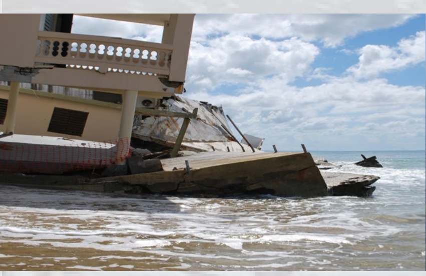
PUERTO RICO COASTAL

DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX D
Economics

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1. EXECUTIVE SUMMARY

The Puerto Rico Coastal Storm Risk Management (PR CSRM or PRCS) feasibility study is an in-depth analysis of the coastline along the San Juan Metro area in the north of the island and the municipality of Rincon in the west[1]. Much of this shoreline is subject to erosion, flooding, and wave forcing caused by both storms and natural shoreline processes. A study was undertaken to assess the feasibility of providing Federal Coastal Storm Risk Management measures to portions of the island's shoreline. The local sponsor for this project, the Puerto Rico Department of Natural and Environmental Resources (DNER), has indicated strong support for feasibility phase studies to address CSRM. In accordance with appropriate federal guidance, an investigation was performed to estimate the economic benefits of alleviating erosion, inundation, and wave-attack damage to coastal infrastructure. The study area was segmented into two distinct focus areas, San Juan and Rincon, and was further delineated based on modeled areas and separable elements (i.e. planning reaches). The planning reaches are discussed more fully in **Section 4** and are displayed in **Figure 1-1**.

Various measures and combinations of measures, discussed in **Section 6**, were considered for the PRCS. This appendix will follow the Main Report in describing the full array of alternatives being considered for recommendation, as well as the current Tentatively Selected Plan (TSP). Of these alternatives, a plan which maximizes net National Economic Development (NED) has been identified as well as a plan which maximizes the net effects of all the measurement accounts found in the Principles and Guidelines (P&G). The four accounts consist of NED, Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ).

[1] The initial scope of the PR CSRM included 11 municipalities, many of which were screened out, see the Main Report for more details since this appendix will focus on only those areas that were modeled.

Figure 1-1: PRCS CSRM Study Delineation

TABLE OF CONTENTS

1. Executive Summary 1-2
1. Introduction 6
2. Existing Conditions 8
2.1 Study Area 8
2.2 Socioeconomic Conditions & Environmental Justice Identification 8
2.2.1 San Juan Metro Area 9
2.2.2 Rincon 12
2.3 Data Collection 14
2.4 Existing Condition Coastal Structure Inventory 15
2.4.1 Structure & Contents Value 15
3. Coastal Storm Risk Management Benefit Approach 16
3.1 Benefit Estimation Approach Using Beach-fx and G2CRM 16
3.1.1 Beach-Fx 16
3.1.2 G2CRM 17
3.2 Model Assumptions 18
3.2.1 Timeframe and Discount Rate 18
3.2.2 Rebuilding 18
3.2.1 Damage Functions 19
3.2.2 Coastal Armoring 20
3.3 Emergency Clean-Up and Evacuation Cost Assignment Methodology 22
3.4 Land Loss Estimation 23
3.5 Performance Metrics for OSE & RED 24
4. Delineation of the Study Area for Planning Purposes 26
5. Future without Project Condition (FWOP) 27
5.1 Rincon FWOP 27
5.1.1 Rincon Damage Distribution by Structure Type 29
5.1.2 Rincon Spatial Distribution of Without Project Damages 29
5.1.3 Rincon FWOP Condemnations 31
5.1.4 Rincon Damage Distribution by Damage Driving Parameter 32
5.1.5 Rincon Temporal Distribution of Damages 32
5.1.6 Rincon Emergency Clean-up and Evacuation Costs 33
5.1.7 Rincon FWOP Damages in Alternative Sea-Level-Rise Scenarios 33

5.1.8 Rincon FWOP Condition Conclusion 5-35
5.2 Condado Future Without Project Condition 5-35
5.2.1 Damages in Sea-Level-Rise Scenarios 5-36
5.2.2 Condado FWOP Conclusion 5-36
5.3 Ocean Park Future-Without Project Condition 5-36
5.3.1 First-Row FWOP Conditions (Beach-Fx) 5-38
5.3.2 Upland Ocean Park FWOP Conditions (G2CRM) 5-43
5.3.3 Ocean Park Future-Without Project Conclusion 5-45
5.4 Isla Verde Future-Without Project Condition 5-45
5.5 Land Loss Damages in the Future-Without Project by Planning Reach 5-47
6. Measure Screening and alternative development 6-48
6.1 Measures Considered 6-48
6.1.1 Structural Measures Considered 6-48
6.1.2 NATURAL AND NATURE-BASED FEATURES 6-49
6.1.3 NON-STRUCTURAL Measures 6-50
6.2 Final Array of Alternatives 6-51
6.2.1 Ocean Park Final Array 6-52
6.2.2 Rincon Final Array of Alternatives 6-53
7. Future With Project Modeling and Alternative Comparison 7-53
7.1 Rincon Future-With Project Preliminary Modeling 7-54
7.1.1 Rincon Beach Nourishment 7-54
7.1.2 Revetment 7-55
7.1.3 Beach Nourishment with Groin 7-55
7.1.4 Acquisition and Relocation 7-56
7.2 Rincon Final Array and Alternative Comparison 7-57
7.2.1 Rincon Final Array NED Comparison 7-58
7.2.2 Rincon Final Array RED Comparison 7-60
7.2.3 Rincon Final Array OSE & EQ Comparison 7-61
7.3 Rincon Alternative Comparison Summary 7-63
7.4 Ocean Park Final Future-With Project Preliminary Modeling 7-64
7.4.1 Ocean Park Preliminary Floodwall Modeling 7-65
7.4.2 Ocean Park Beach Nourishment Modeling 7-66
7.5 Ocean Park Final Array Summary 7-68
8. The Tentatively Selected Plans 8-69

8.1 Rincon Tentatively Selected Plan 8-69
8.1.1 Rincon – Recreation Benefits of the TSP 8-69
8.1.2 Rincon TSP NED Benefits & Costs in the SLR Scenarios 8-72
8.1.3 Rincon TSP Risk and Uncertainty 8-74
8.1.4 Rincon TSP RED, OSE, and EQ Benefits 8-75
8.2 Rincon TSP Benefit Summary 8-76
8.3 Ocean Park Tentatively Selected Plan 8-77
8.3.1 Ocean Park TSP NED Costs & Benefits in the SLR Scenarios 8-77
8.3.2 Ocean Park TSP Recreation Benefits 8-78
8.3.3 Ocean Park TSP OSE & RED Benefits 8-79
8.3.4 Ocean Park Risk and Uncertainty 8-79
8.4 Ocean Park TSP Benefit Summary 8-81

THE TABLES......

Table 2-1: San Juan Area Socioeconomic Information – 2018 5-Year American Community Survey .... **11.**
Table 2-2: Rincon Area Socioeconomic Information – 2018 5-Year American Community Survey .... **16.**
Table 2-3: Total Structure Value and Average First-Floor Elevation by Planning Reach... 16
Table 3-1: PR CSRM Maximum Emergency Clean-Up Cost by Occupancy Type 23
Table 5-1: Distribution of Rincon Damages By Category ($ AAEQ) 29
Table 5-2: Rincon FWOP Damages by Parameter 32
Table 5-3: Ocean Park Upland FWOP Distribution of Damages 5-43
Table 5-4: Ocean Park Upland Summary Statistics in the Sea-Level Rise Scenarios 5-45
Table 5-5: Isla Verde Full Structure Inventory FWOP Damages 5-47
Table 5-6: Isla Verde First-Row Only FWOP Damages 5-47
Table 6-1: Final Array of Alternatives 6-52
Table 7-1: Preliminary Rincon Nourishment Modeling 7-55
Table 7-2: Revetment Modeling Results 7-55
Table 7-3: Preliminary Beach Nourishment with Groins 7-56
Table 7-4: Rincon Final Array NED Comparison 7-59
Table 7-5: Rincon Final Array Comparison - RED 7-60
Table 7-6: Rincon Final Array Comparison OSE and EQ 7-61
Table 7-7: Ocean Park Preliminary Floodwall Modeling - NED 7-66
Table 7-8: Ocean Park Preliminary Sewall Modeling – Comprehensive 7-66
Table 7-9: Incremental Benefits of Ocean Park Seawall Extensions 7-66
Table 7-10: Ocean Park Preliminary Nourishment Modeling 7-67
Table 8-1: TSP Benefits and Damage Reduction (R11-R22) 8-73
Table 8-2: TSP Benefits and Damage Reduction (R11-R20) 8-73
Table 8-3: Acquisition Total First Cost (FY23) 8-73

Table 8-4: Acquisition Total NED Cost (AAEQ) 8-74
Table 8-5: Rincon TSP NED Net-Benefits in the SLR Scenarios 8-74
Table 8-6: Rincon Acquisition Tourism Spending Benefit 8-76
Table 8-7: Rincon TSP Benefit Summary 8-77
Table 8-8: Ocean Park TSP Benefits 8-78
Table 8-9: Ocean Park TSP First Cost (FY23) 8-78
Table 8-10: Ocean Park TSP NED Cost (AAEQ) 8-78
Table 8-11: Ocean Park TSP NED Summary in the SLR Scenarios 8-78
Table 8-12: Ocean Park TSP OSE Benefits 8-79

THE FIGURES...........

Figure 1-1: PRCS CSRM Study Delineation 1-1
Figure 2-1: San Juan Focus Area Census Tract Map 9
Figure 2-2: Map of Initial Study Area 8
Figure 3-1: Example Damage Function 20
Figure 3-2 Condado Floodwall Examples 21
Figure 3-3 Isla Verde Floodwall Examples 21
Figure 3-4: Ocean Park Floodwalls 22
Figure 3-5: Rincon Armoring Examples 22
Figure 4-1: Rincon Planning Reaches 27
Figure 5-1: Rincon Beach-Fx Model Domain 28
Figure 5-2: Rincon FWOP Damages by Reach (AAEQ $ and %) 30
Figure 5-3: Structures at Risk of Condemnation 31
Figure 5-4: Rincon FWOP Condemnations 32
Figure 5-5: Rincon Damages over Time and Space ($ Non-PV) 33
Figure 5-6: Rincon Total Damages by SLR Scenario 5-34
Figure 5-7: Condado Beach-Fx Model Domain 5-35
Figure 5-8: Condado FWOP Damages in Each Sea-Level Rise Scenario 5-36
Figure 5-9: Ocean Park Comprehensive Risk Picture 5-37
Figure 5-10: Ocean Park Beach-Fx Model Domain with First-Row Assets 5-37
Figure 5-11: Ocean Park G2CRM Model Domain with Remaining Assets 5-38
Figure 5-12: Ocean Park First-Row FWOP Damages By Reach 5-39
Figure 5-13: Ocean Park First-Row Damages by Parameter 5-40
Figure 5-14: Ocean Park FWOP Armor Repair Triggers 5-40
Figure 5-15: Ocean Park First-Row FWOP Damages by Time 5-41
Figure 5-16: Frequency of Ocean Park First-Row Condemnations 5-42
Figure 5-17: Ocean Park First-Row FWOP Damages in the Sea-Level Rise Scenarios 5-43
Figure 5-18: Histogram of Ocean Park Upland FWOP Damages Based on 200 Iterations 5-44
Figure 5-19: Ocean Park Upland FWOP Damages in the Sea-Level Rise Scenarios 5-45
Figure 5-20: Isla Verde Full Beach-Fx Modeling Domain 5-46
Figure 5-21: Isla Verde First-Row Beach-Fx Modeling Domain 5-46
Figure 5-22: Ocean Park Pocket Beach Land Loss by Year 5-48
Figure 7-1: Rincon Preliminary Acquisition Footprint 7-57
Figure 7-2: Condemnations by Year in the Acquisition Alternative 7-62
Figure 7-3: Potential Future Rincon Second-Row Acquisitions 7-63

Figure 7-4: Rincon Alternative Comparison Summary 7-64
Figure 8-1: The Beaches of Rincon.. 8-71
Figure 8-2: Stella Beach Visitation Estimates (FWOP Vs. FWP) 8-72
Figure 8-3: Stella Beach UDV (FWP vs. FWOP).. 8-72
Figure 8-4: Rincon TSP Box and Whisker of Benefits Vs. Cost (AAEQ)................................ 8-75
Figure 8-5: Rincon TSP Net-Benefit Scatter Plot (AAEQ)... 8-75
Figure 8-6: Ocean Park TSP Benefit Distribution Box and Whisker vs. Cost (AAEQ)............ 8-80
Figure 8-7: Net-Benefit Scatter Plot.. 8-81

1. INTRODUCTION

The purpose of this appendix is to tell the story of the economics investigation and resulting analysis. A detailed explanation of the quantitative rigor and the precise modeling efforts, from inputs to outputs, which gave rise to the recommended plan will be provided. The subsequent sections will cover the following topics:

- **Existing Conditions**: Items discussed include an assessment of socio-economic conditions, spatial organization of the study area, and an inventory of the coastal infrastructure within the study area.
- **Future Without-project Condition (FWOP)**: The FWOP is a forecast of the economic conditions and structure values located within the project area that are subject to the risks associated with coastal processes and coastal storms. The FWOP is the basis for alternative comparison to obtain the benefits from any potential federal project.
- **Coastal Storm Risk Management (CSRM) Benefits**: This section will cover the methods and assumptions used to estimate the future without-project and future with-project condition using Beach-fx and the Generation II Coastal Risk Model (G2CRM), while also accounting for risk and uncertainty. Discussion of the future-with project condition (FWP) will address the management measures and alternative plans evaluated. In addition, a sensitivity analysis of how the alternatives perform under varying sea-level rise scenarios is provided[2].

- **NED Plan, Total Benefit Plan, & Tentatively Selected Plan and Performance**: This section addresses the quantitative analysis executed to determine which alternative maximizes net NED, which alternative maximizes net benefits under all accounts, and which alternative will be the tentatively selected plan. A detailed description of the performance of the NED plan, including certified cost estimates, will be provided with the same four dimensions described above in the CSRM section. The methodology underpinning the calculation of additional NED benefits provided by the project (i.e. emergency cleanup and evacuation costs, incidental recreation benefits) as well as the methodology used to measure the RED, OSE, and EQ accounts will be summarized as well.

[2] Due to the complex nature of the flooding in some modeled areas, specifically with G2CRM, there will be only a qualitative discussion for the high sea-level change scenario.

2. EXISTING CONDITIONS

A key step in the planning process is to establish the existing (i.e. current) condition by developing an inventory and characterizing the critical resources within the project area. The existing condition is also a key component for identifying historically economically disadvantaged communities and forecasting the FWOP, which is described in detail in **Section 5**.

2.1 Study Area

The initial study area included 11 municipalities, displayed in **Figure 2-1** but was pared down to two, Rincon and San Juan. Four planning reaches were established: Rincon, Condado, Ocean Park, and Isla Verde as shown in **Figure 1-1**. The planning reaches were further screened for alternatives based on the associated risks present in each planning reach. Ultimately, only the Ocean Park and Rincon planning reaches were carried forward for proposed action and that screening process is detailed below in **Section 5** and the main report. All benefit and cost analysis performed and described in this appendix refer specifically to those planning reaches.

Figure 2-1: Map of Initial Study Area

2.2 Socioeconomic Conditions & Environmental Justice Identification

The primary parameters used to describe the demographic and socioeconomic environments include population, employment, and income distribution. There is additional socioeconomic data presented from the Environmental Protection Agency's (EPA) EJScreen Tool. The municipality of Rincon and San Juan will be characterized separately, and data will be presented for tracts that are within the modeled domain and are therefore reflective of the communities directly at risk in this study. The PDT considered environmental justice impacts as required by Executive Order 128981 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (1994), which directs each federal agency to avoid disproportionately high and adverse human health or environmental effects on low-income and minority populations. Federal agencies must conduct their programs, policies, and activities that substantially affect human health or the environment to avoid excluding persons or populations and avoid subjecting persons or populations to discrimination because of their race, color, or national origin. The team also took the analysis one step further and compared alternatives to each other based on the percentage of benefits accruing to three communities in line with current administration's Justice40 Initiative[3] as well as the Comprehensive Documentation of Benefits in Decision Documents (ASA-CW, 2021)(see **Section 7.5**) . The description and identification of the communities in this section is the basis for that comparison.

2.2.1 San Juan Metro Area

To get a better understanding of the specific demographics in this focus area, data from the American Community Survey and the EJScreen Tool was collected at the census tract level within San Juan. Though there are several areas in San Juan where coastal storm risks were evaluated during this planning study, only the Ocean Park planning reach will be described in this section since it is the only reach where action is being proposed (the screening rationale is described in the FWOP discussions below beginning at **Section 5** as well as in the Main Report**).** The census tracts used for Ocean Park were tracts 10, 11, 12, 13.01, and 13.02 as these were the primary tracts in the modeled domain (**Figure 5-11: Ocean Park G2CRM Model Domain with Remaining Assets**). The census tracts are shown in **Figure 2-2**.

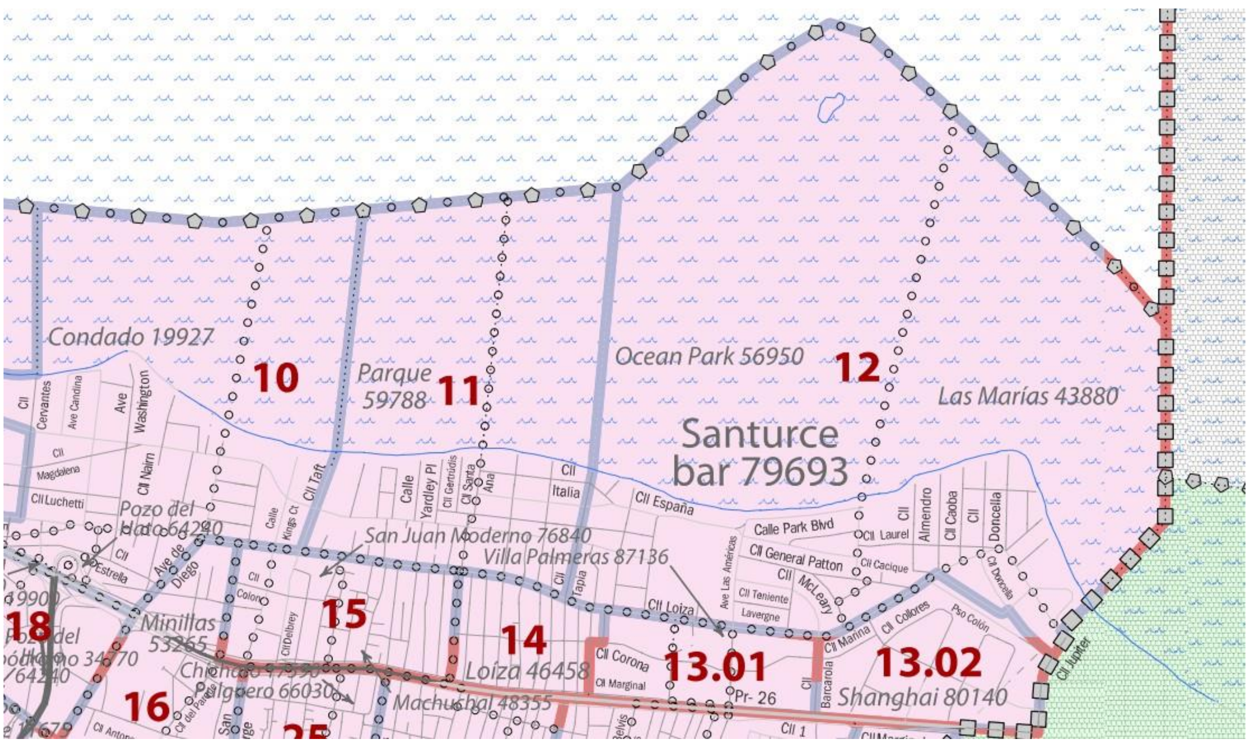


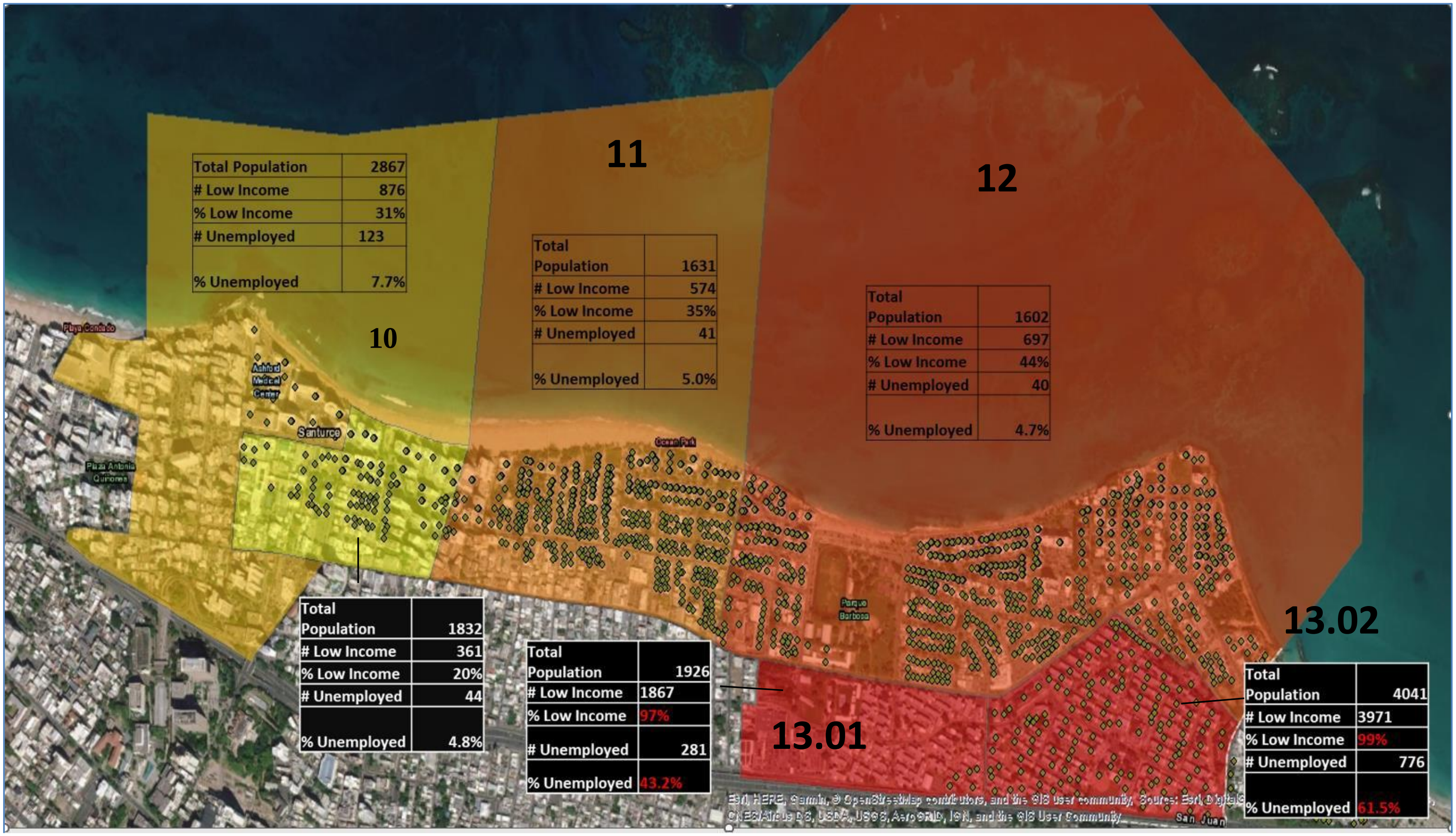
Figure 2-2: Ocean Park Planning Reach Tract Map

[3] https://www.whitehouse.gov/environmentaljustice/justice40/

There are approximately 14,000 people living within each of the abovementioned census tracts. The average unemployment rate is 21.15% which is driven largely by tracts 13.01 and 13.02 which have rates of 43.2% and 61.5% respectively. On average, 54% of the residents are considered low income and 46% live below poverty level. The median income averages $25,948 with census tract 13.02 the lowest at only $3,157. Based on these income and employment figures the PDT determined that each of the census tracts in the study footprint were communities that have been economically disadvantaged (see **Figure 2-3).** Additionally, there is a significant amount of public housing located within the planning reach, such as the Residencial Luis Llorens Torres which is the largest public housing complex in the entire Caribbean. Residencial Luis Llorens Torres spans across census tracts 13.01 and 13.02.

Tract	10	11	12	13.01	13.02
% Below Poverty	15%	26%	11%	84%	93%
Median income (dollars)	$ 42,277	$ 43,472	$ 36,827	$ 4,006	$ 3,157
Mean income (dollars)	$ 77,724	$ 73,494	$ 57,510	$ 16,646	$ 6,445

Table 2-1: Income Data on Ocean Park Census Tracts



*Heat map coloring based on % of population considered low income
*Small green points on map represent assets included in the modeling domain, more discussion on this in the FWOP condition below.

Figure 2-3: Communities of Ocean Park

2.2.2 Rincon

The socioeconomic characteristics of the Rincon Municipality are listed separately as they are different from those found in San Juan and are separable elements with completely separable geographies (see Main Report). The planning reach of Rincon in this feasibility study is represented primarily by census tract 9596, which is located entirely within the barrio of Stella[4].

Stella's unemployment rate of 4.6% is not particularly high compared to the US, but the median income of $29,769 is slightly less than half that of the US. The percent of population living below poverty in Stella is 38.2% and those considered low income represent 75.4%, putting this census tract in the 97th percentile of low income. Based on these socioeconomic parameters, Rincon is also considered to be a community that has been economically disadvantaged.

