principal aesthetic “targets” include the visual perception of San Juan bay’s land- and seascapes, historic features, and certain architecture. The degree to which any adverse feature affects aesthetics is frequently based on scale, position, and proximity relative to the viewer. Temporary impacts to recreational activities during construction and a temporary reduction in the aesthetic appeal during construction are anticipated. However, the CSRM measures could also enhance local aesthetic in the long-term through incorporation of NNBF including living shorelines. In addition, recreational components (pedestrian walkways) could be incorporated into the CSRM measures and could enhance recreational opportunities.

As a public safety measure, boating would be prohibited near the operating construction equipment. Recreational access to these areas would return to pre-construction conditions following completion of the project. Although short-term impacts could occur, no long-term adverse effects are anticipated. Commercial shipping would continue in the Federal navigation channel. Information would be provided to the USCG so they could issue a “Notice to Mariners” prior to initiation of construction and for each major change in the construction activities. This would alert public boaters of areas to avoid and the possibility of limited and restricted access. No significant adverse impacts to recreational boating are expected from the proposed project.

5.1.15 ENVIRONMENTAL JUSTICE

The USACE collected and analyzed information to consider the potential impacts of the proposed action on minority and low-income populations. The information and analyses presented below demonstrates that the proposed action complies with Executive Order 12898 and would not cause disproportionately high and adverse impacts to minority or low-income populations. **Appendix G** provides a full Environmental Justice Analysis report.

The CSRSM area of interest is bordered by numerous EJ communities. Possible factors that could impact EJ communities include those resulting directly from the construction of the project and the secondary effects that could occur as a result of the shoreline improvements. These factors include, but are not limited to the following:

- Construction equipment through neighborhoods
- Noise from construction
- Air emissions from construction
- Affects to subsistence fishermen
- Increasing exposure to contaminants
- Decreasing water quality

5.1.15.1 CONSTRUCTION RELATED IMPACTS

The proposed action consists of a collection of key structural, non-structural and natural and nature-based features in strategic locations in order to increase storm resiliency and flooding within the San Juan Metropolitan area. As such, the construction and operational activities are within the shallow waters of the San Juan Bay, shorelines, and adjacent creeks. The construction and operational work areas are located near residential communities, schools, and hospitals which are situated near the coastal areas of the bay. Impacts from noise, air, and other inconveniences are not likely to significantly impact identified communities. Compared to most large, entirely land-based projects, there is little potential for direct adverse impacts to minority populations, low-income populations, the elderly, or children. The result of the project would provide a benefit to the identified communities, as it will reduce flooding and provide benefits to the coastal communities, such as recreational opportunities. Recreational opportunities include improved access to the coastline, increased natural recreational areas, and improved wildlife and natural communities. As indicated in previous sections of this document, during construction there would be temporary and minor impacts resulting from increase turbidity (decreased water quality) from in-water work. These impacts will be temporary and minor and will not disproportionately impact low-income, minority, juvenile, or elderly populations. Additionally, the potential exists for subsistence fishing along the coast; however, these practices will not be significantly impacted by the proposed project due to the impacts being temporary. The project is likely to increase availability of locations for the local population to fish. No significant impacts to fish populations are expected to result from the construction of the project. In summary, there will be no disproportionately high and adverse impact on low-income, minority resulting from the construction of the project.

5.1.15.2 PUBLIC ENGAGEMENT DURING CONSTRUCTION

An important component of any project is informing the public at all stages of the project (i.e., planning, design, construction, and maintenance). USACE engaged in public outreach efforts through the media and public information meetings during the feasibility phase (planning phase). USACE will provide a contact information link on the public website for anyone with concerns about, or related to, the project.

5.2 CUMULATIVE EFFECTS

5.2.1 CUMULATIVE ACTIVITIES SCENARIO

NEPA, as implemented by Council on Environmental Quality (CEQ) regulations (40 CFR §§ 1500 -1508), requires Federal agencies, including the USACE, to consider cumulative impacts in rendering a decision on a Federal action under its jurisdiction. According to 40 CFR § 1508.7, a *cumulative impact* is the impact on the environment that results from the incremental impact of the proposed project when added to other past, present, and reasonably foreseeable future actions regardless of the agency (Federal or non-Federal) or person that undertakes such other actions; cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

Table 5-4. Summary of Cumulative Effects.

