ECONOMICS PARKING AND ACCESS APPENDIX E

FOLLY BEACH, SOUTH CAROLINA

SEPTEMBER 2021

Prepared by:

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Executive Summary

The Folly Beach Coastal Storm Risk Management Feasibility Study is authorized by Section 216 of the Flood Control Act of 1970, Public Law 91-611 (33 U.S.C. § 549a). The study is a re-evaluation of a 1991 study to determine continued federal interest in Folly Beach in the presence of escalating costs.

►Alternative Evaluation

Upon conduct of a preliminary screening, followed by an evaluation of an array of preliminary alternatives, and a detailed evaluation of a set of final alternatives, the project delivery team has determined a Recommended Plan for reducing coastal storm and erosion damage to infrastructure and land. Alternatives were first evaluated using the then current FY2020 price level, the FY2020 Project Evaluation and Formulation Rate (Federal Discount Rate) of 2.75%, and a 50-year period of analysis with a Base Year of 2024. Structure and content damage, armor construction cost prevented, land loss, and prevention of structure condemnation were included as benefit categories. Incidental recreation benefits were not included until identification of the NED Plan. See Table 1 for more detail on the evaluation of the final array of alternatives. Dune values refer to the height of the dune in NAVD88. All dunes are 5' wide at the crest.

Table 1: Final Alternative Average Annual Net Benefit (FY2020, Model Costs)

Alternative Name	Nourishments (Interval)	Reaches 2-17	Reaches 18-21	Reaches 22-26	Average Annual Cost	BCR	Average Annual Net Benefit
Alternative 1	-	No Action			$0	-	$0
Alternative 2	4 (12 years)	35' Berm, 15' Dune	35' Berm, 15' Dune	50' Berm, 15' Dune	$3,891,000	1.29	$1,110,000
Alternative 3	4 (12 years)	35' Berm, 15' Dune	50' Berm, 15' Dune	50' Berm, 15' Dune	$3,938,000	1.28	$1,100,000
Alternative 4	5 (10 years)	35' Berm, 15' Dune	35' Berm, 15' Dune	50' Berm, 15' Dune	$4,476,000	1.10	$469,000
Alternative 5	5 (10 years)	35' Berm, 15' Dune	50' Berm, 15' Dune	50' Berm, 15' Dune	$4,528,000	1.10	$444,000
Alternative 6	6 (8 years)	15' Berm, No Dune			$4,173,000	0.93	-$280,000

The modeled net benefits of Alternatives 2 and 3 are almost identical. Alternative 3 is the plan that reasonably maximizes net benefits based on expert engineering judgment due to its higher resiliency. Specifically, Alternative 3 provides a more natural transition of sediment across model reaches. The reasoning for increasing the length of the 50-ft berm in Alternative 3 was to extend the wider berm all the way to where the Folly Beach shoreline alignment changes more to the northeast. The shoreline north of this jog faces higher wave energy with a steeper foreshore slope and has a history of higher erosion. Given the limitations in computer modeling resolution and accuracy and from coastal engineering judgement and experience the team is confident that

Alternative 3 reasonably maximizes net benefits by extending the 50-ft berm the relatively short distance to ensure there is no erosion hot spot at the shoreline alignment. The physical difference between the two alternatives is that the 50’ berm extends to reaches 18-21 under Alternative 3. Alternative 3 is the Recommended Plan.

►The Recommended Plan

Alternative 3 is the Recommended Plan. The Recommended Plan consists of a 5.8 mile (30,890 linear foot) main dune and berm combination beach fill. The southwest portion of the project includes a 35 ft wide berm between reaches1 to 17 for 19,170 feet (ft). This includes the 2,200 ft Folly Beach County Park portion of the Recommended Plan plus the 16,970 ft portion of the Recommended Plan between reaches 2-17. The northeast portion includes a 50 ft wide berm between reaches 18 to 26 for 9,720 ft., plus a 50 ft wide berm in the 2,000 ft portion of the Recommended Plan which includes the County-administered Lighthouse Inlet Heritage Preserve. The berm is at elevation 8.0 ft North American Vertical Datum 88 (NAVD88). The Plan includes constructing a new dune or raising the existing dune to a uniform elevation of 15 ft NAVD88 with a minimum top width of 5 ft between reaches 2-26. Neither the County Park in the southern end of the Recommended Plan nor the Lighthouse Inlet Heritage Preserve at the northern end of the Recommended Plan would feature a dune. The beach fill includes a 750-foot tapered transition at the ends of the project and a 500 ft transition between the 35 ft and 50 ft wide berm. During the 50-Year period of recommended federal participation in the Recommended Plan, material for the beach fill would be dredged from two proposed offshore borrow sources and one riverine borrow source and transported to the beach by pipeline for the beach fill construction and all renourishments. The renourishment interval for the project is approximately twelve years. See Figure 1 for an aerial image of the Recommended Plan.

Figure 1: Overview of the Recommended Plan

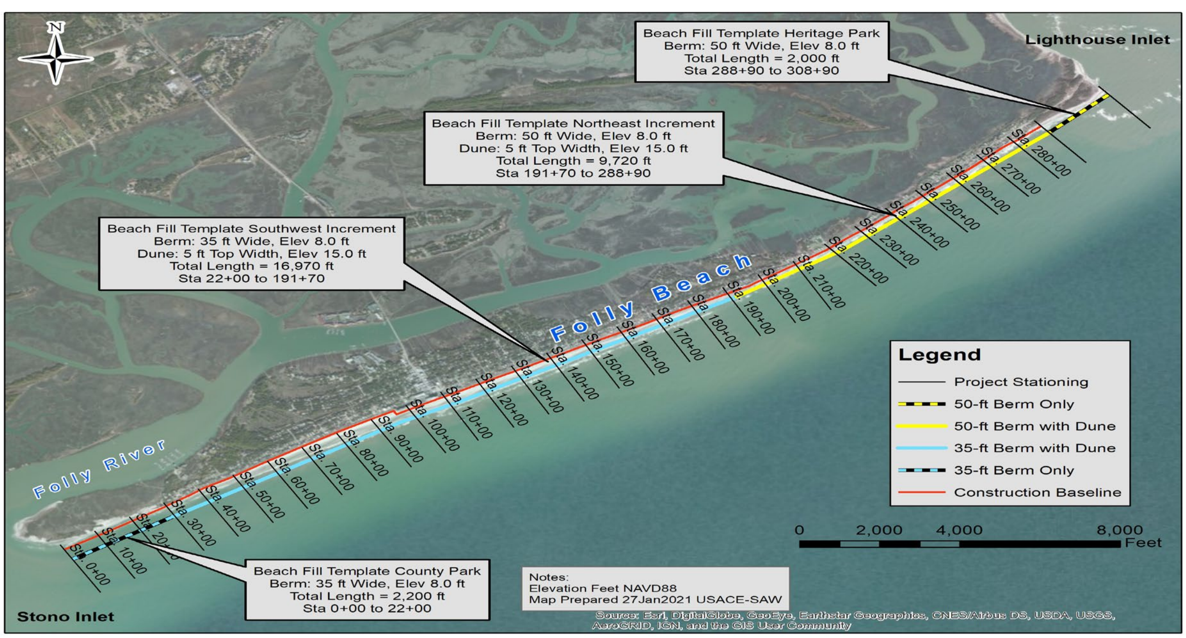

Table 2 provides a summary of the Recommended Plan with and without incidental recreation benefits added at FY2021 Price Level, the FY2021 Federal Discount Rate of 2.5%, and a 50-year period of analysis with a Base Year of 2025. The price level and costs from the Total Project Cost Summary (TPCS) are provided in Appendix A – Cost Engineering and used in Table 2 resulting in a change to the BCR and average annual net benefits from Table 1.

Table 2: Economic Summary of the Recommended Plan

Economic Category	Primary Storm Damage Reduction Benefit	Primary Storm Damage Reduction Benefit + Recreation Benefit for Project Justification	Primary Storm Damage Reduction Benefit + Full Incidental Recreation Benefit
Price Level	FY2021	FY2021	FY2021
FY2021 Water Resources Discount Rate	2.5%	2.5%	2.5%
Average Annual Structure and Content Damage Benefit	$84,000	$84,000	$84,000
Average Annual Damage Element Condemnation Benefit	$10,000	$10,000	$10,000
Average Annual Lot Condemnation Benefit	$1,146,000	$1,146,000	$1,146,000
Average Annual Armor Construction Cost Benefit	$1,069,000	$1,069,000	$1,069,000
Average Annual Land Loss Benefit	$2,455,000	$2,455,000	$2,455,000
Average Annual Incidental Recreation Benefit	-	$4,765,000	$47,753,000
Average Annual Total Benefit	$4,765,000	$9,529,000	$52,518,000
Average Annual Total Cost	$5,500,000	$5,500,000	$5,500,000
Average Annual Net Benefit	-$735,000	$4,029,000	$47,018,000
BCR	0.87	1.73	9.5

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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 assessment of socio-economic conditions, spatial organization of the study area, and an inventory of the coastal infrastructure within the study area.

►**Coastal Storm Risk Management Benefits**
This section will cover the methods used to estimate the future without-project and future with-project conditions using Beach-*fx*, accounting for risk and uncertainty. The future without-project condition will cover the distribution of damages in the following dimensions:

- ►Spatial (Where)
- ►Categorization of structures (What)
- ►Damage diving parameter (How)
- ►Temporal (When)

The future with-project condition discussion will cover the CSRM alternatives analyzed, and the analysis results. In addition, an analysis of alternative performance under low and high sea level change scenarios is provided.

►**NED & Recommended Plan Selection and Performance**
This section addresses the rationale and methodology for plan selection. A detailed description of the performance of the NED Plan is provided with the same 4 dimensions given in the Coastal Storm Risk Management section. A discussion of the project's incidental recreation benefits is also provided.

►**Beach-*fx* Overview**
Beach-*fx* was developed by the USACE Engineering Research and Development Center in Vicksburg, Mississippi. On April 1, 2009, the Model Certification Headquarters Panel certified the Beach-*fx* hurricane and coastal storm risk management (CSRM) model based on recommendations from the CSRM – Planning Center for Expertise. The model was reviewed by the Planning Center for Expertise for coastal and storm damage and found to be appropriate for use in CSRM studies.

Beach-*fx* fully incorporates risk and uncertainty and is used to simulate life-cycle hurricane and storm damages 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 wave attack, erosion, and/or 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 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, roads, vehicles, 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, such as emergency beach/dune fill projects and future armor installation/maintenance.

Data on historic storms, beach survey profiles, and private and commercial 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.

2 Existing Conditions

2.1 Overview of Existing Structures and Data Organization

Economists, real estate specialists, and engineers have collected and compiled detailed structure information for the stretch of shoreline to be modeled in Beach-*fx* as part of the Folly Beach, South Carolina Coastal Storm Risk Management Feasibility Study covering almost 6 miles of shorelines, which includes:

- ►692 Single Family Residences (325 single-story, 367 multi-story)
- ►103 Multi-Family Residences (19 single-story, 84 multi-story)
- ►25 Commercial Structures (15 single-story, 10 multi-story)
- ►260 Dunewalks
- ►830 Vehicles
- ►122 Blocks of City Streets

In total, attribute information for 2,032 separate damage elements (DEs) was populated for economic modeling using Beach-*fx*. The proximity of the buildings to the beach makes them potentially vulnerable to erosion, wave attack, and inundation.

The study area was disaggregated into 9 representative beach profiles, 26 model (Beach-*fx*) reaches, and 620 lots (of which 100 are currently armored, 223 are armorable in the future, and 297 are not armorable in the future) for economic modeling and reporting purposes. Lots are only marked as not armorable if the damage elements contained within are dunewalks or vehicles. All structures and roads are placed in lots that are either currently armored, or armorable in the future. Figure 1 shows an aerial view of the Beach-*fx* model features that represents the shoreline in the study area. This hierarchical structure is depicted as follows:

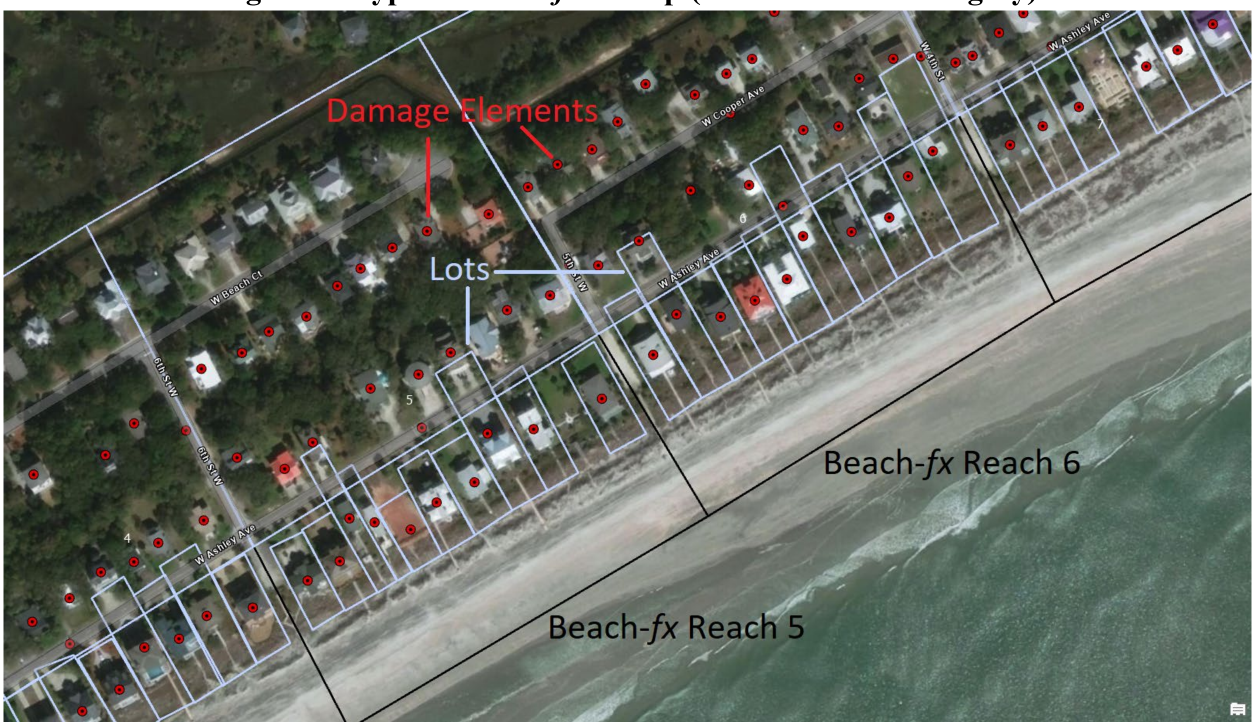
- ►**Beach Profiles**: Coastal beach profile surveys were analyzed by USACE Wilmington District (SAW) Coastal Engineering personnel to develop representative beach profiles that include the dune, berm and submerged portions of the beach. The representative beach profiles are used for shore response modeling in the SBEACH engineering numerical model, and only referred to in this section for informational purposes.
- ►**Beach-*fx* (Model) Reaches**: Quadrilaterals with a seaward boundary that is parallel with the shoreline that contain the Lots and Damage elements, and that are used to

incorporate coastal morphology changes for transfer to the lot level. Model reaches are also useful because they allow modelers to divide 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.

►**Damage Elements**: Represents the smallest 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.

Figure 2: Typical Beach-*fx* Set Up (ArcGIS World Imagery)



Folly Beach has a history of beach intervention including a previous federal project, groins to keep sand on the beach, and emergency intervention post-tropical storm. In recent years, the northeast segment of the island has emerged as the most at risk to high levels of erosion. Aerial imagery goes back almost 30 years, Figure 3 provides a recent history of the northeast segment of the island via Google Earth Pro. Over this timeframe, the shoreline has been highly variable.

Figure 3: Aerial Imagery of Northeast Folly Beach

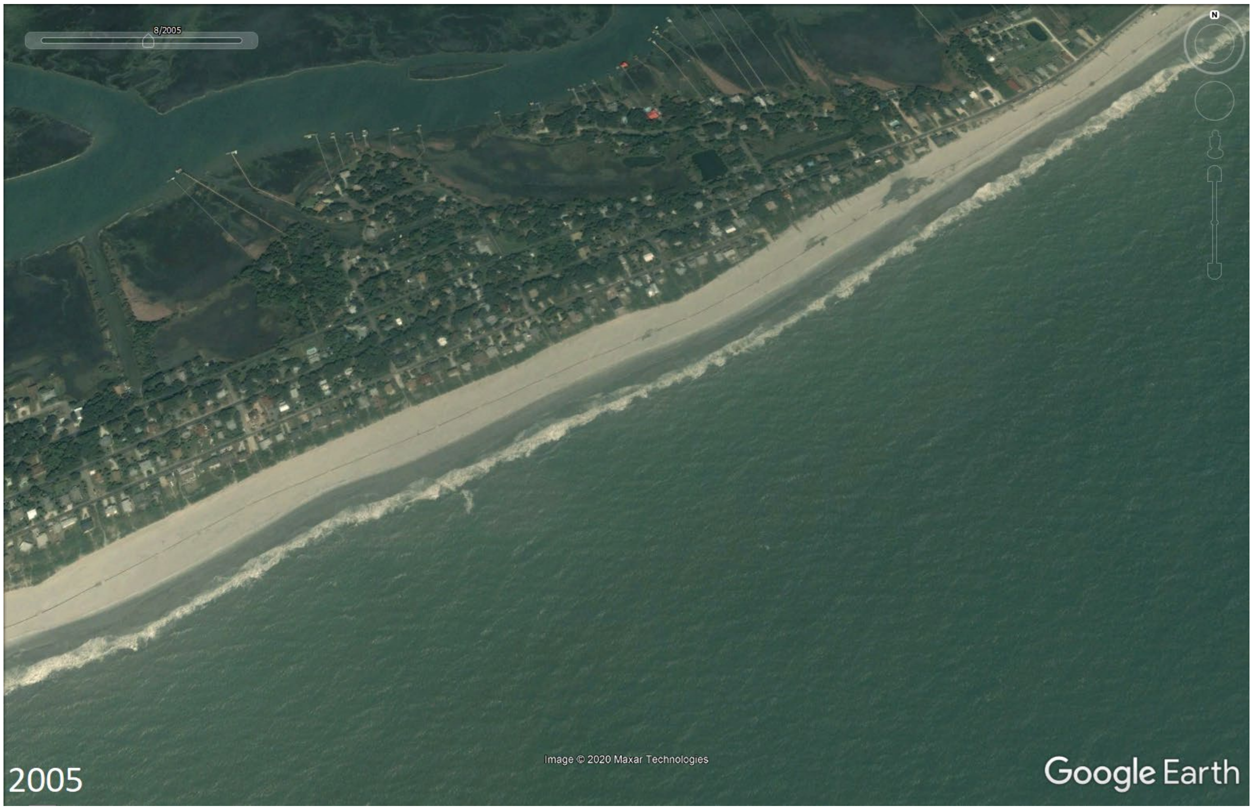

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Image © 2020 Maxar Technologies
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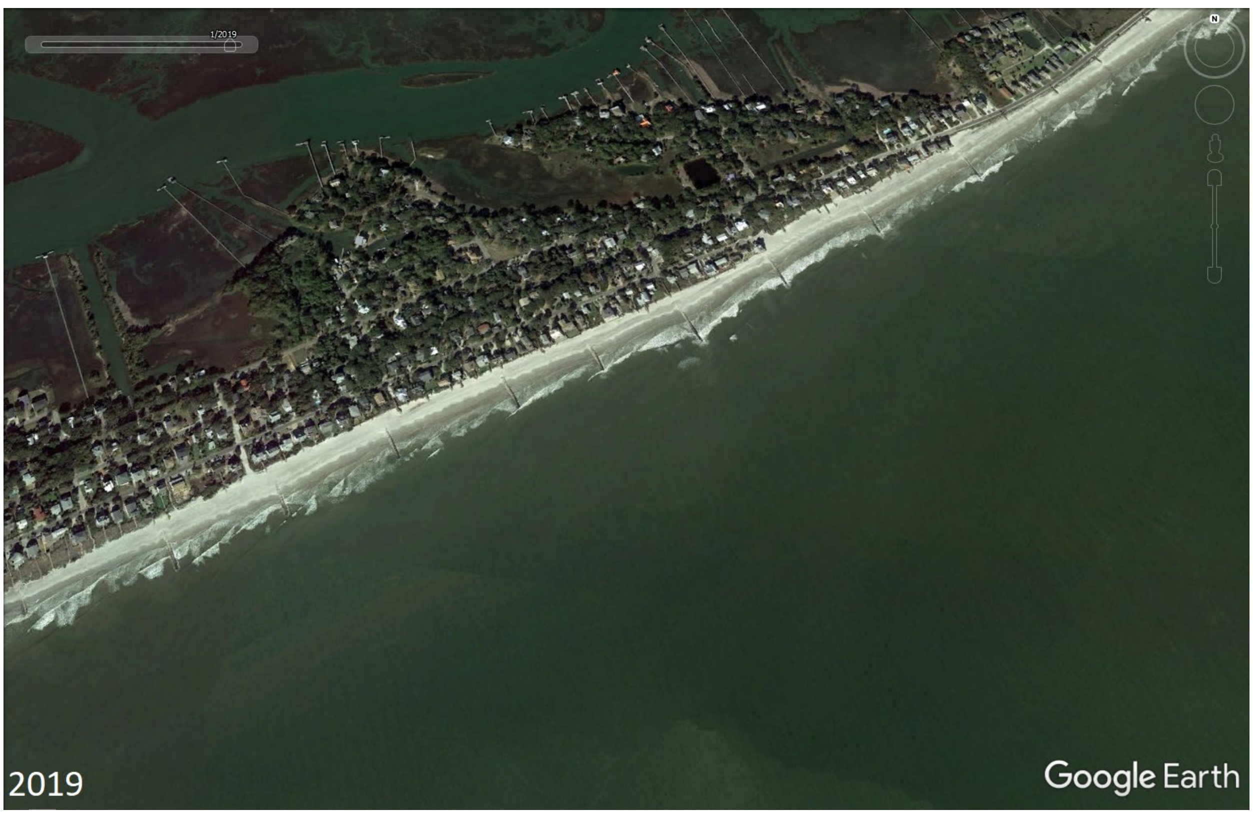
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More details on the establishment of the Profiles and Beach-*fx* Model Reaches, which is primarily based on physical shoreline characteristics, can be found in the Appendix A – Coastal Engineering.

