FLAGLER COUNTY, FLORIDA

HURRICANE AND STORM DAMAGE REDUCTION PROJECT
FINAL INTEGRATED FEASIBILITY STUDY AND
ENVIRONMENTAL ASSESSMENT

Appendix C

Economics

US Army Corps of Engineers ®
Jacksonville District

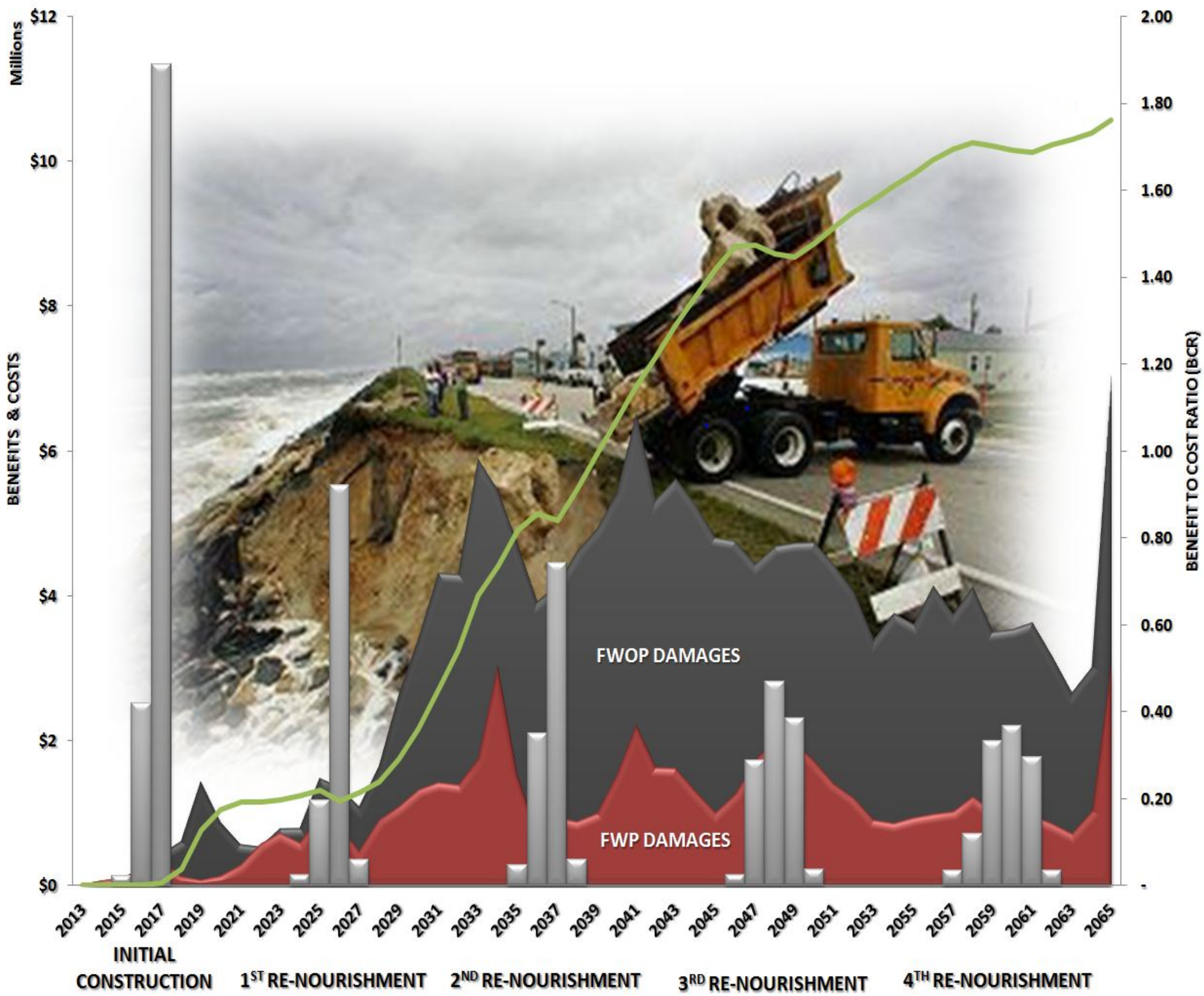
FLAGLER COUNTY, FL

HURRICANE AND STORM DAMAGE REDUCTION STUDY

APPENDIX – C: ECONOMICS

US Army Corps of Engineers, Jacksonville District

8/27/2014



1. EXECUTIVE SUMMARY

Flagler County is located on the northeast coast of Florida to the immediate south of St John's County, and the immediate north of Volusia County. Portions of Flagler County's 18 mile shoreline are subject to erosion caused by both storms and natural shoreline processes. A study was undertaken to assess the feasibility of providing Federal Hurricane and Storm Damage Reduction (HSDR) measures to portions of the Flagler County shoreline. The local sponsor for this project, Flagler County, has indicated strong support for feasibility phase studies for hurricane and storm damage reduction (HSDR) purposes along their shoreline, and has declared willingness and the capability to share applicable costs in the current study. In support of the study, an investigation was performed to estimate the economic benefits of alleviating erosion, storm surge, and wave attack damage to coastal infrastructure.

Alternative Evaluation

Upon conduct of a preliminary screening, followed by a detailed evaluation of a final array of alternatives, the project delivery team has determined a National Economic Development (NED), and a Tentatively Selected Plan (TSP) for reducing coastal storm and erosion damage to infrastructure. These plans were evaluated using FY 2011 price levels and the FY2013 federal water resources discount rate of 3.75%, and a 50 year period of analysis with a base year of 2016. See Table 1-1 for more detail on the evaluation of the final array of alternatives[1]

Table 1-1: Alternative Net Benefits & BCRs

Alternatives	Brief Description	Location[2]	Net Benefits	BCR
A-Dune-H	Dune extension and 10' sacrificial berm	Reach A	$52,000	1.35
A-30	Dune extension and 30' sacrificial berm	Reach A	-$16,000	0.98
B-Dune-H	Dune extension and 10' sacrificial berm	Reach B	-$57,000	0.78
B-30	Dune extension and 30' sacrificial berm	Reach B	-$809,000	0.21
C-Dune-H (NED)	Dune extension and 10' sacrificial berm	Reach C	$1,387,000	2.72
C-30	Dune extension and 30' sacrificial berm	Reach C	$1,065,000	1.9
AC-Dune-H	Dune extension and 10' sacrificial berm	Reach A, Reach C	$1,814,000	2.61
AC-30	Dune extension and 30' sacrificial berm	Reach A, Reach C	$1,206,000	1.69

The plan with the highest net benefits is **AC-Dune-H**. It consists of a 10' dune and beach profile extension in 2 non-contiguous segments, Reach-A (1.7 miles) and Reach-C (2.6 miles). Typically the plan with the highest net benefits is the NED Plan. However, subsequent plan formulation efforts determined that public access in Reach A is negligible. Because Reach A is a separable element that does not have public access, it was screened out after the final array of alternatives had been modeled. More

[1] Costs were developed by SAJ District Cost Engineering personnel in FY2013 dollars and deflated back to 2011 price levels. The original real estate assessment was completed in FY2009, and updated to FY2011 prices using a stratified random sample.

[2] Reach-A is the Painters Hill section of the study area. It is primarily residential and has little public access. Reach-B is the Beverly Beach section of the study area and is located between Painters Hill to the North, and Flagler Beach to the South. Reach-C is located in Flagler Beach between the municipal pier to the north, and Gamble Rogers State Park to the South.

information about the public access issue and the final screening is presented in Section 6 of the main feasibility report.

The NED Plan

With alternative **AC-Dune-H** screened out, the plan with the highest net benefits is **C-Dune-H**. Therefore, it is the NED Plan and the Tentatively Selected Plan (TSP). This is also the plan with the highest Benefit-Cost-ratio (BCR). This plan consists of a 10' dune and beach profile extension in Reach-C only, which is approximately 2.8 miles in length. The following table provides a summary of the NED Plan with and without incidental recreation benefits added at FY14 price levels discounted with the FY14 Water Resources Discount Rate (3.5%). See Table 1-2 for more detail on the NED Plan.

Table 1-2: Economic Summary of the NED Plan

ECONOMIC SUMMARY	STORM DAMAGE REDUCTION BENEFITS	STORM DAMAGE REDUCTION + RECREATION BENEFITS	STORM DAMAGE REDUCTION + RECREATION + TRAFFIC RE-ROUTING BENEFITS
Price Level	FY14	FY14	FY14
FY14 Water Resources Discount Rate	3.50%	3.50%	3.50%
Average Annual Storm Damage Reduction Benefits	$2,159,000	$2,159,000	$2,159,000
Average Annual Recreation Benefits	$0	$72,000	$72,000
Average Annual Traffic Reroute Benefits[3]	$0	$0	$131,000
Average Annual Total Benefits	$2,159,000	$2,231,000	$2,362,000
Average Annual Cost	$1,239,000	$1,239,000	$1,239,000
Average Annual Net Benefits	$920,000	$992,000	$1,123,000
Benefit Cost Ratio	**1.74**	**1.80**	**1.91**

[3] See Addendum B for more information on the estimation of traffic reroute benefits. Here, traffic reroute benefits are based on 2013 AAA Vehicle Operating Cost. Average Annual Benefits were reduced by 26% to only include the gas, oil, maintenance, and depreciation portion of the per mile vehicle operating cost.

TABLE OF CONTENTS

THE TABLES……

THE FIGURES…………

1. INTRODUCTION

The purpose of this economics appendix is to tell the story of the economics investigation, and provide greater detail on the results of the analysis. The sections that follow 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.
- **Hurricane & Storm Damage Reduction Benefits:** This section will cover the methods used to estimate the future without, and future with project condition using Beach-fx, accounting for risk and uncertainty. The future without project condition will cover the distribution of the damages in the following dimensions:
    - Spatial (Where)
    - Categorization of structures (What)
    - Damage driving parameter (How)
    - Temporal (When)
    - The future with project condition discussion will address the alternatives evaluated, and the analysis results. In addition, an analysis of alternative performance under the intermediate and high sea level change scenarios is provided.
- **NED & TSP Plan Selection and Performance:** This section addresses the rationale for NED and TSP selection. A detailed description of the performance of the NED Plan is provided with the same 4 dimensions given in the Hurricane & Storm Damage Reduction section. A discussion on the project's incidental recreation benefits is also provided.

2. EXISTING CONDITIONS

All structure and content values presented in this section are in FY2011 price levels.

2.1 Socio-Economic Conditions

Flagler County is located on the northeast coast of Florida. It has more than seventeen miles of coastline along the Atlantic Ocean. The largest cities in Flagler County are Palm Coast, Flagler Beach, and Bunnell. Much of the study area in the Feasibility study is located within the City of Flagler Beach.

2.1.1 Demographic Characteristics

According to the US Census Bureau, the 2010 population of Flagler County was 95,696, making it the 25th most populous county in Florida (of 67 counties). In past several years, the county has seen rapid population growth. In fact, between 2000 and 2010, the county grew by approximately 92.0%.[1] According to a report by the University of Florida[2], Flagler County is expected to continue growing at a relatively fast pace. The population is estimated to be 136,900 by 2020 and 215,400 by 2040. These projections suggest that Flagler may be one of Florida's fastest growing counties over the next 30 years. The ethnic makeup of Flagler County is relatively homogeneous. Caucasians make up approximately 75.9% of the population[4]. The largest minority group is African Americans, which make up approximately 11.7%. Non-white Hispanics make up 9.0%. All other racial groups make less than 5% of the total population[4].

2.1.2 Economic Characteristics

Flagler County has a service based economy that has benefitted from a gradual influx of retirees since the late 1980s. Currently, the proportion of the population that is 62 years or older is 28.9%, which is well above the national (16.2%) and state average (20.9%).[4] The vibrant service sector includes banking/finance, real estate, insurance, healthcare, and related commercial businesses. The percentage of the workforce employed in social services (defined as educational services, healthcare, or social assistance) is 25.5%, which is above the national (22.8%) and state average (22.5%).[4] Other than services, the primary economic activities in Flagler County are building/construction, tourism, and agriculture.

With several notable attractions located within its borders, tourism is a critical component of the Flagler County economy. In addition to miles of beaches, the county posses numerous access points to the Intercostals Waterway, which is a popular destination for recreational fishing and boating as well as related activities (i.e. water skiing). The county is home to six state parks and "Marineland", one of Florida's original marine mammal parks. Flagler County also benefits from an appealing location between major tourist hubs St. Augustine (to the north) and Daytona (to the south).

---

[1] Source: United States Census Bureau, American Fact Finder

[2] Martinovich, Milenko and Smith, Stan. *Florida population soars in century's first decade, but rate is slowing*. University of Florida News. June 13, 2011.

In addition to tourism, agriculture is an important economic activity in Flagler. According the United States Department of Agriculture, Flagler County has more than 8,000 acres of actively harvested crop land. The largest crops are citrus and potatoes[3]. Livestock farming is also an important activity. The county has several thousand acres of pasture land that support both beef and pork operations.

Income

On average, Flagler County's socioeconomic composition is comparable to the state of Florida. The median household income is $48,708, compared to $ $47,827 for the state of Florida (Census 2010). As of 2010, the percent of individuals living below the poverty line is 13.3%, compared to 14.7% for the state average (Census 2010). The per capita income is $24,455 compared to $26,733 for the state average. The unemployment rate is 10.3%, compared to 8.7% for the state average.

2.2 Data Collection

Economists and real estate specialists have collected and compiled detailed structure information for 9.6 miles of Flagler County's 18 mile coastline, which includes: over 600 single family homes; 102 different multi-family structures; 124 commercial buildings; 9.6 miles of road; and over 477 other structures that are vulnerable to future hurricane and storm damages. In addition, data was collected on nearly 3 miles of coastal armor within Flagler County. In total, over 1,908 damageable structures were collected for economic modeling using Beach-*fx*. The structure inventory includes all structures that are within 500 feet of the mean high water line.

Real Estate professionals from the USACE Jacksonville district (SAJ) using geo-spatial parcel data from Flagler County provided detailed data on each structure including: geographic location, structure type, foundation type, construction type, width, length, number of floors, depreciated replacement value, and year built. Elevation data for enclosed structures was collected by a survey contractor and FEMA elevation certificates were provided by Flagler County. The elevations of paved surfaces such as roads, and parking lots were acquired from USACE SAJ LIDAR data.

Data on all coastal armor was collected from a variety of sources including Florida Department of Transportation (FDOT) contractors, site visits, aerial ortho-photography, and USACE SAJ Coastal Engineering personnel. Coastal armor value was determined by USACE SAJ Cost Engineering personnel.

The Flagler County study area was disaggregated into 4 study reaches, consisting of 6 profiles, 46 model reaches, 315 and lots, for economic modeling and reporting purposes.[4] This hierarchical structure is depicted as follows:

---

[3] United Stated Department of Agriculture. *Cropscape Agricultural data layer*. USDA National Agricultural Statistics Service. 2012

[4] Originally, the study area consisted of 50 model reaches. The Marineland segment was removed from the study area because the structures along the shoreline receive adequate protection from a large granite revetment.

- **Profiles:** Coastal surveys of the shoreline modified by USACE Jacksonville District (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.
- **Study Reaches:** Consists of the political/administrative boundaries of the following cities, townships, municipalities: Painters Hill, Beverly Beach, and Flagler Beach. The distribution of the study area is shown in Table 2-1.
- **Design Reaches:** Refined study reaches used in the economic analysis. The distribution of the study area is shown in Table 2-1.
- **Beach-*Fx* Model Reaches:** Quadrilaterals parallel with the shoreline used to incorporate coastal morphology changes for transfer to the lot level. Model reaches are also useful for dividing study reaches into more manageable segments for analysis.
- **Lots:** Quadrilaterals encapsulated within model reaches used to transfer the effect of coastal morphology changes to the damage element. Lots are also repositories for coastal armor costs, specifications, and failure threshold information. They are referred to in this section for information purposes only.
- **Damage Elements:** Represents a unit of the existing condition coastal inventory and a store of economic value subject to losses from wave attack, inundation, and erosion damages. Damage elements are a primary model input and the topic of focus in this discussion. The primary structure categories are coastal armor and coastal structures.

Table 2-1: Spatial Distribution of Study Area

Municipal	Design Reach	# Miles	Length (ft)	% of Municipality within Study Reach	% of Total
Painters Hill	Reach-A	1.74	9,168	100%	19%
Beverly Beach	Reach-B	1.11	5,841	100%	12%
Flagler Beach	Reach-B	2.16	11,407	35%	24%
	Reach-C	2.80	14,809	46%	31%
	Reach-D	1.18	6,246	19%	13%
Total		8.99	47,471		

The distribution of study reaches, model reaches, and lots for Flagler County are depicted further in Table 2-2.

Table 2-2: Distribution of Model Reaches, & Lots

Design Reach	# Model Reaches	Length (ft)	% of Total
Reach-A	10	9,168	19%
Reach-B	17	17,248	36%
Reach-C	14	14,809	31%
Reach-D	5	6,246	13%
Total	**46**	**47,471**	**100%**

2.2.1 Refined Model Reaches

Early on in the feasibility study, the study area was broken into broad geographic areas (Marineland, Painter's Hill, Flagler Beach, etc) which were referred to as "study reaches". Later in the modeling effort, the study reaches were refined based on engineering and socioeconomic characteristics. As a result, the study reaches used in the economic analysis differ slightly from the original study reaches. The new study reaches are referred to as "design reaches". Figure 3-3 provides a comparison between the design reaches in the economic analysis and the study reaches as they were originally defined. The main report still organizes results by study reach (i.e. geographic area). The appendixes organize results by design reach because all model runs used for alternative comparison analysis were based on the revised design reaches.

The most significant difference between the original areas and the current design reaches is Marineland, an area several miles north of all the other reaches. Preliminary model runs indicated that FWOP damages in Marineland were minimal (less than $2 million in present value damage). This is because the area is already protected by large revetment, and because there are few structures subject to damage. As a completely separable element with only minor damage, it was screened out. This is notable because, though Marineland results are excluded in this appendix, they are reported in the Main feasibility report.

Table 2-3: Summary of Original and Revised Study Reaches

<table>
<tr><th>FDEP R-monument</th><th>Study Reaches</th><th>Preliminary Beach-fx Reaches</th><th>Design Reaches</th><th>Beach-fx Model Reaches</th></tr>
<tr><td>R-1, R-2, R-3, R-4</td><td>Marineland</td><td>ML-1 to ML-4</td><td>NONE</td><td>NONE</td></tr>
<tr><td colspan="5">No reaches between R-4 and R-50</td></tr>
<tr><td>R-50, R-51, R-52, R-53, R-54, R-55, R-56, R-57, R-58, R-59</td><td>Painter's Hill</td><td>PH-1 to PH-10</td><td>Reach A</td><td>RA-1 to RA-10</td></tr>
<tr><td>R-60, R-61, R-62, R-63, R-64, R-65, R-66</td><td>Beverly Beach</td><td>BB-1 to BB-5</td><td rowspan="2">Reach B</td><td rowspan="2">RB-1 to RB-17</td></tr>
<tr><td>R-67, R-68, R-69, R-70, R-71, R-72, R-73, R-74, R-75, R-76, R-77, R-78, R-79</td><td rowspan="3">Flagler Beach</td><td rowspan="3">FB-1 to FB-31</td></tr>
<tr><td>R-80, R-81, R-82, R-83, R-84, R-85, R-86, R-87, R-88, R-89, R-90, R-91, R-92, R-93, R-94</td><td>Reach C</td><td>RC-1 to RC-14</td></tr>
<tr><td>R-95, R-96, R-97, R-98, R-99, R-100, R-101</td><td>Reach D</td><td>RD-1 to RD-5</td></tr>
</table>

The purpose of the feasibility report is to tell the entire story of plan formulation. The purpose of the economics appendix is to provide a technical guide to methods, assumptions, and results of the economic analysis. The economic analysis used for alternative comparison was completed using the current design reaches (A,B,C,D). Thus, Marineland is not included in the Engineering and Economic Appendix.

Another important note is that, for modeling purposes, the broad areas are broken up into smaller increments. Originally, these increments were called preliminary Beach-fx Reaches (PH-1, PH2 or FB-1, FB-2, etc.). And, they are still referred to as preliminary Beach-fx reaches in the main report. However, once the study reaches were refined for the alternative analysis, their names changed. Now they are referred to as Beach-fx model reaches. So, for example, the first study reach (i.e. small model increment) in Painter's Hill was previously referred to as PH-1. Now this same increment is a Beach-fx model reach; it is called "A-1". The economics appendix uses the later nomenclature (Design Reaches and Beach-fx Model Reaches) in all charts and figures.

2.3 Existing Condition Coastal Structure Inventory

Information on the existing economic conditions along the Flagler County coastline was collected for economic modeling purposes using Beach-*fx*. The information on the coastal assets detailed in this section was collected from Flagler County mapping resources, site visits, and contractors. Each parcel along the beach was identified as developed or undeveloped, with streets and parks noted. USACE real estate specialists provided depreciated replacement value of existing structures within the study area.

Coastal armor was inventoried, categorized, and valued based on its composition and level of protection afforded.

2.3.1 Coastal Armor

Coastal armor within the study area was categorized into a number of different types based on construction type, material and elevation. The types of coastal armor were granite revetments, precast concrete panel sea walls, steel sheet pile sea walls, and vinyl bulkheads.

- **ARMOR-A1A:** This type represents the economic costs associated with maintaining the existing revetment and SR-A1A.
- **NEW ARMOR-A1A**: Represents the initial economic cost incurred when erosion gets to within 10-15 ft of the road, which will require repair and/or replacement of the revetment along A1A.
- **BULKHEAD:** Vinyl sheet pile bulkheads erected to protect private residences from erosion
- **N-BULKHEAD:** Represents the economic cost of constructing vinyl sheet pile bulkheads in the future should erosion come within 20 ft of a residence.
- **ROAD1:** Road other than SR-A1A

Coastal armor in Marineland consists of a 1,350-foot granite revetment and a 1,500-foot steel sheet pile sea wall covered by a dune. This shoreline protection effort began after Hurricane Floyd caused significant damage to the area in 1999. Marineland's coastal armor is valued at nearly $10 M.
The only coastal armor found in Painters Hill were two lots with vinyl bulkhead armor units with crest elevations at grade level valued at nearly $232,500. In Beverly Beach there is a large 1,560 foot precast concrete panel sea wall providing protection for an RV park valued at $830,000.