Resource	Past and Present (Baseline/Existing Condition)	Future Without-Project	Future With-Project
Threatened and Endangered Species: Sea Turtles	Four sea turtle species occur in the area (loggerhead, green, hawksbill, and leatherback). Green, hawksbill, and leatherback turtles nest on beaches along the north coast out of the project area. Juvenile green and hawksbill turtles use SAV and nearshore hardbottom areas for feeding, resting, and shelter from predators. Past and current threats to sea turtle populations include artificial lighting, beach armoring, anthropogenic disturbance, trawling, dredging, vessel strikes, fishing gear entanglement, and ingestion of discarded anthropogenic marine debris.	Sea turtle nesting and nearshore habitat use would continue outside the project area. Ongoing threats to sea turtle populations would continue. In the absence of the project, property owners may use armor to protect their property which may result in impacts on SAV and nearshore hardbottom habitat.	CSRM measure construction is not anticipated to result in loss of habitat. Sea turtles may be disturbed by turbidity and noise during construction. Standard protective measures for in-water work would be followed during construction to avoid effects to swimming sea turtles. Due to the small spatial extent and short duration of project impacts, no significant cumulative impacts are anticipated.
Threatened and Endangered Species: Antillean Manatee	The Antillean manatee is common in San Jun bay. Past and current threats to manatee populations include vessel strikes, fishing gear entanglement, loss of foraging habitat (SAV), ingestion of marine debris, pollution, and underwater noise.	Manatees would continue to occur in the area. Ongoing threats to manatee populations would continue.	In addition to ongoing threats, manatees may be disturbed by turbidity and noise during construction. Standard protection measures for in-water work would be followed during construction. These include in part monitoring and shut-down of construction activities should a manatee come within 50-feet. Shoreline stabilization could encourage SAV colonization potentially improving manatee foraging habitat in the area.
Threatened and Endangered Species: Fish	As discussed in Sections 2.2.5.1.1 and 5.1.6.2 above the species are expected to not be present in San Juan bay. Nassau grouper have been badly overfished but were known to occur on the fringing reefs along the north coast in the past. Scalloped hammerhead shark and giant manta ray are oceanic species but could have occurred in the past along the north coast. Populations of these three species have declined, mainly due to fisheries overexploitation and incidental by-catch. Other past and current threats are habitat loss and degradation, entanglement in marine debris, pollution, and anthropogenic disturbance.	These species would continue to be rare in the area. Ongoing threats to populations would continue and may result in further decreases in population size and range.	In addition to ongoing threats, these ESA listed species could be disturbed by turbidity and noise during construction. Due to the small spatial extent and short duration of project impacts, and the expected low abundance in the project area, it is not likely these species would be effected by CSRM measure construction. Habitat benefits provided by the project could improve water quality in the region possibly indirectly benefitting these species.
Threatened and Endangered Species: Corals	As discussed in Sections 2.2.5.1.4 and 5.1.6.5 above, all seven (7) listed species are known to occur on the fringing reefs along the north coast. Past and current threats are habitat loss and degradation from entanglement in marine pollution/debris, degraded water quality, SLR and anthropogenic disturbance.	These species would continue to occur outside the project area. Ongoing threats to populations would continue and may result in further decreases in population size and range.	These species are expected to occur outside the project area on the fringing reefs along the north coast. These listed species are not expected to be affected by CSRM measure construction. Turbidity would be monitored during construction and activities would cease if the 10 NTU above background standard were exceeded and until levels return to background. Due to the small spatial extent and short duration of project effects, and the expected distances from the project area, it is not likely these species would be affected by CSRM measure construction. Habitat benefits provided by the project could improve water quality in the region possibly indirectly benefitting these species.
Threatened and	The Puerto Rican boa is most likely to occur in the WSJB area where more natural areas occur as opposed to the heavily developed Condado lagoon area. Historically, its population and range have	Puerto Rican boa would continue to inhabit the area. Ongoing threats to boa populations	In addition to ongoing threats, boas may be disturbed during construction. There is a small risk of a boa being injured by construction activities, which would be

CHAPTER 5.0 Effects of the Recommended Plan

Resource	Past and Present (Baseline/Existing Condition)	Future Without-Project	Future With-Project
Endangered Species: Puerto Rican Boa	declined, mainly due to habitat loss. Other past and current threats are habitat degradation, pollution, and anthropogenic disturbance.	would continue and could result in further decreases in population size and range.	minimized through required use of standard construction monitoring measures. Due to the small spatial extent and short duration of project effects, the Puerto Rican boa would not likely incur other than minor impacts.
Nearshore Hardbottom	As discussed in Sections 2.2.3 and 5.1.4 above, hardbottom habitat occurs in San Juan bay. Past and current threats are habitat loss and degradation from unabated shoreline erosion and sedimentation, entanglement with marine pollution/debris, degraded water quality, SLR and anthropogenic disturbance.	Hardbottom habitat would continue to occur in San Juan bay. Ongoing threats would continue and may result in further decreases in coverage in San Juan bay.	Hardbottom habitat is not expected to be affected by CSRM measure construction. Turbidity would be monitored during construction and activities would cease if the 10 NTU above background standard were exceeded and until levels return to background. Due to the small spatial extent and short duration of project effects, and the expected lack of direct impacts from the project, it is not likely hardbottom habitat would be affected by CSRM measure construction. The project could provide consolidated hard substrate (rock) which could enhance hardbottom habitat in San Juan bay.
Birds	As discussed in Sections 2.2.6 and 5.1.7 above, bird and bird habitat for shorebirds, seabirds, and migratory birds occurs in San Juan bay. Past and current threats include habitat loss and degradation from unabated shoreline erosion and sedimentation, and anthropogenic disturbance.	Migratory and resident birds would continue to inhabit the San Juan bay area. Ongoing threats would continue and may result in further decreases in habitat and bird occurrence in San Juan bay.	The USACE does not anticipate that avian species, including shorebirds, seabirds, and migratory birds, would be adversely affected by the proposed CSRM measure construction. Individual birds could avoid the active construction areas due to noise and general activity. Beneficial effects to important nesting, foraging, and loafing/roosting habitats for migratory birds should result from the habitat benefits of the nature-based CSRM measures.
Essential Fish Habitat	EFH is the area includes hardbottom habitat (See Section 5.1.4), SAV, estuarine water column, estuarine scrub shrub (mangroves) and palustrine emergent wetlands (See Section 5.1.3). Past and current threats include habitat loss and degradation from unabated shoreline erosion and sedimentation, and anthropogenic disturbance.	Local extents of these EFH areas would fluctuate with natural variability. In the absence of the project, property owners may construct armoring to protect their property, which may result in impacts to nearshore EFH.	The preliminary impact estimates will be revised as necessary once updated field surveys can be conducted. In addition, the preliminary TSP is draft and could be modified to further avoid and minimize impacts. Considering the relatively small TSP footprint, and expected habitat enhancement benefits from construction of the nature-based CSRM measures, the project is not anticipated to significantly affect EFH or federally managed fisheries in Puerto Rico. No long-term impacts anticipated.
Water Quality	The project area consists of Class III waters, which are designated as suitable for recreation, propagation, and maintenance of a healthy, well balanced population of fish and wildlife. The predominant issue that affects water quality in the area is turbidity, which varies significantly under natural conditions (e.g., during storms), sometimes exceeding 29 NTU. Historically, coastal water quality has been affected by unrelated anthropogenic sources such as storm water and effluent runoff	Turbidity would continue to occur intermittently due to storm activity, rainfall, currents, and other natural phenomena. Water quality may deteriorate due to unrelated anthropogenic sources such as storm water and effluent runoff.	In addition to the ongoing natural and anthropogenic fluctuations in water quality, local, short-term turbidity could occur adjacent to the construction sites. BMPs would be implemented during construction to reduce the magnitude and extent of turbidity, and adverse effects on water quality are expected to be minor. Turbidity would be monitored during construction to ensure that

