Appendix E-2

South Padre Island CSRM Economics

U.S. Army Corps of Engineers

Galveston District
Southwestern Division

Appendix E-2

South Padre Island CSRM Economics

for the
Coastal Texas Protection and Restoration Study
Integrated Feasibility Report and
Environmental Impact Statement

October 2018

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Acronyms and Abbreviations

BCR	benefit-to-cost ratio
Coastal Texas Study	Coastal Texas Protection and Restoration Study
FWOP	Future Without-Project
FWP	Future With-Project
LERRD	lands, easements, rights-of-ways, relocations, and disposal/borrow areas
PDT	Project Development Team
UDV	unit day value
USACE	U.S. Army Corps of Engineers
WIS	Wave Information Studies

1.0 INTRODUCTION

1.1 DEMOGRAPHICS

The city of South Padre Island lies on Padre Island in South Texas and is within the boundaries of Cameron County. According to the 2012–2016 American Community Survey published by the U.S. Census Bureau, the estimated population of South Padre Island is 2,888, which is less than one percent of the total county population of 418,875. The population is 52 percent female and 48 percent male for both the city and the county. For the city, 96.4 percent of the population is White, 1 percent Black, and 2.9 percent identified as other race. For the county, 93.8 percent is White, 0.7 percent Black, 0.8 percent Asian, and 5.2 percent identified as some other race. The median age for South Padre Island is 60 years and 31 for the county. The unemployment rate for South Padre Island was 1.8 percent and 9.4 percent for the county. The median household income for South Padre Island is $42,825, while for the county it is $34,578. In the city of South Padre Island, 18.8 percent of the population had incomes below the poverty level, and for Cameron County the ratio is 33 percent.

1.2 HISTORICAL EVENTS

South Padre Island has not been the target of a significant number of storms. Two storms of significance were Beulah in 1967, which caused 15 deaths in Texas and $217 million in damages in the region, and Dolly in 2008, which caused storm surges ranging from 2 to 4 feet along the mid and southern Texas coast. Damages specific to South Padre Island were not reported.

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2.0 EXISTING CONDITIONS AND FUTURE WITHOUT-PROJECT CONDITIONS

Early in the analysis, based preliminary engineering assessments, the study area for the South Padre Island area was defined as the first tier of structures along the beach within the city of South Padre Island, with the western boundary defined as Gulf Boulevard. A windshield survey of the area was done to collect occupancy type, construction materials, and finished floor elevations. Preliminary values were obtained from county appraisal district information, and a sample was evaluated using Marshall & Swift Estimation software to derive depreciated replacement values.

2.1 SUMMARY OF THE STRUCTURE INVENTORY

There were 206 structures in the study area. Of these, 121 pile foundation with enclosed ground level areas, including single-family residences and multifamily residences. There were 74 beach front high rises, which included resorts, hotels, and multifamily residences. There were five two-story residential structures, five commercial non-engineered structures, primarily restaurants and clubs, and one pile foundation with an open ground level area. The depreciated replacement value of the structures ranged from $8,000 to $45,056,363, with a total structure valuation of $640,018,157. Total value of structures and contents was estimated at $852,276, 536.

2.2 FUTURE WITHOUT-PROJECT DAMAGES

The study area was divided into seven reaches, as show on Figure 2-1. Reach 6_Park contained no damage elements. Depth damage curves were adopted from the North Atlantic Comprehensive Study, January 2015, and included pile foundation enclosure, pile foundation open, beach high rise, single-story residence (no basement), two-story residence (no basement), and commercial non-engineered structure. Using a discount rate of 2.75 percent and a period of analysis of 50 years, Beach-fx computed the present value of damages for 300 iterations of storm events. The average of those 300 iterations, along with number of damage elements and an annual average of damages is presented in Table 2-1.

Table 2-1
Number of Damage Elements and Average of Present Value Damages and Annual Average Damages by Reach, 50-Year Period of Analysis, 2.75% Discount Rate, 300 Iterations

	Future Without-Project Damages						
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Total
Number of Damage Elements	2	29	53	36	53	33	206
Average of Present Value of Damages	$56,442	4,920,927	16,856,174	32,906,063	66,984,336	22,282,889	144,006,831
Annual Average Damages	$2,091	182,276	624,368	1,218,871	2,481,161	825,379	5,334,145

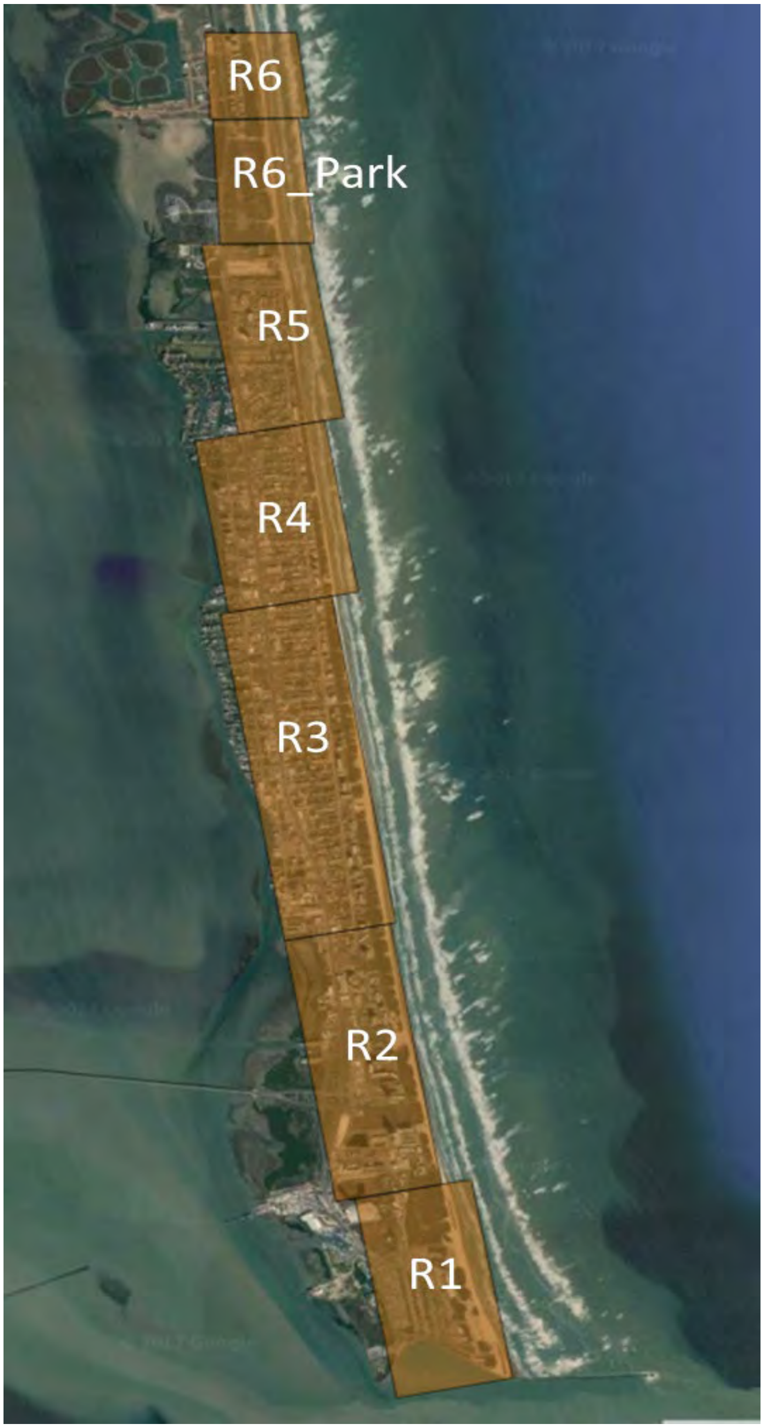

Figure 2-1. Damage Reaches

3.0 FUTURE WITH-PROJECT CONDITIONS

3.1 PRELIMINARY SCREENING OF ALTERNATIVES

For preliminary screening analysis, 18 dune and berm templates were evaluated. For each of the 18 resulting templates, a Beach-fx simulation occurred in which the entire study area (R1–R6; excluding the park) was renourished on an "as-needed" basis. A relative benefit-to-cost ratio (BCR) was computed for each reach that did not consider mobilization costs (Figure 3-1). It should be emphasized that the relative BCR is not reflective of the actual BCR in each reach, but rather allows the reaches that benefit the most from implementation of a renourishment project to be identified. On Figure 3-1, the darker hues indicate a higher relative BCR. It can be seen that reaches R3, R4, and R5 returned the largest relative BCRs. Note that although Reach R5 returned the largest damages (Attachment 1, Section 6.1), it did not receive the largest relative BCRs due to the high cost of renourishing.

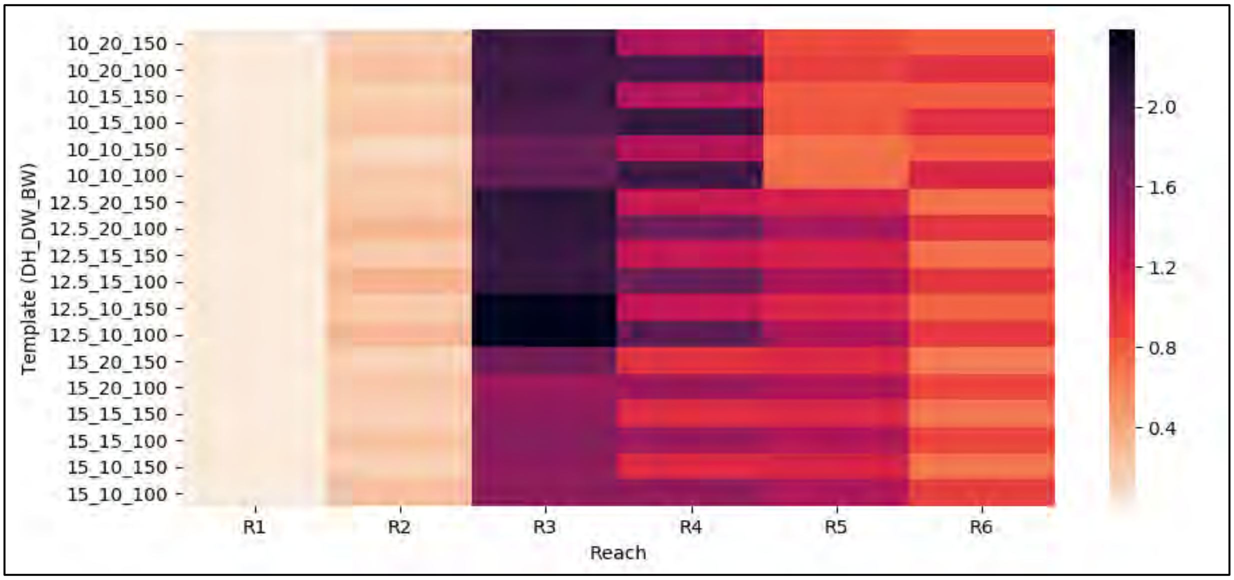

Figure 3-1. Heat Map of Relative Benefit-to-Cost Ratios

Of the 18 original nourishment templates, 8 were considered for further analysis by running additional Beach-fx simulations. For these simulations, cost assumptions were a $3 million mobilization cost and $40 per cubic yard for placement of planned nourishment material. One set of simulations considered renourishing only reaches R3 and R4, whereas the other considered reaches R3, R4, and R5. Similar to the previous simulations, Beach-fx was configured to be renourished on an "as-needed" basis. The resulting average BCRs[1] across 300 lifecycles are shown in tables 3-1 and 3-2. The results show that simulations in which reach R5 is included, result in a 13 to 43 percent reduction in the average BCR. As previously discussed, this is due to the high cost of renourishing reach

[1] Note that the simulations shown in Table 7-3 in Attachment 1 and the resulting average BCRs do not consider reach planform rates, and are thus not reflective of the actual average BCR. Reach planform rates were applied following the identification of a nourishment dune and berm template.

R5. From it can be seen that the template corresponding to a dune height of 12.5 feet, a dune width of 20 feet, and a berm width of 100 feet returned the largest BCR. This template was considered for further analysis.

Table 3-1
Cost, Damages Reduced and Net Benefits for Nourishment of Reaches 3, 4, and 5
(2.75% Discount Rate, 50-Year Period of Analysis, 300 Iterations)

	Reaches 3, 4, and 5										
Alternate	Present Value Planned Mobilization Cost	Present Value Planned Placement Cost	Present Value Total Cost	Present Value Without-Project Damages	Present Value With-Project Damages	Average Annual Cost	Annual Average Without-Project Damages	Annual Average With-Project Damages	Annual Average Benefits	Net Benefits	Benefit to Cost Ratio
15_15_100	$57,832,840	46,457,424	104,290,264	144,006,831	73,939,919	3,863,007	5,334,145	2,738,803	2,595,343	–1,267,664	0.67
15_10_100	58,570,908	45,289,121	103,860,029	144,006,831	74,372,697	3,847,071	5,334,145	2,754,833	2,579,312	–1,267,759	0.67
12.5_20_100	47,526,820	39,618,378	87,145,198	144,006,831	77,914,596	3,227,938	5,334,145	2,886,028	2,448,117	–779,821	0.76
12.5_15_100	48,321,492	40,175,437	88,496,929	144,006,831	77,230,410	3,278,008	5,334,145	2,860,685	2,473,460	–804,548	0.75
12.5_10_150	64,462,888	46,651,262	111,114,150	144,006,831	82,125,343	4,115,770	5,334,145	3,041,998	2,292,147	–1,823,623	0.56
12.5_10_100	47,647,621	38,672,525	86,320,146	144,006,831	78,228,402	3,197,378	5,334,145	2,897,652	2,436,493	–760,884	0.76
10_20_100	23,975,541	24,513,763	48,489,304	144,006,831	108,009,876	1,796,088	5,334,145	4,000,785	1,333,360	–462,728	0.74
10_15_100	18,919,748	22,987,924	41,907,672	144,006,831	112,205,026	1,552,299	5,334,145	4,156,177	1,177,968	–374,331	0.76

Table 3-2. Cost, Damages Reduced, and Net Benefits for Nourishment of Reaches 3 and 4
(2.75% Discount Rate, 50-Year Period of Analysis, 300 Iterations)

	Reaches 3 and 4										
Alternate	Present Value Planned Mobilization Cost	Present Value Planned Placement Cost	Present Value Total Cost	Present Value Without-Project Damages	Present Value With-Project Damages	Annual Average Cost	Annual Average Without-Project Damages	Annual Average With-Project Damages	Annual Average Benefits	Net Benefits	Benefit to Cost Ratio
15_15_100	$14,537,392	26,797,867	41,335,259	144,006,831	99,878,312	1,531,096	5,334,145	3,699,585	1,634,561	103,465	1.07
15_10_100	15,642,314	26,322,523	41,964,837	144,006,831	100,440,542	1,554,416	5,334,145	3,720,410	1,613,735	59,319	1.04
12.5_20_100	8,433,632	19,817,285	28,250,917	144,006,831	106,930,051	1,046,440	5,334,145	3,960,787	1,373,358	326,918	1.31
12.5_15_100	8,704,075	19,165,900	27,869,975	144,006,831	107,727,530	1,032,330	5,334,145	3,990,327	1,343,819	311,489	1.30
12.5_10_150	12,416,326	24,854,508	37,270,834	144,006,831	104,004,970	1,380,546	5,334,145	3,852,440	1,481,706	101,160	1.07
12.5_10_100	9,097,668	18,519,168	27,616,836	144,006,831	109,253,715	1,022,953	5,334,145	4,046,858	1,287,287	264,334	1.26
10_20_100	2,976,623	9,744,826	12,721,449	144,006,831	132,855,867	471,214	5,334,145	4,921,103	413,042	–58,172	0.88
10_15_100	2,561,406	8,213,454	10,774,860	144,006,831	134,756,282	399,111	5,334,145	4,991,497	342,649	–56,462	0.86

4.0 EVALUATION OF FINAL REACHES

For the final evaluation of Reaches 3 and 4, the "renourishment as need" assumption was dropped and various renourishment intervals were considered. In total, 10 renourishment intervals were considered (1, 2, 3, 4, 5, 7, 10, 12, 15, and 20 years), and both the BCR and net benefits were computed for each lifecycle (300 lifecycles). The results of these runs are presented in Table 4-1. From the analysis, the 10-year renourishment cycle was identified as the recommended configuration. While a 15-year cycle presented greater net benefits, from an engineering perspective, it was felt the waiting time was too great to be a practical consideration, given the greater potential for damages.

Table 4-1
Cost, Damages Reduced, and Net Benefits for Nourishment of Reaches 3 and 4, Alternative 12.5_20_100 with Varying Nourishment Cycles
(2.75% Discount Rate, 50-Year Period of Analysis, 300 Iterations)

	Reaches 3, 4, Alternative 12.5_20_100										
Nourishment Cycle (Yearly Interval)	Present Value Planned Mobilization Cost	Present Value Planned Placement Cost	Present Value Total Cost	Present Value Without-Project Damages	Present Value With-Project Damages	Annual Average Cost	Annual Average Without-Project Damages	Annual Average With-Project Damages	Annual Average Benefits	Net Benefits	Benefit to Cost Ratio
1	$57,490,927	58,787,600	116,278,527	144,006,831	99,705,105	4,307,064	5,334,145	3,693,169	1,640,977	–2,666,087	0.38
2	29,080,589	67,484,035	96,564,624	144,006,831	100,571,334	3,576,842	5,334,145	3,725,255	1,608,891	–1,967,952	0.45
3	19,752,753	70,176,689	89,929,442	144,006,831	101,643,730	3,331,069	5,334,145	3,764,977	1,569,168	–1,761,901	0.47
4	15,030,771	66,869,654	81,900,425	144,006,831	102,912,854	3,033,667	5,334,145	3,811,987	1,522,159	–1,511,508	0.50
5	11,716,899	55,585,658	67,302,557	144,006,831	103,634,456	2,492,949	5,334,145	3,838,716	1,495,430	–997,519	0.60
7	9,046,952	48,796,562	57,843,514	144,006,831	105,213,049	2,142,577	5,334,145	3,897,188	1,436,957	–705,620	0.67
10	5,771,000	32,838,513	38,609,513	144,006,831	109,239,669	1,430,132	5,334,145	4,046,338	1,287,808	–142,324	0.90
12	5,480,095	35,262,351	40,742,446	144,006,831	110,365,051	1,509,138	5,334,145	4,088,023	1,246,122	–263,015	0.83
15	4,258,940	29,610,978	33,869,918	144,006,831	112,619,297	1,254,573	5,334,145	4,171,522	1,162,623	–91,950	0.93
20	3,145,493	23,273,952	26,419,445	144,006,831	119,693,419	978,601	5,334,145	4,433,554	900,591	–78,009	0.92

5.0 OPTIMIZATION OF FINAL REACHES

In an attempt to best validate and optimize the engineering assumptions for the Beach-fx runs, several discussions were held with subject matter experts, both within the U.S. Army Corps of Engineers (USACE) and from the private sector. The outcome of those discussions led the Project Delivery Team (PDT) to consider altering settings related to depth of closure.

Within Beach-fx, these two values dictate how nourishment material is placed, as well as how much material is eroded due to sea level change. The depth of closure and width of active profile were originally specified as 30 and 4,000 feet, respectively. These values were updated to 23 and 3,000 feet. A depth of closure of 23 feet was selected to be consistent with the depth of closure implemented in the volume calculations. Furthermore, Wave Information Studies (WIS) data at the South Padre Island indicate a depth of closure of 19 to 23 feet. The width of active profile was determined from the submerged profile data based on the updated depth of closure.

Whereas the updated depth of closure and width of active profile resulted in negligible changes to the Future Without-Project (FWOP) conditions, the Future With-Project (FWP) conditions saw more significant changes.

Renourishment cycles of 5, 10, and 15 years were resimulated, and the results are shown in Table 5-1. It can be seen that the BCR and net benefits resulting from the new depth of closure increase regardless of the renourishment interval. Additionally, it can be seen that there is little variation in the FWP damages, but that the change in BCR and net benefits are caused by a reduction in project costs. The larger variation between the FWP costs are attributed to the decreased depth of closure. Within Beach-fx, the volume (and costs) are proportionately related to the depth of closure. Therefore, a decreased depth of closure results in a decreased cost. For all three simulations, the resulting BCRs increase between 18 to 20 percent, and the rank ordering of the BCRs are the same as that of the original runs. It is expected that regardless of the plan or renourishment interval selected, the increase in BCR will remain the same (about 20 percent). Consequently, it is not necessary to rerun all of the simulations. Rather, the originally selected TSP remains the selected plan, although there are changes to the economic values.

The recommended plan for the South Padre Island component, based on this analysis would be the 12.5-20-100 template alternative with a 10-year renourishment cycle. The average annual net benefits are $82,614, with a BCR of 1.07.

Table 5-1
Cost, Damages Reduced, and Net Benefits for Nourishment of Reaches 3 and 4, Alternative 12.5_20_100 with Varying Nourishment Cycles (2.75% Discount Rate, 50-Year Period of Analysis, 300 Iterations), 23-foot depth of closure

	Reaches 3, 4, Alternative 12.5_20_100, 23-foot depth of closure										
Nourishment Cycle (Yearly Interval)	Average of Present Value Planned Mobilization Cost	Average of Present Value Planned Placement Cost	Present Value Total Cost	Average of Present Value Without-Project Damages	Average of Present Value With-Project Damages	Annual Average Cost	Annual Average Without-Project Damages	Annual Average With-Project Damages	Annual Average Benefits	Net Benefits	Benefit to Cost Ratio
5	$11,718,029	44,211,660	55,929,689	144,200,580	103,874,211	2,071,687	5,341,322	3,847,596	1,493,726	–577,961	0.72
10	5,778,624	26,693,957	32,472,581	144,200,580	109,497,650	1,202,814	5,341,322	4,055,894	1,285,428	82,614	1.07
15	4,258,940	24,353,178	28,612,118	144,200,580	112,973,620	1,059,819	5,341,322	4,184,647	1,156,675	96,856	1.00

6.0 RECREATION

The PDT recognizes that the recommend measure is just economically justified, and with refined cost estimates there is the jeopardy of annual costs exceeding annual benefits. However, a primary economic benefit of the South Padre beaches are the recreation benefits they provide. South Padre Island is one of the premier recreation beaches in Texas and receives millions of visitors each year. Given time and budgetary constraints, a survey approach to determine the recreation benefits is not practical. The PDT chose to evaluate benefits using the unit day value (UDV) methods using annual visitations of 750,000, which is the prescribed limit for using the UDV approach. The PDT realizes that this understates the actual visitation on the beach. Given that renourishment under the selected plan will only be applied to reaches 3 and 4, the number of visitations will need to be proportionately applied. The methodology was to first identify the area of the beaches for these areas for the with- and without-project conditions. The difference in the areas would represent the loss of beach, which is directly related to the loss of recreation benefit. The areas, measured in square feet, are presented in Table 6-1. As shown, the loss of beach in Reach 3 is approximately 676,000 square feet, and in Reach 4 approximately 326,000 square feet for a total of approximately 1,002,000 square feet.