Flagler Beach has the most armor in the study area, much of which is in varying stages of disrepair. There is a 420 foot precast concrete panel sea wall starting 285 feet north of the pier. Starting at 7th St. South and ending at 23rd St. South, there is approximately 15,000 feet of granite revetment maintained by the Florida Department of Transportation (FDOT). This revetment was originally built in the 1960s and 1970s, with additional newer stone being placed during maintenance and repairs. According to FDOT contractors, this revetment is maintained at an annual cost of approximately $1.5 million. Within this area is a steel sheet pile sea wall with concrete cap approximately 150ft in length between 12th St. South and 13th St. South. This armor unit was constructed in December 2005 by FDOT to protect SR A1A from being undermined by erosion. Approximately 410 feet south of 28th street are small precast concrete panel sea walls protecting several commercial concerns toward the southern end of the county. The damageable revetment and road value in Flagler Beach is estimated to be nearly $7.5 M (See Table 2-4).

Significant portions of the study area are protected by coastal armor. In one segment, called Design Reach-C by the study team, the primary structure subject to erosion damage in the baseline future-without project condition is a major road (SR-A1A), which is protected by a rock revetment (see Figure 2-1). This revetment is maintained by the Florida Department of Transportation (FDOT). Data from the FDOT suggest that in the ten year period between 2001 and 2010, an average of approximately $600,000 per year was spent maintaining the revetment. In one year (2001), total maintenance costs exceeded $3 million. Because of the nature of the structure inventory in Design Reach C, prevention of damages to armor represents the largest potential benefit category.

Table 2-4: Existing Damageable Road & Armor Value

Design Reach	Revetment & SR-A1A	Vinyl Bulkhead	Sea-walls
Reach-A		$232,500	
Reach-B			$1,141,250
Reach-C	$7,490,253		
Reach-D			

Figure 2-1: Revetment protecting SR-A1A in Flagler Beach

2.3.2 Structure & Contents Value

The economic value of the existing Flagler County structure inventory represents the depreciated replacement costs of damageable structures and their associated contents along the coastline. Real Estate professionals from the USACE SAJ district worked together with economists and planners to provide economic valuations for all of the 1,301 damageable structures and their contents. These structures have an overall estimated value of $268 M, with structure and content valuations of $177 M and $91 M respectively. The overall distribution of value by study reach is as follows:

Table 2-5: Distribution of Structures & Structure Value by Study Reach

Design Reach	# of Structures	% Structures	Total	% of Value
Reach-A	221	17%	$38,998,933	15%
Reach-B	507	40%	$116,076,382	43%
Reach-C	472	37%	$83,792,131	31%
Reach-D	65	5%	$29,554,554	11%
Total	1265	100%	$268,422,000	100%

Values aggregated by study reach and model reach show significant variation due to differentiation between the type, magnitude, and density of development. Reaches with large commercial or multi-family structures tend to contain greater value than neighboring reaches. Table 2-5 and Table 2-6 provide summaries of inventory values by study reach. A graphical representation is provided in Figure 2-2.

Estimating content values is an important part of developing the structure inventory. Typically, content-to-structure value ratios (CSRVs) are used to define content value as a percentage of the depreciated structure value. In this case, a ratio of 0.50 has been applied to all structures in the study. Given the lack an appropriate empirical study about content values in south Florida, this is a conservative, reasonable assumption that is consistent with ER 1105-2-100. It should be noted that there were a few exceptions to the 0.50 ratio assumption, because there are a number of structures that typically do not have valuable contents. Gazebos, Dunewalks, and pools are examples of structures for which the CSVR was assumed to be zero.

Table 2-6: Economic Value of Structure Inventory by Design Reach

Structure Category	Reach-A	Reach-B	Reach-C	Reach-D	Total	% of Total
Residential	$36,009,849	$84,751,004	$66,578,902	$27,114,814	$214,454,568	**80%**
Public/ Commercial	$1,244,060	$27,185,162	$14,653,002	$766,580	$43,848,804	**16%**
Other Structures	$1,745,024	$4,140,217	$2,560,227	$1,673,160	$10,118,628	**4%**
Total	**$38,998,933**	**$116,076,382**	**$83,792,131**	**$29,554,554**	**$268,422,000**	**100%**

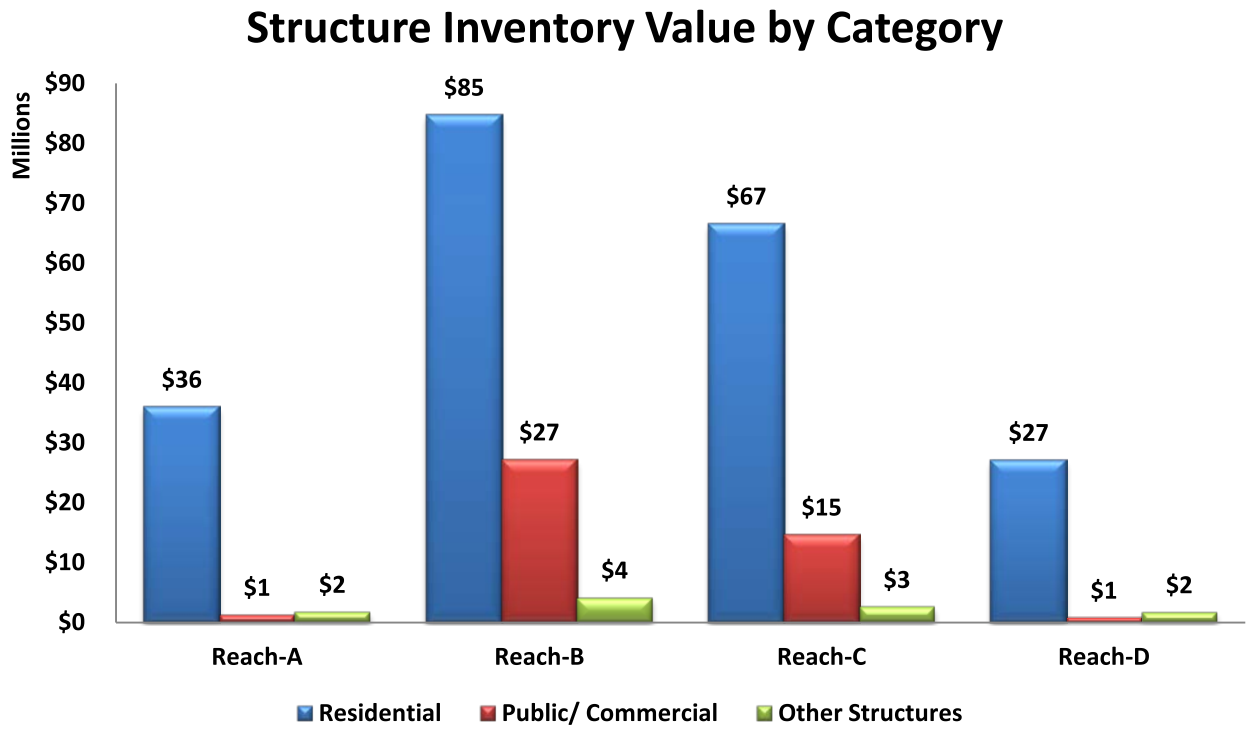


Figure 2-2: Economic Value of Structure Inventory by Design Reach

2.3.3 Residential (SFR)

Single- family residences consist of 1-3 story structures of varying construction type and value. They comprise 47% of the inventory and 56% of the inventory value within the study area. Reach-A, which is made up of Painters Hill, tends to have the greatest value per structure relative to the other three segments. It accounts for 18% of the inventory of single family residences, but 23% of the structure inventory single family residence value. Reach-B contains the second largest number of SFRs and SFR value within the structure inventory. Reach-C has the greatest number of older relatively less valuable residences with 45% of the inventory, and less than 39% of the SFR inventory value.

2.3.4 Multi-Family Residences

Multi-family residences constitute 8% of the structures, and 23% of the existing value. These structures range from 1-4 stories tall. Structures within this category tend to be more substantial in terms of construction, and contain the greatest amount of economic value per structure within the study area. Most of the multi-family residences are located in Reach-B (45%) and Reach-D (43%).

2.3.5 Commercial / Public Structures

Structures within this category include 1-2 story buildings used for public or commercial purposes. Commercial and public buildings represent nearly 9% of the existing structure inventory, and 16% of the overall study area value. Around 94% of these buildings are located in Reach-B (59%) and Reach-C (35%).

2.3.6 Other Structures

This category consists of relatively lower value damageable elements such as garages, storage buildings, dune walks, decks, swimming pools, wood shelters, and parking lots. These structures constitute nearly 36% of the inventory, but only 4% of the value. A detailed summary is provided in Table 2-7.

Table 2-7: Structure Inventory Distribution

Design Reach	Frequency	% of Single Family Structures	% of All Structures	Total	% of Single Family Structure Value	% of Total Value
Reach-A	112	18.6%	8.9%	$35,583,129	23.5%	13%
Reach-B	218	36.2%	17.2%	$56,713,214	37.4%	21%
Reach-C	272	45.1%	21.5%	$58,956,489	38.9%	22%
Reach-D	1	0.2%	0.1%	$227,136	0.1%	0%
Total	603	100%	47.7%	$151,479,967	100%	56%

Design Reach	**Frequency**	**% Multi-Family Structures**	**% of All Structures**	**Total**	**% of Multi-Family Structure Value**	**% of Total Value**
Reach-A	1	1%	0.1%	$426,720	1%	0%
Reach-B	52	51%	4.1%	$28,037,790	45%	10%
Reach-C	35	34%	2.8%	$7,622,413	12%	3%
Reach-D	14	14%	1.1%	$26,887,678	43%	10%
Total	102	100%	8.1%	$62,974,601	100%	23%

Design Reach	**Frequency**	**% Public/Commercial Structures**	**% of All Structures**	**Total**	**% of Public & Commercial Structure Value**	**% of Total Value**
Reach-A	3	3%	0.2%	$1,244,060	3%	0%
Reach-B	65	59%	5.1%	$27,185,162	62%	10%
Reach-C	39	35%	3.1%	$14,653,002	33%	5%
Reach-D	3	3%	0.2%	$766,580	2%	0%
Total	110	100%	8.7%	$43,848,804	100%	16%

Design Reach	Frequency	% Other Structures	% of All Structures	Total	% of Other Structure Value	% of Total Value
Reach-A	105	23%	8.3%	$1,745,024	17%	1%
Reach-B	172	38%	13.6%	$4,140,217	41%	2%
Reach-C	126	28%	10.0%	$2,560,227	25%	1%
Reach-D	47	10%	3.7%	$1,673,160	17%	1%
Total	450	100%	35.6%	$10,118,628	100%	4%

3. <u>HURRICANE & STORM DAMAGE REDUCTION BENEFITS</u>

This section of the appendix covers the approach used to estimate the economic benefits of reducing hurricane and storm related damages in Flagler County using Beach-*fx*. The topics covered include:

- Benefit estimation approach using Beach-*fx*
- The future without project condition
- The future with project condition

3.1 Benefit Estimation Approach using Beach-fx

Beach-*fx* was developed by the USACE Engineering Research and Development Center (ERDC) in Vicksburg, Mississippi. On April 1, 2009 the Model Certification Headquarters Panel certified the Beach-*fx* hurricane and storm damage reduction (HSDR) model based on recommendations from the HSDR - Planning Center of Expertise (PCX). The model was reviewed by the PCX for Coastal and Storm Damage and found to be appropriate for use in coastal storm damage reduction studies. 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. This output is then used to determine the benefits of each alternative. Beach-*fx* fully incorporates risk and uncertainty, and is used to simulate future hurricane and storm damages at existing and future years and to compute accumulated present worth damages and costs. Storm damage is defined as the damage incurred by the temporary loss of a given amount of shoreline as a direct result of waves, erosion, and inundation caused by a storm of a given magnitude and probability. Beach-fx is an event-driven life-cycle model that estimates damages and associated costs over a 50 year period of analysis based on storm probabilities, tidal cycle, tidal phase, beach morphology and many other factors. Damages or losses to developed shorelines include buildings, pools, patios, parking lots, roads, utilities, seawalls, revetments, bulkheads, replacement of lost backfill, etc. Beach-*fx* also provides the capability to estimate the costs of certain future measures undertaken by state and local organizations to protect coastal assets.

Data on historic storms, beach survey profiles, and private, commercial & public structures within the project area is used as input to the USACE Beach-*fx* model. The model is then used to estimate future project hurricane and storm damages.

The future structure inventory and values are the same as the existing condition. This conservative approach neglects any increase in value due to future development. Due to the uncertainty involved in projections of future development, using the existing inventory is preferable and considered conservative for Florida where coastal development has historically increased in density and value. The Beach-fx model results for the future with project (FWOP) condition are summarized in later in this section.

The future without project damages will be used as the base condition. Potential alternatives are measured against this base condition. The difference between with and without project damages will be used to determine project benefits.

Once benefits for each of the alternatives are calculated, they will be compared to the costs of implementing the alternative. Dividing the benefits of an alternative by the costs of the alternative yields a Benefit-to-Cost Ratio (B/C Ratio). This ratio must be greater than 1.0 in order for the alternative to be justified and implementable (i.e. the benefits must be greater than the costs). The federally preferred plan (NED – National Economic Development Plan) 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). Furthermore, each project area is evaluated on an incremental basis. That is, each portion of the project must be justified independently, or it cannot be constructed.

3.2 Assumptions

- **Start Year:** The year in which the simulation occurs is 2012
- **Base Year:** The year in which the benefits of a constructed federal project would be expected to begin accruing is 2018
- **Period of Analysis:** 50 years
- **Discount Rate:** 3.5% FY2013 Federal Water Resources Discount Rate
- **Coastal Armor Assumptions:**
    - As previously mentioned, the rubble revetment in Reach-C is maintained by the Florida Department of Transportation (FDOT). Data from the FDOT suggest that in the ten year period between 2001 and 2010, an average of approximately $600,000 per year was spent maintaining the revetment. Therefore, it is assumed that should erosion occur within 5-10 feet of the road, similar measures will be undertaken.
    - Armor costs were based on FDOT data collected between 2000 and 2011. The distribution of armor and road cost (respectively) per linear foot are as follows:
        - Minimum: $60.39 / $124.84
        - Most Likely: $348.01/ $461.16
        - Maximum: $650.48/ $555.31
    - If erosion occurs within 20-30 ft of a private residence on the seaward side of SR-A1A, it is assumed that homeowners will erect vinyl bulkhead armor units to protect their property.
- **Number of Times Rebuilding Allowed Assumptions**
    - Dunewalks: 4-10X
    - Armor / Road: 40X
    - Remaining: 5X

3.3 Future without Project Condition (FWOP)

Future without project condition damages range between $66.4 and $93.6M present value dollars. Descriptive statistics on the FWOP model results are as follows:

- Mean: PV $78,704,034 (AAEQ~ $3,355,156)
- Standard deviation: $5,769,298 (AAEQ~ $245,945)
- Median: $78,315,163 (AAEQ~ $3,338,575)
- # Iterations: 100

Figure 2-1 provides an illustration of FWOP results as a probability distribution. Approximately 85% of the distribution is between $68M and $79M. The distribution is also characterized by a relatively high peak and a slightly positive skew. This suggests that the uncertainty surrounding the damages is relatively small, and to the extent the damages deviate from the mean, they are more likely to be greater than the mean, rather than less.

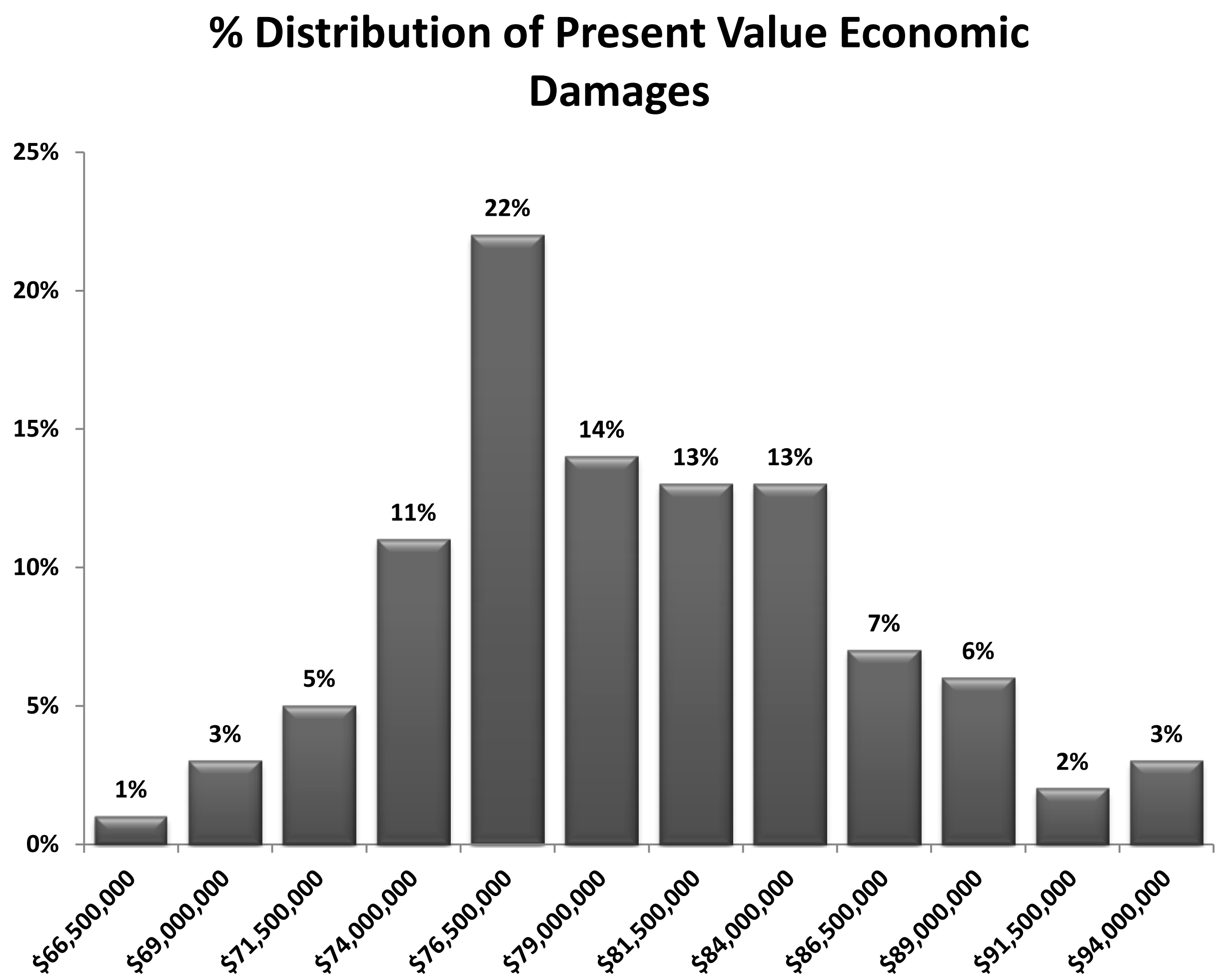


Figure 3-1: Probability Distribution of the Future without Project Condition Results

Pursuant to estimating future without project condition damages and associated costs for the study area in Flagler County, Beach-*fx* was used to estimate damages and costs in the following categories:

- Damages:
  - 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 virtually all of the damages for the FWOP.
  - Contents Damage: The material items housed within the aforementioned structures (usually air conditioned and enclosed) that are potentially subject to damage. Content damages are extremely small, making up about 0.75% of the total.

Coastal Armor Cost: Beach-*fx* provides the capability to estimate the costs incurred from measures likely to be taken to protect coastal assets and or prevent erosion in the study area. Based on the existence of coastal armor units throughout the study area, Beach-*fx* was used to estimate the costs of erecting such measures throughout the period of analysis. The following sections will address the FWOP damages distributed by structure type and category, damage driving parameter, space, and time.

3.3.1 Damage Distribution by Structure Category and Type

This section addresses what is being damaged in the future without project condition by structure category and type.

Table 3-1: Distribution of Damages by Damage Category

Category	Type	Structure	Contents	Total	% of Total
Armor / Roads	BULKHEAD	$6,359,601	$0	$6,359,601	8%
	N-BULKHEAD	$5,266,378	$0	$5,266,378	7%
	NEW ARMOR	$10,746,608	$0	$10,746,608	14%
	ARMOR-A1A	$50,273,763	$0	$50,273,763	64%
	ROAD1	$76,169	$0	$76,169	0%
Armor / Roads Subtotal		$72,722,519	$0	$72,722,519	92%
Other Structures	POOL	$34,989	$0	$34,989	0%
	DUNEWALK	$2,725,959	$0	$2,725,959	3%
	SHELTER	$650,495	$0	$650,495	1%
	STORAGE	$65,987	$40,912	$106,900	0%
	PARKING	$36,312	$0	$36,312	0%
	DECK	$180,290	$0	$180,290	0%
Other Structures Subtotal		$3,694,033	$40,912	$3,734,945	5%
Public/ Commercial	COMM1	$272,360	$190,652	$463,012	1%
	COMM2	$119	$6	$124	0%
Public/ Commercial Subtotal		$272,479	$190,658	$463,137	1%
Residential	SFR1	$236,864	$163,436	$400,300	1%
	SFR2	$680,457	$455,906	$1,136,364	1%
	MFR2	$35	$0	$35	0%
	SFR3	$1,133	$759	$1,892	0%
	MFR1	$192,789	$52,053	$244,842	0%
Residential Subtotal		$1,111,278	$672,155	$1,783,433	2%
Grand Total		$77,800,309	$903,725	$78,704,034	100%

Table 3-1 provides greater detail on the composition of the FWOP damages by categorization. The coastal inventory was categorized as 'Armor / Roads', 'Public / Commercial', 'Residential', and 'Other Structures'. The percentage distribution of the damages by category is as follows:

- Armor / Roads: 92%
- Other Structures: 5%
- Residential: 2%
- Public / Commercial: 1%

3.3.1.1 *Armor / Roads:*

The overwhelming majority of damages in this category include the cost of maintaining the revetment protecting SR-A1A and the estimated cost of new measures taken to protect SR-A1A. As shown in Figure

3-4 and Figure 3-2, the overwhelming majority of these costs are incurred in Reach-C. The Reach-C damages consist of primarily of maintenance to the existing revetment, and extension of the revetment to the south. Within Reach-A, the damages consist primarily of building and repairing the sheet pile vinyl bulkheads for structures designated armorable in the future.
The purpose of coastal armor is to protect coastal infrastructure from hurricane and storm damage. For this reason these structures not only absorb the strongest forces, but do so with the greatest frequency.