CHAPTER 5.0 Effects of the Recommended Plan

Resource	Past and Present (Baseline/Existing Condition)	Future Without-Project	Future With-Project
	resulting in increased nutrients and freshwater inputs. Urbanization and population growth in the region contributes to coastal water quality degradation.		Commonwealth water quality standards are met. Due to the small spatial extent and short duration of project impacts, no long-term effects are expected.
Cultural Resources	The project area is in a historically significant area, with archaeological sites, historic structures, and historic districts.	Project-specific impacts would be avoided, but risk of storm damages to cultural resources to may not reduced.	The reduced risk may lead to development, but resources would continue to be protected by local laws and regulations.

5.2.1.1 SEA-LEVEL CHANGE

Potential relative sea-level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. Future sea-level change is likely to result in both direct and indirect impacts on nearshore marine resources in the project area. Direct impacts could include changes in the areal extent of exposed hardbottom habitat due to sand movement. Indirect impacts could result from increased beach erosion, which may prompt more frequent (and possibly more extensive) beach nourishment projects in the area. The largest uncertainty is predicting the level and types of human activities that may be conducted to protect the shoreline in response to advancing sea level.

USACE Circular No. 1165-2-211 provides estimates of sea level rise ranging from 0.39 ft. (0.12 m) to 2.1 ft. (0.63 m) over the next 50 years. The U.S. ClimateMid Atlantic Region details both how sea-level change affects coastal environments and what planners should address to protect the environment and economy. Those structures and policies would not necessarily accommodate a significant acceleration in the rate of sea-level rise.

5.2.1.2 CONCLUSIONS

Potential cumulative impacts on many resources were considered as part of this study and the majority of these resources were determined to have little risk of being cumulatively impacted. These included land use, terrestrial natural resources, threatened or endangered species, other fish and wildlife, managed fishes, the estuarine water column, certain water quality parameters (turbidity and hazardous and toxic constituents), sediments (hazardous and toxic constituents), coastal barrier resources, bay shorelines and adjacent properties), air quality, noise, aesthetics, cultural and historic resources, environmental justice, and recreation.



6 Environmental Compliance

6 ENVIRONMENTAL COMPLIANCE*

This chapter discusses the status of coordination and compliance of the tentatively selected plan (TSP) with environmental requirements. Additionally, it shows how the TSP meets USACE Environmental Operating Principles.

6.1 SCOPING

The NEPA scoping period for the study was initiated by letter dated October 16, 2018. Public and interagency meetings were then held November 8, 2018 in San Juan. Comments and feedback received were primarily concerning sea turtles, manatees, coral reefs/benthic resources, fish habitat, public safety, recreation and tourism. Pertinent correspondence associated with this NEPA scoping process is included in **Appendix H**.

6.2 COOPERATING AGENCIES

This proposed project has been coordinated with the following agencies, among others: USFWS, NMFS, U.S. Environmental Protection Agency (EPA), State Historic Preservation Officer (SHPO), Department of Natural and Environmental Resources, Puerto Rico Environmental Quality Board and OGP. The EPA by electronic correspondence dated November 13, 2018 indicated they will be a Participating Agency under NEPA and E.O. 13807 (“One Federal Decision”). USFWS by letter dated November 15, 2018 indicated they will not be able to be a cooperating agency for the NEPA process; however, the USFWS will provide technical assistance regarding possible impacts to fish and wildlife resources. The NMFS by letter dated December 21, 2018 accepted USACE’s invitation to participate as a cooperating agency. As a cooperating agency, NMFS will provide comments on the draft IFR/EA and participate in teleconferences. Correspondence from all Federal and State agencies is included in **Appendix H**.