Beach-*fx* handles economic considerations at the Lot and Damage Element levels. These considerations include armor construction costs at the lot level and the extent of damage and rebuilding costs at the Damage Element level. When damages occur in Beach-*fx*, Damage Elements may be partially rebuilt depending on the extent of modeled damage. Beach-*fx* calculates rebuild costs as the difference in the structures depreciated replacement value before and after the damage occurs. Section 2.2 will provide further detail on the Lot and Damage Element attribute data that makes up the structure inventory for this project area.

2.2 Data Collection for Structure Inventory

Information on the existing economic conditions along the Folly Beach study area coastline was collected for economic modeling purposes using Beach-*fx*. The information on the coastal assets detailed in this section was collected from mapping resources and site visits.

2.2.1 Lots – Coastal Armor

Beach-*fx* handles coastal armoring parameters and condemnation at the lot level. Lots are designated as being either armored, armorable in the future, or not armorable, based on coastal regulations that dictate armor construction and local history on armor permitting and construction. Since armoring forms one of the major roles of lots in Beach-*fx*, the location and length of potential future armoring dictates the seaward boundary of most lots.

Data on coastal armor within the project area was collected from aerial photography and USACE Wilmington District (SAW) Coastal Engineering personnel.

The area modeled contains several types of existing coastal armor including seawalls and revetments constructed of various materials. Most of this existing armor has been constructed to protect single family residences from erosion damages. Figure 5 shows the lots color coded by armor status for a typical stretch of shoreline. Lots that are already armored are shown in green.

The project area shoreline that is not currently armored has been categorized as being either armorable in the future or not armorable. This categorization is based on the assumed likelihood that armor would or would not be constructed by local interests should property be threatened in the future by coastal processes.

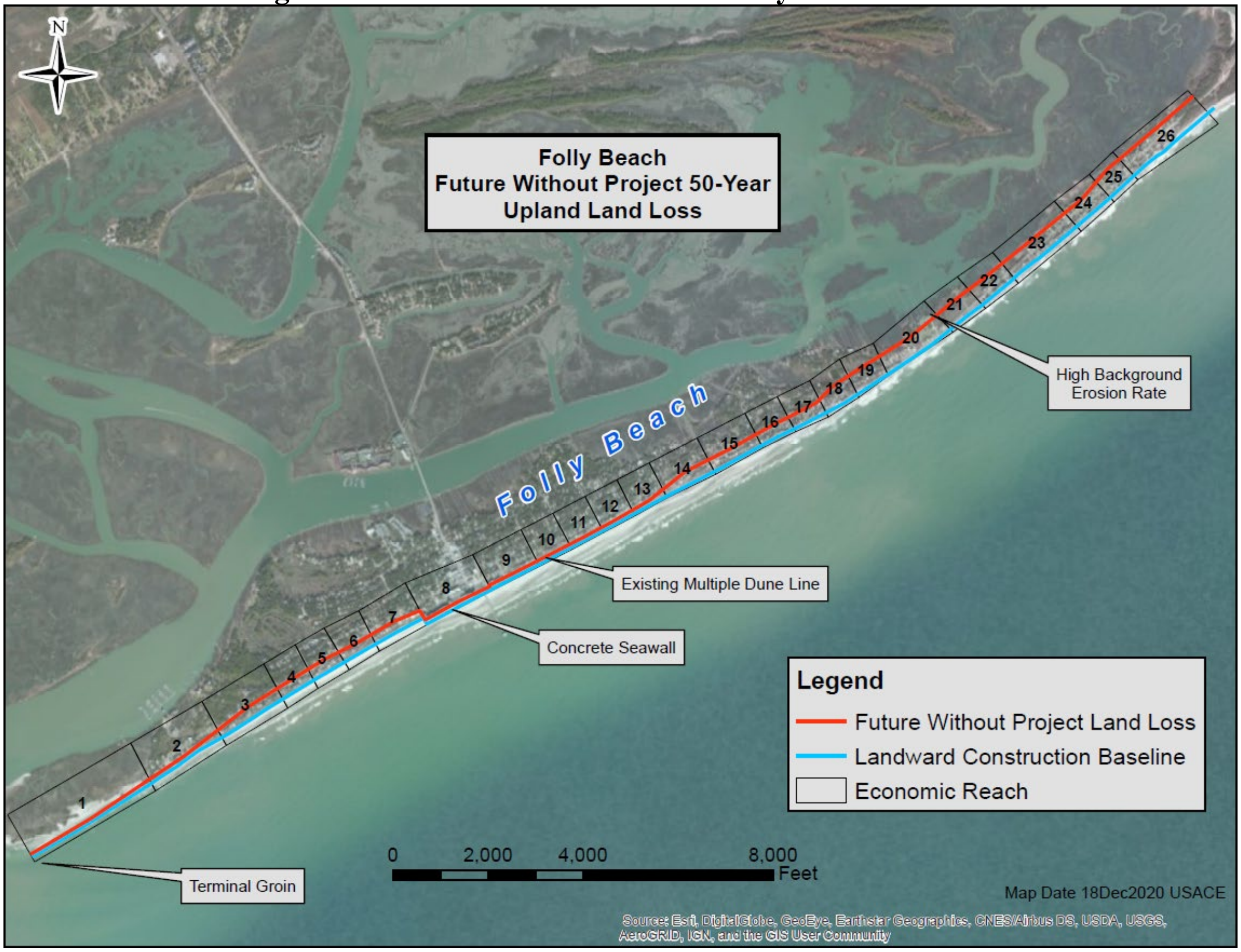
Lots designated as armorable in the future are shown in yellow in Figure 5. It is assumed that certain structures along the shoreline would be armored by local interests in a similar manner to existing armor as erosion continues to threaten homes and property. In Folly Beach, new armor construction must abide by local regulations. These regulations were used for the basis of the specifications dictating how future armor for family homes would perform. It is assumed that the South Carolina Department of Transportation SCDOT would construct armor in order to protect the seaward most roadway (W Ashley St west of Center St, E Artic Ave east of Center St) if threatened by erosion. This road is the first line of defense for which many homeowners access their property. The SCDOT already installed a heavy-duty revetment in an area that has seen all its developable land seaward of the road erode. This area is comprised of Beach-*fx* model reaches 20 and 21 and is known locally as "the washout."

The coastal process between armor, erosion, and land loss is very interconnected in the real world, which cannot be completely captured by any model. In Beach-*fx* erosion is caused by two factors: first, gradually by the slow background process of the system; second, by storms events which cause a large amount of erosion at once. Beach-*fx* only calculates erosion damage when a storm occurs, and if armor is present (assuming it did not fail during the storm) then any erosion damage is removed. While a simplification, this process accurately captures the interaction between armor, and erosion damage to structures.

The shortcoming is when land loss is added to the analysis. In Beach-*fx*, land loss is calculated on the reach level (as opposed to armor at the lot level) and is calculated as if there is no armor present. The standard approach is to assume that no land loss occurs in the presence of armor. However, in Folly Beach the gradual background erosion process is quite substantial, and the quality of armor installed by individual households is low, causing the armor to be destroyed relatively frequently. These two observations imply that there would be a non-zero amount of land loss past the armor line in the first row of structures. Given the tools in Beach-*fx*, land loss can only be assumed to be zero in the presence of armor, or completely unimpeded by the presence of armor. Neither of these assumptions is correct, with reality lying somewhere between.

The decision was made to include land loss for the first row of structures which are only defended by armor installed by individual homeowners. This assumption has severe impacts, because it allows inclusion of land loss and lot condemnation due to land loss. Land loss and lot condemnation become the two largest primary benefit categories in the analysis. Due to the uncertain nature of this assumption, sensitivities are run to capture the risk with this approach. Figure 4 shows the expected extent of erosion given no intervention or slowdown due to the presence of armor.

Figure 4: Worst Case Scenario with 50 years of Erosion



SAW personnel developed cost estimates for four unique types of existing or potential future armor in the study area. Table 3 shows the armor attributed used in the model.

Table 3: Model Armor (FY2021)

Armor Type	CSRM Function	Land Loss Beyond Armor	Cost per Linear Foot	Mob and Demob
SCDOT Revetment	Protect Road	No	$3,000	-
USACE Revetment	Potential Alternative	No	$6,000	-
Seawall	Protect Commercial Center	No	$3,000	$30,000
Individual Homeowner	Protect Individual Property	Yes[1]	$1,000	$1,500

[1]Assumption evaluated by sensitivity analysis in section 4.8.

Not armorable lots are shown in red in Figure 5. It is assumed that these lots would not be armored in the future because the DEs contained in the lots would not benefit from armoring. The DEs in these lots are dunewalks that are seaward of expected armor placement, or lots containing vehicles, which are only subject to inundation damages and therefore receive no benefits from armoring.

Figure 5: Lot Armor Status

2.2.2 Damage Elements – Structure and Contents Value

Beach-*fx* handles economic considerations at the DE level. These considerations include extent of damage, cost to rebuild, and time to rebuild. Beach-*fx* uses user-defined damage functions to calculate the extent of damage. For each damage element, the following information is input into Beach-*fx*:

- ►Geographical reference (northing and easting of center point)
- ►Alongshore length and cross-shore width
- ►Usage (e.g., single family, multi-family, commercial, walkover, pool, gazebo, tennis court, parking lot)
- ►Number of floors
- ►Construction type (e.g., wood frame, concrete, masonry)
- ►Foundation type (e.g., shallow piles, deep piles, slab)

- ►Armor type (e.g., seawall)
- ►Ground and/or first floor elevation
- ►Value of structure (replacement cost less depreciation)
- ►Value of contents

The geospatial location and footprint of the damage elements was verified using aerial photography in ArcMap Pro. The occupancy, construction, and foundation type of each damage element was gathered from the Charleston County property appraiser information and visual observations by SAW staff. First floor elevations of all the damage elements in the study area were obtained via combining LiDAR topology data and manual recording of how far above ground elevation the first floor of each structure is. The uncertainty of the first floor elevations was set at +/- .197', which is the margin of error of the LiDAR data.

Real Estate professionals from USACE Savannah District (SAS) provided depreciated replacement values for a sample of damage elements in April 2020. The sample of structures sent to SAS contained a range of different occupancy types, ages, and quality ratings. The most valuable structures (obtained from Charleston County tax records) were sent separately, in addition to this sample. SAS personal used the Marshall & Swift Valuation software to obtain depreciated replacement values. Depreciated replacement values for other structures were extrapolated from the sample sent to SAS based on the value/square foot from structures of the same occupancy type and of a similar age and quality. An uncertainty of +/- 13% was assigned to these costs. +/- 13% is the percent change from one standard deviation for the mean single-family property's value/square foot. Single-family properties were used because they make up most of the structures on Folly Beach and most of the sample sent to SAS. This value was used for multi-family and commercial structures because the number of those structures in the sample was not determined adequate to obtain a reliable estimate.

The value for roads was taken to be $97 per foot, the value for Milling and Resurfacing a 2 Lane Rural Road with 5' Paved Shoulders from the Florida Department of Transportation. A value of $134 was used for Center St, and 150' of Ashley Ave where it connects to Center St. This is the value for Milling and Resurfacing 3 Lane Rural Road with 5' Paved Shoulders and Center Turn Lane from the Florida Department of Transportation. Lengths were measured in ArcMap Pro.

For dunewalks, a value of $150/linear foot was used. This is taken from previous USACE CSRM studies and deemed appropriate in this analysis given similarities in the function of the construction. Values for vehicles are taken to be 11.9% of the total value from the National Structure Inventory. The percentage is based on Economic Guidance Memorandum (EGM) 09-04, which states that 11.9% of vehicles get left behind in a flooding event with 12 hours or more warning. The minimum value for vehicles is 0% while the maximum is 19.4%, which is the number of households that do not move at least one vehicle if given 6-12 hours' notice of a flood event. An uncertainty of +/- 10% was assigned the values for roads and dunewalks. Lengths were measured in Esri's ArcMap Pro.

Contents values were assumed to be 43.4% ± 25.0% of the structure value for single-story residences and 40.2% ± 25.9% for multi-story residences, following EM 1110-2-1619. Content (minimum, most likely, and maximum) values for commercial structures came from IWR 96-R-12 and range from (17%, 45%, 81%) for hotels and restaurants and (0%, 145%, 312%) for other commercial structures. Other DEs (roads, dunewalks, and vehicles) had zero content value.

2.3 Structure Inventory Overview

The economic value of the existing structure inventory represents the depreciated replacement costs of damageable structures and their associated contents within the study area along the coastline. The damage element inventory includes 2032 damageable structures with an overall estimated value of $258 million, with structure and content valuations of $183 M and $75 M respectively.

Values aggregated by occupancy type show that most of the value in Folly Beach is in single-family homes and multi-story multi-family buildings. Table 4 provides the distribution of values broken down by damage element type.

Table 4: Distribution of Value by Damage Element Type (FY 2021)

Damage Element	Number of Elements	Total Value	Average Value	Percent of Total
Single-Story Commercial	15	$6,361,000	$424,000	2.5%
Multi-Story Commercial	10	$16,860,000	$1,686,000	6.5%
Single-Story Single-Family	325	$49,790,000	$153,000	19.3%
Multi-Story Single-Family	367	$112,035,000	$305,000	43.5%
Single-Story Multi-Family	19	$3,276,000	$172,000	1.3%
Multi-Story Multi-Family	84	$56,731,000	$675,000	22.0%
Road	122	$4,908,000	$40,000	1.9%
Dunewalk	260	$2,971,000	$11,000	1.2%
Vehicle	830	$4,721,000	$6,000	1.8%
Total	2032	$257,652,000	-	100%

3 Coastal Storm Risk Management Benefits

This section of the appendix covers the approach used to estimate the economic benefits of reducing hurricane and storm related damages in Folly Beach, South Carolina 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* 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 CSRM alternatives. This output is then used to determine the benefits of each alternative.

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 Folly Beach where coastal development has historically increased in value.

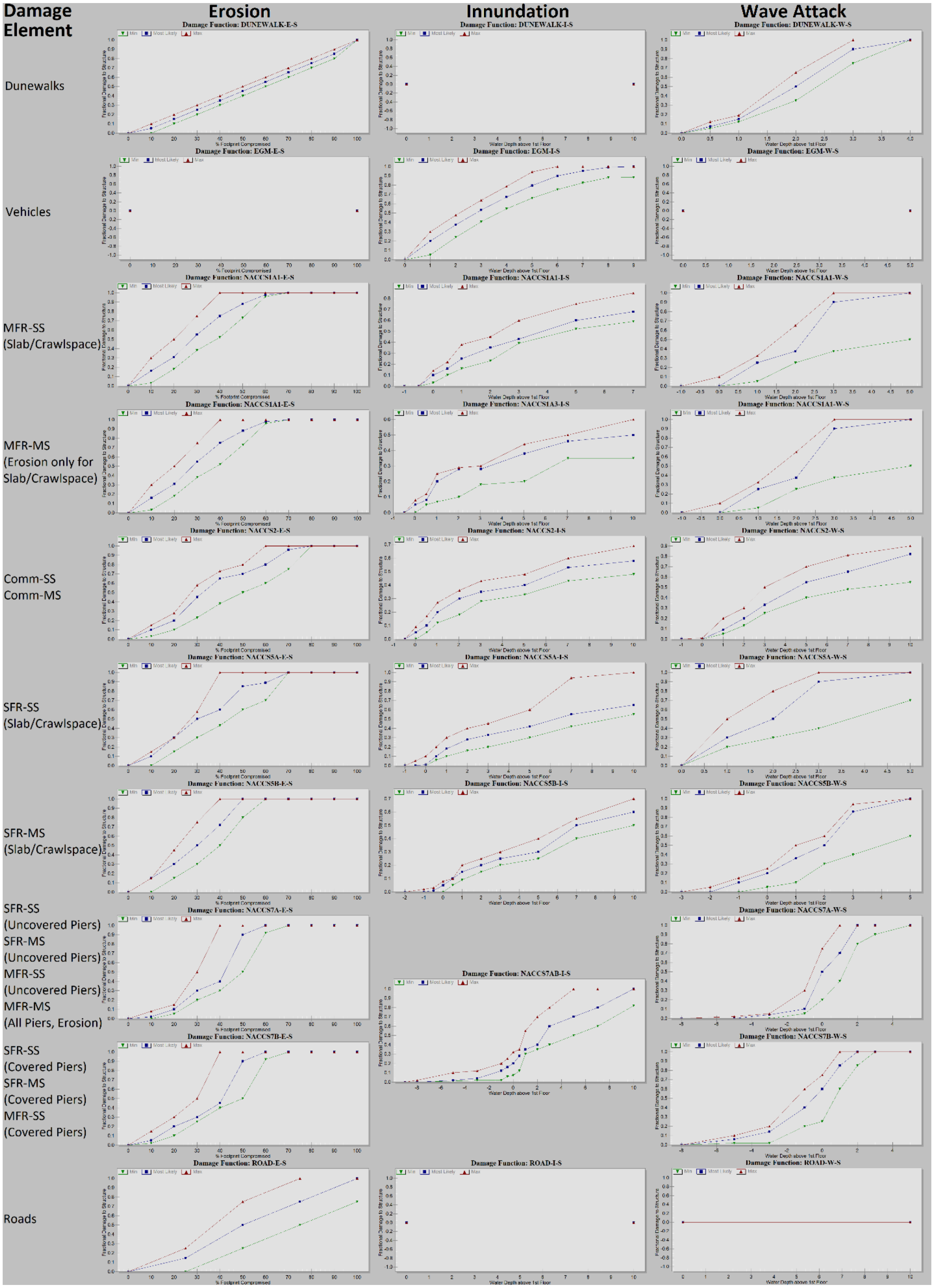
The future without-project damages will be used as the base condition. Potential alternatives are measured against this base condition. The difference between with and without-project damages will be used to determine project benefits.

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 (BCR). The federally preferred plan (NED – National Economic Development Plan) is the plan that reasonably maximizes net benefits consistent with protecting the nation's environment. Net benefits are determined by subtracting the cost of any given alternative from the benefits of that alternative (Benefits – Costs = Net Benefits).

3.2 Model Assumptions

►**Start Year**: The year in which the simulation begins is 2019
►**Base Year**: The year in which the benefits of a constructed federal project would be expected to begin accruing is 2025
►**Period of Analysis**: 50 years (2025 to 2075)
►**Discount Rate**: 2.5% FY2021 Federal Discount Rate
►**Damage Functions**: Damage functions developed by the North Atlantic Coast Comprehensive Study (NACCS) were used for buildings. Figure 6 provides all damage functions used in the model and which damage elements they are applied to. Content damage functions are not provided visually, because they are similar to the damage functions used for structures. All NACCS damage functions provided have an associated content damage function that is available from the NACCS report. Non-NACCS damage functions do not have content damage functions, because the associated damage elements have zero content value. The dunewalk function was created by SAJ staff. The damage functions from EGM 09-04 were used for vehicles, while the road damage function was obtained from the USACE CSRM Flagler Beach Feasibility Study.

Figure 6: Damage Functions for Structural Damage



►**Coastal Armor**:

►Existing armor set at the lot level will protect the damage elements in that lot from erosion damage until failure is triggered. The structures can still suffer from wave and inundation damage. If the armor fails structures will be subject to erosion damage until the armor is rebuilt.

►When erosion reaches the seaward edge of armorable in the future lots, armor will be constructed at this location. Before the armor is built the damage elements are subject to damages. Once construction of the armor is completed, armor will function normally.

►Shorefront properties that are not armorable will not be armored in the future because the cost of armor would not likely be warranted to protect the relatively low value structures on these lots (dunewalks and vehicles).

►While armor eliminates damage from erosion, it does not stop the background erosion process within Beach-*fx*. This makes it difficult to determine the loss of land associated with armored properties. With the tools available in Beach-*fx* there are two analytical options; erosion continues unimpeded by armor (although no properties are damaged), or armor stops erosion immediately and indefinitely. The reality is that erosion will behave somewhere between these extremes. SAJ economics staff decided, that because erosion rates are significant in many areas of Folly, to use the scenario where erosion continues past individual homeowner armor during the plan formulation process. This decision was made because the individual homeowner armor is not typically built to the same standard as a government agencies or commercial owners, and therefore more prone to failure. Additionally, most homeowner armor in Folly is built to mitigate damage from large storm events rather than to prevent the slow background erosion process. This is the most impactful modeling decision based on the large benefit swings associated with changes to the assumptions. Sensitivities regarding this decision are presented in section 4.8.2.