[4] In Puerto Rico a barrio is a legal subdivision of a municipality

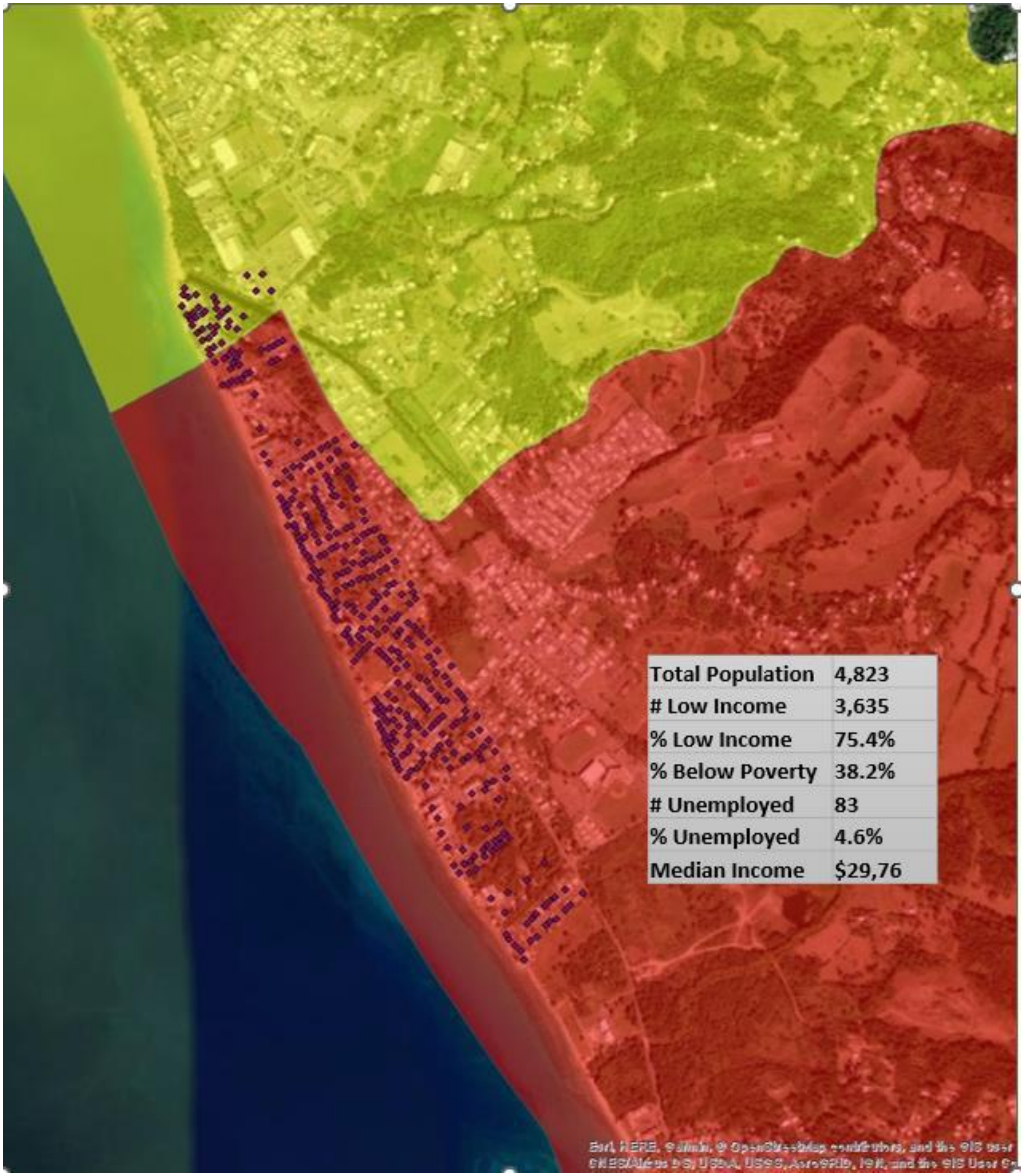


Figure 2-4: Rincon (Stella) Socioeconomic and Environmental Justice Statistics

Within the study area there is a middle school, Jorge Seda Crespo, which serves the student population of Stella and other barrios of Rincon grades 6-8.[5] For the 2017-2018 school year, 90% of the students at Jorge Crespo were eligible for free (83%) or reduced (7%) school lunch.

Tourism plays an outsized role in the employment picture for the barrio of Stella. Most of the accommodations, food services, retail trade, recreation and other services are in support of the tourism industry and those employment categories represent ~58% of the industries employing Stella residents.

Figure 2-5: Employment by Industry in Stella

2.3 Data Collection

Economists and real estate specialists have collected and compiled detailed structure information for the four planning reaches. In total, approximately 2,800 assets were collected for economic modeling using both Beach-fx and G2CRM. Real estate professionals from the USACE Savannah District (SAV), using geo-spatial parcel data from Puerto Rico's Centro de Recaudación de Ingresos Municipales (Municipal Revenues Collection Center or CRIM), provided detailed data on each structure including geographic location, structure type, foundation type, construction type, number of floors, depreciated replacement value, and approximate foundation height[6].

The PR CSRM Beach-Fx study area consists of 25 profiles, and 51 model reaches, and over 100 lots for economic modeling and reporting purposes. This hierarchical structure is depicted as follows:

- **Profiles:** Coastal surveys of the shoreline modified by USACE SAJ Coastal Engineering personnel to apply coastal morphology changes to the model reach level. Profiles are strictly used for modeling purposes and only referred to in this section for informational purposes. Specific information regarding the makeup of the profiles can be found in the Engineering Appendix of this report.
- **Beach-Fx Model Reaches:** Quadrilaterals parallel with the shoreline used to incorporate coastal morphology changes for transfer to the lot level. Each model reach is separately subjected to environmental forcing irrespective of neighboring reaches.

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[5] The school is located in Rincon Planning Reach A (reference below sections on segmentation of the study area) which was screened out.

[6] Estimated foundation height was used to establish a structure's first-floor elevation.

- **Lots:** Quadrilaterals encapsulated within reaches used to transfer the effect of coastal morphology changes to the damage element. Lots also ensure that the model does not overstate damages by placing value parameters around rebuilding (this is discussed further in **Section 3.2**).
- **Damage Elements:** Represent a unit of coastal inventory in the existing condition and a store of economic value subject to losses from wave-attack, inundation, and erosion damages. Damage elements are also used for estimation of emergency clean-up costs (e.g. debris removal) and evacuation costs. These assets are a primary model input and the topic of focus in the following section.

2.4 Existing Condition Coastal Structure Inventory

Information on the existing economic conditions within the four planning reaches was collected for economic modeling purposes. The information on the coastal assets detailed in this section was collected from SAV real estate and site visits. Each parcel was identified as developed or undeveloped, with streets and parks noted. USACE real estate specialists provided depreciated replacement value of existing structures.

2.4.1 Structure & Contents Value

The economic value of the existing structure inventory represents the depreciated replacement costs of damageable structures (i.e. damage elements or assets) and their associated contents. Real Estate professionals from the USACE SAV district worked together with economists and planners to provide economic valuations for all 2,800 damageable structures and their contents. These damage elements have an overall estimated value of $3B (FY23). Content values were established as a ratio to overall structure value. When applicable, content-to-structure ratios were based off the USACE IWR 2012 "*Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation"* report. Many items in the structure inventory had a CSVR of 0% (e.g. roads, dunewalks, parking lots). It is also important to note that content valuation considers only those contents anticipated to be at risk from flood, wave, and erosion and, specifically in cases of high-rise structures, may not include total contents[7]. As a result, the average CSVR across the entire study area is roughly 20%. The overall distribution of value by planning reach is summarized in **Table 2-2**.

Planning Reach / Model Domain	Most-Likely Structure and Content Value (FY23)	Most-Likely Average First-Floor Elevation (Ft. PRVD02)
Condado	$ 577,820,703	16.7
Isla Verde	$ 939,282,473	10.0
Ocean Park (First-Row)	$ 228,569,985	9.1

[7] Users of the NACCS damage functions for high-rise buildings are advised that "the damage to high rise buildings should be calculated as a percent of the first ten stories" and this guidance was followed for the PRCS study.

Rincon	$ 79,450,490	9.6
Ocean Park (Upland)	$ 1,135,621,653	6.6
Total	$ 2,960,745,304	10.4

Table 2-2: Total Structure Value and Average First-Floor Elevation by Planning Reach

3. COASTAL STORM RISK MANAGEMENT BENEFIT APPROACH

This section of the appendix covers the approach used to estimate the economic benefits of managing coastal storm risks in the study area using Beach-fx and G2CRM. The topics covered include:

- Benefit Estimation Approach Using Beach-fx and G2CRM
- Performance Metrics for OSE and RED P&G accounts
- FWOP Condition
- The Future-With Project Condition (FWP)

3.1 Benefit Estimation Approach Using Beach-fx and G2CRM

In any feasibility study the FWOP damages are used as the base condition and potential project alternatives are measured against this base. The difference between FWOP and FWP damages from both models will be used to determine primary CSRM benefits.

Once benefits for each of the project alternatives are calculated, they will be compared to the costs of implementing the alternative. Dividing the total benefits by the total costs of the alternative yields a benefit-to-cost ratio (BCR). This ratio must be greater than 1.0 (i.e. the benefits must be greater than the costs) in order for the alternative to be economically justified. The federally preferred plan, or NED, is the plan that maximizes net benefits. Net benefits are determined by simply subtracting the cost of any given alternative from the benefits of that alternative ($Benefits - Costs = Net\ Benefits$). When applicable, these models will also be utilized to measure impacts to the remaining three P&G accounts (RED, OSE, EQ). The methodology of quantifying impacts to the other accounts will be detailed in separate sections. The following sections will discuss the two models used in this study as well as detail the assumptions underpinning the models.

3.1.1 Beach-Fx

Beach-fx was developed by the USACE Engineering Research and Development Center in Vicksburg, Mississippi. On April 1, 2009 the Model Certification Headquarters Panel certified the Beach-fx CSRM model based on recommendations from the Planning Center of Expertise (PCX) and in accordance with EC 1105-2-412 (Assuring Quality of Planning Models). The model was reviewed by the PCX for Coastal and Storm Damage and found to be appropriate and certified for use in CSRM studies and is therefore the required model for use in the PR CSRM Study. The model links the predictive capability of coastal evolution modeling with project area infrastructure information, structure and content damage functions, and economic valuations to estimate the costs and total damages under various shore protection alternatives. The output generated from the model is then used to determine the benefits of each alternative. As an event-based Monte Carlo life-cycle simulation, Beach-fx fully incorporates risk and uncertainty. It is used to simulate coastal storm risks at existing and future years and to compute accumulated present-worth damages and costs. Storm damage is defined as the ongoing monetary loss to contents and structures incurred as a direct result of waves, erosion, and inundation caused by a storm of a given magnitude and probability. Additional categories of evacuation and emergency clean-up costs are also estimated using Beach-fx and added to the content and structure damages for inclusion in the benefit base. The model also computes permanent shoreline reductions so that land-loss benefits can be derived exogenously. These damages and associated costs are calculated over a 50-year period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Beach-fx also provides the capability to estimate the costs of certain future measures undertaken by individual property owners as well as state and local organizations to protect coastal assets. Based on these attributes, Beach-fx is an ideal economic modeling tool for use in the PR CSRM study.

Of course, the abovementioned computations require inputs from USACE personnel in order to function accurately. Data on historic storms, beach survey profiles, and private, commercial and public structures within the project area are used as these inputs. The future structure inventory and values are the same as the existing condition. This approach neglects any increase in value accrued from future development. Using the existing inventory is considered preferable due to the uncertainty involved in projections of future development.

3.1.2 G2CRM

G2CRM is distinguished from other models currently used for that purpose by virtue of its focus on probabilistic life cycle approaches. This allows for examination of important long-term issues including the impact of climate change and avoidance of repetitive damages. G2CRM is a desktop computer model that implements an object-oriented probabilistic life cycle analysis (PLCA) model using event-driven Monte Carlo simulation (MCS). This allows for incorporation of time-dependent and stochastic event-dependent behaviors such as sea level change, tide, and structure raising and removal. The model is based upon driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas (model areas) of different types that may interact hydraulically and may be defended by coastal defense elements that serve to shield the areas and the assets they contain from storm damage. Within the specific terminology of G2CRM, the important modeled components are:

1. Driving forces - storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models.
2. Modeled areas - 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.
3. Protective system elements - 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 Floodwalls.
4. 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.

The model deals with the engineering and economic interactions of these elements as storms occur during the life cycle, areas are inundated, protective systems fail, and assets are damaged and lives are lost. A simplified representation of hydraulics and water flow is used. Modeled areas currently include unprotected areas and coastal uplands defended by a Floodwall or bulkhead. Protective system elements are limited to bulkheads/Floodwalls.

3.2 Model Assumptions

Model accuracy is not only dependent upon inputs but also requires a meticulous level of thought be given to the parameters (i.e. assumptions) under which the model is bound. This section describes some key assumptions specific to the PR CSRM study and the resulting consequences. Every attempt was made to keep modeling assumptions the same between G2CRM and Beach-Fx. However, due to differences in the models some assumptions needed to be adjusted in order to properly reflect real-world physical conditions within each model. Specific differences in assumptions will be identified and all others are identical.

It is important to note that each focus area (Rincon, Condado, Ocean Park, and Isla Verde) were all modeled separately for Beach-Fx, with four separate modeling databases. This was required due to the complexity of the shoreline shape as well as the differences in the coastal processes subjected to each individual focus area. G2CRM was specifically utilized for the Ocean Park Planning Reach[8] due to the nature of the flooding problems inherent in this area.

3.2.1 Timeframe and Discount Rate

- **Start Year:** The year in which the simulation begins for **G2CRM** is 2022 in order to capture risk from storms and the associated changes in dynamic inventories between current conditions and the base year. For **Beach-Fx** the start year was set to 2028. This year determines the starting shoreline position which will be impacted by standard erosion and storm forces throughout the period of analysis. It is also the starting point for the sea-level rise projections. The reason 2028 was selected was to ensure that, if necessary, hard structures that would come online in the base year, such as break waters, could most accurately be modeled.
- **Base Year:** The year in which the benefits of a constructed federal project would be expected to begin accruing is 2029.
- **Period of Analysis:** 50 years, from 2029 to 2078.
- **Discount Rate:** 2.25% FY2022 Federal Water Resources Discount Rate. During the development of this report and appendices the FY23 Discount Rate of 2.5% was released. The economic analysis for the FWOP, NED, and TSP will be updated using the updated Discount Rate for release of the final report.
- **Iterations:** The number of iterations run within Beach-fx was decided based on model run time and model stabilization. FWOP simulations were run using 100 iterations in **Beach-Fx** and 300 iterations in **G2CRM.** For the preliminary array of alternatives in Beach-Fx, 25 iterations were run for comparison purposes. Once the array of alternatives was whittled down to a final array 100 iterations were run to ensure model convergence.

3.2.2 Rebuilding

The rebuilding parameter allows the economic modelers to account for real-world constraints on how quickly and how often a damaged asset can be restored to its full value. In Beach-Fx, rebuilding does not refer to a total rebuild event (i.e. 100% of structure value), but rather a repair event (i.e. some non-zero percent of value intended to restore the structure). In G2CRM, a

[8] Segments of the Isla Verde Planning reach were combined into the G2CRM model domain and are still described as Ocean Park Planning reach for feasibility study purposes.

specific threshold is identified as to when an event is considered a rebuild. For PRCS that threshold was set to 50%. Allowing for an unlimited amount of rebuilding in the period of analysis may be unrealistic for a CSRM study and can potentially overstate damages in the FWOP. Puerto Rico experiences a high volume of storms in any given year so there exists potential for a high frequency of minor repairs. As a result, the modelers selected a maximum number of rebuilds at 50 (once per year in the period of analysis).

Another item for modeling consideration is that within these FEMA high hazard zones a rebuilding permit is technically not allowed on a structure that is not up to current code if said structure incurs damages of 50% or greater in a single event. In the parlance of municipal coding, these structures are called "non-conforming structures". The structure inventory within Beach-fx is static, which makes reflecting this behavior a difficult task for modelers. In G2CRM, on the other hand, it is easier to account for these types of structures by removing them for future consideration if they are not estimated to be elevated or brought up to current code. This model behavior matches the requirement set forth in Section 308 of the Water Resources Development Act (WRDA) of 1990 which states:

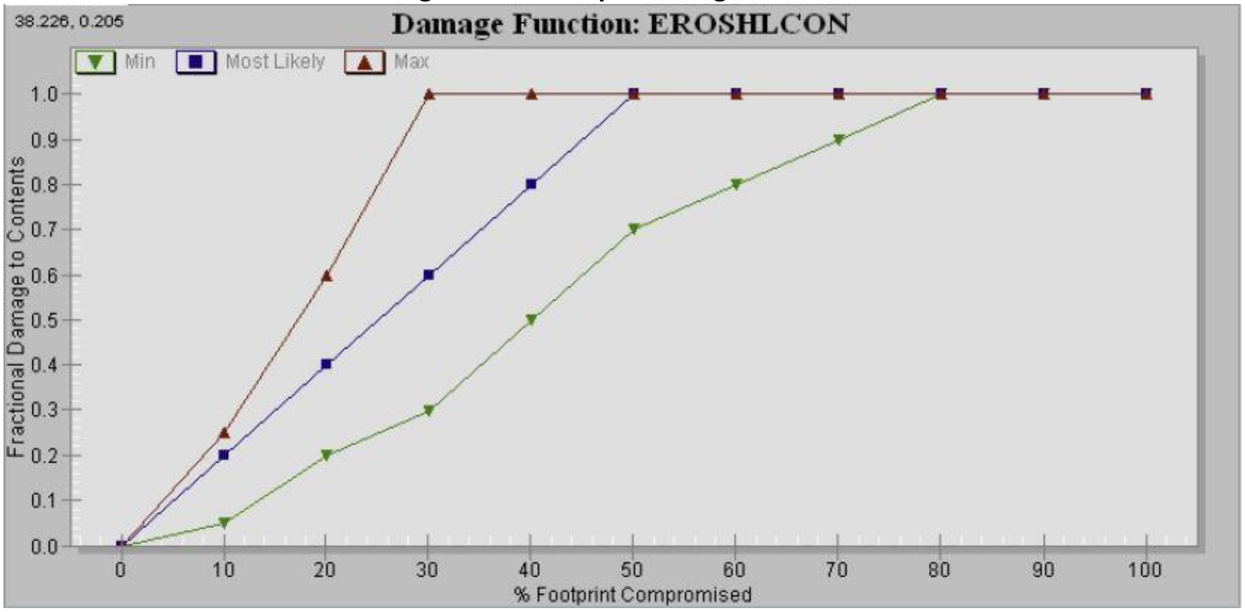
"(a) Benefit -Cost Analysis.--The Secretary shall not include in the benefit base for justifying Federal flood damage reduction projects- (1)(A) any new or substantially improved structure (other than a structure necessary for conducting a water-dependent activity) built in the 100-year flood plain with a first floor elevation less than the 100 -year flood elevation after July 1, 1991".

Thus, once a non-conforming structure is damaged beyond 49% it is removed from the inventory. This is accomplished in G2CRM on the front end by simply identifying non-conforming structures and reducing their number of rebuilds to 1. The static inventory in Beach-Fx requires post-processing to accomplish this behavior and so a python script was developed to identify when a structure reaches the threshold.

3.2.1 Damage Functions

Damage functions are used within the model to determine the extent of storm-induced damages attributable to any specific combination of damage element type, foundation type, and construction type. For Beach-Fx, there are a total of six types of damage function which include erosion damages, inundation damages, and wave damages for both contents and structure. For G2CRM the only damage function utilized is inundation for both contents and structures. The functions are completely user-definable within the model and transfer damages to the individual damage elements. Damage is determined as a percentage of overall structure or content value using a triangular distribution (minimum, most likely, maximum). The range of percentage points used for the damage is determined by parameters dependent upon which function is being triggered. For erosion it is dependent upon the extent to which the structure's footprint has been compromised and inundation and wave-attack are dependent upon storm-surge heights in excess of first-floor elevation. An example diagram of how these damage functions operate is provided by **Figure 3-1**.

Figure 3-1: Example Damage Function



For the vast majority of aforementioned residential combinations within this study the damage functions used were those developed by the USACE North Atlantic Division in the "North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk" (NACCS Report), section "Physical Depth Damage Function Summary Report" (January, 2015). For non-residential damage functions, the Institute for Water Resource (IWR) publication "Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation" (Davis, 2013) was used. However, the wave damage functions needed to be adjusted for certain damage elements based on their relative position in the upland. In order to account for the fact that property and structures in the first row would attenuate wave energy, properties in the second and third rows were assigned altered wave damage functions. Properties located in the second row had a downward revision to the fractional damage at every wave height whereas the properties in the third row had the null wave damage function assigned since it is assumed that properties set that far back would not incur damages from wave attack due to attenuation.

3.2.2 Coastal Armoring

Beach-fx allows for assumptions surrounding coastal armoring (e.g. sandbags, breakwaters, floodwalls, rip rap) as well. A user can define the different types of armoring applied to individual damage elements as well as a distance trigger, applied at the lot level, which will prompt construction of said armor. A detailed inventory of lots that are already armored was developed by SAJ economists for input into Beach-fx based on detailed site visit photography provided by SAJ Coastal EN.

For the PR CSRM the coastal armoring assumptions differed in the San Juan modeled areas from Rincon. This difference was based on the design level and construction condition of the armoring. Within Rincon it was common for rock of various size (i.e. riprap) to simply be placed at the lot line in a haphazard manner. This riprap placement was not of engineering design and was assumed to have low failure thresholds. In San Juan more robust floodwalls and revetments were common armor types in each of the planning reaches. These floodwalls had higher failure thresholds. Failure thresholds were informed by the *"Lee County, Florida Shore Protection Project Gasparilla Island Segment – Section 934 Report*" as well as based on best professional judgment with input from SAJ Coastal EN. Picture examples of the various floodwall types that helped inform these assumptions and cataloging of armor inventory are provided in the following figures.

Local permitting practices were also factored into how and when armoring would be triggered. Since it is not permissible to place structures in the Maritime Terrestrial Zone (MTZ) it was assumed that property owners would only place revetments and structures within their property falling outside of the MTZ.

Pictures from left to right: Robust Floodwall tied into the bedrock in Planning Reach Condado West Headland; Robust emergent Floodwall with buried foundation in Condado Punta Piedrita

Figure 3-2 Condado Floodwall Examples

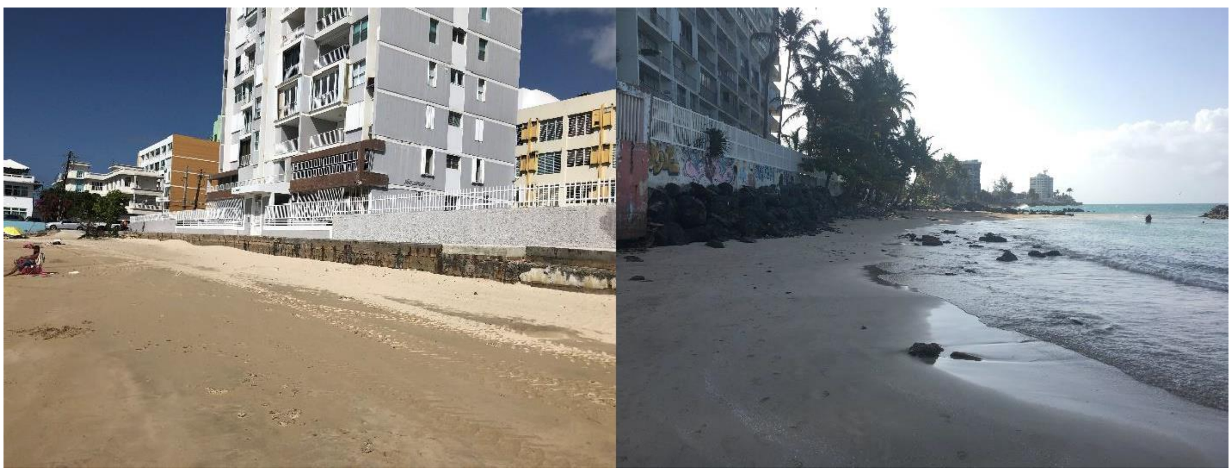


Figure 3-3 Isla Verde Floodwall Examples

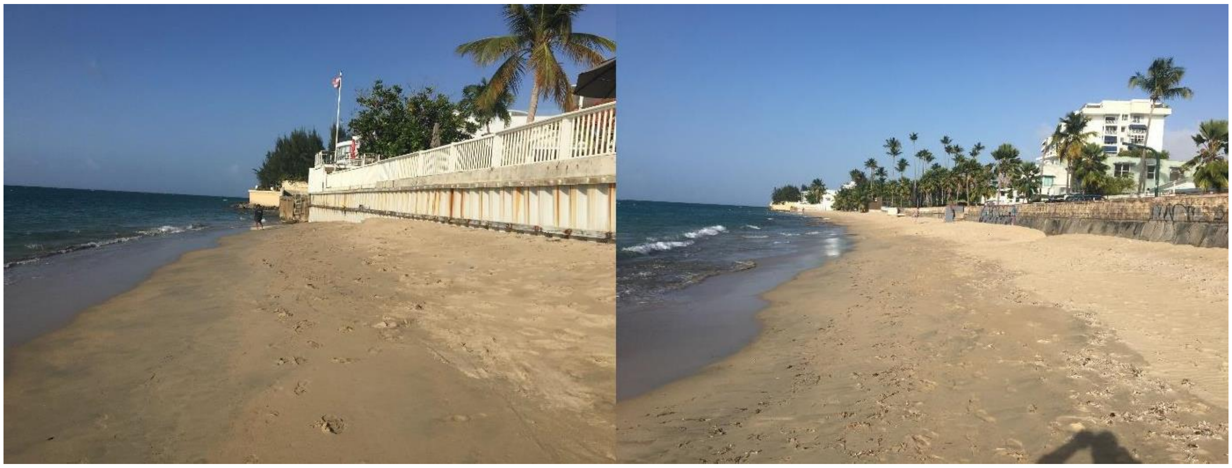


Figure 3-4: Ocean Park Floodwalls

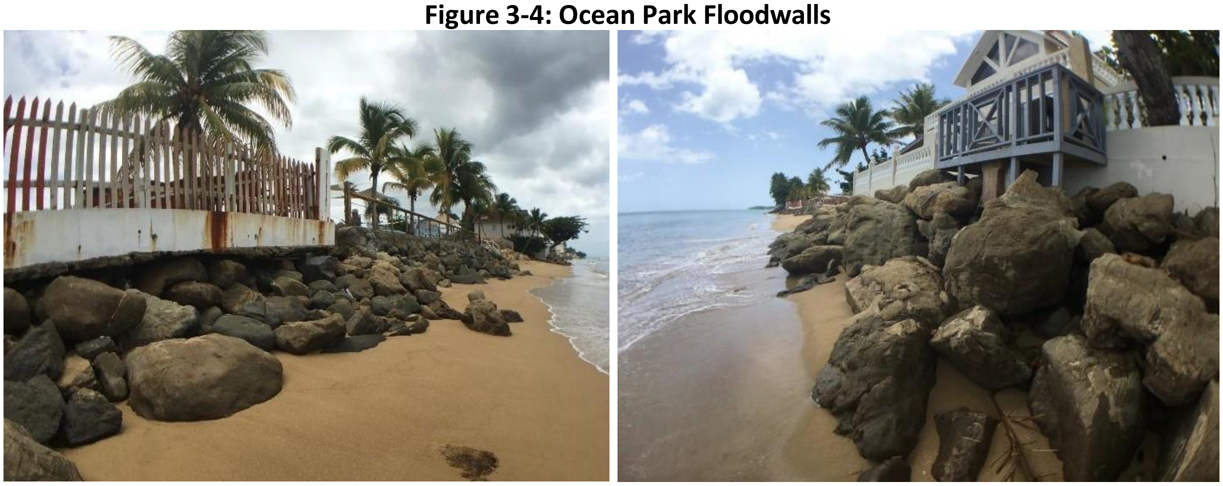


Figure 3-5: Rincon Armoring Examples

3.3 Emergency Clean-Up and Evacuation Cost Assignment Methodology

This category of cost is part of the NED analysis per section 3-4 of ER 1105-2-100 and is ultimately added to the FWOP damages to estimate the benefit base against which FWP alternatives are compared. Commercial and residential assets within the inventory were assigned a maximum emergency clean-up and evacuation (ERC&E) cost to estimate the impacts from coastal storms to these important NED benefit categories. Due to study schedule limitations and a large scope, site specific data was not available prior to release of this draft report. As a result, data was leveraged from the 2012 "*Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes*" to determine inputs for this PR CSRM. Clean-up and evacuation costs from the report were in 2010 price-levels and were therefore updated to FY22[9] using the Consumer Price-Index (CPI). Being an island, it is likely that Puerto Rico clean-up and evacuation costs would be higher than those estimated via expert elicitation for the Louisiana Study and thus represents a conservative estimate. However, this is deemed appropriate for this study under the 3x3 and risk-informed decision-making paradigm

[9] ERC&E will be updated to FY23 for final report

exemplified by the USACE. Maximum evacuation costs were estimated at $6,960 for each household, and maximum emergency clean-up costs are presented by occupancy type in **Table 3-1.** A separate Beach-fx model database was created strictly for computing ERC&E cost estimates in the FWOP and FWP. The structure inventory was manipulated such that the structure value was replaced with the emergency clean-up costs shown in **Table 3-1** and the content value was replaced with the abovementioned maximum evacuation cost for residential structures only. The damage function assigned to these costs estimates was also derived for the Louisiana Study and applied appropriately to each category and occupancy type.