3.3.1.2 *Other Structures*

Other structures include garages, dunewalks, decks, outdoor shelters, and other relatively less expensive non-conditioned structures. This was the second highest category of damages due to the frequency of exposure to the damage driving parameters and proximity to the shoreline. Dunewalks receive the most damage within this category. These structures are rarely protected by coastal armor units, are built for outdoor use, tend to be closer to the shoreline, and tend to be less costly to rebuild. As a result, these damage elements are hit by the damage driving parameters more often, and rebuilt with a greater frequency. With the exception of garages and storage buildings, these damage elements are not subject to contents damage.

3.3.1.3 *Residential & Public / Commercial*

The remaining two categories constitute virtually insignificant proportions of the FWOP damages (~2.14%), but represent the overwhelming majority of the structure inventory value. These structures tend to be of more robust construction, located further away from shoreline, and protected by coastal armor units. All of these damage elements are subject to content damage.

3.3.2 Spatial Distribution of Without Project Damages

Reaches-A&C account for around 86% of the damages, while Reaches-B & D comprise the remainder. Reach-C accounts for the lion's share of total damage; significantly more than all other study reaches combined. These results are summarized in Table 3-2.

Table 3-2: FWOP present value damages by Design Reach

Design Reach	Damages	%
Reach-A	$14,527,576	18%
Reach-B	$7,587,015	10%
Reach-C	$53,514,849	68%
Reach-D	$3,074,593	4%
Total	**$78,704,034**	**100%**

Figure 3-2 provides an illustration of FWOP damages by model reach and structure category. Figure 3-3 illustrates the spatial distribution of damages and erosion rates by range monument. Both figures show greater damages between range monument R050 and R056, followed by smaller, relatively stable damages until range monument R080-R095. The spatial distribution of damages shows the following pattern:

- **Reach-A:**
  - **R050-R056**: Reach-A has relatively larger erosion rates and damages between R051 and R057. The average erosion rate is about .98 ft/yr.
  - **R056-R060**: The erosion rate and the damages decrease through this spatial increment.

- **Reach-B:**
  - **R061-R067**: Erosion rates are relatively small, averaging around .21 ft/yr. FWOP damages begin to creep upward moving southward.
  - **R067-R080**: Reach-B has relatively smaller erosion rates and more stable damages. However, erosion rates rise considerably at R066, and fall considerably at R079. There is a small increase in damages as the erosion rates creep upward, but nothing significant.
- **Reach-C:**
  - **R080-R083**: The erosion rates begin to move upward, and spike between R082-R083. The damages are larger between R080 and R081, but fall for the remainder of this range. The existing revetment begins around R080, and continues until R090.
  - **R083-R090**: Average erosion rates are relatively lower, averaging around .41 ft/yr through this spatial increment. However, the damages are the greatest within this spatial increment, primarily because this area contains majority of the existing revetment.
  - **R090-R095**: Erosion rates begin an upward creep, but damages begin to move down.
- **Reach-D:**

  R095-R000: This is the southernmost spatial increment in the study area. The erosion rates are relatively higher, but damages are relatively lower.

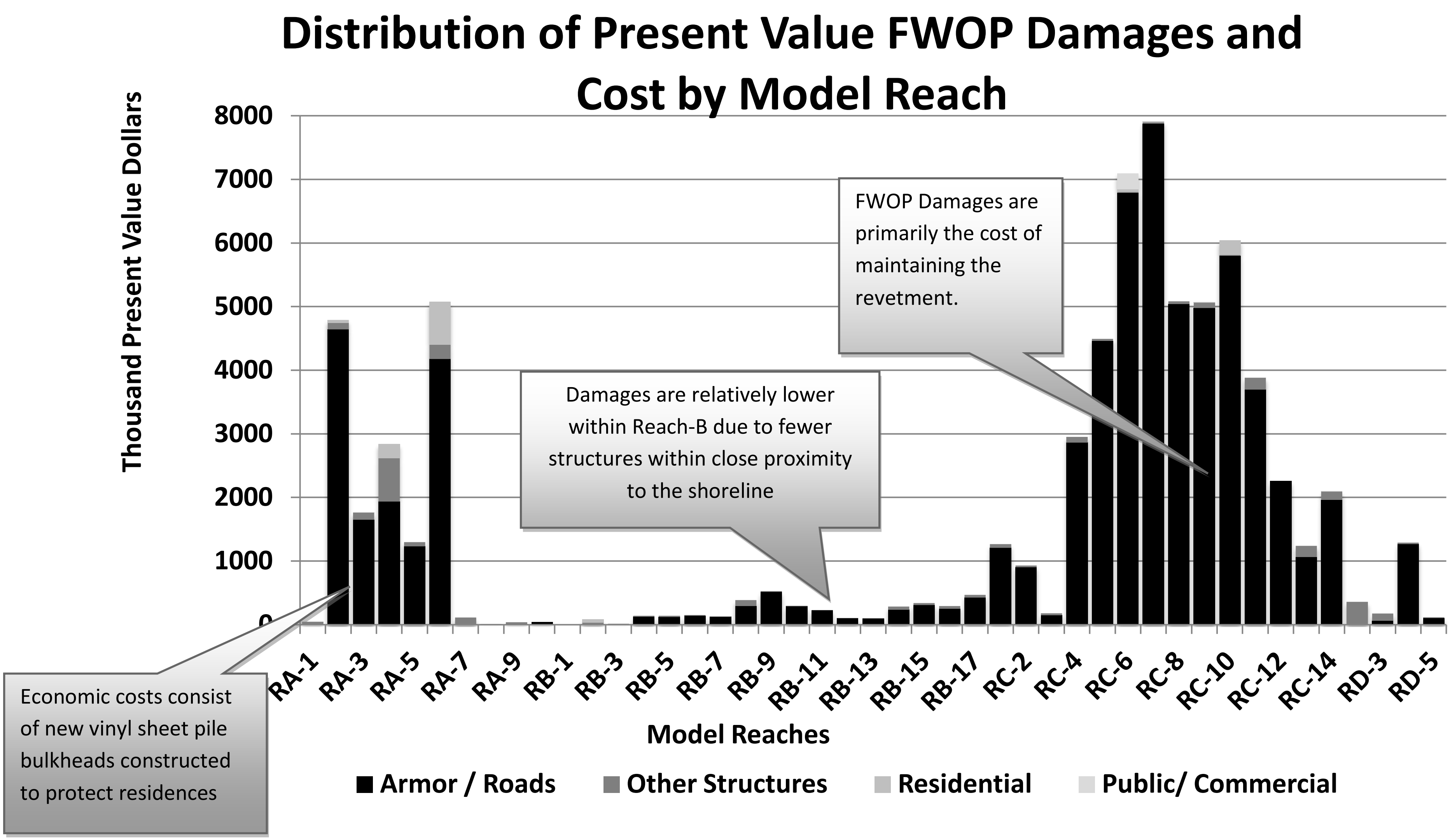


Figure 3-2: Distribution of FWOP Economic Damages by Model Reach

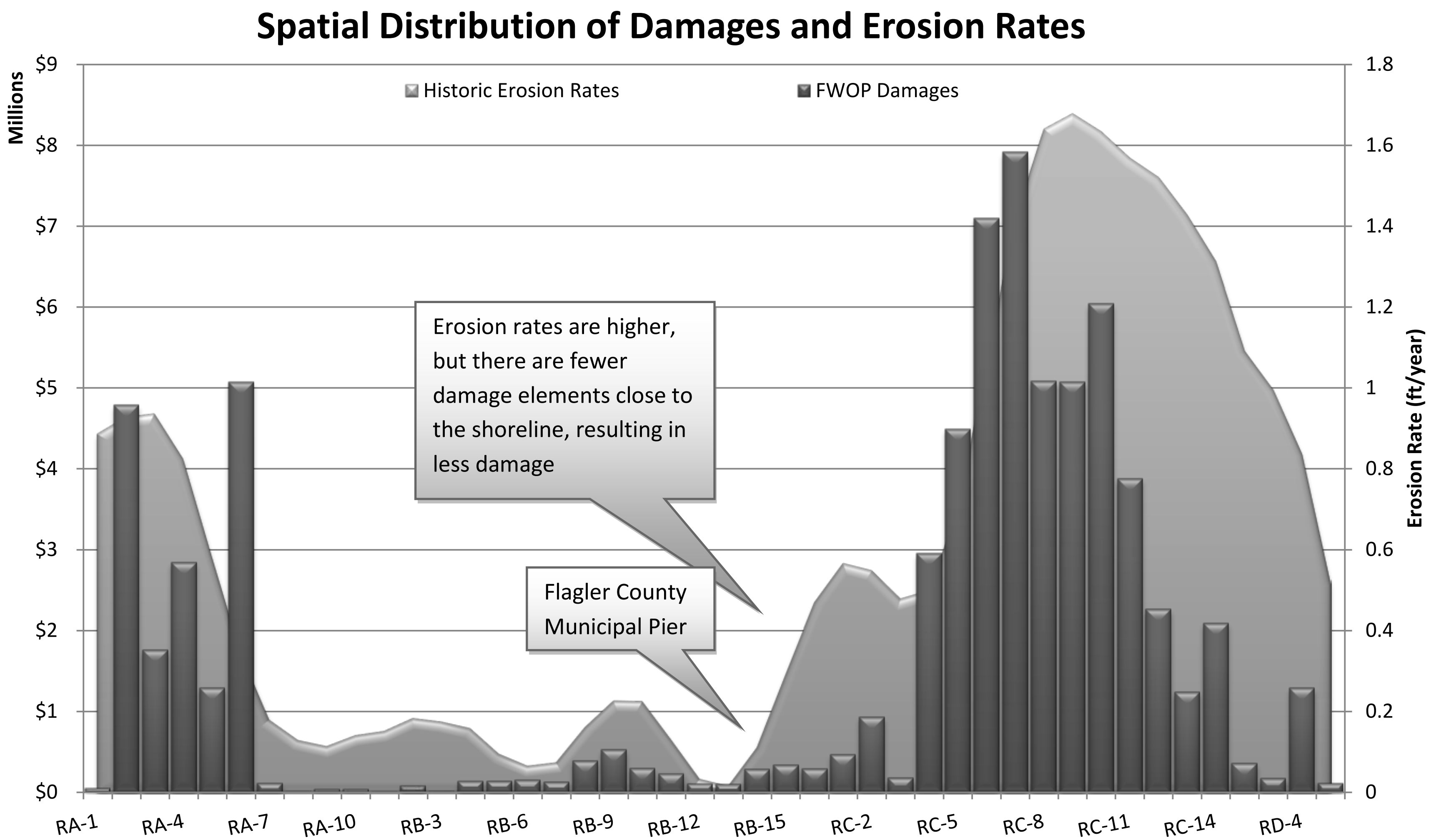


Figure 3-3: Spatial Distribution of Damages and Erosion Rates by Model Reach

Table 3-3: Spatial Distribution of Damages by Type

Number	Reach	Armor / Roads	Other Structures	Residential	Public/ Commercial	Total	% of Total
5	RA-1		$46,872	$3		**$46,875**	**0.1%**
6	RA-2	$4,643,295	$98,365	$49,205		**$4,790,866**	**6.6%**
7	RA-3	$1,648,593	$112,283	$439		**$1,761,315**	**2.4%**
8	RA-4	$1,933,873	$685,597	$223,765		**$2,843,235**	**3.9%**
9	RA-5	$1,229,364	$66,087			**$1,295,452**	**1.8%**
10	RA-6	$4,177,781	$225,759	$672,259		**$5,075,799**	**7.0%**
11	RA-7		$113,388			**$113,388**	**0.2%**
12	RA-8		$10,284			**$10,284**	**0.0%**
13	RA-9		$36,476			**$36,476**	**0.1%**
14	RA-10	$38,581				**$38,581**	**0.1%**
15	RB-1		$6,876			**$6,876**	**0.0%**
16	RB-2		$28,858	$50,541		**$79,400**	**0.1%**
17	RB-3		$13,612			**$13,612**	**0.0%**
18	RB-4	$124,214	$15,016			**$139,230**	**0.2%**
19	RB-5	$120,635	$19,417			**$140,052**	**0.2%**
20	RB-6	$137,318	$12,950			**$150,268**	**0.2%**
21	RB-7	$123,781	$3,849			**$127,630**	**0.2%**
22	RB-8	$290,807	$95,761			**$386,568**	**0.5%**
23	RB-9	$515,061	$9,355			**$524,416**	**0.7%**
24	RB-10	$287,943	$6,721			**$294,664**	**0.4%**
25	RB-11	$223,602	$4,081			**$227,682**	**0.3%**
26	RB-12	$101,140	$2,597			**$103,737**	**0.1%**
27	RB-13	$94,843	$2,805			**$97,648**	**0.1%**
28	RB-14	$233,163	$49,862			**$283,025**	**0.4%**
29	RB-15	$307,926	$29,055			**$336,981**	**0.5%**
30	RB-16	$248,613	$40,954			**$289,566**	**0.4%**
31	RB-17	$425,839	$40,527			**$466,366**	**0.6%**
32	RC-1	$1,207,150	$58,708			**$1,265,858**	**1.8%**
33	RC-2	$901,670	$27,090			**$928,760**	**1.3%**
34	RC-3	$148,373	$30,995			**$179,368**	**0.2%**
35	RC-4	$2,861,943	$90,978			**$2,952,921**	**4.1%**
36	RC-5	$4,460,612	$32,772			**$4,493,384**	**6.2%**
37	RC-6	$6,787,477	$15,373	$43,239	$250,034	**$7,096,124**	**9.8%**
38	RC-7	$7,877,107	$24,270	$13,730		**$7,915,108**	**11.0%**
39	RC-8	$5,042,495	$40,834			**$5,083,329**	**7.0%**
40	RC-9	$4,978,627	$82,877	$10,137		**$5,071,641**	**7.0%**
41	RC-10	$5,799,078	$10,264	$231,172		**$6,040,515**	**8.4%**
42	RC-11	$3,695,869	$185,092		$367	**$3,881,328**	**5.4%**
43	RC-12	$2,261,106				**$2,261,106**	**3.1%**
44	RC-13	$1,063,971	$174,826			**$1,238,797**	**1.7%**
45	RC-14	$1,962,829	$129,902	$264	$215	**$2,093,210**	**2.9%**
47	RD-2		$358,299			**$358,299**	**0.5%**
48	RD-3	$60,166	$113,340			**$173,506**	**0.2%**
49	RD-4	$1,265,624	$24,165			**$1,289,790**	**1.8%**
50	RD-5	$102,980	$11,386			**$114,366**	**0.2%**

As can be seen from the information in the tables, there is a great deal of variability in the amount of damages amongst the project reaches. This is explained by the large number of variables, all of which the Beach-*fx* model takes into account. Examples of variation between the project areas result from the following:

- Density and amount of development
- Typical size and value of structures
- Typical distance between structures and mean-high water
- Size, shape and location of the dunes and coastal morphology
- Rate of erosion for each reach
- Amount and type of coastal armoring present
- Eligibility of homeowners to construct coastal armoring.

3.3.3 Damage Distribution by Damage Driving Parameter

Virtually all of the FWOP damages and costs are attributable to erosion. The distribution of damages is as follows:

- Erosion: 99.49%
- Inundation: 0.05%
- Wave Attack: 0.47%

3.3.4 Temporal Distribution of Damages

Figure 3-4 provides an illustration of the FWOP condition armor and road economic costs over time. Figure 3-5 illustrates the damages over time by study reach, and Figure 3-6 displays the damages over time by structure category. It can be seen that the damages modeled in Reach-C during the first 10 years of the simulation (2013-2023) are actually less than the actual costs incurred by FDOT for maintaining the road from 2000-2010. It is only after 2027 in the model that without-project damages start to increase dramatically. Only after the cumulative effects of storms, sea level rise, and erosion over time begin to take their toll does the model begin to show significant damage. Model results indicate that the FWOP damages are likely to increase significantly in the mid to late 2020's, decrease somewhat by around 2050, but remain relatively high for the remainder of the period of analysis.

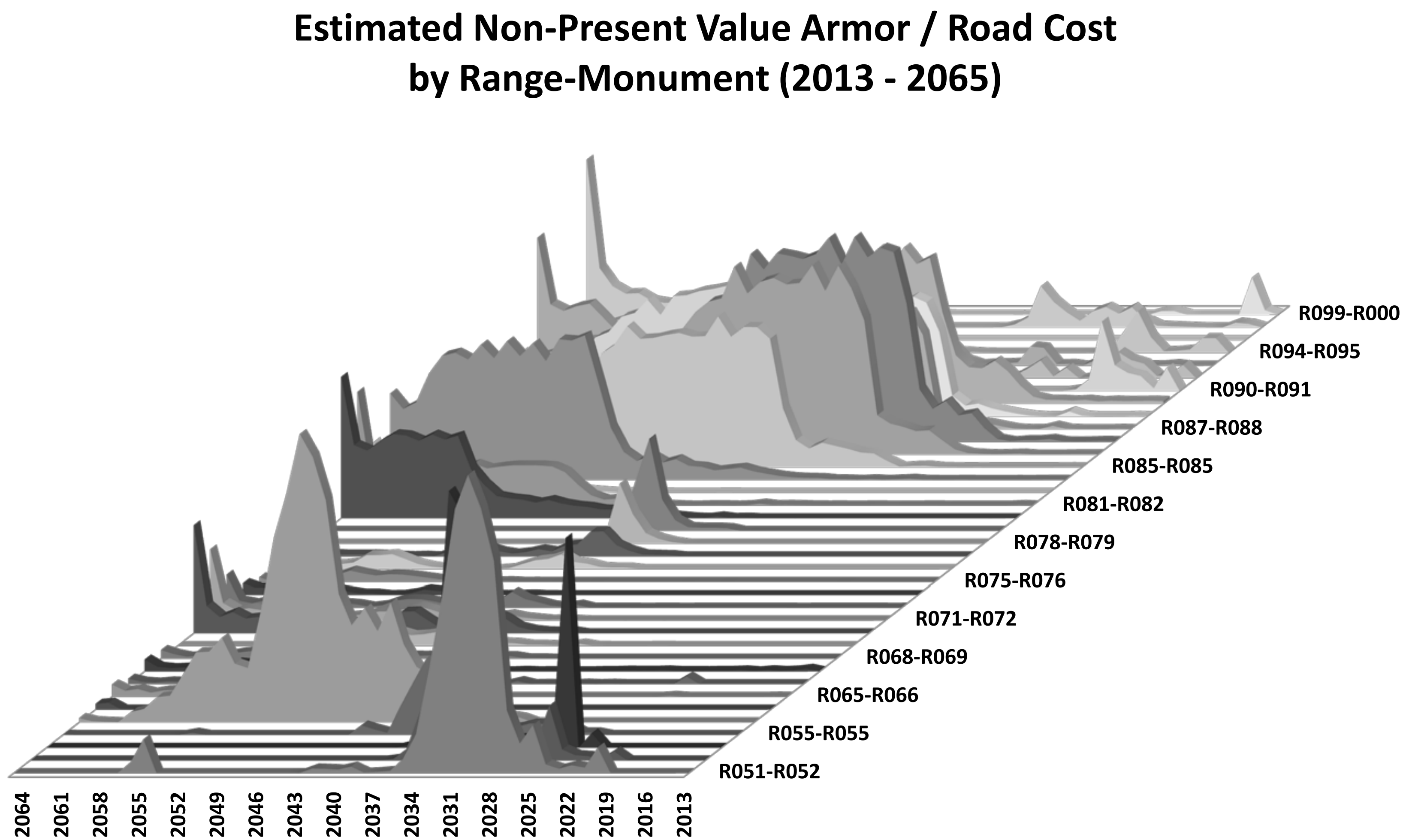


Figure 3-4: Distribution of Non-Present Value Armor/Road Cost over Space and Time