►**Number of Times Rebuilding Allowed**: The maximum number of structure rebuilds that can be specified for damage elements. Based on the assumed likeliness that certain types of damage elements will eventually stop being rebuilt by property owners, the following are the number of times that rebuilding is allowed for certain types of damage events:

►Minor Damage Event: A minor damage event is any damage incurred that results in less than 50% of the structure value of the asset being lost from the event. For minor damage events, assets can be rebuilt an unlimited number of times. Rebuilds from these events is captured inside Beach-*fx*.

►Major Damage Event: A major damage event is any damage incurred that results in more than 50% of the structure value of the asset being lost from the event. For major damage events, assets are assumed to lose their entire value and are removed from the inventory. This effectively limits the number of rebuilding times to zero. This is because local law requires any new construction to be built on a pile foundation. The first-floor elevation of these structures would be such that they are no longer in harm's way, thus making them ineligible to receive future damage. Roads and vehicles are an exception to this is and can be rebuilt as many times as necessary. Removing structures that suffer major damage is handled in post-processing outside the model.

►**Future Development**: It should be noted that future development has not been assumed to occur on currently vacant lots. The damages and benefits are based only on existing infrastructure. Any future construction would be subject to 33 USC 2318, however, in Folly new constructions must be built on piled foundations. Due to the local regulation, any future construction is assumed to be built to a standard such that it is not subject to damage, and thus not an eligible source of benefits. Given uncertainty about what may happen in the future, this is a conservative, but defensible, assumption.

►**Content-to-Structure Value Ratios:** Because site specific surveys about content values are not available, content values follow from EM 1110-2-1619 for residential structures and from IWR 96-R-12 for commercial structures.

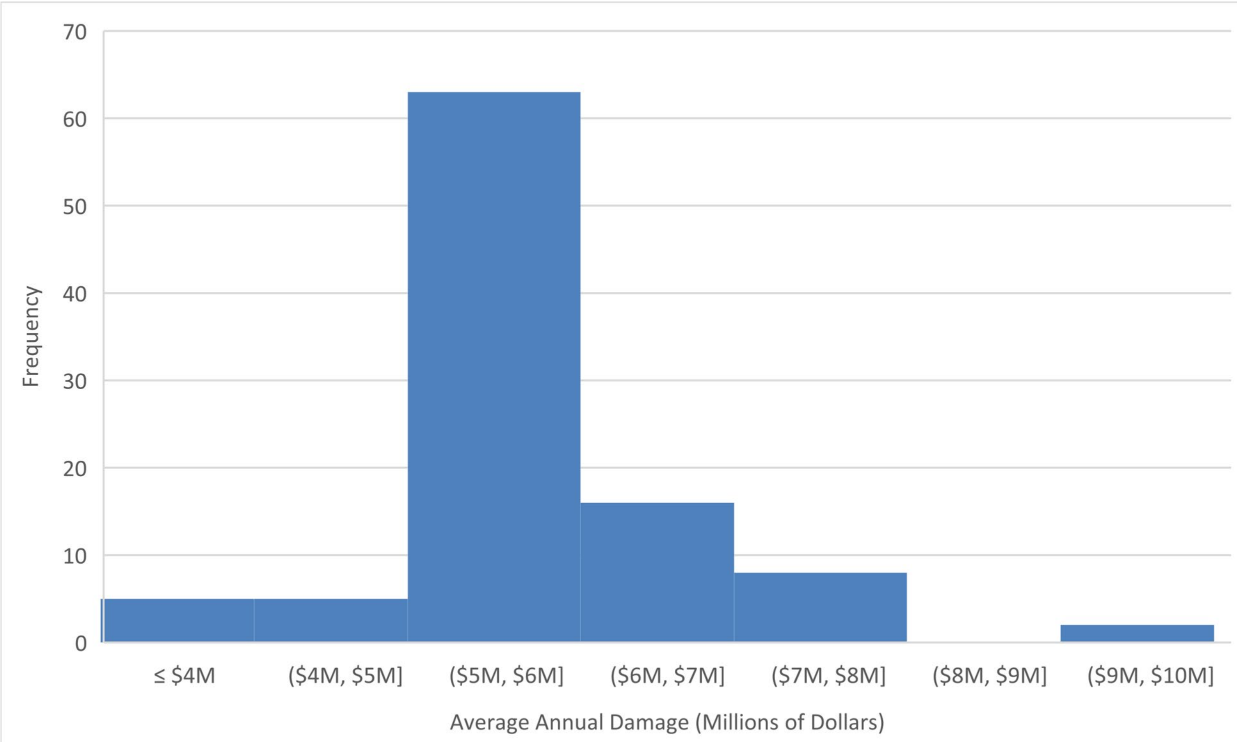
3.3 Future Without-Project Condition

100 iterations of the intermediate sea level rise (SLR) scenario in FY2021 prices and the FY2021 discount rate of 2.5% were used as the basis for the future without-project condition (FWOP) damage presented in this section. More information on why the intermediate SLR was used can be found in Appendix A – Coastal Engineering. The FWOP condition damage across the study area range between $3.1 and $9.8 million average annual present value dollars. 100 iterations were determined to be adequate for the analysis as the moving average of damages and armor costs normalize around 80 iterations. Descriptive statistics on the average annual FWOP model damages are as follows:

- ►Mean PV: $5,754,000
- ►Median: $5,555,000
- ►Standard deviation: $1,001,000

Figure 7 provides an illustration of FWOP results as a probability distribution based on the analysis of the model outputs. The distribution is characterized by a high peak and long right tail. This suggests a relatively stable model with only moderate variability between iterations. The reason for the long tail is due to land loss. Land loss is a primary benefit, and is highly dependent on constant background erosion, rather than randomly generated storms. Land loss acts as minimum cap on damages.

Figure 7: Distribution of Average Annual Future Without-Project Damage (FY2021)



3.3.1 Damage Distribution by Structure Category and Type

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

►**Structure and Content Damage**: Structure damage is economic losses resulting from the structures situated along the coastline being exposed to wave attack, inundation, and erosion damages. Content damage is from the material items housed within the structures (usually air conditioned and enclosed) that are potentially subject to damage. Structure and content damage combined make up approximately 3.0% of the total FWOP damages.

►**Damage Element Condemnation**: Properties can be condemned if they suffer a major damage event (damage greater than 50% of pre-storm value.) Damage element condemnation is only calculated on the structure value remaining after accounting for storm damage, so that double-counting does not occur. Once a property is condemned, any damage it would have incurred had it not been condemned is removed from the benefit pool, to prevent double counting. Structures can only be condemned for one type of condemnation. Damage element condemnation accounts for 0.3% of total FWOP damage.

►**Lot Condemnation**: Damageable elements in Beach-*fx* are placed in lots. If enough of the land inside the lot erodes, the lot is considered condemned. This damage category captures the value of anything within a lot when it is condemned. Lot condemnation is only calculated on the remaining value after accounting for storm damage, so that double-counting does not occur. Once a property is condemned, any damage it would have incurred had it not been condemned is removed from the benefit pool, to prevent double counting. Structures can only be condemned for one type of condemnation. Lot condemnation accounts for 24.0% of total FWOP damages.

►**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. Armor costs account for approximately 21.0% of the total FWOP damages.

►**Land Loss**: Any loss of permanent developable land is counted as a damage category and can be estimated with output from Beach-*fx*. Land loss results in 51.7% of the total FWOP damages.

Table 5 provides greater detail on the composition of the average FWOP damages by category and damage element type.

Table 5: Average Annual FWOP Damage by Category and Type (FY2021)

DE Type	Structure and Content Damage	Damage Element Condemnation	Lot Condemnation	Armor Cost	Land Loss	Total Damage	% of Total
Single-Story Commercial	$0	$0	$0	$0	$0	$1,000	0.0%
Multi-Story Commercial	$5,000	$2,000	$5,000	$7,000	$0	$18,000	0.3%
Single-Story Single-Family	$48,000	$5,000	$315,000	$156,000	$0	$524,000	9.1%
Multi-Story Single-Family	$63,000	$7,000	$909,000	$122,000	$0	$1,101,000	19.1%
Single-Story Multi-Family	$4,000	$0	$7,000	$1,000	$0	$12,000	0.2%
Multi-Story Multi-Family	$34,000	$6,000	$94,000	$31,000	$0	$165,000	2.9%
Road	$0	$0	$0	$893,000	$0	$893,000	15.5%
Dunewalk	$7,000	$0	$51,000	$0	$0	$58,000	1.0%
Vehicle	$10,000	$0	$0	$0	$0	$10,000	0.2%
Land	$0	$0	$0	$0	$2,973,000	$2,973,000	51.7%
Total	$172,000	$19,000	$1,380,000	$1,210,000	$2,973,000	$5,754,000	100%

3.3.1.1 Commercial Buildings

Commercial buildings consist of two groups, single-story and multi-story, of varying construction type and value. This category is mostly located in the commercial hub on Center St. This hub is slightly inland and has a healthy berm and dune in the existing condition. The result is that a low 0.3% of the total FWOP damages are associated with damage to commercial buildings.

3.3.1.2 Single Family Residences

Single family residences consist of two groups, single-story and multi-story, of varying construction type and value. This category accounts for a large amount of the non-land loss damages. 28.2% of the total FWOP damages are associated with damage to these damage elements.

3.3.1.3 Multi Family Residences

Multiple family residences consist of two groups, single-story and multi-story, of varying construction type and value. This is another large category of value and damages in the FWOP. 3.1% of the total FWOP damages are associated with damage to these damage elements.

3.3.1.4 Roads

Roads make up a large percentage of FWOP damages relative to their value. This is due to the modeling assumption that states the SCDOT would build a heavy-duty revetment to protect the seaward roadway when erosion reaches the road. Roads account for 15.5% of the damages in the FWOP.

3.3.1.5 Dunewalks

Dunewalks are rarely protected by coastal armor, 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.

3.3.1.6 Vehicles

Vehicles makes up an almost negligible amount of the total damages in the FWOP due to most vehicles being taken with the owners during storm events.

3.3.1.7 Land

Land loss makes up a large part of the total damages in the FWOP due to the high land values and erosion rates on Folly Beach. Second row land values per square foot were used for these estimates in accordance with ER 1165-2-130 and ER 1105-2-100. Land loss is responsible for over half (51.7%) of the damage in FWOP. USACE policy only allows damage to be counted for losses to developable land.

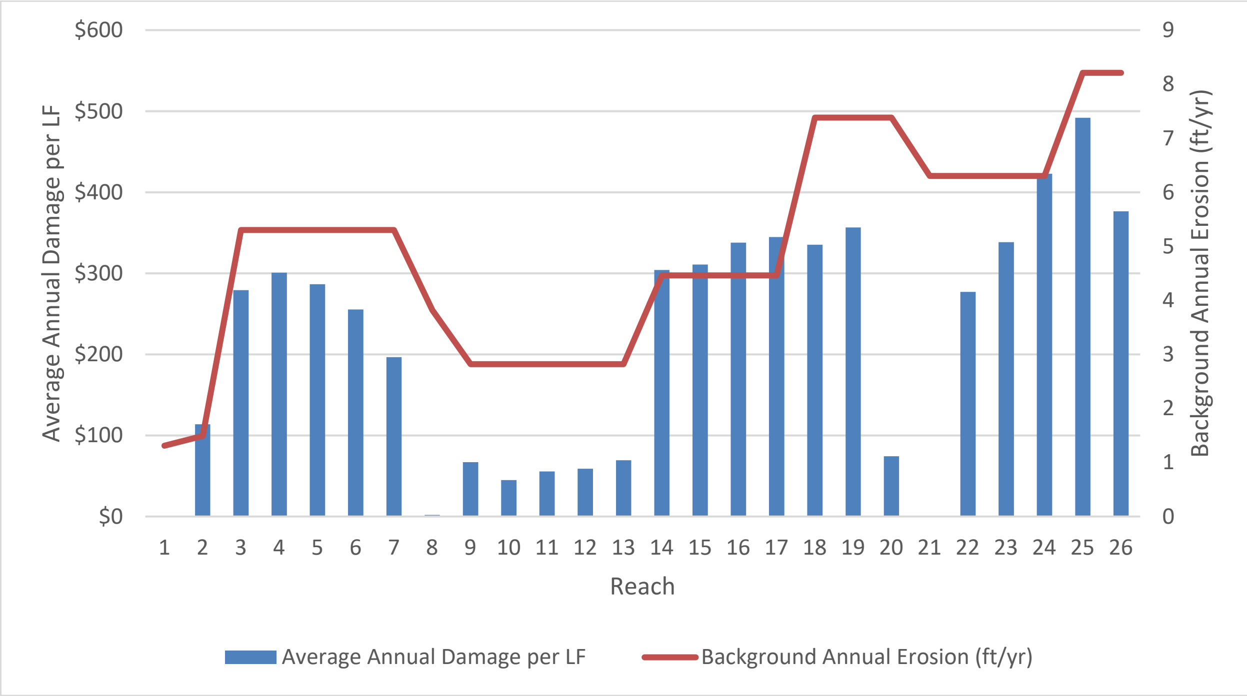
There are several reaches within the area modeled where the FWOP damages and armor costs are the greatest. The segment that includes model reaches 1-17 accounts for about 51.5% of the overall FWOP damages, and the segment that includes model reaches 18-26 accounts for about

48.5% of the overall FWOP damages. These results are summarized in Table 6. The primary driver of differences in spatial damages are erosion rates. Figure 8 illustrates relationship between erosion rate and FWOP damages per linear foot by reach.

Table 6: Average Annual FWOP Damage by Category and Reach (FY2021)

Beach-*fx* Reach	Annual Erosion (ft/yr)	Structure and Content Damage	Damage Element Condemnation	Lot Condemnation	Armor Cost	Land Loss	Total Damage	% of Total
1	1.31	$0	$0	$0	$0	$0	$0	0.0%
2	1.49	$8,000	$1,000	$38,000	$26,000	$129,000	$202,000	3.5%
3	5.30	$11,000	$1,000	$91,000	$111,000	$209,000	$423,000	7.4%
4	5.30	$5,000	$1,000	$59,000	$54,000	$110,000	$229,000	4.0%
5	5.30	$3,000	$0	$60,000	$49,000	$106,000	$219,000	3.8%
6	5.30	$2,000	$0	$37,000	$52,000	$98,000	$191,000	3.3%
7	5.30	$7,000	$1,000	$45,000	$66,000	$107,000	$226,000	3.9%
8	3.82	$1,000	$0	$0	$2,000	$0	$3,000	0.1%
9	2.82	$10,000	$2,000	$15,000	$18,000	$30,000	$76,000	1.3%
10	2.82	$7,000	$1,000	$4,000	$12,000	$10,000	$35,000	0.6%
11	2.82	$7,000	$1,000	$5,000	$14,000	$16,000	$42,000	0.7%
12	2.82	$7,000	$1,000	$7,000	$17,000	$13,000	$44,000	0.8%
13	2.82	$5,000	$1,000	$6,000	$23,000	$19,000	$54,000	0.9%
14	4.46	$10,000	$1,000	$77,000	$64,000	$192,000	$344,000	6.0%
15	4.46	$16,000	$2,000	$71,000	$66,000	$200,000	$353,000	6.1%
16	4.46	$5,000	$1,000	$66,000	$51,000	$140,000	$263,000	4.6%
17	4.46	$9,000	$1,000	$67,000	$52,000	$130,000	$259,000	4.5%
18	7.38	$5,000	$0	$90,000	$40,000	$118,000	$254,000	4.4%
19	7.38	$5,000	$1,000	$50,000	$66,000	$155,000	$276,000	4.8%
20	7.38	$8,000	$0	$34,000	$31,000	$49,000	$121,000	2.1%
21	6.30	$0	$0	$0	$0	$0	$1,000	0.0%
22	6.30	$10,000	$1,000	$56,000	$67,000	$106,000	$241,000	4.2%
23	6.30	$9,000	$1,000	$121,000	$116,000	$332,000	$580,000	10.1%
24	6.30	$9,000	$1,000	$118,000	$62,000	$204,000	$394,000	6.9%
25	8.21	$3,000	$0	$130,000	$47,000	$155,000	$335,000	5.8%
26	8.21	$8,000	$1,000	$134	$103,000	$343,000	$589,000	10.2%
Total	-	$172,000	$19,000	$1,380,000	$1,210,000	$2,973,000	$5,754,000	100%

Figure 8: Spatial Distribution of Damage and Erosion Rates by Reach (FY2021)



3.3.2 Damage Distribution by Damage Driving Parameter

Just about all the FWOP damages and costs are attributed to erosion. This is because the armor cost, land loss, and property condemnation can be indirectly attributed to erosion. Below is the distribution of total damage by driving parameter:

- ►Erosion: 97.2%
- ►Inundation: 1.3%
- ►Wave Attack: 1.5%

3.3.3 Temporal Distribution of Damages

Figure 11 illustrates the non-present value damages by study reach and over time. There is a great deal of variability in the amount of damages amongst the Beach-*fx* reaches. This is explained by the large number of variables, all of which the Beach-*fx* model considers. Examples of variation between the reaches 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
- ►Timing that property owners construct coastal armoring in the future.

3.3.4 FWOP Damages in Alternative Sea Level Rise Scenarios

The FWOP condition was modeled for three SLR scenarios. ER 1110-2-8162 *Incorporating Sea Level Change in Civil Works Programs* 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. The Beach-*fx* results presented above refer to the intermediate scenario. The results associated with the other two SLR scenarios are presented here. The three level rise scenarios are graphically shown in Figure 3.3 of the Main Report.

Table 7 provides an overall summary of FWOP average present value damage and armor costs for each SLR scenario. The total damage increases by 8.0% from the low to intermediate scenarios, and 31.9% from the intermediate to high scenarios. Erosion is the primary damage driver, accounting for 97.3% and 96.0% of the FWOP damage in the low and high SLR scenarios, respectively.

Figure 9 shows the distribution of average present value FWOP damages by model reach and Figure 10 and 12 show the distribution of average non-present value FWOP damages over time for the low and high SLR scenarios, respectively. The SLR results suggest that damages increase as the erosion rate increases (more structures become subject to damage sooner).