Occupancy Type	Maximum Emergency Clean-Up Cost
One-Story Slab Home	$ 7,300
Two-Story Slab Home	$ 9,778
Multi-Family Residence	$ 13,205
General Nonresidential	$ 49,832

Table 3-1: PR CSRM Maximum Emergency Clean-Up Cost by Occupancy Type

3.4 Land Loss Estimation

In outlining the process and procedures to be used in the evaluation of CSRM projects, ER-1105-2-100 details the inclusion of land loss due to erosion, stating that such damages should be computed as the market value of the average annual area expected to be lost. Prevention of land loss is a component of primary benefits and is computed based on output data from Beach-fx. Land loss benefits must be added to the structure and content benefits as computed by Beach-fx to obtain the total CSRM benefits of the project.

Following the guidance provided, two key pieces of information are needed to calculate land loss benefits of a CSRM project: (1) the square-footage of the land lost each year and (2) the market value of land in the project footprint.

In the case of the PRCS, annual reduction of upland width across all Beach-fx study reaches was obtained from the Beach-fx LandLoss.csv output files based on modeled changes to the shoreline. However, land loss was only calculated on privately owned land subject to loss where armor was not present. As mentioned in section 3.2.2 on coastal armoring, some lots armorable in the future would not have armor triggered until some private land was lost due to the MTZ delineation. Additionally, ER 1165-2-130 does not allow land loss benefits be claimed for beach areas subject to temporary shoreline recessions. Thus, changes in upland width rather than changes in berm or dune width are used as the appropriate measure of land loss.

For Beach-fx model reaches located within the study area the basis of the annual changes in upland width calculation for the FWOP is the width in each reach in the model base year (2029) and the width of each subsequent year. The same calculation is then done for each alternative and the comparison of upland width change from the FWOP and FWP in a given year results in the cumulative loss of land for that specific model reach. However, for the purpose of calculating land loss benefits, the annual loss of width is needed. This is obtained by taking the cumulative change in width in a given year and subtracting from it from the cumulative change in width from the previous year. This calculation results in the yearly incremental change in upland width for a given reach.

Using the annual decrease in width for a specific reach and the corresponding length of shoreline eligible for land-loss benefits, the total annual square-footage of land lost is obtained on a reach-by-reach basis and then summed across all study reaches for a given project year.
As the second component of the land-loss benefits calculation, ER 1105-2-100 instructs that nearshore land values be used to estimate the value of land lost. Currently the value being used per square-foot is $68 in San Juan based on the report "Nearshore Waterfront Land Valuation" conducted by SAJ Real Estate Division specifically for the PRCS. Rincon land value was estimated but there is no land loss forecast in the FWOP condition due to existing and future armoring.

3.5 Performance Metrics for OSE & RED

The problems apparent in the existing condition required additional metrics to identify positive or negative effects of this study's planning measures and alternatives in each planning reach. These metrics were also necessary to identify an alternative which maximizes net benefits across all four P&G accounts. This section of the report details the specific performance metrics that were utilized in the PRCS. Not all the performance metrics were applicable in each planning.

For the OSE account there were several metrics. The first was utilizing a social vulnerability index, divided into quintiles, so that the PDT could understand how the risk, measured in damages, from coastal storms is transmitted to the most vulnerable. The inability for the most vulnerable to adapt, respond, and recover from coastal storms is well documented. Following Hurricane Katrina in New Orleans there is evidence to suggest vulnerable communities experience much larger building repair and recovery times and permanent displacements increase in likelihood following severe storm damages (Cutter, et al., 2006). Once the risk to these communities was understood the reduction of that risk from proposed measures or alternatives could be evaluated and displayed as part of decision making.

Another metric utilized for the OSE account was the number of condemnations that occur in the planning reaches. Condemnations were measured by a significant damaging event that resulted in the inability to rebuild the property. The damaging event is captured in the NED analysis but the impacts to the community beyond the physical structure damages are not captured by NED and were therefore captured in the OSE account. Condemned buildings can adversely impact a community through urban/community blight. Community blight is a well-documented phenomenon with wide-ranging consequences such as a decrease in surrounding property values, adverse impacts to local housing markets, safety hazards, and reduced local tax revenues (Housing and Urban Development, 2018). Blight can materialize in various forms but for this specific discussion regarding Rincon the reference is to destroyed structures from coastal erosion. These destroyed structures result in hazardous debris (e.g. large broken concrete slabs, rebar, glass, various metals) strewn about the beach. These structures are often left behind with no evidence of intent to remove; the beachside rubble that were once structures, having collapsed during Hurricane Maria in 2017, remain today (see **Figure 3-6** for an example). This sort of blight is potentially contagious. "Blight can spread at an incredible speed. Thus, it must be prevented and eradicated as soon as it surfaces. If blight is allowed to reach a more advanced stage, it causes other serious problems such as drug and alcohol abuse or prostitution thereby contributing to rising crime rates. Residents of blighted areas have lower qualities of life, including malaise and insecurity. They often find themselves in situations of greater physical and mental stress." (Pinto, Ferreira, Spahr, Sunderman, & Pereira, 2022).

Figure 3-6: Example of Existing Condition Condemned Structure in Rincon

For the RED account the following performance metrics were established based on problems identified in the existing condition:

- Tourism Expenditures – Tourism spending has direct, indirect, and induced effects on output, income, and employment within a regional economy. Each of the planning reaches within this study are potentially important for the tourism industry both at the local municipal level as well as island wide and the alternatives and measures proposed may influence the levels of tourism spending. Tourism spending will be measured in dollars.
- Business Disruptions – Coastal storms have impacts on the business community beyond the physical damage to structures. To understand the wider economic impacts of coastal storms typically requires advanced input-output or computable general equilibrium models that are beyond the scope of this study. However, to capture some of these risks beyond physical damages the PDT has decided to measure the number of days a business will be disrupted both directly by the natural hazard and then the secondary interruptions that occur from repair events. This metric will be measured in number of days of disruption.
- Local Tax Receipts – As mentioned above, each of the planning reaches suffers from potential structure losses to the degree where rebuilding is not possible. Further, evidence indicates severe storms are causing residents to permanently flee the island. After Hurricane Maria

almost 4%, or 130,000 residents, permanently relocated (Sutter, 2018). Puerto Rico overall has experienced a decline in population over the last decade of 11.8%, or 439,915 people. Since there is a direct linkage between coastal storm risks and regional population exodus, the lost property tax revenue from destroyed and abandoned structures will be estimated and recorded as a performance metric.

- Jobs Supported – Project expenditures will be used to measure the number of jobs supported in the regional economy.

4. DELINEATION OF THE STUDY AREA FOR PLANNING PURPOSES

The Puerto Rico Coastal Study initial study area considered over 12 locations around the island coastline identified by the Department of Natural and Environmental Resources (DNER), the non-federal sponsor, as having coastal damages and warranting investigation via a feasibility study. These areas are located in San Juan, Vega Baja, Arecibo, Aguadilla, Aguada, Rincón, Anasco, Mayaguez, Cabo Rojo, Loiza, Luquillo, and Humacao. The refined study area approved during the 3x3x3 exception request (see Main Report for details) included four planning reaches: Condado, Ocean Park, Isla Verde and Rincón, which subsequently were delineated into planning reaches (see **Figure 1-1**). Modeling showed little to no damages or associated risk in Condado and Isla Verda planning reaches. The study focused on finding CSRM solutions in the Ocean Park and Rincón planning reaches. However, this appendix will still display FWOP condition in the reaches that were screened but modeled.

Rincon originally comprised of two planning reaches geographically separated by a stream, Quebrada Los Ramos, to the north (Rincon A, green in figure) and south (Rincon B, blue in figure) as depicted in **Figure 4-1**. However, prior to the 3x3x3 exemption the PDT made a risk-informed decision to screen Rincon A from modeling. This decision was based on earlier iterations of modeling which demonstrated very low risks. When the study restarted following the 3x3x3 exemption with new modeling inputs Rincon A was not included in the modeling effort. Each individual section discussing FWOP modeling (i.e. Rincon, Ocean Park, Isla Verde, Condado) will display a detailed map of the modeling domain.

Figure 4-1: Original Rincon Planning Reaches

5. FUTURE WITHOUT PROJECT CONDITION (FWOP)

5.1 Rincon FWOP

Figure 5-1: Rincon Beach-Fx Model Domain

Descriptive statistics on the average annual damages per the FWOP model results are as follows:

- Mean: $1,010,900
- Standard deviation: $261,300
- Coefficient of Variance: 0.26
- Median: $976,600

The standard deviation is significantly smaller than the mean damage, seen in the coefficient of variance. This relation indicates little volatility of the FWOP damage incurred in the project area throughout the 100 iterations. The steady stream of damages is primarily due to the constant background erosion processes as well as the high vulnerability of structures in the first row. Pursuant to estimating FWOP damages and associated costs for the study area in Rincón, Beach-fx was used to estimate damages and costs in the following categories:

- Structure Damage: Economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Structure damages account for 75% of the damages for the FWOP.
- Contents Damage: The material items housed within the structures (usually air-conditioned and enclosed) that are potentially subject to damage. Content damages are 19% of the total damages.
- Armor Build/Repair Cost: Economic losses due to repair or new construction of coastal armoring. Armor damages are 7% of the total damages.

5.1.1 Rincon Damage Distribution by Structure Type

This section addresses what is being damaged in the FWOP by structure type and **Table 5-1** provides greater detail on those damages. As one can see, a majority of damages are to residential structures which account for 64% of the total. Despite hotels being a small percentage of assets within the inventory, they account for 30% of damages due to their dominant location in the first row where the coastal storm risk is the highest.

Asset Type	AAEQ FWOP Damages	Percent of Total
Single-Family (Multi-Story)	$323,000	32%
Hotel	$301,800	30%
Multi-Family Residences	$229,100	23%
Armor	$65,700	6%
Single-Family (Single-Story)	$53,600	5%
High-Rise Buildings	$36,900	4%
Roads	$800	0%
Total	**$1,010,900**	**100%**

Table 5-1: Distribution of Rincon Damages By Category ($ AAEQ)

5.1.2 Rincon Spatial Distribution of Without Project Damages

FWOP damages are consistent across reaches except for model reach R18 which accounts for 28% of all damages. The spatial damage results are summarized in **Figure 5-2**. Most important is the fact that the first-row of structures across all reaches are exposed to high levels of risk in the future. Most of these structures face future condemnation in which erosion causes enough damage where rebuilding becomes impossible. **Figure 5-3** displays the consistent risk of condemnation across the entire Rincon Planning Reach.

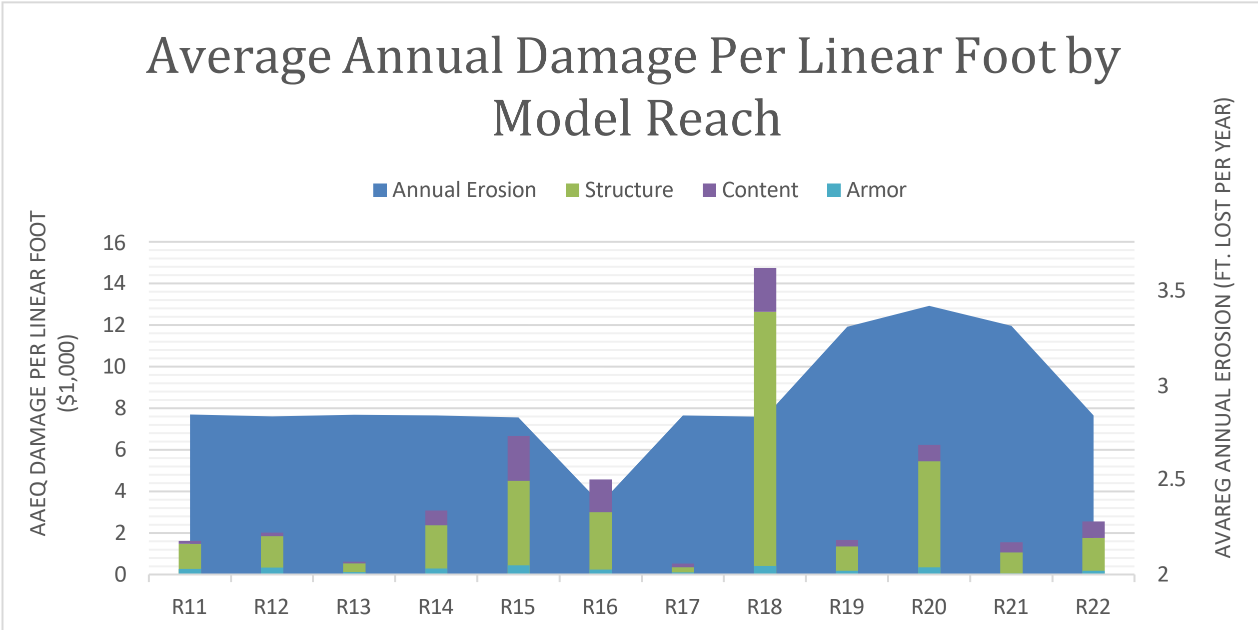


Figure 5-2: Rincon FWOP Damages by Reach (AAEQ $ and %)

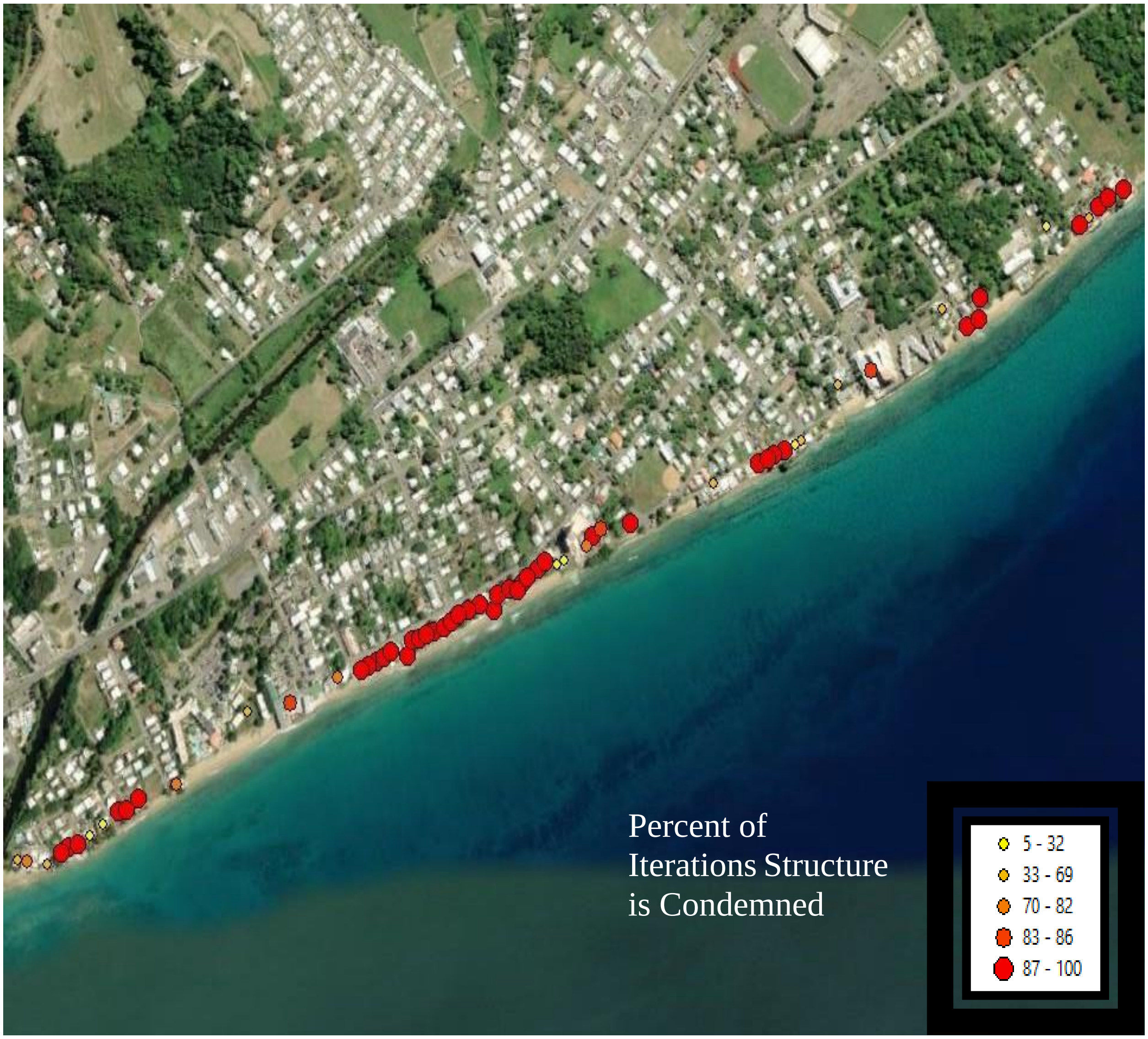


Figure 5-3: Structures at Risk of Condemnation

5.1.3 Rincon FWOP Condemnations

On average there are 57 structures that are condemned in the FWOP condition in Rincon. These condemnations occur relatively frequently in the POA, happening on average in year 18. 75% of all the condemnations occur in or before year 25 and 50% of all condemnations occur at or before year 15. See **Figure 5-4,** which is a scatter plot of all the condemnations across the 100 modeled iterations and demonstrates the trend of early POA condemnation.

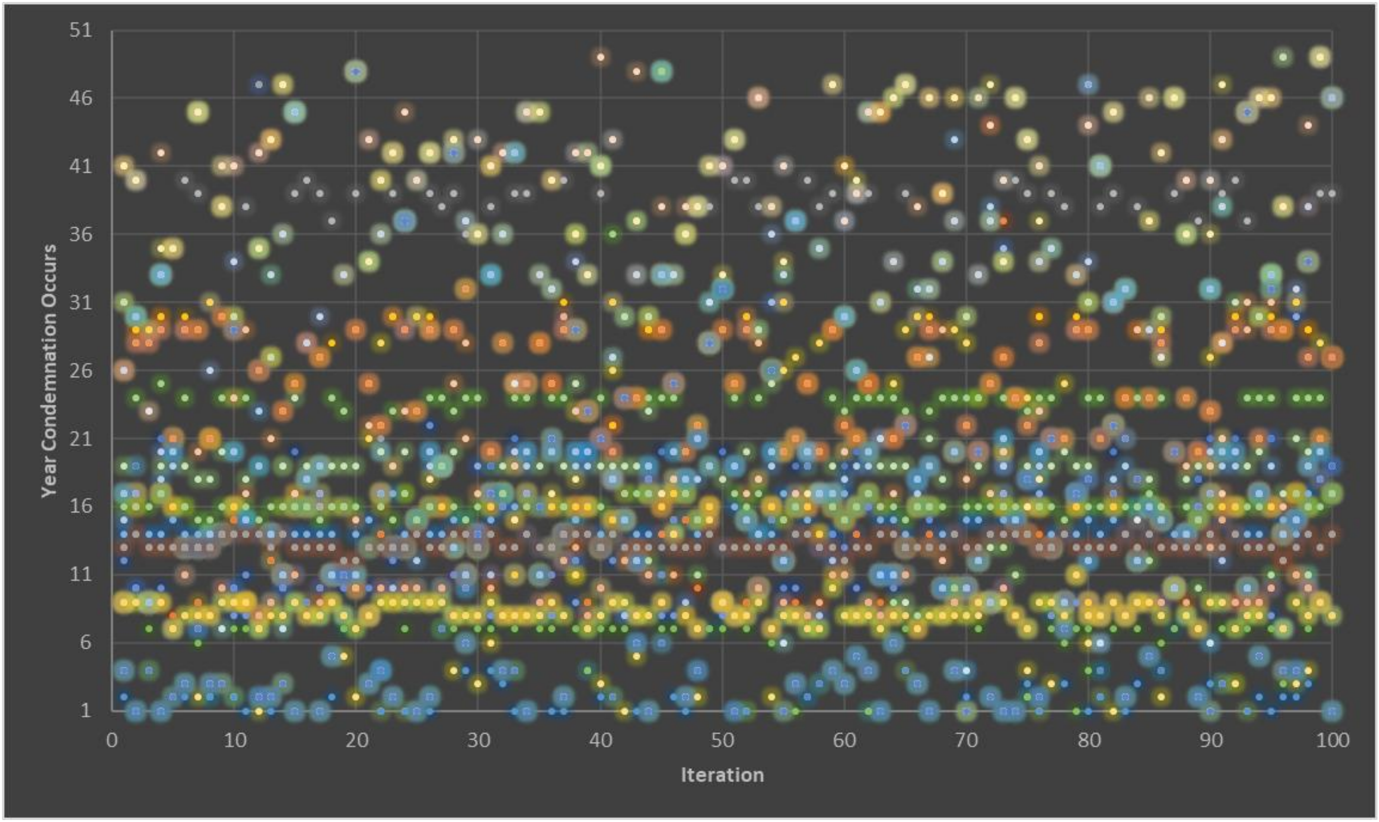


Figure 5-4: Rincon FWOP Condemnations

5.1.4 Rincon Damage Distribution by Damage Driving Parameter

Erosion is the primary damage driver in Rincon. The risk from flood and wave are low to none, accounting for a combined 5% of FWOP damages. This is unsurprising given the propensity for condemnation from erosion across the entire first row, as discussed above. The PDT based alternative formulation on the threat of erosion based on this data.

Rincon FWOP (AAEQ)		
Parameter	FWOP Damages	% of Total
Flood	$ 48,700	5%
Wave	$ 2,500	0%
Erosion	$ 894,100	88%
Armor Repair Cost	$ 65,700	6%
TOTAL	$ 1,010,900	100%

Table 5-2: Rincon FWOP Damages by Parameter

5.1.5 Rincon Temporal Distribution of Damages

FWOP damages occur early in the POA. The severity of erosion, which leads to condemnation, peaks in the years between 2037 and 2047. Once structures are condemned they are not subject to repetitive damages, which accounts for the lower risk of damages towards the end of the life-cycle.