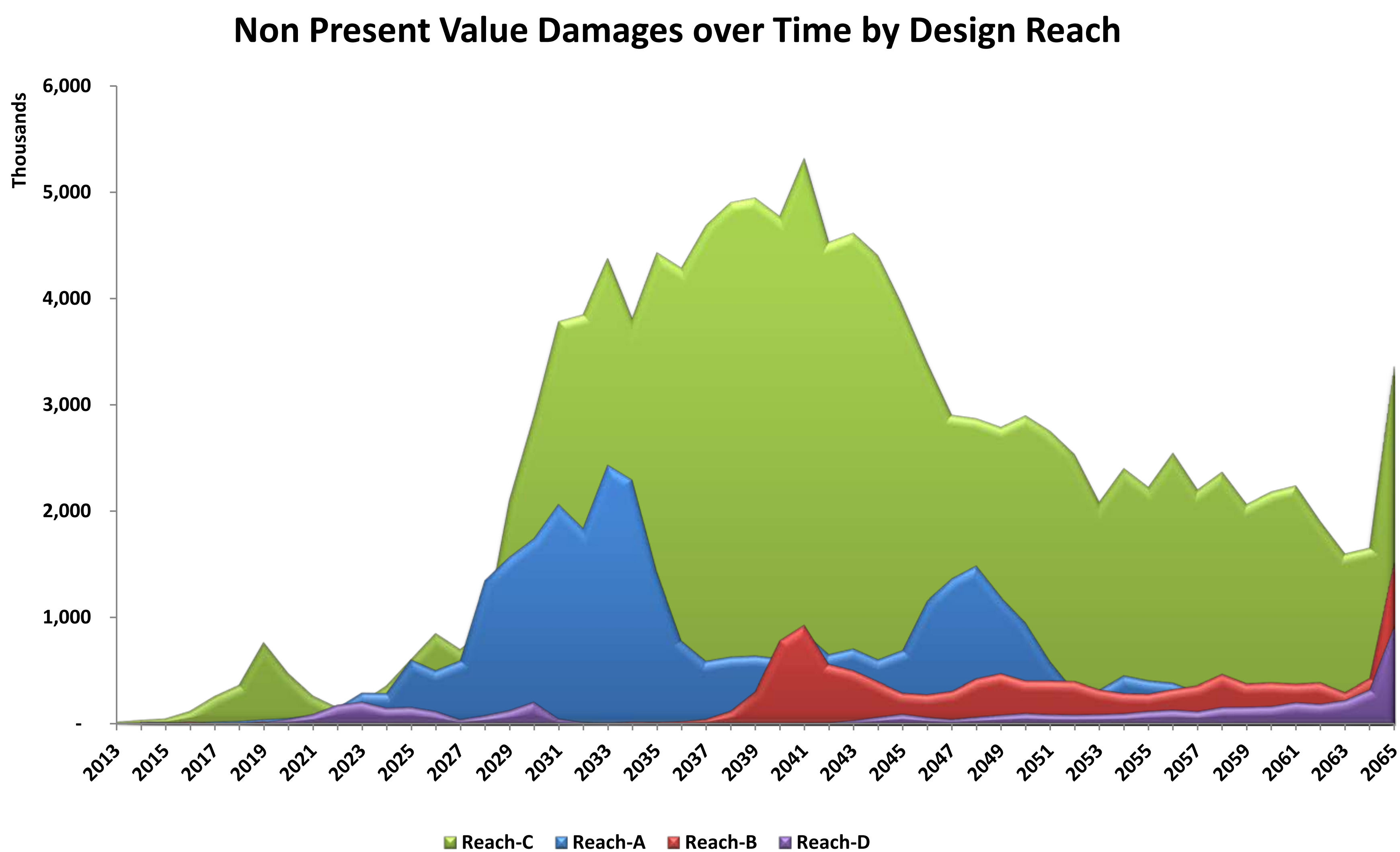


Figure 3-5: Damages over Time by Design Reach

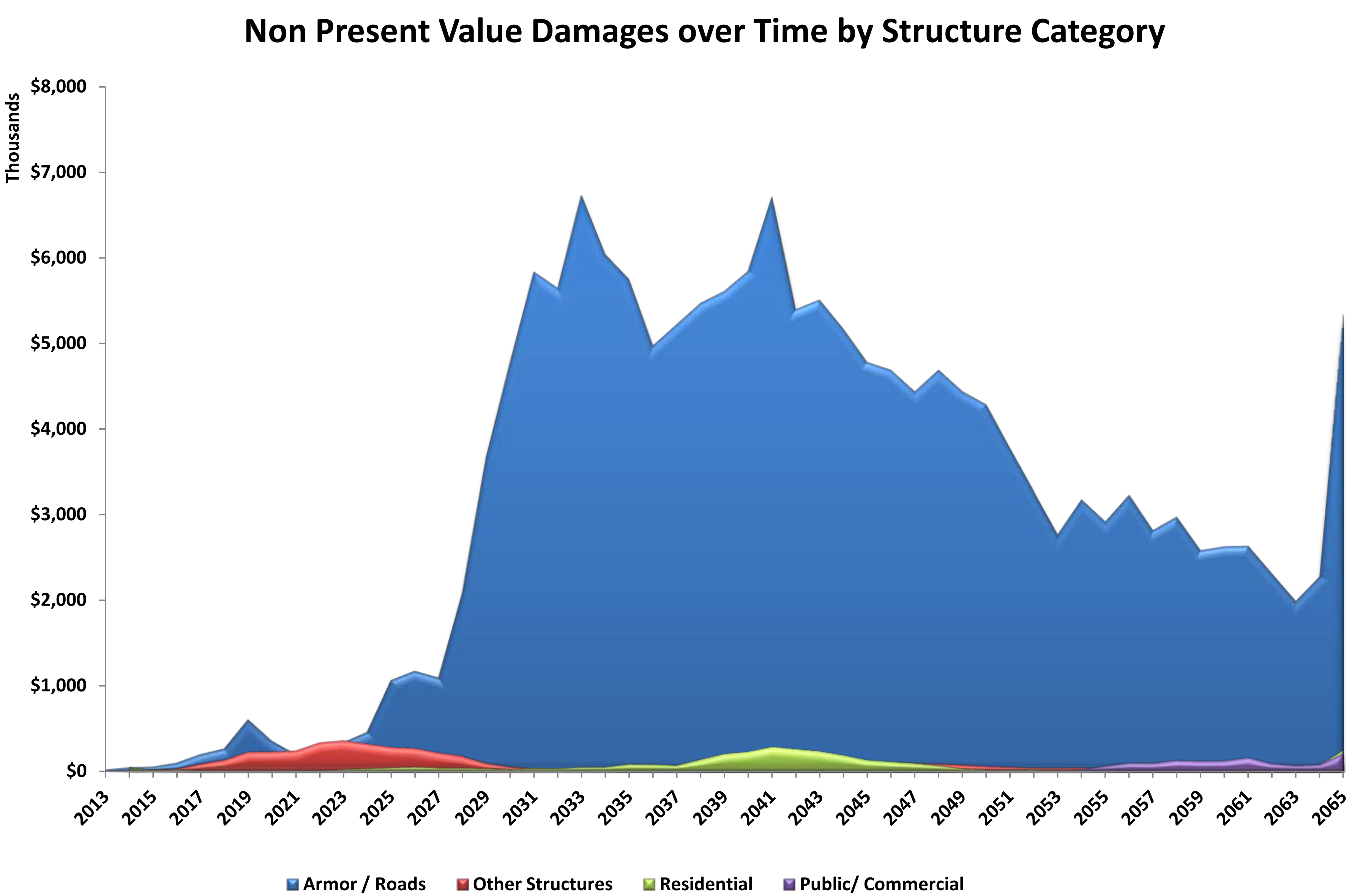


Figure 3-6: Damages over Time by Structure Category

3.3.5 FWOP Damages in alternative Sea Level Rise (SLR) scenarios

As noted in Section 3 of the Feasibility Report, the FWOP was modeled in three sea level rise (SLR) scenarios. EC 1165-2-211 provides both a methodology and a procedure for determining a range of sea level rise estimates based on the local historic sea level rise rate, the construction (base) year of the project, and the design life of the project. In Flagler County the average baseline (SLR1), intermediate (SLR2) and high (SLR3) sea level rise rates were found to be 0.0075 feet/year, 0.0159 feet/year, and 0.0424 feet/year, respectively. The Beach-*fx* results presented above refer to the baseline scenario (SLR1), which is based on the historic erosion rate. The results associated with the other two SLR scenarios are presented here. Figure 3-7 provides an overall summary of damages in each SLR scenario. Figure 3-8 provides a graphical illustration of the damages by reach. Figure 3-9 provides a graphical illustration of the damages over time. Figure 3-10 provides a graphical illustration of the cumulative damages over time. Table 3-4 shows the distribution of damages by category. Table 3-5, Table 3-6, Table 3-7, and Table 3-8 shows a detailed breakdown of the damages by model reach.

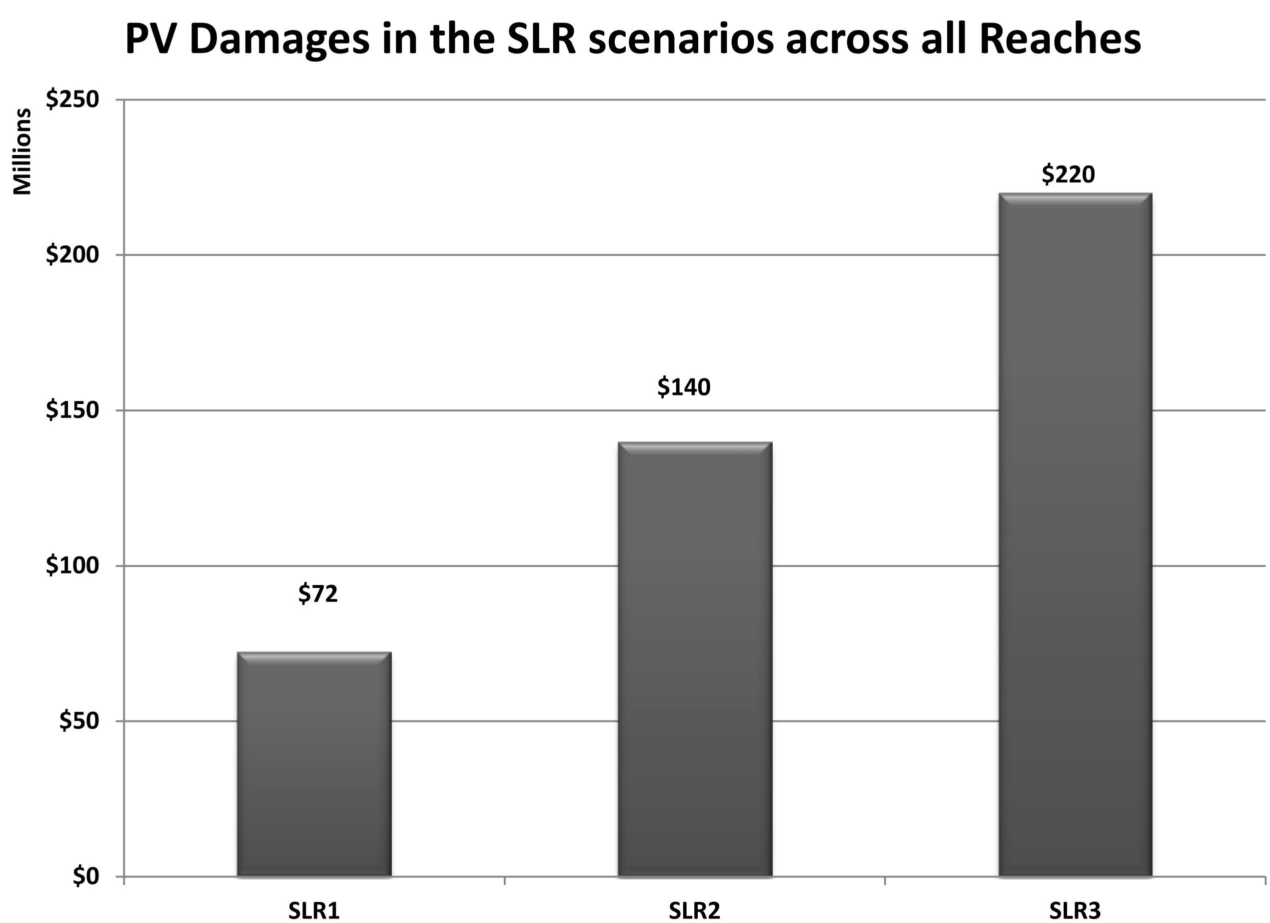


Figure 3-7: Damages by SLR Scenario

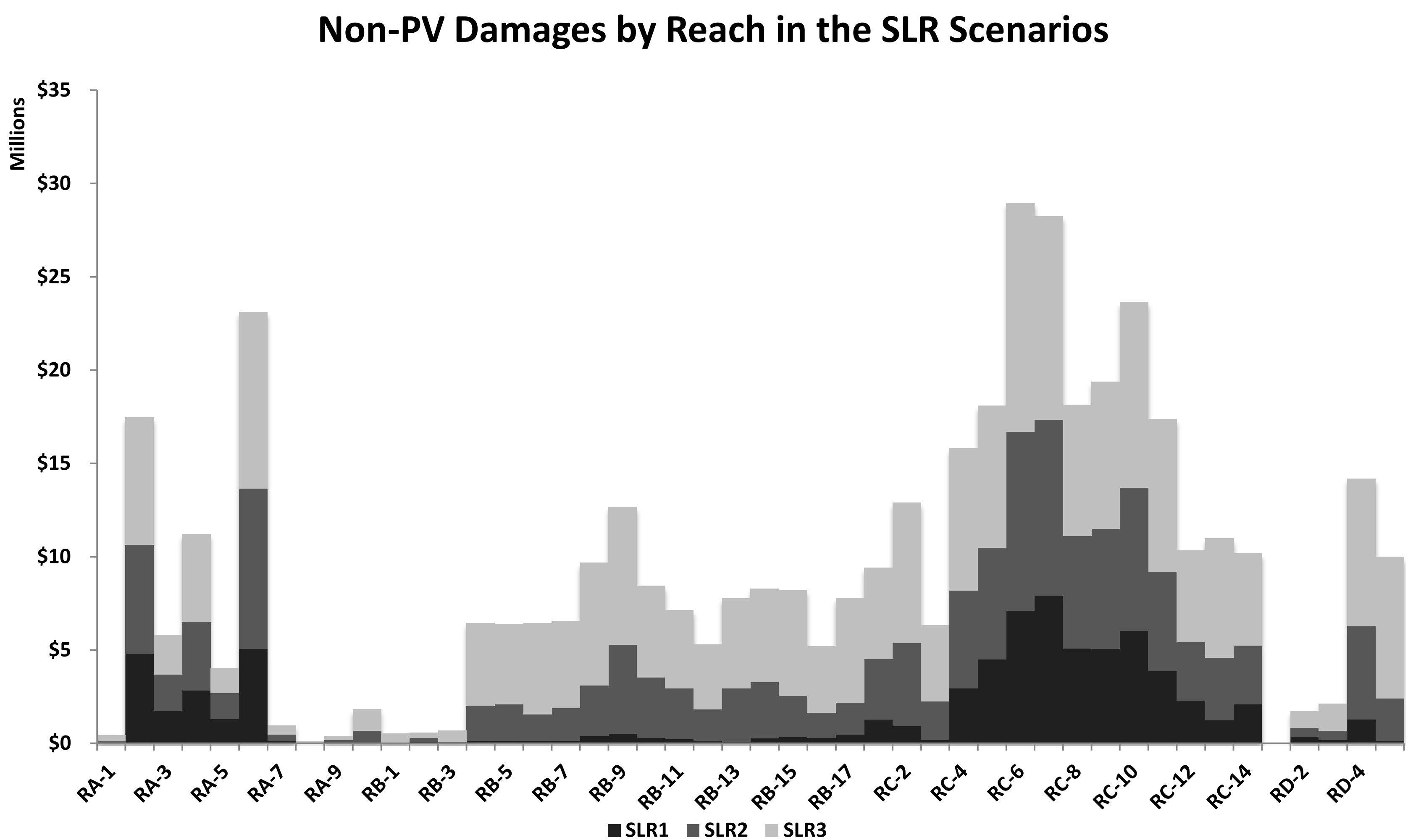


Figure 3-8: Total Damages by Model Reach

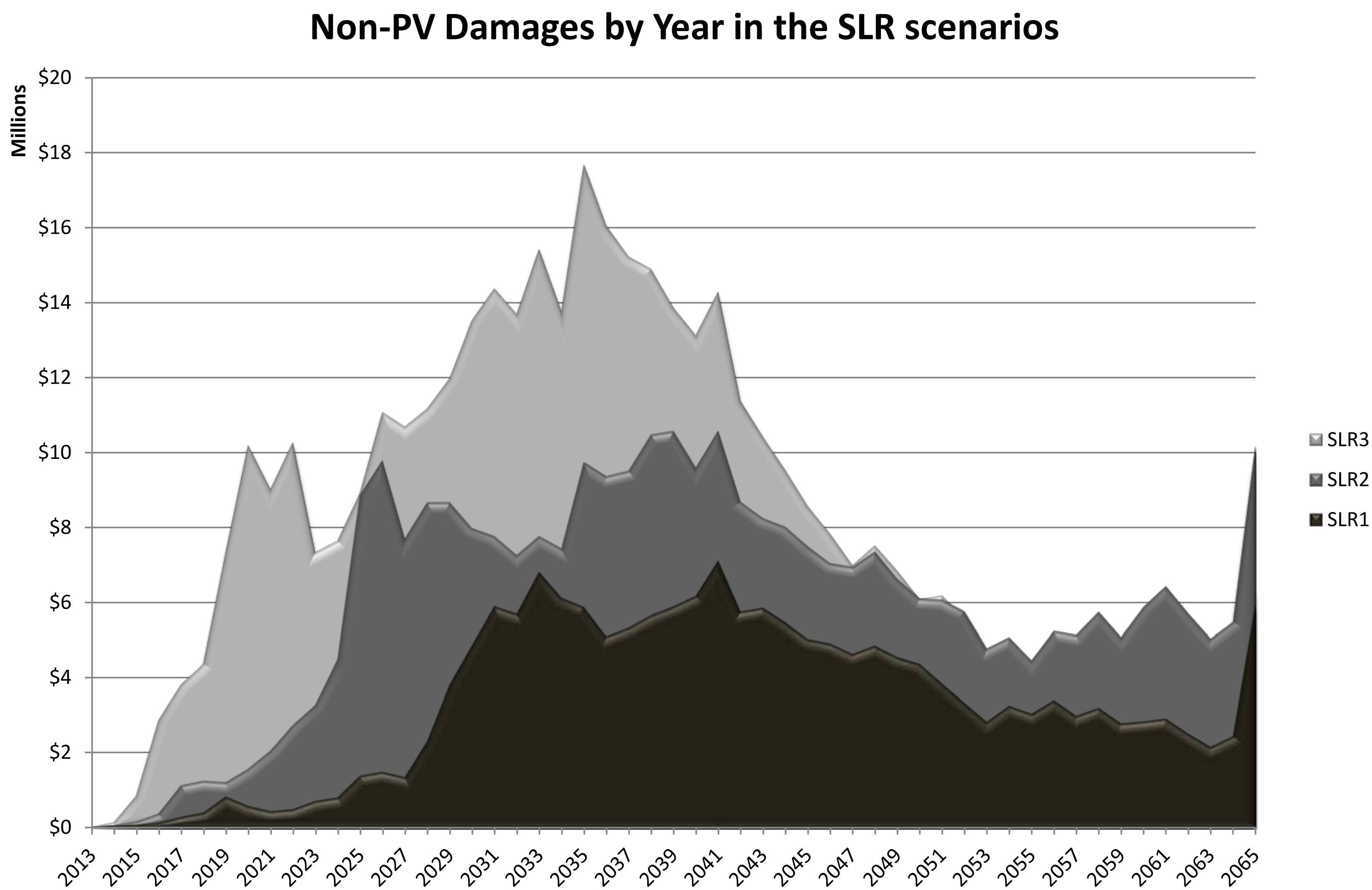


Figure 3-9: Damages over Time by Sea Level Rise Scenario

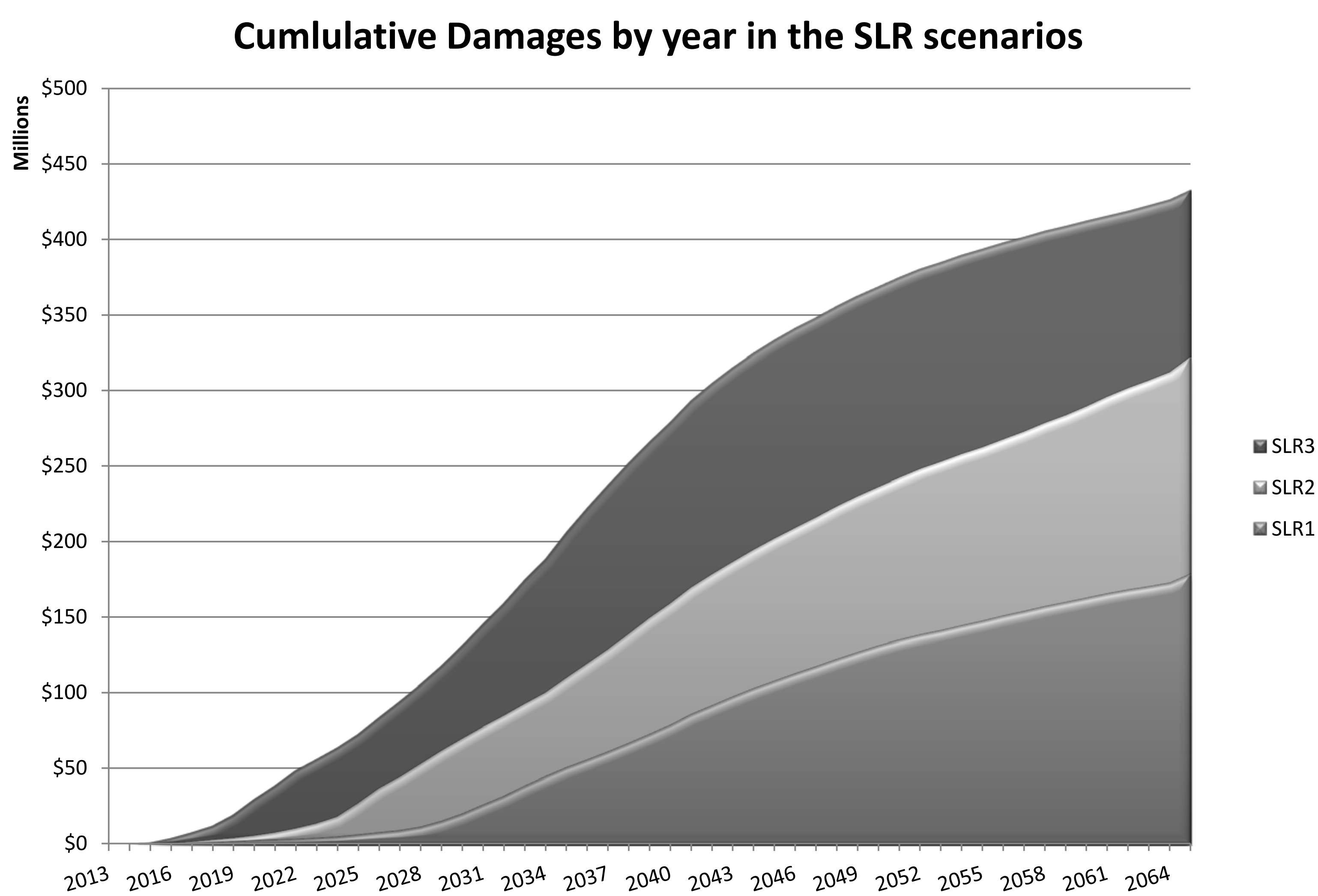


Figure 3-10: Damages over Time by Sea Level Rise Scenario

Table 3-4: Distribution of Damages by Category in the SLR scenarios

Category	Type	SLR1	SLR2	SLR3
Armor / Roads	**ARMOR-A1A**	$48,204,649	$99,854,604	$162,441,440
	BULKHEAD	$10,453,408	$13,950,103	$14,037,219
	N-BULKHEAD	$3,215,765	$5,211,348	$6,685,037
	SEAWALL	$0	$5,181	$100,386
	NEW ARMOR-A1A	$5,464,717	$10,548,905	$13,897,104
	ROAD1	$39,631	$499,823	$1,314,861
	ROAD3	0	0	$102,564
Armor / Roads Subtotal		$67,378,169	$130,069,964	$198,578,611
Other Structures	**DECK**	$146,340	$258,136	$398,800
	DUNEWALK	$2,356,115	$3,432,450	$4,554,684
	GARAGE	$0	$4,037	$66,138
	PARKING	$16,497	$178,198	$371,990
	POOL	$26,371	$77,882	$201,092
	SHELTER	$562,412	$789,485	$924,687
	STORAGE	$80,845	$248,864	$315,234
	TENNIS-CT	0	0	$22,834
Other Structures Subtotal		$3,188,580	$4,989,052	$6,855,459
Public/ Commercial	**COMM1**	$250,180	$1,351,986	$3,417,876
	COMM2	$195	$8,676	$101,758
	PUBLIC1	0	$23,400	$393,149
Public/ Commercial Subtotal		$250,376	$1,384,062	$3,912,783
Residential	**MFR1**	$230,997	$636,034	$1,529,002
	MFR2	$106	$1,376	$32,398
	SFR1	$275,201	$729,713	$2,509,395
	SFR2	$786,644	$1,660,904	$5,518,761
	SFR3	$428	$59,811	$729,913
Residential Subtotal		$1,293,374	$3,087,837	$10,319,469
Grand Total		$72,110,499	$139,530,914	$219,666,322