Table 7: Average Annual FWOP Damage by SLR Scenario (FY2021)

SLR Scenario	Structure and Content Damage	Damage Element Condemnation	Lot Condemnation	Armor Cost	Land Loss	Total Damage
Low	$153,000	$17,000	$1,286,000	$1,087,000	$2,783,000	$5,326,000
Intermediate	$172,000	$19,000	$1,380,000	$1,210,000	$2,973,000	$5,754,000
High	$314,000	$34,000	$1,968,000	$1,586,000	$3,687,000	$7,589,000

Figure 9: Average Annual FWOP Damage by Model Reach and SLR (FY2021)

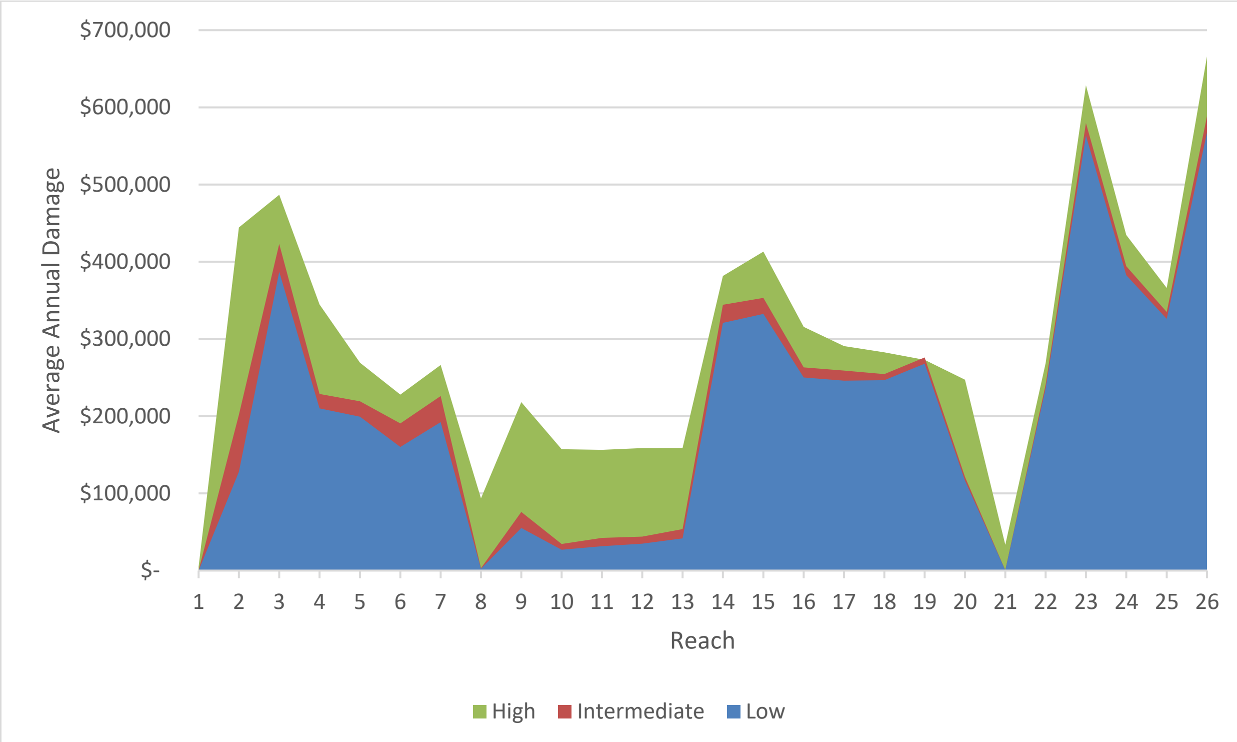


Figure 10: Non-Present Value FWOP Damage over Time, Low SLR (FY2021)

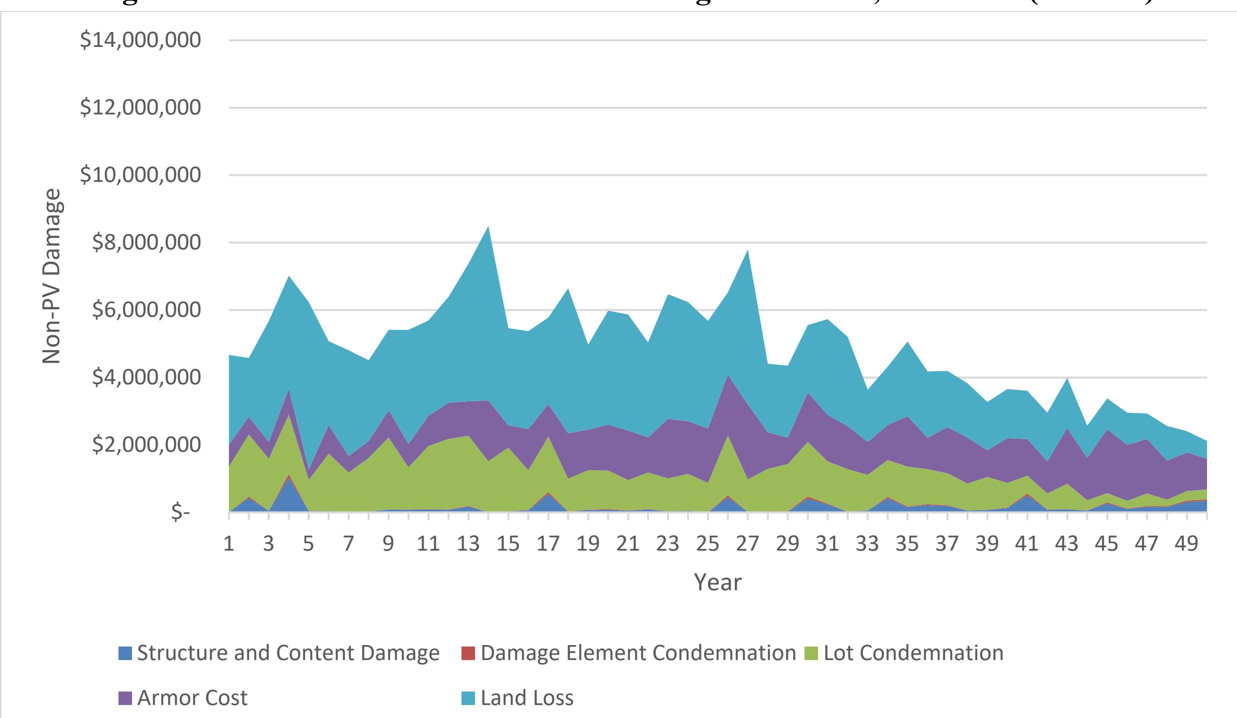


Figure 11: Non-Present Value FWOP Damage over Time, Intermediate SLR (FY2021)

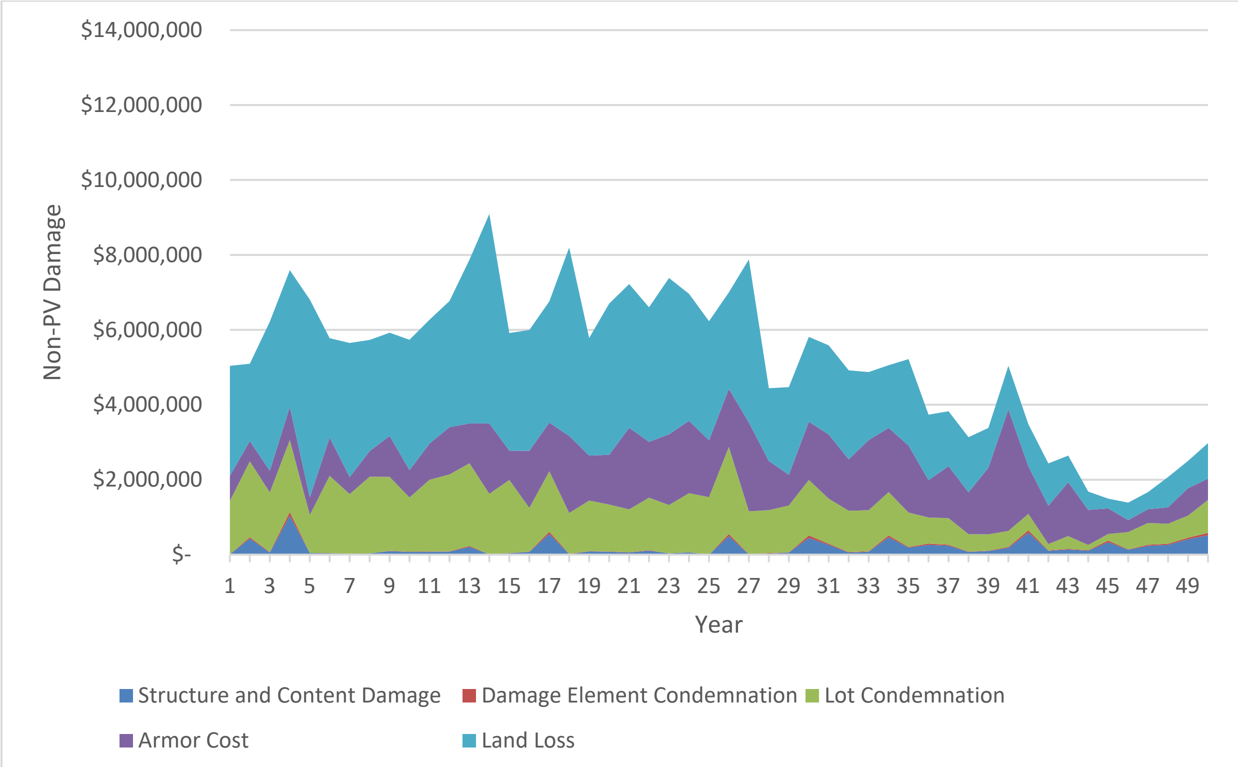
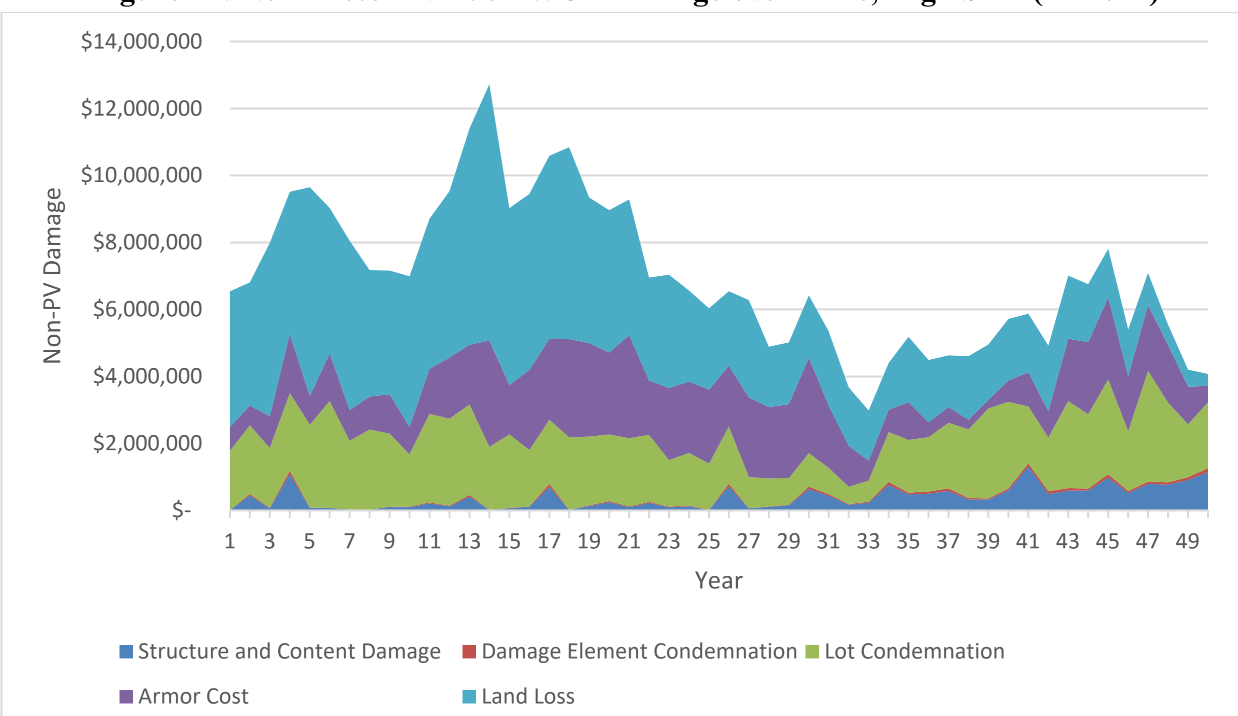


Figure 12: Non-Present Value FWOP Damage over Time, High SLR (FY2021)



3.3.5 FWOP Condition Conclusion

►Most of the FWOP damages are associated with family residences located along the shoreline.
►The overwhelming majority of the damage and armoring is directly or indirectly caused by erosion.
►Damages in the future without-project condition increase in the accelerated sea level rise scenarios.
►Folly Beach is not particularly sensitive to SLR scenarios in regard to FWOP damages.

3.4 Future With-Project (FWP) Conditions

This section of the appendix tells the story behind the evaluation and comparison of Folly Beach CSRM study alternatives. A description of the alternatives and their performance in terms of benefits and costs are provided in the sub-sections that follow. Values in section 3.4 were calculated in FY2020 using a 2.75% Federal Discount Rate at FY2020 price levels while costs presented only include unit, mobilization, and demobilization costs.

3.4.1 Management Measures

Management measures were selected to accomplish at least one of the planning objectives for the Folly Beach study. Both nonstructural measures and structural measures were identified. The following is a summary of the management measures considered for the study area.

►**Structural Measures**:
- ►Breakwaters
- ►Seawalls
- ►Groins
- ►Revetments
- ►Berm Enhancement
- ►Dunes and Vegetation

►**Nonstructural Measures**:
- ►No Action
- ►Relocation of Structures
- ►Retreat
- ►Floodplain and regulatory restrictions
- ►Community Education
- ►Updating Evacuation Plans
- ►Floodplain and Building Code Updating

During the plan formulation process, management measures were screened against thirteen 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 due to issues such as feasibility or environmental concerns. See section 4.05.1 (for structural measures) or 4.05.02 (for non-structural) of the Main Report for further discussion on why individual measures were screened out. No nonstructural measure carried forward to the modeling stage. Three structural measures were carried forward to the modeling stage: Dunes and Vegetation, Beach Nourishment, and Revetments. More information about each measure is provided below.

►**Dunes and Vegetation**: This measure would include placement of beach compatible material, from either upland, inlet, or offshore sources, in a dune feature. 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 where needed. Engineering design work on the most feasible implementation plan for dunes and vegetation can be found in the Appendix A – Coastal Engineering.

►**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. Engineering design work on the most feasible implementation plan for beach nourishment can be found in the Appendix A – Coastal Engineering.

►**Revetment**: This measure would involve building a heavy-duty revetment seaward of the existing property lots. There would be no dune or berm associated with the construction. The revetment option was not fully developed by engineering because of environmental concerns.

3.4.2 Alternative Development

An alternative plan is a set of one or more management measures functioning to address one or more objectives. Each project alternative is a combination of a selected measure and the reaches where it would be applied. Fully developed alternatives consisting of dune, beach nourishment, and revetment measures were carried forward in all Beach-*fx* reaches.

3.4.2.1 Initial Screening in Beach-*fx*

Modeling alternatives in Beach-*fx* is a time-consuming process; a single 100 iteration simulation can take most of a day. Therefore, it was not practical to fully model many alternatives for screening purposes. Therefore, the first stage of preliminary Beach-*fx* alternatives were run for 20 iterations rather than 100.

The dune and beach nourishment alternatives were set up to be modeled in any of the Beach-*fx* reaches for any combination of no dune, 14’, or 15’ NAVD88 high x 5’ wide (at crest) dune along with 25’, 50’, and 75’ berm extensions. Screened dune heights stopped at 15’, because damage caused by wave and flood heights greater than 15’ accounted for less than .1% of damage in all three sea-level conditions examined in the FWOP analysis. Wider dunes were considered, but the net benefits favored widening the berm, rather than the dune. More information on the development of the shoreline response database and alternative templates can be found in the Appendix A – Coastal Engineering. The ‘Planned Nourishment’ inputs were entered into Beach-*fx* for the nourishment alternatives. The model was run for these FWP alternatives for the entire length of the study area. For the initial set of screenings, the model was set to nourish the beach approximately every 10 years. This assumption is relaxed later. Cost calculations in the initial screenings use the same mobilization cost and unit costs as later, fully fledged alternatives. More information on the nourishment triggers and minimum volume thresholds used can be found in the Appendix A – Coastal Engineering.

The revetment plan was modeled in Beach-*fx* by replacing the individual property owner's armor, with a heavier duty construction. In the Beach-*fx*, this is assumed to prevent any erosion past the armor line and be impervious to failure.

Initial Beach-*fx* model runs showed that a wide variety of dune and beach nourishment alternatives were economically justified. Similarly, the revetment option is the superior plan for the northeastern segment of the island, past the washout. To ensure that the full range of options were contained in the screenings, a 100' berm extension and no dune was added to the set of screening options. The initial runs showed the 25' berm extension and 15' high dune had the highest net benefits. Engineering was concerned with the practicality of upkeeping a small berm. As such, a 35' berm and 15' high dune option was added to the analysis. Table 8 summarizes the results from the initial Beach-*fx* screening exercise for the most promising templates.

Table 8: Average Annual Net Benefit for Initial FWP Modeling by Reach (FY2020)

Beach-*fx* Reach	15' Dune 25' Berm	15' Dune 35' Berm	15' Dune 50' Berm	No Dune 75' Berm	Revetment
1	-$30,000	-$39,000	-$59,000	-$56,000	-$654,000
2	$60,100	$49,000	$37,000	$27,000	-$164,000
3	$204,000	$207,000	$218,000	$209,000	$78,000
4	$119,000	$123,000	$127,000	$122,000	$60,000
5	$114,000	$121,000	$119,000	$114,000	$51,000
6	$92,000	$94,000	$91,000	$86,000	$26,000
7	$84,000	$79,000	$72,000	$67,000	-$37,000
8	$107	$104,000	$98,000	$86,000	-$111,000
9	$5,000	$0	-$6,000	-$17,000	-$169,000
10	-$8,000	-$11,000	-$18,000	-$23,000	-$136,000
11	-$5,000	-$7,000	-$12,000	-$18,000	-$125,000
12	$0	-$3,000	-$7,000	-$14,000	-$118,000
13	-$3,000	$2,000	-$2,000	-$8,000	-$113,000
14	$109,000	$128,000	$140,000	$120,000	$124,000
15	$119,000	$140,000	$148,000	$128,000	$112,000
16	$99,000	$112,000	$119,000	$102,000	$106,000
17	$101,000	$112,000	$118,000	$105,000	$95,000
18	$80,000	$89,000	$72,000	$66,000	$126,000
19	$112,000	$104,000	$89,000	$93,000	$111,000
20	-$190,000	-$191,000	-$224,000	-$253,000	-$219,000
21	-$141,000	-$153,000	-$165,000	-$173,000	-$190,000

22	$33,000	$25,000	$38,000	$35,000	$88,000
23	$201,000	$179,000	$206,000	$219,000	$254,000
24	$173,000	$167,000	$190,000	$200,000	$229,000
25	$137,000	$151,000	$131,000	$156,000	$220,000
26	$223,000	$223,000	$172,000	$199,000	$325,000
Reaches 2- 17	$1,198,000	$1,250,000	$1,242,000	$1,084,000	-$321,000
Reaches 18-21	-$138,000	-$152,000	-$227,000	-$267,000	-$173,000
Reaches 22-26	$767,000	$745,000	$737,000	$808,000	$1,116,000
Mob	$707,000	$769,000	$805,000	$805,000	-
Reaches 2-26 w/ Mob	$1,120,000	$1,074,000	$947,000	$820,000	$622,000

Based on the initial screening results, three potential plans were identified and summarized in Table 9. Reach 1 was screened out due to the only asset being the County Park, which is not in the federal interest. Reaches 9-13, while having negative benefits, were carried forward at this part of the process due to how close they were to being economically justified. Reaches 20 and 21, otherwise known as "the washout", were included in the plan to maintain a consistent project across the barrier island. The Revetment Plan was not selected for further consideration, despite having the largest net benefits in reaches 18-26 due to environmental concerns. More information on this can be found in section 4.07 of the Main Report.

Table 9: Potential Alternatives from Screening Results

Plan Prefix	**Description**
Previously Authorized Project	A re-creation of the previously authorized project. This is a 15' berm and no dune for reaches 2-26. The re-nourishment interval for this plan would be 8 years.
BeachAA	The top performing dune/berm plan. This is a 35' berm and 15' high x 5' wide (at crest) dune for reaches 2-21, and a 75' berm with no dune for reaches 22-26.
BeachBB	Slightly larger berm and dune system than the BeachAA plan. This is a 50' berm and 15' high x 5' wide (at crest) dune for reaches 2-26.

3.4.2.2 Beach Alternative Optimization in Beach-*fx*

The initial screening assumed that the beach would be nourished approximately every 10 years. This optimization exercise relaxes that assumption to find the optimal nourishment interval. This was done in Beach-*fx* by varying the mobilization threshold. The mobilization threshold states how much sand is necessary to place on the beach before the model triggers a nourishment.

Including the initial construction, as few as three total nourishment were considered (an average gap of 17 years) up to a maximum of seven total nourishments (an average gap of about 8 years).

The Beach-*fx* iteration count was increased to 100 for this stage of alternative identification. The BeachAA plan was run for 3, 4, 5, 6, and 7 total nourishments. The BeachBB plan, being a larger template, was only run for 3, 4, and 5 total nourishments. The results of the optimization exercise were that the option with four total nourishments had the highest net benefits. However, BeachAA_4 performed the best in reaches 2-19 and BeachBB_4 performed the best in reaches 22-26. A combined plan BeachAB_4 was created specifically to test if this combination would yield higher net benefits as the sum two parts. BeachAB_4 is a 35' berm for reaches 2-21 and a 50' berm for reaches 22-26. All reaches (except reach 1) have a 15' high NAVD88 x 5' wide (at crest) dune. BeachAB_4 comprised of 4 total nourishments (including initial construction) over the period of analysis. A breakdown of the optimization results can be found in Table 10.

Table 10: Beach-*fx* FWP Modeling Optimization Results (FY2020)

Plan Name	Total Nourishments	Average Annual FWP Damage	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
BeachAA_7	7	$1,050,000	$5,458,000	$4,429,000	1.23	$1,029,000
BeachAA_6	6	$1,184,000	$5,324,000	$4,263,000	1.25	$1,061,000
BeachAA_5	5	$1,428,000	$5,080,000	$3,995,000	1.27	$1,085,000
BeachBB_5	5	$1,326,000	$5,182,000	$4,182,000	1.24	$1,000,000
BeachAA_4	4	$1,735,000	$4,773,000	$3,655,000	1.31	$1,119,000
BeachBB_4	4	$1,587,000	$4,921,000	$3,857,000	1.28	$1,064,000
BeachAB_4	4	$1,746,000	$4,763,000	$3,616,000	1.32	$1,146,000
BeachAA_3	3	$2,395,000	$4,113,000	$3,477,000	1.18	$636,000
BeachAB_3	3	$1,949,000	$4,559,000	$3,631,000	1.26	$928,000

3.4.3 Alternative Comparison

The BeachAB_4 plan was carried forward as the basis for the beach nourishment alternative. In addition to a no action plan, three other alternatives were built around the BeachAB_4 plan as well as a plan meant to mimic the previously authorized project. The final alternative capture potential sources of benefits that might arise from including planform rates into the analysis, as previous model runs did not include planform rates. These options include, 1) extending the 50' berm to reaches 18-21, due to the high erosion rates, or 2) adding a nourishment to account for additional sand leaving the system via the planform rates. Alternative 6 is meant to mimic the 1992 authorized plan. The final alternatives are summarized in Table 11.