Table 6-1
Beach Areas for With and Without-Project Condition

Condition	R1	R2	R3	R4	R5	R6	R6_Park	Total
With-Project Area	2,494,700	3,810,161	4,021,139	1,488,945	1,105,120	863,955	1,253,842	15,037,861
Without-Project Area	2,494,700	3,810,161	3,344,870	1,162,733	1,105,120	863,955	1,253,842	14,035,380
Difference	0	0	676,269	326,212	0	0	0	1,002,481

With the assumption of 750,000 visitors per year, the visitors per square foot of beach in the with-project condition is 750,000/15,037,861 = 0.04987. Give there is a total loss of beach in the without-project condition of 1,002,481, the annual loss in visitors is estimated at 0.04987 x 1,002,418 = 49,998, or approximately 50,000 visitors.

UDV for general recreation for fiscal year 2018 range from $4.05 to $12.15. Applied to the annual loss of visitors, the annual loss of recreation benefits would range from $202,491 to $607,474. For evaluation, the more conservative value will be considered.

6.1 ALTERNATIVE REFINEMENTS

After identifying the 10-year nourishment cycle as the most cost effective plan, quantities were refined, and costs estimated for that plan, including real estate costs. Costs were developed for an initial construction, or the first placement of material, and out-year nourishments every 10th year following. Consistent with costs for other alternatives in the Coastal Texas Protection and Restoration Study (Coastal Texas Study), a low, average, and high cost estimate was developed in order to present a range of costs. The real estate baseline cost identifies the estimated cost associated with the project for the lands, easements, rights-of-ways, relocations, and disposal/borrow areas (LERRD) required for the construction, operation, and maintenance of the proposed project. The cost considers not only the estimated land value but also labor associated with the acquisition process, potential condemnations, required appraisals, surveys, title commitments, and attorney opinions for both Federal and non-Federal Sponsors potential costs. The baseline cost was determined with the assumption that the proposed measure footprint will be adjusted in the future to minimize ownership impacts. The results of the refined costs, real estate costs, and recreation benefits are presented in Table 6-2. As shown, net benefits range from $138,000 using a low cost estimate to –$71,000 with the high cost estimate, with BCRs ranging from 1.10 to 0.95. Although the BCRs are near unity with the existing level of information, the PDT feels that recreation benefits are significantly underestimated. Additional effort spent during final design to more properly capture those benefits using a more detailed survey method should yield considerably larger recreation benefits and generate larger net benefits for the alternative.

Table 6-2
First Costs, Real Estate Costs Recreation Benefits, and Benefit to Cost Ratios
(October 2017 Prices, 50-Year Period of Analysis, 2.75% Interest Rate)

Cost Estimate Level	Initial Construction and Out-Year Nourishment	Real Estate	Initial Construction and Out-Year Nourishment including Real Estate	Average Annual Initial Construction	Average Annual Nourishment	Average Annual Cost	Average Annual Benefits	Recreation Benefits	Net Benefits	Benefit to Cost Ratio
Low Cost	69,011,000	2,565,000	71,576,000	212,299	1,137,728	1,350,027	1,285,428	202,491	137,892	1.10
Average Cost	74,762,000	2,565,000	77,327,000	222,070	1,232,531	1,454,601	1,285,428	202,491	33,318	1.02
High Cost	80,513,000	2,565,000	83,078,000	231,842	1,327,335	1,559,177	1,285,428	202,491	–71,258	0.95

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Attachment

South Padre Island, Texas Coastal Storm Damage Reduction Feasibility Study

Attachment

South Padre Island, Texas
Coastal Storm Damage Reduction Feasibility Study
for the
Coastal Texas Protection and Restoration Study
Integrated Feasibility Report and
Environmental Impact Statement

October 2018

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Acronyms and Abbreviations

AER	Applied Erosion Rate
BCR	benefit-to-cost ratio
BUDM	beneficial use of dredged material
CBI	Conrad Blucher Institute
CDF	cumulative distribution function
CENAP	USACE, North Atlantic Philadelphia District
CHS	Coastal Hazards System
FEMA	Federal Emergency Management Agency
FWOP	Future Without-Project
FWP	Future With-Project
NED	National Economic Development
PDT	Project Development Team
SRD	shore response database
TSP	Tentatively Selected Plan
USACE	U.S. Army Corps of Engineers
WIS	Wave Information Studies

1.0 INTRODUCTION

1.1 STUDY AREA AND HISTORY

Since 1988, dredged material from the Brazos Santiago Pass has been placed either in a nearshore berm, or on the beach at South Padre Island, Texas (Perry, 2017). The U.S. Army Corps of Engineers (USACE) Galveston District has requested a feasibility study of permanent beach nourishment alternatives for South Padre Island. This study requires the identification of a Tentatively Selected Plan (TSP) for coastal flood reduction and focuses on future conditions in the absence of the presently implemented beneficial use project.

The area under consideration spans approximately 5 miles north of the Brazos Santiago Pass (Figure 1-1) and includes the entire area of development for South Padre Island. The island is vulnerable to coastal erosion, ocean-side inundation, and direct wave impact. The project alternatives analyzed considered beach renourishment as a sacrificial solution to reduce the damages produced by these three damage-driving parameters.

Figure 1-1: South Padre Island

1.2 BEACH-FX MODEL

The planning model Beach-fx was used to analyze both the future without-project (FWOP) conditions and planned nourishment alternatives. Beach-fx is an engineering economic model that implements Monte-Carlo methods to quantify the uncertainty associated with future beach renourishment projects (Gravens et al., 2007). The model is event-driven and provides estimates of storm damages along coastal zones. Beach-fx simulates the condition of a beach profile, as it evolves due to storms and background erosion. Typical Beach-fx simulations include 100–300 lifecycles, each with a unique sequence and number of storm events. Across all lifecycles, the model returns average historically observed rates (number and frequency of storm events, shoreline erosion, etc.).

Input to Beach-fx includes meteorology, coastal morphology, economics, and planning processes. A simplified model architecture of Beach-fx can be seen on Figure 1-2. Beach-fx is a data-driven model in that it relies on relational databases that are accessed at runtime. The input database contains information that defines the study area and includes initial conditions, plausible storm events, storm occurrence rates, and damageable elements. The output database stores various model simulation statistics and output.

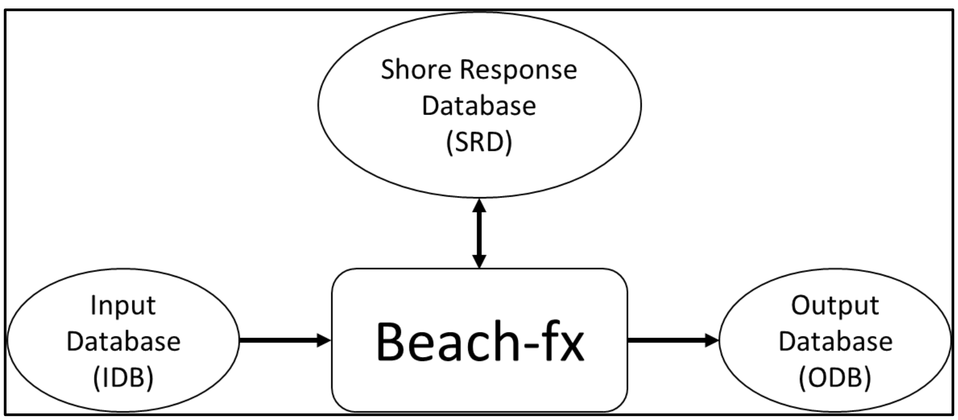

Figure 1-2: Simplified Beach-fx Computational Architecture

Within Beach-fx, no profile response computations are performed at runtime. Rather, the shore response database (SRD) is populated externally and contains the profile responses to storm events as well as cross-shore profiles of damage driving parameters (inundation, erosion, and waves). At runtime, the SRD serves as a lookup table providing post-storm profile information and cross-shore profiles of damage drivers for each pre-storm profile and storm event.

1.3 APPENDIX OVERVIEW

The purpose of this Appendix is to describe in detail the input employed in the application of Beach-fx to South Padre Island, as well as the results of the model runs. This appendix is divided into seven subsequent sections detailing the environmental/meteorological forcing, beach profile analysis, population of the Beach-fx SRD, calibration of Beach-fx and model assumptions, FWOP model runs, and future with-project (FWP) model runs.

2.0 ENVIRONMENTAL FORCING

This section provides details into the development of environmental forcing for South Padre Island. Within Beach-fx, a representative storm suite (consisting of storm surge hydrographs and coincident wave information), and storm seasons describe the environmental forcing for the area under consideration. The representative storm suite was used to populate the SRD.

2.1 PROBABILISTIC STORM DATABASE

A comprehensive suite of synthetic tropical storm surge hydrographs spanning the entire probabilistic space was previously developed through the application of high fidelity numerical models for hydrodynamics (ADCIRC; Hench, 1994) and waves (STWAVE; Massey et al., 2011) in support of the Federal Emergency Management Agency's (FEMA) Flood Insurance Study: Coastal Counties, Texas (USACE, 2011). The numerically generated storm surge hydrographs resulting from this study are stored in the Coastal Hazards System (CHS; https://chs.erdc.dren.mil) at over 4,000 save points. Each of the 446 plausible tropical storms have been assigned spatially dependent relative probabilities of occurrence based on the storm characteristics and intensities (Melby et al., 2015).

2.2 IDENTIFICATION OF A SAVE POINT

Because there are multiple save points near South Padre Island, a single one was selected to provide environmental forcing for Beach-fx. The selection of a save point considered both the water depth and spatial location. Because the seaward boundary in SBEACH (storm response model used for this study; Larson et al. (1990) is near the depth of closure, the save point must be located in a similar water depth (approximately 30 feet [9 meters].). Likewise, the ideal save point is spatially located near the center of the entire study area. In the CHS there were approximately 15 save points that were available for consideration on the oceanside of South Padre Island. The save points were first filtered based on the water depth and then the location. ADCIRC Station 86 (Figure 2-1) met the water depth criteria at

Figure 2-1: Location of ADCIRC Save Point 86

approximately 35.7 feet. Although Station 86 is near the northern end of the study domain, it was deemed appropriate because deviations in the storm surge hydrograph time series are not expected to be significant between the location of the save point and the center of the study area (about 3 miles).

2.3 IDENTIFICATION OF REPRESENTATIVE STORMS

At each save point, there are 446 unique storm surge hydrographs and coincident significant wave height time series corresponding to each synthetic tropical storm event. It is not feasible to populate the shore response database in Beach-fx using all available storms, therefore a representative storm suite was developed (Gravens and Sanderson, 2017). Because storms possess locational characteristics, the storm suite was first reduced based on storms whose storm track fell within a 200-kilometer radius of the project site (Figure 2-2). Use of a 200-kilometer radius is consistent with the methodology used to generate the storm recurrence rates (Melby, 2015). This step reduced the storms under consideration from 446 to 286.

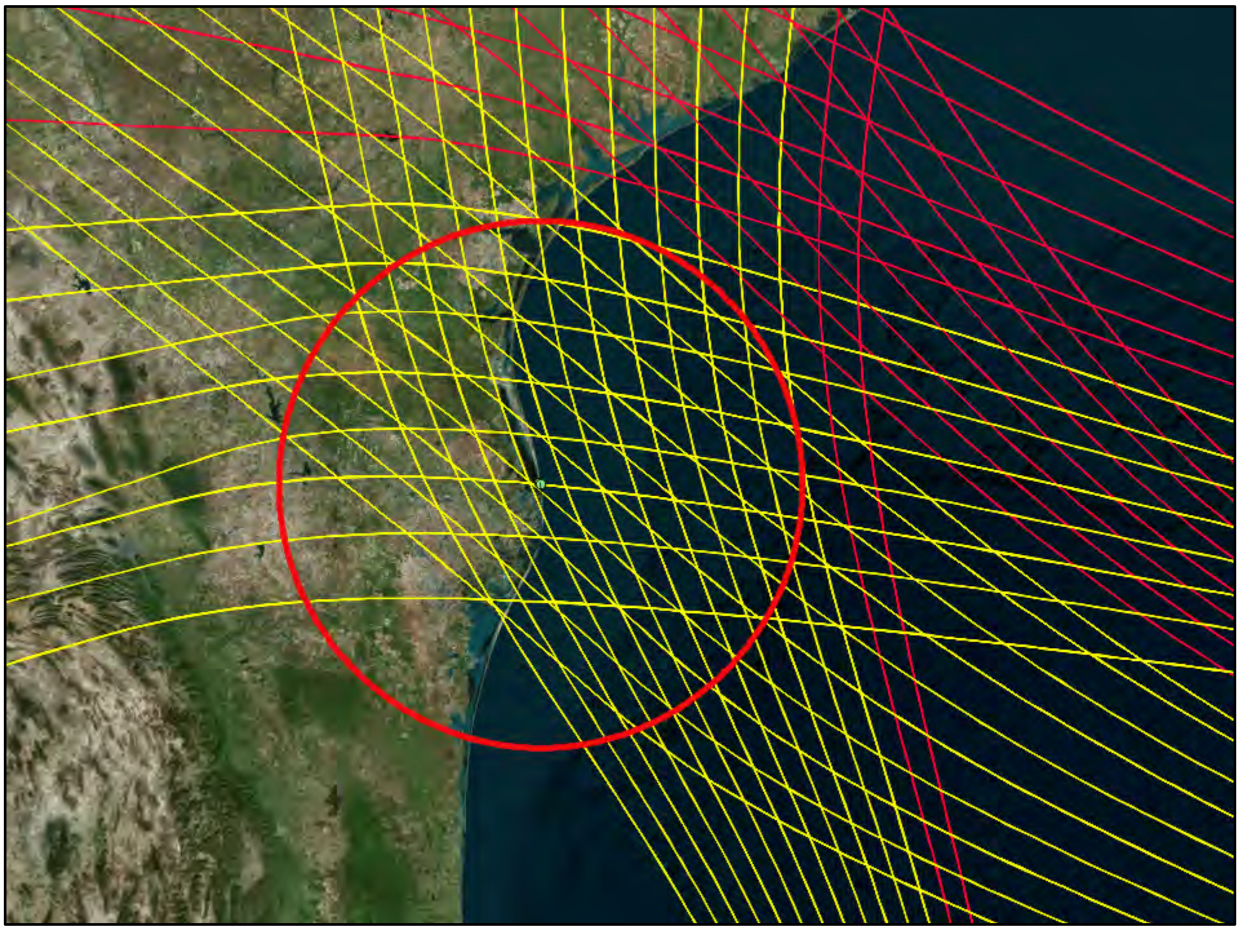

Figure 2-2: Selection of Storms within 200-kilometer Radius
(yellow storm tracks are those that pass within a 200-kilometer radius)

The remaining 286 storms were classified based on the peak surge (ranging from approximately 0.5–3.5 meters) and grouped into 12 clusters (Table 1). The lower and upper cluster ranges were defined such that there were a similar number of storms in each cluster. If the range of peak values that each cluster is composed of had equal spacing throughout, the number of storms in each cluster would have resulted in a significantly uneven distribution. For example, comparing the number of storms in range 0.5 to 1.0 meters vs. 3.0 to 3.5 meters results in 112 storms versus 7 storms, respectively. The spacing seen in Table 2-1 results in the cluster with the largest amount of storms containing 42 storms and the smallest cluster containing 7 storms.

Table 2-1
Cluster (Greater than or equal to lower value)

Cluster Number	Cluster Spacing (meters)	Range of Peak Values (meters)	Number of Storms
1	0.2	0.5–0.7	15
2	0.1	0.7–0.8	28
3		0.8–0.9	42
4		0.9–1.0	27
5		1.0–1.1	33
6	0.2	1.1–1.3	35
7		1.3–1.5	24
8	0.25	1.5–1.75	22
9		1.75–2.0	20
10	0.5	2.0–2.5	16
11		2.5–3.0	17
12		3.0–3.5	7

The storms contained within each cluster were subsequently aligned at the peak surge and plotted together. When selecting representative storms, the goal was to identify a single storm in each cluster that has a peak surge near the mean of the cluster's range and possesses an average storm duration. Of the 12 clusters, there were 8 in which this was possible. Figure 2-3 shows an example of a representative storm.

The remaining four clusters were not representable by a single storm, and consequently, these storms were divided into sub-clusters. From the sub-clusters two representative storms could be identified. Three of the remaining four clusters had notable long and short duration storms (example of selection shown on Figure 2-4). In Cluster 11, a single representative storm could not be identified, nor could short and long duration storms, thus, storms with small and high amplitudes were selected (Figure 2-5). The identification of clusters and subsequent storms used to represent each (sub-) cluster resulted in 16 representative storm events.

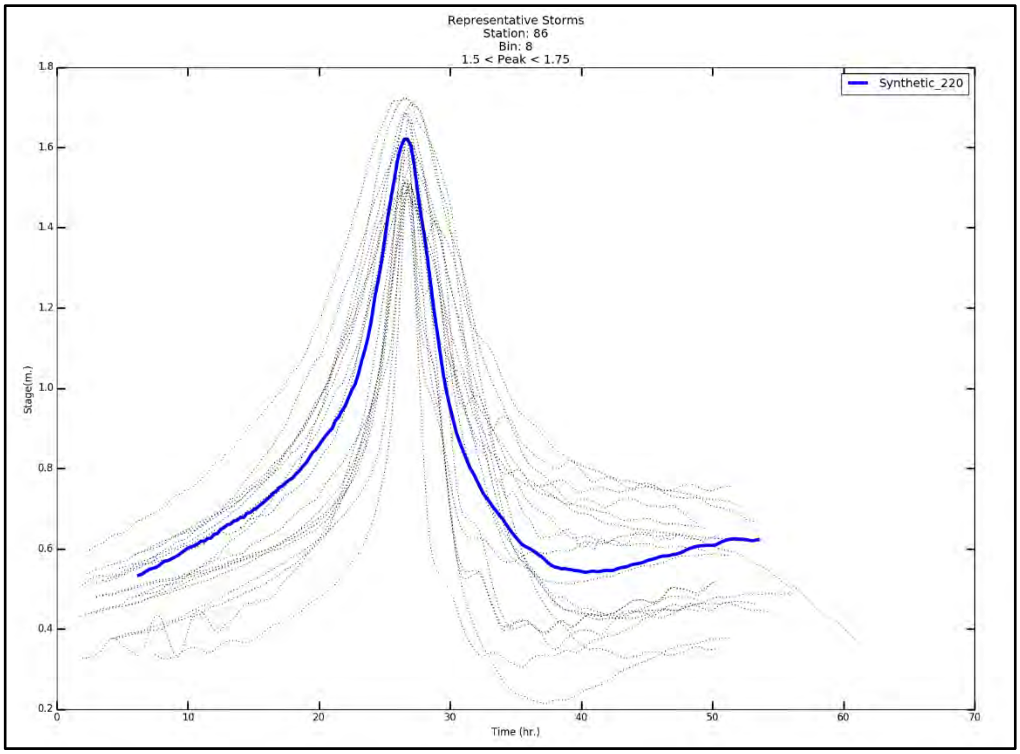

Figure 2-3: Single Representative Storm for Cluster 8

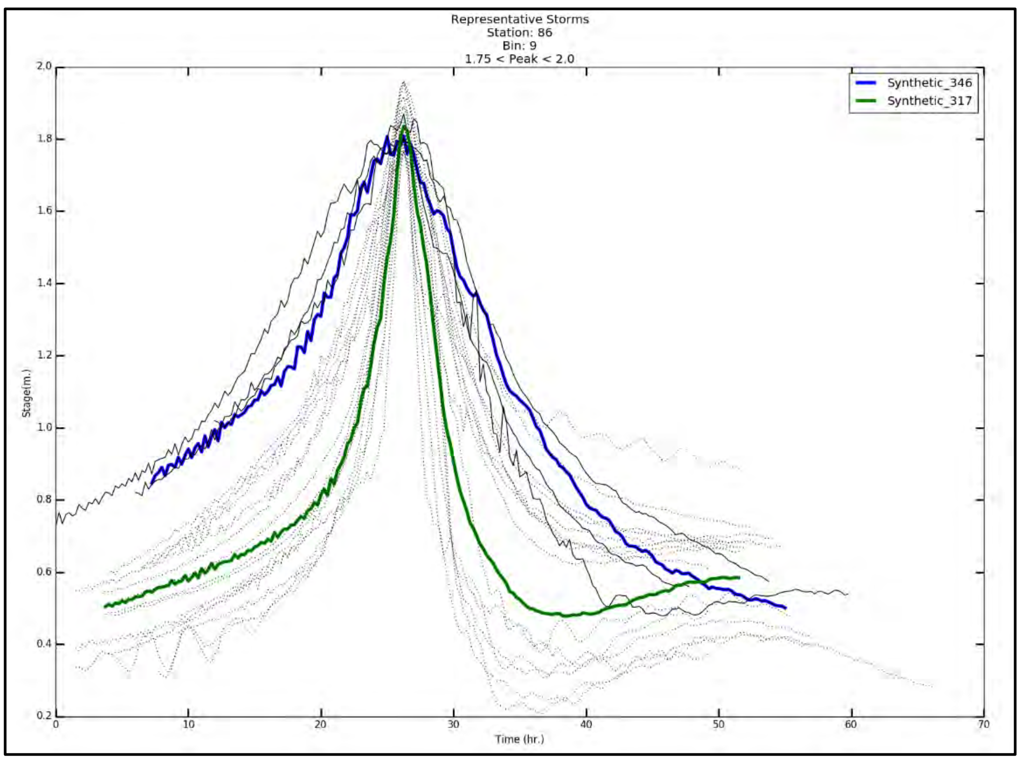

Figure 2-4: Two Representative Storms for Cluster 9 (Short and Long)

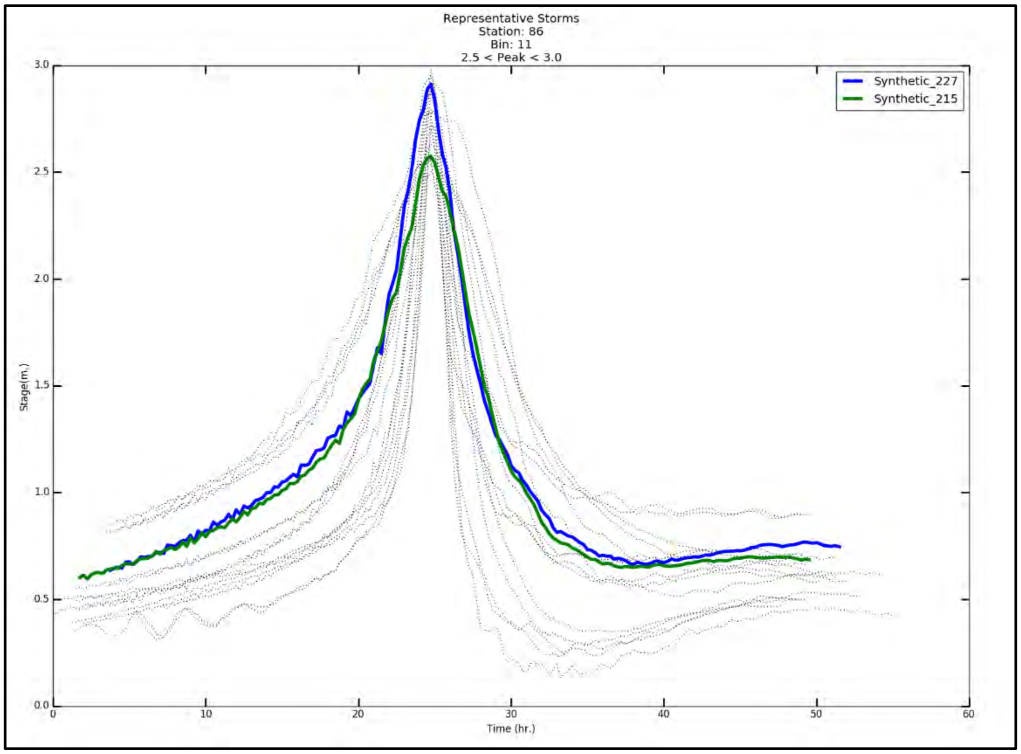

Figure 2-5: Two Representative Storms for Cluster 11 (Short and Tall)

Each representative storm was assigned a relative probability that facilitates the storm selection process in Beach-fx. The probabilities assigned to each storm event dictate how often one storm event is selected relative to other storms. As a part of the FEMA study, each storm was allocated an individual probability of occurrence that is dependent on the storm characteristics and intensities. Each of the selected 16 representative storms were assigned a relative probability that is the sum of the probabilities that the storm represents (Table 2-2). For example, storm 133 represents the 15 storms in Cluster 1, therefore, the relative probability of the representative storm of Cluster 1 is the sum of the 15 storms represented.