Table 3-5: Reach A SLR Scenario FWOP PV Damages

Number	Model Reach	SLR1	SLR2	SLR3
5	RA-1	$46,875	$72,372	$311,249
6	RA-2	$4,790,866	$5,838,331	$6,844,719
7	RA-3	$1,761,315	$1,932,332	$2,121,858
8	RA-4	$2,843,235	$3,687,295	$4,682,775
9	RA-5	$1,295,452	$1,403,428	$1,328,497
10	RA-6	$5,075,799	$8,579,488	$9,455,086
11	RA-7	$113,388	$367,184	$484,295
12	RA-8	$10,284	$25,519	$51,097
13	RA-9	$36,476	$134,656	$186,242
14	RA-10	$38,581	$632,900	$1,164,208
15	RB-1	$6,876	$35,540	$486,408
Subtotal		**$16,019,147**	**$22,709,046**	**$27,116,434**

Table 3-6: Reach B SLR Scenario FWOP PV Damages

Number	Model Reach	SLR1	SLR2	SLR3
16	RB-2	$79,400	$224,767	$277,862
17	RB-3	$13,612	$77,585	$605,109
18	RB-4	$139,230	$1,890,483	$4,428,443
19	RB-5	$140,052	$1,940,531	$4,320,609
20	RB-6	$150,268	$1,387,768	$4,908,105
21	RB-7	$127,630	$1,756,261	$4,674,481
22	RB-8	$386,568	$2,721,631	$6,580,553
23	RB-9	$524,416	$4,754,518	$7,391,292
24	RB-10	$294,664	$3,233,026	$4,907,770
25	RB-11	$227,682	$2,716,262	$4,193,314
26	RB-12	$103,737	$1,718,270	$3,467,167
27	RB-13	$97,648	$2,859,803	$4,816,607
28	RB-14	$283,025	$2,998,286	$5,021,710
29	RB-15	$336,981	$2,203,986	$5,670,627
30	RB-16	$289,566	$1,352,566	$3,563,276
31	RB-17	$466,366	$1,710,263	$5,617,501
Subtotal		**$3,660,845**	**$33,546,006**	**$70,444,426**

Table 3-7: Reach C SLR Scenario FWOP PV Damages

Number	Model Reach	SLR1	SLR2	SLR3
32	RC-1	$1,265,858	$3,243,569	$4,898,295
33	RC-2	$928,760	$4,455,684	$7,520,455
34	RC-3	$179,368	$2,058,203	$4,082,726
35	RC-4	$2,952,921	$5,232,964	$7,620,405
36	RC-5	$4,493,384	$5,978,513	$7,613,629
37	RC-6	$7,096,124	$9,590,704	$12,273,793
38	RC-7	$7,915,108	$9,438,487	$10,898,935
39	RC-8	$5,083,329	$6,019,301	$7,038,634
40	RC-9	$5,071,641	$6,424,807	$7,890,239
41	RC-10	$6,040,515	$7,654,979	$9,945,553
42	RC-11	$3,881,328	$5,301,515	$8,179,236
43	RC-12	$2,261,106	$3,171,822	$4,905,164
44	RC-13	$1,238,797	$3,349,259	$6,391,303
45	RC-14	$2,093,210	$3,134,792	$4,941,704
Subtotal		**$50,501,449**	**$75,054,599**	**$104,200,071**

Table 3-8: Reach D SLR Scenario FWOP PV Damages

Number	Model Reach	SLR1	SLR2	SLR3
45	RD-1	$0	$0	$31,783
47	RD-2	$358,299	$471,611	$908,426
48	RD-3	$173,506	$486,841	$1,467,312
49	RD-4	$1,289,790	$4,974,501	$7,912,278
50	RD-5	$114,366	$2,288,310	$7,585,590
Subtotal		**$1,935,961**	**$8,221,263**	**$17,905,390**
Grand Total		**$72,117,402**	**$139,530,914**	**$219,666,322**

The SLR results suggest that damages increase significantly as the erosion rate increases. With greater erosion, more structures are damaged more quickly. This increase in damage is observed across all model reaches. However, it is particularly notable in study Reach B. In the baseline FWOP condition, less than $4 million in present value damages are recorded in Reach B. In Intermediate condition (SLR2), this figure jumps to $33.5 million. In the high condition (SLR3), this figure reaches $70 million. Despite this dramatic increase, it continues to be the case that the greatest FWOP damages occur in Reach C. This is true in all SLR scenarios.

The reason Reach C continues to be receive more damage than any of the other reaches is because damage to the existing armor along A1A continues to be the largest damage category in all three scenarios. As seen in Table 3-4, damage to the existing revetment increases dramatically in the Intermediate and High scenarios. In all three scenarios, the cost of maintaining protection for SR-A1A is much larger than the damage that accrues to any of the other damage element categories. However, as seen in Table 3-4, damages increase in all categories as sea level rise increases. This increase in damages is particularly notable for bulkheads, single family residences, and commercial structures.

3.3.6 FWOP Condition Conclusion

- Most of the FWOP damages consists of the cost of maintaining protection for SR-A1A in Reach C and existing residences in Reach-A.
- The overwhelming majority of the damage is structural in nature, and is caused by erosion.
- Proximity to the shoreline and exposure to recurring damages are the most important factors for determining structure damage. Structures that receive the most damage are armor units and dunewalks.
- Damages in the future without project condition increase in the two sea level rise scenarios. This is particularly true in study Reach B. In all three SLR scenarios, Reach C has greater damages than any of the other reaches. This is because the cost of maintaining protection for SR-A1A increases dramatically in the SLR scenarios.

3.4 Future with Project Condition

This section of the appendix tells the story behind the evaluation and comparison of the Flagler County HSDR study alternatives. A description of the alternatives and their performance in terms of benefits and costs are provided in the sub-sections that follow.

3.4.1 Management Measures

Management measures were selected to accomplish at least one of the planning objectives for the Flagler County study. Both nonstructural (NS) measures and structural (S) measures were identified. All possible measures were considered, including those beyond the authority of USACE to implement. The following is a summary of the management measures considered for Flagler County.

- **Structural Measures:**
  - Seawalls
  - Revetments
  - Sand Covered Soft Structures
  - Beach Nourishment
  - Groins
  - Submerged Artificial Reefs
  - Near shore sand placement
  - Emergent Breakwaters
  - Dunes and Vegetation
  - Pressure Equalizing Modules
  - Undercurrent Stabilizers
- **Non-structural Measures:**
  - No Action

- Coastal Construction Control Line
- Moratorium on Construction
- No Growth Program
- Relocation of Structures
- Flood Proofing
- Condemnation and Land Acquisition

During the plan formulation process, management measures were screened against seven criteria. Benefits and costs were not calculated at this early stage of formulation, though a qualitative assessment of potential benefits was conducted. Ultimately, most of these measures were screened out. Two structural measures were carried forward to the modeling stage: Dunes and Vegetation and Beach Nourishment. More information about each measure is provided below. More information about the management measure screening process is provided in Section 5 of the main report.

Dunes and Vegetation: This measure would include placement of beach compatible material, from either upland or offshore sources, in a dune feature adjacent to the existing bluff. The top elevation of the dune would be such to tie into the bluff. The front slope of the dune would be a function of the material grain size and construction equipment. Vegetation would be planted after initial placement of the dune material. Preliminary engineering design work concluded that the most feasible plan for dunes and vegetation would have the following characteristics:

- Extension from the existing seaward face of the dune or existing armor (revetment/seawall) out to approximately 300 feet offshore or approximately to the -5 foot (NAVD 88) depth contour.
- Construction such that the dune will extend approximately 10 feet seaward from its existing location and the dune elevation will as closely as possible match the elevation of the existing dune elevation (15-20 feet NAVD 88).
- Construction such that the berm will extend approximately 10 feet seaward from its existing location. This berm extension is described as “sacrificial” in the sense it is designed to erode away throughout the life of the project.
- Periodic re-construction of the dune extension and sacrificial berm. The “trigger” for re-construction is complete erosion of the sacrificial berm.
- Construction using a hydraulic dredge to transport material from a borrow area located approximately 7 miles offshore.

Other construction methods were explored, including truck haul of fill material. But, the hydraulic dredge was determined to be the most cost effective by a wide margin.

Beach Nourishment: This measure includes initial construction of a beach fill and future re-nourishments at regular intervals. Re-nourishment of the beach would be undertaken periodically to maintain the erosion control features within design dimensions. Preliminary engineering design work and economic analysis suggested that the most feasible plan for beach nourishment would have the following characteristics:

- Extension from the existing seaward face of the dune or existing armor (revetment/seawall) out to approximately 300 feet offshore or approximately to the -5 foot (NAVD 88) depth contour.
- Construction such that the dune will extend approximately 10 feet seaward from its existing location and the dune elevation will as closely as possible match the elevation of the existing dune elevation (15-20 feet NAVD 88).
- Construction such that the berm will extend approximately 20 feet seaward from the extended dune face. This berm is described as “sacrificial” in the sense it is designed to erode away throughout the life of the project.

- Periodic re-construction of the dune extension. The “trigger” for re-construction is complete erosion of the berm extension.
- Construction using a hydraulic dredge to transport material from a borrow area located approximately 7 miles offshore.

The two remaining management measures are similar in that they both include an extension of the existing dune. The first measure, dunes and vegetation, is only a dune extension. The second measure also includes a 20 foot berm. In both cases, periodic nourishment would be required to continue accruing benefits throughout the project life.

3.4.2 Alternative Development

An alternative plan is a set of one or more management measures functioning to address one or more objectives. A key aspect of the Flagler County study is that each study reach (A,B,C,D) is treated as a separable element. Therefore, each project alternative is a combination of a selected measurement measure and the study reaches where it would be applied. Between the two remaining management measures and the four study reaches, eight fully developed alternatives were carried forward to be modeled in Beach-fx. This represents a reasonable number of project alternatives.1 The naming convention for the alternatives is described below.

- ADuneH: Reach-A; Dune extension, and 10’ sacrificial berm constructed with a with a hydraulic dredge
- ADune30: Reach-A; Dune extension with a hydraulic dredge and a 30’ berm
- BDuneH: Reach-B; Dune extension, and 10’ sacrificial berm constructed with a with a hydraulic dredge
- BDune30: Reach-B; Dune extension with a hydraulic dredge and a 30’ berm
- CDuneH: Reach-C; Dune extension, and 10’ sacrificial berm constructed with a with a hydraulic dredge
- CDune30: Reach-C; Dune extension with a hydraulic dredge and a 30’ berm
- ACDuneH: Combination of Reaches A and C; ; Dune extension, and 10’ sacrificial berm constructed with a with a hydraulic dredge
- ACDune30: Combination of Reaches A and C; Dune extension with a hydraulic dredge and a 30’ berm

It should be noted that many other combinations were considered during the plan formulation process. However, preliminary modeling indicated that the other alternatives would not be economically justified. For example, an ABC-Dune-H alternative was screened out because Reach B, which is a separable element, is not economically justified. The same is true for ABCD-Dune-H; both the B and D segments are not incrementally justified.

Larger beach nourishment alternatives were also considered. Preliminary Beach-*fx* modeling was used to simulate the performance of 10 foot dune extensions with wider berms (40 feet, 60 feet, etc.). However, these other potential designs were screened out due to unfavorable performance. In all test model runs, the wider berms generated comparable benefits to the 20 foot berm, but at a much higher

---

[1] Modeling alternatives in Beach-*fx* is a time consuming process; a single 100 iteration simulation takes at least six hours. Therefore, it was not practical to fully model a large number of alternatives.

cost. As a result, they were eliminated from consideration before the final array of alternatives was developed. In fact, most of the larger beach nourishment alternatives had costs that were greater than all of the damages in the FWOP condition. Even if such a project eliminated 100% of the damages, it would still not be economically justified.

3.4.3 Alternative Comparison

All the alternatives described above were modeled in Beach-fx using full (100 iteration) life cycle simulations. The results of these simulations were used to select the NED Plan. The results of the alternative comparison are presented in Table 3-9 and Table 3-10.

Table 3-9: AAEQ Damages for Final Array of Alternatives

Alternatives	PV Damages - without project	PV Damages - with project	PV Benefits
A-Dune-H	$72,117,402	$67,181,814	$4,935,588
A-30	$72,117,402	$56,637,602	$15,479,800
B-Dune-H	$72,117,402	$67,630,503	$4,486,899
B-30	$72,117,402	$67,406,158	$4,711,244
C-Dune-H	$72,117,402	$22,985,862	$49,131,540
C-30	$72,117,402	$21,639,792	$50,477,610
AC-Dune-H	$72,117,402	$6,159,992	$65,957,410
AC-30	$72,117,402	$5,711,302	$66,406,100

Table 3-10: AAEQ Benefits and Costs for Final Array of Alternatives

Alternatives	Benefits	Cost	Net Benefits	BCR
A-Dune-H	$220,000	$170,000	$52,000	1.35
A-30	$690,000	$700,000	-$16,000	0.98
B-Dune-H	$200,000	$250,000	-$57,000	0.78
B-30	$210,000	$1,030,000	-$809,000	0.21
C-Dune-H (NED)	$2,190,000	$810,000	$1,387,000	**2.72**
C-30	$2,250,000	$1,180,000	$1,065,000	1.90
AC-Dune-H	$2,940,000	$1,130,000	$1,814,000	2.61
AC-30	$2,960,000	$1,750,000	$1,206,000	1.69

The plan with the highest BCR is C-Dune-H. The plan with the highest net benefits is AC-Dune-H. Typically, the plan with the highest net benefits is the NED Plan. However, subsequent plan formulation efforts determined that public access in Reach A is negligible. Because Reach A is a separable element that does not have public access, it was screened out after the final array of alternatives had been modeled. More information about the public access issue and the final screening is presented in Section 6 of the main feasibility report.

Finally, the plan can be considered robust in the sense that it is economically justified in all 100 iterations simulated by Beach-*fx*. Table 3-11 shows the mean, minimum, and maximum net benefits for all project alternatives over all 100 iterations. Table 3-12 shows the minimum, mean, and maximum benefit-cost ratios. As seen in these tables, the TSP continues to be economically justified even in the simulations in which it is least effective. Therefore, the Beach-*fx* results suggest that the NED Plan can be considered robust.

Table 3-11: Range of potential net benefit outcomes for all alternatives

Alternatives	Minimum	Mean	Maximum
ADuneH	($4,200,000)	$1,200,000	$5,100,000
A30	($2,700,000)	($300,000)	$2,800,000
BDuneH	($4,800,000)	($1,300,000)	$3,400,000
B30	($20,100,000)	($18,200,000)	($13,800,000)
CDuneH (NED)	$24,100,000	$31,100,000	$38,800,000
C30	$16,800,000	$23,900,000	$31,200,000
ACDuneH	$32,300,000	$40,700,000	$48,900,000
AC30	$18,500,000	$27,100,000	$34,900,000

Table 3-12: Range of potential benefit-cost ratios for all alternatives over 100 iterations

Alternatives	Minimum	Mean	Maximum
ADuneH	0.07	1.35	2.57
A30	0.83	0.98	1.17
BDuneH	0.17	0.78	1.58
B30	0.13	0.21	0.40
CDuneH (NED)	**2.31**	**2.72**	**3.10**
C30	1.63	1.90	2.15
ACDuneH	2.27	2.61	2.91
AC30	1.48	1.69	1.88

3.4.4 Performance of NED Plan in the SLR scenarios

An important question about the TSP is its performance under different SLR scenarios. Each of the SLR scenarios described in the main report are considered equally likely to occur. Therefore, if the project does not perform, then it cannot be considered a completely effective plan. **Table 5-6** shows the BCRs and net benefits of the plan in the different SLR scenarios.

Table 3-13: AAEQ Benefits and Costs for NED Plan in different SLR scenarios

SLR Scenario	Benefits	Cost	Net Benefits	BCR
Baseline (SLR1)	$2,190,000	$810,000	$1,387,000	**2.72**
Intermediate (SLR2)	$3,475,000	$1,155,000	$2,320,000	**3.01**
High (SLR3)	$4,625,000	$1,581,000	$3,044,000	**2.93**

As shown in **Table 5-6**, though the benefits of the project increase significantly in the SLR scenarios, the costs also increase. The costs increase because re-nourishment is triggered more frequently. Thus, the project performance (in terms of the benefit-cost ratio) is relatively constant throughout the SLR scenarios. The damages and average re-nourishment intervals are summarized in **Table 5-7**.

Table 3-14: Damages and Re-nourishment Intervals in the SLR scenarios

SLR Scenario	Expected Re-nourishment Interval	Total PV Damages without project	Total PV Damages with project
Baseline (SLR1)	11 years	$72,117,402	$22,892,141
Intermediate (SLR2)	9 years	$139,530,914	$61,565,718
High (SLR3)	6 years	$219,530,914	$115,914,610

Because both costs and benefits are increasing, the net benefits actually increase with increasing rates of sea level rise. Overall, these SLR results suggest that the NED Plan is both effective and robust in all three simulated scenarios.

4. THE NED PLAN

With alternative AC-Dune-H screened out, the plan with the highest net benefits is C-Dune-H. Therefore, it is the NED Plan and the Tentatively Selected Plan (TSP). This is also the plan with the highest Benefit-Cost-ratio.

4.1 Structure Inventory Adjustments

In this section, the structure inventory was inflated from FY2011 to FY2014 price levels to match the project cost, which have also been refined to a higher level of detail. Benefits and costs have been discounted using the FY 2014 Federal Water Resources Discount Rate of 3.5%. The structure inventory was updated as follows:

- **Roads, Armor and Other Structures**
  - Source of Indices - CWCCIS
  - Inflation Factor - 1.05
- **Residential Structures**
  - Source of Indices – Housing price component of the CPI[1]
  - Inflation Factor – 1.04
- **Commercial and Public Buildings**
  - Source of Indices –Non-Residential Rents component of PPI[2]
  - Inflation Factor – 1.04

REFINEMENTS TO THE ARMOR AND ROAD COSTS

- **Revetment & Road Cost Per LF**
  - Minimum - $97.03
  - Most Likely - $423.87
  - Maximum - $631.63
- **New Revetment Cost Per LF**
  - Minimum - $365.41
  - Most Likely - $524.21
  - Maximum - $683.00

4.2 Project Cost Refinements

The costs were further refined by SAJ Cost Engineering to a higher level of detail. In addition, the current costs account for the demolition of approximately 42 dune walkovers, of which 21 will be reconstructed. Table 4-1 provides greater detail on the distribution of cost by nourishment.

Table 4-1: Project Cost Refinements[3]

	Initial Construction	1st Re-Nourishment	2nd Re-Nourishment	3rd Re-Nourishment	4th Re-Nourishment	Total Cost
Quantity (yd^3)	330,000	320,000	320,000	320,000	320,000	**1,610,000**
Mobilization	$1,184,043	$1,167,182	$1,167,182	$1,167,182	$1,167,182	**$5,852,773**
Prep Work[4]	$455,642	$352,516	$352,516	$352,516	$352,516	**$1,865,705**
Dredging	$3,244,858	$3,145,051	$3,145,051	$3,145,051	$3,145,051	**$15,825,062**
Associated General Items[5]	$1,758,552	$167,655	$167,655	$167,655	$167,655	**$2,429,172**
Lands & Damages	$2,768,000					**$2,768,000**
PED	$1,343,400	$685,000	$685,000	$685,000	$615,000	**$4,013,400**
Construction Management	$478,000	$362,000	$362,000	$362,000	$362,000	**$1,926,000**
Total Cost	**$11,232,495**	**$5,879,404**	**$5,879,404**	**$5,879,404**	**$5,809,404**	**$34,680,112**

[1] The index for the Fort Lauderdale MSA was used because it was the closest Floridian MSA for which FY2014 price indices were available.
[2] PPI is the Producer's Price Index. The national average was used for these structures.
[3] The costs in Table 4-1 do not include the contingency.
[4] Prep work includes the $103.343 dune walkover demolition costs.
[5] Associated General Items includes the $921,437 cost of reconstructing the 21 public dune-walkovers.

Table 4-1 provides greater detail on the distribution of cost by nourishment. Project costs were modified further for entry into the Beach-*fx* user interface. All onetime costs that only occur during the initial construction were not represented in the model (These costs were added back in for the life cycle cost calculations). Mobilization and prep work were entered as part of the mobilization costs, while the remainder was factored into the model as unit placement cost. The costs were averaged over all construction events in the life cycle to determine the values to be entered into Beach-fx (shown in Table 4-2).