Table 11: Description of Final Alternatives

Alternative Name	Nourishments (Interval)	Reaches 2-17	Reaches 18-21	Reaches 22-26
Alternative 1	-	No Action		
Alternative 2	4 (12 years)	35’ Berm, 15’x5’ Dune	35’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune
Alternative 3	4 (12 years)	35’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune
Alternative 4	5 (10 years)	35’ Berm, 15’x5’ Dune	35’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune
Alternative 5	5 (10 years)	35’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune	50’ Berm, 15’x5’ Dune
Alternative 6	6 (8 years)	15’ Berm, No Dune		

Alternative 2 and Alternative 4 were screened out from the final array because they did not provide robust protection in reaches 18-21. The reasoning for increasing the length of the 50-ft berm in Alternative 3 and Alternative was to extend the wider berm all the way to where the Folly Beach shoreline alignment changes more to the northeast. The shoreline north of this jog faces higher wave energy with a steeper foreshore slope and has a history of higher erosion. More information on the screening criteria can be found in section 4.07.1 of the Main Report. The remaining final alternatives were run in Beach-*fx* using 100 iteration simulations. The results of these simulations were used to determine the National Economic Development (NED) Plan, presented in Table 12. The final array includes planform rates, a slight modification of the sea level change rate and a risk informed decision to alter the borrow source sequencing due to concerns with the river’s ability to recharge fast enough between nourishments.

Table 12: Economic Overview of Final Alternatives (FY2020)

Alternative Name	Average Annual FWP Damage	Average Annual Benefit	Average Annual Cost	BCR	Average Annual Net Benefit
Alternative 1	$6,508,000	$0	$0	-	$0
Alternative 3	$1,469,000	$5,039,000	$3,938,000	1.28	$1,100,000
Alternative 5	$1,537,000	$4,971,000	$4,528,000	1.10	$444,000
Alternative 6	$2,615,000	$3,893,000	$4,173,000	0.93	-$280,000

Alternative 3 is the NED plan as it maximizes net benefits.

4 The Recommended Plan

Alternative 3 is the Recommended Plan. The Recommended Plan has been extended from what was presented in Table 11 to include a berm only in the County Park (Beach-*fx* Reach 1) and the Lighthouse Inlet Heritage Preserve to the northeast. This decision was made based on information related to section 111 (see Appendix G – Section 111). Analysis presented in this section includes the County Park and the Lighthouse Inlet Heritage Preserve, albeit insignificantly. The park includes a single road, dunewalk, and two public structures for park access. The Lighthouse Inlet Heritage Preserve was not modelled because it contains no economic assets. The NED benefit to the area is zero.

4.1 Beach-*fx* Modeling and Project Costs

The Beach-*fx* model results describing the physical performance of the Recommended Plan will not change from the simulation run for the final array of alternatives. The physical performance results most relevant to the economic analysis are the nourishment volumes and the timing of nourishment events.

Beach-*fx* is a life cycle simulation model. One iteration represents one 50-year life cycle. All iterations within the model simulation are unique. The average initial construction volume over 100 iterations is 2,169,000 cubic yards (cy). The average volume of all re-nourishments over 100 iterations is 8,487,000 cubic yards. The average time interval between nourishment events over 100 iterations is 12 years. Table 13 provides a summary on the volume of material per construction event over the 100 iterations modeled.

In most projects, the initial construction consists of the highest volume. This is not the case for this project, because there is an existing federal project at Folly Beach. As a result, the initial construction behaves similarly to a renourishment from a volume perspective. Nourishment volumes increase slightly over time due to rising sea levels eroding more sand over the 12-year cycle. The final nourishment is designed to last 14 years rather than 12 years resulting in a larger volume. More information on the borrow sources can be found in Appendix C – Geotechnical Engineering.

Table 13: Beach-*fx* Volume and Source per Construction Event (cy)

Event	Source	Year	Average	Min	Max
Initial Construction	Lighthouse Inlet Heritage Preserve	2025	2,169,000	2,108,000	2,484,000
1st Re-nourishment	Stono Ebb Shoal	2037	1,871,000	1,743,000	2,484,000
2nd Re-nourishment	Stono Ebb Shoal	2049	2,040,000	1,637,000	2,614,000
3rd Re-nourishment	Stono Ebb Shoal	2061	2,408,000	2,109,000	3,013,000

The final run of alternatives used a 12-year fixed nourishment interval rather than a dynamic approach. Extra volume was included as part of the final renourishment to extend over the final two years. A description of the Recommended Plan is as follows:

- ►**Name (Description)**: Alternative 3 (Construction of 35' foot equilibrated berm extension for reaches 1-17 and a 50' berm extension for reaches 18-26 and the Lighthouse Inlet Heritage Preserve. The project template will include a dune feature for reaches 2-26 that is at a height of 15' NAVD88 and is 5' wide at the crest. A dredge will be used to fill the template with sand from offshore sources. The local sponsor has indicated that residents support dredging from Folly River, if possible given changes in future CBRA interpretation, as it makes the river easier to navigate. Quantifying the extent of the dredging benefit would go beyond the time and budget allocated in this analysis.
- ►**Average Nourishment Events**: 1 Initial Construction + 3 Re-nourishments
- ►**Number of Nourished Reaches**: 26 + Lighthouse Inlet Heritage Preserve
- ►**Nourished Reaches**: Beach-*fx* Reach 1 – 26 + Lighthouse Inlet Heritage Preserve
- ►**Average Volume of Initial Construction**: 2,169,000 cy
- ►**Average Volume of Each Periodic Nourishment**: 2,106,000 cy
- ►**Average Periodic Nourishment Interval**: Approximately 12 years
- ►**Initial Construction Duration**: 6 months
- ►**Interest During Construction**: $254,000 (at 2.5% annual interest rate)

The cost estimate for the Recommended Plan was developed by SAW Cost Engineering. Table 14 provides details on the distribution of cost by nourishment event. This estimate assumed that initial construction would occur in 2025 and re-nourishment events would occur approximately 12-year interval. The cost estimate for the final periodic nourishment assumes an additional 16.7% of the Beach-*fx* reported volumes to bring the project to the end of the 50-year period of Federal participation. Costs are project first costs (middle column of TPCS) at FY2022, include a contingency, and include both the CSRM and section 111 costs. Costs are converted to present value (relative to the project base year of 2025) and to FY21 (price level of benefits) for the economic analysis. Additional details on the project costs can be found in Appendix D - Cost Engineering.

Estimated project costs were calculated outside the Beach-*fx* user interface. The beach nourishment cost information that can be input to Beach-*fx* is limited to a single unit construction cost ($/cy) and a single mobilization cost. The Beach-*fx* model applies these two costs in the same way for each nourishment event regardless of the borrow source. Unique about this study, there was five distinct borrow sources identified by the Geotechnical engineers. All five of these borrow areas have different unit costs and three of them were ultimately included in the Recommended Plan. The only way to consider all borrow areas was to use Beach-*fx* to provide nourishment volumes and calculate the costs in Excel, outside the model.

The cost analysis showed that the Folly River borrow source was the cheapest option for each nourishment. However, due to changes in guidance regarding CBRA interpretation, the decision was made to use the Lighthouse Inlet Heritage Preserve and the Stono Ebb Shoal.

Table 14: Recommended Plan Project Cost from TPCS

Item	Fiscal Year	Average Volume (cy)	First Cost from TPCS	Present Value[1]
Initial Construction PED	2024	-	$1,277,000	$1,269,000
Initial Construction	2025	2,169,000	$44,927,000	$47,877,000
Total Initial Construction Cost	-	2,169,000	$46,204,000	$49,196,000
Interest During Construction	2025	-	-	$254,000
1st Renourishment PED	2036	-	$1,304,000	$959,000
1st Renourishment	2037	1,871,000	$47,610,000	$40,979,000
2nd Renourishment PED	2048	-	$1,336,000	$713,000
2nd Renourishment	2049	2,040,000	$57,321,000	$32,640,000
3rd Renourishment PED	2060	-	$1,304,000	$530,000
3rd Renourishment	2061	2,408,000	$57,203,000	$27,907,000
Total Renourishment Cost	-	6,319,000	$166,080,000	$103,728,000
Economic Cost	-	8,487,000		$153,127,000
Average Annual Economic Cost	-	-	-	$5,399,000
Average Annual OMRR&R	-	-	-	$101,000
Average Annual Total Cost	-	-	-	$5,500,000

[1]FY2021 Price Level, FY2021 Federal Discount Rate of 2.5%, FY2025 Base Year

Even though Beach-*fx* models allow for cost variability by tabulating costs when nourishment events occur for each unique iteration, the final net benefits and BCR presented in the conclusion of this appendix will reflect re-nourishment costs occurring at the average 12-year interval. In that way the costs used to calculate the economics of the project will match the costs presented in the TPCS found in Appendix D – Cost Engineering.

Interest during construction (IDC) for the initial nourishment was also calculated for the Recommended Plan. As stated in ER 1105-2-100 Para. D-3.e. (11), IDC "represents the opportunity cost of capital incurred during the construction period." IDC is only calculated for initial construction. Using the estimated initial construction period of six months, the initial construction costs are assumed to be distributed equally across each month of the construction period. IDC is compounded monthly, and costs are taken to be incurred at the midpoint of each month for the purposes of the IDC calculation. Total IDC for initial construction of the Recommended Plan is $254,000 at the annual interest rate of 2.5%. Middle of the month uniform payments were assumed. This economic cost is factored into the net benefits and BCR presented for the Recommended Plan. Operation, Maintenance, Repair, Replacement and Rehabilitation

(OMRR&R) cost of $101,000 annually is included in the net benefit and BCR to account for future escarpment removal, vegetation maintenance, long term monitoring, and sand rebalancing.

4.2 Benefits of the Recommended Plan

The economic benefits of the plan are generated by reductions in coastal storm damages. The benefits described in this section do not include recreation benefits, which are discussed later in this appendix. As described in Table 15, the model results suggest that the alternative is effective at reducing coastal storm damages in the study area, caused primarily by erosion. In the with-project condition, 83% of damages are prevented within the entire study area.

Table 15: Recommended Plan Residual Damages by Reach (FY2021)

Beach-*fx* Reach	Average Annual FWOP Damage	Average Annual FWP Damage	Average Annual Benefit	% of Damage Prevented
1	$0	$0	$0	44%
2	$202,000	$66,000	$135,000	67%
3	$423,000	$24,000	$399,000	94%
4	$229,000	$13,000	$216,000	94%
5	$219,000	$12,000	$208,000	95%
6	$190,000	$10,000	$180,000	95%
7	$226,000	$15,000	$211,000	93%
8	$3,000	$1,000	$2,000	67%
9	$76,000	$30,000	$46,000	61%
10	$35,000	$13,000	$21,000	62%
11	$42,000	$17,000	$26,000	61%
12	$44,000	$27,000	$17,000	39%
13	$54,000	$42,000	$12,000	22%
14	$344,000	$71,000	$273,000	79%
15	$353,000	$66,000	$288,000	81%
16	$263,000	$52,000	$212,000	80%
17	$259,000	$56,000	$203,000	78%
18	$254,000	$28,000	$226,000	89%
19	$276,000	$26,000	$250,000	91%
20	$121,000	$44,000	$78,000	64%
21	$1,000	$0	$0	57%
22	$241,000	$70,000	$171,000	71%
23	$580,000	$118,000	$461,000	80%
24	$394,000	$82,000	$312,000	79%
25	$335,000	$52,000	$283,000	85%
26	$589,000	$56,000	$532,000	90%
Total	$5,753,000	$989,000	$4,765,000	83%

Most of the benefits are associated with reductions in damage to land loss and reductions to structure condemnation in oceanfront buildings. Reaches 8-13 have a low level of damage prevention, due to the presence of the naturally forming dune. Due to this dune, the FWOP damage is primarily damage that is not preventable by a dune system. As such, the recommended dune and berm system has relatively low damage prevention in reaches 8-13. While the plan does not perform well in reaches 8-13, the FWOP damage in those reaches is minimal and the cost of including these reaches is low. Additionally, the damage prevention in the other 20 reaches is substantial. Table 16 provides a summary of what types of damage is being prevented from the Recommended Plan.

Table 16: Damage and Benefit by Damage Source, Recommended Plan (FY2021)

Damage Source	Average Annual FWOP Damage	Average Annual FWP Damage	Average Annual Benefit	% of Damage Prevented
Erosion	$12,000	$1,000	$10,000	88%
Inundation	$73,000	$35,000	$38,000	52%
Wave Attack	$87,000	$51,000	$36,000	41%
Damage Element Condemnation	$19,000	$9,000	$10,000	52%
Lot Condemnation	$1,380 ,000	$234,000	$1,146,000	83%
Armor Cost	$1,209,000	$140,000	$1,069,000	88%
Land Loss	$2,973,000	$517,000	$2,455,000	83%
Total	$5,753,000	$989,000	$4,765,000	83%

The economic analysis uses a conservative approach and assumes no future increases in the value of the structure inventory. If the value of the structure inventory were to increase, the FWP damage (i.e. residual risk) would increase similarly. However, the Folly Beach oceanfront is almost completely developed. Any increase would have to originate from upgrades to structures rather than building on vacant land. While these upgrades are likely to occur, it is just as likely that the other benefit categories (land value, cost of armor construction) will increase in value. A simultaneous increase would cause nominal risk to increase, but the percent of damage prevented by the Recommended Plan would remain constant. Furthermore, if future construction is built to a higher standard than the current development, residual risk to structures would decrease. If future construction was included in the analysis, it is likely that the percentage of residual risk would decrease, because residual risk to structures is higher than to other benefit categories.

4.3 Sea Level Rise Considerations

An important question about the Recommended Plan 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. However, the optimization was performed under the Intermediate SLR scenario. The benefits presented in this section do not include recreation benefits. Table 17 shows the average BCRs and net benefits of the plan in the different SLR scenarios.

Table 17: Recommended Plan Benefit and Cost for Different SLR Scenarios (FY2021)

SLR Scenario	Average Annual Benefit	Average Annual Cost[1]	BCR	Average Annual Net Benefit
Low	$4,434,000	$4,918,000	0.90	-$484,000
Intermediate	$4,765,000	$5,500,000	0.87	-$735,000
High	$6,209,000	$7,286,000	0.85	-$1,078,000

[1]Costs extrapolated from TPCS based on quantity differences in Beach-*fx*.

As shown in Table 17, though the average benefits of the project increase significantly in the SLR scenarios, the average 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 average re-nourishment intervals and damages are summarized in Table 18.

Table 18: Nourishment Intervals and Damage for Different SLR Scenarios (FY2021)

SLR Scenario	Number of Nourishments	Average Annual FWOP Damage	Average Annual FWP Damage
Low	Initial Construction and 3 Renourishments	$5,326,000	$892,000
Intermediate		$5,753,000	$989,000
High		$7,589,000	$1,380,000

Because both costs and benefits are increasing, the net benefits increase with increasing rates of sea level rise. Overall, these SLR results suggest that the Recommended Plan is effective in all three simulated SLR scenarios. Note that the recommended nourishment interval is fixed at the request of the coastal engineers. It is possible that greater benefits could be achieved for the low and high SLR scenario by varying the nourishment interval in those scenarios.

4.4 Distributional Uncertainty and Viability of the Recommended Plan

Beach-*fx* is a life-cycle model that outputs a range of possible results from implementing the Recommended Plan. This range of outputs can be used to quantify the uncertainty associated with the performance of the Recommended Plan as required by ER 1105-2-101. Quantifying this uncertainty allows for a more complete understanding of how the Recommended Plan should be expected to perform, compared to only considering the average results. This section will present the distributional uncertainty (not uncertainty from model assumptions, see section 4.7) associated with the Recommended Plan and show how viable the Recommended Plan is expected to be. The benefits presented in this section do not include recreation benefits and are presented in the Intermediate SLR scenario unless stated otherwise.

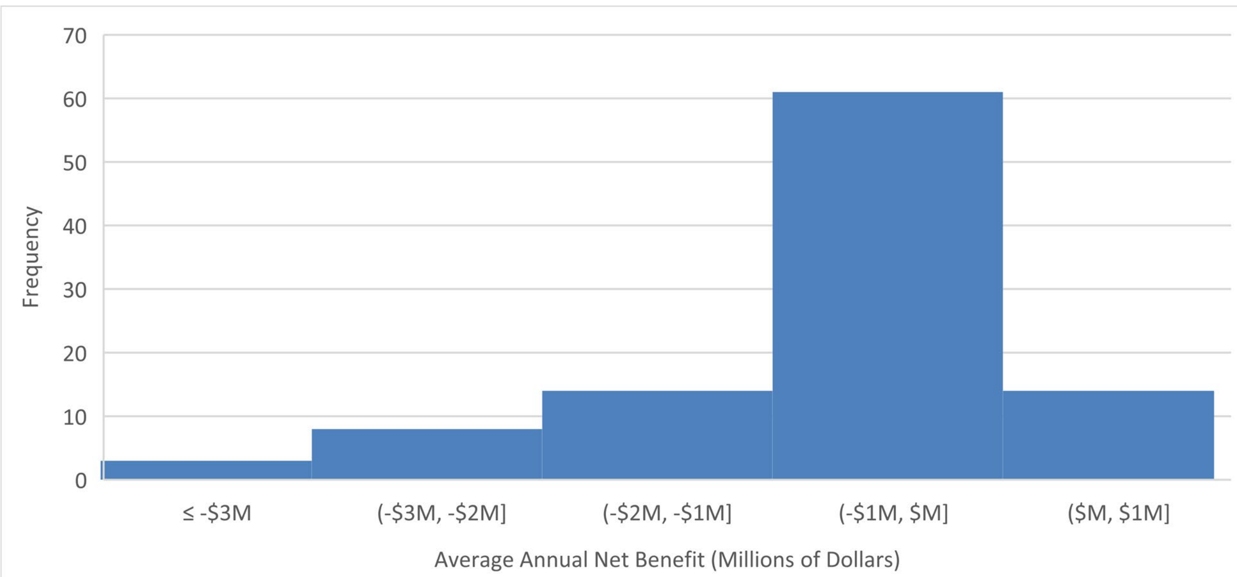
Table 19 shows the range of possible costs and benefits over the 100 life cycles (iterations) modeled in Beach-*fx*. Figure 13 shows the frequency distribution of net benefits provided by the Recommended Plan over the 100 life cycles modeled.

Table 19: Range of Recommended Plan Cost and Benefit (FY2021)

Statistic	Average Annual Benefit	Average Annual Cost[1]	BCR	Average Annual Net Benefit
Average	$4,765,000	$5,500,000	0.87	-$735,000
Median	$5,089,000	$5,455,000	0.93	-$352,000
Minimum	$1,724,000	$5,262,000	0.30	-$3,965,000
Maximum	$6,133,000	$6,002,000	1.09	$504,000
Standard Deviation	$846,000	$145,000	0.16	$935,000

[1]Costs extrapolated from TPCS based on quantity differences in Beach-*fx*.

Figure 13: Distribution of Recommended Plan Average Annual Net Benefit (FY2021)



The results show that the Recommended Plan will produce positive net benefits in 14 out of the 100 life cycles modeled (without yet adding incremental recreation benefits). Table 20 shows how the viability of the Recommended Plan varies for the three SLR scenarios.

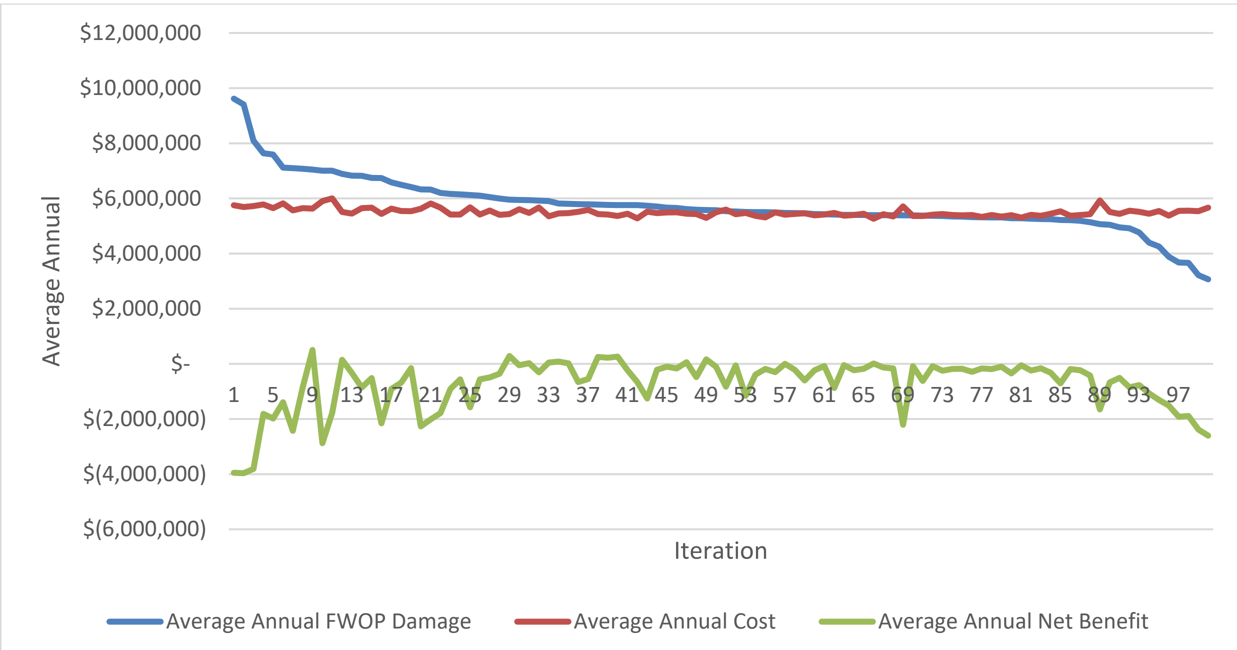
Table 20: Recommended Plan Viability by SLR (Averages from Intermediate SLR)

With Respect to Having…	Low SLR Recommended Plan Viability	Intermediate SLR Recommended Plan Viability	High SLR Recommended Plan Viability
> Average Net Benefit	74%	67%	55%
> 0 Net Benefit	28%	14%	7%
> Average BCR	72%	67%	64%
> Average Cost[1]	0%	39%	100%
> Average +20% Cost[1]	0%	0%	100%

[1]Costs extrapolated from TPCS based on quantity differences in Beach-*fx*

Figure 14 shows the costs and net benefits for each iteration sorted by the model iteration having the greatest FWOP damages. The results show that the model iterations with very high FWOP damage or very low FWOP damage have the generally have the lowest net benefits, while costs are relatively constant. Iterations with high FWOP damages are due to multiple large storms. As seen previously, the Recommended Plan does not perform as well against wave and flood damage which is the main incremental damage source in the high FWOP damage runs. As is expected, the low FWOP damage runs do not have a large enough benefit pool and result in small amount of net benefits. The Recommended Plan is the most effective under standard conditions.