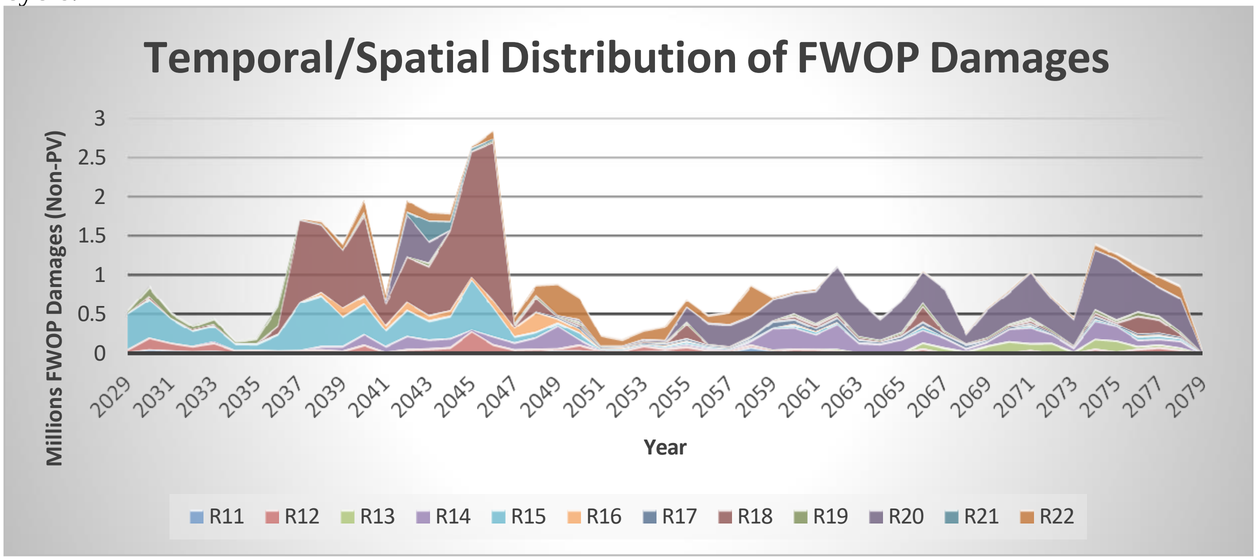


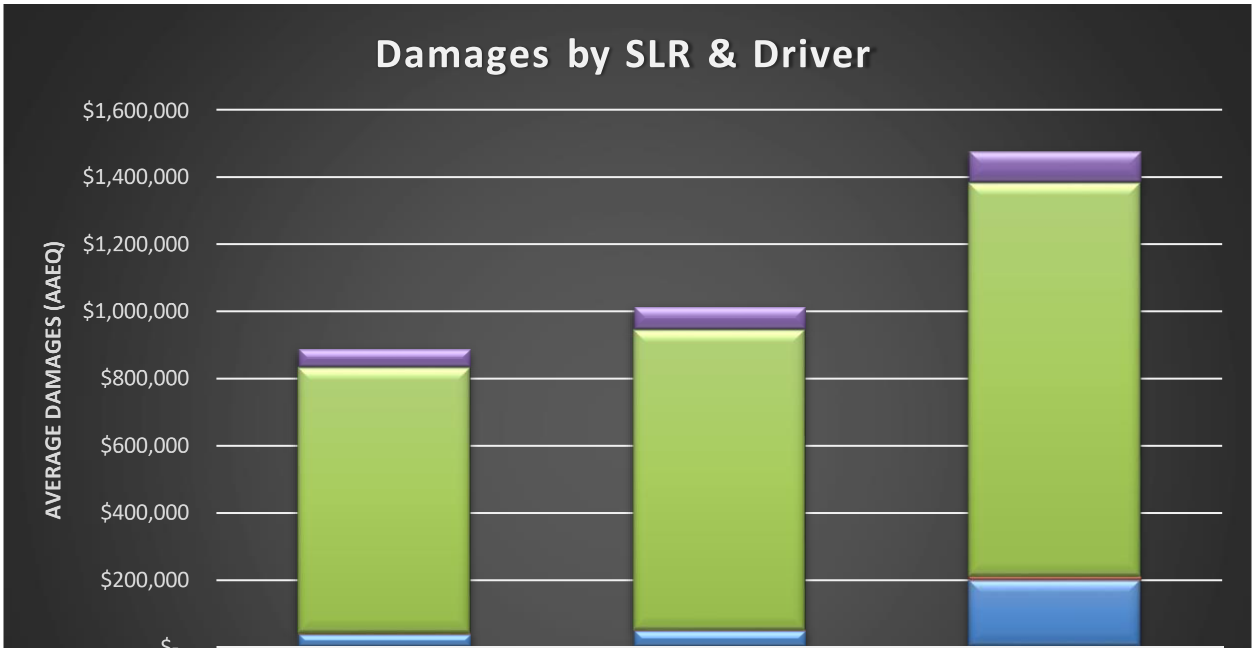
Figure 5-5: Rincon Damages over Time and Space ($ Non-PV)

5.1.6 Rincon Emergency Clean-up and Evacuation Costs

Emergency clean-up and evacuation (ERC&E) costs were not computed for Rincon since flood damages were almost non-existent. Erosion damages do cause debris that requires removal (and thus incurs a cost), however, the evidence in Rincon suggests that in the FWOP the municipality will not remove this debris. This is apparent based on condemned structure debris from Hurricane Maria still in place and is a large portion of the Other Social Effects (OSE) discussion found in Section 3.5.

5.1.7 Rincon FWOP Damages in Alternative Sea-Level-Rise Scenarios

Evaluating sea-level rise (SLR) is a vital component in the planning process to ensure alternatives are selected based on risk-informed analysis. To incorporate risk into the analysis the FWOP must be run assuming three distinct future rates of SLR. EC 1165-2-211 provides both a methodology and a procedure for determining a range of SLR estimates based on the local historic rate, the construction (base) year of the project, and the design life of the project. In Rincón the average baseline (SLR1), intermediate (SLR2) and high (SLR3) rates were found to be 0.0098 feet/yr, 0.0218 feet/yr, and 0.0596 feet/yr, respectively. The Beach-*fx* results that were presented above refer strictly to the intermediate scenario. The results comparing the SLR scenarios are presented here. Figure 5-6 provides an overall summary of damages in each SLR scenario.



	Base	Intermediate	High
Armor	$52,400	$65,700	$90,900
Erosion	$791,200	$894,100	$1,171,000
Wave	$1,800	$2,500	$10,500
Flood	$38,800	$48,700	$200,000

Figure 5-6: Rincon Total Damages by SLR Scenario

- Base – $884,200
- Intermediate - $1,010,900
- High - $1,472,400

The SLR results are intuitive in the sense that one would expect damages to be positively correlated with water levels (i.e. as water levels increase throughout the period of analysis so do damages). What is important to note, however, is the magnitude of the effect. From the low to intermediate scenario the difference was a mere 0.012 ft/yr in average SLR and resulted in an increase of roughly 14.0% in annual damages. From the intermediate to high scenario there was a 0.0378 ft/yr average rise difference with a corresponding increase of 46%, or roughly $462,000 in annual damage. From the low to high scenario damages increase by 67%. There is very little shift in what drives the damages from the low to the intermediate scenario. In the high sea level rise scenario flooding is more of a risk than in the intermediate since second row and beyond structures become inundated. However, erosion still represents 85% of FWOP damages.

5.1.8 Rincon FWOP Condition Conclusion

- Very low risk in the northern section of Rincon, reaches R01-R10, lead the PDT to screen this section out for alternative consideration.
- Damages are largely driven by erosion damage.
- The majority of the damage is structural in nature. Residential structures account for 64% of all damages with additional repair costs associated with residential armor.
- Damages in the FWOP increase significantly in the high sea level rise scenario.

5.2 Condado Future Without Project Condition

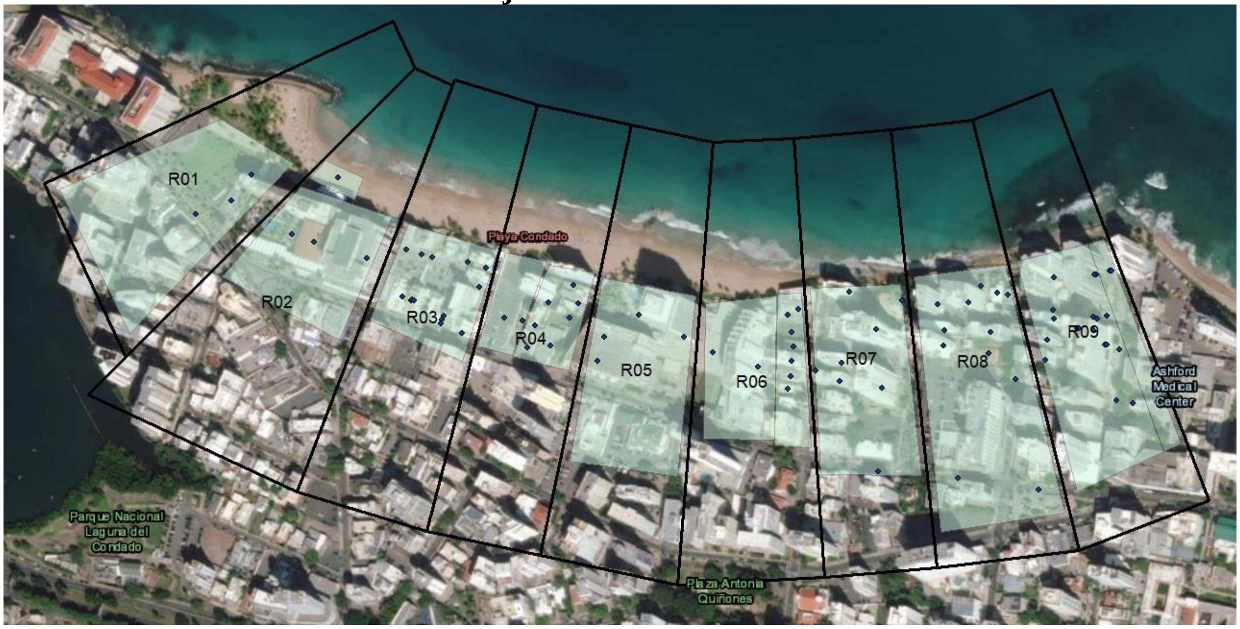


Figure 5-7: Condado Beach-Fx Model Domain

Initial modeling indicated Condado was at very low risk from CSRM damages. The PDT decided early on that, due to this low risk, no action was likely the best outcome and therefore the modeling detailed in this report will not be as detailed as other model segments. Damages per the Condado FWOP model results are as follows:

- Mean Structure, Content, Armor Damage: $89,000 (AAEQ)
- Damages:
  - Structure & Content Damage: Economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Structure and content damages account for 23%, or $20,000 AAEQ, of the damages for the FWOP. All structure and content damages are isolated to Reach R02 and primarily attributed to a single structure located on the berm at a very low elevation. The damages occur primarily from wave and inundation.
  - Armor Damage: Damage to existing armor and construction of new armor are responsible for 77%, or $68,000 AAEQ, of FWOP damages and occur in reaches R02 and R09.

5.2.1 Damages in Sea-Level-Rise Scenarios

The change in damages from the low curve to the intermediate curve has a relatively muted impact, with an estimated increase of only 14%, all of which comes from increases in armor costs. The similarity in structure and content damages results from the fact that a single structure drives the results and therefore damages are heavily reliant on the point in time when the single structure is condemned. Under the high scenario damages increase dramatically as the risk from coastal storms is finally transmitted into the upland and the impacts from erosion are more acute. FWOP damage goes from $89,000 in the intermediate scenario to $1,793,000 in the high scenario. In the high, 92% of damages are from structure and contents and 91% of those damages are attributable to a single high-value structure. The remaining 8% are for armor repair costs, of which 55% are attributable to the same single property. It is important to note that ER 1105-2-100, under the section header "Specific Policies", states that, "The Corps will not participate in structural flood damage reduction for a single private property."

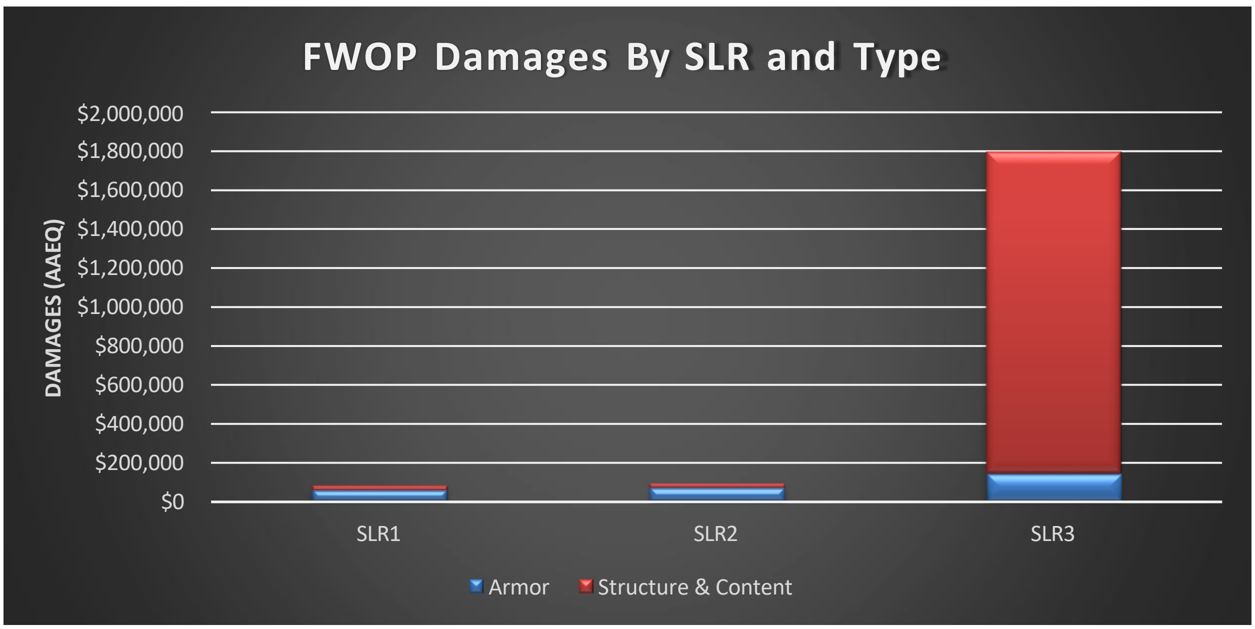


Figure 5-8: Condado FWOP Damages in Each Sea-Level Rise Scenario

5.2.2 Condado FWOP Conclusion

Total damages in the intermediate SLR FWOP condition are $89,000 AAEQ, representing a very low level of estimated risk to infrastructure. Most of the structure and content damages are attributed to a single private structure and the majority of overall damages come from coastal armor construction or repair to a limited spatial extent. Storm risks increase dramatically in the high sea level rise scenario as the impacts from erosion increase greatly. Over 90% of all damages in the high scenario accrue to a single private structure.

5.3 Ocean Park Future-Without Project Condition

Ocean Park is the only planning segment where both Beach-Fx and G2CRM were utilized for plan formulation decisions. This is due to the way in which flooding enters the upland through specific breach points at topographically low areas, Barbosa Park and what is referred to as the "Skate Park", which is an abandoned parcel of land that is currently utilized as a skateboarding park (see **Figure 5-9** for an upfront comprehensive look at the risk Ocean Park faces). The flooding experienced here makes G2CRM the superior model for comparing alternatives. Beach-Fx was utilized for the first-row of structures across the entire area as it is able to better gauge risk from erosion and wave attack and compare alternatives for addressing those specific risk factors. **Figure 5-10** and **Figure 5-11** represent the Beach-Fx and G2CRM modeling domain respectively.

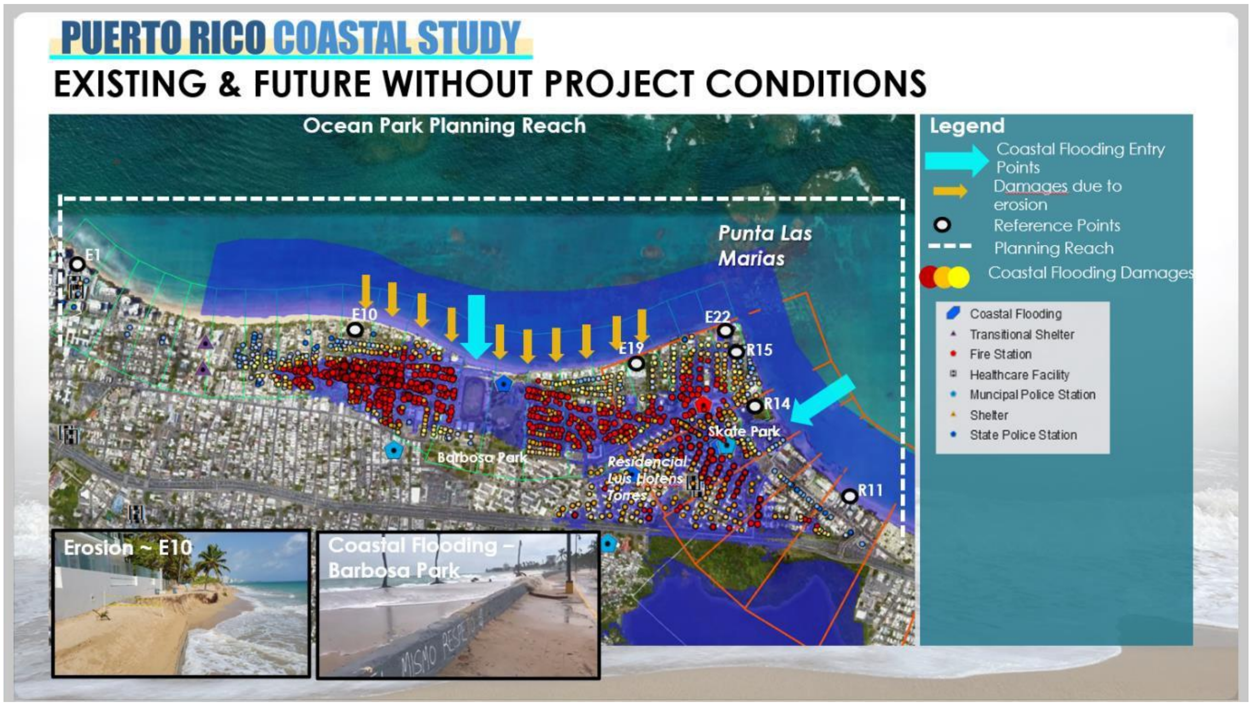


Figure 5-9: Ocean Park Comprehensive Risk Picture

Figure 5-10: Ocean Park Beach-Fx Model Domain with First-Row Assets

Figure 5-11: Ocean Park G2CRM Model Domain with Remaining Assets

Ocean Park has by far the largest amount of damages estimated in the FWOP condition. This is a large focus area and is densely populated with a contingent of single-family and multi-family homes. Many of the structures within Ocean Park have very low FFE's and make this focus area extremely vulnerable to inundation in the future if no action is taken. Many of these structures are not up to current code (i.e. they are non-conforming structures) due to their FFE positioned below base flood elevation (BFE) in this high-hazard zone.

- Mean First-Row Damages (Beach-Fx): $1,461,000 (AAEQ)
- Mean Upland Damages (G2CRM, includes ERCE): $2,960,000 (AAEQ)
- Total Average Damages: $4,421,000

The following sections of the report will be segmented based on model since each model was setup to address a specific component of the coastal storm risk this area faces.

5.3.1 First-Row FWOP Conditions (Beach-Fx)

The Beach-Fx model domain for Ocean Park was setup in a manner to handle the assets most at risk to erosion and wave attack. This also includes assets in lots which are armored or anticipated to be armored in the future and will, therefore, incur armor building or repair costs. Of the $1,461,000 AAEQ in FWOP damages, 90% of them are to structure and content and 10% are attributed to armor costs.

5.3.1.1 *Spatial Distribution of Damages*

As displayed above in Figure 5-10, the Beach-Fx domain is arranged with reach E01 in the west near Condado and spans east to reach E22 adjacent to Isla Verde. **Figure 5-12** below displays FWOP damages by model reach.

The large public space, Barbosa Park, is located in reaches E14 and E15. There is a medical complex, with hospitals and doctor's offices, in the west in reaches E01 to E02. However, damages are virtually non-existent in reaches E01-E06, accounting for only 2% of total damages. 96% of those damages arise from armor build or repair costs.

Moving towards the center of the model domain and just west of Barbosa Park are reaches E07 to E13. This group of reaches has around a third of total damages in the FWOP condition. These damages are primarily to structures and contents, accounting for around 86% in this group of reaches.

There are no first-row structures located in Barbosa Park so damages therein are zero. However, this area is a major point of recreational value which will be discussed more when the recreation analysis is finalized. To the east of Barbosa are reaches E16 to E22 where the remaining two-thirds of damages occur. As in the reaches just to the west of Barbosa, the damages here are primarily structure and content based, accounting for 91% of the damages. This area is heavily armored in the existing condition with robust Floodwalls so armor repair or new build costs only account for 9% of the damages.

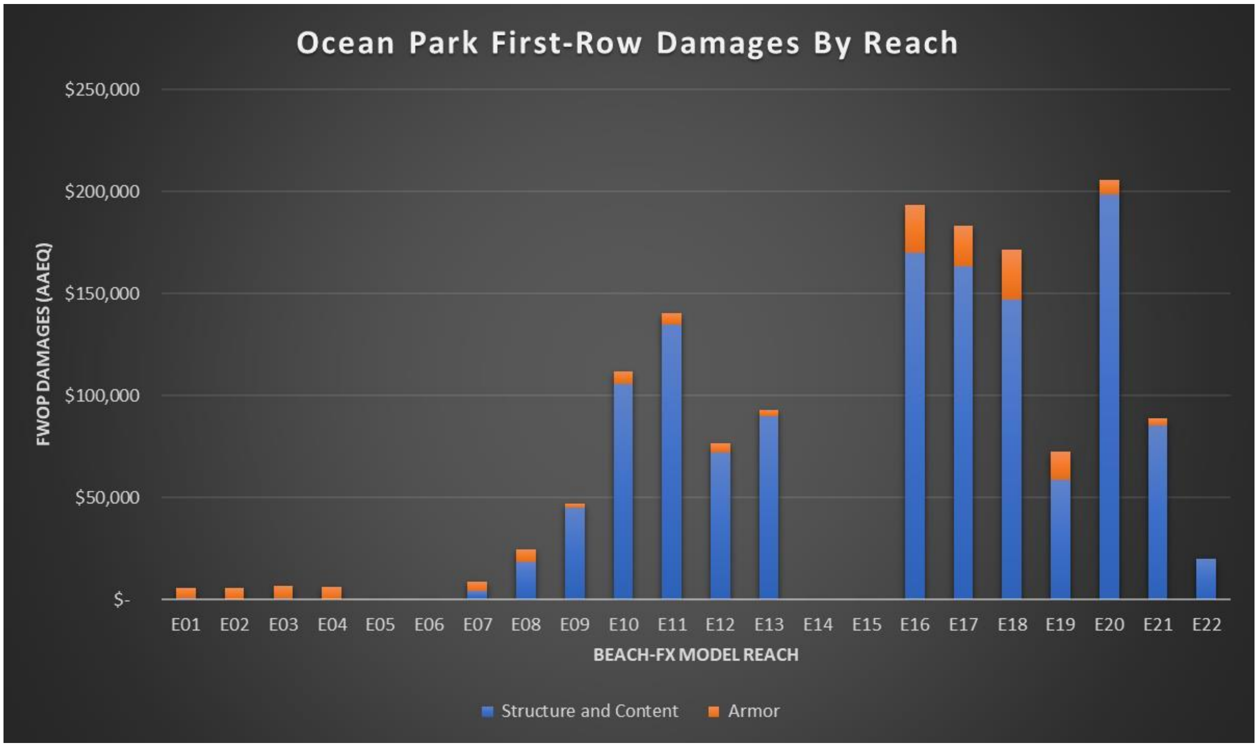


Figure 5-12: Ocean Park First-Row FWOP Damages By Reach

5.3.1.2 *Ocean Park First-Row Damages by Damage Driving Parameter*

Overall, FWOP damages in the first-row of Ocean Park are driven by a blend of the three damage driving parameters and to a lesser degree armor repair costs. Wave damage accounts for the largest share at 40% with erosion and flood very similar at 27% and 23% respectively. Armor repair costs account for 10% of overall damages.

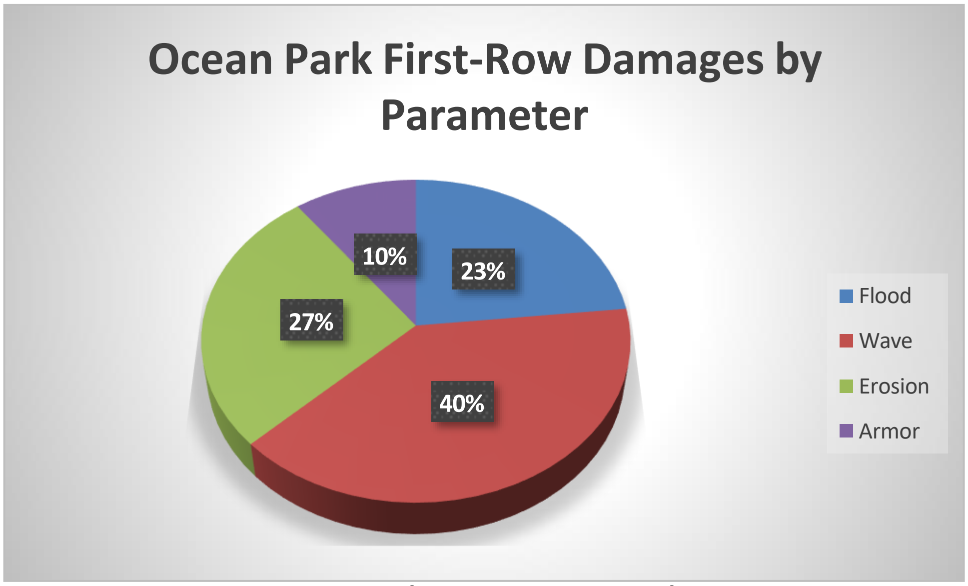


Figure 5-13: Ocean Park First-Row Damages by Parameter

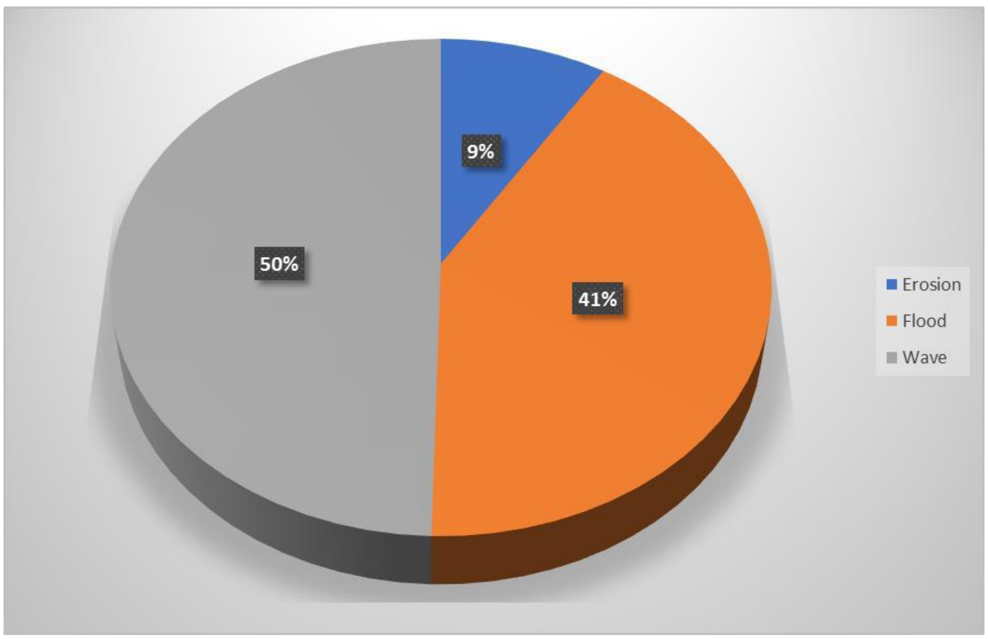


Figure 5-14: Ocean Park FWOP Armor Repair Triggers

5.3.1.3 *Ocean Park Temporal Distribution of First-Row Damages*

Damages are somewhat evenly distributed throughout the period of analysis. A perfectly equal distribution would see 2% of damages in every year, but the random nature of storm impacts is demonstrated by the small peaks and valleys throughout **Figure 5-15.** The damages are somewhat higher in the later years as inundation and wave levels increase and the impacts of cumulative erosion occurs. The drop off in damages near the very end of the POA represents the fact that many of the first-row structures are damaged beyond the 50% threshold and are removed from the inventory.