Table 4-2: Representing the Project Costs in Beach-*fx*

Event	yd3	Mobilization	Placement Cost	Placement Cost/CY
Initial Construction	330,000	$1,901,743	$10,764,025	$32.62
1st Re-nourishment	320,000	$1,902,902	$5,686,831	$17.77
2nd Re-nourishment	320,000	$1,902,902	$5,686,831	$17.77
3rd Re-nourishment	320,000	$1,902,902	$5,686,831	$17.77
4th Re-nourishment	320,000	$1,902,902	$5,600,731	$17.50
Average	**322,000**	$1,902,670	$6,685,050	$20.69

A summary description of the Beach-fx cost inputs and outputs is as follows:

- **Beach-fx inputs for the NED Plan**
  - One-Time [6]cost of $1.2 M was excluded from representation in the model, but added back in to the life cycle cost calculations.
  - Mobilization Cost - $1,902,670
  - Unit Placement Cost - $20.69/$yd^3$
  - # Iterations – 100
- **Beach-fx outputs for the NED Plan**
  - Total Volume Placed - 1,584,654 yd^3
  - PV Mobilization Cost - $4,138,903
  - PV Placement Cost - $12, 071,722

Table 4-3 provides summary statistics on the volume of material per construction event. The 1st and 2nd re-nourishments tend to require less material relative to the initial construction and the 3rd and 4th re-nourishment events.

Table 4-3: Beach-fx Volume per Construction Event

Number	Frequency	Mean	SD	Min	Max
1	Initial Construction	325,825	6,221	322,674	354,025
2	1st Re-nourishment	312,987	10,907	301,619	353,216
3	2nd Re-nourishment	313,772	7,262	302,423	342,960
4	3rd Re-nourishment	317,318	11,334	301,442	345,503
5	4th Re-nourishment	318,072	6,671	302,154	352,623

[6] One time cost include lands & damages administration and acquisition costs, dune planting, and the demolition and reconstruction of dune walkovers.

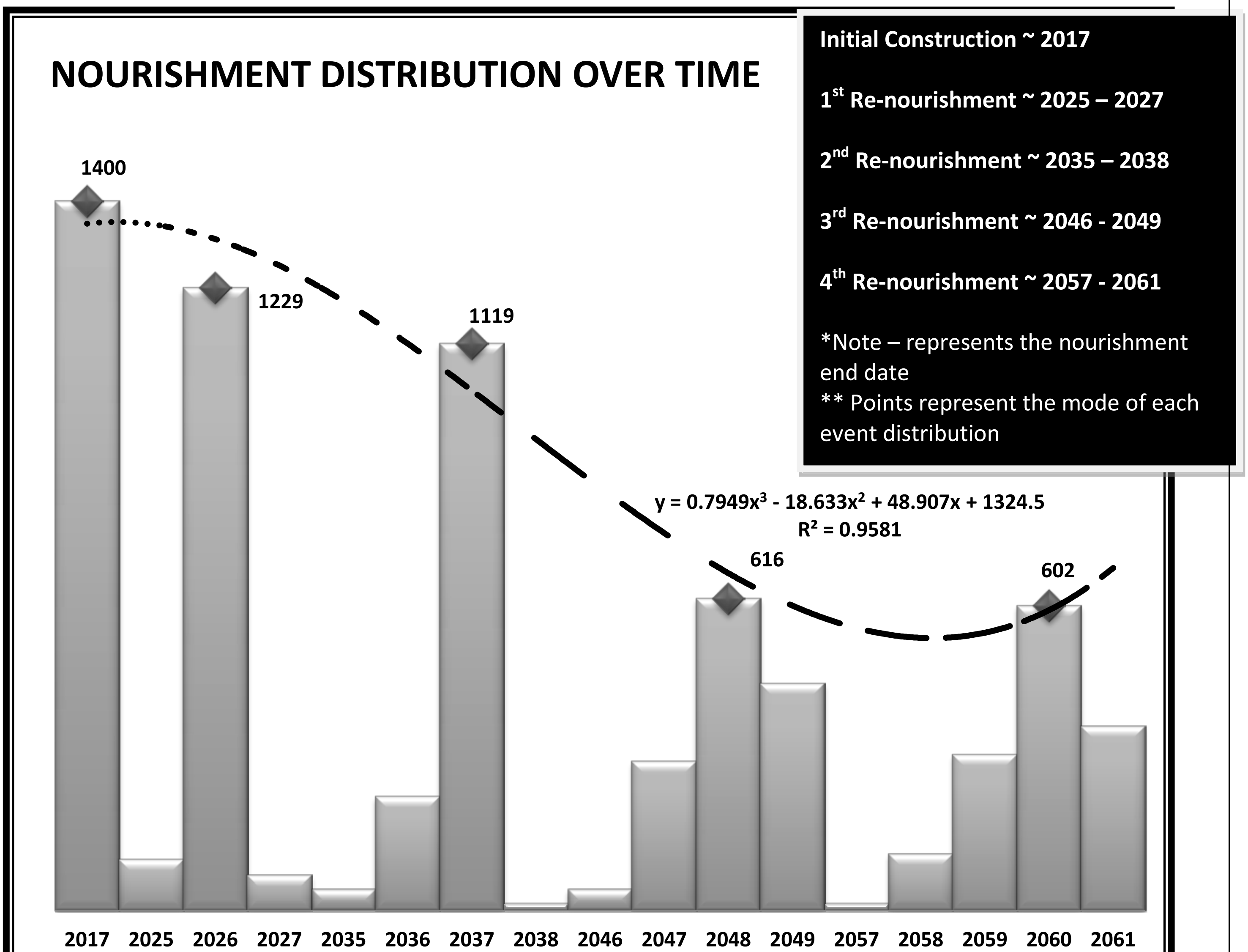


Figure 4-1: Frequency Distribution of Nourishments over Time

Figure 4-1 illustrates a frequency distribution of nourishments over time. Based on these results, the most likely nourishment years would be 2017, 2026, 2037, 2048, & 2060. However, the distribution of each construction event is noticeably flatter and less peaked than the prior event. Initial construction spreads just over 1 year. The 1st and 2nd re-nourishments are distributed over 3 & 4 year time spans respectively. The 3rd and 4th re-nourishments are distributed over 4 and 5 year time frames respectively. Model results indicate the amount of uncertainty surrounding the nourishment interval increases with each nourishment event at a nonlinear rate. This is because of the conditional nature of beach nourishment coupled with the interplay of all the variable factors in the model cause the number of possible nourishment years to grow relative to the median year for each construction event distribution over time.

It should be noted that Beach-fx is a life cycle simulation model. These results are based on 100 iterations generating over 7,000 observations of nourishment events. All iterations within the simulation are unique. The values presented in the figure above are essentially probabilistic nourishment events.

Traditionally, in HSDR studies, a fixed re-nourishment interval is defined and optimized for the life of the project. This interval is based in part on a clear distinction between a design berm and advance fill. With Beach-*fx*, no such distinction is defined. Rather, re-nourishment events are triggered within the model when specific criteria are met. In this case, the triggers were set up to simulate a point at which the dune extension and sacrificial berm had eroded away and were no longer capable or preventing or reducing damages. Based on these parameters, the expected re-nourishment interval is eleven years. In reality, this interval could vary depending erosion and storm events. More information about the re-nourishment triggers is provided in the engineering appendix. Ultimately, planning based on life-cycle modeling results in plans that are more resilient and adaptable. Life-cycle modeling allows planners to design projects while recognizing the inherent uncertainty that exists when future events are simulated.

The cost and nourishment volume distribution by event provided by SAJ cost engineering personnel was distributed over the period of analysis in the same proportions as the Beach-fx outputs. Table 4-4 provides detail on the life cycle cost distribution.

Table 4-4: Distribution of Nourishment Volume over Time[7]

Event	Year	Frequency	Percentage	Volume	Cost	Present Value Cost
Initial Construction	**2017**	1400	100%	325,825	$13,951,220	$14,439,512
1st Re-nourishment	**2025**	101	7%	22,417	$547,545	$430,365
	2026	1229	88%	273,689	$6,662,701	$5,059,732
	2027	70	5%	16,880	$379,487	$278,441
2nd Re-nourishment	**2035**	42	3%	9,255	$227,692	$126,871
	2036	225	16%	50,724	$1,219,778	$656,681
	2037	1119	80%	250,702	$6,066,365	$3,155,454
	2038	14	1%	3,090	$75,897	$38,143
3rd Re-nourishment	**2046**	42	3%	9,488	$227,692	$86,900
	2047	294	21%	65,733	$1,593,844	$587,727
	2048	616	44%	137,403	$3,339,482	$1,189,785
	2049	448	32%	104,694	$2,428,714	$836,037
4th Re-nourishment	**2057**	14	1%	3,026	$75,036	$19,615
	2058	112	8%	24,953	$600,291	$151,617
	2059	308	22%	70,889	$1,650,799	$402,847
	2060	602	43%	136,358	$3,226,562	$760,756
	2061	364	26%	82,846	$1,950,945	$444,437
	Total	**7000**		**1,587,974**	**$44,224,051**	**$28,664,922**

[7] The cost shown in Table 4-4 do include contingency and are used in all final BCR computations.

A description of the NED plan is as follows:

- **Name/Description:** CDuneH - 10' dune extension (note: the construction template will include a 10' sacrificial berm) constructed with a with a hydraulic dredge
- **Avg # Nourishment Events:** 1(ea)Initial Construction / 4(ea) Re-nourishments
- **# Nourished Reaches:** 14
- **Range of Nourished Reaches:** RC1 – RC14
- **Avg Volume of Each Nourishment**: 317,595 yd^3
- **Total Volume over project life cycle:** 1,587,974 yd^3
- **Initial Construction Duration** ~ 6 months
- **Interest During Initial Construction** ~ $163,106

4.3 Benefits of the NED Plan

The economic benefits of the plan are generated by reductions in erosion damages. As described in Table 4-5, the model results suggest that the alternative is highly effective at reducing erosion damages. In the with-project condition, the vast majority of damages in Reach C are prevented.

Table 4-5: PV of Damages in Reach C

Number	Reach	FWOP DAMAGES	FWP DAMAGES	PV BENEFITS	% DAMAGE PREVENTED
32	RC-1	$2,304,585	$467	$2,304,118	99.98%
33	RC-2	$1,109,732	$1,753	$1,107,979	99.84%
34	RC-3	$416,811	$19	$416,793	100.00%
35	RC-4	$4,655,106	$21,685	$4,633,421	99.53%
36	RC-5	$3,550,288	$8,516	$3,541,772	99.76%
37	RC-6	$6,139,952	$20,356	$6,119,596	99.67%
38	RC-7	$4,646,251	$61,194	$4,585,057	98.68%
39	RC-8	$4,429,101	$20,146	$4,408,954	99.55%
40	RC-9	$4,681,635	$37,916	$4,643,719	99.19%
41	RC-10	$6,988,182	$295,654	$6,692,528	95.77%
42	RC-11	$6,625,129	$1,148,376	$5,476,753	82.67%
43	RC-12	$3,410,176	$580,175	$2,830,001	82.99%
44	RC-13	$1,540,723	$57,723	$1,483,001	96.25%
45	RC-14	$3,017,180	$81,679	$2,935,501	97.29%
	Total	**$53,514,850**	**$2,335,657**	**$51,179,193**	**95.64%**

Most of the benefits are associated with reductions to armor damage along the A1A revetment. In the with-project condition, the cost of maintaining and repairing the revetment is significantly less than it would be in the without project condition. This reduction is the primary source of economic benefits. As seen in Table 4-5, the alternative is highly effective; it prevents 95% of total damages in Reach C. As seen in Table 4-6 the total cost of maintaining the A1A revetment decreases from $53.5 million in the FWOP condition to $2.3 million in the 'with project' condition.

It should be noted that CDuneH is not only highly effective, it is also efficient. Because the plan successfully reduces the vast majority of damages, a larger project is not necessary. A constructed berm, such as a project simulated with alternative C-30, would generate similar benefits at much higher cost. This is why the benefit-cost ratio is much lower for C-30 than it is for Reach CDuneH.

Table 4-6: PV Damages by Category

Category	Damage Element Type	FWOP	FWP	Benefits	% Change
Armor / Roads	**BULKHEAD**	$6,359,601	$6,360,599	$0	0.00%
	N-BULKHEAD	$5,266,378	$5,215,954	$50,424	0.96%
	NEW ARMOR	$10,746,608	$8,764,278	$1,982,330	18.45%
	ARMOR-A1A	$50,273,763	$2,623,382	$47,650,381	94.78%
	ROAD1	$76,169	$50,799	$25,371	33.31%
	Subtotal	$72,722,519	$23,015,012	$49,708,505	68.35%
Other Structures	**POOL**	$34,989	$31,332	$3,657	10.45%
	DUNEWALK	$2,725,959	$1,957,367	$768,593	28.20%
	SHELTER	$650,495	$649,183	$1,313	0.20%
	STORAGE	$106,900	$100,198	$6,702	6.27%
	PARKING	$36,312	$7,366	$28,946	79.71%
	DECK	$180,290	$174,192	$6,097	3.38%
	Subtotal	$3,734,945	$2,919,637	$815,308	21.83%
Public/ Commercial	**COMM1**	$463,012	$0	$463,012	100.00%
	COMM2	$124	$0	$124	100.00%
	PUBLIC1	$0	$0	$0	0.00%
	Subtotal	$463,137	$0	$463,137	100.00%
Residential	**SFR1**	$400,300	$307,094	$93,206	23.28%
	SFR2	$1,136,364	$982,900	$153,464	13.50%
	MFR2	$35	$0	$35	100.00%
	SFR3	$1,892	$1,509	$383	20.26%
	MFR1	$244,842	$0	$244,842	100.00%
	Subtotal	$1,783,433	$1,291,503	$491,930	27.58%
	GRAND TOTAL	**$78,704,034**	**$27,226,152**	**$51,478,880**	**65.41%**

Figure 4-2 provides detail on the accumulation of damages, benefits, and costs over time. Figure 4-3 graphically illustrates the accumulation of benefits over time and space.

For the Recommended Plan, the berm width, dune width, and dune height planned nourishment triggers were set at 0, 0.91, and 0.9, respectively. The mobilization threshold was set to 300,000 cubic yards. Together, the triggers and the mobilization threshold allow for the optimization of the beach fill based on the physical dimensions of the project, as well as assumptions regarding tolerable erosion limits and reasonable fill volumes. Sensitivity analysis of the nourishment triggers and mobilization threshold indicated that threshold volume was the dominant parameter for optimizing project cost for an alternative in which the berm width has a zero value. A mobilization threshold of 300,000 cubic yards was found to be (when combined with the above nourishment triggers), the most optimal threshold value. Decreasing the threshold decreased the net NED benefits. Increasing the threshold above 300,000 cubic yards produced a small increase in the net NED benefits. However, it also allowed segments of the dune to erode to beyond the existing project condition. This was not considered to be an acceptable assumption. The net benefits associated with the 300,000 and 400,000 cubic yard thresholds are $26,803,584 and $26,810,596 respectively. Figure 4-4 provides added detail on model sensitivity to the volume of material placed during each construction event.