Figure 14: Recommended Plan Cost and Benefit by FWOP Damage (FY2021)



4.5 Land Loss Benefit

In outlining the process and procedures to be used in the evaluation of coastal storm risk management projects, ER 1105-2-100 mentions the inclusion of land loss due to erosion, stating that such damages should be computed as the market value of the average annual area expected to be lost. Prevention of land loss is a component of primary benefits but is not computed within the Beach-*fx* model. Thus, calculation of land loss benefits must be completed outside of the model and added to the structure and contents damage and armor costs benefits as computed by Beach-*fx* to obtain the total benefits of the project.

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

In the case of Folly Beach, only land that was part of a city parcel was considered for land loss. ER 1165-2-130 does not allow land loss benefits to be claimed for beach areas subject to temporary shoreline recessions.

Land loss was calculated on per iteration basis. If, during an iteration, the land loss encroached on a city parcel that land would be no longer be considered developable. If this happened in the FWOP, and not in the FWP, then it was claimed as a benefit in that iteration.

Armor in Beach-*fx* prevents erosion damage but does not stop the background erosion process. Given the high erosion rates in Folly, it was assumed that land loss would continue past armoring put up by individual property owners, but not past SCDOT or USACE revetments. The model results are sensitive to this assumption, and the effects on the Recommended Plan of changing the assumption are discussed in a later sub-section of this appendix.

As the second component of the land loss benefits calculation, ER 1105-2-100 instructs that nearshore land values be used to estimate the value of land lost. The SAS Real Estate Department estimated a nearshore land value of $50.70 (FY2020 price level) per square foot for the Folly Beach study area.

Land loss calculations were made using the technique described, on an iteration-by-iteration and reach-by-reach basis. Values for land loss were included in alternative development, as they varied with alternatives, and presented in every part of the economic appendix.

4.6 Structure Condemnation Benefit

In Beach-*fx*, a lot is considered condemned if erosion reaches the centroid of the lot. If a lot is condemned, the damage elements on the lot are not damaged solely because the lot status has changed. It was the conclusion of SAJ Economists that if half of the footprint of a building were to be eroded away, that the building would be uninhabitable and thus economic damage would have occurred. This regional/local model was tested and certified for a one-time by the CSRM-PCX.

To account for this in the benefit pool, lots for ocean-front properties were drawn such that the centroid of the lot was roughly equal to the center of the property's foundation, as viewed in ArcGIS Pro.

The above procedure allowed post-processing of structure condemnation benefits. If Beach-*fx* marked a lot in front of the SCDOT road revetment (first row) as condemned, then every damage element on that lot would immediately be added to the pool of damages (at the current present value). This was done in both the FWOP and FWP conditions, meaning structure condemnation would only result in a benefit if it occurred in the FWOP and not in the FWP. Additionally, any future damage done to a condemned property was removed from the damage pool, to avoid double counting.

Post-processing for structure condemnation was done on an iteration-by-iteration and lot-by-lot basis. Values for structure condemnation were included in alternative development, as they varied with alternatives, and presented in every part of the economic appendix.

4.7 Regional Economic Development Benefit

Regional Economic Development (RED) benefits of the Recommended Plan were calculated the USACE Regional Economic System (RECONS), a USACE certified model. The cost estimate from the TPCS along with OMRR&R costs were input into the long-term impacts and contributions model of RECONS. The work activity input for each cost expenditure was coordinated with SAW cost engineering. RED benefits of the Recommended Plan in FY2021 prices can be seen in Table 21.

Table 21: RED Benefits of the Recommended Plan (FY2021)

Area Type	Local Capture	Output	Jobs (FTE)	Labor Income	Value Added
Local					
Direct Impact		$187,116,000	25.6	$105,601,000	$123,285,000
Secondary Impact		$141,544,000	16.0	$49,078,000	$79,896,000
Total Impact	$187,116,000	$328,661,000	41.6	$154,678,000	$203,180,000
State					
Direct Impact		$191,775	27.6	$107,131,000	$126,608,000
Secondary Impact		$152,754,000	17.3	$51,323,000	$84,217,000
Total Impact	$191,775,000	$344,530,000	44.9	$158,455,000	$210,826,000
US					
Direct Impact		$229,868,00	30.3	$119,797,000	$143,928,000
Secondary Impact		$380,122,000	32.8	$121,478,000	$206,307,000
Total Impact	$229,868,000	$609,990,000	63.1	$241,276,000	$350,235,000

4.8 Incidental Recreation Benefit

According to ER 1105-2-100, incidental recreation benefits can be calculated in CSRM studies. While recreation benefits cannot make up more than 50% of the total benefits needed for project justification, the guidance states that "if the criterion for participation is met, then all recreation benefits are included in the benefit to cost analysis."

4.8.1 Travel Cost Method

ER 1105-2-100 specifies that benefits arising from recreation opportunities created by a project be measured in terms of willingness-to-pay (WTP). Three acceptable calculation methods are outlined: (a) the travel cost method (TCM), (b) the contingent valuation method, and (c) the unit day value method (UDV).

The typical approach for feasibility studies is the UDV method, due to its low cost and the fact that recreation is not a primary benefit source (cannot be used for plan formulation.) According to ER 1105-2-100 Appendix E, the UDV method can only claim benefits for up to 750,000 annual visitors. In the instance where annual visitation exceeds 750,000, either a regional/site-specific TCM or contingent valuation model should be used, lest benefits be forgone. The team determined that a region specific TCM model was appropriate due to the high levels of visitation to Folly Beach.

ER 1105-2-100 Appendix E explains the travel cost method,

> "The basic premise of the travel cost method is that per capita use of a recreation site will decrease as out-of-pocket and time costs of traveling to the site increase, other variables being constant. TCM consists of deriving a demand curve by using variables costs of travel and the value of time as proxies for the price."

For this study, evaluating recreation TCM benefits included two primary efforts: determine the willingness-to-pay for Folly Beach and estimate annual equilibrium visitation over the period of analysis.

4.8.1.1 WTP Model

USACE contracted out the first step of the TCM analysis to recreation demand experts at the University of Georgia – Athens (UGA). The researchers were hired as part of a joint effort organized by multiple USACE studies, including, but not limited to the Folly Beach, Miami-Dade, Pinellas County, and Collier County Feasibility Studies. They were able to use data from the Deepwater Horizon Oil Spill to estimate WTP for different recreation locations within the regional footprint of USACE South Atlantic Division (SAD). Their analysis included modern statistical techniques to derive WTP estimates with the Deepwater Horizon data. While the tools for demand estimation have improved in the last few decades, the basic premise outlined in ER 1105-2-100 is still the guiding principle. The report from UGA is included as a sub-appendix to this report to provide further information on the data and analytical techniques used in the analysis.

4.8.1.2 Equilibrium Visitation Model

The analysis by UGA provides the WTP based on the study area's current condition, as well as a method for evaluating changes to the beach's condition. USACE economists developed a supplemental spreadsheet model that takes the WTP values and applies them to a supply and demand framework. This framework, which incorporates site specifics, provides a total recreational benefit of the Recommended Plan over the period of analysis, relative to the future without.

Beach visitors need a certain amount of space to recreate, and a large beach can accommodate more visitors. In the spreadsheet model, this is the supply. Supply determines the maximum number of possible daily visitors, based on the size (length and width) of the beach. The supply varies between the FWOP and FWP, and can also vary within the FWP, for example following a nourishment.

Demand in the spreadsheet model is based on annual visitation demand. Visitation demand can be determined by different factors, such as traffic data, hotel bookings, surveys, or other site-specific information. Demand could also be limited by parking and access availability or hotel capacity. Demand is constant across the FWOP and FWP. This is unlikely to be true, but there is no way to estimate the difference, so this conservative approach is used.

The model disaggregates the annual demand into daily demand estimates. The estimated daily demand is capped by the maximum daily supply (for both the FWOP and FWP) and then the WTP values provided by UGA are applied to the equilibrium visitors. Note, the WTP values are applied to more visitors in the FWP (more beach space, assuming sufficient demand) and at a higher value (better recreation experience, as estimated by UGA researchers). Finally, the total benefits for the FWOP and FWP are aggregated over the period of analysis and the difference is taken.

4.8.2 Recreation Benefit

Based on information provided by UGA, the WTP for a day visit is $27.80 for a single day visitor and $91.99 per day for multiple day visitors. Their data shows that 27.4% of user days were from single day users, for a weighted average of $74.40. Data from Beach-*fx* was used to determine the beach supply for the FWOP and FWP. Annual visitation was set using a combination of data from the Deepwater Horizon dataset and information in an April 2015 report entitled "The Economic and Fiscal Impacts of Folly Beach on the Charleston Area and the State of South Carolina", which was conducted by Charleston County's Office of Tourism Analysis.

The 2015 report estimates that 91% of non-resident (defined as the outside the tri-county Charleston area) visitors include a trip to the beach. Folly Beach attracts 21% of all visitors to their beach. This implies that of the non-resident Charleston area visitors that visited a beach, 23% (21%/91%) visit Folly beach. Data from the Deepwater Horizon survey shows that there are 7,749,833annual beach user-days associated with multi-day trips to the Charleston area.[1]Applying the 23% figure from the 2015 report, results in 1,788,000annual user days to Folly Beach associated with multi-day trips. Additionally, the Deepwater Horizon data for Georgia (the closest state to South Carolina for which there is data) estimates that 27.4% of user days originate from single-day trips, for an additional 674,000 annual user days. The total annual visitation demand used in the recreation analysis is 2,462,000 user days.

Demand was assumed not to increase over the timespan of the study, nor was demand assumed to be limited by infrastructure constraints. It is likely that visitation demand will increase over the next fifty years but there are not reliable methods to determine by how much. The decision to assume no increase was made because it was the most conservative approach given the lack of

[1]The 7.75 million visitors do not include visitors originating from anywhere within a one-day drive of the Gulf coast, due to the nature of the Deepwater Horizon survey. As such, the number is conservative and an underestimate. This discrepancy is not expected to be significant, because it is highly likely that beachgoers living so close to the Gulf would visit one of their nearby options, rather than Folly Beach.

information. To support the second assumption, visitation demand must be compared to Folly's infrastructure capacity, this includes (1) parking capacity, and (2) residential/hotel capacity.

Folly Beach takes great pride in their commitment to offering parking and access. Almost every street that dead ends into the beach has a public access and parking turnoff. In addition, it is legal to park on the side of the road on almost any street in town. The combination of these two access methods fulfills the parking capacity component. Parking and access requirements are discussed further in section 4.7.3.

Since Folly Beach has shown the ability to host this amount of visitation, and the visitation estimate does not include any increase in demand over the period of analysis, no comprehensive analysis was done on the residential/hotel capacity in Folly. 1,788,000 person-nights is almost 5,000 people per day and more during peak demand months. The city has one major hotel on the beach, and multitudes of smaller bed and breakfasts/vacation rentals all within walking distance of the beach.

Using the WTP numbers from UGA researchers and the spreadsheet model results in an estimated total present value of recreation benefits of $47,753,000 in average annual terms (FY2021 prices at a discount rate of 2.5%).

4.8.3 Parking and Access

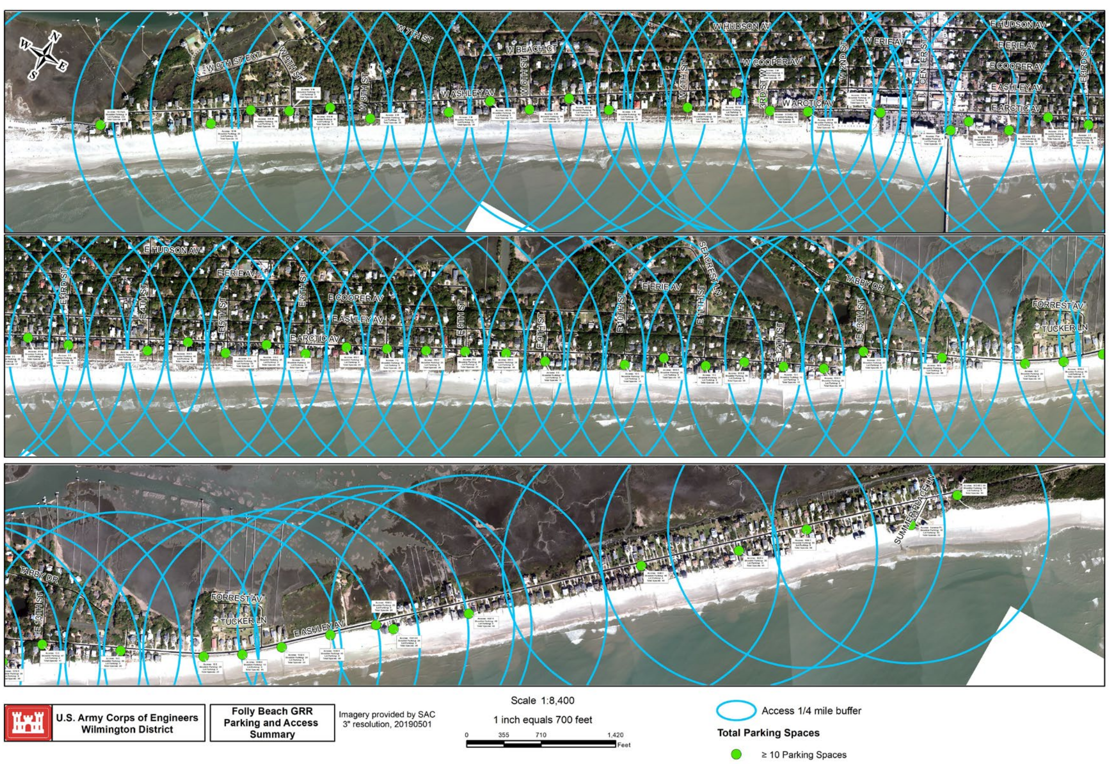
The Army Corps of Engineers has several requirements that must be met to fully cost share in a shore protection project (see ER 1105-2-100 and ER 1165-2-130). One of these requirements is that the beaches must be available for public use. As described in ER 1165-2-130 (Federal Participation in Shore Protection, paragraph 6.h.) public use implies reasonable access and parking. USACE Wilmington District, additionally, has developed more specific minimum parking requirements for participation in shore protection projects within the District's boundaries.

ER 1165-2-130 stipulates that in order to qualify for Federal cost sharing of Hurricane and Storm Risk Management projects, the local community must, at a minimum, provide public access and parking within a one quarter mile radius of any point of the project. Parking must satisfy the lesser of beach capacity or peak hour demand for that beach community. The peak demand hour had been previously identified as noon on the 4th of July holiday by USACE. The Wilmington District has further established a ten-space minimum for parking lots within one-quarter mile of each required public access point. Total beach visitation and the associated recreation benefit depend on day trip visitors having adequate available public parking. In areas where adequate parking is not provided, the recreation benefits for that portion of the project cannot be counted towards the justification of the project.

Folly Beach has 53 public beach access points within the project limit. The access points generally consist of small parking areas and wooden walkways to the beach often supplemented with shoulder parking. The County Park in Reach 1 and the commercial district in reach 8 have larger parking access points. Most areas of the project are within .25 miles of a public access area, much of the beach having multiple access points within the .25-mile threshold. See Figure 15 for an aerial overview of the public access locations. The only segment of the project that does not meet the parking and access requirement is the Lighthouse Inlet Heritage Preserve to the northeast. The Lighthouse Inlet Heritage Preserve has a public parking and access point at the southwest entrance. Pedestrians have beach access, but vehicles cannot continue past this point. In the recreation analysis, only the first .25 miles of the Lighthouse Inlet Heritage Preserve is eligible for inclusion. This area is justified and funded based on section 111, rather than CSRM benefits, so the lack of parking and access does not impact project justification.

The City of Folly Beach has demonstrated that they have provided enough public access locations across the project area to satisfy the .25-mile requirement. Additionally, the number of spots must meet the lesser of beach capacity or peak hour demand for that beach community beach. There is a total of 1,694 parking spots available among the 53 public access points. Beach capacity peaks directly after a nourishment at 32,500. Between multiple visitors per vehicles, vehicles turnover, private parking from vacation rentals and hotels, and street parking, it was determined that Folly Beach contained the necessary parking capacity to meet peak-demand.

Figure 15: Overview of Public Access Locations



4.9 Risk and Uncertainty of the Recommended Plan

This sub-section outlines the two significant outlying contributors to risk and uncertainty in the economic modeling.

4.9.1 Inconsistency in Hard Structure Modeling

FWOP modeling assumed that individual property owners would continue to construct and repair armoring to their property consistent with the Folly Beach Code of Ordinances § 151.23, provided by the City of Folly Beach. Furthermore, it was assumed that if erosion was so severe as to reach the main roadway, the SCDOT would construct a revetment to protect the roadway, as they have done previously in reaches 20 and 21.

Based on the ubiquitous nature of armor and revetments on Folly's shoreline, a revetment option was initially included as part of the initial screenings. In the highly erosional areas (reaches 22-26) the revetment option had over 50% greater net benefit relative to the eventual recommendation ($1,116,000 to $737,000 average annual.) The revetment option was not carried forward past this point.

Economic modeling includes armor in the FWOP (for homeowners, commercial structures, and by the state to project roadways, if necessary) while it was determined that armoring is not a federal option. The decision to not consider a revetment alternative leaves the economic modeling inconsistent with the plan formulation.

4.9.2 Sensitivity to Armoring Assumption

Previously in this appendix, it was identified that the economic results were extremely sensitive to a modeling assumption. This assumption is whether erosion continues past armor installed by individual property owners. In the analysis prior to this sub-section, it was assumed that individual property owner's armor did not stop erosion. This sub-section will present a series of results with adjustments to that assumption.

The first sensitivity assumes that the new lot condemnation benefit category is not applicable. In this sensitivity, the erosion continues past individual homeowner armor, but the model does not condemn the lots, and the value remaining on the lot when condemned is not added to the benefit pool. Because the lots these properties reside on are not being condemned, there is more potential for the assets to be damaged resulting in higher erosion, inundation, and wave attack benefits. Additionally, there is an increase in armor cost, as armor would not be rebuilt on a condemned lot but is rebuilt if lot condemnation is turned off. The effect of removing the benefit category is a loss of $458,530 in average annual benefits, or 9.6% of the benefit pool.

The second assumes that erosion does not continue past the individual homeowner armor. In this sensitivity, there is no lot condemnation as all properties are either armored currently or armored eventually and the erosion never encroaches on the property to condemn the lots. Land loss is the single largest benefit category and in this scenario, there is no land loss to claim. Armor benefits are also reduced, as it would no longer be necessary for the SCDOT to construct robust revetments in front of the roads once the first row of structures erode away. 73% of project benefits are not present in this analysis. The project fails to reach a BCR of 0.5 required for the consideration of recreation benefits.

Reality is likely a mix of the two extremes, however, given the limitations of Beach-*fx* it was required one be selected over the other. The decision was made to continue with the analysis that includes lot condemnation as well as the assumption that armor continues past individual homeowner armor. Table 22 shows the benefits by category of the Recommended Plan and the two sensitivities. Table 23 provides updated BCRs and net benefits for the sensitivities.

Table 22: Benefits by Source, Recommended Plan, Sensitivities (FY2021)

Benefit Source	**Erosion Past Individual Homeowner Armor**		**No Erosion Past Individual Homeowner Armor**
	With Lot Condemnation	**Without Lot Condemnation**	
	Primary Analysis	**Sensitivity Analysis**	
Erosion	$10,000	$68,000	$68,000
Inundation	$38,000	$83,000	$83,000
Wave Attack	$36,000	$558,000	$558,000
Damage Element Condemnation	$10,000	$17,000	$17,000
Lot Condemnation	$1,146,000	$0	$0
Armor Cost	$1,069,000	$1,126,000	$562,000
Land Loss	$2,455,000	$2,455,000	$0
Total	$4,765,000	$4,306,000	$1,287,000
%Δ from Primary Analysis	-	-9.6%	-73.0%

Table 23: Overview of the Recommended Plan, Sensitivities (without Recreation, FY2021)

Assumptions		**Context**	**Average Annual Benefit**	**Average Annual Cost**	**BCR**	**Average Annual Net Benefit**
Erosion Past Individual Homeowner Armor	With Lot Condemnation	Primary Analysis	$4,765,000	$5,500,000	0.87	-$735,000
	Without Lot Condemnation	Sensitivity Analysis	$4,306,000	$5,500,000	0.78	-$1,194,000
No Erosion Past Individual Homeowner Armor			$1,287,000	$5,500,000	0.23	-$4,213,000

Given the high erosion rates in Folly, the decision was made to focus on the situation where erosion continued in the presence of armor to reduce erosion damage. The Recommended Plan was optimized with respect to continued erosion and yields a BCR close to unity of 0.87. Under the extreme sensitivity exercise, the BCR of the Recommended Plan drops to 0.23. Realistically, the truth is somewhere between the two. The wide range of the BCR represents significant risk that the Recommended Plan is failing to deliver the stated benefits.