Each of the selected representative storms have associated significant wave height time series that were generated as a part of the FEMA study. The 16 surge and wave time series associated with the representative storms were used as input to the shore response model SBEACH.

Table 2-2
Representative Storms and Relative Probabilities

Bin	Storm	Number of Storms Represented	Probability
1	133	15	0.0889
2	131	28	0.0857
3	238	42	0.1819
4 – long	282	22	0.0953
4 – short	470	5	0.0207
5	229	33	0.1230
6	279	35	0.1391
7 – long	230	15	0.0715
7 – short	447	9	0.0202
8	220	22	0.0560
9 – long	346	4	0.0181
9 – short	317	16	0.0443
10	214	16	0.0295
11 – high	227	9	0.0028
11 – small	215	8	0.0222
12	218	7	0.0008

2.4 TIDE ANALYSIS

Within Beach-fx, tides are represented by three statistically defined cosine tides (low, medium, and high amplitude) combined at four variations in phase shifts with the storm surge hydrograph peaks (high tide, mid-tide falling, low tide, and mid-tide rising). A discrete 19-year long equilibrium tidal record at South Padre Island was generated. The tidal record did not exceed ±0.46 meter (about1.5 feet). From the discrete time series, a cumulative distribution function (CDF) was created, ranging from –0.46 to +0.46 meter with increments of 0.00025 meter. The probability of the tide having a value that fell within each bin was computed, and the CDF generated (Figure 2-6).

From the CDF, only the upper and lower quartiles were considered because it is assumed that regardless of the tide amplitude (high, medium, or low), all tides pass through the middle 50 percent (Figure 2-7). Furthermore, the upper and lower quartiles were each divided into an upper quartile, middle half, and lower quartile. The tide values associated with the midpoint of each of these ranges were identified (Figure 2-8). These are the tide values associated with the cumulative probabilities of 0.03125, 0.125, 0.21875, 0.78125, 0.875, and 0.96875.

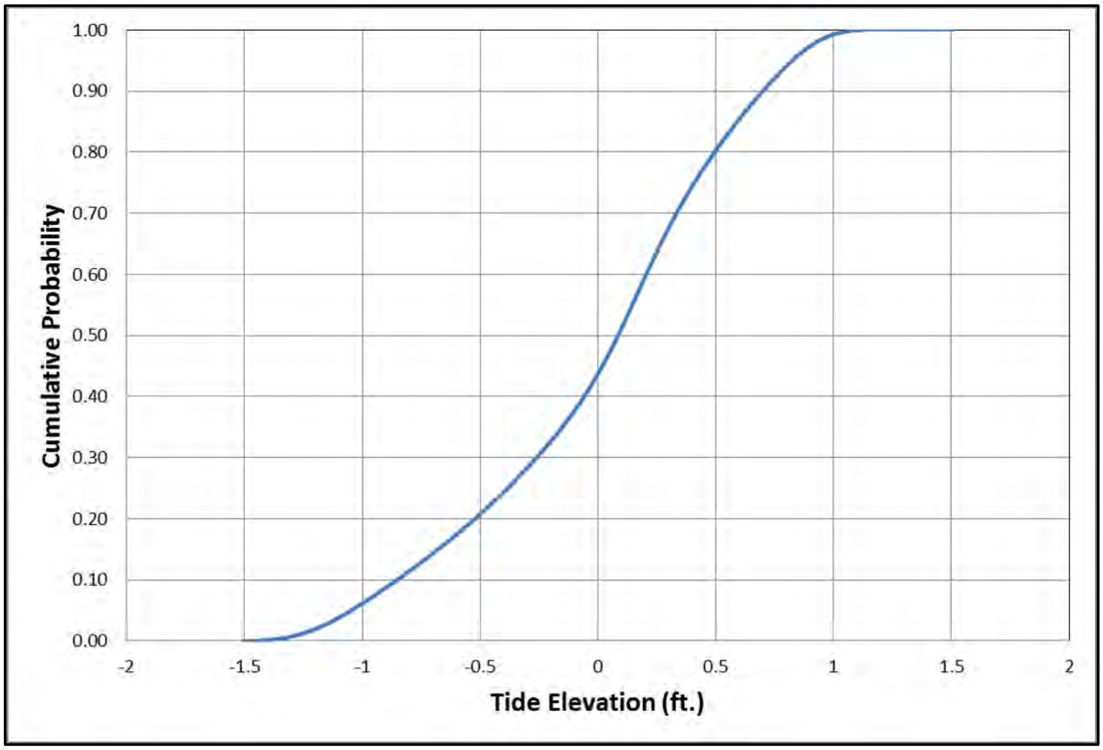

Figure 2-6: Tidal CDF

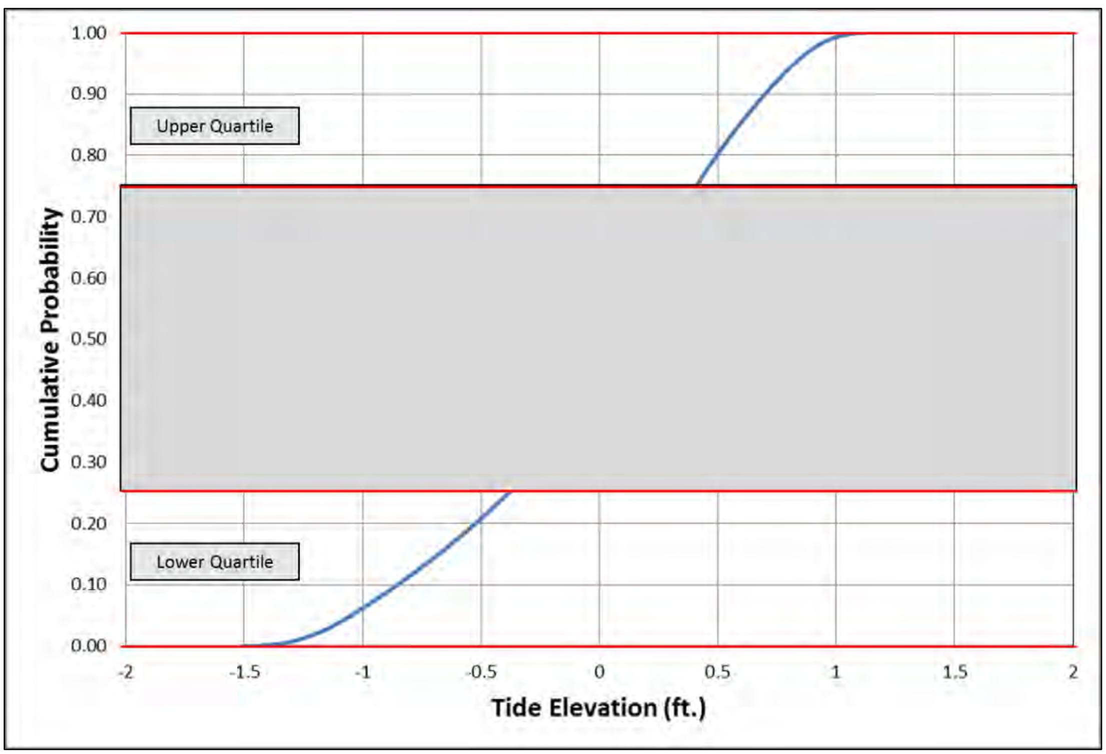

Figure 2-7: Upper and Lower Quartile

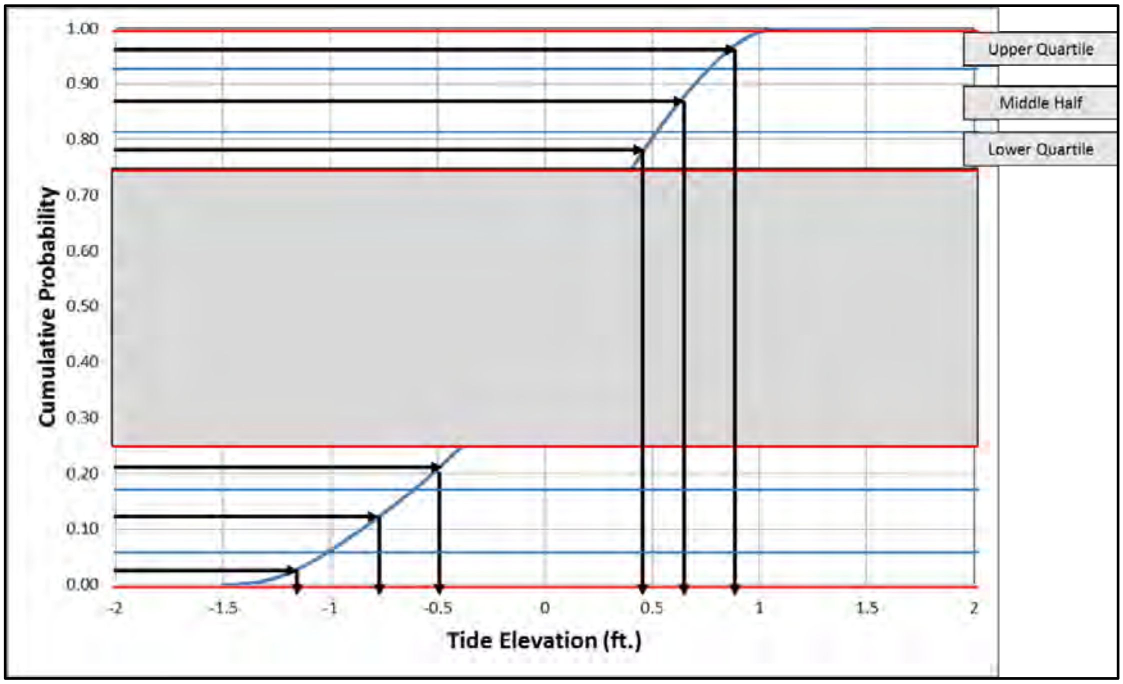

Figure 2-8: Identification of Tide Elevations

The tide ranges were then computed as the difference between the high, medium, and low values. The idealized cosine approximations are then centered about zero. The results from this process are shown in Table 2-3.

Table 2-3
Results from Tidal Analysis

Tide	CDF Lower Bound	CDF Upper Bound	CDF Midpoint	Elevation (feet)	Cosine Approximations (feet)
HL	0	0.0625	0.03125	–1.15037	–1.027
ML	0.0625	0.1875	0.1250	–0.76710	–0.707
LL	0.1875	0.2500	0.21875	–0.46889	–0.466
M	0.2500	0.7500	-	-	-
LH	0.7500	0.8125	0.78125	0.462482	0.466
MH	0.8125	0.9372	0.87500	0.647435	0.707
HH	0.9375	1.000	0.96875	0.902695	1.027

From the idealized cosine approximations, three diurnal tides were developed and combined with each storm surge hydrograph. The tides underwent a phase shift such that the peak surge of the hydrograph aligned with each tide at high tide, mid-tide falling, low tide, and mid-tide rising (Figure 2-9). The combination of the three tidal ranges at the four phase shifts resulted in 12 possible total water elevations for each storm (192 total water elevations).

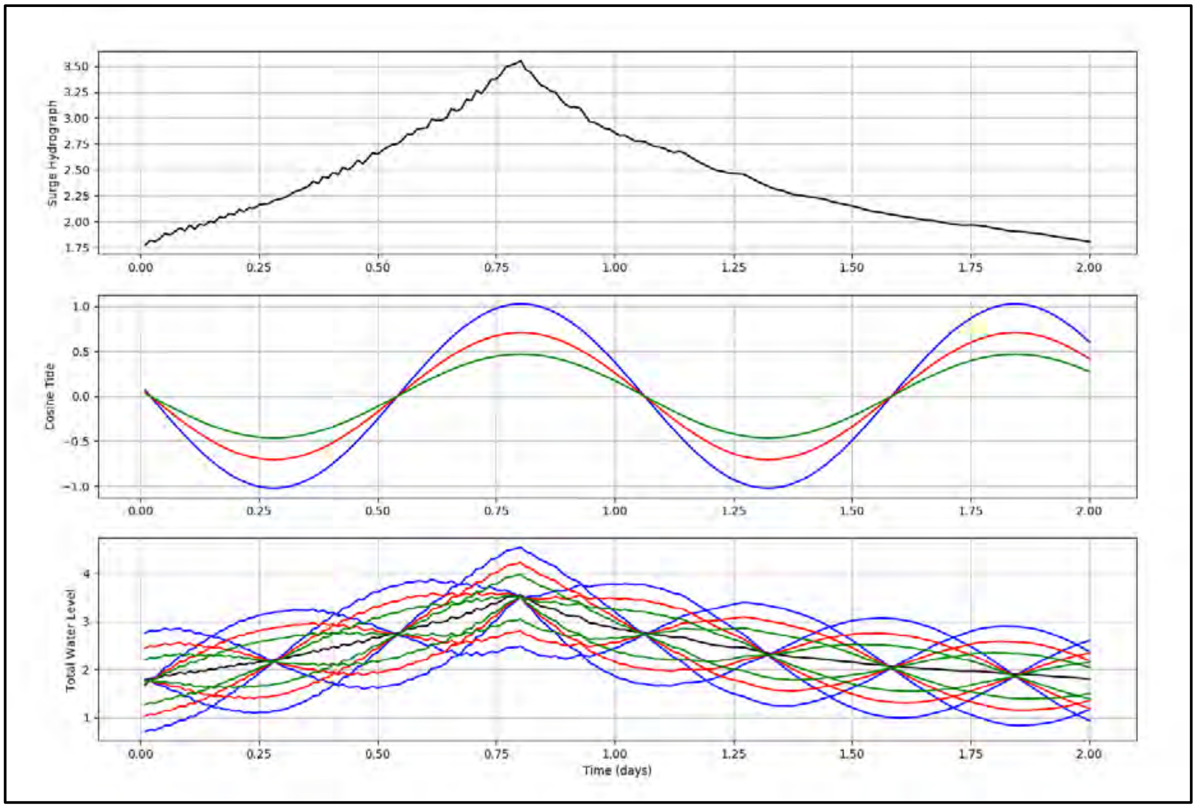

Figure 2-9: Combining Storm Surge Hydrograph with Idealized Tides

Because the spring-neap tide cycle follows a harmonic pattern (e.g., low, medium, high, medium, low, etc.), then the probability of a total water elevation that was combined with a medium amplitude tide is twice that of the low and high counterparts. Each of the total water elevation's relative probabilities were updated to reflect this cyclical behavior. Table 2-4 shows an example of storm 229's updated relative probabilities.

Table 2-4
Total Water Elevation Relative Probabilities

Storm 229	Original Relative Probability: 0.1230	
Tide Amplitude	Phase Shift	Relative Probability
High	High Tide	0.007688
High	Mid-tide Falling	0.007688
High	Low Tide	0.007688
High	Mid-Tide Rising	0.007688
Medium	High Tide	0.015375
Medium	Mid-tide Falling	0.015375
Medium	Low Tide	0.015375
Medium	Mid-Tide Rising	0.015375
Low	High Tide	0.007688
Low	Mid-tide Falling	0.007688
Low	Low Tide	0.007688
Low	Mid-Tide Rising	0.007688

2.5 STORM SEASONS

Whereas each storm's assigned relative probability determines when storms are sampled relative to each other, storm seasons in Beach-fx dictate how often storm events occur. Storm seasons for South Padre Island were specified on a monthly basis using the storm rates available on the CHS, and the distribution of storm occurrence published in the NACCS report (Cialone et al., 2015). The monthly rates of occurrence are as follows: June – 0.04, July – 0.04, August – 0.26, September – 0.48, October – 0.12, and November – 0.06. The storm occurrence rates in the CHS are available as both high- and low-intensity storm rates and are defined as storms/year/kilometer. The storm rates were summed and multiplied by the diameter of the area under consideration (in this case 400 kilometers). The storm occurrence rate was then multiplied by the monthly weights to determine the monthly occurrence rates, or storm seasons (Table 2-5).

Table 2-5
Storm Seasons

High Intensity Storm Rate (storms/year/km)	1.36E-04	Storm Occurrence Rate (storms/year)	0.1512
Low Intensity Storm Rate (storms/year/km)	2.42E-04		
Month	Distribution	Storm Season Probability	
June	0.04	0.006048	
July	0.04	0.006048	
August	0.26	0.039312	
September	0.48	0.072576	
October	0.12	0.018144	
November	0.06	0.009072	

2.6 SEA LEVEL RISE

Within Beach-fx, sea level rise is computed according to ER 1100-2-8162 (USACE, 2013). The tide gauge at Port Isabel, Texas (Gauge 8779770) was chosen to represent the relative sea level change. The sea level change trend at Port Isabel, Texas, is +0.01289 foot/year. Figure 2-10 shows the three possible sea level change scenarios, low, intermediate, and high. All Beach-fx runs were conducted under the intermediate scenario to be consistent with the Texas Coastal Study.

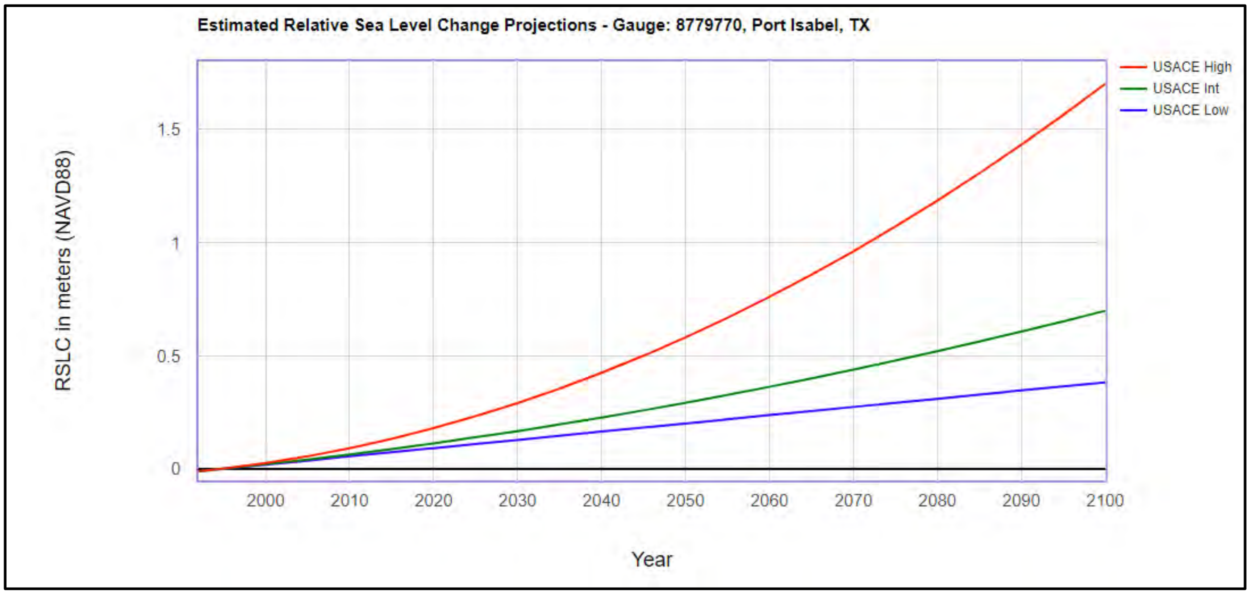

Figure 2-10: Sea Level Change at Port Isabel (Gauge 8779770)

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3.0 BEACH PROFILE ANALYSIS

This section provides details into the development of the idealized existing upper beach profiles and averaged submerged profiles. Combined with the representative storm suite, the idealized profiles were used in the profile response modeling (Section 4).

3.1 LOCATION OF SURVEYS

Beach profile surveys are taken along a single transect that starts from the dry portion of the beach and extends into the water. These surveys result in distance-elevation coordinates that characterize beach conditions such as dunes, berms, and offshore bars.

Beach surveys at South Padre Island were available that spanned 1995 to 2015. The Conrad Blucher Institute (CBI) surveys were available beginning in 1995 and HDR Engineering in 2011. The CBI set up 25 survey reference monuments, starting from the southern end of the island approximately 0.4 mile north of the Brazos Santiago Pass (CBI 1) and spanning nearly 5 miles north, to their final survey reference monument (CBI 25). HDR surveys were available from 2011–2015 and were taken at the 25 CBI monuments, but were expanded approximately 1.4 miles further north than the CBI monuments. Furthermore, HDR surveys were taken at various intervals between the pre-existing CBI monuments. In total, HDR surveys were available at 53 survey locations. HDR survey points were labeled according to their location relative to the jetty at the southern end of the island, spanning from STA 5+00 just north of the jetty to STA 350+00 approximately 6.6 miles north of the jetty. All survey data were provided in North American Vertical Datum 88. The CBI (red) and HDR (cyan) survey start and end locations can be seen on Figure 3-1; all profile transects can be seen on Figure 3-2.

Figure 3-1: Location of Start and End Survey Points

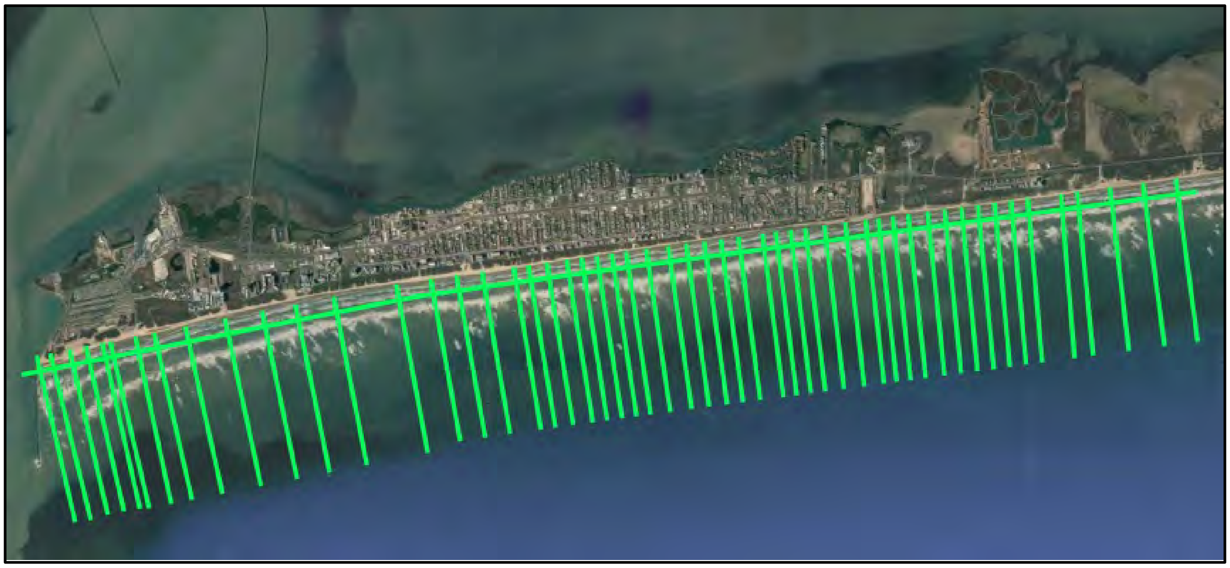

Figure 3-2: All Profile Transects

3.2 GROUPING SIMILAR PROFILES

A Beach-fx study is divided into project reaches that are areas of morphologic similarity. Depending on the beach conditions and the length of a study area, typical Beach-*fx* projects can contain between three and nine reaches. Each reach is represented by a single cross-shore profile and is composed of two segments (upper and submerged profiles).