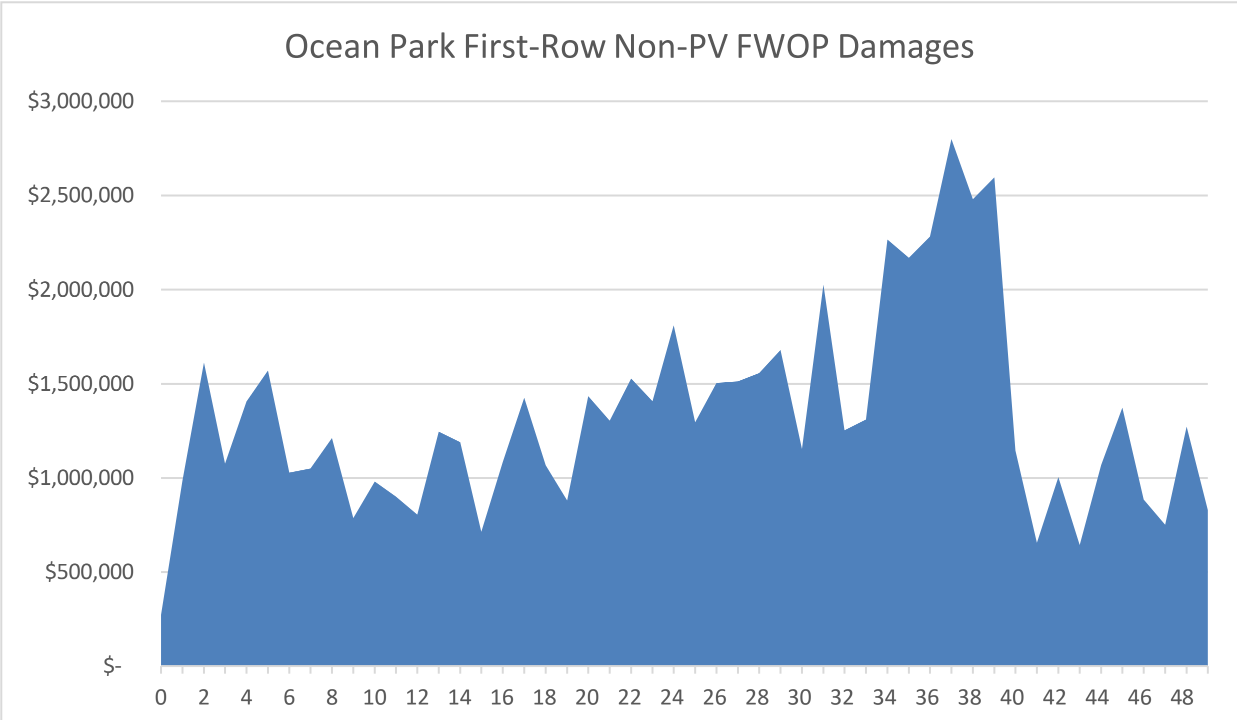


Figure 5-15: Ocean Park First-Row FWOP Damages by Time

5.3.1.4 *Ocean-Park First-Row Condemnations*

The first-row of structures are subject to total-loss condemnations throughout the period of analysis, similar to impacts identified in Rincon above. On average, 41 structures are condemned in the FWOP. The average year in which these structures are condemned is year 43, meaning the vast majority of these condemnations occur late in the period of analysis. Figure 5-16 displays the frequency of condemnations by plotting the year in which the condemnation of each asset[10] occurs in each iteration of the model run. What this plot shows is there are a relatively select few assets which are at risk of condemnation early in the POA (i.e. the light green plots occurring prior to year 15) but the condemnations cluster after year 35. In fact, 76% of condemnations occur after year 39.

[10] Only assets that were condemned on average (50 iterations or more) were included in the plot.

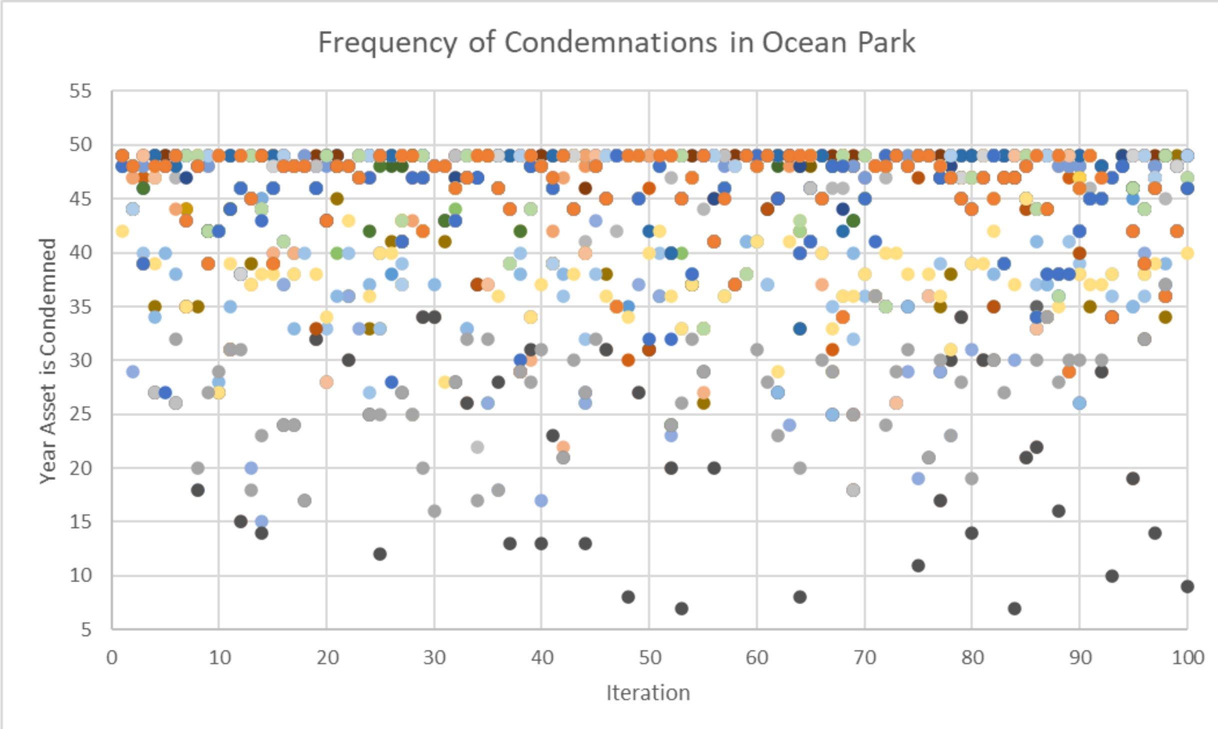


Figure 5-16: Frequency of Ocean Park First-Row Condemnations

5.3.1.5 *Ocean Park First-Row Damages in Alternative Sea-Level-Rise Scenarios*

Damages increase steadily in each scenario. From the low to intermediate there is around a 20% increase, going from $1,221,000 to $1,461,000, and again from the intermediate to the high another 20% to $1,767,000. The damage driving parameters remain somewhat consistent throughout the scenarios as well. One of the reasons for the lack of a severe increase in the scenarios is the fact that these first-row structures are at high risk from the baseline (low) scenario. Many of the structures are estimated to be condemned throughout the period of analysis and therefore damages reach a point of saturation regardless of how the sea levels rise.

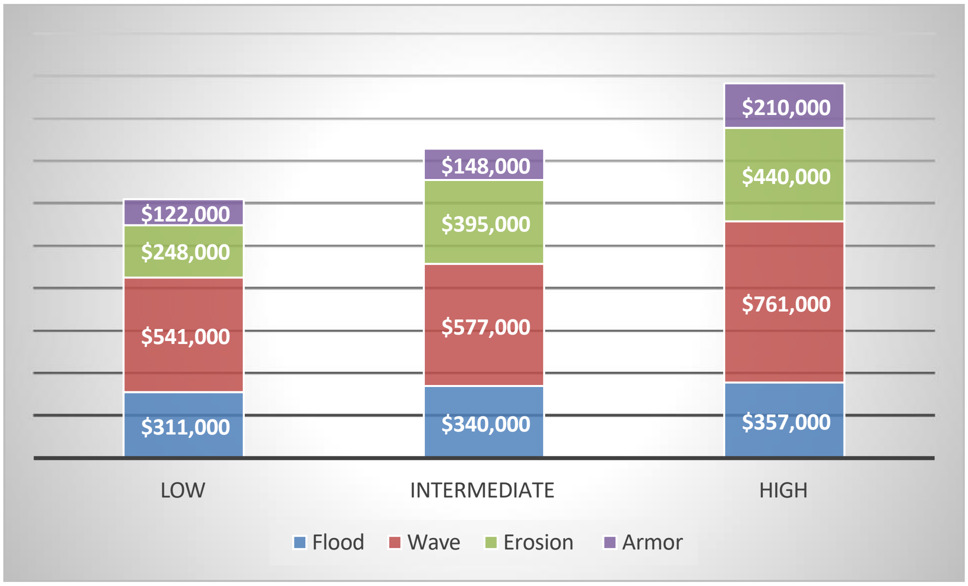


Figure 5-17: Ocean Park First-Row FWOP Damages in the Sea-Level Rise Scenarios

5.3.2 Upland Ocean Park FWOP Conditions (G2CRM)

As mentioned above the G2CRM model was used for plan formulation and risk identification based on knowledge of the inundation flow paths in this area. Beach-Fx has limitations for measuring flooding given it puts all assets on a single line within a profile and the ground-surface elevation of the upland is a single average height. Additionally, it assumes a uniform decay rate of inundation the further inland the water travels. Therefore Beach-fx is unable to measure spillover effects from inundation from one profile to the next (i.e. lateral flooding) nor is it able to identify specific breach points for inundation and the ponding of that water at specific low points through the modeled area. G2CRM can handle the lateral spread of coastal waters and can identify the specific breach points as well as the ponding that occurs when the upland has specific low points. Therefore, in a potential with-project condition it is far more adept at being able to handle specific measures which target these breach points. The following sections discuss the inundation risks to Ocean Park as measured by G2CRM.

5.3.2.1 *Summary of FWOP Risk in Ocean Park Upland (G2CRM)*

The moving average of upland damages in Ocean Park as modeled by G2CRM are $2,960,000 (AAEQ). **Table 5-3** presents the quartiles of risk and Figure 5-18 shows a histogram of the damages based on the 200 modeled iterations. These damages include ERC&E costs as described above in **Section 3.3**

Minimum Value	Lower Quartile	Median Value	Upper Quartile	Maximum Value
$ 242,000	$ 1,757,750	$ 2,829,000	$ 3,761,500	$ 9,290,000

Table 5-3: Ocean Park Upland FWOP Distribution of Damages

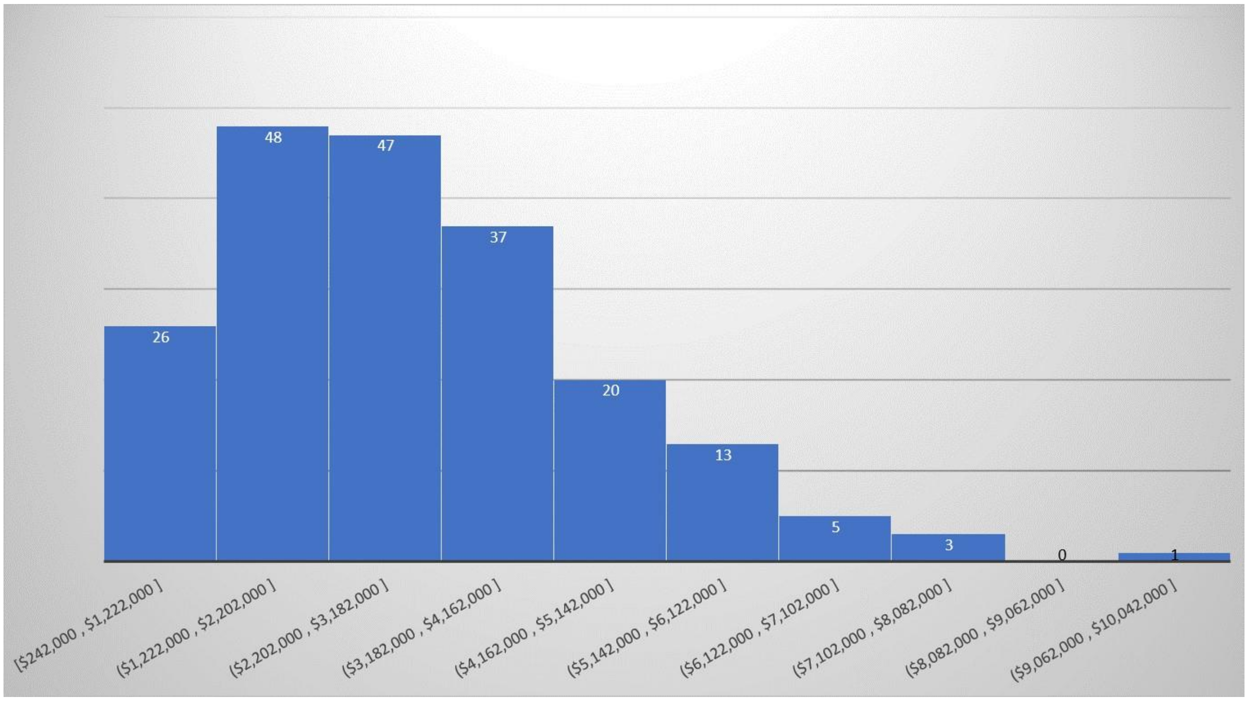


Figure 5-18: Histogram of Ocean Park Upland FWOP Damages Based on 200 Iterations

5.3.2.2 *Ocean Park FWOP Business Disruptions*

Using the G2CRM modeling outputs the PDT economists analyzed commercial assets in the structure inventory in order to measure the number of days in which these businesses will experience disruption due to coastal storm risk (inundation). The number of days that flood waters occupied a building were combined with the number of days, on average, a business would spend repairing/rebuilding (i.e. time to rebuild). It was assumed that business would not start again until all repairs were complete. On average, Ocean Park experiences 269 disruption days due to flood impacts and an additional 6,970 disruption days resulting from repair activities. This sort of economic impact arising from coastal risk is a regional economic impact and will therefore be considered in the RED account when comparing alternatives.

5.3.2.3 *Ocean Park FWOP Upland Damages in the Sea Level Rise Scenarios*

FWOP damages in the SLR scenarios increase exponentially from the base to the high. The base scenario estimates $764,000 (AAEQ) in damages with an increase of 287% to the intermediate scenario at $2,960,000. Even more extreme, FWOP damages increase 700% going from intermediate to high. The estimates in the sea-level rise scenarios highlight the extreme vulnerability of this area to inundation. Important to note about the high sea level rise scenario is the fact that the flow path changes dramatically as well. Flood waters are no longer contained to the two breach points described above. Overtopping begins to occur at various points along the coast as well as heavy influence from the San Jose Lagoon (i.e. back bay influences). The modeling conducted within this effort does not adequately capture the risk posed from the back bay and therefore any attempts to formulate alternatives to address the high SLR scenario would require a scope change in the study. In other words, the damages estimated in this effort in the high do not fully capture the risk and therefore residual risk from any alternative will not be able to be estimated. Additional risk metrics and their changes based on SLR scenario can be reviewed in **Table 5-4** below.

SLR Scenario	Average Damages (AAEQ)	Average # of Structures Removed	Average Life Loss
Base	$ 764,000	45	4
Intermediate	$ 2,960,000	174	8.1
High	$ 23,679,000	458	156

Table 5-4: Ocean Park Upland Summary Statistics in the Sea-Level Rise Scenarios

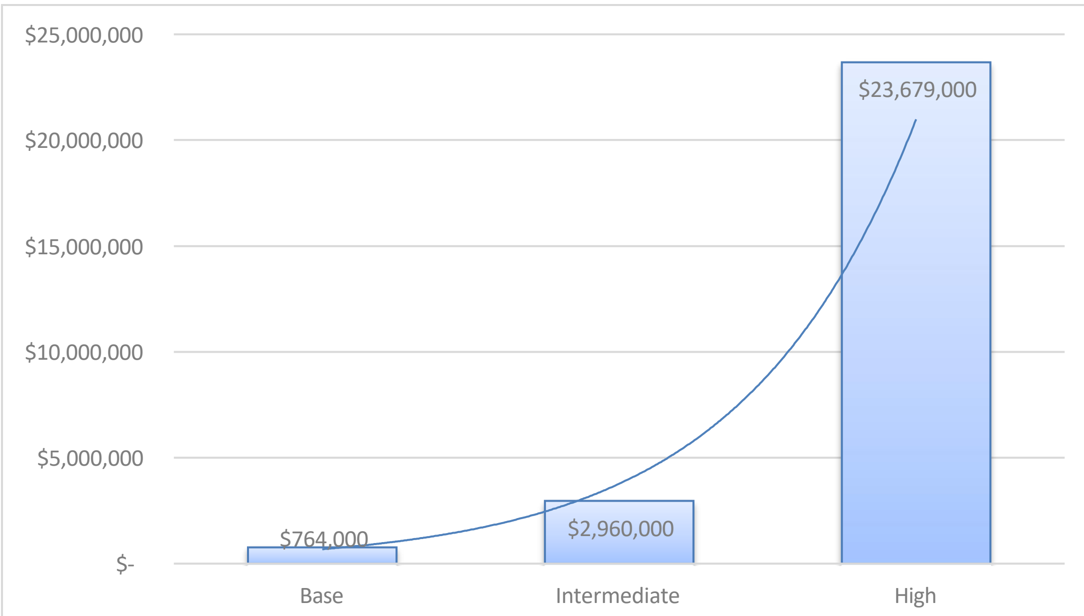


Figure 5-19: Ocean Park Upland FWOP Damages in the Sea-Level Rise Scenarios

5.3.3 Ocean Park Future-Without Project Conclusion

Total FWOP damages including first-row, upland, and ERC&E costs are estimated at $4,421,000 AAEQ. There are a total of 7,239 business disruption days.

- Ocean Park is relatively more vulnerable due to the many structures with low FFE's and a lower ground-surface elevation across the entire focus area.
- Damages are relatively evenly distributed throughout the period of analysis.
- Damages in the FWOP increase dramatically in the high SLR scenario but are also very high in the intermediate condition indicating a high level of vulnerability for Ocean Park.

5.4 Isla Verde Future-Without Project Condition

6.

Figure 5-20: Isla Verde Full Beach-Fx Modeling Domain

Figure 5-21: Isla Verde First-Row Beach-Fx Modeling Domain

Early modeling of Isla Verde indicated very low FWOP damages. As a result, the PDT concluded early on that no-action was the most likely outcome for dealing with the problems along the entire poc beach (as described in more detail in the Main Report). Moreover, some portion of the Isla Verde Beach-Fx model domain contains overlap with the Ocean Park G2CRM flood model as shown above in **Figure 5-11,** including the "Skate Park" (R14 in **Figure 5-21** above), which is one of the identified points of entry for inundation . Due to the nature of the flooding in this area the G2CRM model was the primary model for steering plan formulation.

Thus, this section on Isla Verde, with specific respect to the Beach-Fx modeling, will not have as detailed a description of damages as the previous modeled areas have. However, tables will be displayed so that readers and decision makers can review the low damages in this area and understand the PDT's decision to limit the modeling efforts in this focus area (i.e. no ERC&E modeling runs were performed). The Isla Verde segment was modeled in two different ways. The first way was to include the entire structure inventory in the Beach-Fx model in order to gauge the risk directly related to coastal storm risk from all parameters (i.e. flood, wave, erosion). Separately, the assets that overlapped with the G2CRM Ocean Park inventory were removed and then only the first-row structures were analyzed in order to gauge risk in the same manner as the Ocean Park planning reach. Average FWOP damages for the entire Isla Verde segment in the intermediate are $318,000 (AAEQ).

Isla Verde Full FWOP Damages (AAEQ)	
Low SLR	$ 133,000
Intermediate SLR	$ 318,000
High SLR	$ 2,544,000

Table 5-5: Isla Verde Full Structure Inventory FWOP Damages

It is important to note that 60% of all damages in the high sea level rise scenario come from a single reach (R08). 17% of the damages come from flooding in reaches R11-R15 which overlap with the Ocean Park G2CRM modeling domain and were handled there for plan formulation purposes. Due to the low risk from coastal storms this reach was screened from alternative formulation. See **Table 5-6** for a summary of first-row damages within the Beach-Fx model domain that were used as part of the benefit base in the Ocean Park upland plan formulation analysis.

Isla Verde First-Row R11-R15 FWOP Damages (AAEQ)	
Base SLR	$24,000
Intermediate SLR	$32,000
High SLR	$118,000

Table 5-6: Isla Verde First-Row Only FWOP Damages

5.5 Land Loss Damages in the Future-Without Project by Planning Reach

Section 3.4 describes the methodology used for estimating land loss. In this section the FWOP land loss will be estimated for each applicable pocket beach since these are the only areas not currently armored or armored in the future subject to land loss. For PRCS, the only reach where land loss is a significant factor across the period of analysis is the Ocean Park Pocket Beach since Condado, Rincon, and Isla Verde are either already armored or have armor triggered prior to any upland losses. Over the 50-years approximately 250,000 square feet of land is estimated to be lost in Ocean Park which, in FY22 present-value dollars is approximately $17M. The average annual equivalent losses are approximately $561,000 (FY22 discount rate).

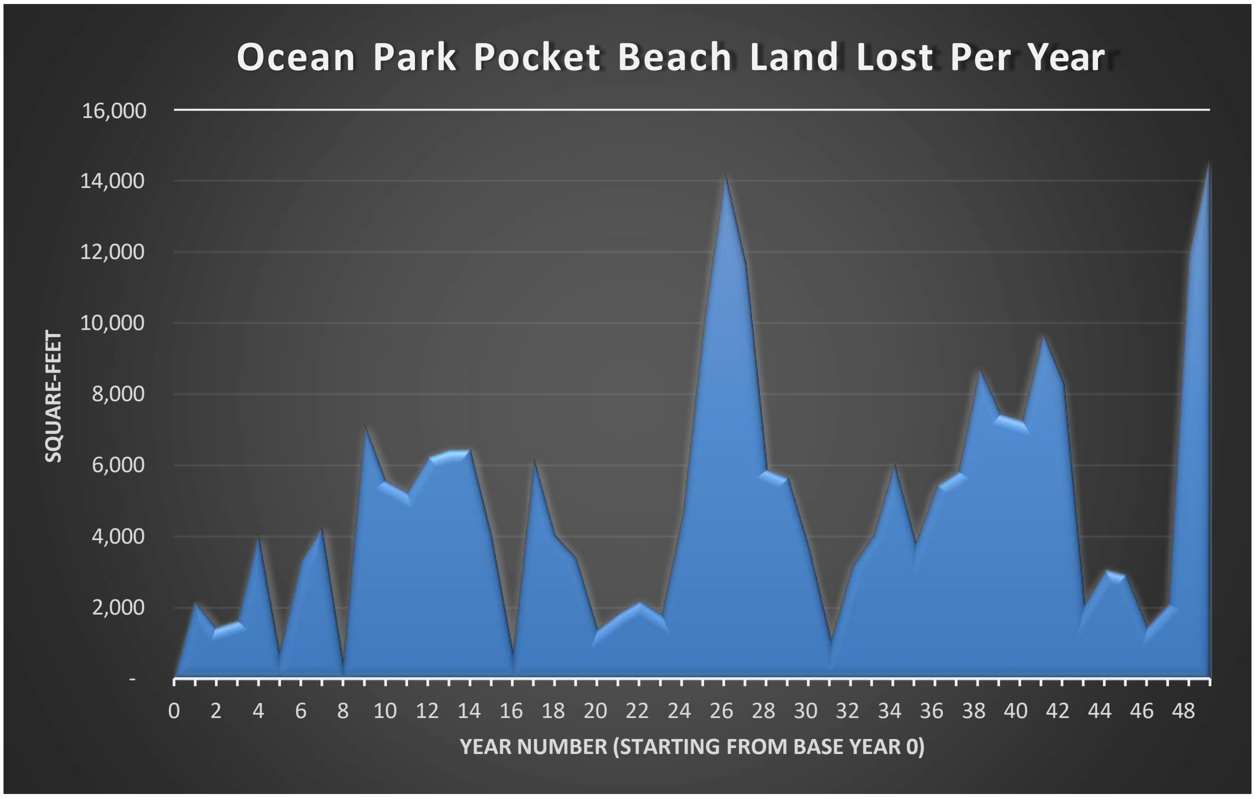


Figure 5-22: Ocean Park Pocket Beach Land Loss by Year

7. MEASURE SCREENING AND ALTERNATIVE DEVELOPMENT

This section of the appendix tells the story behind the evaluation and comparison of the PRCS CSRM study alternatives. A description of the alternatives, their performance in terms of benefits and costs, and the methods used for screening are provided in the subsequent sections.