6.3 LIST OF RECIPIENTS

The NOA of the draft IFR/EA and Draft FONSI will be mailed to those listed in Appendix H, Mailing List.

6.4 COMMENTS RECEIVED AND RESPONSE

Comments received during scoping and public meetings are discussed in Section 6.1 above and included in **Appendix H**. Comments received in response to release of this draft IFR/EA will be discussed here and included in Appendix H as well.

6.5 ENVIRONMENTAL COMMITMENTS

USACE shall comply with the terms and conditions resulting from ESA consultations with the USFWS and NMFS, and the Water Quality Certification issued by DNER.

SEA TURTLES IN THE WATER

- The contractor shall instruct all personnel associated with the project of the potential presence of these species and the need to avoid collisions with them. All construction personnel are responsible for observing water-related activities for the presence of sea turtles.

- The contractor shall advise all construction personnel that there are civil and criminal penalties for harming, harassing, or killing sea turtles, which are protected under the Endangered Species Act of 1973.
- Siltation barriers shall be made of material in which a sea turtle cannot become entangled, be properly secured, and be regularly monitored to avoid protected species entrapment. Barriers may not block sea turtle entry to or exit from the area.
- All vessels associated with the construction project shall operate at "no wake/idle" speeds at all times while in the construction area and while in water depths where the draft of the vessel provides less than a four-foot clearance from the bottom. All vessels will preferentially follow deep-water routes (e.g., marked channels) whenever possible.
- If a sea turtle is seen within 100 yards of the active construction or vessel movement, all appropriate precautions shall be implemented to ensure its protection. These precautions shall include cessation of operation of any moving equipment closer than 50 feet of a sea turtle. Operation of any mechanical construction equipment shall cease immediately if a sea turtle is seen within a 50-ft radius of the equipment. Activities shall not resume until the sea turtle has departed the project area of its own volition.
- Any collision with and/or injury to a sea turtle shall be reported immediately to the National Marine Fisheries Service's Protected Resources Division (727-824-5312) and the local authorized sea turtle stranding/rescue organization.

MANATEES

- All vessels associated with the construction project shall operate at "Idle Speed/No Wake" at all times while in the immediate area and while in water where the draft of the vessel provides less than a 4 foot clearance from the bottom. All vessels will follow routes of deep water whenever possible.
- Siltation or turbidity barriers shall be made of material in which manatees cannot become entangled, shall be properly secured, and shall be regularly monitored to avoid manatee entanglement or entrapment. Barriers must not impede manatee movement.
- All on-site project personnel are responsible for observing water-related activities for the presence of manatee(s). All in-water operations, including vessels, must be shut down if a manatee(s) comes within 50 feet of the operation. Activities will not resume until the manatee(s) has moved beyond the 50-foot radius of the project operation, or until 30 minutes elapses if the manatee(s) has not reappeared within 50 feet of the operation. Animals must not be herded away or harassed into leaving.
- Any collision with or injury to a manatee shall be reported to Department of Natural and Environmental Resources Law Enforcement (787-724-5700) and the USFWS Caribbean Ecological Services Field Office (787-851-7297).

- Temporary signs concerning manatees shall be posted prior to and during all in-water project activities. All signs are to be removed by the contractor upon completion of the project. Example awareness signs are located here: <https://www.fws.gov/caribbean/es/documents/ManateeSignsLetreros.pdf>.

PUERTO RICAN BOA

The U.S. Fish and Wildlife Service has developed recommendations to avoid or minimize impacts on the boa during a project development in an area where the boa may occur. The recommendations are the following:

- Prior to any earth movements or vegetation clearing, the boundaries of the project area, the buffer areas and areas to be protected should be clearly marked in the project plan and in the field.
- A pre-construction meeting should be conducted to inform supervisors and employees about the conservation of protected species, as well as penalties for harassing or harming such species.
- Prior to any use of machinery on areas where the boa may occur, the vegetation should be cleared by hand to provide time to the boa, if present, to be detected or move away from the area. All personnel involved in site clearing must be informed of the potential presence of the snake, and the importance of protecting the snakes.
- Site personnel should be conscious of the possibility of boas sunning in open areas.
- Before activities commence each workday during the vegetation clearing phase, the experienced personal in identifying and searching for boas should survey the areas to be cleared that day, to ensure that boas are not present or affected within the work area. If boas are found within the working area, activities should stop at the area where the boas are found until the boas move out of the area on their own. Activities at other work sites, where no boas have been found after surveying the area, may continue. If relocation of the species is necessary, any relocated boas should be transferred by authorized personnel of the Department of Natural and Environmental Resources (DNER) to appropriate habitat close to the project site. Any findings should be reported to the Service and to the DNER Ranger office so they can further assist you in developing sound conservation measures and specific recommendations to avoid, minimize and/or compensate for any impacts to this species.
- Strict measures should be established to minimize boa casualties by motor vehicles or other equipment. Before operating or moving equipment and vehicles in staging areas near potential boa habitats (within 25 meters of potential boa habitat), these should be thoroughly inspected to ensure that no boas are lodged in the standing equipment or vehicles. If boas are found within vehicles or equipment, authorized personnel of DNER must be notified immediately for proper handling and relocation. Any relocated boas should be transferred to appropriate habitat close to the project site.