4.10 Economics of the Recommended Plan at a Discount Rate of 7%

Typically, the economic analysis is presented at the current fiscal year's federal discount rate, which has been the case for the previous economics analysis. Occasionally, federal agencies wish to see the economic analysis at a discount rate of 7%. Table 24 provides economics results considering CSRM benefits only, CSRM benefits with recreation for project justification, and CSRM benefits with full recreation benefits, all at 7%.

Table 24: Economic Summary of the Recommended Plan at a Discount Rate of 7%

Economic Category	Primary Storm Damage Reduction Benefit	Primary Storm Damage Reduction Benefit + Recreation Benefit for Project Justification	Primary Storm Damage Reduction Benefit + Full Incidental Recreation Benefit
Price Level	FY2021	FY2021	FY2021
OMB Discount Rate	7%	7%	7%
Average Annual Structure and Content Damage Benefit	$70,000	$70,000	$70,000
Average Annual Damage Element Condemnation Benefit	$7,000	$7,000	$7,000
Average Annual Lot Condemnation Benefit	$1,354,000	$1,354,000	$1,354,000
Average Annual Armor Construction Cost Benefit	$950,000	$950,000	$950,000
Average Annual Land Loss Benefit	$2,938,000	$2,938,000	$2,938,000
Average Annual Incidental Recreation Benefit	-	$5,320,000	$41,887,000
Average Annual Total Benefit	$5,320,000	$10,639,000	$47,207,000
Average Annual Total Cost	$6,835,000	$6,835,000	$6,835,000
Average Annual Net Benefit	-$1,515,000	$3,804,000	$40,372,000
BCR	0.78	1.56	5.9

The Recommended Plan has a lower BCR at an interest rate of 7%, because costs are incurred earlier in the period of analysis, while benefits are distributed roughly uniformly across the 50 years. While the net benefits are lower, the project is still justified with the inclusion of recreation benefits equal to CSRM benefits.

5 Conclusion

Table 25 provides a summary of the Recommended Plan with recreation benefits added expressed in average annual equivalent terms.

Table 25: Economic Summary of the Recommended Plan

Economic Category	Primary Storm Damage Reduction Benefit	Primary Storm Damage Reduction Benefit + Recreation Benefit for Project Justification	Primary Storm Damage Reduction Benefit + Full Incidental Recreation Benefit
Price Level	FY2021	FY2021	FY2021
FY2021 Federal Discount Rate	2.5%	2.5%	2.5%
Average Annual Structure and Content Damage Benefit	$84,000	$84,000	$84,000
Average Annual Damage Element Condemnation Benefit	$10,000	$10,000	$10,000
Average Annual Lot Condemnation Benefit	$1,146,000	$1,146,000	$1,146,000
Average Annual Armor Construction Cost Benefit	$1,069,000	$1,069,000	$1,069,000
Average Annual Land Loss Benefit	$2,455,000	$2,455,000	$2,455,000
Average Annual Incidental Recreation Benefit	-	$4,765,000	$47,753,000
Average Annual Total Benefit	$4,765,000	$9,529,000	$52,518,000
Average Annual Total Cost	$5,500,000	$5,500,000	$5,500,000
Average Annual Net Benefit	-$735,000	$4,029,000	$47,018,000
BCR	0.87	1.73	9.5

Portions of Folly Beach's shoreline are vulnerable to coastal erosion and storm damage. 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. In the high sea level rise scenario, damages increase substantially, and are marginally lower in the low sea level rise scenario compared to the intermediate sea level rise scenario.

To reduce future damages, many management measures were considered. After a detailed investigation and extensive modeling effort, a plan was selected that minimizes risk while reasonably maximizing expected future net benefits. This plan, Alternative 3, involves initial and periodic nourishment of a 35-foot equilibrated berm extension for the southwest and center of the barrier island, and a 50-foot equilibrated berm extension for the area in the northeast. The project template will include a dune feature at 15' NAVD88 high by 5' wide (at the crest). A dredge will be used to fill the template with sand from the Lighthouse Inlet Heritage Preserve and the Stono Ebb Shoal. The average annual net benefits of the Recommended Plan are $47,018,000 if the full incidental recreation benefits are included, $4,029,000 if the maximum allowable recreation for justification is included, and -$735,000 without recreation.

Sub-Appendix: Recreation Memo

Economic Analysis for Folly Beach, SC:

Use Values, Visitor Totals, and the Influence of Beach Replenishment

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Submitted June 30, 2021

Introduction

This document presents results of an economic analysis for valuing beach erosion management projects in Folly Beach, SC. The report makes use of existing data to estimate economic value of beach recreation and conduct economic assessment of beach replenishment projects relevant to the US Army Corps of Engineers.[2] The primary data comprise information collected between 2011 and 2013 as part of the *Deepwater Horizon* (DWH) *Oil Spill* damage assessment. The data collection efforts were extraordinary, costing approximately $40 million and producing 43,000 phone interviews of US residents, almost 2.5 million beach overflight photos, roughly 38,000 onsite counts, and approximately 129,000 onsite interviews. As part of the damage assessment case, researchers determined that conditions had returned to normal starting February 2011 for Florida Peninsula beaches, and starting November 2011 for Louisiana, Mississippi, Alabama and Florida Panhandle beaches. This determination informed the legal proceedings surrounding settlement discussions and was subjected to academic peer review (Tourangeau et al. 2017). Given our focus on South Carolina beaches in the current analysis, the DWH datasets, combined, provide between 19 and 29 months of beach recreation data during baseline conditions (i.e., after the DWH oil spill effects dissipated). Dr. Roger von Haefen (NC State), who served as an expert

[2] The project “Estimating Recreation Value and NED Benefits of Federal Shore Protection Projects” [Project CESU-Gulf: FP00017344; Award # AWD00011629; 1/1/20 – 2/13/22] was primarily designed to use survey data [OMB Control Number 0710-CBRS, Expiration Date 28/02/2021], but the COVID-19 pandemic has made collecting onsite data impossible at the present time. As an alternative, we have used existing data to produce economic value and utilization estimates.

consultant on the DWH damage assessment, provides access and expertise for use of these data.

Folly Beach, South Carolina

Folly Beach is the closest sandy coastline to Charleston, SC, and as such provides a regional and national destination for South Carolinians and other visitors looking for a mix of historic city and coastal recreation. With an average elevation under 20 feet, Charleston is in danger of flooding due to coastal storms and sea level rise. Two feet of sea level rise could cause 1,163 homes to be chronically flooded on the Charleston Peninsula (Darlington 2009). Along the coast, the average beach erosion rate in the Charleston area is estimated at 0.3 and 1.8 m/y (Kelly, Pilkey & Cooper 2009). Many parts of the shoreline have embraced beach nourishment as a way to combat loss of beach sand. Folly Beach is one of those locations.

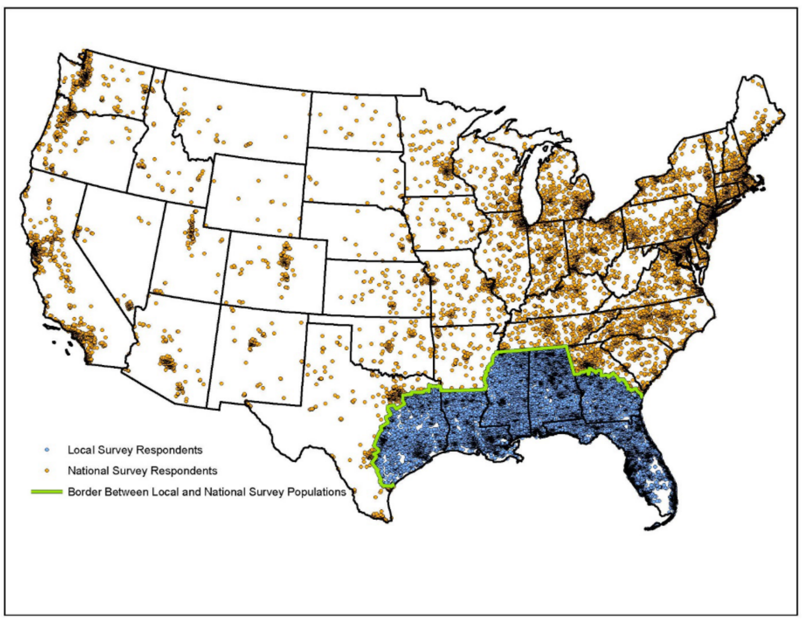
The tourism industry in Charleston brought in roughly 7.3 million visitors in 2018, contributing 8.1 billion dollars in total economic impact to Charleston economy. This includes an estimated 2.8 billion in labor earnings and 949.8 million dollars generated in lodging sales (Office of Tourism Analysis 2019). Roughly 24% of sales in Charleston can be attributed to tourism. Top attractions in Charleston include beaches, the Charleston City Market, and historic houses/plantations. Most visitors are Caucasian and over 50 years old. More than half of visitors to Charleston are repeat visitors. Many visitors come from surrounding states including North Carolina and Georgia. Average group size is between two and three people, usually without children. Visitors to Charleston have upper-middle income and spent an average of $228 per person, per day and $863 per adult, per trip.

Data

Telephone data were collected from households residing in two geographic strata; 1) a local stratum consisting of Louisiana, Alabama, Mississippi, and Florida as well as parts of Texas and Georgia that are within a half-day's drive of the Gulf Coast); and 2) a national stratum which is composed of the remaining contiguous United States - see Figure 1. Across both strata, roughly 300,000 households were sent a short mail "screener" survey in late 2011 or early 2012 that included a $5 incentive and asked for a phone number where they could be contacted. The response rate to this screener survey was 46%. Beginning in early 2012, the local and national phone surveys were administered by *Westat* to a stratified random sample of households who provided their phone numbers through the screener survey. These surveys were conducted in multiple waves through the summer of 2013 using a CATI (computer assisted telephone interviewing) program. Each sampling wave was an independent cross-section, and no households were sampled in multiple waves. The overall response rate for the phone surveys was 26%.

Detailed information on all primary-purpose, shoreline recreation trips to coastal areas in Texas, Louisiana, Mississippi, Alabama, Florida and Georgia (hereafter the six-state region) during the 2-3 month (local survey) or 6-7 month (national survey) reporting period was collected from a randomly selected adult in the household. In sum, data for roughly 43,000 adults and 26,000 trips were collected. The data provide a complete and representative picture of single- and multiple-day shoreline recreational trips by residents of the contiguous US to coastal areas and beaches in the six-state region from January 2012 to June 2013.[3] For beach destinations outside the six-state region, the data provide useful but more limited information on beach recreation decisions.

Figure 1: Survey Strata and Respondents for Deepwater Horizon Oil Spill Data



Focusing on the telephone data for Georgia and South Carolina, the sampling protocol produced 151 and 675 multi-day trips to Georgia and South Carolina beaches, respectively. Most of the South Carolina trips (417) are to the Myrtle Beach area, and 124 trips are to the Charleston area. In addition, the data includes 496 single-day trips to Georgia beaches but, due to a lack of geographic coverage with the sampling protocols, no single-day trips to South Carolina beaches.

[3] Notably, the entire 19-month data collection period occurred after the DWH spill impacts had dissipated and recreation conditions had returned to baseline (Tourangeau et al. 2017).

Using the sampling weights, we estimate 39,724,218 user days associated with multi-day trips to South Carolina beaches, and 7,749,833 user days associated with multi-day trips to Charleston-area beaches. For Georgia beaches, we estimate 2,212,034 user days associated with multi-day trips, 833,330 user days associated with single-day trips, and 3,045,364 total user days.

To estimate user days at Folly Beach, we adopt the following approach. In a recent report commissioned by the USACE, Rhodes and Pan (2015) estimate that 23.1 percent of non-local visitors to beaches in the three counties that comprise the greater Charleston region visited Folly Beach.[4] Combined with our estimate of user days associated with multi-day trips, this implies 1,788,423 user days associated with multi-day trips to Folly Beach. To estimate user days associated with single-day trips, we assume that the percentages of user days associated with single- and multi-day trips at Folly Beach are the same as what we observe in Georgia (27.4% and 72.6%, respectively). Under this assumption, our implied estimate of user days associated with single-day trips at Folly Beach is 673,745 and our total estimate of user days is 2,462,168.

Table 1 presents names and descriptions for variables used in our travel cost analysis.

Table 1: Variable Descriptions

Variable Name	Definition
Trips	Trips to Georgia & South Carolina coastal recreation areas (annualized)
GA or SC site travel cost	Expected travel cost (i.e., frequency-weighted average of driving and flying travel costs) to coastal recreation areas in Georgia & South Carolina (2012 $s)
Substitute site travel costs	Expected travel cost (i.e., frequency-weighted average of driving and flying travel costs) to the nearest coastal recreation area in one of eight different regions outside of Georgia & South Carolina (2012 $s).
Household income	In 1000s of 2012 $s
College	= 1 if respondent is college graduate
Kids	# of children in respondent's household (count)
Age	Age of respondent
Retired	= 1 if respondent is retired
White	= 1 if respondent identifies as white
Male	= 1 if respondent is male

[4] Specifically, Rhodes and Pan estimate that 91 percent of non-local visitors to the three counties that comprise the Charleston region visited a beach, and 21 percent visited Folly Beach in particular. This implies that 21/91 = 23.1 percent of beachgoers visited Folly Beach.

In Table 2, we present two sets of summary statistics. Panel A includes summary statistics for the full sample of survey respondents that report trips to Georgia beaches, and Panel B includes summary statistics for the subsample of respondents that report only multi-day trip data to South Carolina beaches. As a point of clarification, our trips variable used in estimation is an annualized measure that accounts for the fact that different respondents have reporting periods of different lengths. For Georgia beaches, our mean single-day trips is 0.06 per year, and our mean multi-day trips is 0.01 per year. The average roundtrip travel cost to Georgia beaches is $401. For South Carolina beaches, our mean multi-day trips is 0.08 per year, and the average roundtrip travel cost is $552. For both Georgia and South Carolina beaches, we also have a bevy of substitute prices that represent the cost of accessing other types of Southeastern, Gulf Coast, other East Coast, Great Lakes, and West Coast sites. Average household income is roughly $69,000 for the Georgia beach sample and roughly $78,000 for the South Carolina beach sample; 38 (49) percent of visitors have a college degree in the Georgia (South Carolina) beach sample, and the average household in both samples has roughly 0.5 kids. The average respondent age is 56 (55) years, and 41 (36) percent are retired. 86 (88) percent of respondents self-report as Caucasian, and 44 (44) percent are male.

Table 2: Summary Statistics – Unweighted

Panel A – Single-Day and Multi-Day Trips to Georgia Beaches (N = 41,691)

Variable Name	Mean	St. Dev.	Min	Max
Single-Day Trips	0.06	2.34	0	345
Multi-Day Trips	0.01	0.28	0	29
GA travel cost	401.98	343.83	8.92	14,840.05
Substitute site travel costs				
SC (Primary Substitute)	426.28	327.96	10.96	15,154.45
MS, AL & FL Gulf	411.13	318.01	44.22	13,474.46
FL Atlantic	435.31	326.89	27.21	14,522.74
TX & LA	489.12	319.32	26.41	13,046.06
East Coast - NC to Southern VA	438.85	314.38	0.57	13,172.23
East Coast - Northern VA to NY	461.15	283.44	0.20	12,463.30
New England	556.39	286.34	0.29	13,497.36
Great Lakes	434.36	266.25	0.51	11,463.76
West Coast – CA	702.91	295.77	0.21	14,901.15
West Coast – OR & WA	816.30	337.11	0.14	17,410.27
Household income	68.57	76.10	0	4,000
College	0.38	0.49	0	1
Kids	0.49	0.93	0	20
Age	56.30	16.60	17	100
Retired	0.41	0.49	0	1
White	0.86	0.35	0	1

Male	0.44	0.50	0	1
Panel B – Multi-Day Trips to South Carolina Beaches (N = 13,407)				
Variable Name	**Mean**	**St. Dev.**	**Min**	**Max**
Multi-Day Trips	0.08	0.54	0	21.41
SC travel cost	552.32	408.13	10.96	15,154.45
Substitute site travel costs				
GA (Primary Substitute)	616.43	397.83	15.62	14,840.05
MS, AL & FL Gulf	656.84	349.56	94.16	13,474.46
FL Atlantic	639.22	354.45	60.33	14,522.74
TX & LA	706.11	318.36	51.23	10,931.94
East Coast - NC to Southern VA	486.45	397.16	0.57	13,172.23
East Coast - Northern VA to NY	393.91	361.87	0.20	12,044.04
New England	489.47	370.96	0.29	13,497.36
Great Lakes	336.55	300.89	0.51	11,463.76
West Coast – CA	683.10	359.73	0.21	13,235.87
West Coast – OR & WA	756.92	389.84	0.14	16,723.15
Household income	78.24	84.53	0	4,000
College	0.49	.50	0	1
Kids	0.46	0.94	0	11
Age	54.68	17.40	18	99
Retired	0.36	0.48	0	1
White	0.88	0.33	0	1
Male	0.44	0.50	0	1

Note: Roughly 1,300 observations were dropped during the data cleaning process.

Methods

USACE guidelines (2000) prohibit beach replenishment for the sole purpose of recreation, but National Economic Development (NED) benefits do include willingness to pay for enhancement of recreation facilities (in addition to storm protection). The travel cost method, the contingent valuation method, and the unit-day method are approved for valuating beach recreation, though use of unit-day values is discouraged for sites that generate more than 750,000 visits per annum. The identifying assumption of all recreation demand-travel cost models is that distance from recreation sites is exogenous, so opportunity costs of recreation trips (in terms of monetary and time costs) permit an assessment of tradeoffs between travel costs and trips on either the extensive or intensive margin.

Landry, et al. (2020) outline how the DWH data can be used to estimate economic values for beach management, focusing primarily on the Random Utility Model (RUM) of site choice and the site demand model (for assessing the number of trips taken to a site). The RUM is primarily useful for evaluating the influence of site characteristics (like beach quality) on utility and choice, but can also be used to estimate values for lost and closed beach sites. Notably, the RUM is not well-suited for valuing specific sites, as it typically has a single travel cost parameter (which implies all trips exhibit the same trip value). The site demand model, on the other had is well suited for estimating site specific economic value.

For this assessment, we use DWH telephone data to estimate demand at the intensive margin: how many trips do households take to Folly Beach and how might these trips change with beach width. The DWH data, however, are not focused on East Coast beaches north of Georgia. As such, if the data were trained on only Folly Beach, it would not include day-users, only those that stay overnight. To ameliorate this problem, we model a joint model of demand for two aggregate sites, one representing trips to South Carolina beaches and the other representing trips to Georgia beaches. We pull data from both the local and national DWH telephone recreation data sets, but we recognize that each data set provides an incomplete picture of recreational activity. In particular, the local DWH survey only includes single and multiple day trips to Georgia beaches from respondents residing in the Southeast region highlighted in Figure 1, whereas the national DWH survey includes only multiple day trips to Georgia and South Carolina from people residing outside the Southeast region. These differences in geographic and trip-type coverage influence our modeling approach, which we describe below.

We assume that individuals attain utility from trips to South Carolina & Georgia beaches and other beach sites serving as substitutes. The utility function is given by:

$$u(x,x_s,h) = f(x) + g(x_s,h)$$

where x represents trips to South Carolina/Georgia beaches, x_s represents trips to other substitutes sites, and h is a composite commodity that represents other goods and services. The cost of a beach trip is given by tc = *monetary* + *opportunity cost of time*, and prices and income (m) are normalized by numeraire price (p_h). As described in English et al. (2018), travel cost is estimated as a weighted average of driving and flying travel costs where the weights are proportional to the observed frequency that households of different sizes and incomes travel by the alternative modes to beaches in the Gulf Coast region. Driving costs are constructed by summing out-of-pocket costs derived from AAA's *Your Driving Costs* and time costs that assume the opportunity cost of time is 1/3rd the implicit wage rate. Flying costs account for money and time costs associated with: 1) driving from one's residence to a nearby airport; 2) flying to an airport near the recreation destination; and 3) driving from the airport to the recreation destination. All cost and income measures are in 2012 values, although welfare measures are inflated to 2020 dollars.