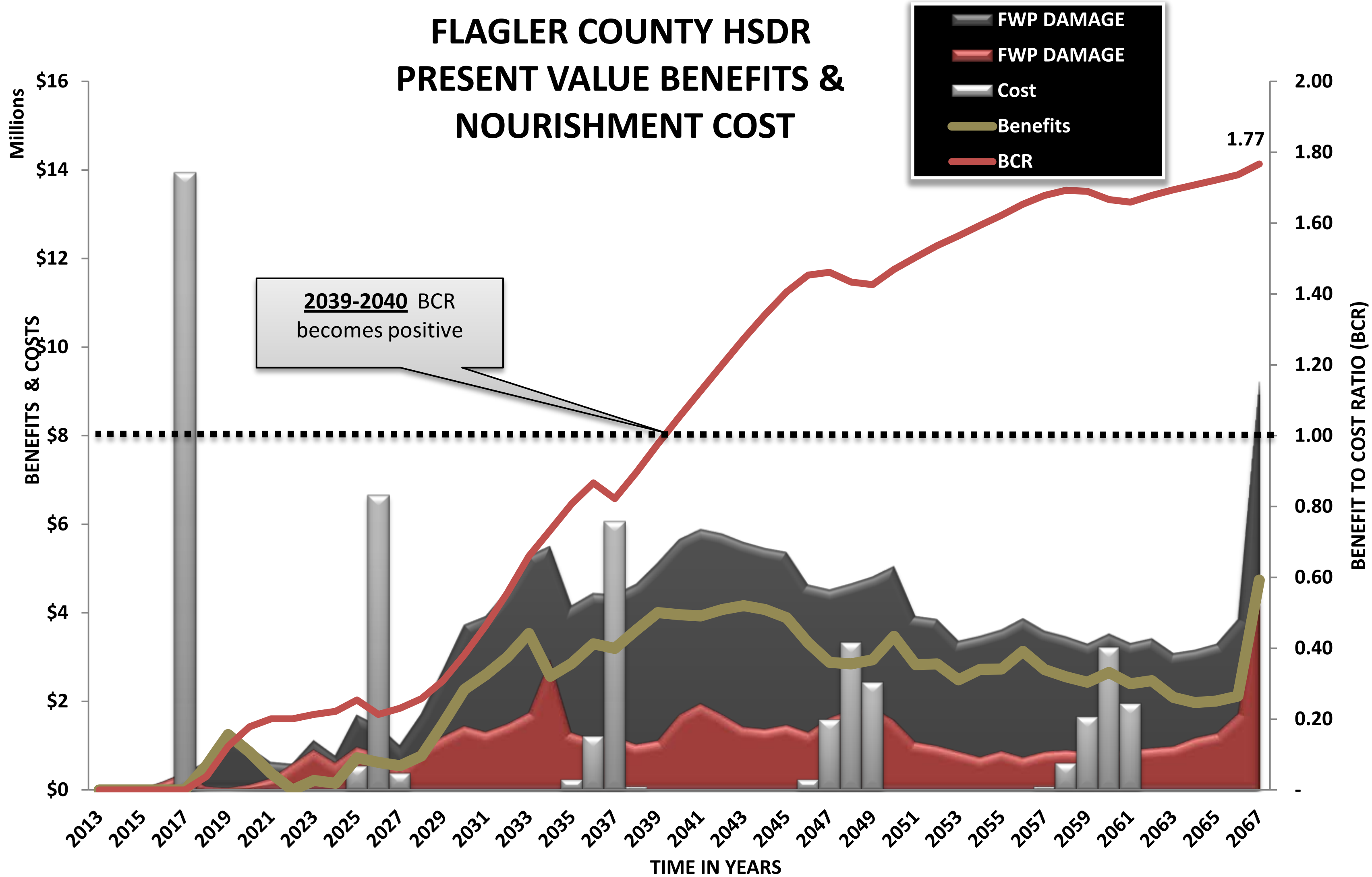


Figure 4-2: Present Value Damages, Benefits, and Costs over Time

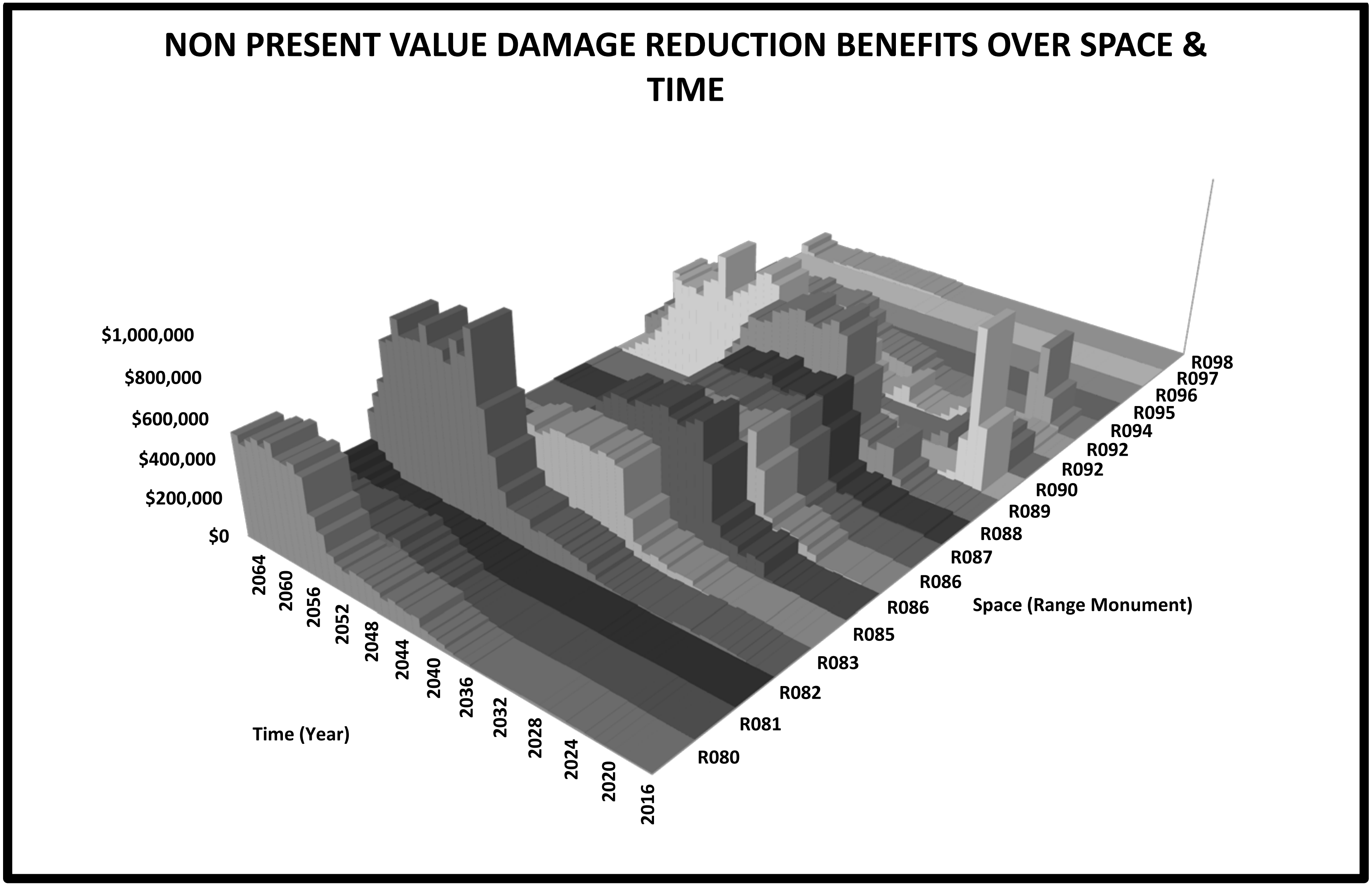


Figure 4-3: Non Present Value Benefits over Space & Time

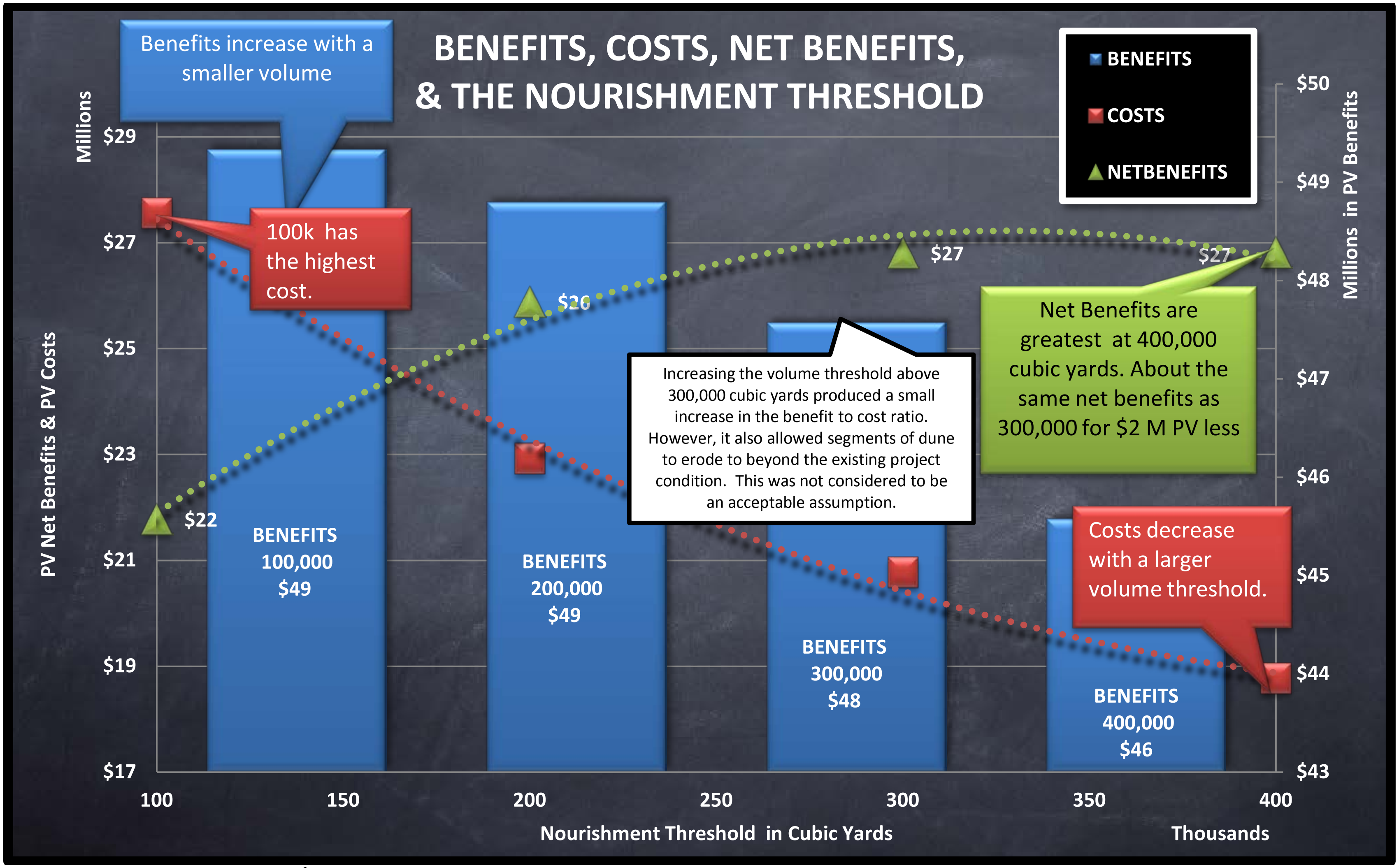


Figure 4-4: Volume Sensitivity[1]

[1] Benefits and costs in this chart extracted from Beach-fx outputs, and do not include the contingency.

4.4 **Incidental Recreation Benefits**

According to ER-1105-2-200, incidental recreation benefits can be calculated in HSDR studies. Recreation benefits are not to be used in plan formulation, but they can constitute up to 50% of total project benefits.

Typically in coastal studies, recreation benefits are calculated using the travel cost method (TCM). The basis for this method is the concept that by increasing the carrying capacity of a particular recreation resource, a project may reduce the travel time (and travel cost) associated with recreation visits. In this case, preliminary investigations concluded that there is no excess demand for recreation in Flagler County. Therefore, the travel cost method is not applicable.

However, even though a project in Flagler County would not increase the *availability* or *quantity* of recreation in the project area, there may be some benefits associated with increasing the *quality* of recreation that is already occurring. This is the basis for the Unit Day Value (UDV) method.
In the Flagler County Feasibility study, recreation benefits were calculated using the UDV method, as described in EGM 09-03 and in Appendix E of ER 1105-2-100. The Unit Day Value method estimates a user's willingness to pay for a given recreational opportunity, a dollar amount the recreational experience would be worth to them were they required to pay for it. This value is estimated via a series of criteria applied to the various recreational facilities and opportunities provided by the project; criteria gauging the overall quality of the experience, availability, carrying capacity, accessibility, and environmental factors. Each criterion can be assigned one of five possible scores, representing it's rating from low to high with a corresponding range of point values. These point values are summed together and applied a dollar day value based on the current UDV guidance. The current unit day values, provided by USACE Economic Guidance Memo #12-03, *Unit Day Values for Recreation*, FY 2014, are presented in Table 4-7**.** Linear interpolation was used to estimate the dollar value of point score between. So, for example, a point score of 2 corresponds with a dollar value of $3.94.

Table 4-7: Current Unit Day Values for Recreation

Point Values	General Recreation Values (FY14)	General Fishing and Hunting Values (FY14)
0	$3.84	$5.52
10	$4.56	$6.24
20	$5.04	$6.72
30	$5.76	$7.44
40	$7.20	$8.17
50	$8.17	$8.89
60	$8.89	$9.85
70	$9.37	$10.33
80	$10.33	$11.05
90	$11.05	$11.29
100	$11.53	$11.53

The recreation point values assigned to Flagler County vary by year. They are summarized in Table 4-8**.**

Table 4-8: Total Unit Day Point Scores applied to Flagler County

Year	Without Project	With Project
2010	50	50
2016	50	50
2020	48	50
2030	45	50
2040	42	50
2050	39	50
2060	36	50

The point assignments are based on qualitative criteria; they depend on best professional judgment (also referred to as "judgment criteria"). The differences in the assigned point scores vary for each category depending on the relevant recreation facilities. The following list briefly explains the logic behind some of the judgment criteria applied to Flagler County.

- **Recreation Experience:** Flagler Beach was assigned a point score of 15, which corresponds to "several general recreation activities and one high value activity". Beaches offer visitors the opportunity to experience several general activities, including swimming and walking. They also provide the opportunity for at least one high value activity at a time, such as wind-surfing. This point score does not change between the 'with' and 'without' project condition, because the proposed project would have no effect on the number of recreation opportunities.
- **Availability of Opportunity:** Flagler Beach was assigned a point score of 2, which corresponds to "several opportunities within one hour of travel time a few within 30 minutes". Flagler Beach is within easy driving distance of several other popular beaches, including Palm Coast, St. Augustine, and Daytona Beach. This point score does not change between with and without project condition, because the proposed project would have no effect on the availability of other recreation opportunities.
- **Carrying Capacity:** In the base year the without project condition (2016), Flagler Beach was assigned a score of 8, which corresponds to "adequate facilities". Over time, the carrying capacity of Flagler beach is expected to deteriorate somewhat, as damages are inflicted on the existing dune and its protective revetment. By 2050, the score assigned to Flagler County was reduced to 5, which corresponds to "basic facilities". While beach recreation will still be possible in 2050, the available facilities will be of lower quality than they are now. In the 'with project' condition, the point score was held constant at 8, because the project is expected to prevent most of the damage in the project area.
- **Accessibility:** In the base year the without project condition (2016), Flagler Beach was assigned a score of 15, which corresponds to "good access to and within site". Over time, the accessibility of Flagler beach is expected to deteriorate somewhat, as damages are inflicted on the revetment, the road, and the dune walks. By 2050, the score assigned to Flagler County was reduced to 10, which corresponds to "fair access to and within site". In the with project condition, the point score was held constant at 8, because the project is expected to prevent most of the damage in project area.
- **Environmental:** In the base year the without project condition (2016), Flagler Beach was assigned a score of 10, which corresponds to "above average aesthetic quality". Over time, the aesthetic quality of Flagler beach is expected to deteriorate somewhat, as damages are inflicted on the dune,

the revetment, and the dune walks. By 2060, the score assigned to Flagler County was reduced to 6, which corresponds to “average aesthetic quality”. In the with project condition, the point score was held constant at 10, because the project is expected to prevent most of the damage in project area.

After assigning point scores and dollar values, these values must be assigned to expected recreation visits over the life the project. In 2010, the total number of beach visits in Flagler County was estimated to be 626,467 (for the entire year). This estimate is based on projections provided by the State of Florida “Trends and Conditions Report-2008” for northeast Florida, the 2007 Florida Statewide Recreation Plan (SCORP), and county tourism allocation projections developed for the Nassau County Florida General Reevaluation Report. The number of visits is projected to increase to 791,295 by 2050 and 1,265,250 by 2050.

Of course, these projections are for the entire county. The selected plan (**CDuneH)** only applies to small portion of the county’s coastline. An assessment of public parking and access facilities in Flagler County concluded that only 12% of the available public parking spaces are located within the project area (Reach C). Therefore, 12% was used as a proxy value for the proportion of recreation visits that could benefit from the project. The unit day values developed above were only applied to 12% of the projected visits in Flagler County.

Using these methods, the total present value of recreation benefits was estimated to be **$1,696,452**, or **$72,326** in average annual terms.

5. CONCLUSION

Table 5-1 provides a summary of the NED Plan with recreation and traffic rerouting benefits added expressed in average annual equivalent terms. The alternative comparison was based on screening level costs, which were in FY11 price levels. This summary has been updated to FY14 price levels.

Table 5-1: Economic Summary

ECONOMIC SUMMARY	STORM DAMAGE REDUCTION BENEFITS	STORM DAMAGE REDUCTION + RECREATION BENEFITS	STORM DAMAGE REDUCTION + RECREATION + TRAFFIC RE-ROUTING BENEFITS
Price Level	FY14	FY14	FY14
FY14 Water Resources Discount Rate	3.50%	3.50%	3.50%
Average Annual Storm Damage Reduction Benefits	$2,159,000	$2,159,000	$2,159,000
Average Annual Recreation Benefits	$0	$72,000	$72,000
Average Annual Traffic Reroute Benefits[1]	$0	$0	$131,000
Average Annual Total Benefits	$2,159,000	$2,231,000	$2,362,000
Average Annual Cost[2]	$1,239,000	$1,239,000	$1,239,000
Average Annual Net Benefits	$920,000	$992,000	$1,123,000
Benefit Cost Ratio	**1.74**	**1.80**	**1.91**

Portions of Flagler County's shoreline are vulnerable to coastal erosion and storm damage. This is particularly true in southern portion of Flagler beach, designated Reach C in this study. Beach-*fx* modeling has demonstrated that significant economic damage from coastal forces can be expected to occur over the next 50 years in the future without project condition. The majority of this damage accrues to the existing revetment that was constructed to protect State Road A1A. In the two alternative Sea Level Rise scenarios, damages increase substantially.

[1] Traffic reroute benefits are based on operating cost that include tires, maintenance, gas, oil, and depreciation.
[2] Includes additional monitoring cost incurred by the local sponsor.

In order to reduce future damages, a large number of management measures were considered. After a detailed investigation and extensive modeling effort, a plan was selected that maximizes expected future net benefits. This plan, **CDuneH**, consists of a 10’ dune extension (including a 10’ sacrificial berm as part of the construction template) constructed with a hydraulic dredge and periodically re-nourished in eleven year intervals. This alternative has been identified as the NED Plan and the Tentatively Selected Plan because it successfully prevents most of the future erosion damage that can be expected to accrue in Reach C. The net benefits of the NED plan range between $937,000 and $1,185,000.

The plan is effective and efficient. It is also robust, in the sense that it continues to be economically justified in all simulated model iterations and in all three sea level rise scenarios. Though the recommended plan is relatively small in scope and scale, it represents the most prudent investment of Federal dollars.

Economics Addendum A: The Specification of Armor as a Damage Element

Synopsis: The purpose of this document is to explain the Jacksonville District's approach for modeling coastal armor damage in the Corps certified storm damage reduction model, *Beach-fx*. It is part of an effort to engage the model developer and the Hurricane and Storm Damage Reduction (HSDR) PCX as the Feasibility Study is developed. This document only addresses the method for specifying coastal armor as a damageable element within Beach-fx.

Background: Flagler County is located on the northeast coast of Florida approximately midway between the Florida/Georgia state line and Cape Canaveral. The county has approximately 18 miles of sandy shoreline, all of which are authorized for Federal study. The coast has no inlets or embankments and the beaches are typically fronted by steep dune faces or rock revetment.
The Flagler County SPP economic analysis was initiated in FY2008. In mid-FY2012, the project schedule was accelerated in anticipation of rescoping due to implementation of SMART Planning guidelines. According to the accelerated schedule, the identification of the Tentatively Selected Plan (TSP) is to take place in December 2012. This will be followed by TSP optimization and the completion of the draft feasibility report in January 2013.

Modeling Challenges: Significant portions of the study area are protected by coastal armor. In one segment, called Design Reach C by the study team, the only structure subject to erosion damage in the baseline future-without project condition is a major road (SR-A1A), which is protected by a rock revetment (see **Figure 1**). This revetment is maintained by the Florida Department of Transportation (FDOT). Data from the FDOT suggest that in the ten year period between 2001 and 2010, an average of approximately $600,000 per year was spent maintaining the revetment. In one year (2001), total maintenance costs exceeded $3 million.

Due to the nature of the structure inventory in Design Reach C, prevention of damages to armor represents the largest potential benefit category in this area. Therefore, accurate simulation of armor damage is critically important.

Throughout the study effort, estimating armor damage has been a consistent challenge. Initial *Beach-fx* model results appeared to indicate that damage to the existing armor in Reach C was being significantly underestimated. Furthermore, the project alternatives did not appear to be generating realistic results. Some of the alternatives modeled were expected to reduce armor damage. However, the preliminary runs did not show this; armor damage was almost identical in the with and without project condition.

The issues with modeling armor damage in Flagler County are linked two inter-related facts:

1.) The accrual of damage to the revetment is gradual and incremental in nature. However, the armor damage function in *Beach-fx* is set up as binary calculation Either the armor fails, or it does not fail. There is no way so simulate gradual accrual of damage that does not lead to failure.

2.) The costs incurred to are really more akin to maintenance costs than to "armor damage". Therefore, the potential benefits of project in Reach C are reductions to maintenance costs. With dune construction or coastal nourishment, armor maintenance events will be less frequent and less costly. This results in economic benefits.

After extensive effort to calibrate the model to generate realistic armor maintenance costs, the study team concluded that a different modeling approach was warranted.

New Approach to Modeling Armor Maintenance Costs: To address this issue, a method was devised to represent the revetment and SR-A1A as a damageable element within the model. Conceptually, damage elements representing the cost of maintaining the armor and the road would be placed along the shoreline along the seaward edge of each lot. The damage element length would extend from the seaward toe of the revetment to the landward shoulder of the road. Rather than armor failure thresholds, damage functions would be used to estimate the damages.

Advantages of this Approach

- Allows the modeler to include greater flexibility in the representation of armor damage. Three damage functions allow the modeler to incorporate greater nuance into the armor damage calculations. Representing the armor as an auto-located linear damage element affords the ability to model the revetment as it conforms to the profile shape.
- Incorporates uncertainty into the armor damage calculations. The current armor feature allows only single discrete values, rebuild times, and failure thresholds to be used to represent armor. By using a damage element, uncertainty can be represented in the value, damage driving parameter, and the rebuild times.
- Easier to disaggregate spatial and temporal damages to armor. Using the approach as described makes it much easier to determine how, when, and where damages are estimated to occur.
- Responsive to the modeled alternative. The model is much more responsive in terms of representing alternative performance.

Challenges and Workarounds

- Representing the initial construction of armor. *Beach-fx* allows the user to simulate actions that would be taken in the future to protect property against storm damages. Using the prescribed approach makes simulating future behavior more challenging. Modeling future behavior was accomplished by creating a damage element type to represent initial armor construction, constructing a damage function that would spike to representing initial construction, and turning the number of times rebuilt attribute to 1. This "new armor" damage element was spatially located where initial construction would be anticipated to occur within the life cycle.
- Simulating armor as a damage element removes the protective attributes of the armor. The advantage of using the armor feature of *Beach-fx* is that while functioning, it simulates the prevention of erosion damages. The prescribed method does not incorporate this feature. To get around this limitation the following actions were taken:
    - The erosion protection feature of Beach-*fx* was left active while zeroing out the cost of armor protection as a lot level attribute.
    - active in the model road/armor maintenance cost was incorporated into the damage element.

Model Setup

1. Create the Damage Element Types: Five new damage element types were created to model the different kinds of armor in the study area, and the different conditions in which they would The following damage element types were created:
    a. *ARMOR-A1A & NEW ARMOR:* Existing and anticipated revetment built by FDOT to protect SR-A1A. This damage element type constitutes the overwhelming majority of the overall damages and is the primary focus of this write-up.
    b. *BULKHEAD & N-BULKHEAD:* Existing and anticipated vinyl pile bulkheads used to protect private residences in the Painters Hill (Reach-A) segment of the study area. These were used in concert with the armoring feature included in the model to achieve the spatial disaggregation of the damages, while protection for the residences in the study area.
    c. *SEAWALL:* Concrete panel and sheet pile metal seawalls, which receive little or no damage.
2. Create the Damage Functions: The damage functions are based on a collaborative effort by SAJ Economics and Coastal Engineering personnel. They were developed based on the armor failure thresholds pulled from the previously specified lot level attributes, where armor was initially specified.
    a. Damage Functions:
    The following section documents the damage functions. No damage accrues to the element until at least 50% of the footprint is compromised**.** As previously explained, these functions are based on the failure thresholds that were previously developed for the Flagler study. **Figure 2** shows the road damage function. As previously explained, the armor and the road itself are being modeled as a single integrated damage element. As seen in the table, the cost of a maintenance event is not incurred until at least 50% of the footprint in compromised. This is based on the assumption that the road must be

significantly damaged to warrant the cost of a maintenance event. **Figure 3** shows the damage function that was designed for the seawalls and bulkheads. In this case, the armor functions just as it would normally in *Beach-fx*. No damage occurs until 90-100% footprint is compromised, at which point the armor fails.

Figure 2: ARMOR-A1A Erosion Damage Function

% Footprint Compromised	Min	Most Likely	Max
0	0	0	0
10	0	0	0
20	0	0	0
30	0	0	0
40	0	0	0
49	0	0	0
50	0.5	0.5	0.5
60	0.51	0.6	0.75
70	0.52	0.7	1
80	0.53	0.8	1
90	0.54	0.9	1
100	0.55	1	1
	0	0	0

Figure 3:ARMOR-BULKHEAD Erosion Damage Function

% Footprint Compromised	Min	Most Likely	Max
0	0	0	0
90	0	0	0
100	1	1	1
	0	0	0

3. Spatially Locate the Damage Elements: Damage elements were dispersed throughout the study area on the seaward edge of the encompassing lot (ranging from 1 to 5 damage elements per lot). To model the initial construction of a revetment, the "NEW ARMOR" damage element type was spatially located were FDOT could be anticipated to take measures if SR-A1A were to be threatened by erosion. This damage element would accrue damages when hit, and then be deactivated. An "ARMOR-A1A" damage element was placed several feet behind the "NEW ARMOR", to capture recurring damages.

4. Determine the Damage Element Attributes: Armor value is based on actual maintenance cost provided by FDOT between 2000 and 2010. These figures were converted to a cost per LF, and are shown below.

Statistic	Cost/LF
Min	$60.39
Most Likely	$348.01
Max	$650.48

Cost/LF was multiplied by the along shore length of each damage element. Each ARMOR-A1A damage element was assigned a shore perpendicular width of ~70'. Previous rebuild times were also incorporated in the damage element.

Conclusion

The SAJ PDT feels confident in the results using this approach to model armor maintenance costs. The results we are getting with this method are reasonable and the method more accurately reflects what actually happens along the Flagler coast compared to other approaches to model armor.

Economics Appendix Addendum B: Future Without Project Condition Traffic Analysis Model Specification

1.1 Introduction

The purpose of this document is to describe the method used for estimating the cost of traffic rerouting due to erosion induced road/armor damage. Costs associated with traffic re-routing can be represented as damage elements and modeled to coincide with armor/road maintenance events. The purpose of this writing is to document the advantages theoretical considerations, methods, and results for estimating these costs using Beach-fx.

The advantages of this approach are analytical consistency, ease, and the ability to account for time sensitive conditions. Each traffic rerouting event can be tied to the occurrence of an armor/road structure damage event. Damage elements representing the revetment could be reconfigured to contain the overall present value traffic rerouting cost, and be easily extractible from model outputs. Knowing when and where traffic flow is most likely to be impacted in a study area could be of assistance in informing the plan formulation process. Model results could also provide support for sea level rise adaptation strategy considerations.

1.2 Theoretical Considerations

This section covers the theoretical underpinnings of representing the accrual of traffic re-routing costs as a damage element within Beach fx. The structure value of a particular damage element represents the depreciated replacement cost of the material and labor resources necessary for its existence. A damage elements content value can be envisioned conceptually as the opportunity cost of those resources typically deemed necessary to utilize the structure in a manner consistent with its intended purpose. For example, residential structures, content value is thought of as furniture, electronics, appliances, and other items not part of the structure, but commonly understood to be “necessary” to realize the benefits of housing. Commercial structure content values typically consist of the capital implements and/or inventory necessary to conduct the business associated with the structures intended business function. Therefore, the opportunity costs that must be incurred in order to use a road for its primary function (facilitating motorized transport) are the operating cost of the vehicles using the road.

However, the transportation value of a road consists of the difference between the cost of vehicle operation on the road in question and the cost of vehicle operation on the next best alternative route. This difference represents the ‘benefit foregone’ of no longer having the road in place. If the benefit that must be foregone due to road erosion damage can be: a)assessed a monetary value; b) applied coincident with the incursion of structure damage to the road providing the benefit; and c) cease to be applied when the road is repaired and serviceable, then that value can be stored as a data attribute within Beach-fx.