WATER QUALITY

- The Contractor shall monitor water quality (turbidity) at the construction sites, as required by the 401 Water Quality Certification.
- If turbidity values at the construction site exceed permitted values, the Contractor shall suspend

all construction activities. Construction shall not continue until water quality meets state standards.

OTHER

- Migratory birds (adult birds, eggs and chicks) shall be protected during construction activities.
- In the event that cultural resources are discovered, then protective measures shall be utilized.
- The environmental resources within the project boundaries and those affected outside the limits of permanent work would be protected during the entire period of work.
- An oil spill prevention plan shall be required.

6.6 COMPLIANCE WITH ENVIRONMENTAL REQUIREMENTS

6.6.1 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) OF 1969

Environmental information on the project has been compiled in this draft IFR/EA. This draft IFR/EA will be coordinated with interested stakeholders for review and comment. The project is in compliance with the National Environmental Policy Act.

6.6.2 ENDANGERED SPECIES ACT OF 1973

Recent USACE consultations under Section 7 of the Endangered Species Act were conducted with the National Marine Fisheries Service for San Juan Harbor in 2016 and 2018 (Consultation Number SER-2013-10961 and SER-2017-18763). The 2018 BO anticipated effects to corals and critical habitat associated with transit and disposal of dredged materials within the Condado lagoon would be discountable. USACE anticipates the construction of CSRMs around the shoreline of Condado lagoon (and at WSJB) would likewise have discountable effects to corals and DCH, with use of BMPs during construction. The USACE will initiate consultation with both the USFWS and NMFS concurrently with noticing of this draft IFR/EA. USACE initial determination is construction of the TSP may affect, but would be not likely to adversely affect ESA listed species. All correspondence can be found within Appendix H: Pertinent Correspondence. This project will be in full compliance with the Endangered Species Act.

6.6.3 FISH & WILDLIFE COORDINATION ACT OF 1958

In accordance with an interagency agreement between the USFWS and USACE, coordination with the USFWS shall be conducted through the NEPA scoping process and the Endangered Species Act. The project will be in full compliance with the Act.

6.6.4 NATIONAL HISTORIC PRESERVATION ACT OF 1966 (*INTER ALIA*)

The Proposed Action will be in compliance with Section 106 of the National Historic Preservation Act. USACE has initiated consultation, consulted on a tentative APE prior to determination of a TSP, and

received concurrence on the development of a programmatic agreement. Pursuant to 54 U.S.C. 306108, 36 CFR 800.4(b)(2), and 36 CFR 800.14(b)(1)(ii), USACE will defer final identification and evaluation of historic properties until after project approval, additional funding becomes available, and prior to construction by executing the programmatic agreement. A draft programmatic agreement has been provided to SHPO and ICP, and is included as an appendix to this report.

6.6.5 CLEAN WATER ACT OF 1972

A Section 401 water quality certification (State permit) application will be submitted to DNER, and USACE will obtain this certification prior to construction. All Commonwealth water quality requirements would be met. A Section 404(b) evaluation is included in this report as Appendix G, Attachment 1. The project shall be in full compliance with this Act.

6.6.6 CLEAN AIR ACT OF 1972

The short-term impacts from construction equipment associated with the project would not significantly impact air quality. No air quality permits would be required for this project. San Juan bay is designated as an attainment area for Federal air quality standards under the Clean Air Act. Because the project is located within an attainment area, USEPA's General Conformity Rule to implement Section 176(c) of the Clean Air Act does not apply and a conformity determination is not required.

6.6.7 COASTAL ZONE MANAGEMENT ACT OF 1972

A Federal consistency determination (CD) in accordance with 15 CFR 930 Subpart C is included in this report as Appendix G. The USACE CD determined the proposed activity is consistent to the maximum extent practicable with the enforceable policies of the Puerto Rico Coastal Management Program. The CD will be submitted to the PRPB and Commonwealth concurrence is anticipated after public review of the draft IFR/EA. At this time, this project is in compliance with this Act.

6.6.8 FARMLAND PROTECTION POLICY ACT OF 1981

No prime or unique farmland would be impacted by implementation of this project. This Act is not applicable to the project.

6.6.9 WILD AND SCENIC RIVER ACT OF 1968

No designated Wild and Scenic river reaches would be affected by project related activities. This project is in compliance with this Act.

6.6.10 MARINE MAMMAL PROTECTION ACT OF 1972

USACE does not anticipate the take of any marine mammal during any activities associated with the project. Trained observers will monitor construction activities to insure appropriate actions are taken to avoid adverse effects to listed and protected marine mammal species during project construction. Therefore, this project is in compliance with this Act.

6.6.11 ESTUARY PROTECTION ACT OF 1968

In the Estuary Protection Act Congress declared that many estuaries in the United States are rich in a variety of natural, commercial, and other resources, including environmental natural beauty, and are of immediate and potential value to the present and future generations of Americans. This Act is intended to protect, conserve, and restore estuaries in balance with developing them to further the growth and development of the Nation. The SJBE is of national significance; the proposed nature-based features will be designed to provide habitat while minimizing shoreline erosion, therefore, this project is consistent with the purposes of this Act.