The upper beach profiles represent the initial project conditions and were developed from the most recent profile surveys available (in this case HDR surveys from 2015). The 53 available surveys were reduced to 6 reaches, each with a unique upper beach profile. The profiles in each reach were aligned at the dune and berm features present and averaged together. The resulting averaged features were then combined to develop the representative upper beach profiles.

The Andy Bowie County Park is present in Reach R6 where there are damageable elements north of the park and none within it. This reach was divided into two sub-reaches, “R6” and “R6_park” (Figure 3-3) such that the distinction is noted. Both R6 and R6_park share the same upper beach and submerged profile, although the division allows for the testing of different planned nourishment alternatives.

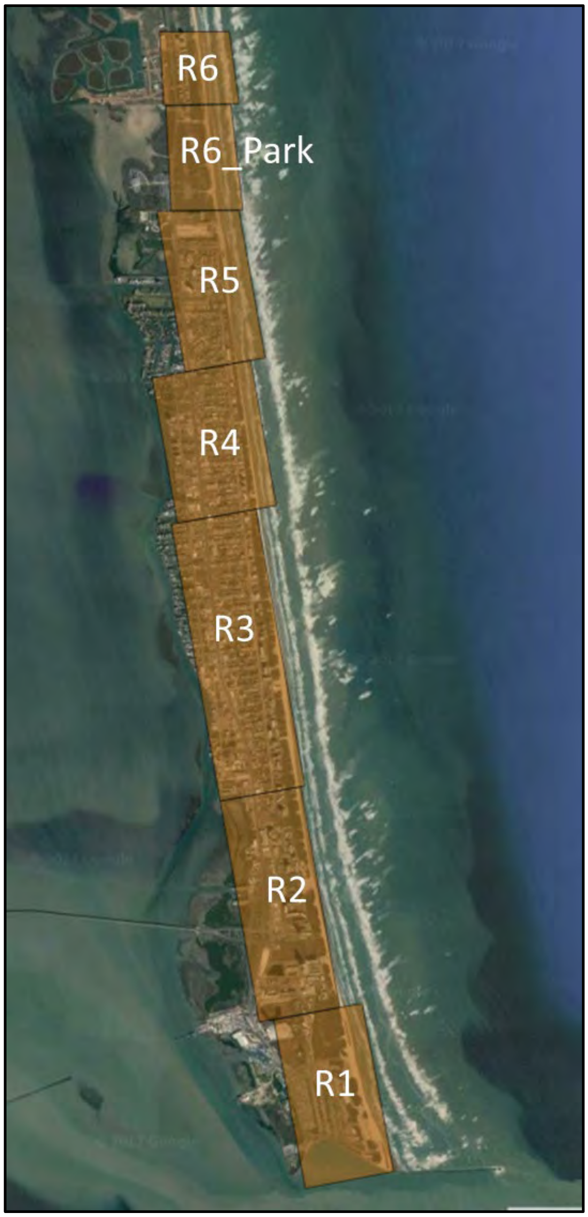

Figure 3-3: South Padre Island Beach-fx Reaches

The submerged profiles were developed from both spatially and temporally averaged surveys to represent the profile at any future date. Through an analysis of the submerged profiles, it was decided that there would be five unique submerged profiles. Reaches 4 and 5 are represented by submerged profile 4. Similar to the upper beach profiles, the submerged profiles were developed by aligning the profiles at key morphologic features (inshore bar, central bar, and if present offshore bar), then averaging. A summary is shown in Table 3-1.

Table 3-1
South Padre Island Beach-fx Reaches

Reach	Station Start	Station End	Reach Distance (feet)	Submerged Profile
R1	STA 5+00	STA 40+84	4,558	1
R2	STA 50+32	STA 95+52	5,946	2
R3	STA 114+57	STA 179+50	7,667	3
R4	STA 183+93	STA 217+83	3,970	4
R5	STA 225+00	STA 256+10	4125	
R6_Park	STA 260+00	STA 290+00	2830	5
R6	STA 290+00	STA 305+00	1950	

3.3 IDEALIZED PROFILES

Beach-fx uses a simplified representation of the beach profile such that key morphological features are defined by single values such as dune height, dune width, berm width, etc. (Figure 3-4). Figures 3-5 to 3-12 show the representative upper beach profiles, as well as the idealized profiles for reaches R1–R6. Each of the idealized profiles were combined with the averaged submerged profiles as outlined in Table 3-1 (Reach R6 and R6_Park share the same upper and submerged profiles). The representative profile for Reach R5 resulted in a double dune feature. It is not possible to model this in Beach-fx, thus, a single, wide dune was identified as the idealized profile.

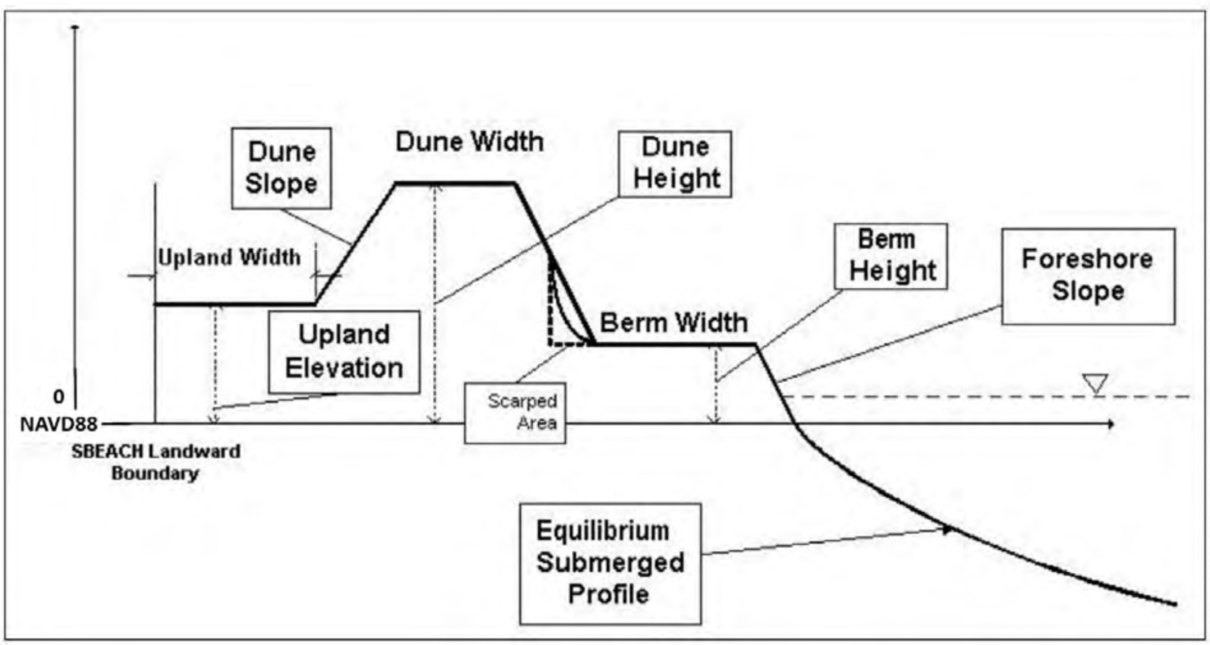

Figure 3-4: Beach-fx Idealized Upper Beach Profile

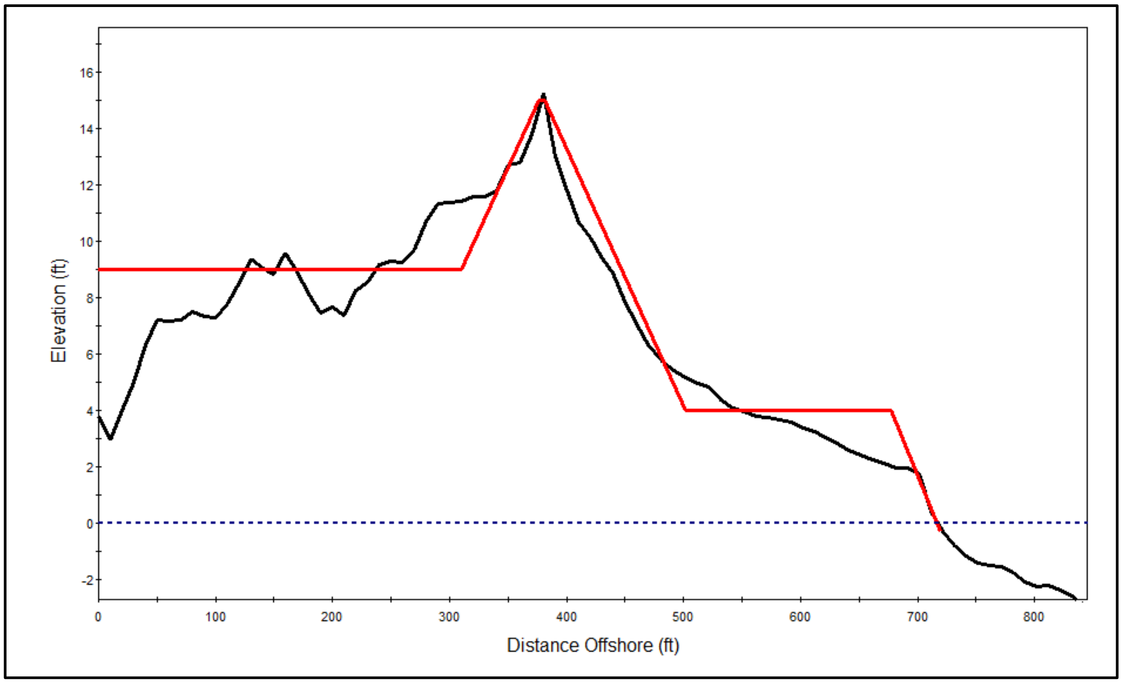

Figure 3-5: Reach R1

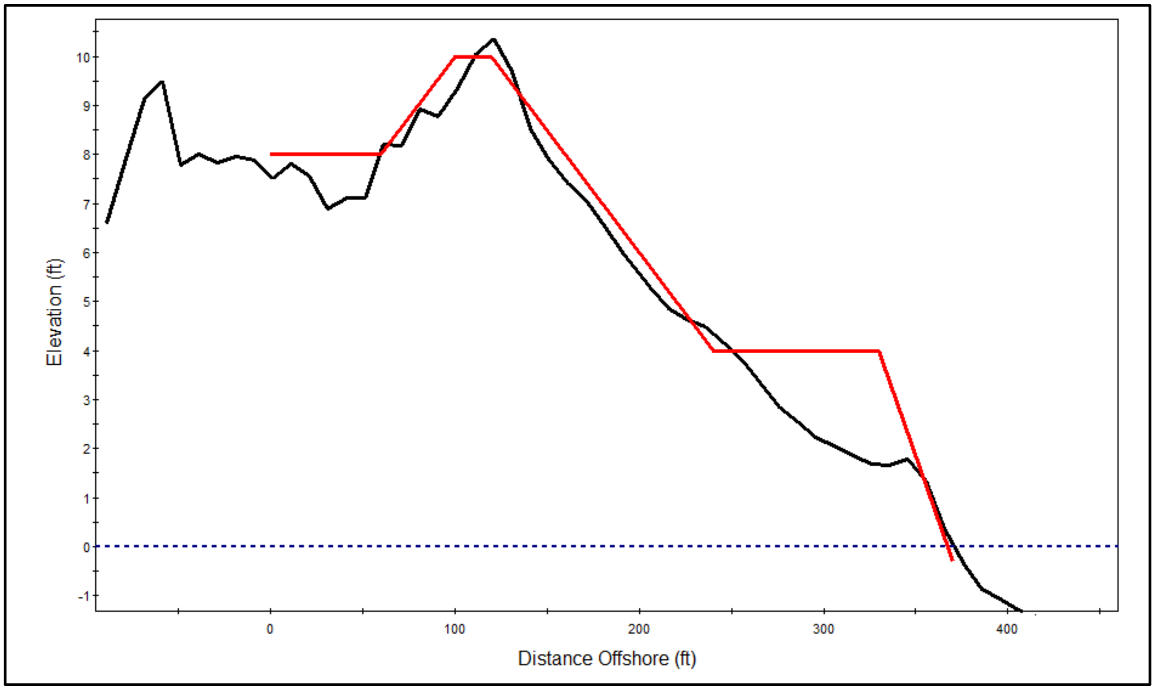

Figure 3-6: Reach R2

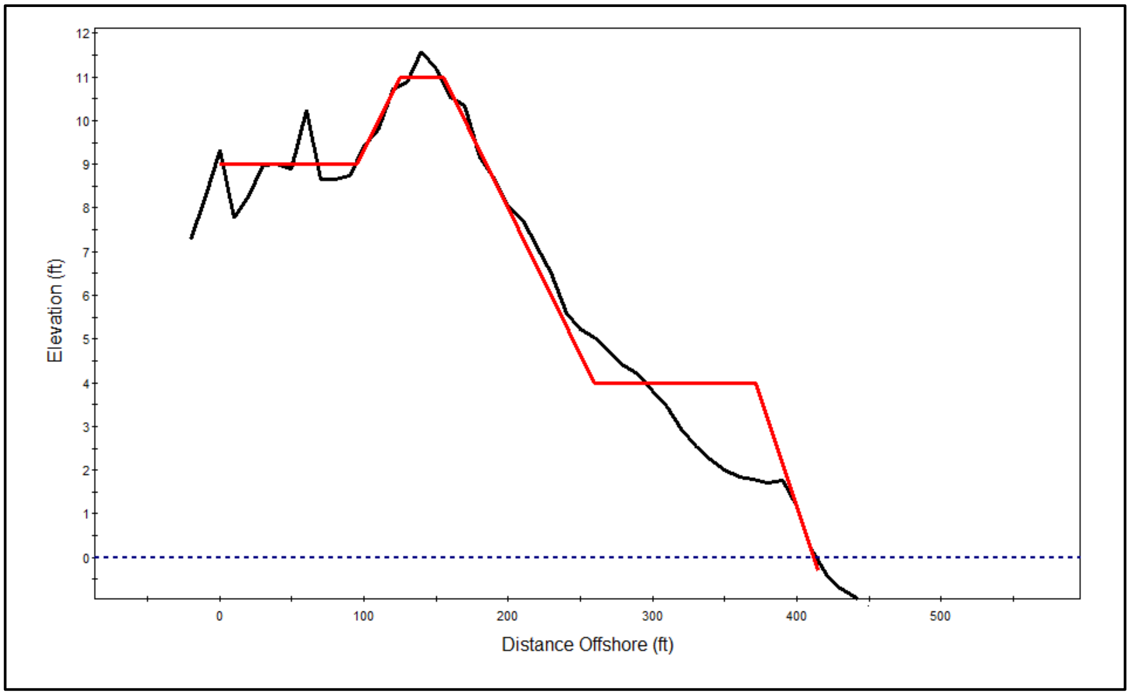

Figure 3-7: Reach R3

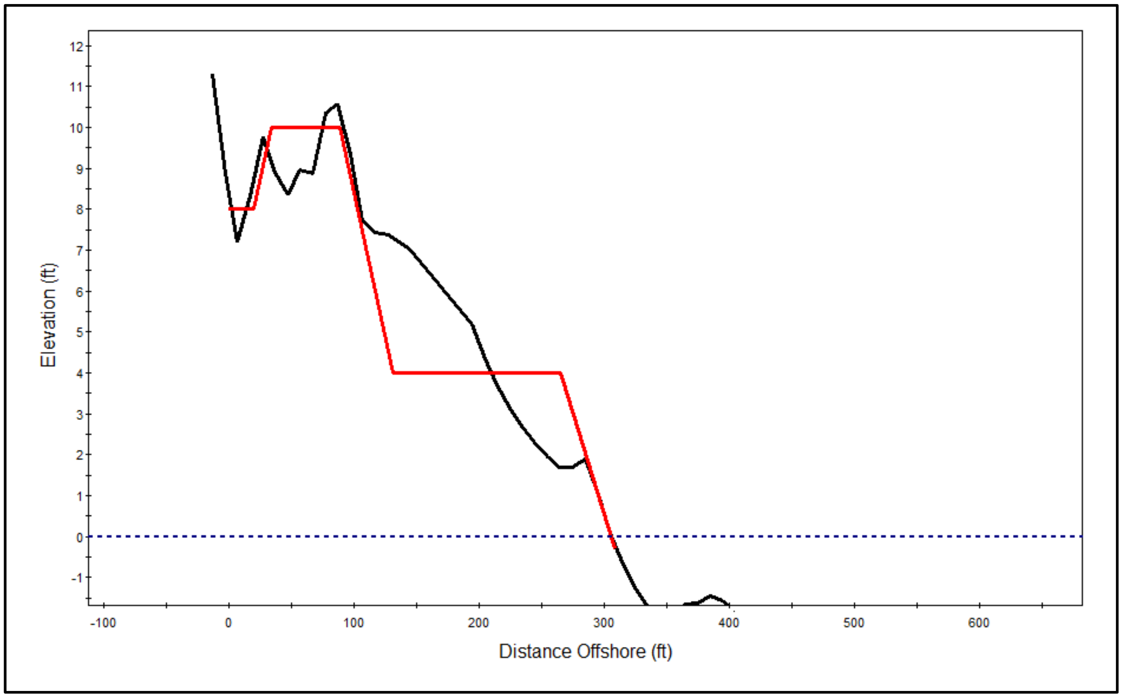

Figure 3-8: Reach R4

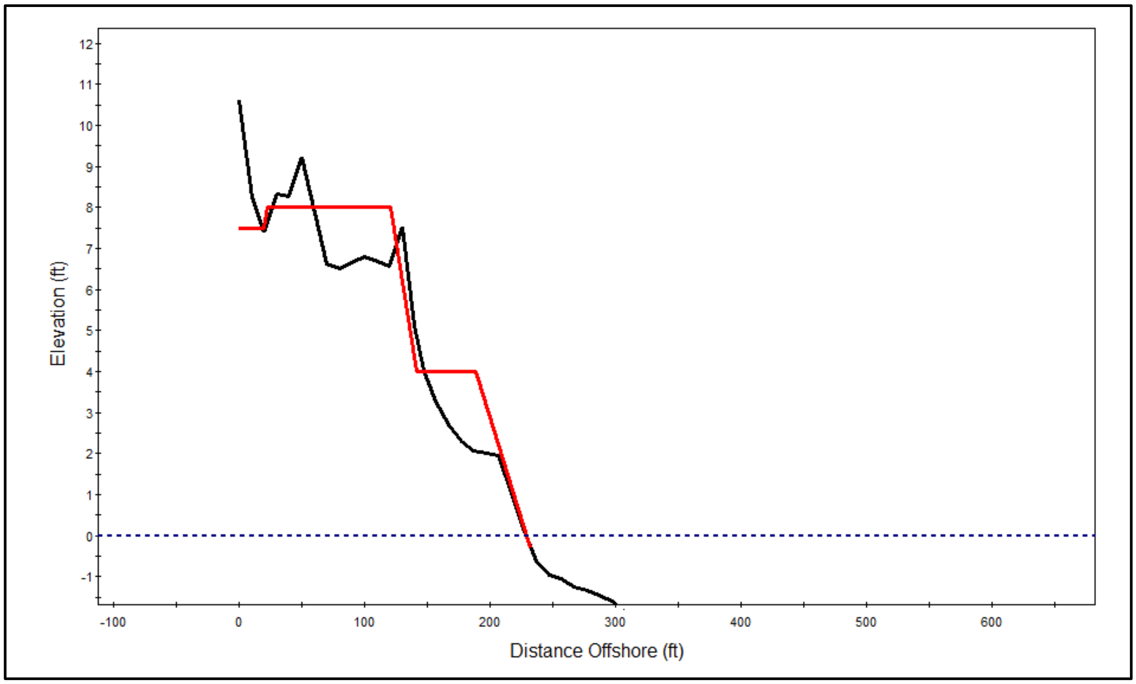

Figure 3-9: Reach R5

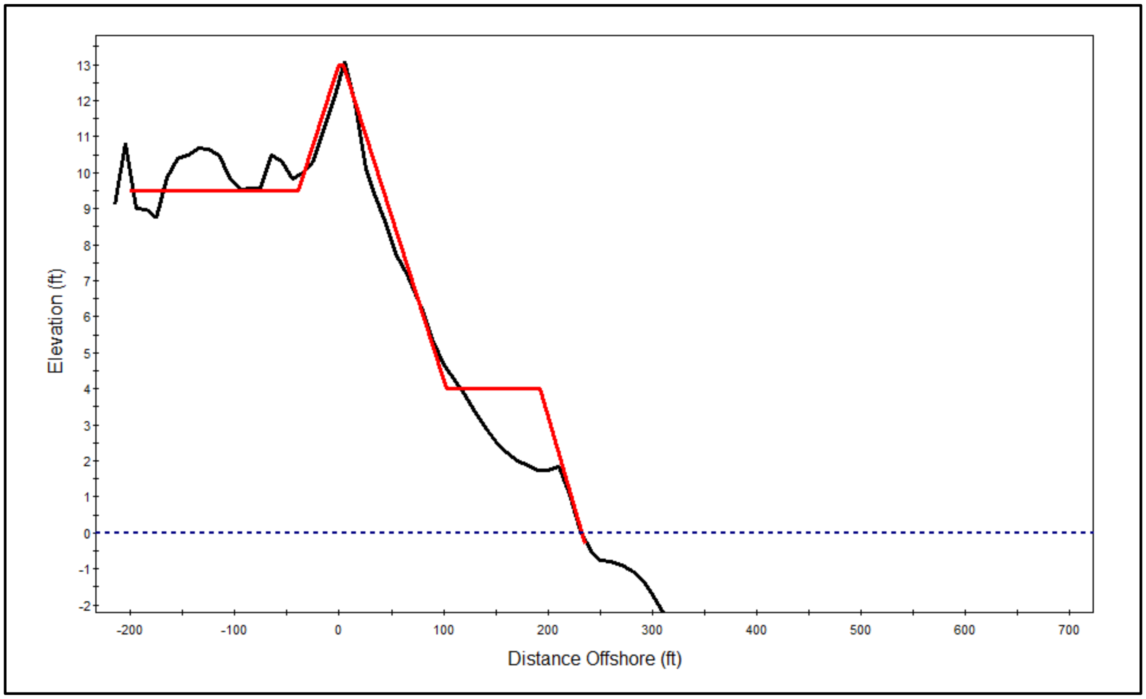

Figure 3-10: Reach R6 and R6_Park

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4.0 PROFILE RESPONSE MODEL RUNS

This section provides details into the SBEACH runs performed to populate the Beach-fx SRD. Because no shore response computations are performed at runtime, and instead the SRD is used as a look-up table, then the SRD must contain all of the profiles that are expected to be encountered over a lifecycle. Maximum beach template conditions were specified, and the profile parameter space was populated between the maximum and minimum possible conditions. The profile parameter space, combined with the plausible storm suite, resulted in over 500,000 SBEACH runs.