1.3 Method

This section of the appendix addresses the development of the triangular distribution of traffic costs and traffic reroute costs per damage element as well as the means by which these costs are stored and applied within Beach-fx. As alluded to in the previous section, these costs are stored as damage element level attributes in a triangular distribution of the structure value. Development of traffic costs within the study area encompasses the following components: 1) vehicle operating costs; 2) FDOT average annual daily traffic counts; and 3) typical and reroute travel distances within the study area.

1.3.1 Vehicle Operating Costs

The vehicle operating costs are based on the 2013 AAA per mile vehicle operating costs.[1] Vehicle operating cost per mile range from $0.52 for small sedans traveling 20,000 miles/year to $1.00 for 4WD sport utility vehicles traveling 10,000 miles/year.[2] The 2013 values were used to stay consistent with the price level for the rest of the structure inventory.

Vehicle operating costs were further refined by applying a percentage to each vehicle type category based on a 1999 US Department of Transportation study.[3] The percentage values derived in Table 1-1 were applied to estimate the composite cost in the last column in Table 1-2. The composite cost represents the range of operating costs per mile for vehicle travel.

Table 1-1: Distribution of Vehicle Types according to NPTS

VEHICLE TYPE	AVERAGE ANNUAL MILES DRIVEN	%
Automobile	11,318	22%
Van	14,389	28%
Sport Utility + Pickup	25,262	50%

Table 1-2: Development of Operating Costs per Mile

MILES/YEAR	COMPOSITE SEDAN	MINIVAN	SUV	COMPOSITE COST
10,000	$0.78	$0.84	$1.00	$0.91
15,000	$0.61	$0.65	$0.77	$0.70
20,000	$0.52	$0.56	$0.66	$0.60

---

[1] "Your Driving Cost, 2013 Edition", by AAA. Vehicle operating costs assume the vehicle travels 10,000, 15,000, and 20,000 miles per year.

[2] Decreased depreciation includes vehicles with an mileage accrual rate of less than less than 15,000 per year. Increased depreciation includes vehicles with mileage accrual rate of greater than 15,000 per year.

[3] "Growth in Motor Vehicle Ownership and Use: Evidence from the Nationwide Personal Transportation Survey" by Don Pickrell & Paul Schimek

1.3.2 Average Annual Daily Traffic Counts

Average Annual Daily Traffic Counts[4] (AADT): AADT spatial data is published by FDOT was geospatially associated with each traffic reroute damage element using GIS. Figure 1-1 illustrates the daily traffic count by range monument. Vehicle operating costs were applied to the AADT to convert the traffic count into value.

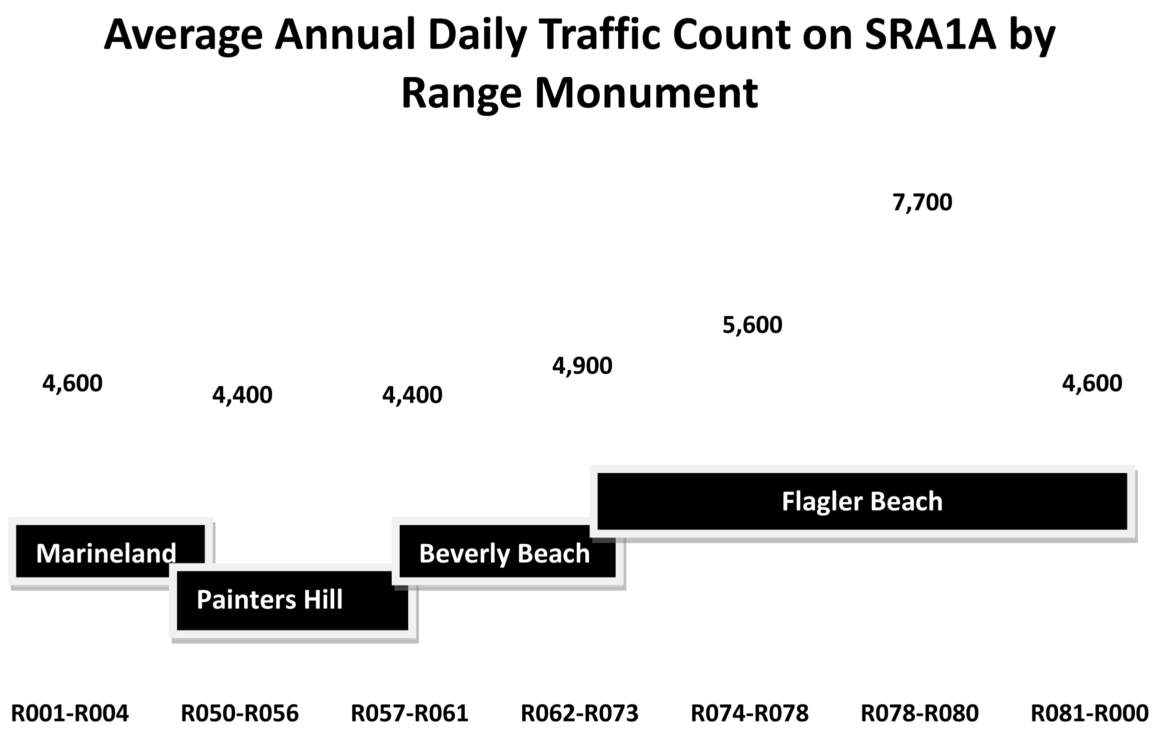


Figure 1-1: Average Annual Daily Traffic Counts

1.3.3 Typical and Re-routed Travel Distances

Table 1-3: Route Distances by Economic Reach

ECONOMIC REACH	TYPICAL LENGTH IN MILES	RE ROUTED LENGTH IN MILES	TOTAL LENGTH IN MILES GIVEN A REROUTE EVENT
MARINELAND	0.63	8.00	8.63
PAINTERS HILL	1.74	20.00	21.74
BEVERLY BEACH	1.11	20.00	21.11
FLAGLER BEACH	6.15	0.25	6.40

The distance vehicles are likely to travel both with and without a reroute event is the next component of estimating the costs of rerouting traffic due to armor/road maintenance events. Applied re-routing distances are largely dependent on the location of the armor maintenance event.

[4] An annual average daily traffic count is the number of vehicles that travel a certain stretch of road divided by the # of days in the year.

1.3.4 Estimation of Traffic Cost

As mentioned previously, the damage element content value attributes were used to store the traffic value for each road/armor damage element. The value per lineal foot of road was estimated using the following equation:

$$TC_L = ((V_n * AADT)R_L)/5280\ ft$$

Where:

TC_L = traffic cost per lineal foot of road

V_N= vehicle operating cost per mile (V_1= minimum, V_2= most likely, V_3= maximum)

AADT = average annual daily traffic count in vehicles per day

R_L = length of the road segment coincident with the FDOT traffic count in miles

The structure value triangular distribution for the damage element representing a particular segment of SRA1A was calculated using the following formulas[5]:

StructureMin: $TC_{DEMIN} = (TC_{V1} * DE_L)t_{DE}$

StructureML: $TC_{DEML} = (TC_{V2} * DE_L)t_{DE}$

StructureMax : $TC_{DEMAX} = (TC_{V3} * DE_L)t_{DE}$

Where:

$TC_{DEMIN,\ DEML,\ DEMAX}$= traffic cost of road segment represented by a damage element (triangular distribution)

$TC_{V1,\ V2,\ V3}$ = triangular distribution of traffic cost per lineal ft based on the min ($0.60), most likely ($0.70), and max ($0.91) vehicle operating cost per mile

DE_L = length of the damage element in ft (parallel to the coastline)

t_{DE} = most likely rebuild time of the damage element in days

Table 1-4 provides greater detail on the distribution of distances, traffic counts, and traffic value per lineal foot within the study area.

Table 1-4: Flagler County HSDR AADT Distribution

FLAGLER COUNTY DISTRIBUTION OF TRAFFIC & ESTIMATED COST/LF					
Location	Road Length Miles	AADT Counts	Min $/LF	Most Likely $/LF	Max $/LF
R001-R004	0.33	4,600	0.17	0.20	0.26
R050-R056	0.96	4,400	0.48	0.56	0.73
R057-R061	0.25	4,400	0.12	0.15	0.19
R062-R073	0.69	4,900	0.38	0.45	0.58
R074-R078	0.27	5,600	0.17	0.20	0.26
R078-R080	0.12	7,700	0.10	0.12	0.16
R081-R000	1.11	4,600	0.58	0.68	0.88

[5] Traffic costs per LF are based on vehicle operating cost per mile for a composite of sedan sizes, minivans, and SUV/trucks valued at .60, .70, & .91 cents per mile per year respectively.

1.3.5 Damage Function Application/Assumptions:

Road damage from erosion that undermines an area less than or equal to 70% of the road footprint is assumed to reduce the roads throughput by half. Road damage from erosion greater than 70% is assumed to produce a traffic rerouting event. This can be modeled using damage functions (discussed below). Approximate traffic rerouting distances were applied to SRA1A damage elements by study reach as follows: Marineland ~ 8 miles; Painters Hill ~ 20 miles; Beverly Beach ~ 20 miles; Flagler Beach ~ 0.25 miles.

Reroute cost were specified within Beach-fx by: estimating the cost of a traffic reroute event per damage element; determining the ratio of reroute cost to the traffic cost per damage element; and incorporating that ratio into an erosion structure damage function.

A triangular distribution of reroute cost per damage element was estimated as follows:

$$\boldsymbol{TC_{ALT} = (D_{ALT} * TC_{L})t_{DE}}$$

Where:

$\boldsymbol{TC_{ALT}}$ = traffic cost incurred due to a traffic reroute event

$\boldsymbol{TC_{DE}}$ = Traffic cost of the road segment represented by a damage element

$\boldsymbol{D_{ALT}}$ = reroute distance in ft

$\boldsymbol{TC_{L}}$ = traffic cost per lineal foot of road ($\boldsymbol{TC_{L1}}$= minimum, $\boldsymbol{TC_{L2}}$= most likely, $\boldsymbol{TC_{L3}}$= maximum)

$\boldsymbol{t_{DE}}$ = most likely rebuild time of the damage element associated with the traffic reroute in days

Upon estimation of the traffic reroute costs, the ratio of traffic reroute cost per damage element to traffic cost per damage element was determined and specified within a number of damage functions. These functions were grouped according to each respective ratio of traffic reroute cost to damage element traffic cost. Table 1-5 and Figure 1-3 provides greater detail on the damage element types and functions used.

Table 1-5: Damage Element Types & Functions

DAMAGE ELEMENT TYPES & FUNCTIONS			
Damage Element Type	Damage Function Description	Fractional Damage to Structure 1% 70%	> 70%
SRA1A-1	ERO-SRA1A-1	0.5	1.04
SRA1A-2	ERO-SRA1A-2	0.5	12.52
SRA1A-3	ERO-SRA1A-3	0.5	13.70
SRA1A-4	ERO-SRA1A-4	0.5	19.08

Table 1-5 shows detail on the factors that are applied to the traffic values to estimate the cost of constraining / rerouting traffic. Most of the traffic reroute events take place in Flagler Beach.

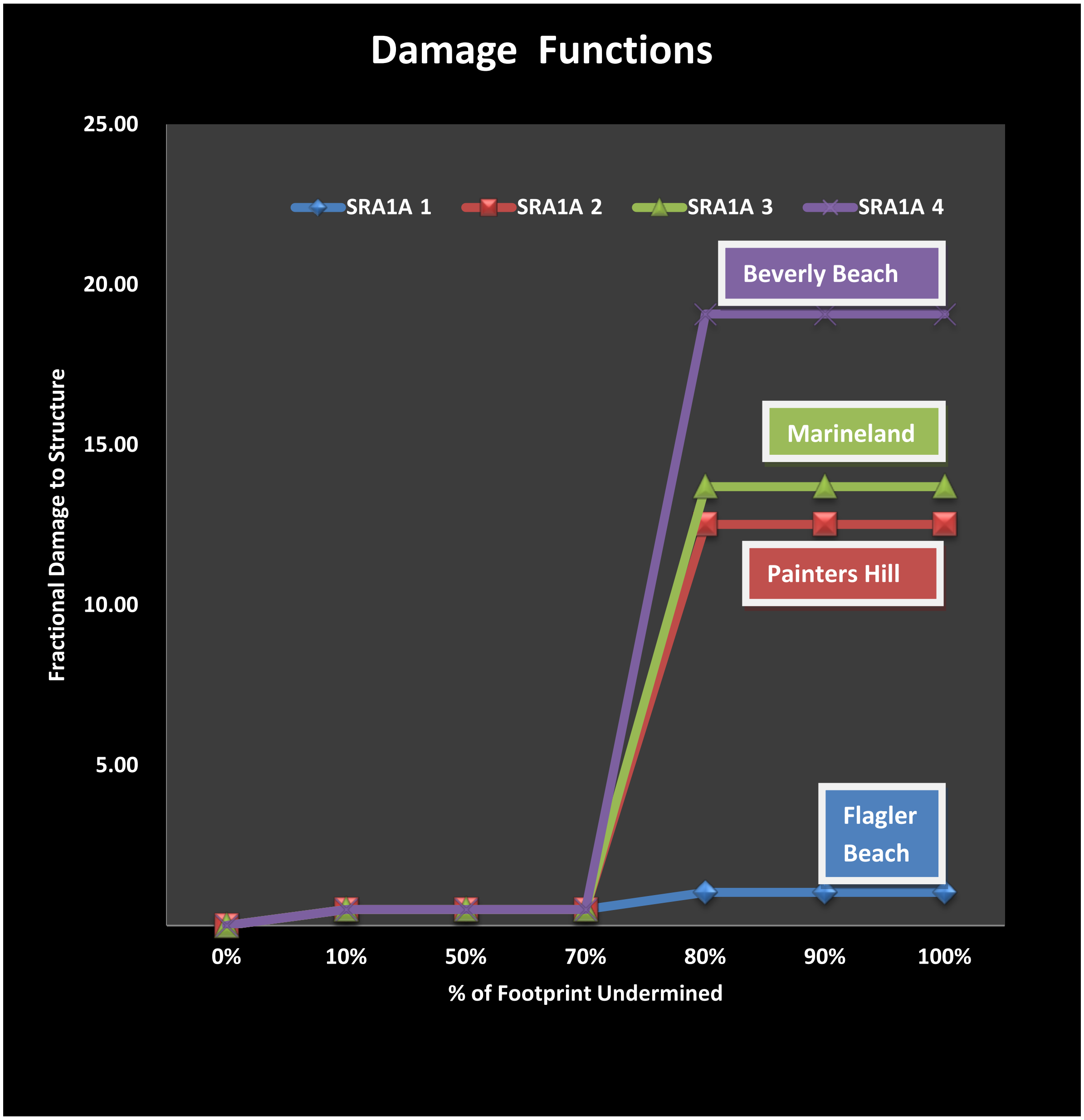


Figure 1-2: Damage Functions

Figure 1-3 provides an illustration of the new damage functions created to model the impact of road erosion on SRA1A's traffic within the study area. Percentages of the road's footprint undermined ranging between 1% - 70 % results in the loss of ½ of the traffic value. This essentially means that the roads average daily usage has been cut in half, by maintaining a single lane while repairs are made. When the percentage of footprint undermined exceeds 70%, the damage function generates a loss equivalent to the cost of a reroute event. Thus both lanes are closed and traffic must be rerouted. An explanation of the damage function examples depicted in the figure is as follows:

- ERO-SRA1A-1: TC_{ALT}/ TC_{DE} = 1; describes the relationship between road/armor damage and maintenance events and traffic reroute costs in the Flagler Beach portion of the study area.
- ERO-SRA1A-2: TC_{ALT}/ TC_{DE} = 2; describes the relationship between road/armor damage and maintenance events and traffic reroute costs in the Painters Hill portion of the study area.
- ERO-SRA1A-3: TC_{ALT}/ TC_{DE} = 3; describes the relationship between road/armor damage and maintenance events and traffic reroute costs in the Marineland portion of the study area.
- ERO-SRA1A-4: TC_{ALT}/ TC_{DE} = 4; describes the relationship between road/armor damage and maintenance events and traffic reroute costs in the Beverly Beach portion of the study area..

2 Traffic Cost Benefits

Traffic cost benefits are the difference in the cost for traffic between the future without and the future with project conditions. Both alternative scenarios were simulated in Beach-Fx using the following parameters:

- Base Year ~ 2018
- # of Observations/ Iterations~ 100
- Price Levels ~ FY 2014
- Discount Rate ~ 3.50%
- Foundation Critical Erosion Value = .8 ft
- Time to build roads triangular distribution
  - Minimum: 5 LF/day
  - Most likely: 7 LF/day
  - Maximum: 10 LF/day

Table 2-2 provides detail on the Beach-Fx result statistics, while Figure 2-1 illustrates the distribution of the benefits. The recommended plan produces $176,000 in average annual benefits. The benefits were reduced by about 26% to account only for the portion of the operating cost that varies with distance.

Table 2-1: % Distribution of Vehicle Operating Cost

Costs	% of Vehicle Operating Cost/Mile
Gas & Oil	23%
Maintenance	10%
Tires	2%
Insurance	10%
License & Registration	6%
Depreciation	40%
Financing	9%

Table 2-1 displays the distribution of vehicle operating cost on a percentage basis. Gas, oil, maintenance, tires, and depreciation are the portion of the cost that varies with distance. The combination of these cost components equal 74% of the cost to operate a vehicle. Based on these figures, the traffic benefits were reduced from $176,000 to $131,000.

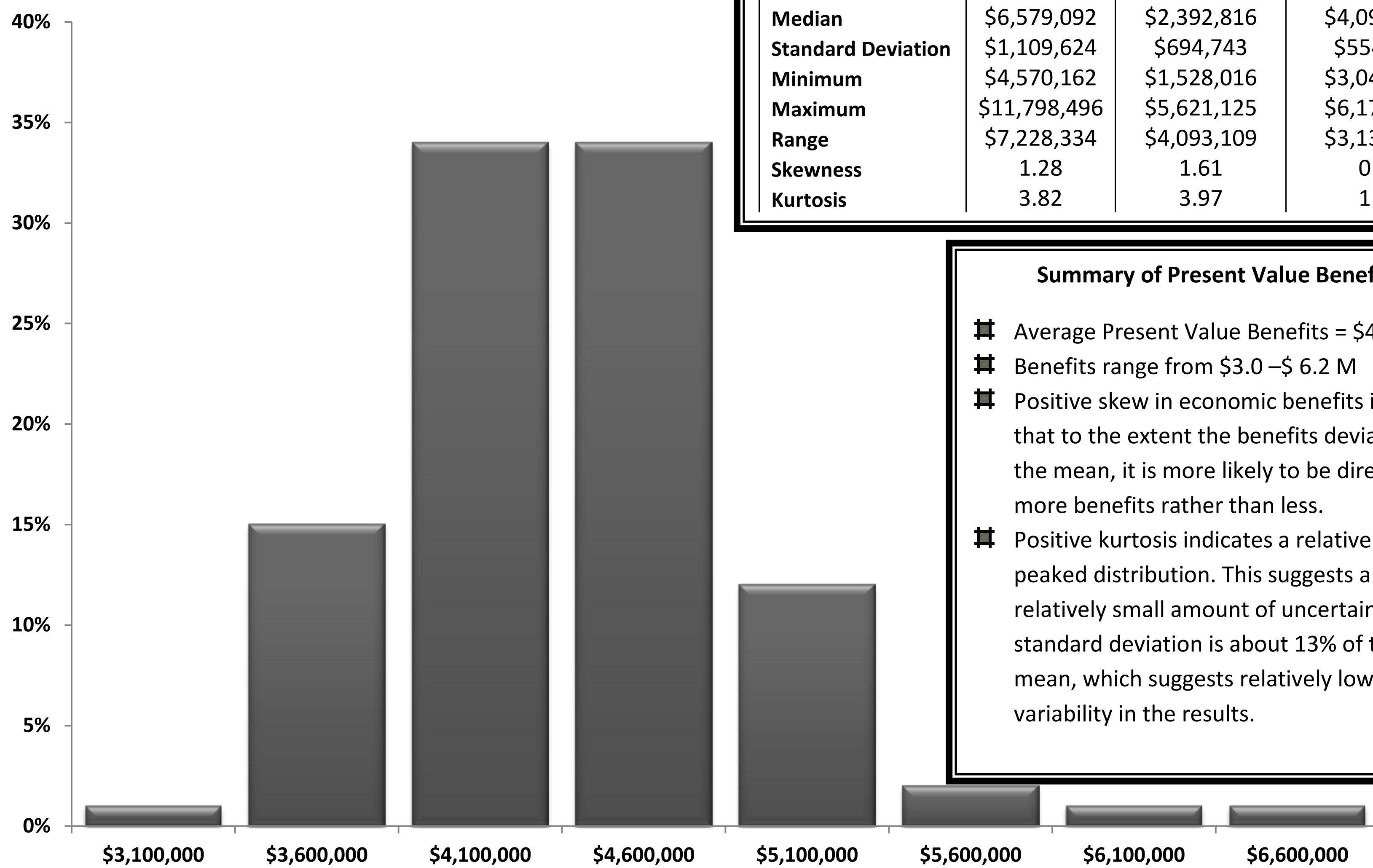


Table 2-2: Beach Fx Result Statistics

Statistic	Future w/o Project Condition	Future with Project Condition	Economic Benefits
Mean	$6,680,654	$2,548,321	$4,132,332
Median	$6,579,092	$2,392,816	$4,098,401
Standard Deviation	$1,109,624	$694,743	$554,279
Minimum	$4,570,162	$1,528,016	$3,042,146
Maximum	$11,798,496	$5,621,125	$6,177,371
Range	$7,228,334	$4,093,109	$3,135,225
Skewness	1.28	1.61	0.93
Kurtosis	3.82	3.97	1.68

Summary of Present Value Benefits

- Average Present Value Benefits = $4.1 M
- Benefits range from $3.0 –$ 6.2 M
- Positive skew in economic benefits indicates that to the extent the benefits deviate from the mean, it is more likely to be direction of more benefits rather than less.
- Positive kurtosis indicates a relatively peaked distribution. This suggests a relatively small amount of uncertainty. The standard deviation is about 13% of the mean, which suggests relatively low variability in the results.

Figure 2-1: Distribution of Traffic Benefits