6.6.12 FEDERAL WATER PROJECT RECREATION ACT

The principles of the Federal Water Project Recreation Act, (Public Law 89-72) as amended, have been fulfilled by complying with the recreation cost-sharing criteria as outlined in Section 2 (a), paragraph (2).

6.6.13 MAGNUSON-STEVENSON FISHERY CONSERVATION AND MANAGEMENT ACT OF 1976

Pursuant to the 2019 EFH Finding between USACE and NMFS, USACE's Notice of Availability of the draft IFR/EA will initiate consultation under the Magnuson-Stevens Fishery Conservation and Management Act. The EFH assessment can be found in sections 2.2.1-2.2.4 and 5.1-5.5. The USACE has determined, based on the preliminarily estimated impacts, the project is not anticipated to significantly affect EFH or federally managed fisheries in Puerto Rico. The project is in compliance with the Act and the Corps will consider recommendations from NMFS.

6.6.14 COASTAL BARRIER RESOURCES ACT AND COASTAL BARRIER IMPROVEMENT ACT OF 1990

The Coastal Barrier Resources Act (CBRA) and the Coastal Barrier Improvement Act of 1990 (CBIA) limit federally subsidized development within the CBRA Units to limit the loss of human life by discouraging development in high risk areas, to reduce wasteful expenditures of Federal resources, and to protect the natural resources associated with coastal barriers. CBIA provides development goals for undeveloped coastal property held in public ownership, including wildlife refuges, parks, and other lands set aside for conservation ("otherwise protected areas," or OPAs). These public lands are excluded from most of the CBRA restrictions, although they are prohibited from receiving Federal Flood Insurance for new structures.

There are limits to Federal expenditures related to actions that could affect a unit. The proposed project would not affect the three CBRS Units located near San Juan bay, PR-87 Punta Vacía Talega and PR-87P Punta Vacía Talega OPA approximately 13-19 km east and PR-86P Punta Salinas OPA approximately 6 km west (Figure X). This project is in compliance with the Act.

6.6.15 RIVERS AND HARBORS ACT OF 1899

The proposed work is not anticipated to obstruct navigable waters of the United States. The proposed action will be subject to public notice and other evaluations normally conducted for activities subject to the Act. The project will be in compliance with this Act.

6.6.16 ANADROMOUS FISH CONSERVATION ACT

This Act authorizes the Secretaries of the Interior and Commerce to enter into cooperative agreements with the States and other non-federal interests for conservation, development, and enhancement of anadromous fish and to contribute up to 50 percent as the Federal share of the cost of carrying out such agreements. As this project is not receiving funding for these purposes, this Act does not apply.

6.6.17 MIGRATORY BIRD TREATY ACT AND MIGRATORY BIRD CONSERVATION ACT

Migratory birds would be minimally affected by construction. USACE will include our standard migratory bird protection requirements in the project plans and specifications and will require the Contractor to abide by those requirements. Construction activities will be monitored at dawn or dusk daily during the nesting season to protect nesting migratory birds. If nesting activities occur within the construction area, appropriate buffers will be placed around nests to ensure their protection. The project is in compliance with these Acts.

6.6.18 UNIFORM RELOCATION ASSISTANCE AND REAL PROPERTY ACQUISITION POLICIES ACT OF 1970.

The purpose of PL 91-646 is to ensure that owners of real property to be acquired for Federal and federally assisted projects are treated fairly and consistently and that persons displaced as a direct result of such acquisition will not suffer disproportionate injuries as a result of projects designed for the benefit of the public as a whole.

While one of the alternatives considered during plan formulation included the acquisition of real property, this is not part of the Recommended Plan. Therefore, this project does not involve any real property acquisition or displacement of property owners or tenants. Therefore, this Act is not relevant to this project.

6.6.19 EXECUTIVE ORDER (EO) 11990, PROTECTION OF WETLANDS

Approximately 14.8 acres of wetlands are preliminarily estimated to be affected by project activities. The nature-based CSRM measures will provide some wetland functions. Please see **Appendix G** conceptual mitigation plan for more information. This project will result in no net loss of wetland functions and will be in compliance with the goals of this Executive Order.

6.6.20 E.O 11988, FLOOD PLAIN MANAGEMENT

To comply with EO 11988, the policy of USACE is to formulate projects that, to the extent possible, avoid or minimize adverse effects associated with the use of the floodplain and avoid inducing development in the floodplain unless there is no practicable alternative. No activities associated with this project are located within a floodplain, which is defined by EO 11988 as an “area which has a one percent or greater chance of flooding in any given year.” The project is located within the Coastal High Hazard Area (CHHA), as defined by EO 11988 as an “area subject to inundation by one-percent-annual chance of flood, extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms.” The project shoreline is significantly developed, and further development is anticipated to be minimal.

CSRM projects are inherently located in coastal areas, and are often located in CHHAs based on the problems the project is seeking to alleviate. The primary objective of the St. Lucie County Coastal Storm Damage Reduction Project is to reduce infrastructure damage. There is no practicable alternative that could be located outside of the CHHA that would achieve this objective.

For the reasons stated above, the project shall be in compliance with EO 11988, Floodplain Management.

Executive Order 11988 requires Federal agencies avoid, to the extent possible, the long and short term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities."