4.1 MAXIMUM AND MINIMUM PROFILE CONDITIONS

On South Padre Island, a robust dune system is present north of the project study domain, with an existing dune height of approximately 20 feet. Based on these conditions, South Padre Island's Erosion Response Plan, and discussion with the USACE Galveston District, idealized maximum conditions for the entire project domain were developed (Table 4-1).

Table 4-1
Maximum Dune Conditions

Parameter	Maximum Values
Dune elevation	20 feet
Dune Width	30 feet
Berm Elevation	4 feet
Berm Width	200 feet
Dune Slope	1:4

A 20-foot dune elevation and a 200-foot berm width were chosen based on the existing conditions north of the study domain. A 30-foot dune width was chosen to meet the requirement outlined in South Padre Island's Erosion Response Plan specified as, "the base dune depth should be a minimum of 60 feet, with 100 feet preferable" (Ravella et al., 2012). The existing berm elevation of 4 feet was not increased as a part of the dune template. A dune slope of 1:4 was chosen as being typical for beach renourishment projects. Figures 4-1 to 4-6 show the existing idealized upper beach profiles (blue) along with the proposed maximum conditions for the six reaches in the project domain.

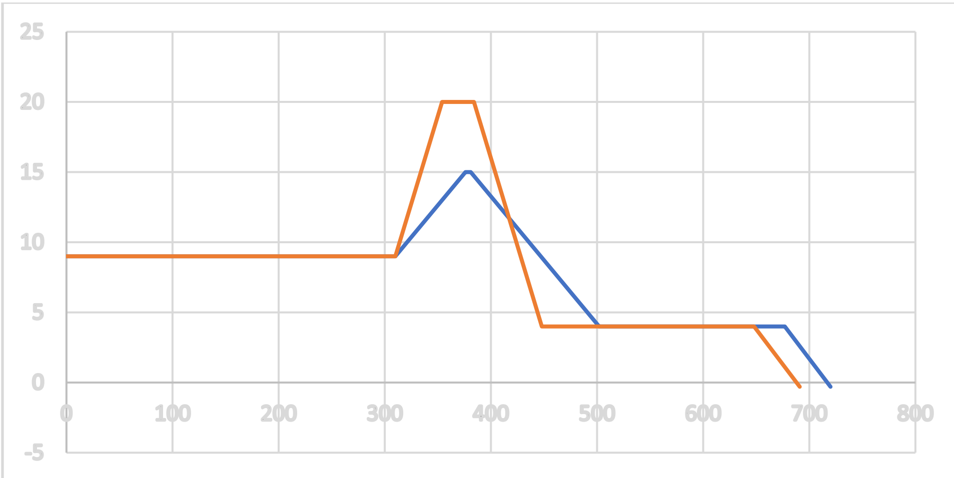

Figure 4-1: Reach 1 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles

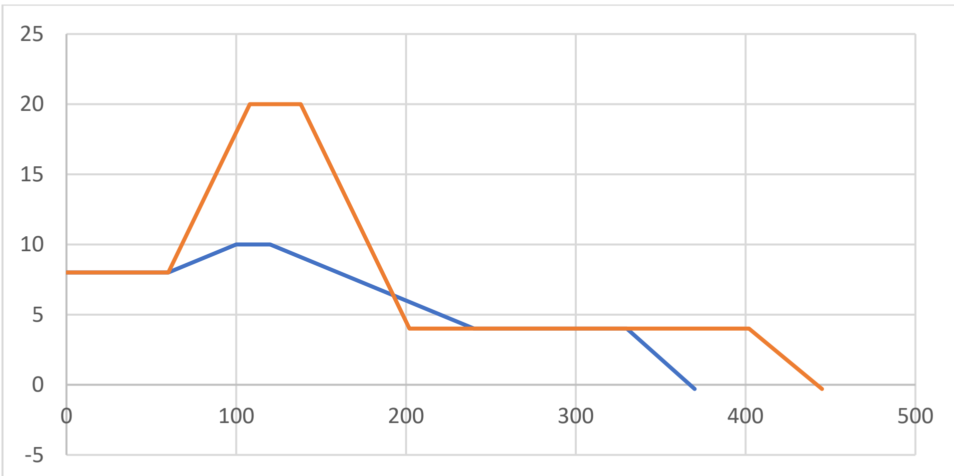

Figure 4-2: Reach 2 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles

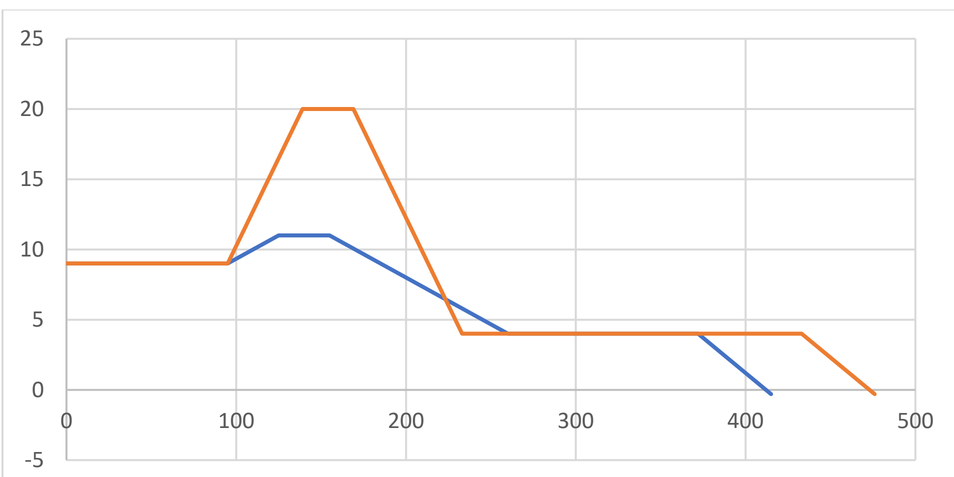

Figure 4-3: Reach 3 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles

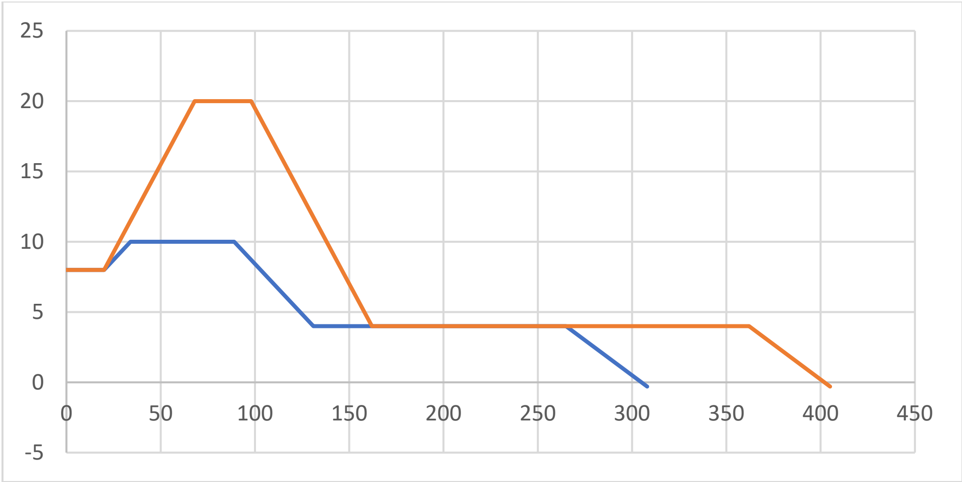

Figure 4-4: Reach 4 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles

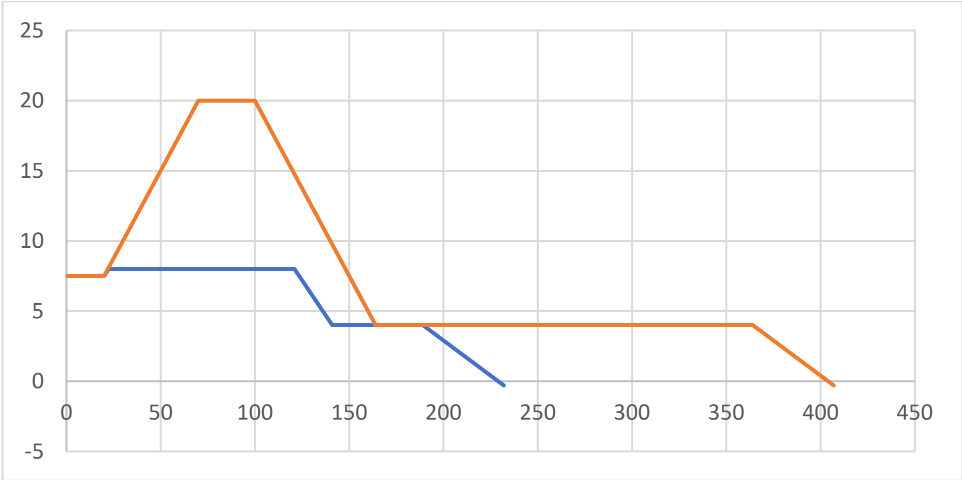

Figure 4-5: Reach 5 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles les

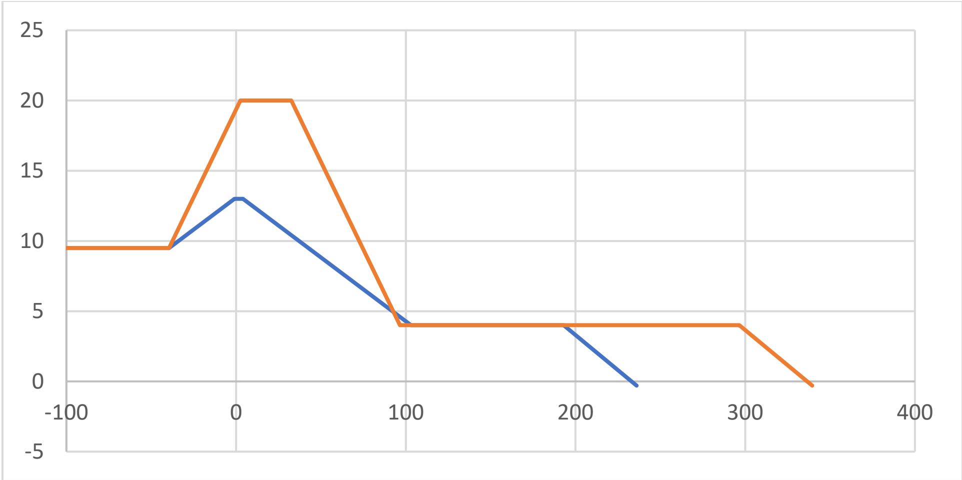

Figure 4-6: Reach 6 Existing Idealized (blue) and Maximum (orange) Upper Beach Profiles

The minimum conditions in the SRD were composed of a beach that has no dune and berm. The minimum dune height was specified as the larger of the upland elevation or the berm elevation (in this case, the upland elevation was used for all reaches, as it is higher than the berm elevation). By incrementally adjusting the dune height (2 feet), dune width (5 feet), and berm width (20 feet) from the maximum conditions to the minimum conditions, the profile parameter space was populated. The resulting number of profiles in each reach are shown in Table 4-2.

Table 4-2
Number of Profile Configurations in Profile Parameter Space

Reach	No. Dune Height Conditions	No. Dune Width Conditions	No. Berm Width Conditions	No. of Profiles
R1	6	7	11	462
R2	7	7	11	539
R3	6	7	11	462
R4	7	7	11	539
R5	7	7	11	539
R6	6	7	11	462
Total				3,003

Any combination of dune height, dune width, and berm width that fell between the maximum and minimum conditions were available to be tested as planned nourishment alternatives.

4.2 SBEACH RUNS

To populate the SRD, the profile response model SBEACH (Larson and Kraus, 1990) was utilized. SBEACH was calibrated, and the final parameter values were determined as shown in Table 4-3. Considering that it is necessary for every profile to have a response to every plausible storm event, a total of 576,576 SBEACH runs were computed (Table 4-4).

Table 4-3
SBEACH Calibration parameters

Parameter	Value Used
Median grain size	0.16 mm
Maximum slope prior to avalanching	20 degrees
Transport rate coefficient, K	1.50E-06 (m^4/N)
Overwash transport parameter	5.0E-04
Coefficient for slope dependent term, ε	2.0E-03 (m^2/s)
Transport rate decay coefficient multiplier, λ	0.5 (m^{-1})
Water temperature	20 °C

Table 4-4
Total SBEACH Runs

Reach	Profiles	Water Elevation Time Series	SBEACH Runs
R1	462	192	88,704
R2	539	192	103,488
R3	462	192	88,704
R4	539	192	103,488
R5	539	192	103,488
R6	462	192	88,704
Total	3,003		576,576

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5.0 HISTORIC EROSION RATES AND CALIBRATION

This section provides details into the analysis of the historically observed shoreline change rates and calibration of Beach-fx. Beneficial use of dredged material (BUDM) has taken place on South Padre Island since 1988. Shoreline change rates were estimated in the absence of this project, and Beach-fx was calibrated to these values.

5.1 BENEFICIAL USE PROJECT

BUDM placement has been implemented on South Padre Island since 1988, resulting in dredged material from the Brazos Santiago Pass placed either in a nearshore berm or directly on the beach. Table 5-1 gives an overview of the dates, location, and amount of placement from 1988–2014. The shaded boxes indicate material that was placed directly on the beach and the distance from the Brazos Santiago Pass, whereas a location of “Berm” indicates material that was placed in a nearshore berm.

Table 5-1
History of Dredged Material Placement at South Padre Island

Year	Location (miles)	Amount (cubic yards)
1988	Berm	220,000
1991	Berm	580,000
1995	Berm	750,000
1997	3.45–4.59	490,000
1997	Berm	396,000
1999	1.52–2.27	495,000
1999	Berm	195,000
2000	3.90–4.51	370,000
2002	3.48–4.13	330,000
2002	Berm	329,000
2003	Berm	356,000
2005	0.18–0.57	49,000
2005	3.45–4.03	229,000
2006	Berm	340,000
2007	Berm	443,000
2008	Berm	500,000
2009	3.95–4.83	407,000
2010	0.13–0.64	90,000
2010	4.45–5.02	130,000
2011	0.19–0.47	199,000
2011	4.55–5.06	368,000
2012	0.19–0.47	140,000
2012	4.45–4.92	210,000
2014	Berm	305,000

This feasibility study considered future conditions at South Padre Island in the absence of continued BUDM. The nourishment projects evaluated (Section 7) were modeled as an alternative, more permanent solution to the informal BUDM that has occurred in the past.

5.2 HISTORIC EROSION RATES

Beach-fx was calibrated to return on average across 300 lifecycles, the historically observed shoreline change rates. Each reach (R1, R2 …) was calibrated to a single value representing the average observed shoreline change rates within that reach.

Historic shoreline positions at South Padre Island were available for 1937 and 1995 (Figure 5-1). By computing the distance between the shorelines at each profile transect and dividing by the time span (59-years), the shoreline change rates were determined (feet/year).

Figure 5-1: Historic Shoreline Positions
1937 (red) and 1995 (black)

HDR Engineering has been providing South Padre Island with annual reports that document the history of the beneficial use placement on the island as well as rates of shoreline change. HDR reports from 2015 (Perry, 2015) and 2016 (Perry, 2017) were provided to ERDC-CHL. The 2016 surveys were taken in the winter months where "larger wave events, and at times higher water elevations/tides, tend to occur," and often result in a winter profile that is "typically narrow and steeper" than its summer counterpart. These narrow profiles resulted in shoreline change rates that were lower than expected. Because of the inconsistencies in when the surveys were conducted, the shoreline change rates in the 2015 HDR report were employed to characterize the erosion rates at South Padre Island. Figure 5-2 shows the shoreline changes from 1995 to 2015 (blue), 1937 to 1995 (black), as well as the location of each reach (varying colors along the x-axis). The Brazos Santiago Pass is located at *x=0*.

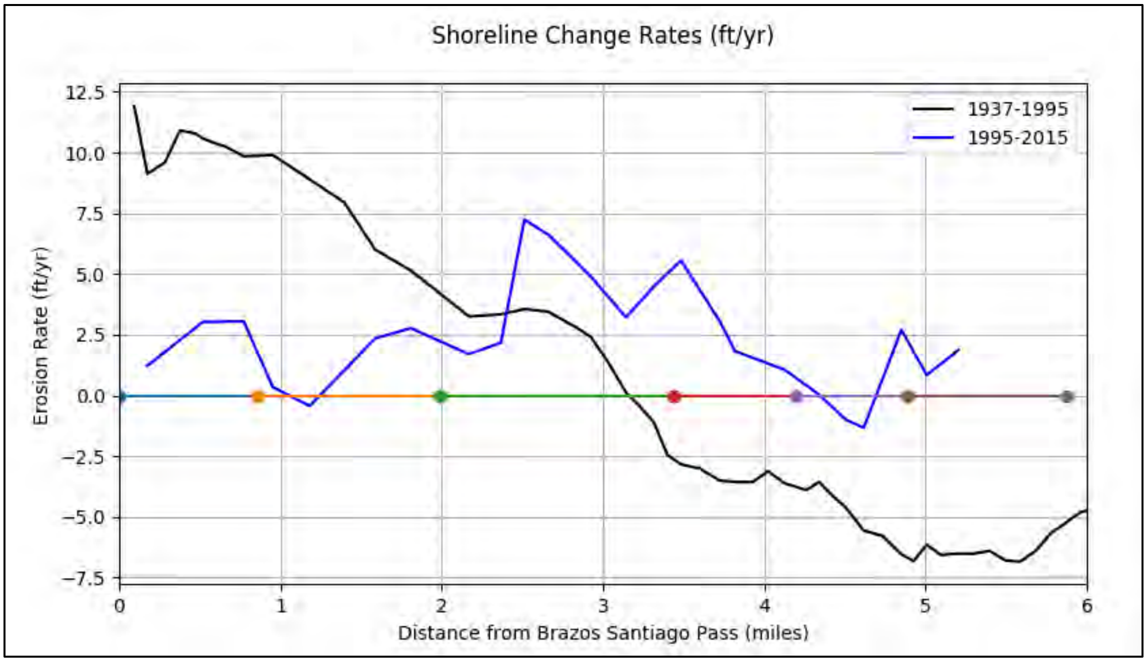

Figure 5-2: Shoreline Change Rates at South Padre Island

Due to the construction of the jetty at the Brazos Santiago Pass, the 1937–1995 shoreline shows accreting tendencies to the south that transition to erosion at the north. It can also be seen that since the beneficial use project has been implemented, the shoreline has been accreting across nearly the entire island.

The large accretion at the southern end of the island from 1937 to 1995 has stabilized and it is expected that in the absence of beneficial use placement, the shoreline will not return to these values. This is likewise evident from the decreased shoreline change rates in Reaches R1 and R2 comparing 1937 to 1995 (no beneficial use) and 1995 to 2015 (beneficial use). With the beneficial use project in place, the shoreline at the southern end of the island has not shown increased accretion rates.

Therefore, to determine shoreline change rates in the absence of a beneficial use project, the 1937 to 1995 shoreline change rates could not be directly used. Rather, the 1995 to 2015 rates were used in conjunction with the history of material placed on the beach (Table 5-1).

Shoreline Change Rates in Absence of Beneficial Use

The amount of sand placed through the beneficial use projects was converted to a contribution to shoreline change (yd^3 to feet/year). It was assumed that the active profile at South Padre Island is 27 feet (23 feet depth of closure plus 4 feet berm height). From the nourishment start and end positions available in Table 5-1, the total volume placed in each reach was computed. If a nourishment project spanned more than one reach, it was assumed that the material was placed equally across the segment of beach. The total volume in each reach was assumed to stay in that reach, and the amount of additional beach was determined by dividing the placed volume by the length of reach and the depth of the active profile. The average additional change per year due to the nourishment projects was then computed by dividing by the number of years that the nourishment projects have been in place (1995 to 2015; 21 years). These values were then subtracted from the average shoreline change rates of each reach. Figure 5-3 shows the resulting shoreline change rates in the absence of a beneficial use project (green) along with the observed average shoreline change rates for 1995 to 2015 (blue).

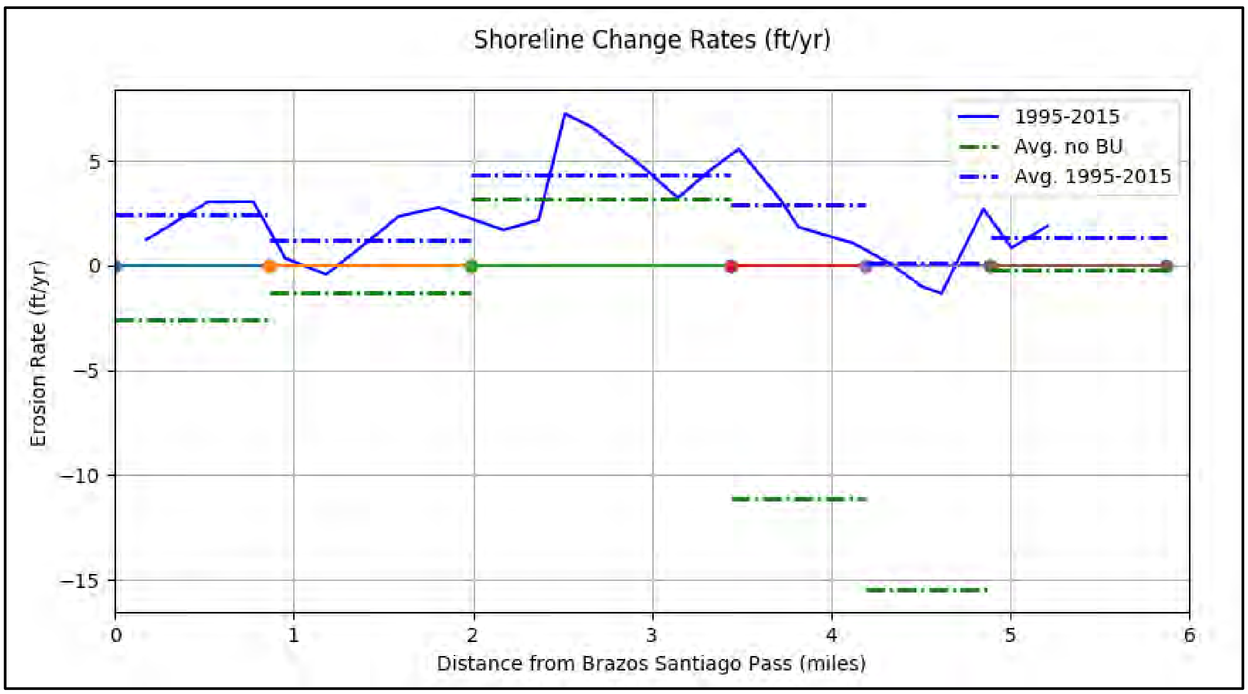

Figure 5-3: Average Computed Shoreline Change Rates in Absence of Beneficial Use Project

The resulting shoreline change rates for reaches R1–R3, returned reasonable values, whereas reaches R4 to R6 did not. Erosion greater than 10 feet/year is not expected to occur at South Padre Island, when the long-term trends show erosion up to approximately 7 feet/year. Furthermore, comparing reaches R5 and R6, it is not expected that the former has an erosion rate greater than 15 feet/year, whereas the latter results in almost no erosion.