Recreation Demand Estimation

Following standard practice (Haab and McConnell 2002; Parsons 2017), we assume a semi-log specification for trip demand:

$$E(y_{ih}) = w_{ih}\exp(\beta' \mathrm{x}_{ih}), \qquad (1)$$

where **x** includes travel cost (*tc*) to South Carolina/Georgia beaches and substitutes site, household income (*m*), and household characteristics (**z**). Individuals are indicated by i=1,…, N; sampling strata are give by h = 1, … H, and w_{ih} is a weight that corrects for individual characteristics and stratum. Given that our primary objective is welfare assessment, we build on LaFrance (1990) and von Haefen (2002) in modeling demand as an incomplete demand system for k + 1 site destinations, treating the other k sites as separable in the utility function to preserve symmetry of the Slutsky substitution matrix (LaFrance 1990; von Haefen 2002), which is necessary to ensure integrability.

Since they are appropriate for analysis of dependent variables that are non-negative integers, count data models are often used to estimate site frequency recreation demand models. The most basic version of the count data model is represented by the Poisson distribution, which in the regression context (conditional expectations of dependent variable) is given by:

$$\boldsymbol{f}(\boldsymbol{y}_{\boldsymbol{ih}}|\mathbf{x}_{\boldsymbol{ih}}) = \boldsymbol{w}_{\boldsymbol{ih}}\frac{\mathbf{exp}(-\boldsymbol{\mu})\boldsymbol{\mu}^{\boldsymbol{y}_{\boldsymbol{ih}}}}{\boldsymbol{y}_{\boldsymbol{ih}}!}, \qquad \text{for } y_{ih} = 0, 1, 2, 3, \ldots \qquad (2)$$

where y_{ih} is individual site demand in stratum h (with covariates x_{ih} including travel cost, income level, and other factors), $\boldsymbol{\mu} = \mathbf{exp}\,(\boldsymbol{\beta}'\boldsymbol{x}_{\boldsymbol{ih}})$, and β represents an unknown vector of parameters to be estimated. The basic Poisson specification does not allow for random variation in recreation demand (there is no error term in equation (2)) and imposes equality of mean and variance of recreation demand.

The Poisson model can be modified to allow for overdispersion and unexplained randomness by introducing an additional parameter; the Gamma distribution is conjugate to Poisson (meaning the prior distribution of parameters and the sampling distribution have the same shape) with parameters $(\frac{\mathbf{1}}{\boldsymbol{\alpha}}, \boldsymbol{\alpha\mu})$, where the first parameter is the scale for Gamma and second parameter is shape. The resulting mixture model is Negative Binomial. A popular parameterization, referred to as NB2 (Cameron and Trivedi 2013), is given by:

$$f(y_{ih}|\mathbf{x}_{ih}) = w_{ih} \frac{\Gamma(y_{ih}+\alpha^{-1})\alpha^{y_{ih}}(\mu)^{y_{ih}}(1+\alpha\mu)^{-(y_{ih}+\alpha^{-1})}}{\Gamma(y_{ih}+1)\Gamma(\alpha^{-1})} \tag{3}$$

where α is an additional parameter to be estimated. The variance of individual demand is given by Var[$y_{ih}|\mathbf{x}_{ih}$] = $\mu + \alpha\mu^2$, and dispersion (variance divided by the mean) is proportional to the mean 1 + $\alpha\mu$. A likelihood ratio test (LRT) of the null hypothesis that α = 0 can provide evidence of overdispersion. Notably for welfare analysis, expected trips for these models are given by $\boldsymbol{\mu_i} = \mathbf{exp}\,(\boldsymbol{\beta}'\mathbf{x}_i)$, so estimates of consumer surplus and compensating variation are straightforward.

We estimate a series of pooled travel cost recreation demand models with the following generic structure:

$$lnE(trips_{ij}) = \alpha_j + \left(\beta^{own} + \beta_j^{multi} + \beta_j^{sc}\right)tc_{ij}^{own} + \sum_{k=1}^{K} \beta^{sub_k} tc_{ij}^{sub_k} + \lambda y_i + \delta \boldsymbol{d_i} \tag{4}$$

where i indexes respondents and j takes on three values with j=1 corresponding to multiple day trips to South Carolina beaches from respondents in the local and national DWH surveys, j=2 corresponding to multiple day trips to Georgia beaches from respondents in the local and national DWH surveys, and j=3 corresponding to single day trips to Georgia beaches from only respondents in the national DWH survey. This structure implies that we are differentiating between single and multiple day trips, which is consistent with many published recreation demand studies (Shaw and Ozog 1999; Yeh et al. 2006; Kaoru 1995; Hoehn et al. 1996), but here the approach is motivated in large part because we do not have any data on single day trips to South Carolina beaches. Equation (4) models (the natural log of) a respondent's trip demand as a function of own-site travel cost (tc_{ij}^{own}), up to K substitute site travel costs ($tc_{ij}^{sub_k}$), income (y_i) and observable demographics ($\boldsymbol{d}_i$). It is worth noting that we allow for heterogeneity across the three commodities in terms of the constant term (α_j) and own-site travel cost across multiple- and single-day (β_j^{multi}) as well as Georgia and South Carolina () trips, but the other parameters are restricted to be equal across all trips to preserve parameter parsimony.

We consider both Poisson and Negative Binomial econometric specifications, and to account for potential cross-equation correlations for a given respondent, we cluster our standard errors at the individual level. Table Y (see attached) reports a selective set of parameter estimates for the models we consider. Table Z reports the implied user day values where we divide the per-trip values by the average trip length (= 3.365 days). The table also reports a weighted average of user day values that assume that 27.4% of user days are associated with single-day trips.

Welfare Analysis

The value of access to recreation sites can be approximated by consumer surplus. This welfare measure approximates willingness to pay for access to Folly Beach. Given the semi-log functional form, consumer surplus is given by:

$$CS_{ij} = -\frac{\exp(\boldsymbol{\beta}\prime\boldsymbol{x_i})}{\beta_j^{tc}} \quad (5)$$

where $\beta_j^{tc} = \beta^{own} + \beta_j^{multi} + \beta_j^{SC}$ is the travel cost coefficient for j=1,2,3. The value of a single trip is given by the absolute value of the inverse of travel-cost; dividing this quantity by the average number of days-per-trip produces the daily welfare estimate:

$$CS\ per\ day_i = -\frac{1}{\beta_j^{tc}} \times \frac{1}{days\ per\ trip} \quad (6)$$

The delta method is used to produce confidence intervals around daily CS.

Results

Likelihood ratio tests consistently reject the equi-dispersion restriction imposed by the Poisson model (equations 2 versus 3), but because the Poisson model is a mean fitting distribution and often has better in-sample prediction properties (Haab and McConnell 2002), we present empirical results for both Poisson and Negative Binomial specifications in Table 3. All of the results reported are consistent with equation 4. The models pool single- and multi-day trip demand for Georgia and multi-day trip demand for South Carolina beaches and include several substitute-site prices as additional controls. For each model presented in Table 3, the travel cost coefficient is negative and statistically significant, indicating price elasticity estimates for single-day trips ranging from 1.45 to 2.83, price elasticity estimates for multi-day trips ranging from 1.21 to 1.72.[5] Household income is positive and statistically significant in all models, with income elasticities ranging from 0.60 to 1.70 across different models and sub-populations. We find that males are significantly less likely to take trips in 3 out of 4 models, but the other

[5] To calculate these elasticities, we use the formula $-\beta_j^{tc}p$, where $\beta_j^{tc} = \beta^{own} + \beta_j^{multi} + \beta_j^{SC}$ for j=1,2,3, and p is the expected price for trip-takers in the population.

demographics generally do not play an important role in explaining trip demand. In addition to affecting the travel cost coefficient, multi-day and Georgia trips are less frequent.

The inclusion of travel costs for substitute sites plays a limited role in the models. The travel cost for the primary substitute site (i.e., the South Carolina travel cost for the Georgia trips and the Georgia travel cost for the South Carolina trips) is negative, small in magnitude and highly significant in Models (3) and (4) which suggests that South Carolina and Georgia beaches are gross complements, but the other substitute site prices vary in sign, are small in magnitude, and generally not significant. Model (4) has the high log-likelihood value and the best fit according to the Bayesian Information Criteria.

Table 3: Count Data Travel Cost Models for South Carolina/Georgia

	(1)	(2)	(3)	(4)
	Poisson w/o Substitute Site Travel Costs	Neg. Binomial w/o Substitute Site Travel Costs	Neg-Binomial w/ Southeastern Substitute Site Travel Costs	Neg-Binomial w/ Southeastern and National Substitute Site Travel Costs
Travel Cost (*j*=1)	-0.0801***	-0.0435***	-0.0445***	-0.0432***
	(-4.65)	(-2.91)	(-2.97)	(-2.92)
Travel Cost x Multi Day (*j*=2)	0.0741***	0.0368**	0.0378**	0.0373**
	(4.31)	(2.46)	(2.50)	(2.48)
Travel Cost x South Carolina (*j*=3)	0.00125	0.00235**	0.00269***	0.00230***
	(1.11)	(2.57)	(3.29)	(3.20)
Constant (*j*=1)	1.399*	-0.573	-1.539	-2.305**
	(1.88)	(-0.60)	(-1.59)	(-2.11)

Multi-Day Trip	-5.329***	-2.878***	-2.956***	-2.881***
Constant (*j*=2)	(-7.31)	(-3.47)	(-3.54)	(-3.44)
South Carolina Trip	2.049***	1.607***	1.746***	1.890***
Constant (*j*=3)	(5.72)	(5.11)	(4.87)	(5.02)
College Graduate	0.392**	-0.00574	0.0299	0.0377
	(2.22)	(-0.03)	(0.15)	(0.20)
Kids	-0.0840	-0.225*	-0.213*	-0.205*
	(-0.95)	(-1.68)	(-1.87)	(-1.93)
Age	-0.00230	-0.00691	-0.00746	-0.00737
	(-0.42)	(-1.17)	(-1.26)	(-1.22)
Retired	0.00254	-0.0764	-0.0294	0.000214
	(0.01)	(-0.25)	(-0.10)	(0.00)
White	0.138	-0.414	-0.402	-0.335
	(0.44)	(-0.92)	(-1.04)	(-0.99)
Male	-0.197	-0.469**	-0.454**	-0.415**
	(-1.11)	(-2.00)	(-2.11)	(-2.08)

income in $1000s	0.0109***	0.0221***	0.0144***	0.0105**
	(11.24)	(12.94)	(4.33)	(2.03)
Substitute-Site Travel Costs				
Primary Substitute Site - Either SC or GA			-0.00640***	-0.00507***
			(-5.09)	(-4.53)
NC to Southern VA			0.00363***	0.00277
			(2.71)	(1.60)
MS, AL & FL Gulf Coast			0.00484	0.00243
			(1.21)	(0.85)
FL Atlantic			-0.00151	-0.000334
			(-0.48)	(-0.13)
TX & LA			0.00171	0.00245**
			(1.37)	(2.03)
Northern VA to NY				-0.00171
				(-1.13)

New England				0.00161
				(1.45)
Great Lakes				0.000706
				(1.44)
California				-0.000959
				(-0.96)
OR & WA				0.000981
				(0.89)
Observations	96789	96789	96789	96789
Log-Likelihood	-37,701,160	-26,273,684	-25,964,559	-25,862,949
Bayesian Info. Criteria	75,402,470	52,547,529	51,929,337	51,726,174

t statistics in parentheses; * p<.1, ** p<.05, *** p<.01.

Table 4 presents point estimates and 95% confidence intervals for user day values across alternative trip lengths, destination beaches, and empirical models. We also present a weighted average user day estimate of single- and multi-day trips that may be useful in applications where trip length is unknown. A few patterns emerge. On a user day basis, South Carolina trips are generally more valuable than Georgia trips, although the differences we report are not always statistically significant. User day values associated with multi-day trips are consistently higher than those associated with single-day trips, and these differences are generally statistically significant. If we focus on the results for South Carolina beaches, the preferred model (4) implies a user day value for single-day trips of $27.23 (95% confidence interval, $8 - $47), a user day value for multi-day trips of $91.99 (95% confidence interval, -$1 - $185), and a weighted average user day value of $74.40 (95% confidence interval, $7 - $142). The corresponding results for Georgia beaches are generally lower. To put these numbers in perspective, Table 5 presents some daily and per-trip beach value estimates from the literature. All values are inflated to 2020 dollars using the CPI.

Table 4: User Day Values (2020 US Dollars)

User Day Values

Model	Georgia Single Day	Georgia Multi Day	Georgia Weighted Average	South Carolina Single Day	South Carolina Multiple Day	South Carolina Weighted Average
1 - Poisson w/o substitute-site travel costs	$14.20 ($8,$20)	$56.49 ($44,$69)	$44.91 ($35,$54)	$14.43 ($8,$21)	$71.46 ($37,$106)	$55.84 ($31,$81)
2 - Neg. Binomial w/o substitute-site travel costs	$26.16 ($9,$44)	$50.59 ($41,$60)	$43.90 ($36,$52)	$27.66 ($8,$47)	$78.06 ($45,$111)	$64.25 ($39,$89)
3 - Neg. Binomial w/ Southeast substitute-site travel costs	$25.59 ($9,$42)	$50.26 ($25,$75)	$43.50 ($25,$62)	$27.23 ($8,$46)	$83.68 ($16,$151)	$68.22 ($19,$117)
4 - Neg. Binomial w/ Southeast & national substitute-site travel costs	$26.32 ($9,$44)	$56.59 ($22,$91)	$48.30 ($23,$74)	$27.80 ($8,$47)	$91.99 (-$1,$185)	$74.40 ($7,$142)

95% confidence intervals reported in parentheses. Weighted average estimates assume 27.4% of user days are associated with single-day trips.

There are no perfect comparisons from the literature, as most samples are either collected onsite (Bin et al. 2005; Parsons et al. 2013; Landry et al. 2016) or drawn from coastal counties (Lew and Larson 2008; Pendelton et al. 2012) or the state under study (Liu and Egan 2019; Landry et al. 2020). Still, the collection of value estimates provides context for assessing the magnitude of our estimates for South Carolina/ Georgia beaches. Utilizing a pooled, single-site count data regression model, Bin et al. (2005) find beach value estimates for sites similar to Miami-Dade County that range from $21 (Fort Macon, NC) to $50 (Topsail Island, NC) per person, per day. Also utilizing onsite data, Parsons et al. (2016) find estimates of $41 per person, per day in Delaware, while Landry et al. (2016) find estimates of $91 per person, per day for Cape Hatteras, NC. All of these models control for onsite sampling by correcting for endogenous stratification of the dependent variable, but other biases may persist in the day (e.g. time-onsite biases). The data originally presented by Whitehead et al. (2008) utilize a sample of households within 120 miles of the beach and are subsequently analyzed by Landry and Liu (2009) and Whitehead et al. (2010). Value estimates from the studies pertain to Southeast North Carolina beaches (from Bogue Banks to Brunswick County on the South Carolina border) and range between $135 and $165 per person, per trip (note, these value estimates are NOT per day).

Table 5: Beach Valuation Estimates

Paper	Site	State	Value	Unit	Year	Sample
Bin et al. MRE 2005	FORT MACON	NC	$20.62	individual/day	2003	Onsite
Bin et al. MRE 2005	WRIGHTSVILLE	NC	$24.83	individual/day	2003	Onsite
Bin et al. MRE 2005	TOPSAIL	NC	$50.23	individual/day	2003	Onsite
Lew and Larson 2008	SAN DIEGO	CA	$32.78	individual/day	2000/01	Telephone San Diego County
Whitehead et al. MRE 2008	SE NC Beaches	NC	$134.53	individual/trip	2003	120 miles from beach
Landry and Liu JEEM 2009	SE NC Beaches	NC	$165.00	individual/trip	2003	120 miles from beach
Whitehead et al. ERE 2010	SE NC Beaches	NC	$138.00	individual/trip	2003	120 miles from beach
Pendleton et al. 2012 CEP	California	CA	$149.00	individual/trip	2000	Los Angeles & Orange Counties
Parsons et al. MRE 2013	Delaware	DE	$41.19	individual/day	2010/11	Onsite
Landry et al. MRE 2016	CAPE HATTERAS	NC	$91.38	individual/day	2002	Onsite
Liu & Egan ERE 2019	Ohio	OH	$86.24	household/day	2012	Ohio residents
Landry, et al. JEEM 2020	North Carolina	NC	$128.32	household/day	2013	State-wide phone survey

Benefit Transfer
In order to assess the influence of beach replenishment on recreation value, we need to understand how changes in site conditions (e.g. beach width, beach length, sand quality, dune height) affect recreation behavior and values. Improvements in beach area (length and/or width) would provide more space for recreation, can reduce congestion, and may improve beach aesthetics. For example, beach replenishment can provide continuous beach at high tide, which can make exercise (walking, jogging, biking) more pleasant and feasible. These changes in site quality can affect the extensive margin (which individuals choose to visit the beach relative to another beach or an alternative activity), the intensive margin (how many trips to visitors take to the site), and may have impacts on non-use values (e.g. existence values relating to maintaining the beach ecosystem).

There is limited information on how changes in the beach affect value. Whitehead et al. (2008) combine revealed (RP) and stated preference (SP) demand for beach recreation to assess how willingness-to-pay changes with access (available parking and short walk to the beach) and beach width (increase average width by 100 feet). Their baseline consumer surplus (based on RP data) is $94 per household, per trip; using SP demand data they estimate a $25 increase for better beach access (26.6% increase in WTP) and $7 for increasing beach width (7.5% increase in WTP). Notably, the Whitehead study deals primarily with local users (with 120 miles of the beaches under study), but since their sample included non-users, their estimates could apply to both extensive and intensive margins. Status quo beach conditions in their study area entail beach width that ranges between 10 and 100 feet, with an average of 75 feet. Thus, the SP beach width improvement scenario involves changing beach width by $\%\Delta Q = \frac{100}{75} \times 100 = 133\%$, which produces a WTP elasticity of $\varepsilon_{WTP} = {}^{\%\Delta WTP}/_{\%\Delta Q} = {}^{26.6}/_{133}$=0.2. Thus, increasing beach width by 1% increases WTP by 0.2%.

Parsons et al. (2013) take a similar approach but focus on a wider population of users, intercepted onsite in Delaware. Beaches along the Delaware Bay range in width from 50 to 100 feet. Their baseline RP estimates of WTP is $35 (weighted average across day users and overnight visitors). Using SP responses on change in visitation in response to changes in beach width, they estimate that reducing beach width to one-quarter of current width results in welfare losses of $4.84 (about 13.8% reduction in WTP), while doubling current beach width results in welfare gains of $2.83 (about 8% increase). Utilizing 75 feet as the status quo beach width, these results suggest that loss of 56 feet would correspond with the first scenario (final beach width around 19 feet), while doubling would result in beach width of 150 feet. These results correspond with elasticity estimates of $\varepsilon_{WTP} = {}^{\%\Delta WTP}/_{\%\Delta Q} = {}^{13.83}/_{75} = 0.184$ for reducing beach width and $\varepsilon_{WTP} = {}^{\%\Delta WTP}/_{\%\Delta Q} = {}^{8.08}/_{100} = 0.081$ for increasing beach width.

Lastly, a recent paper by Landry, Shonkwiler, and Whitehead (2020) utilizes a structural approach to identify demand for beach trips and WTP for maintaining beach width (utilizing contingent valuation responses). Their derivation of WTP is based on recovery of the expenditure function through integration of the trip demand equation. The constant of integration is specified to represent potential non-use value. This approach permits testing for weak complementarity (absence of non-use value), which the authors reject. Thus, their welfare estimates for changes in beach width take account of use and non-use values and incorporate both RP and SP data.

In distinction to Whitehead, et al. (2008) and Parsons, et al. (2013), identification of the value of beach in the Landry, Shonkwiler, and Whithead paper is based on variation in beach width in the RP data (as revealed in visitation to beaches of various width) and the SP data (as introduced in contingent valuation scenarios. Empirical estimates from the preferred model indicate mean WTP of \$0.2459 per meter and median WTP of \$0.4773 per meter of beach width. As these are both reasonable measures of central tendency, we treat the former as a lower bound and the latter as an upper bound. Since these are annualized household measures, they would have to be converted to estimate changes in units of per individual, per trip. For example, transferring the lower bound welfare estimate results in the following estimate:

$$WTP_{LB} = \$0.2459/meter \times \frac{1}{2.13 \times 1.73} = \$0.0667/meter \text{ per individual, per day}$$

While the upper bound produces an estimate of:

$$WTP_{UB} = \$0.4773/meter \times \frac{1}{2.13 \times 1.73} = \$0.1295/meter \text{ per individual, per day}$$

Mean WTP for beach erosion control in Landry, Shonkwiler, and Whitehead is \$7.91, while median WTP is \$10.70. Using these point estimates and the average beach width of 49.71 meters produces WTP elasticities of $\varepsilon_{WTP}^{LB} = {\partial WTP}/{\partial Q} \times \frac{Q}{WTP} = 0.0667 \times \frac{49.71}{7.91} = 0.419$ and $\varepsilon_{WTP}^{UB} = {\partial WTP}/{\partial Q} \times \frac{Q}{WTP} = 0.1295 \times \frac{49.71}{10.7} = 0.602$.

Given measures of current beach width on Folly Beach, the baseline values in Table 4 can be rescaled to use benefit transfer from any or all of the above studies. Once with- and without-project estimates are defined, benefits and costs will be converted to present discounted values, using a range of discount rates, for benefit-cost analysis. Any uncertainty related to analytical assumptions can be assessed via sensitivity analysis (USACE 2020).

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