The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, requires an eight step process that agencies should carry out as part of their decision making on projects that have potential impacts to, or are within the floodplain. The eight steps and project-specific responses to them are summarized below.

1. **Determine if a proposed action is in the base floodplain (that area which has a one percent or greater chance of flooding in any given year).** The proposed action is within the base floodplain. However, the project is designed to reduce damages to existing infrastructure located landward of the proposed project.
2. **If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.** Chapters 3 discusses the process of screening and analyzing both measures and alternatives. Nonstructural, structural, and NNBF measures were all considered in the process.
3. **If the action must be in the floodplain, advise the general public in the affected area and obtain their views and comments.** An Environmental Assessment (EA) is being developed concurrently with the study. During this process the local stakeholders and the general public have been afforded the opportunity to review and comment on the study recommendations.

4. **Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified.** The anticipated impacts and environmental compliance associated with the Tentatively Selected Plan are summarized in Chapters 5 and 6. The project is not expected to alter or impact the natural or beneficial flood plain values.
5. **If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists.** The project provides benefits primarily for existing and previously approved development, and is not likely to induce significant development. Nonstructural components of the project, and real estate requirements required for construction of the project will reduce the level of development that is at risk.
6. **As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the “no action” alternative.** The project is not expected to induce development in the flood plain. In areas where the project will impact the natural or beneficial flood plain values, environmental mitigation is planned. Due to the built-out level of the city the impact to natural floodplains is considered minimal. Chapter 3 of this report summarizes the alternative identification, screening and selection process. The “no action” alternative was included in the plan formulation phase.
7. **If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.** The Draft Integrated Feasibility Report and EA will be provided for public review. Public meetings will be scheduled during the public review period. Comments received will be addressed and, if appropriate, incorporated into the Final Report.
8. **Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.** The tentatively selected plan is the most responsive to all of the study objectives and the most consistent with the executive order.

6.6.21 E.O. 12898, ENVIRONMENTAL JUSTICE

On February 11, 1994, the President of the United States issued Executive Order 12898, *Federal Actions to Address Environmental Justice Populations and Low-Income Populations*. The Executive Order mandates that each Federal agency make environmental justice part of the agency mission and to address, as appropriate, disproportionately high and adverse human health or environmental effects of the programs and policies on minority and low-income populations.

Any potential adverse effects of the proposed action would be more likely to affect those of higher socioeconomic status, such as large watercraft owners or those living in the coastal area surrounding the project. The beneficial effect of a wider, more sustainable beach would benefit all members of the public who are able to obtain transportation to access the beach. The storm damage reduction benefits are

primarily benefitting the landowners in this area. There are no disproportionate adverse impacts to minority or low income implementation of the project. See Appendix G for the Environmental Justice analysis.

6.6.22 E.O. 13045, DISPARATE RISKS INVOLVING CHILDREN

On April 21, 1997, the President of the United States issued Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks*. The Executive Order mandates that each Federal agency make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children and ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks.

As the proposed action does not affect children disproportionately from other members of the population, the proposed action would not increase any environmental health or safety risks to children.

6.6.23 E.O. 13089, CORAL REEF PROTECTION

The EO refers to "those species, habitats, and other natural resources associated with coral reefs." Coral reefs are not anticipated to be affected by construction activities due to distances from the project area. The project is in compliance with this EO.

6.6.24 E.O. 13112, INVASIVE SPECIES

The proposed action will require the mobilization of construction equipment from other geographical regions. Construction equipment has the potential to transport species from one region to another, introducing them to new habitats where they are able to out-compete native species. The proposed project would include measures to clean construction equipment before and between use which should reduce the potential for the introduction and spread of invasive species.

6.6.25 ENVIRONMENTAL OPERATING PRINCIPLES

1. Foster sustainability as a way of life throughout the organization.

The proposed project formulated measures and alternatives by considering sustainable measures that would mimic the existing site conditions to every extent possible, both when considering structural, non-structural and natural and nature-based features. Measures were formulated and combined into alternatives with long term adaptability and resilience in mind, to reduce the risk of damages from storm surge combined with sea level change.

2. Proactively consider environmental consequences of all USACE activities and act accordingly.

Each measure and subsequently each alternative considered both positive and negative effects in the environmental quality account. Effects were avoided and minimized by considering width footprints of measures, and choosing measures that would have minimal impacts to resources.

Additionally, living shorelines consider the native vegetation within the area, and were chosen to create habitat in those environments while serving the function to reduce damages from storm surge.

3. Create mutually supporting economic and environmentally sustainable solutions.

The above description in number 2 demonstrates how environmental effects were considered during the formulation process and in some areas will create additional habitat. The entire TSP will support the San Juan Metro Area by providing a comprehensive plan to allow communities experience less damages from storms and hurricanes, and recover faster after storms. Additionally, several of the features (living shorelines, breakwaters) bring in recreational elements which can bring communities together, as well as potentially support tourism, therefore strengthening the economy, community and environment together.

4. Continue to meet our corporate responsibility and accountability under the law for activities undertaken by USACE, which may impact human and natural environments.

This report includes all information necessary to document how the project meets USACE's corporate responsibility and accountability requirements for actions that may impact human and natural environments.

5. Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs.

The team is involved throughout the study process to ensure that environmental considerations are taken into account for the life of the project.