To alleviate these inconsistencies, the average erosion rates in reaches R4–R6 were represented by the shoreline change data available from 1937–2015. Figure 5-4 shows the historical shoreline change from 1937–1995 (black), the shoreline change from 1995 to 2015 (blue), and the average shoreline change rates in each reach (horizontal lines). Table 5-2 summarizes the average shoreline change rates that were used in the Beach-fx calibration.

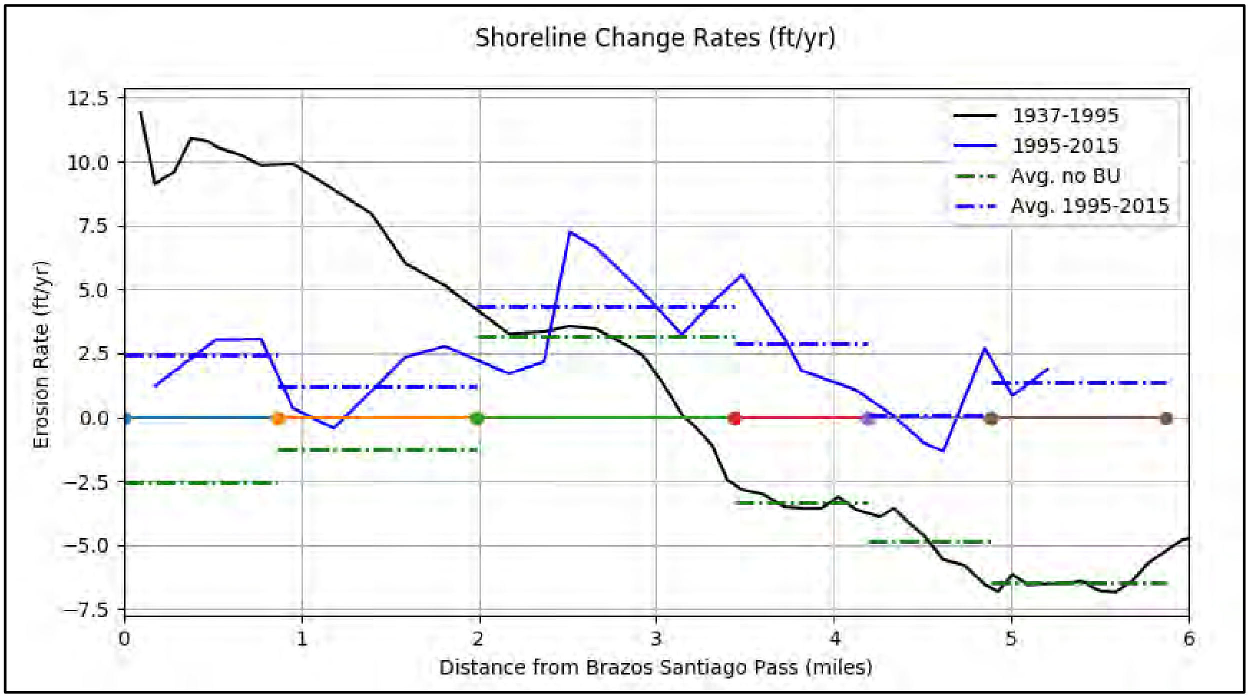

Figure 5-4: Final Average Shoreline Change Rates

Table 5-2
Average Shoreline Change Rates at South Padre Island
in the Absence of the Beneficial Use Project

Reach	Shoreline Change Rate (feet/year)
1	–2.561
2	–1.269
3	3.181
4	–3.313
5	–4.866
6	–6.462

5.3 ALIBRATION

Calibration in Beach-*fx* ensures that the average erosion rate over a project simulation (300 iterations) is equal to the available historical data. The average erosion rate is a function of the storm induced erosion rate, berm width recovery factor, and the Applied Erosion Rate (AER). To determine the AER, an iterative method was implemented. The berm width recovery factor was set to 90 percent for all iterations.

To initiate the calibration process, the AER was first set to zero, and the storm-induced erosion rates were determined. The AER was then updated in subsequent iterations such that the storm induced erosion rates in conjunction with the AER, equaled the target shoreline change rate. This process was repeated until the average shoreline change rates observed in each reach were equal to the target historical shoreline change rates. Table 5-3 shows the results from the calibration procedure.

Table 5-3
Results from Calibration Procedure

Reach	Target Shoreline Change Rate (no BU)	AER (no BU)
1	–2.561	–0.366
2	–1.269	0.851
3	3.181	5.294
4	–3.313	–1.341
5	–4.866	–2.813
6	–6.462	–4.645

6.0 FUTURE WITHOUT-PROJECT CONDITIONS

This section details the FWOP conditions at South Padre Island. In keeping with the rest of the Texas Coastal Study, the project start date was defined as 2035. Beach-fx simulations typically occur over a 50-year period, resulting in an end date of 2085. To compare the FWOP and FWP conditions, the same period of analysis is considered. Beach-fx was configured to simulate 2031 to 2085, with a 4-year base period (2031 to 2035) in which no project is implemented. The FWOP conditions provide the potential benefit pool that is available in the absence of a shore protection project.

6.1 POTENTIAL BENEFIT POOL

The FWOP analysis involved the simulation of 300 unique 54-year lifecycle simulations (2031 to 2085), in which no Federal coastal flood reduction project was implemented. All economic calculations are expressed in 2035 dollars (base year 2035) and use an interest rate of 2.75 percent. This analysis considered the damages done to both structures and contents as potential benefits. The distribution of combined structure and content damages for the 300 lifecycles can be seen on Figure 6-1.

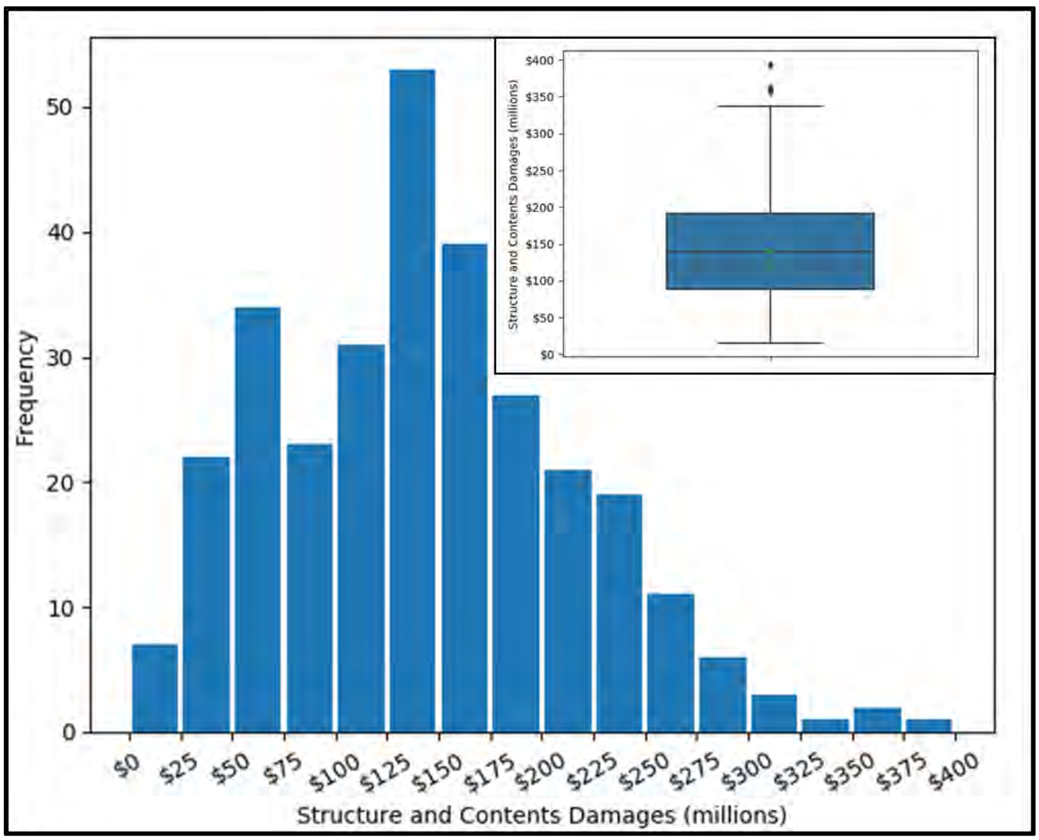

Figure 6-1: FWOP Structure and Contents Damages

It can be seen that the damages approach a normal distribution with a slight skew to the right. The structure and contents damages average $144.00 million. As seen in the box and whisker plot of Figure 6-1, there are three statistical outliers corresponding to damages greater than approximately $350 million. The frequency of damages between $125 and $175 million account for 30 percent of all Beach-fx lifecycles (92/300 simulations).

The combined structure and contents damages by reach can be seen on Figure 6-2, and the number of damage elements and average damages by reach can be seen in Table 6-1. The majority of damages occur in Reach R5 with an average damage value of $66.98 million. Reaches R3 to R6 have significant damages with each reach averaging above $10 million. As expected, larger damages occur at the northern portion of the island, where the shoreline is erosive (R4 to R6). Although Reach R3 is accretional, it has a large number of damageable elements (53) that result in considerable damages. From Figure 6-2 and Table 6-1, it can be seen that the potential net benefit pool is the largest at the northern end of the island.

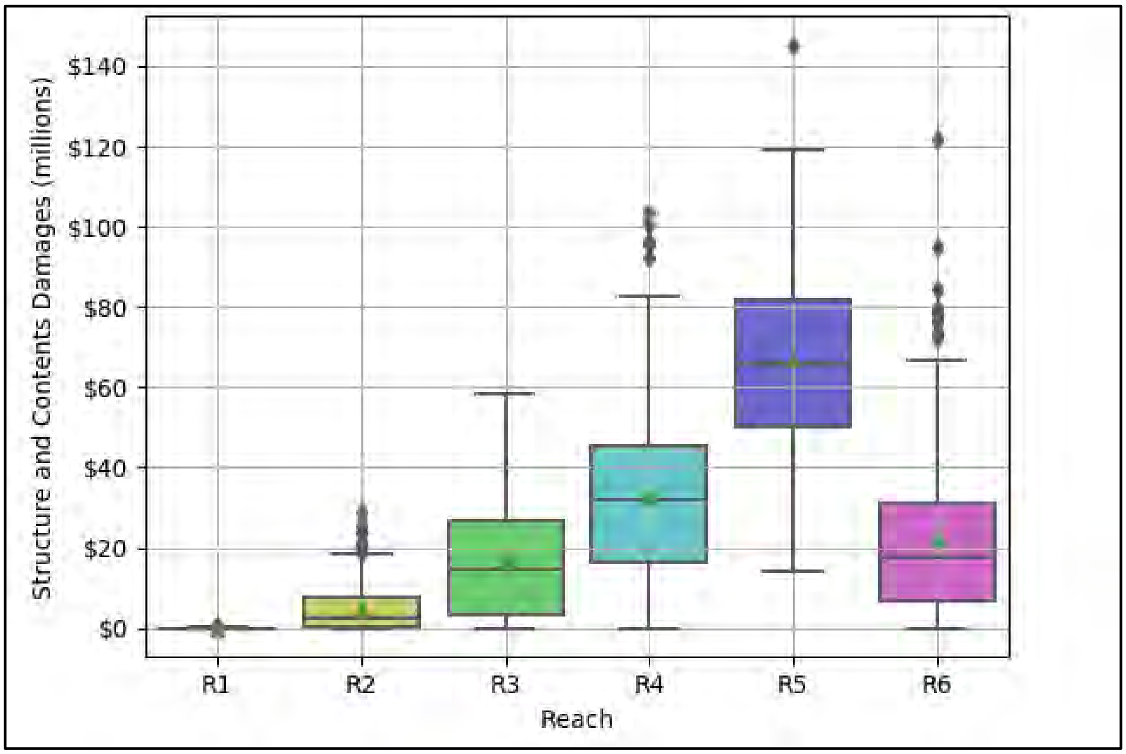

Figure 6-2: FWOP Structure and Contents Damages by Reach

Table 6-1
Number of Damage Elements in Each Reach

Reach	Number of Damage Elements	Average Damages (millions)
R1	2	$0.056
R2	29	$4.921
R3	53	$16.856
R4	36	$32.906
R5	53	$66.984
R6	33	$22.283
R6_park	0	n/a

7.0 FUTURE WITH-PROJECT CONDITIONS

This section details the FWP test conditions at South Padre Island, as well as the net benefits associated with each alternative. In total, 18 dune and berm templates were considered with variations in dune height, dune width, and berm width.

7.1 EVALUATION OF NOURISHMENT ALTERNATIVES

Net Benefits and Benefit to Cost Ratio

To measure the feasibility of a project, both the net benefits and the benefit-to-cost ratio (BCR) were considered. The net benefits are defined as:

$$Net\ Benefits = Benefits_{Damages} + Benefits_{Costs\ Avoided} - Costs_{PN} \qquad (7.1)$$

Where $Benefits_{Damages}$ represent the reduction in damages due to the implementation of a project (FWOP damages – FWP damages), and $Benefits_{Costs\ Avoided}$ represent any collateral costs that are circumvented due to the implementation of the project (for example armor construction and emergency nourishment costs).

Additionally, the BCR is defined as:

$$BCR = \frac{Benefits_{Damages} + Benefits_{Costs\ Avoided}}{Costs_{PN}} \qquad (7.2)$$

Typically, the net benefits and BCR consider benefits associated with both damage reduction and costs avoided. In this case, no armor (Section 8.9) or emergency nourishment was considered, thus, the benefits only considered those related to a reduction in damages. The costs associated with a project include mobilization ($3,000,000) as well as the placement of planned nourishment material ($40/yd^3).

Identification of Nourishment Template

Nourishment templates in Beach-fx are defined by variations in dune height, dune width, and berm width. Following initial sensitivity runs consisting of select renourishment templates (e.g., maximum conditions in SRD and current beach conditions), three variations in dune height, three variations in dune width, and two variations in berm width were identified to be tested. The combination of dune height, dune width, and berm width values resulted in a total of 18 permutations (Table 7-1).

Table 7-1
Nourishment Alternatives

	Minimum (feet)	Maximum (feet)	Change (feet)	Permutations
Dune Height	10	15	2.5	3
Dune Width	10	20	5	3
Berm Width	100	150	50	2
			Total	18

For each of the 18 resulting templates, a Beach-fx simulation occurred in which the entire study area (R1 to R6; excluding the park) was renourished on an "as-needed" basis. A relative BCR was computed for each reach that did not consider mobilization costs (Figure 7-1). It should be emphasized that the relative BCR is not reflective of the actual BCR in each reach, but rather allows the reaches that benefit the most from implementation of a renourishment project to be identified. On Figure 7-1, the darker hues indicate a higher relative BCR. It can be seen that reaches R3, R4, and R5 returned the largest relative BCRs. Note that although Reach R5 returned the largest damages (Section 6.1), it did not receive the largest relative BCRs due to the high cost of renourishing.

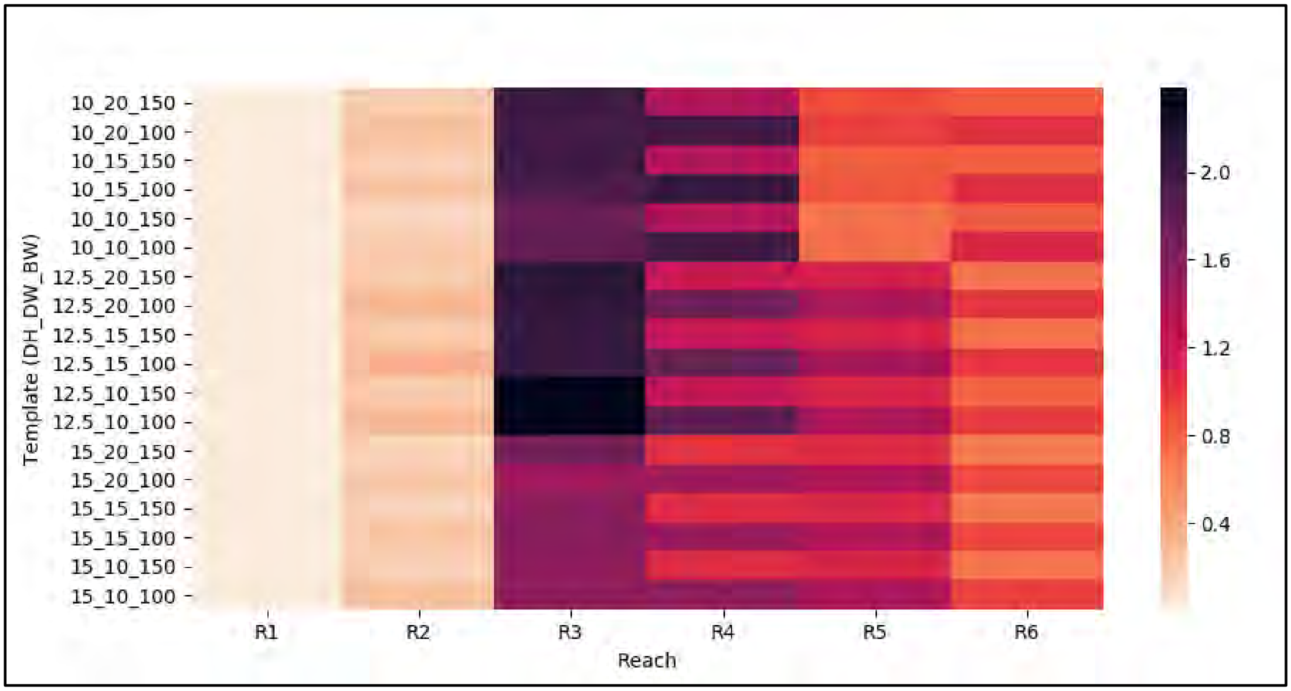

Figure 7-1: Heat Map of Relative BCRs

Of the 18 original nourishment templates, 8 were considered for further analysis by running additional Beach-fx simulations (Table 7-2). One set of simulations considered renourishing only reaches R3 and R4, whereas the other considered reaches R3, R4, and R5. Similar to the previous simulations, Beach-fx was configured to be renourished on an "as-needed" basis. The resulting average BCRs[1] across 300 lifecycles are shown in Table 7-2. The results show that simulations in which Reach R5 is included, result in a 13 to 43 percent reduction in the average BCR. As previously discussed, this is due to the high cost of renourishing Reach R5. From Table 7-2, it can be seen that the template corresponding to a dune height of 12.5 feet, a dune width of 20 feet, and a berm width of 100 feet returned the largest BCR. This template was considered for further analysis.

Table 7-2
Average BCR When Renourishing Separate Reaches

Template (DH_DW_BW)	R3 and R4	R3, R4, and R5
10_20_100	0.895	0.752
10_15_100	0.897	0.780
12.5_20_100	**1.189**	**0.733**
12.5_15_100	1.167	0.726
12.5_10_100	1.129	0.734
12.5_10_150	0.949	0.543
15_15_100	0.958	0.650
15_10_100	0.924	0.649

7.2 REACH PLANFORM RATES

In Beach-fx, reach planform rates (feet/year) are an additional shoreline change rate that is applied due to the placement of nourishment material. To determine the project induced shoreline change, an analytical model was implemented (Pelnard-Considere, 1956). This model assumes a rectangular beach fill with a user specified berm width of 100 feet, and a longshore placement width of approximately 11,600 feet (length of reaches R3 and R4). The equation implemented in the model is given by:

$$y(x,t) = \left(\frac{Y}{2}\right)\{\mathrm{erf}\left[\left(\frac{l}{4\sqrt{Gt}}\right)\left(\frac{2x}{l}+1\right)\right] - \mathrm{erf}\left[\left(\frac{l}{4\sqrt{Gt}}\right)\left(\frac{2x}{l}-1\right)\right] \qquad 7.3$$

Where, x and t are the longshore distance and time, respectively. Y is the placement length, l is the project length, and G is the diffusivity parameter, given by:

$$G = \frac{K H_b^{5/2}\sqrt{g\gamma}}{8(s-1)(1-n)(d_c+B)} \qquad 7.4$$

Where K is the longshore transport coefficient, H_b is the breaking wave height, g is the acceleration of gravity, γ is the wave breaker index, s is the specific gravity of the sediment, n is the porosity of the sediment, d_c is the depth

[1] Note that the simulations shown in Table 7-2 and the resulting average BCRs do not consider reach planform rates and are thus not reflective of the actual average BCR. Reach planform rates were applied following the identification of a nourishment dune and berm template.

of closure and *B* is the berm height. The longshore transport coefficient, *K*, was estimated using del Valle et al. (1991), and given by:

$$K = 1.4e^{-2.5d_{50}} \quad 7.5$$

The resulting shoreline position at 1, 2, 3, 4, 5, 7, 10, 12, 15, 20, and 50 years after placement are shown on Figure 7-2. The reach planform rates specified in Beach-fx were computed based on the average change from the initial shoreline position to that of the shoreline at year *N*. A single value was identified for both the placement area (reaches R3 and R4), and the reaches adjacent to the placement area (reaches R2 and R5). The resulting reach planform rates in feet/year are shown in Table 7-3.

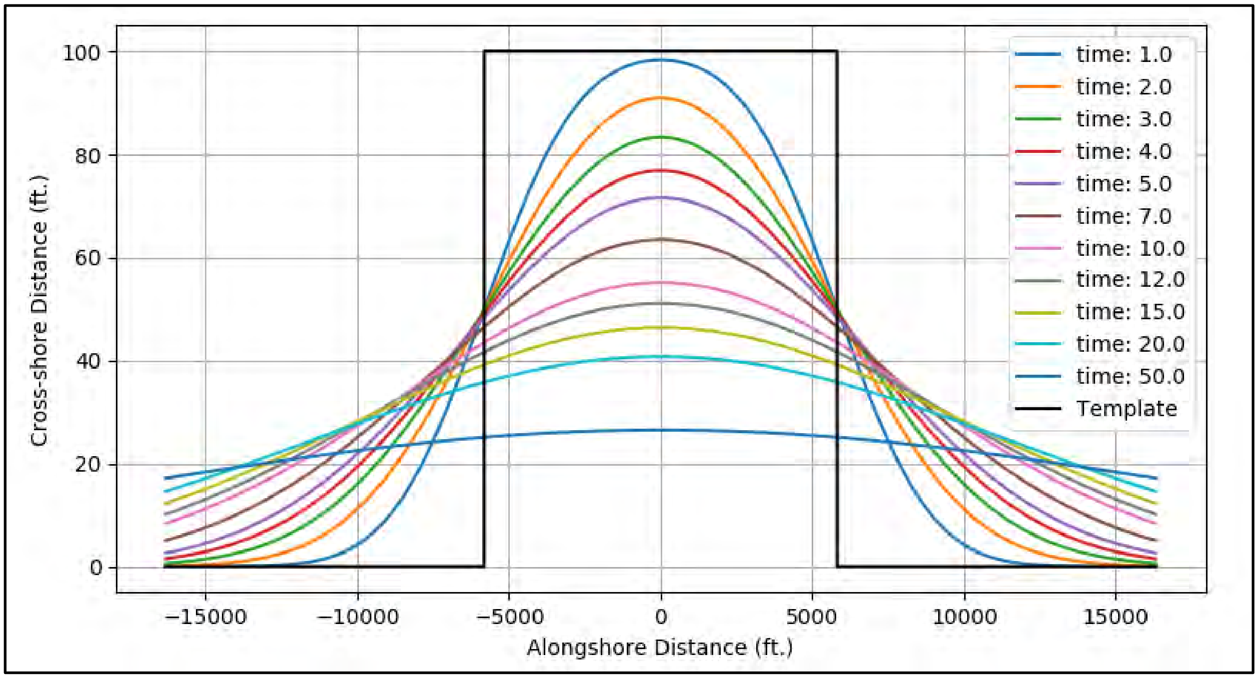

Figure 7-2: Analytical Solution to Shoreline Change Rates

Table 7-3
Reach Planform Rates

Renourishment Interval	Placement Area Rate (feet/year)	Adjacent Area Rate (feet/year)
1	–16.7	9.2
2	–11.8	6.5
3	–9.6	5.3
4	–8.3	4.5
5	–7.3	4.0
7	–6.1	3.2
10	–4.9	2.4
12	–4.3	2.1
15	–3.7	1.7
20	–3.0	1.3

7.3 RENOURISHMENT INTERVALS

By utilizing the reach planform rates, and the selected template (dune height of 12.5 feet, dune width of 20 feet, and a berm width of 100 feet), additional Beach-fx simulations were completed with varying renourishment intervals. In total, 10 renourishment intervals were considered (1, 2, 3, 4, 5, 7, 10, 12, 15, and 20 years), and both the BCR and net benefits were computed for each lifecycle (300 lifecycles). Figures 7-3 and 7-4 show box and whisker plots representing the distribution of BCRs and net benefits at each renourishment interval.