7.1 Measures Considered

Below is a list of measures considered during the study. Please see Appendix F: Plan Formulation for a more detailed explanation of the measure and the consideration of these measures in the planning process.

7.1.1 Structural Measures Considered

S-1: Floodwall/Floodwall with toe protection (CF, WA, E)): Floodwalls with toe protection and floodwalls are interchangeable at this phase of the study in terms of the function they provide. Floodwalls and floodwalls with toe protection are delineated further in this report in terms of design footprint (i.e.: Floodwalls with toe protection use a slightly wider footprint than floodwalls when backfill and/or toe protection is included).

Floodwall structures in the study area could be constructed either seaward of existing floodwalls, to protect historic value as well as to avoid disruption of engineering structural integrity of the existing floodwall function, or landward, to provide access to existing waterfront features.

COMBINABILITY: This measure is dependent on the incorporation of S-6 and could be combined with other measures. This is mutually exclusive of S-2, but could be adjacent to S- 2.

S-2: Revetment (E/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. 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. COMBINABILITY: This could be a stand-alone alternative, or combined with S-1 but it is mutually exclusive of NNBF-1 (WA) and NNBF-2 (WA).

S-3: Groins/T-Head Groins (E/WA). A series of groins in the problem area would help hold a beach in front of existing development and prevent further losses of land. The construction of groins would have to be supplemented with nourishment so that adjacent beaches would not be starved of sand. For this reason, groins are considered a method to help hold the fill in place and to reduce periodic nourishment requirements. The groins would be constructed of large size rock, designed to interlock together and with a foundation such to avoid subsidence. The groins would be placed perpendicular to the shoreline and would extend from above the mean high-water line out into shallow water. The length, orientation, and head of the structure (T-head or not) would be designed based on wave conditions, storms and sediment transport. The beach fill material would come from offshore and/or upland borrow areas. Combinability: This measure would need to be combined with beach nourishment or dunes only.

S-4: Breakwaters (E/WA). The construction of breakwaters offshore along the study focus areas is considered as a management measure to stabilize the existing beach and reduce damages to shorefront properties. Such structures reduce the amount of wave energy reaching the shoreline behind them. As a result, the rate of annual erosion could decrease. The breakwaters would be constructed of large size 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 breakwaters would be constructed in segments separated from each other to prevent infilling between the existing beach and the breakwaters. The elevation and length of each breakwater segment and the distance between segments would be designed using the wave and sediment transport characteristics of the reach. 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. Combinability: This could be a stand- alone alternative, but better storm damage reduction is achieved when combined with beach nourishment or dunes only.

7.1.2 NATURAL AND NATURE-BASED FEATURES

NNBF-1: Beach nourishment with vegetated dune (E/WA). This management measure includes initial construction of a beach fill, as well as a smaller vegetated dune, and future nourishments at regular intervals. Dune interactions are widely known to be essential to beach functions in terms of adding valuable storm protection and are proposed together for this feature. Nourishment of the beach would be undertaken periodically to maintain the erosion control features within design dimensions.

Dimensions of the beach fill would be based on economic optimization of benefits provided with consideration to cost, as well as the potential environmental impacts. Combinability: This could be a stand- alone alternative or combined with Floodwalls, revetments, breakwaters and groins.

NNBF-2: Vegetated Dune (E/WA). The presence of dunes is essential if a beach is to remain stable and able to accommodate the stress from unpredictable storms and extreme conditions of wind, wave, and elevated sea surfaces. Dunes maintain a sand repository that, during storms, provide sacrificial sand before structures would be damaged. The dune system provides a measure of public safety and property protection. Proper vegetation on dunes increases sand erosion resistance by binding the sand together via extensive root masses penetrating deep into the sand. Further, such vegetation promotes dune growth through its sand trapping action when significant wind action transports substantial quantities of sand. This measure would include placement of beach compatible material, from either upland or offshore sources, in a dune feature where a berm is not feasible. If in the existing conditions there is a dune, the top elevation of the constructed dune would tie into the existing dune. The front slope of the dune would be a function of the material grain size and construction equipment. Vegetation would be planted after placement of the dune material. Combinability: This could be a stand- alone alternative, but better storm damage reduction is achieved when combined with groins and breakwaters.

NNBF-3 (WA): Artificial Reef: 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. COMBINABILITY: This measure would need to be combined with other coastal flooding reduction measures to fulfill both the coastal flooding, erosion, and wave attack reduction objectives.

7.1.3 NON-STRUCTURAL Measures

NS-1: Relocation of Critical Infrastructure (CF/E/WA): 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 would be identified, and where feasible, such structures would be moved further landward on their parcels to escape the vulnerable area. COMBINABILITY: This measure would need to be combined with other structural or NNBF measures that would reduce coastal flooding.

NS-2: Floodproofing (Wet) (CF): 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. COMBINABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-3: Elevate structures (CF): This measure, in combination with other measures, could reduce damages to structures by re-building them to higher elevations. COMBINABILITY: This measure could be a stand-alone alternative or could be combined with other measures.

NS-4: Acquisition of land and structures (CF/E/WA): 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. COMBINABILITY: In some planning reaches 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 planning reaches where coastal flooding is a major component of risk).

NS-5: Coastal Regulatory Program: A coastal regulatory program could be established, similar to the state of Florida's Coastal Construction Control Line (CCCL). It does not prohibit construction, but does provide stringent structural restrictions and provides for improving building regulations that could be implemented by the Commonwealth of Puerto Rico. The island-wide implementation of this measure would allow increasing the setback for future construction or increasing the standards for future construction to reduce the risk of storm damages. The erosion of the shoreline would continue at the present rate, unabated by this measure. Although, this kind of regulation could not be implemented by the USACE, this measure could be enforced by the Commonwealth or local governments. Combinability: This measure would need to be combined with other measures to achieve project purposes.

NS-6: Re-Zoning: Re-zoning could apply to phasing out development in low lying areas over time. This would be a measure implemented by the non-federal sponsor. COMBINABILITY: This measure would need to be combined with other structural or NNBF measures that would reduce coastal flooding.

NS-7 (SS): Improved public outreach: Measures to convey wave action 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. COMBINABILITY: This measure would need to be combined with other structural or NNBF measures that would reduce coastal flooding.

NS-8 (SS): Improved evacuation plan and notification systems: 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. COMBINABILITY: 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.

As a note, 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 which is designated for both planning reaches, and therefore was not eligible for the initial measures list.

These measures were scored and alternatives were formulated based on the scoring. This appendix will focus on the discussion of the final array of alternatives but a detailed evaluation of the intermediate screening can be found in Appendix A: Plan Formulation.

7.2 Final Array of Alternatives

Each of the alternatives listed below is described further in the subsequent text. Rationale for how each alternative is conceptually considered and how it was further refined for the final array is presented.

Ocean Park Planning Reach	
Alternative 1	**No Action**
Alternative 2	**Floodwall with toe protection (E13 to E15, R14)**
Alternative 3	**Floodwall with toe protection (E13 to E15, R14) + beach nourishment with vegetated dunes (E10-E19)**
Alternative 4	**Floodwall (up to E10-E19) + R14**
Alternative 5	**Floodwall with toe protection (E13 to E15, R14) + Acquisition of structures and property**
Rincón Planning Reach	
Alternative 1	**No Action**
Alternative 2	**Revetment (Rock) R11 to R22**
Alternative 3	**Beach Nourishment with vegetated dunes (R11 to R22) plus groins**
Alternative 4	**Acquisition of structures and property (R11 to R22)**

Table 6-1: Final Array of Alternatives

7.2.1 Ocean Park Final Array

Alternative 1 – No Action: In absence of an actionable plan, coastal flooding will continue to occur routinely during minor and major storm events. Life safety from coastal flooding will continue to be at risk, road access to critical infrastructure will be limited or non-accessible, and homes, business buildings and other structures and property will be damaged.

Alternative 2 –Floodwall with toe protection (E13 to E15, R14): This alternative would reduce the risk of coastal flooding at the most critical areas, Barbosa Park and the skate park. The Floodwall would be set back from the shoreline along the existing small Floodwall/bench or could be placed further inland in place of the existing road. It would have small backfill behind it. This option would preserve the beach in front of the Floodwall, and also allow public access over it to maintain existing accessibility to the beach park. It would also be set back from the shoreline in the skate park area to allow for ease of construction (R14 into smaller portion of R15 and R13). Portions of the Floodwall which are not set back on dry land would require some small sand fill to be feasible for construction due to limited existing land in those areas, and would include toe protection which would likely be rock armoring.

Alternative 3 - Floodwall with toe protection (E13 to E15, R14) + beach nourishment with vegetated dunes (E10-E19): See the Floodwall description from Alt 2. In addition to reducing the risk of coastal flooding, this alternative also would include a berm and vegetated dune with a periodic nourishment over a 50-year period of analysis to reduce the risk of erosion and wave attack for the adjacent coastal fronting structures along the areas which were shown in modeling results to receive the most erosion related damages, along E10 to E19. The width and height of the dune would be refined prior to the final array of alternatives and is discussed further prior to the final array of alternatives.

Alternative 4 – Floodwall (up to E10-E19) + R14: See the Floodwall description from Alt 2. In additional to reduction in the risk of coastal flooding, this alternative would extend the Floodwall west and east to reduce the risk of not only coastal flooding but also erosion in the adjacent

coastal fronting structures along E10 to E19. The extended Floodwalls would require some small sand fill to be feasible for construction due to limited existing land in those areas, and would include toe protection which would likely be rock revetment.
Alternative 5 – Floodwall (up to E10-E19) + R14 + Acquisition: Alternative 5 is the same as Alternative 2, but also introduces a non-structural measure and nature-based feature which is acquisition of structures to the west of Barbosa Park and restoration of those parcels to a natural beach.

7.2.2 Rincon Final Array of Alternatives

Alternative 1 – No Action: In the absence of an actionable plan, individual property owners along the shoreline will attempt to reduce risk locally with low-cost, ad-hoc solutions such as rock, gabions (metal meshes containing rocks), or floodwalls, incurring repeated expense and probable failure and condemnation. Approximately 57 structures are projected to structurally fail and become condemned. Condemned structures are likely to become derelict and unlikely to be removed, further exacerbating erosion on surrounding shorelines. Residents will be forced to move, likely out of the area and potentially out of Puerto Rico, reducing not only the strength of the cultural identity of the community but also reducing the tax base and impairing the economy.

Alternative 2 - Revetment (Rock) R11 to R22: This alternative would propose rock revetment, along the coastal fronting areas from R11 to R22 to reduce the risk of erosion and wave attack and protect structures and property from existing damages or damages in the future. In areas already set back from the ocean with existing sandy beach, the revetment would be seaward of the rock revetment, thus holding the existing sand in place. In areas already critically eroded, the rock revetment would be close to the shoreline and could be directly in front of existing structures.

Alternative 3: Beach nourishment with vegetated dunes (R11 to R22) plus groins: This alternative would include a beach and vegetated dune to reduce the risk of erosion and wave attack. It would require rock groins perpendicular to the shoreline to effectively hold the sand until the next renourishment. The width and height of the beach and dune, as well as the number of groins estimated to be most effective, would be refined prior to the final array of alternatives and is discussed further in Section 6: Measure Screening and alternative development

Alternative 4: Acquisition of structures and property (R11 to R22): This alternative would estimate a footprint for acquiring property Structures within that footprint would be acquired, demolished and removed. This would be recommended to be paired with a coastal construction control line (CCCL) to be established and enforced by the local sponsor/municipality. This alternative would reset the shoreline and an appropriate distance behind it to natural beach to reduce the risk of erosion and wave attack to structures behind the established line.

8. FUTURE WITH PROJECT MODELING AND ALTERNATIVE COMPARISON

This section of the report will detail the alternative modeling and screening of alternatives which gave rise to the final array. As mentioned above, Condado and Isla Verde were screened for FWP modeling due to the low risk from coastal storms. There were several measures and alternatives that were screened prior to modeling and more information on that process can be found in Appendix F: Plan Formulation.

8.1 Rincon Future-With Project Preliminary Modeling

8.1.1 Rincon Beach Nourishment

Costs were estimated using an offshore borrow source and were refined several times throughout the modeling process. The PDT used best professional judgment based on the type of risk faced by Rincon (i.e. primarily erosion instead of flooding or wave) quantity availability, erosion rates, and planform rates to determine templates for modeling. It was apparent very early in the modeling that any nourishment interval beyond 10 years was insufficient to provide any type of real risk reduction. Many of the ten-year intervals showed to have poor damage reduction. For example, a 20-foot berm extension nourished every 10 years was shown to only reduce damages by 23% (see **Table 7-1).** Below is a table of all the preliminary[11] nourishment modeling that took place. The naming convention for the alternative is as follows: BermWidth_DuneHeightDuneWidth_NourishmentInterval. For example B10_H12W10_10YR is a 10' berm extension with a dune 12' high and 10' wide (PRVD02) nourished every 10 years. If an alternative is listed as "Dex" it means it maintains the existing condition dune. Due to the very high cost of nourishment and relatively low damage value in Rincon the net-benefits were negative across the board and to a high degree. The best NED performing nourishment was a 20' berm with the existing dune nourished every 10 years and had net-benefits of -$163,265,000 present-value or -$5,472,000 AAEQ. The worst NED performing alternative was a 20' berm with a 12' high, 10' wide, dune nourished every 5 years. This had net-benefits of -$313,425,000 present-value, or -$10,506,000 AAEQ. The PDT used these results to determine that a groin field should likely be modeled to see if there could be any cost saving or more effective damage reduction to improve nourishment effectiveness. Based on these preliminary modeling results, a nourishment without a groin was not carried forward to the final array of alternatives.

Alt Name	FWOP Damage	FWP Damage	Damage Reduction	Benefits	Total Cost	Net Benefits	BCR
No Action	$ 27,288	$ 27,288	0	0	0	0	N/A
B20_Dex_10YR	$ 27,288	$ 21,146	23%	$ 6,142	$ 169,407	$ (163,265)	0.04
B20_Dex_5YR	$ 27,288	$ 4,711	83%	$ 22,577	$ 193,944	$ (171,367)	0.12
B30_Dex_10YR	$ 27,288	$ 21,703	20%	$ 5,585	$ 216,576	$ (210,991)	0.03
B10_H12W10-10YR	$ 27,288	$ 3,210	88%	$ 24,078	$ 223,553	$ (199,475)	0.11
B30_Dex_5YR	$ 27,288	$ 4,512	83%	$ 22,776	$ 250,850	$ (228,074)	0.09
B20_H12W10-10YR	$ 27,288	$ 3,277	88%	$ 24,011	$ 268,247	$ (244,236)	0.09

[11] This modeling was conducted prior to cost refinements and some modeling refinements that changed the FWOP totals to a minor degree. All information gathered during this modeling phase was still valid despite further refinements.

B10_H12W10-5YR	$ 27,288	$ 1,577	94%	$ 25,711	$ 292,074	$ (266,363)	0.09
B20_H12W10-5YR	$ 27,288	$ 1,701	94%	$ 25,587	$ 339,012	$ (313,425)	0.08

*All dollar values are in $1,000's Present-Value

Table 7-1: Preliminary Rincon Nourishment Modeling

8.1.2 Revetment

Revetment was shown to be extremely effective in stopping the coastal storm risks in Rincon since the threat is primarily due to erosion. Revetment was assumed to be placed across the entirety of the planning reach, from modeling reach R11 to R22 and would be built and maintained to a standard where erosion damages would not cause failure. Preliminary modeling showed that revetment reduced 94% of all damages with net-benefits of -$34,112,000 or -$1,143,000. Based on preliminary modeling revetment was carried forward to the final array of alternatives for comparison. Costs were further refined once an alternative was carried to the final array.

Alt Name	FWOP Damage	FWP Damage	Damage Reduction	Benefits	Total Cost	Net Benefits	BCR
No Action	$ 27,288	$ 27,288	0	0	0	0	N/A
Revetment	$ 27,288	$ 1,654	94%	$ 25,634	$ 59,746	$ (34,112)	0.43

All dollar values in $1,000's Present-Value

Table 7-2: Revetment Modeling Results

8.1.3 Beach Nourishment with Groin

Beach-fx is not capable of modeling direct impacts from groin fields and therefore the team needed to estimate the effects on erosion exogenously. The PDT engineers estimated that a field of approximately 12 groins would be necessary and this field of groins would reduce planform rates by 50% (See Engineering Appendix for more details). Introducing groins made the nourishment alternative more effective by allowing a smaller berm template to provide a much higher level of damage reduction. However, the additional cost of the groin field still meant the overall NED impacts were largely net negative. The best performing alternative, a 10' berm with the existing dune, had net-benefits of -$132,102,000 present-value or -$4,428,000 AAEQ. Despite the net-negative benefits, nourishment with groins was carried forward due to NFS desire. The three nourishment and groin combinations with the highest net-benefits were carried forward to the final array of modeling and are highlighted in **Table 7-3**.

Alt Name	FWOP Damage	FWP Damage	Damage Reduction	Benefits	Total Cost	Net Benefits	BCR
G50_B10_Dex_10YR	$ 27,288	$ 8,766	68%	$ 18,522	$ 150,624	$ (132,102)	0.12
G50_B10_Dex_5YR	$ 27,288	$ 4,992	82%	$ 22,296	$ 162,690	$ (140,395)	0.14
G50_B20_Dex_10YR	$ 27,288	$ 9,808	64%	$ 17,480	$ 180,384	$ (162,904)	0.10
G50_B20_Dex_5YR	$ 27,288	$ 4,642	83%	$ 22,646	$ 200,663	$ (178,017)	0.11

G50_B30_Dex_10YR	$ 27,288	$ 10,559	61%	$ 16,729	$ 211,250	$ (194,521)	0.08
G50_B30_Dex_5YR	$ 27,288	$ 4,537	83%	$ 22,751	$ 240,123	$ (217,372)	0.09
G50_B10H12W10_10YR	$ 27,288	$ 1,511	94%	$ 25,777	$ 255,028	$ (229,251)	0.10
G50_B20H12W10_10YR	$ 27,288	$ 1,644	94%	$ 25,644	$ 284,738	$ (259,094)	0.09
G50_B30H12W10_10YR	$ 27,288	$ 1,495	95%	$ 25,793	$ 312,887	$ (287,094)	0.08
G50_B10H12W10_5YR	$ 27,288	$ 427	98%	$ 26,861	$ 317,156	$ (290,295)	0.08
G50_B30H12W10_5YR	$ 27,288	$ 133	100%	$ 27,155	$ 371,320	$ (344,165)	0.07

All Dollar Values in $1,000's

Table 7-3: Preliminary Beach Nourishment with Groins

8.1.4 Acquisition and Relocation

Acquisition was proposed in Rincon in order to remove assets most at-risk from coastal storms and relocate the residents. Preliminary modeling of acquisition was not conducted as costs were not yet refined. However, due to the positive estimated impacts on RED, OSE, and EQ, acquisition and relocation were carried forward. The below section on the final array of alternatives and comparisons has the model results for Acquisition. **Figure 7-1** highlights the preliminary parcels that are targeted for acquisition. See the main report for the strategy on how acquisitions were selected.

Figure 7-1: Rincon Preliminary Acquisition Footprint

8.2 Rincon Final Array and Alternative Comparison

The final array of alternatives to be compared were No Action, Groins with Beach Nourishment, and Acquisition. Three different combinations of beach nourishment were modeled as these were determined to be the most cost effective. Comparisons utilizing the four P&G accounts were utilized and will be discussed separately in each section.

7.2.1 Rincon Final Array NED Comparison

The NED plan in Rincon was identified as the No Action plan as this was the alternative which maximized net-NED benefits at $0. Recreation benefits were calculated based on Unit Day Values (UDV) and the methodology is discussed more fully in **Section 8.1.1**. The next best policy-compliant[12] NED alternative was Revetment with primary net-NEDbenefits of -
$2,714,000 (AAEQ). The next highest NED alternative if incidental recreation benefits are included is the Acquisition plan with -$2,620,000. All the nourishment alternatives are large net-negative plans resulting from the high cost. See

Alt	Alternative	Total Cost	Primary CSRM Benefits	Damage Reducti on	Recreation Benefits	Total NED (Including Incidental Rec)	Primary NED Net-Benefits (No Rec)	Primary BCR	Total N Net-Benefit s	ED
1	No Action	$ -	$ -	N/A	$ -	$ -	$ -	N/A	$	-
2	Revetment	$ 3,717	$ 1,003	92%	$ -	$ 1,003	$(2,714)	0.27	$ (2, 7	14)
4	Acquisition	$ 3,715	$ 599	55%	$ 496	$ 1,095	$(3,116)	0.16	$ (2, 6	20)
3A	20' Berm w Groin Field 5-Year Cycle	$ 6,512	$ 873	63%	$ 275	$ 1,149	$(5,638)	0.13	$ (5, 3	63)
3C	10' Berm w/ Groin Field 10-Year Cycle	$ 6,339	$ 685	80%	$ 64	$ 749	$(5,654)	0.11	$ (5, 5	90)
3B	10' Berm w/ Groin Field 5-Year Cycle	$ 7,249	$ 860	79%	$ 128	$ 987	$(6,390)	0.12	$ (6, 2	62)

*All Dollar Values in $1,000's

AAEQ

Table 7-4 for a summary of Rincon's NED alternatives comparison.

[12] USACE policy dictates that recreation benefits are incidental and are not considered if an alternative does not achieve at least 50% of costs in benefits (i.e. the alternative must have primary BCR of .50 or more).

Alt	Alternative	Total Cost	Primary CSRM Benefits	Damage Reduction	Recreation Benefits	Total NED (Including Incidental Rec)	Primary NED Net-Benefits (No Rec)	Primary BCR	Total NED Net-Benefits	Total BCR (Including Rec)
1	No Action	$ -	$ -	N/A	$ -	$ -	$ -	N/A	$ -	N/A
2	Revetment	$ 3,717	$ 1,003	92%	$ -	$ 1,003	$(2,714)	0.27	$ (2,714)	0.27
4	Acquisition	$ 3,715	$ 599	55%	$ 496	$ 1,095	$(3,116)	0.16	$ (2,620)	0.29
3A	20' Berm w Groin Field 5-Year Cycle	$ 6,512	$ 873	63%	$ 275	$ 1,149	$(5,638)	0.13	$ (5,363)	0.18
3C	10' Berm w/ Groin Field 10-Year Cycle	$ 6,339	$ 685	80%	$ 64	$ 749	$(5,654)	0.11	$ (5,590)	0.12
3B	10' Berm w/ Groin Field 5-Year Cycle	$ 7,249	$ 860	79%	$ 128	$ 987	$(6,390)	0.12	$ (6,262)	0.14

*All Dollar Values in $1,000's AAEQ

Table 7-4: Rincon Final Array NED Comparison

7.2.2 Rincon Final Array RED Comparison

Each of the alternatives were also compared using RED metrics which included tourism spending, local property tax receipts, and jobs maintained. Each of these metrics were computed as follows:

- Tourism Expenditures – The USACE certified RED model, RECONS, was run using the "Economic Impacts of Recreation Module". Visitation data utilized for this module used the same visitation data from the recreation analysis but it was assumed that 22.2% of visitation would be lost to the region of Rincon (Glagow & Train, 2018). Tourism spending via local visitation in the area under the FWOP condition was compared to tourism expenditures in each alternative scenario.
- Local Tax Receipts – As described in **Section 5.1.3**, there are 57 expected structure condemnations in the FWOP condition which will result in reduced property tax receipts for the local government. To estimate alternative impacts on local tax revenues it was assumed that each owner of a condemned structure would discontinue tax payments and, thus, any avoided condemnation resulted in an increase in tax receipts. Tax receipts were calculated at present-value since condemnations occur at various points throughout the POA.
- Jobs Supported – Again the USACE certified RECONS model was used to estimate the number of jobs supported. Jobs supported were a direct result from project expenditures with the exception of Acquisition, which was not estimated to support any jobs via project spending.

Alternative	Tourism Expenditures Maintained (AAEQ)	Property Tax Receipts Maintained (AAEQ)	Jobs Supported
No Action	$ -	$ -	
Revetment	$ -	$ 8,000	488
Acquisition	$ 3,372,000	$ 4,000	0
G50_B10_Dex_10YR	$ 1,143,000	$ 4,000	482
G50_B20_Dex_5YR	$ 3,284,000	$ 6,000	565
G50_B10_Dex_5YR	$ 2,180,000	$ 6,000	593

Table 7-5: Rincon Final Array Comparison - RED

The largest overall RED impact comes from the tourism expenditures maintained under the Acquisition alternative which is $3,372,000 (AAEQ). Property tax receipts maintained is a benefit category that was somewhat irrelevant due to the low incidence of property tax collection in Rincon. The most expensive alternative, a 10' berm with groin field maintained every five years, also supported the most jobs.

7.2.3 Rincon Final Array OSE & EQ Comparison

The main OSE measure by which alternatives were compared in Rincon were condemnations. To measure an alternatives impact on blight the FWOP number of condemnations was compared to the FWP condemnations. The results are described in **Table 7-6**. The main EQ metric used for alternative comparison was habitat units (HU). The methodology for HU computation is not detailed in this appendix but can be found in the Environmental Appendix. The only alternative to have a positive change in HU's from the FWOP condition is acquisition and relocation with 12.2 habitat units estimated.

Alternative	Habitat Units	Condemnations Avoided	Percent Condemnations Reduced	First-Row Condemnations Avoided	Percent of First-Row Condemnations Avoided
No Action	0	0	0%	0	0%
Revetment	0	57	100%	57	100%
Acquisition	12.2	30	53%	47	82%
G50_B10_Dex_10YR	0	30	53%	30	53%
G50_B20_Dex_5YR	0	43	75%	43	75%
G50_B10_Dex_5YR	0	42	74%	42	74%

Table 7-6: Rincon Final Array Comparison OSE and EQ

Revetment avoided the most condemnations by securing the shoreline from all future erosion through the 50-year POA. The Acquisition alternative was, obviously, successful in reducing the number of first-row condemnations by 82% as those were most of the assets acquired. However, erosion is anticipated to continue through the 50 years and some of the second-row structures, not impacted in the FWOP due to armoring, now become at-risk of condemnation. Acquisitions avoid, on average, 53% of condemnations. However, it is important to note that the second-row of structures does not become at-risk until much later in the POA. In fact, only 7 of the condemnations occurring in the Acquisition alternative occur on average before year 30. The average year for condemnation in Acquisition is 33. This indicates that Acquisition is extremely effective in reducing condemnations for the first 35 years, see **Figure 7-2** below. Acquisitions may be further refined to include additional assets and the PDT has identified potential second-row parcels that can be acquired to further reduce the risk of future condemnations as shown in Figure 7-3.