6. Leverage scientific, economic and social knowledge to understand the environmental context and effects of USACE actions in a collaborative manner.

The entire Project Delivery Team understands the need to consider the environment during its decision-making process, and worked collaboratively with agencies to foster education and sharing of policies and best management practices.

7. Employ an open, transparent process that respects views of individuals and groups interested in USACE activities.

The actions taken to involve the public, resource agencies, and NGOs who may be interested in the project are outlined in Section 6.1 through 6.4 of this report.



7 Recommendations

7 RECOMMENDATIONS

The Tentatively Selected Plan (TSP) includes levees (2 miles), a series of breakwaters over 0.7 miles along the Cataño shoreline, seawalls (6.7 miles), elevated living shoreline (2.3 miles), a storm surge gate/sluice gate on the Malaria Canal, and associated inland hydrology feature (to allow rainfall runoff with constructed features). The TSP also contributes to creation of habitat and incorporates recreation features. Although the TSP was formulated to avoid and minimize impacts to every extent possible, impacts are expected to occur and as such the TSP includes mitigation. It is also recommended that the non-federal sponsor and local communities pursue non-structural measures, such as improved public outreach about coastal flooding, improved evacuation plans and notification systems, and evaluations of re-zoning over time as needed.

Additionally, the study team determined that reaches 4-6 have multiple sources of coastal flooding influences and the uncertainty in the exchanges of flow between them is too high without performing more extensive hydrologic modeling. The problem in these reaches is a combination of precipitation with storm surge analysis that could not be performed within this study. The study team acknowledges there are flooding problems, resulting in potential risk to critical infrastructure and socially vulnerable communities from hydrologic induced flooding (precipitation) in addition to storm surge in reaches 4 through 6. These areas are recommended to be evaluated under a separate study in order to adequately address both storm surge and precipitation holistically, using the same study authority that is used for this study.

I have given consideration to all significant aspects in the overall public interest including engineering feasibility, economic, social, cost and risk analysis, and environmental effects. The TSP described in this draft report provides the optimum solution for coastal storm risk management benefits within the study area that can be developed with the framework of the formulation concepts.

7.1 ITEMS OF LOCAL COOPERATION

Recommendations for provision of Federal participation in the Recommended Plan described in this report would require the project sponsor to enter into a written Project Partnership Agreement (PPA), as required by Section 221 of Public Law 91-611, as amended, to provide local cooperation satisfactory to the Secretary of the Army. Such local cooperation shall include:

- a. Provide 35 percent of project costs assigned to coastal and storm damage reduction and 50 percent of costs assigned to recreation costs, as further defined below:
 - a. Provide, during design, 35 percent of design costs allocated to coastal and storm damage reduction and 50 percent of costs assigned to recreation costs in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;
 - b. Provide all lands, easements, rights-of-way, including suitable borrow areas, and perform or assure performance of all relocations, including utility relocations, as

determined by the Federal Government to be necessary for the initial construction, periodic nourishment or operation and maintenance of the project, all in compliance with applicable provisions of the Uniform Relocation and Assistance and Real Property Acquisition Policies Act of 1970, as amended (42 U.S.C. 4601-4655) and the regulations contained in 49 C.F.R. Part 24;

- c. Provide, during construction, any additional amounts necessary to make its total contribution equal to 35percent of project costs assigned to coastal and storm damage reduction;
- b. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the outputs produced by the project, hinder operation and maintenance of the project, or interfere with the project's proper function;
- c. Inform affected interests, at least yearly, of the extent of protection afforded by the project; participate in and comply with applicable federal floodplain management and flood insurance programs; comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12); and publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;
- d. Operate, maintain, repair, replace, and rehabilitate the completed project, or function portion of the project, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable federal and state laws and regulations and any specific directions prescribed by the Federal Government;
- e. For so long as the project remains authorized, ensure continued conditions of public ownership and use of the project features;
- f. Hold and save the United States free from all damages arising from the initial construction, operation, maintenance, repair, replacement, and rehabilitation of the project, except for damages due to the fault or negligence of the United States or its contractors;
- g. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 USC 9601-9675, that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be necessary for the initial construction, periodic nourishment, operation and maintenance of the project;
- h. Assume, as between the Federal Government and the non-federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way required for the initial construction, periodic nourishment, or operation and maintenance of the project;
- i. Agree, as between the Federal Government and the non-federal sponsor, that the non-federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability,

CHAPTER 7.0: Recommendations

- and, to the maximum extent practicable, operate, maintain, repair, replace, and rehabilitate the project in a manner that will not cause liability to arise under CERCLA;
- j. Keep the recreation features and other associated public use facilities open and available to all on equal terms

Andrew Kelly, P.E.
Colonel, U.S. Army
District Commander



8 LIST OF PREPARERS

8.1 PREPARERS

This Feasibility Study with integrated Environmental Assessment was prepared by the following U.S. Army Corps of Engineers and Bureau of Ocean Energy Personnel (BOEM) personnel:

Stacey Roth, P.E. (USACE)

Environmental Engineer

Paul DeMarco (USACE)

Biologist

Chris Altes (USACE)

Archeologist

8.2 REVIEWERS

This report was reviewed by the following personnel:

Angela Dunn

Biologist

Sheila Hint

Project Manager



9 References

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