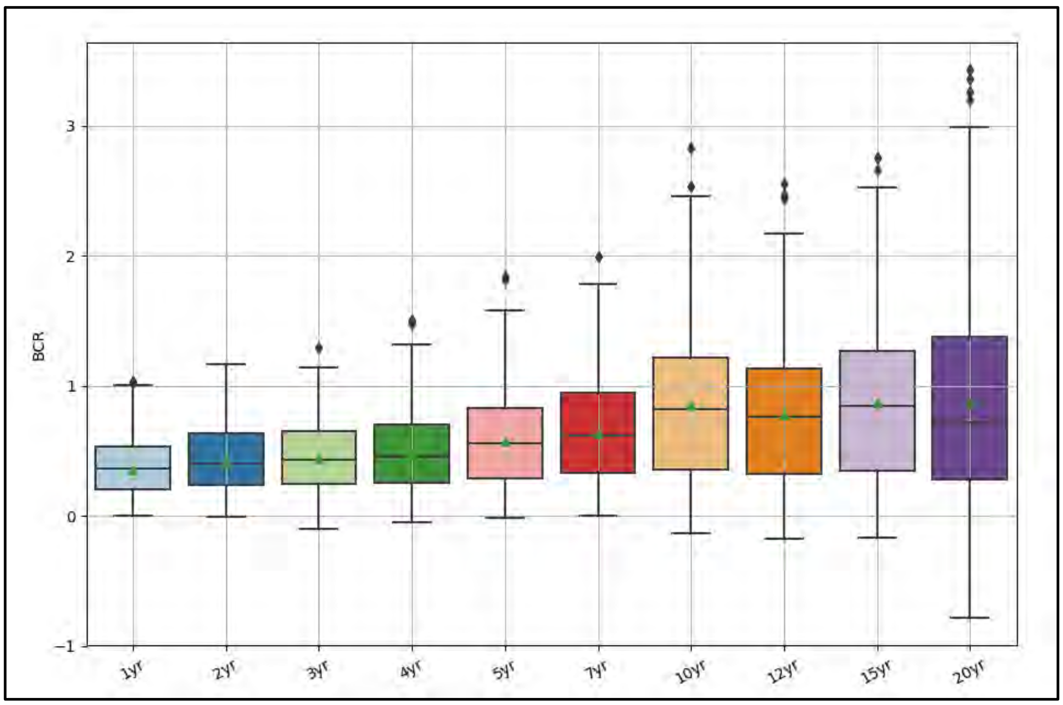

Figure 7-3: Box and Whisker Plot of BCRs at Varying Nourishment Intervals

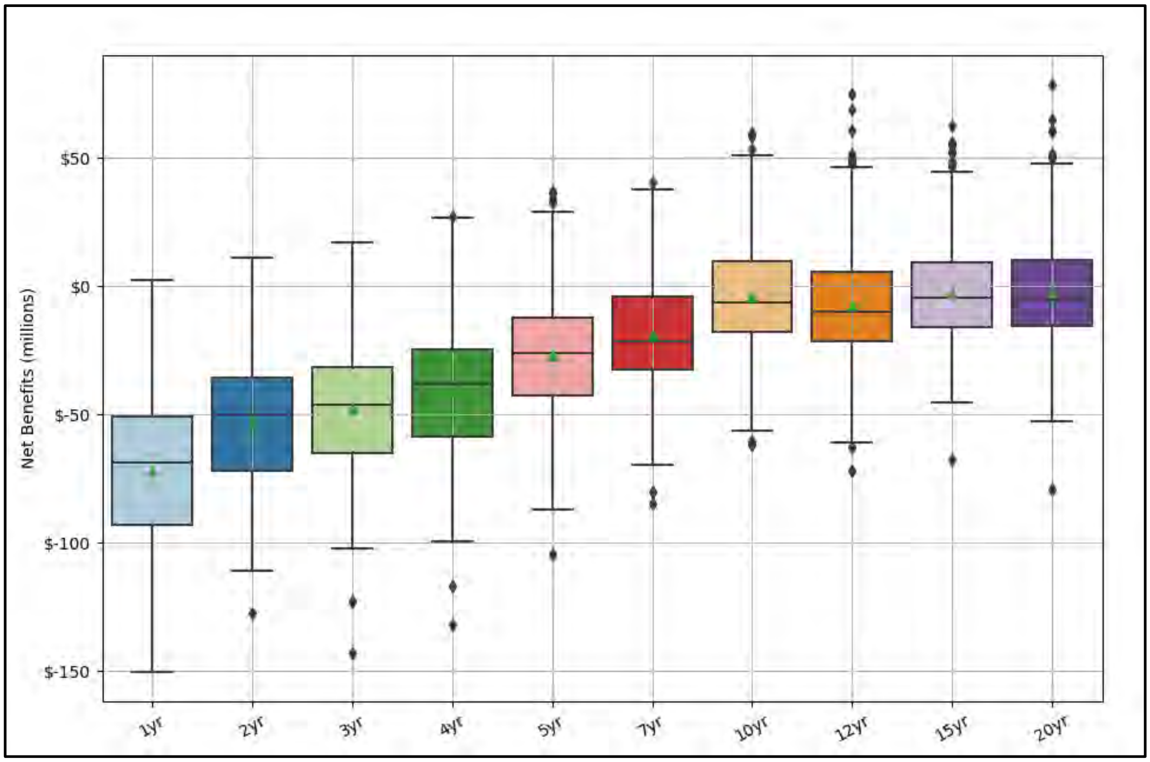

Figure 7-4: Box and Whisker Plot of Net Benefits at Varying Nourishment Intervals

It can be seen that, in general, larger benefits result from increasing the nourishment interval up to the 10-year cycle. Beyond the 10-year cycle, there is no significant increase in the benefits, with the 12-year cycle showing a slight decrease. Figure 7-3 shows that there are some simulations that result in a negative BCR. This indicates that with the implementation of a renourishment project, larger damages occur than the identical without project conditions. This is due to both the robust initial conditions at South Padre Island, as well as the increased erosion rates due to the placement of additional material (reach planform rates).

Because the benefits plateau beyond the 10-year renourishment interval, this cycle is selected as the optimal renourishment interval. When considering the renourishment interval, it is beneficial to select the plan that returns the largest BCRs at the shortest renourishment interval. This reduces the vulnerability of the beach between nourishment cycles. Although, the 15- and 20-year renourishment intervals return slightly higher net benefits, they are not recommended as the optimal plan because of the long duration between renourishment events. There is no significant increase in net benefits beyond the 10-year renourishment interval that would justify the increased vulnerability.

7.4 SELECTED PLAN – OVERVIEW AND DISCUSSION

The beach template (DH-12.5 feet, DW-20 feet, BW-100 feet), coupled with a 10-year renourishment interval make up the selected beach renourishment plan at South Padre Island. The average BCR and net benefits across all 300 lifecycles are $0.85 and -$3.84 million, respectively. Although the average BCR is less than one and the net benefits are negative, these values only consider National Economic Development (NED) benefits. In addition to the NED benefits, implementation of a beach renourishment project at South Padre Island would likely result in additional Regional Economic Development benefits. The distribution of net benefits across all lifecycles can be seen on Figure 7-5 and Figure 7-6.

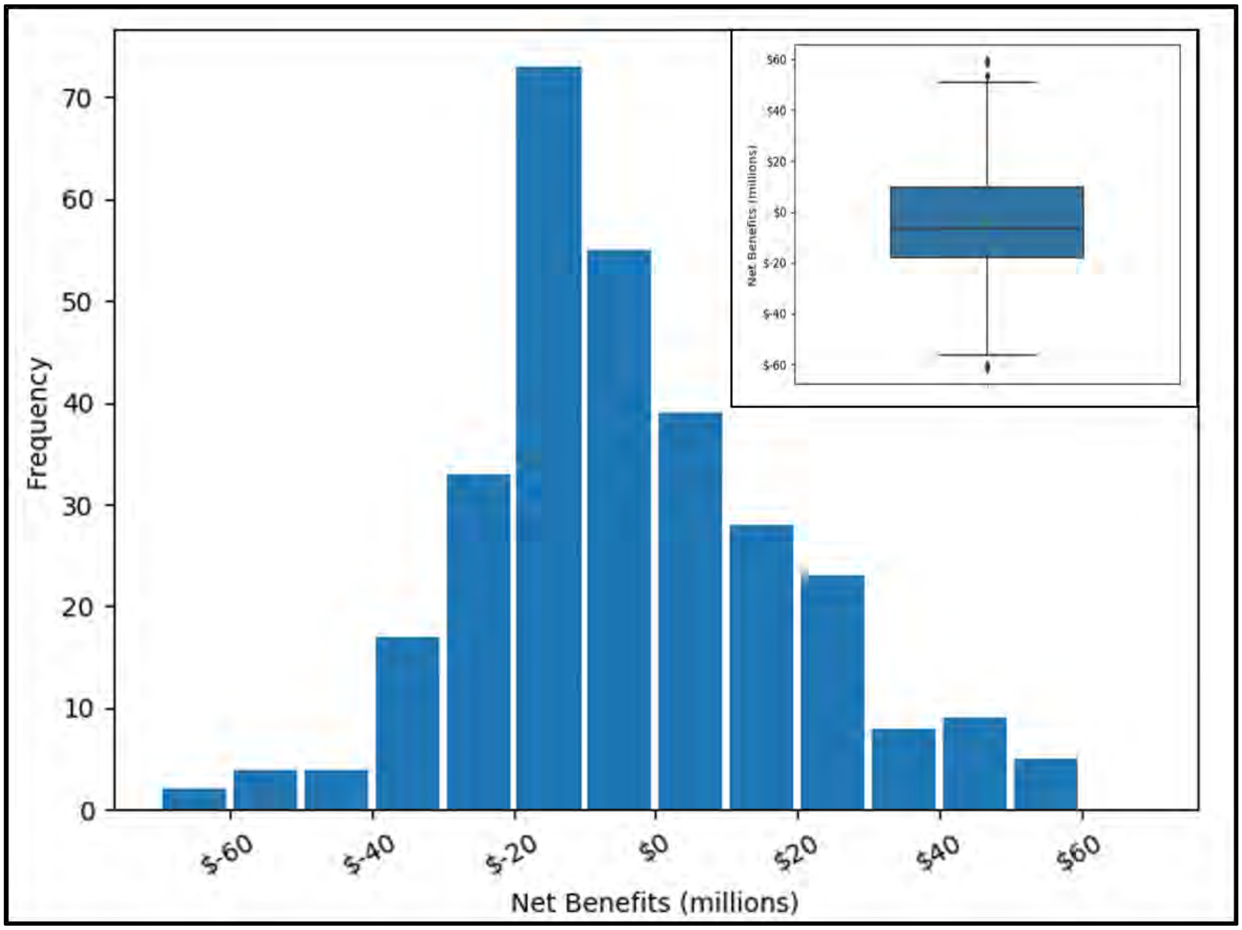

Figure 7-5: Distribution of Net Benefits of TSP

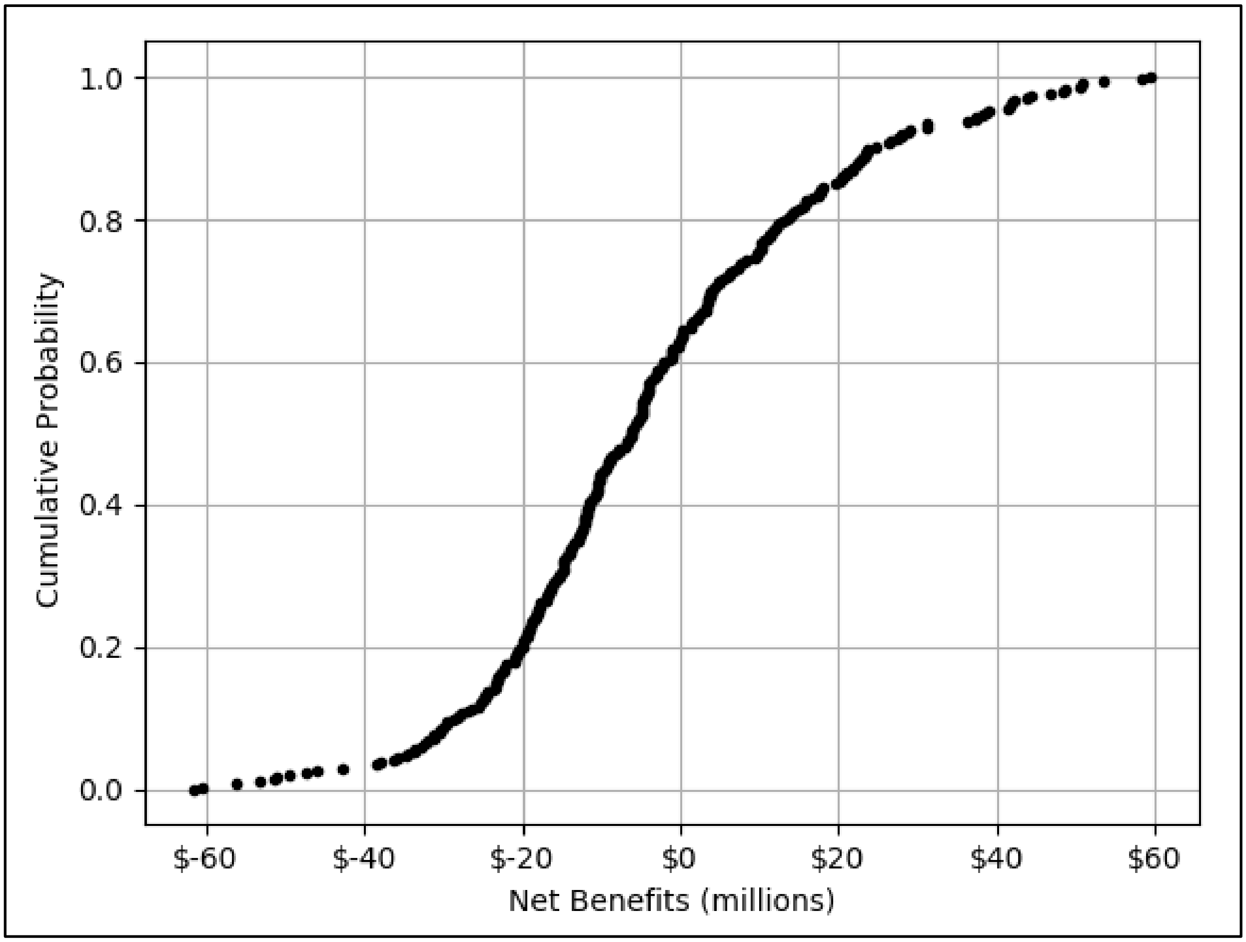

Figure 7-6: Empirical Cumulative Distribution Function of Net Benefits

The net benefits are normally distributed with five statistical outliers (three upper and two lower). Of the 300 lifecycles, 112 lifecycles returned positive net benefits (37.3 percent), whereas the remaining 188 lifecycles returned negative net benefits (62.7 percent).

Each lifecycle was classified as returning either positive or negative net benefits and plotted as a histogram grouped by the number of storms (Figure 7-7). It can be seen that, in general, lifecycles with few storm events returned negative net benefits (e.g., two to six storms). Conversely, lifecycles with a relatively large number of storm events showed a higher chance of returning positive net benefits (e.g., 8–12 storms). Across all 300 lifecycles, Beach-fx returned an average of 8.227 storms. If eight storms are expected to occur over the 50-year period, then the selected project has a 57 percent chance of being economically justified (e.g., with 8 storm events, 25 lifecycles returned positive net benefits, whereas 19 returned negative). Figure 7-7 can similarly be read in the same way for varying number of potential storm events over a 50-year period.

As previously mentioned, the average NED-BCR and net benefits are both below $1 and $0, respectively. The benefits computed herein do not consider Regional Economic Development benefits, which could increase the total benefits. The negative net benefits are most likely driven by the robust initial beach conditions at South Padre Island.

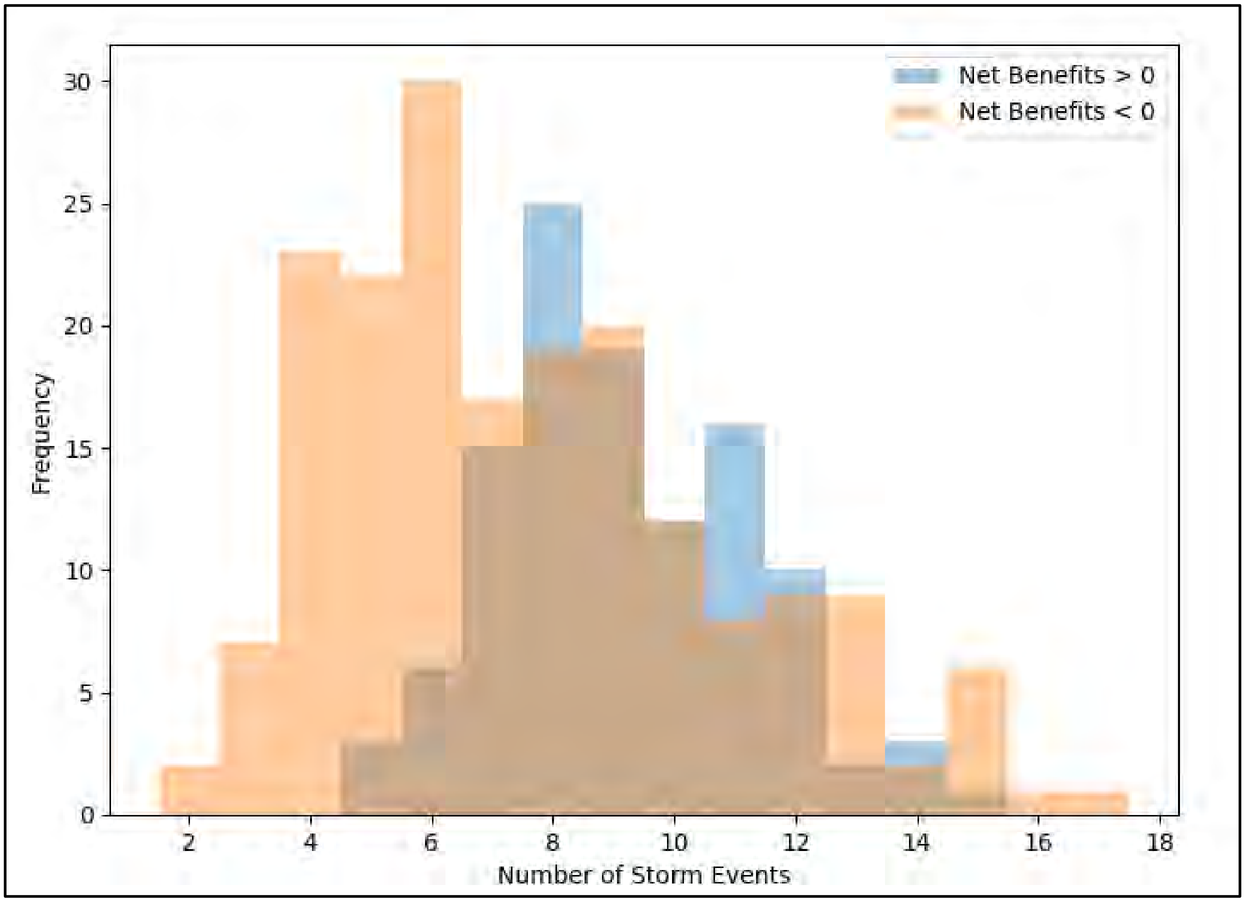

Figure 7-7: Histograms of Positive and Negative Net Benefit Lifecycles vs. Number of Storm Events.

7.5 DEPTH OF CLOSURE MODIFICATIONS FOLLOWING IDENTIFICATION OF TSP

Following the selection of the beach template and renourishment interval that returned the largest net benefits and BCR, minor modifications to Beach-fx were implemented. Additional model reviews were completed by both AECOM and CE-SAJ. The primary takeaway from these conversations resulted in modifications to the Beach-fx depth of closure and width of active profile. Within Beach-fx, these two values dictate how nourishment material is placed, as well as how much material is eroded due to sea level change (Bruun, 1954). The depth of closure and width of active profile were originally specified as 30 and 4,000 feet, respectively. These values were updated to 23 and 3,000 feet. A depth of closure of 23 feet was selected to be consistent with the depth of closure implemented in the volume calculations (Section 5.2). Furthermore, Wave Information Studies (WIS) data at the South Padre Island indicate a depth of closure of 19–23 feet (Brutsché et al, 2014). The width of active profile was determined from the submerged profile data based on the updated depth of closure.

Changes to the depth of closure and width of active profile resulted in minor variation in the without project conditions. The distribution of FWOP damages can be seen on Figure 7-8. The average damages with the update depth of closure and width of active profile increased from $144.00 to $144.20 million.