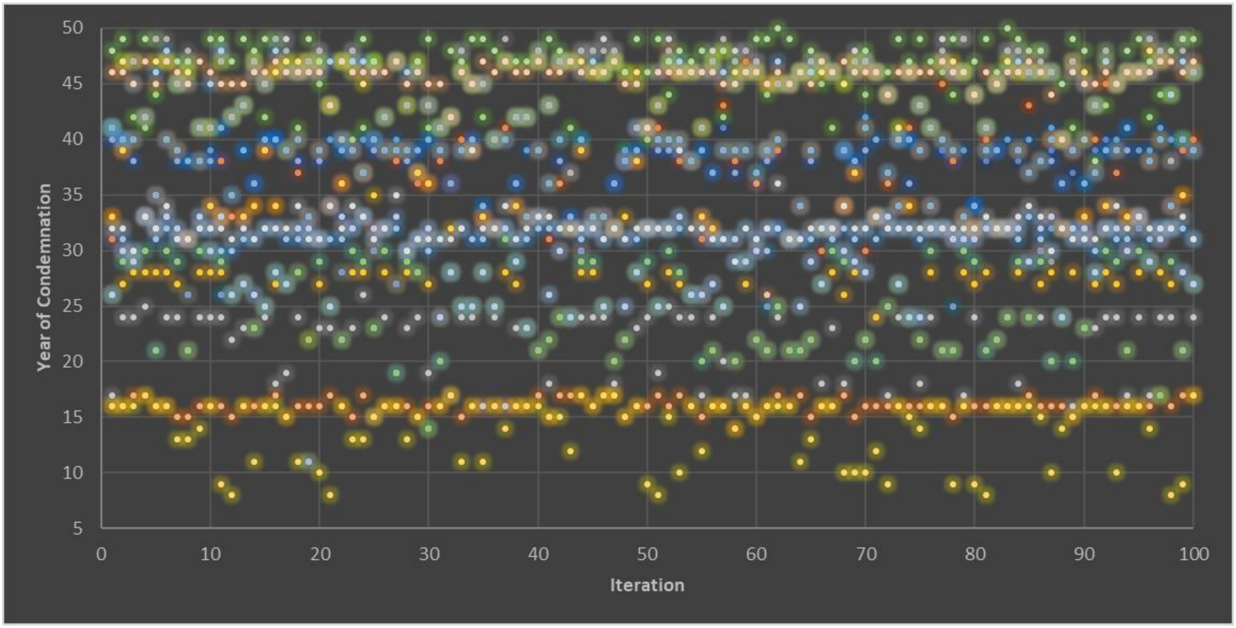


Figure 7-2: Condemnations by Year in the Acquisition Alternative

Figure 7-3: Potential Future Rincon Second-Row Acquisitions

8.3 Rincon Alternative Comparison Summary

The NED plan has been identified as the No-Action plan since the remaining alternatives have negative net NED benefits. Revetment is effective at reducing the majority of damages, with 92% damages reduced and 100% condemnations reduced. However, revetment does not capture any recreation benefits and is one of the worst in RED performance. There are also unquantified impacts of revetment that include induced erosion in adjacent shorelines[13] outside of the model

[13] The adjacent shorelines are the primary recreation beaches that the economy of Rincon relies on.

domain, adverse aesthetic impacts and extreme opposition by the public and the NFS that would fall in the OSE account. For a more detailed discussion on the adverse impacts of revetment see the Main Report and the Plan Formulation Appendix.

The nourishment alternatives incur large economic cost and come with additional environmental risks, such as potential turbidity that could impact Tres Palmas, a nationally protected Marine Reserve rich in biodiversity and coral reef that attract surfers from around the world. Acquisition of first-row structures is the only alternative to accrue positive impacts in all four P&G accounts and is the least-cost alternative. The majority of residual damages occur in reaches outside of the acquisition footprint (model reaches R20-R22). Condemnations in the second row do not generally occur until much later in the POA. Further, Acquisition is adaptable and can also be further refined to target additional structures in the second-row. It is for these reasons that Acquisition is the TSP. See **Figure 7-4** for a comprehensive graphic on the alternatives compared.

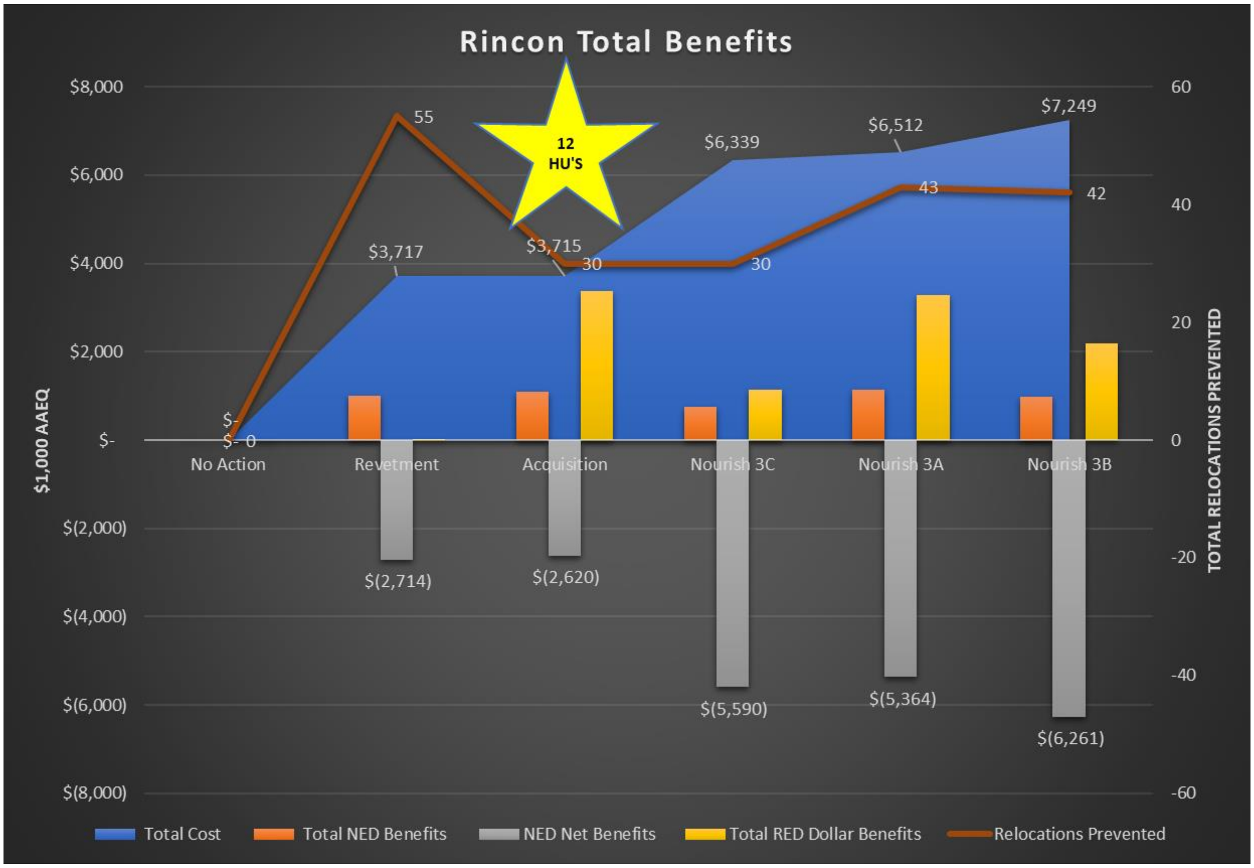


Figure 7-4: Rincon Alternative Comparison Summary

8.4 Ocean Park Final Future-With Project Preliminary Modeling

Ocean Park modeling was conducted in Beach-Fx and G2CRM. FWOP results showed that most of the coastal risk came from inundation to the upland through two specific points, Barbosa Park and the "skate park" (see sections on Ocean Park FWOP above). As a result alternative formulation started with addressing the inundation problem to the upland and then considered alternatives to address the risk to first-row structures. Floodwalls of various heights were considered at just Barbosa Park and the skate park, then extensions were considered to protect first-row structures, and finally a combination of Floodwall at the two entry points with beach nourishment to protect first-row structures were considered.

7.4.1 Ocean Park Preliminary Floodwall Modeling

The initial Floodwall heights considered were 6-ft, 7-ft, and 8-ft. For the 8-ft wall additional model reaches, beyond Barbosa Park and the skate park, would need to have Floodwalls added to keep the 8-ft height consistent and protect against inundation. Additional metrics were also considered in the preliminary modeling phase, such as business disruptions reduced (see **Section 5.3.2.2)**, life loss, and the portion of benefits accrued to the most socially vulnerable[14]. Social vulnerability was measured by likelihood (since asset level demographics are unavailable) and described as very high, high, moderate, low, and remote. The 7-ft Floodwall was the NED maximizing alternative and provided many of the comprehensive benefits of the 8-ft Floodwall at a much lower cost (see **Table 7-7** and **Table 7-8).** At this point in the modeling and analysis the PDT was aware of the risk of floodwall costs increasing with further refinements and soonly the 7-ft Floodwall was carried into the final array due to the overall effectiveness at a comparatively lower cost.

Extending the Floodwalls to address the problems faced by first-row structures was also considered. This effort was conducted in the Beach-Fx modeling domain and benefits and costs of the proposed extensions were ascribed solely to the first-row structures to avoid duplication of benefits included in the G2CRM domain. The incremental benefits of extending the Floodwall were relatively low and the incremental costs high. Further, there were virtually no additional comprehensive benefits achieved since few first-row structures in the asset inventory are businesses (thus no business disruption prevented benefits) and the first-row assets are considered remote likelihood of social vulnerability. See Table 7-9 for a review of the incremental benefits of extending the floodwalls. Floodwall Extension C, which extends the wall beyond Barbosa Park west to reach E10, was carried forward to final array of alternatives.

An additional alternative was carried into the final array which was not modeled during this preliminary phase since costs were being developed during that time. The alternative is essentially the 7-ft floodwall in Barbosa and skate park with a few first-row properties acquired. Model results for this alternative are presented below in **Section 7.5.**

Alternative	Height	Range (Model Reaches)	Benefits (PV)	Total Cost (PV)	Net-Benefits (PV)
Floodwall	6	E13-E15, IV14	$78,489,000	$ 55,500,000	$22,989,000
Floodwall	7	E13-E15, IV14	$85,628,000	$ 55,500,000	$30,128,000
Floodwall	8	E13-E19, E21-E11, IV14-IV15	$102,485,000	$ 138,822,000	($36,337,000)

[14] The likelihood of social vulnerability was established by placing assets into quintiles based on depreciated replacement value.

Table 7-7: Ocean Park Preliminary Floodwall Modeling - NED

P&G Account	CSRM Benefit Category & Metric		Units	6ft Floodwall	7ft Floodwall	8ft Floodwall
NED	**CSRM**	**CSRM Benefits**	$ PV	$78,489,000	$85,268,000	$102,485,000
RED	**Business Disruption Prevention Benefits (2023 – 2079)**	**# Days from Flooding**	# days	229	257	262
		# Days from Repairs	# days	5,995	6,621	6,733
OSE	**CSRM Benefit Distribution by Social Vulnerability Likelihood**	**1_Very High**	%	32%	31%	31%
		2_High	%	6%	6%	6%
		3_Moderate	%	7%	7%	7%
		4_Low	%	11%	11%	11%
		5_Remote	%	12%	12%	12%
	Life Safety Risk	**Life Loss Prevented**	# Lives	6	7	8

Table 7-8: Ocean Park Preliminary Sewall Modeling – Comprehensive

Alternative	Height	Total Range with Addition (Model Reaches)	Incremental Benefits (PV)	Incremental Cost (PV)	Incremental BCR	Incremental Net-Benefits (PV)
Floodwall Extension A	7	E10-E19, IV14	$ 14,166,000	$ 67,789,000	0.21	$ (53,623,000)
Floodwall Extension B	7	E13-E19, IV14	$ 7,976,000	$ 27,116,000	0.29	$ (19,140,000)
Floodwall Extension C	7	E10-15, IV14	$ 6,190,000	$ 20,337,000	0.30	$ (14,147,000)

Table 7-9: Incremental Benefits of Ocean Park Seawall Extensions

7.4.2 Ocean Park Beach Nourishment Modeling

Beach Nourishment was also considered for the risks to first-row structures. Placement of Beach Nourishment would occur in model reaches E10-E19 where sand was needed most. There is not estimated to be much recreation benefit from nourishment since reaches in the west, E01-E09 have robust existing berms that are able to absorb recreation demand throughout the POA.

Like Rincon, Ocean Park faced high nourishment costs since the borrow area was from an upland source and required truck haul. The NED net-benefits for nourishment ranged from -$98M to -$121M (PV) or -$3.3M to -$4.1M AAEQ. The PDT carried a single nourishment alternative into the final array, which is highlighted in **Table 7-10**.

Berm (Ft.)	Dune Height (Ft PRVD02)	Dune Width (Ft. PRVD02)	Nourish Interval (Year)	Total FWOP Damages	Total FWP Damages	Total Benefits	Cost	Net-Benefits	BCR
0	12	10	5	$ 43,592	$ 16,909	$ 26,683	$ 124,809	$ (98,126)	0.21
10	12	20	5	$ 43,592	$ 14,001	$ 29,591	$ 136,401	$ (106,810)	0.22
10	12	20	10	$ 43,592	$ 20,602	$ 22,990	$ 121,592	$ (98,602)	0.19
20	12	20	5	$ 43,592	$ 13,877	$ 29,715	$ 150,617	$ (120,902)	0.20

All Dollar Values in $1,000's PV

Table 7-10: Ocean Park Preliminary Nourishment Modeling

8.5 Ocean Park Final Array Summary

Alternative 2, Floodwall at Barbosa Park and the skate park (model reaches E13-15, R14) was ultimately selected as the TSP in Ocean Park. This alternative had the highest NED net-benefits, the greatest proportion of benefits accruable to individuals categorized with a "very high" likelihood of being socially vulnerable (over 40% for individuals with "moderate to very high" likelihood, making this alternative consistent with the Justice40 initiative), and the highest number of life loss prevented. Alternative 2 is also identified as the plan which maximizes net-comprehensive-benefits consistent with guidance from the memorandum dated 5 January 2021, "Comprehensive Documentation of Benefits in Decision Document" (Assistant Secretary of the Army, Civil Works.

Alt #	Alt Name	NED Benefits	Cost	Net-Benefits	BCR	Business Disruptions Reduced
1	No Action	$0	$0	$0	N/A	-
2	Floodwall (E13 to E15, R14)	$2,870,000	$2,169,000	$701,000	1.32	6,878
3	Floodwall & Beach Nourishment	$3,162,000	$6,524,000	($3,362,000)	0.48	6,878
4	Floodwall Extension (E10-E15, R14)	$3,078,000	$2,625,000	$453,000	1.17	6,878
5	Floodwall & Acquisition	$2,908,000	$3,252,000	($344,000)	0.89	6,878

Alternative #			1	2	3	4	5
OSE	**CSRM Benefit Distribution (%) by Social Vulnerability Likelihood**	**1_Very High**	0%	31%	28%	29%	30%
		2_High	0%	6%	5%	6%	6%
		3_Moderate	0%	7%	6%	6%	7%
		4_Low	0%	11%	10%	10%	11%
		5_Remote[15]	0%	45%	50%	49%	46%
	Life Safety Risk	**Life Loss Prevented (# of Lives)**	0	7	7	7	7

[15] Included in "Remote" are benefits accrued to businesses since the social vulnerability of the business owners was not identified during this study.

9. THE TENTATIVELY SELECTED PLANS

Alternative 2 in Ocean Park, a floodwall at Barbosa and the skate park, is the TSP and Alternative 4 in Rincon, Acquisition and Relocation. This section will more thoroughly discuss the refined benefits, refined costs, and the risks and uncertainties of the TSP's, as well as their performance in the three sea-level rise scenarios.

9.1 Rincon Tentatively Selected Plan

9.1.1 Rincon – Recreation Benefits of the TSP

According to ER-1105-2-200, incidental recreation benefits that result from the construction of a project can be calculated and added to overall project benefits in CSRM studies. Recreation benefits are not to be used in plan formulation, but they can be included in total project benefits so long as primary benefits (i.e. CSRM benefits) constitute 51% of the benefits required for economic justification. Recreation benefits represent a vital component of a CSRM project and access for the public to use and recreate on the beach is the foundation for federal interest in the project.

Typically in coastal studies, recreation benefits are calculated using the travel cost method (TCM). The basis for this method is that by increasing the carrying capacity of a particular recreation resource, a project may reduce the travel time and costs associated with recreation visits. In this case, adjacent beaches provide recreation experience adequate for demand within Rincon with minimal associated travel costs. However, there are residents and visitors staying within lodging directly located in the TSP area that have a willingness-to-pay (WTP) for improvements along this stretch of beach. Therefore, this recreation analysis will use the Unit Day Value (UDV) methodology to estimate the benefits of a project. It is important to note that there is a more in-depth analysis of recreation related to PRCS, as a part of broader regional effort, being executed that will utilize the Contingent Value Method (CVM) via surveys of the public. The broader regional effort covers CSRM studies within the USACE South Atlantic Division (SAD) Area of Responsibility (AOR) that were funded by the Bipartisan Budget Act of 2018 (BBA 2018). However, results from the CVM effort were not available in time for this draft report and UDV will be used as a placeholder. The UDV methodology used herein will be a hybrid of UDV and CVM in which a beach user's change in WTP to a with-project condition is informed by other CSRM recreation studies that utilized the CVM but will be constrained by the maximum visitation and maximum WTP value described in EGM 22-03. It is anticipated that a USACE Chief's Report will include recreation benefits from the CVM. Though, it is important to note that primary CSRM benefits for the Rincon planning reach are not sufficient to allow recreation benefits as part of an official NED net-benefit or BCR analysis but will be used as part of the comprehensive benefits analysis.

The first step in determining the recreation benefits that arise from a project the PDT must first estimate the number of visitors that are expected directly in the footprint of the project. Many data sources pertaining to visitation are heavily aggregated, so this task is difficult, especially in an area like Rincon where existing data sources are scarce. The specific beaches that fall within the proposed project footprint are Amas Beach, Stella, and Playa Corcega (Stella Beaches). The Municipality of Rincon contains many high-quality intersite substitutes for these beaches including several that are included in various "Top Ten" lists of Puerto Rico beaches (e.g. Steps

Beach in the Tres Palmas Marine Reserve); see **Figure 8-1**. Island-wide visitation data was used from a report produced by Inteligencia Económica (Inteligencia Económica, 2016) and was combined with visitation trends within the island found in the report Plan de Adaptación al Cambio Climático (PACC Report) (Compañía de Turismo de Puerto Rico, 2016). The PACC Report detailed the percentage of total beach visits that could be expected within Rincon. Given the ample substitutes in Rincon it was necessary to further refine the visitation to estimate beach goers visiting the Stella Beaches. Various sources were used to further refine the visitation including annual estimated hotel occupancy rates in the project footprint and review aggregation websites. The estimated annual visitation at the base year (2029) was estimated to be 29,566. A 2.4% growth rate, based on PACC Report estimates, was used. Visitation in the FWOP condition was expected to be constrained by erosion and development along the shoreline restricting access to the beach as described in the Rincon FWOP section (**5.1**). Background erosion rates and the existing berm width were used to estimate available beach square-footage. Each visitor was assumed to require 100-square feet of beach with a daily turnover of two visitors. In the FWOP visitation was expected to be constrained to zero by 2031, at which point there would not be sufficient access or sufficient consistent available berm width to support beach recreation. In the FWP condition with the TSP, Acquisition, visitation remains unconstrained until 2072 at which point visitation begins to decline by about 1.2% annually until the end of the POA. Figure 8-2 below demonstrates the visitation in the FWOP and FWP under the TSP. It is important to note that some of the modeling reaches within Rincon lose fully carrying capacity in the FWP, but adjacent reaches are able to absorb the visitation. This is consistent with the residual damages encountered in the TSP.

Figure 8-1: The Beaches of Rincon

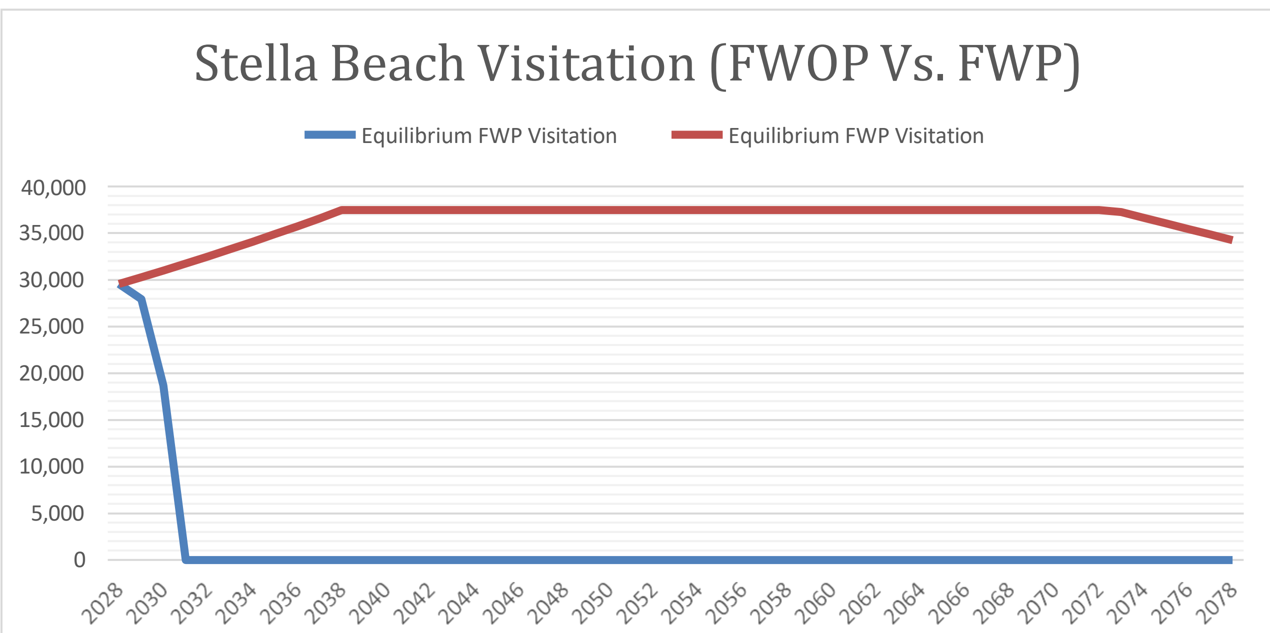


Figure 8-2: Stella Beach Visitation Estimates (FWOP Vs. FWP)

The next step in determining recreation benefits is to determine the WTP in both the FWOP and FWP. Since the beach is degraded in the existing condition, the WTP was estimated at $5.00 using the UDV criteria in EGM 22-03. As the beach further erodes and the conditions worsen the FWOP see a decline and flatlined WTP to $2.90. The increased berm width made available by removing the first-row structures and regrading the area with sand increases the WTP to the EGM 22-03 maximum of $13.50 throughout most of the POA. The WTP decreases somewhat, to $12.62, beginning in year 2056 as the beach begins to further erode and by the end of the POA the WTP has reached $4.18; see Figure 8-3.

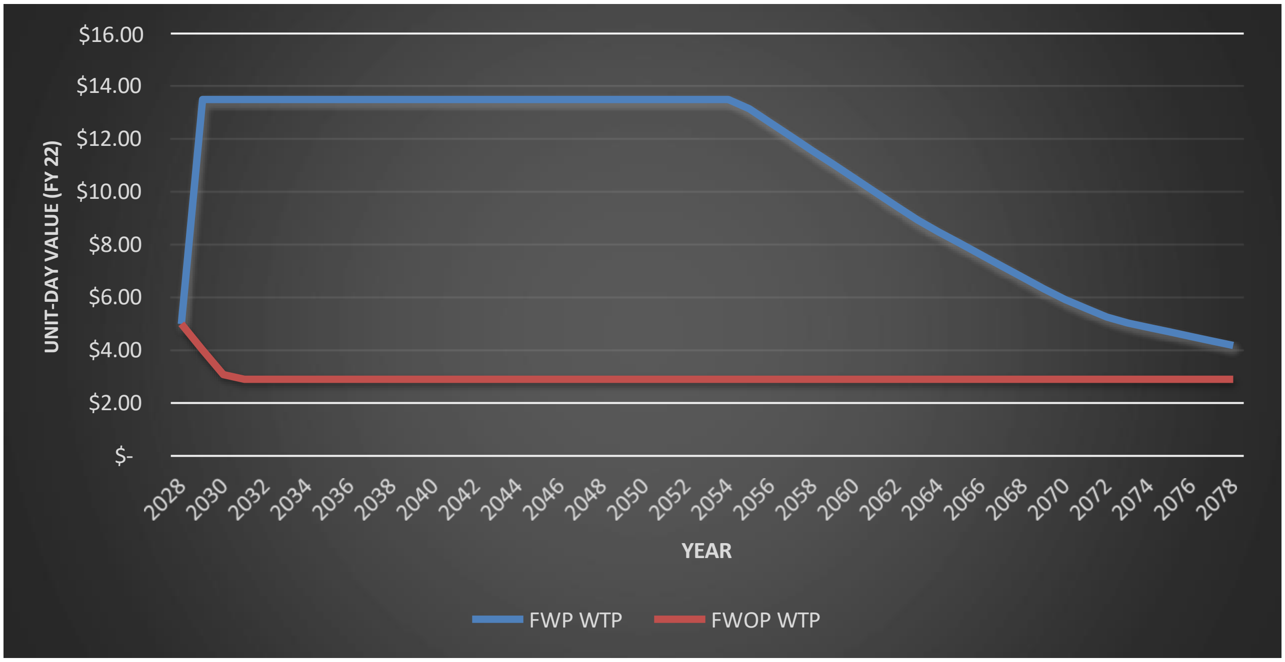


Figure 8-3: Stella Beach UDV (FWP vs. FWOP)

Taking the annual visitation and multiplying it by the UDV gives the recreation benefit in any given year. The FWOP and TSP were compared on a year-by-year basis and the discounted difference was taken as the recreation benefit. Alternative 4, Acquisition, provides $12,713,000 (PV) or $426,000 (AAEQ).