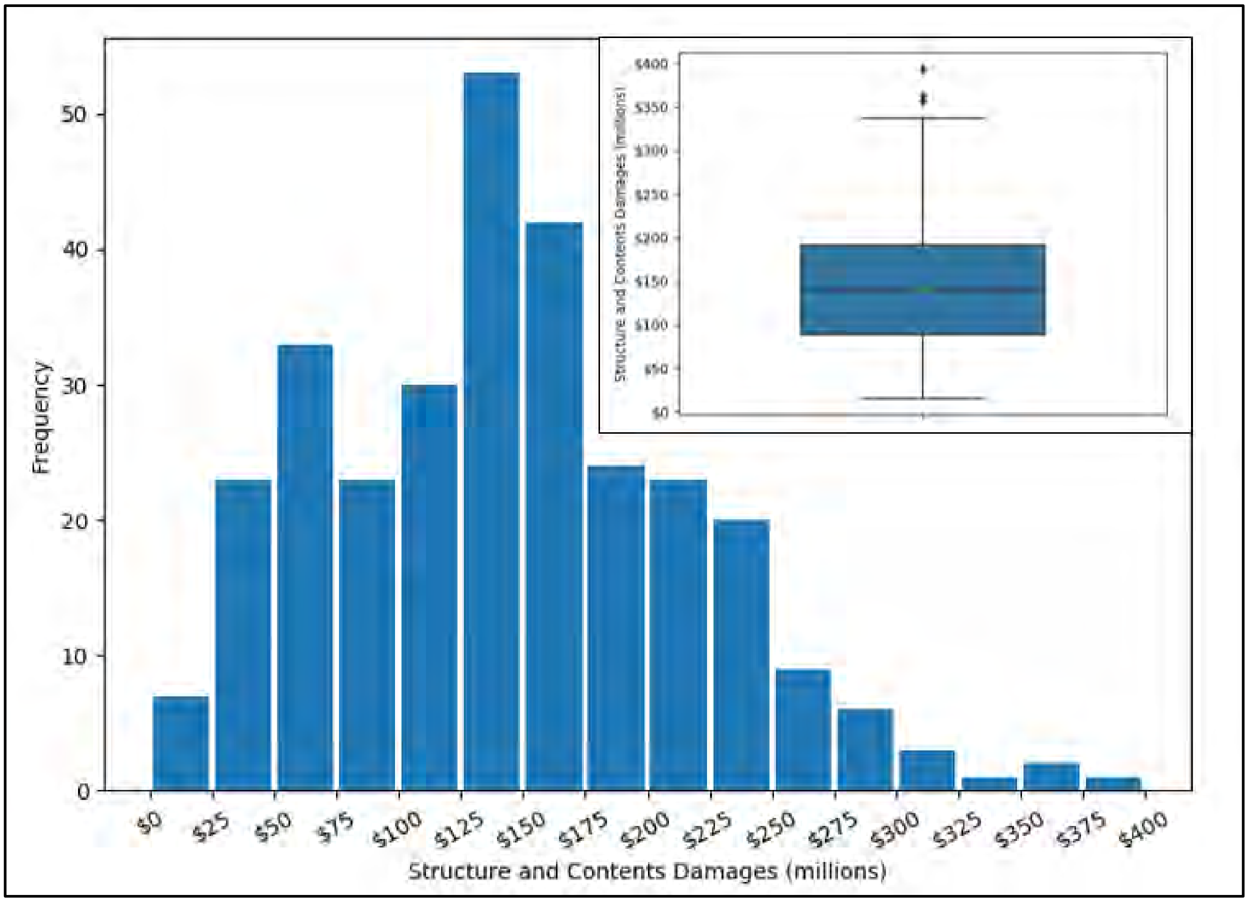

Figure 7-8: FWOP Damages Following Modifications to Depth of Closure and Width of Active Profile

Whereas the updated depth of closure and width of active profile resulted in negligible changes to the FWOP conditions, the FWP conditions saw more significant changes. Table 7-4 shows the averages of the original model runs and the updated model runs.

Renourishment cycles of 5, 10, and 15 years were resimulated. It can be seen that the BCR and net benefits resulting from the new depth of closure increase regardless of the renourishment interval. Additionally, it can be seen that there is little variation in the FWP damages, but that the change in BCR and net benefits are caused by a reduction in project costs. The larger variation between the FWP costs are attributed to the decreased depth of closure. Within Beach-fx, the volume (and costs) is proportionately related to the depth of closure. Therefore, a decreased depth of closure results in a decreased cost. For all three simulations, the resulting BCRs increase between 18–20 percent, and the rank ordering of the BCRs are the same as that of the original runs. It is expected that regardless of the plan or renourishment interval selected, the increase in BCR will remain the same (about

20 percent). Consequently, it is not necessary to rerun all of the simulations. Rather, the originally selected TSP remains the selected plan, although there are changes to the economic values.

Table 7-4
Comparison of Original and New Depth of Closure

		Depth of Closure/ Width of Active Profile (feet)	
	PN Interval	30/4000 (original)	23/3000 (new)
BCR	5	0.574	0.688
Net Benefits		–$26,930,182	–$15,603,320
FWP Damages		$103,634,456	$103,874,211
FWP Costs		$67,302,557	$55,929,689
BCR	10	0.850	1.008
Net Benefits		–$3,842,351	$2,230,348
FWP Damages		$109,239,669	$109,497,650
FWP Costs		$38,609,514	$32,472,582
BCR	15	0.869	1.026
Net Benefits		–$2,482,384	$2,714,841
FWP Damages		$112,619,297	$112,873,620
FWP Costs		$33,869,918	$28,612,118

As outlined in the Section 7.3, although the 15-year renourishment interval returned a larger BCR and net benefits, it is not recommended due to the increased vulnerability of the beach between renourishment intervals. As a result, the 10-year renourishment interval is selected. The distribution of net benefits for the TSP can be seen on Figures 7-9 and 7-10.

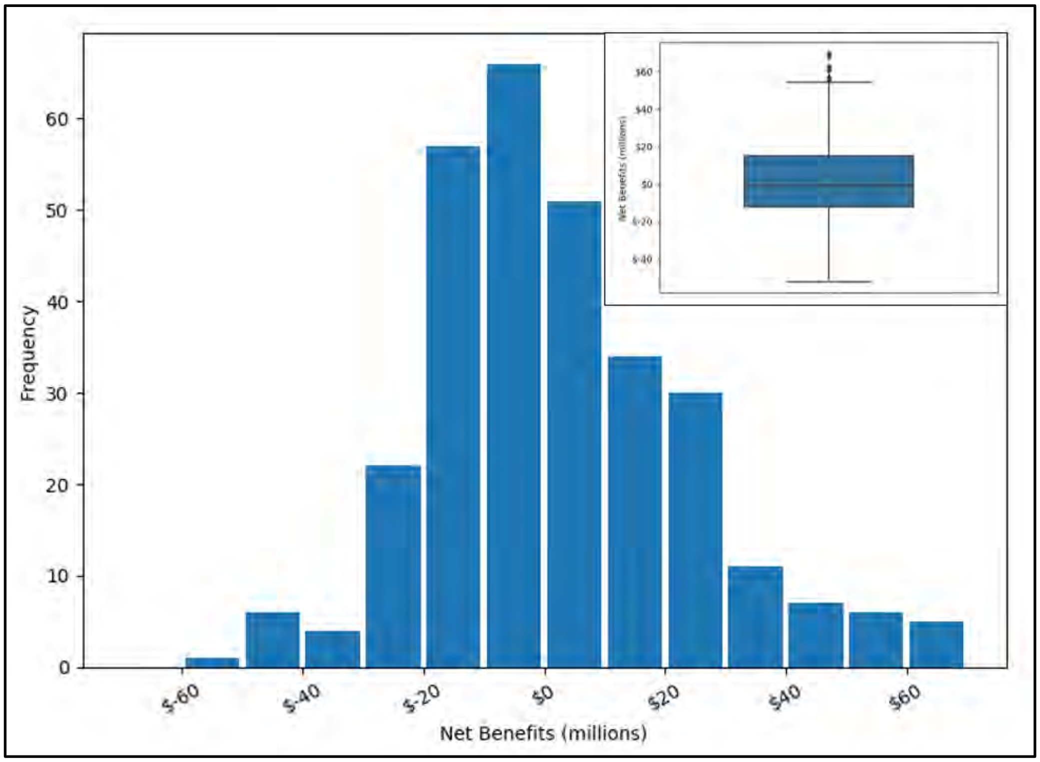

Figure 7-9: Distribution of Net Benefits of TSP

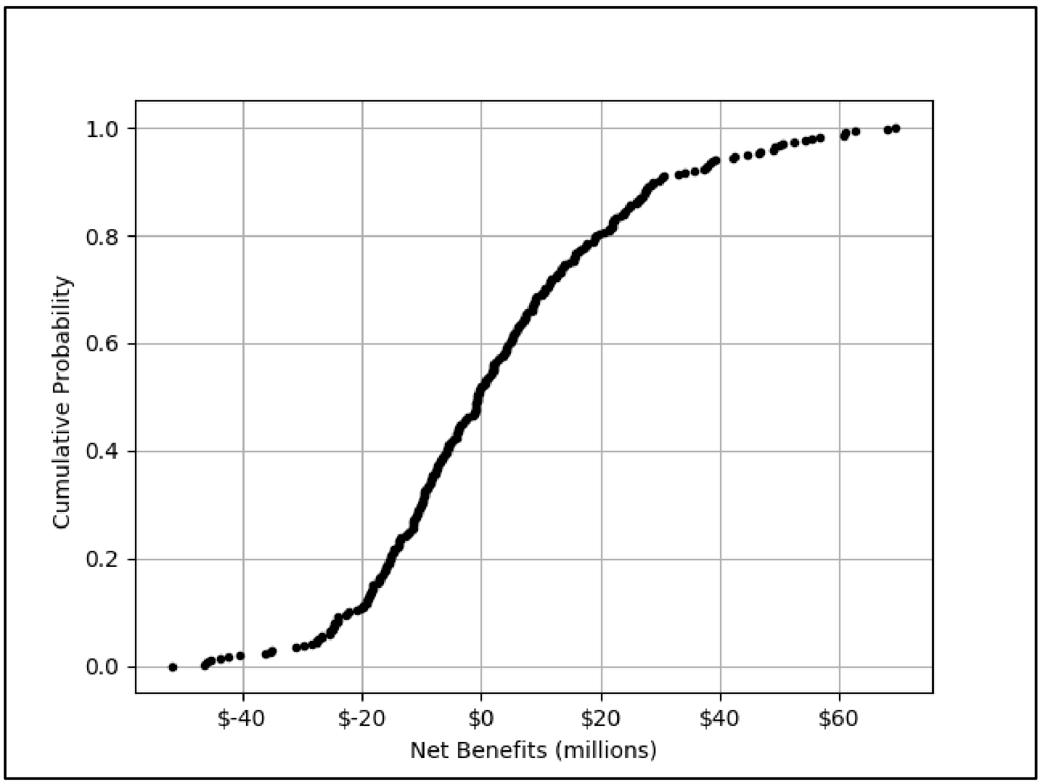

Figure 7-10: Empirical CDF of Net Benefits

8.0 COMMENTS ARISING FROM DISTRICT QUALITY CONTROL REVIEW

As a part of the Beach-fx modeling at South Padre Island, a District Quality Control review was completed by the USACE North Atlantic Philadelphia District (CENAP). A number of comments were received and addressed by the project PDT. This section details the comments that have been received to date, as well as the responses from the PDT. Some of the comments outlined in this section were "not a [part of a] formal District Quality Control comment list, but rather… some initial questions".

8.1 MOBILIZATION THRESHOLD

In Beach-fx, the mobilization threshold is specified as a volume in cubic yards that must be exceeded to justify mobilization for placement of nourishment material. The mobilization threshold was initially set to 100,000 cubic yards.

<u>CENAP Comment(s):</u> *Mobilization Threshold – probably unnecessary to have a value greater than 0 here. Can assume all nourishment cycles will be completed.*

<u>PDT Response:</u> Although not specified as *0*, the mobilization threshold was updated to *1* to ensure that mobilization and nourishment occur at the nourishment cycle. The PDT did not specify a value of *0* due to the treatment of mobilization in Beach-fx. With the threshold set at *0*, at each nourishment cycle, the reach would be triggered for nourishment, and mobilization costs applied, regardless of if any material was placed. A mobilization threshold of *1*, ensured that at least 1 cubic yard of sand was required before mobilization costs were applied.

8.2 BACK-BAY FLOODING

In Beach-fx, back-bay flooding is a user option that allows one to simulate the bay-side flooding of barrier islands. It is possible to implement protective features in Beach-fx that prevent bay-side flooding. Back-bay flooding was initially turned off.

<u>CENAP Comment(s):</u> (1) *Back Bay Flooding – Boolean flag is unchecked. Is there evidence of co-incident inundation in this area? Can affect inundation reduction benefits.*

(2) *Investigate back bay flooding. If there is no evidence of co-incident flooding then this is a non-issue, but with back bay flooding turned off, you may be overstating inundation reduction benefits. If you feel that still water will flank the dune or flood from the back bay, then it would be prudent to turn on this flag.*

<u>PDT Response:</u> An investigation into bay side flood reduction alternatives was beyond the scope of the Beach-fx work at South Padre Island. Because no back-bay flooding alternatives were considered, then any damages resulting from the FWP conditions will negate the damages resulting from the FWOP conditions. Regardless, a test simulation occurred in which back-bay flooding was turned on for both FWOP and FWP conditions. The

results (Table 8-1) show that the differences are negligible. The PDT concluded that the remaining simulations will occur in the absence of back-bay flooding.

Table 8-1
Sensitivity Test of With and Without Back-Bay Flooding

	No Back-Bay Flooding	With Back-Bay Flooding
FWOP Damages	$144,006,831	$144,028,188
FWP Damages	$125,241,602	$125,389,770
PN Costs	$15,479,983	$15,479,983
BCR	1.1654	1.1518

8.3 MAXIMUM NUMBER OF REBUILDS

An option is available in Beach-fx that allows the user to specify the maximum number of rebuilds that will occur to a single damage element before the damage element is removed from the inventory. For all damage elements at South Padre Island, this value was set to 9,999.

<u>CENAP Comment(s):</u> (1) *Number of Rebuilds – why 9999?*

(2) *The number of rebuilds is set quite high. As it reads now, the owner of the building will repair his structure 9999 times in the exact same manner across the 50-year project life. If Damage Element condemnation is turned on (any damage over 50 percent results in removal from the inventory) then this is not a huge issue. Also, removal from the inventory doesn't necessarily mean demolished, but could also include structure elevation. For large commercial or apartment structures, it's OK to not have damage element condemnation turned on as these structures are not easily elevated. Would require a full deconstruction and a new structure on the same parcel of land.*

<u>PDT Response:</u> The PDT specified the number of rebuilds to 9999 as a placeholder to allow an “infinite” number of rebuilds. Historically, there is no evidence at South Padre Island that land will remain vacant if a structure is removed. This applies even if the structure is completely destroyed.

8.4 CONTROL LINE OFFSET

The control line offset in Beach-fx allows the user to specify a distance from the centroid of a lot to the seaward toe of the dune, which will mark the lot as condemned. The condemnation of a lot prohibits rebuilding of damage elements within the lot. This option was initial set to *0*.

<u>CENAP Comment(s):</u> *Control Line Offset – affects timing of [Lot] condemnation. May consider moving back (negative number) depending on condemnation results.*

<u>PDT Response:</u> Sensitivity tests were performed with varying control line offset values ranging from *0* to *-100* feet. The PDT decided to keep the control line offset at *0* feet due to the fact that the majority of lots on seaward

side of the island do not have land behind the structures. The PDT feels that a control line offset of *0* is the most feasible option.

8.5 FOUNDATION TYPES

Foundation types in Beach-fx alter how a structure behaves to erosion damages. Three foundation types are pre-defined in the model (Slab, Pile, and Pile16), with an option for the user to define more to meet case specific needs. The predefined foundation types, Pile and Pile16, define to the depth of the pile below the surface (8 and 16 feet, respectively).

<u>CENAP Comment(s):</u> (1) *Foundation Types – Pile vs Pile16 have different critical erosion amounts. Can drastically alter erosion damage results.*

(2) *I'm guessing that the model will be very sensitive to the selection of Pile16 vs Pile8 foundation types, so you'll need to develop a criteria for applying Pile16 or Pile8 for each structure. If the model results are not very sensitive, then it's a moot point and you don't need to worry about it.*

<u>PDT Response:</u> The selection of foundation type for each damage element was distinguished based on the type of structure. When creating the structure inventory, the PDT was informed that all structures in the damage element inventory are supported by a pile foundation. Within Beach-fx, all beach high rise structures were assigned a Pile16 foundation, whereas all other structures were assigned a pile foundation.

8.6 TIME TO REBUILD

Beach-fx allows the user to specify the amount of time it takes a structure to be rebuilt from damages received. Each structure was assigned a unique time to rebuild.

<u>CENAP Comment(s):</u> *Time to Rebuild – not uniform; even among the same Damage Element type. How were these developed?*

<u>PDT Response:</u> The time to rebuild was based on best judgment from the size/type/number of floors of the structure.

8.7 REACH PLANFORM RATES

Reach planform rates are discussed in detail in Section 7.2. The specification of reach planform rates in Beach-fx allow the user to model the project induced shoreline change rates that result from perturbations in the shoreline.

<u>CENAP Comment(s):</u> (1) *Reach Planform Rate – already discussed but will alter alternative selection due to nourishment volume (and subsequent cost) changes.*

<u>PDT Response:</u> Reach planform rates were identified analytically as outlined in Section 7.2. An analytical solution was chosen over a longshore transport model such as GenCade or Genesis due to time constraints.

8.8 DEPTH OF CLOSURE/WIDTH OF ACTIVE PROFILE

The depth of closure and width of active profile options in Beach-fx are related to the Bruun rule (Bruun, 1954) and sea level rise. These values were initially set as the default Beach-fx values.

CENAP Comment(s): *Depth of Closure/Width of Active Profile – were these developed together?*

PDT Response: The depth of closure and width of active profile were updated in the final model. The depth of closure was specified as 30 feet to be consistent with the SBEACH runs that were completed. The width of the active profile was specified as 4,000 feet based on the average cross-shore distance to the depth of closure for each representative submerged profile.

8.9 ARMORING

Armoring in Beach-fx is specified at the lot level and protects damages elements within the lot from damages caused by erosion. Armoring units can fail, leaving the damage elements susceptible to erosion damages. Furthermore, if an armoring unit fails, there are costs associated with reconstruction. The vast majority of lots within Beach-fx were initially specified as armored.

CENAP Comment(s): (1) *Armor (Lot)/Armor (DE) – you have armor input for almost every Lot and Damage Element. Armor can have a massive impact on damage calculations and seems to have issues with high erosion rates. I would consider running a sensitivity test comparing your current model results (with armor) to an identical model that removes armor input (no armor) to measure the level of impact.*

(2) *Armor. This is probably the most important point. I would heavily recommend a sensitivity test with removing all Armor and comparing these results with the original estimates. If none of the alternatives are justified even after this sensitivity, then there is no actionable alternative. If the BCR does creep above 1.0, then the next step is to evaluate which armor meets Corps standards and can be included, and which armor cannot be considered to reliably reduce erosion/wave/inundation impacts. For NAP, two sites in a recent GI had extensive armoring, but these were private, ad hoc measures and none of them met Corps standards. As such they were not included in the final model.*

PDT Response: As noted by CENAP, Beach-fx was initially set up such that most units were considered armored. A typical example of a structure at South Padre Island with a retaining wall facing seaward is shown on Figure 8-1. The city of South Padre Island does not consider the protective structures shown on Figure 8-1 to be armoring and refuses to use the term "seawall." The PDT decided to run Beach-fx without armoring and place this option in the Risk Register, to be addressed later if necessary.

Figure 8-1: Example of Retaining Wall at South Padre Island

8.10 INCREASED BERM WIDTH FOR INCREASED NOURISHMENT CYCLE

CENAP Comment(s): *When deciding on your berm width, consider the minimum berm acceptable at a given location. For example, if I want to maintain a 25-foot berm width for Reach R4 with a With-Project erosion rate of 2 feet per year, then the berm width for the 1-year nourishment cycle is 27 feet. For the 5-year cycle, the berm width is 35 feet and so on. You'll have developed that matrix of Dune + Berm conditions and the resulting Reach Planform Rates and will need to apply that value for each alternative.*

PDT Response: Before a dune/berm template was identified, the PDT tested two variations in berm width (100, 150 feet; Section 7.1). The berm width of 100 feet returned the greatest BCR when the selected reaches were specified to be renourished as needed. Due to time constraints, varying berm widths based on the nourishment cycle could not be tested. The PDT feels that because the two variations in berm width were initially tested, then additional variations will not alter the TSP significantly. Furthermore, the results showed that an increase in berm width from 100 to 150 feet did not cause an increase in the BCR, but rather caused a reduction.

8.11 EROSION RATE IN REACH R3

Within Beach-fx, shoreline change rates are a result of storm induced changes, berm width recovery from the storms, the applied erosion rate, and (under FWP conditions) the reach planform rates. The applied erosion rate is adjustable and allow the user to calibrate Beach-fx to historically observed shoreline change rates. At South Padre Island, an average shoreline change rate was computed for each reach based on the procedure outlined in Section 5.2. This procedure resulted in negative values for all reaches, except Reach R3.

CENAP Comment(s): *Investigate the erosion rate at Reach R3 first. This is a fundamental variable that will heavily affect your Without- and With-Project Conditions. Whatever erosion rate you specify, you'll need to be prepared to justify that rate (and the rates for all the other Reaches as well).*

PDT Response: The PDT ran a sensitivity test with an arbitrary applied erosion rate of –1.5 feet/year in Reach R3. Although Beach-fx proved to be sensitive to the negative applied erosion rate, the PDT feels confident in the applied erosion rates that were originally specified in Section 5.3. HDR engineering completed a similar analysis in which they estimated the erosion rates in the absence of any beneficial use projects (HDR, 2010). Figure 8-2 shows the results from the HDR analysis, in which the segment of shoreline between survey stations 130+00 and 185+00 result in a positive shoreline change. Stations 130+00 to 185+00 correspond approximately to Reach R3.

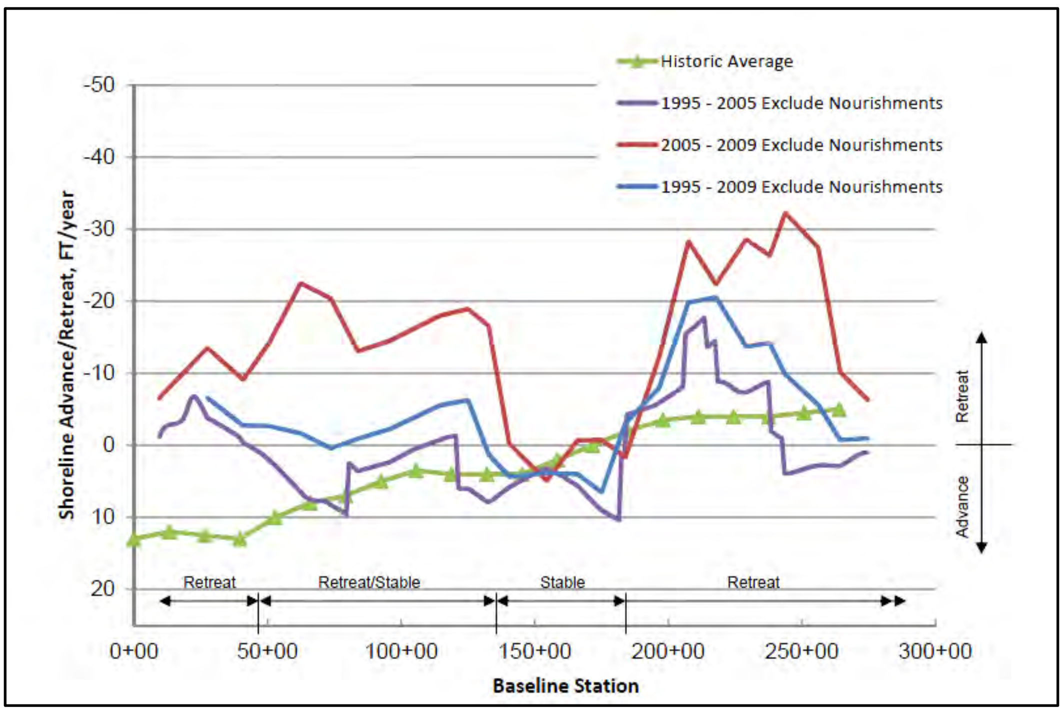

Figure 8-2: Shoreline Change from HDR Engineering

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