9.1.2 Rincon TSP NED Benefits & Costs in the SLR Scenarios

It is important to note that modeling assumptions did change between the FWOP and FWP Acquisition scenario. It was assumed that if acquisitions are implemented in order to restore the shoreline, no future armoring (e.g. seawalls, rip rap, revetments) would be placed along the shoreline. The acquisition footprint was based on the intermediate SLR scenario, not the high. Therefore, there are additional damages in the high SLR FWP scenario without armoring than in the high FWOP. This indicates that if evidence shows sea levels are trending towards the high curve the acquisition strategy would need to be adapted and the footprint for asset purchases would need to be extended to achieve any level of coastal storm risk management. This is not an indication that the recommended plan induces damages but is rather a function of utilizing the same assumptions for the FWP condition in each of the SLR scenarios.

In the intermediate SLR scenario the acquisition strategy is effective in reducing 58% of FWOP damages. Included in the residual damages are those that occur in model reaches where no acquisition is occurring (R20-R22) which makes up 61% of all residual damages. If only considering reach R11-R19, where acquisition occurs, the FWP condition is a reduction of 78% of damages. In the low SLR scenario 69% of all damages are reduced. 67% of the residual damages in the low scenario are attributable to the model reaches R20-R22 where no acquisitions occur. See **Table 8-1** and **Table 8-2** for details on the TSP benefits and damage reduction in the SLR scenarios.

SLR Scenario	FWOP	Acquisition	Benefits	% Damage Reduction
Low	$ 884,200	$274,000	$ 610,200	69%
Intermediate	$ 1,010,900	$424,000	$ 586,900	58%
High	$ 1,472,500	$1,571,000	$ (98,500)	N/A

Table 8-1: TSP Benefits and Damage Reduction (R11-R22)

SLR Scenario	FWOP Damages (R11-R19)	Acquisition Damages	Benefits	% Damge Reduction
Low	$ 702,000	$92,000	$ 610,000	87%
Intermediate	$ 847,000	$260,000	$ 587,000	69%
High	$ 997,000	$1,095,000	$ (98,000)	N/A

Table 8-2: TSP Benefits and Damage Reduction (R11-R20)

	Mitigation	Construction[16]	Real Estate[17]	Total
Alt 4 - Acquisition	$ -	$ 15,426,774	$ 95,421,477	$ 110,848,251

*All Values in FY 23

Table 8-3: Acquisition Total First Cost (FY23)

	Mitigation	Construction	Real Estate	OMRR&R	IDC	Total
Alt 4 - Acquisition	$ -	$ 517,000	$ 3,198,000	$ 8,000	$ 2,000	$ 3,725,000

*All Values in AAEQ

[16] Includes PED, S&A, and contingency.
[17] Includes administrative cost and contingency

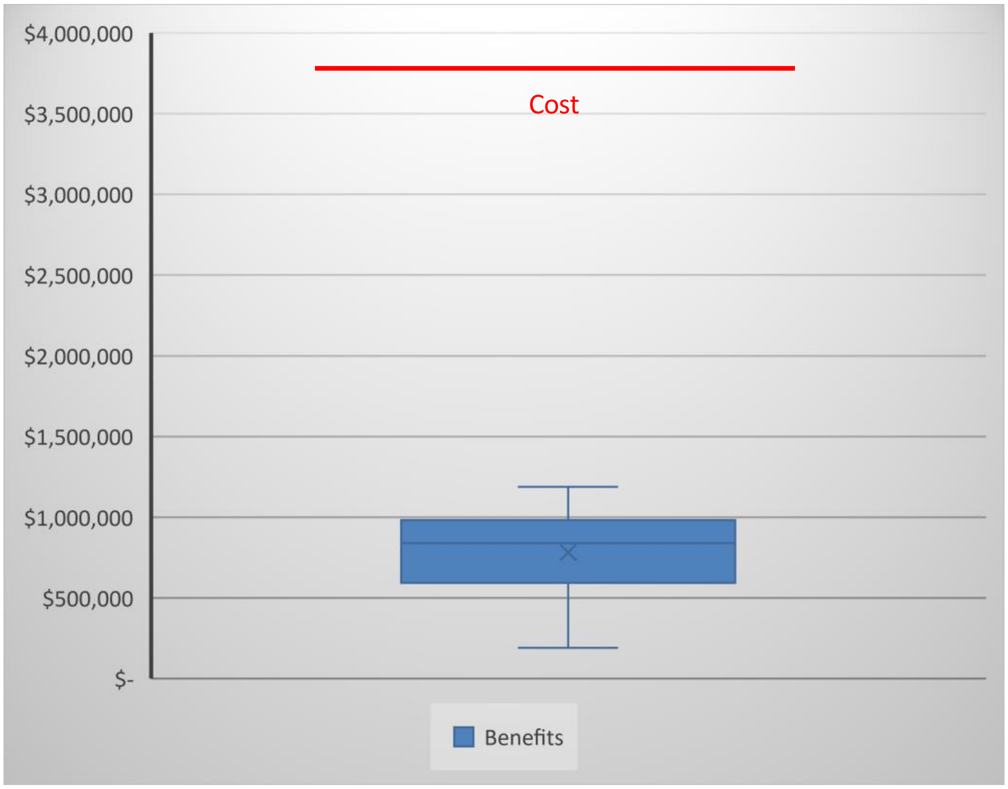
Table 8-4: Acquisition Total NED Cost (AAEQ)

SLR Scenario	TSP Benefits[18]	TSP Cost	TSP Net-Benefits	TSP BCR
Low	$ 610,000	$3,725,000	$ (3,115,000)	0.16
Intermediate	$ 587,000	$3,725,000	$ (3,138,000)	0.16
High	$ (98,000)	$3,725,000	$ (3,823,000)	N/A

Table 8-5: Rincon TSP NED Net-Benefits in the SLR Scenarios

9.1.3 Rincon TSP Risk and Uncertainty

Consistent with ER 1105-2-101, Risk Assessment for Flood Risk Management Studies, the probability that the TSP has positive or negative net-benefits was calculated and some descriptive statistics on net-benefits will be presented in this section. As shown in Figure 8-4 below, 100% of the iterations for the Acquisition alternative present a BCR below 1.0. The range of BCR's is .05 to .32. With all BCR's below 1.0 obviously all iterations will also have negative net-benefits. The range of net-benefits is -$3,535,000 to -$2,536,000 (AAEQ).



[18] Benefits do not include recreation benefits as including them would not be policy compliant. The summary table of the TSP below includes recreation benefits for informational purposes.

Figure 8-4: Rincon TSP Box and Whisker of Benefits Vs. Cost (AAEQ)

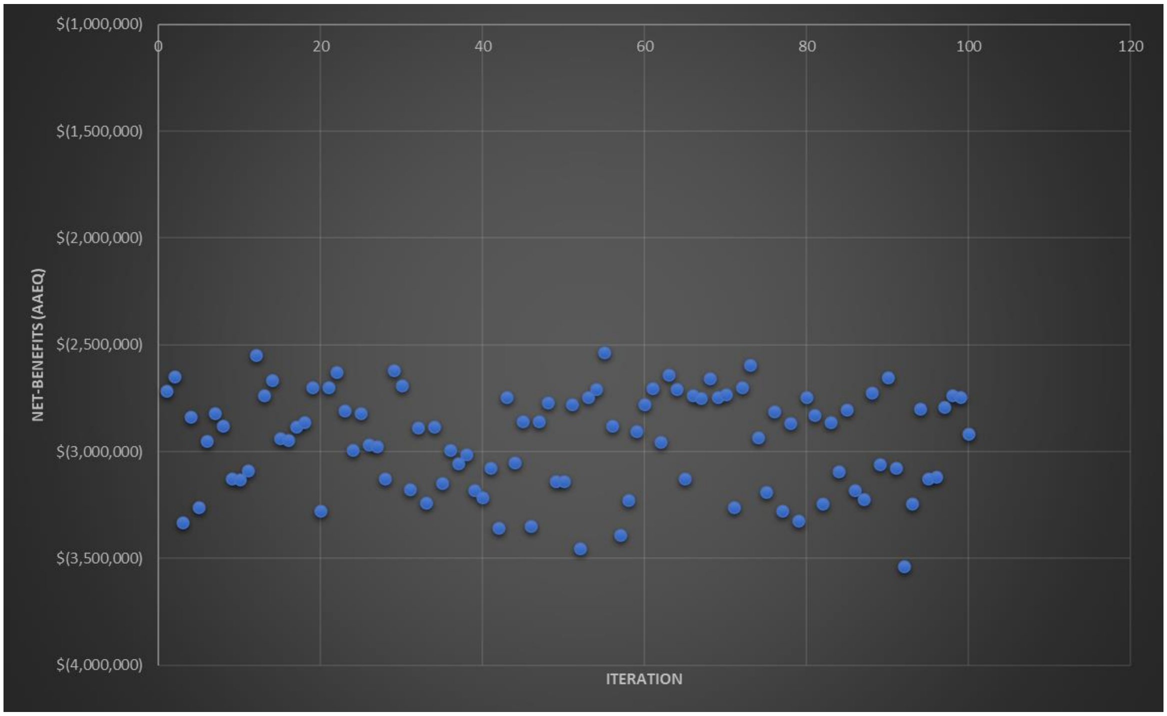


Figure 8-5: Rincon TSP Net-Benefit Scatter Plot (AAEQ)

9.1.4 Rincon TSP RED, OSE, and EQ Benefits

As mentioned above, Acquisition was the only alternative to provide benefits in each of the four P&G accounts. Habitat units (EQ) are achieved by restoring the shoreline to it's more natural state. This includes both beach and aquatic habitat and the estimated habitat unit lift is 12.2.

By increasing the amount of space for recreation and removing unsightly and condemned structures (both in the existing and FWOP condition) the Acquisition alternative will maintain $3,372,000 in average annual tourism spending in Rincon (see **Table 8-6).**

IMPLAN Sectors	Industries	Output
	Direct Impacts	
406	Retail - Food and beverage stores	$270,859
408	Retail - Gasoline stores	$256,827
410	Retail - Sporting goods, hobby, musical instrument and book stores	$47,065
412	Retail - Miscellaneous store retailers	$78,760
504	Other amusement and recreation industries	$182,918
507	Hotels and motels, including casino hotels	$3,214,400
509	Full-service restaurants	$924,607

512	Automotive repair and maintenance, except car washes	$21,928
Direct Impact		$4,997,364
Secondary Impact		$9,994,727

Total Impact (FY 23)	$14,992,091
Total Impact Annualized	$15,329,000
Intersite Substitution[19]	$11,957,000
Alternative 4 - Acquisition - Local Tourism Benefit	**$3,372,000**

Table 8-6: Rincon Acquisition Tourism Spending Benefit

Acquisition will also reduce 84% of first-row condemnations and 53% of total condemnations. Condemned buildings can adversely impact a community through urban/community blight. Community blight is a well-documented phenomenon with wide-ranging consequences such as a decrease in surrounding property values, adverse impacts to local housing markets, safety hazards, and reduced local tax revenues (Housing and Urban Development, 2018). These destroyed structures result in hazardous debris (e.g. large broken concrete slabs, rebar, glass, various metals) strewn about the beach. These structures are often left behind with no evidence of intent to remove; the beachside rubble that were once structures, having collapsed during Hurricane Maria in 2017, remain today. This sort of blight is potentially contagious. “Blight can spread at an incredible speed. Thus, it must be prevented and eradicated as soon as it surfaces. If blight is allowed to reach a more advanced stage, it causes other serious problems such as drug and alcohol abuse or prostitution thereby contributing to rising crime rates. Residents of blighted areas have lower qualities of life, including malaise and insecurity. They often find themselves in situations of greater physical and mental stress.” (Pinto, Ferreira, Spahr, Sunderman, & Pereira, 2022). The Acquisition alternative in Rincon gives the community a potential reprieve from the stresses induced by condemned structures and provides a means of access and enjoyment of the shoreline not present in a future where no action is taken.

9.2 Rincon TSP Benefit Summary

Acquisition in Rincon is the only recommended alternative to achieve benefits in all four P&G accounts. The NED impact is net-negative whether or not recreation benefits are included. If evidence suggests sea levels are trending towards the USACE high sea-level rise scenario the acquisition footprint would need to be expanded in order to achieve any of the benefits described in this report. As an adaptation strategy the team is considering potential expansion of acquisitions to support the benefits (see **Figure 7-3: Potential Future Rincon Second-Row Acquisitions**). Acquisition will reduce FWOP damages by 52% and restore the natural shoreline of Rincon and access to it. It alleviates the traumatic impacts to the local community of having abandoned and destroyed structures dotting the shoreline which has been their backyard for decades.

National Economic Development	**NED Primary Benefits (AAEQ)**	**$ 587,000**
	NED Cost (AAEQ)	**$ 3,725,000**

[19] Intersite substitution reflects the estimated amount of transfers likely to occur within the Municipality of Rincon, which is the local impact area measured. The substitution coefficient was based on existing research which showed not all visits would substitute for local areas but would instead be lost at a rate of, on average, 22% (Glagow & Train, 2018).

	NED Primary Net-Benefits (AAEQ)	**$ (3,138,000)**
	NED Primary BCR	**0.16**
	Recreation Benefits (AAEQ)	**$ 426,000**
	NED Net-Benefits With Recreation (AAEQ)	**$ (2,712,000)**
	NED BCR with Recreation	**0.27**
Regional Economic Development	Tourism Expenditures Maintained (AAEQ)	$ 3,372,000
Other Social Effects	First-Row Condemnations Avoided	82%
	Total Condemnations Avoided	53%

Table 8-7: Rincon TSP Benefit Summary

9.3 Ocean Park Tentatively Selected Plan

9.3.1 Ocean Park TSP NED Costs & Benefits in the SLR Scenarios

Alternative 2, Floodwalls at Barbosa Park and the skate park, provides a robust level of damage reduction in the low and high SLR scenarios. Benefits for the high SLR were not computed since the compound flooding from the back-bay area makes residual risk with a project in place unquantifiable in the current effort[20]. However, there would be some level of benefits since a significant amount of risk associated with overtopping of surge from the coast would be reduced. In the intermediate and low damages are reduced by 91% and 95% with benefits of $2,816,000 and $692,000 (AAEQ) respectively (**Table 8-8)**. Total first cost of the floodwall is $64,719,713 (FY23, Table 8-9) with an NED cost of $2,396,000 (**Table 8-10**). The low SLR has net-benefits of -$1,704,000 (AAEQ) and BCR of 0.3 while the high SLR has net-benefits of $420,000 (AAEQ) and a BCR of 1.2 (

SLR Scenario	FWOP Damages (AAEQ)	Alt 2 - Floodwall Damages (AAEQ)	NED Benefits (AAEQ)	NED Cost	Net-Benefits	BCR	Damages Reduced
Base	$ 764,000	$72,000	$ 692,000	$ 2,903,000	$ (2,211,000)		91%

[20] Residual risk can be quantified and benefits could be produced if the portion of risk attributable specifically to the back-bay was known. In order to measure that risk the current study would need a significant expansion of scope.

Intermediate	$ 2,960,000	$144,000	$ 2,816,000	$ 2,903,000	$ (87,000)	1.0	95%

Table 8-11).

SLR Scenario	FWOP Damages (AAEQ)	Alt 2 - Floodwall Damages (AAEQ)	NED Benefits (AAEQ)	Damages Reduced
Base	$ 764,000	$72,000	$ 692,000	91%
Intermediate	$ 2,960,000	$144,000	$ 2,816,000	95%

Table 8-8: Ocean Park TSP Benefits

	Conservation & Monitoring	Construction	Real Estate	Total First Cost
Alt 2 - 7' Seawall	$ 411,000	$ 49,628,995	$ 14,679,718	$ 64,719,713

*All amounts in FY23 Dollars and include contingency. Construction includes PED and S&A.

Table 8-9: Ocean Park TSP First Cost (FY23)

	Conservation & Monitoring	Construction	Real Estate	OMRR&R	IDC	Total
Alt 2 - 7' Seawall	$ 14,000	$ 1,663,000	$ 492,000	$ 709,000	$ 25,000	$ 2,903,000

Table 8-10: Ocean Park TSP NED Cost (AAEQ)

SLR Scenario	FWOP Damages (AAEQ)	Alt 2 - Floodwall Damages (AAEQ)	NED Benefits (AAEQ)	NED Cost	Net-Benefits	BCR	Damages Reduced
Base	$ 764,000	$72,000	$ 692,000	$ 2,903,000	$ (2,211,000)		91%
Intermediate	$ 2,960,000	$144,000	$ 2,816,000	$ 2,903,000	$ (87,000)	1.0	95%

Table 8-11: Ocean Park TSP NED Summary in the SLR Scenarios

9.3.2 Ocean Park TSP Recreation Benefits

Incidental recreation benefits for Ocean Park have not yet been determined. There is currently a contract underway to measure the effects of recreation benefits and this report will be updated when recreation benefits are available.

9.3.3 Ocean Park TSP OSE & RED Benefits

To understand how the floodwall alternative would accrue benefits in the OSE account the planning reach was broken down into quintiles based on the likelihood of social vulnerability. The likelihoods established were very high, high, moderate, low, and remote. Residential asset values were used as proxies for social vulnerability (i.e. the lower the asset value, the more likely the social vulnerability). Benefits on an asset basis were then measured and grouped into these quintiles of likelihood. Additionally, life loss metrics were used to quantify benefits of the TSP. The TSP in Ocean Park prevents 7 lives lost and 44% of the NED benefits accrue to individuals estimated to be at moderate to very high likelihood of being socially vulnerable. Further, a portion of those benefits accrue to one of the largest public housing complexes in the Caribbean, Residencial Luis Llorens Torres. Residents within this housing complex are in the 99th percentile of low income and have one of the highest measures of social vulnerability in the country.

Alternative			TSP – 7' Floodwall
OSE	**CSRM Benefit Distribution (%) by Social Vulnerability Likelihood**	**1_Very High**	31%
		2_High	6%
		3_Moderate	7%
		4_Low	11%
		5_Remote[21]	45%
	Life Safety Risk	**Life Loss Prevented (# of Lives)**	7

Table 8-12: Ocean Park TSP OSE Benefits

RED benefits were measured by the number of business disruptions prevented. When a business is flooded revenues are lost and operations interrupted not only during the storm event while flood waters occupy the structure but also in the aftermath while the business owner must make necessary repairs before operations can continue safely. The TSP in Ocean Park is estimated to prevent 6,878 days of business disruptions, representing a very large revenue benefit to the businesses located within the community.

9.3.4 Ocean Park Risk and Uncertainty

Consistent with ER 1105-2-101, Risk Assessment for Flood Risk Management Studies, the probability that the TSP has positive or negative net-benefits was calculated and some descriptive statistics on net-benefits will be presented in this section.

57% of TSP iterations produced positive net-benefits, with a maximum of $6,130,000 and a minimum of -$2,296,000 AAEQ. The maximum BCR is 3.56 with a minimum BCR of 0.04. The minimum BCR comes from an iteration in which very minimal damages are estimated and thus there are very few benefits. The maximum BCR comes from an iteration in which there are $9,290,000 AAEQ FWOP damages and the TSP is successful in reducing 92% of those damages.

[21] Included in "Remote" are benefits accrued to businesses since the social vulnerability of the business owners was not identified during this study.

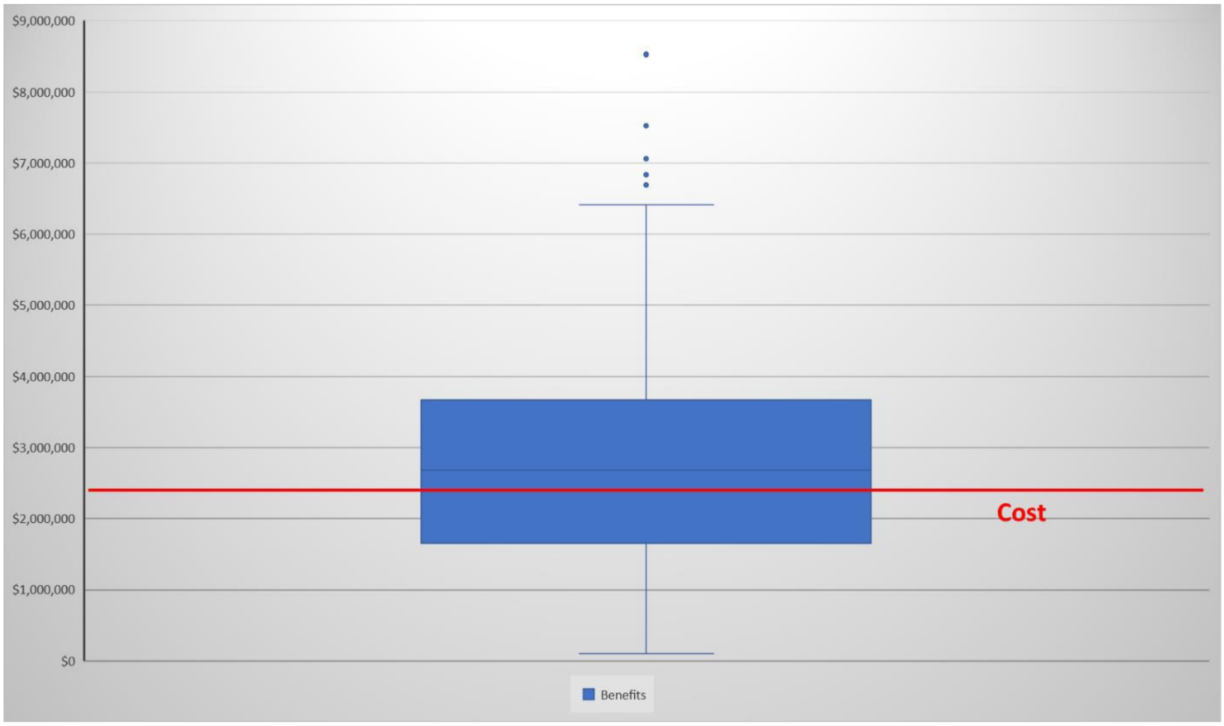


Figure 8-6: Ocean Park TSP Benefit Distribution Box and Whisker vs. Cost (AAEQ)

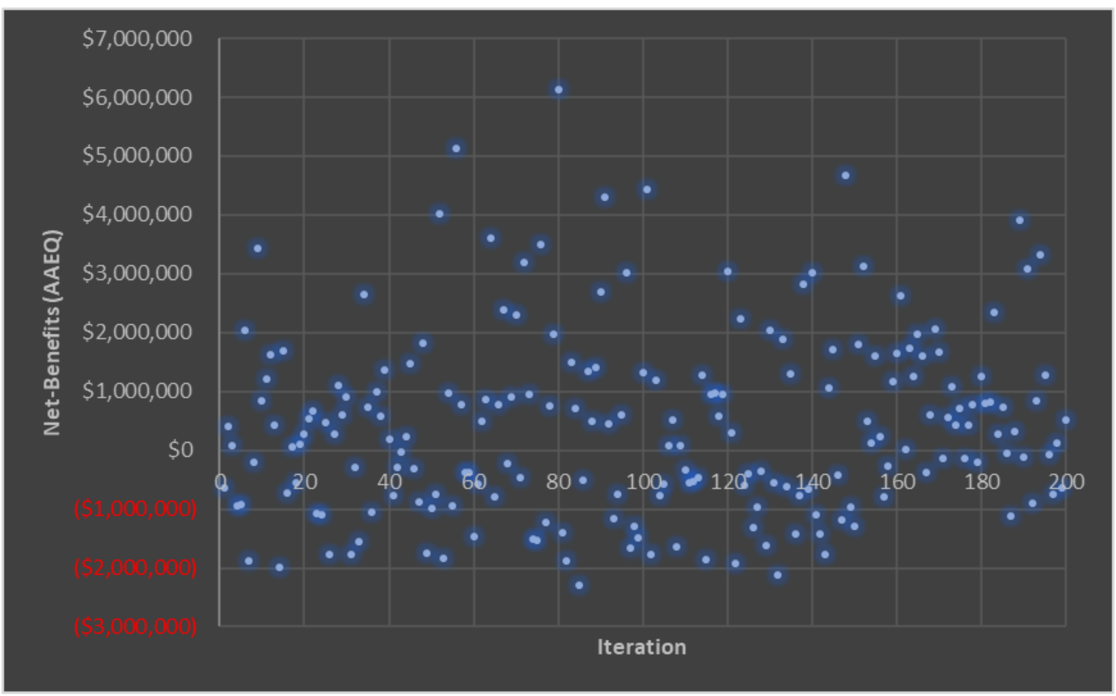


Figure 8-7: Net-Benefit Scatter Plot

9.4 Ocean Park TSP Benefit Summary

The 7' elevation (PRVD02) Floodwall in Ocean Park will increase resiliency to the community and provides a large portion of benefits to communities that have been economically disadvantaged. The TSP is effective in reducing the risk of large NED economic damages as well as effective in reducing the risk to local business owners through decreased business interruptions. The current configuration of the TSP also provides some additional recreation benefits by opening up more beach access for visitors and residents, which is not often the case with floodwalls.

National Economic Development	NED Primary Benefits	$ 2,816,000
	NED Cost	$ 2,396,000
	NED Primary Net-Benefits	$ 420,000
	NED Primary BCR	1.2
	Recreation Benefits	TBD
	NED Net-Benefits With Recreation	TBD
	NED BCR with Recreation	TDB
Regional Economic Development	Business Interruptions Prevented	6,878
Other Social Effects	Percent of Benefits Accruing to historically economically disadvantaged communities	42%