TAYLOR ENGINEERING, INC.

Coastal Erosion Planning and Response Act (CEPRA) Economic and Natural Resource Benefits Study

Texas

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Coastal Erosion Planning and Response Act (CEPRA)
Economic and Natural Resource Benefits Study

Prepared for

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by

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EXECUTIVE SUMMARY

The Texas Legislature requires the General Land Office (GLO) to report the economic and natural resource benefits derived from Coastal Erosion Planning and Response Act (CEPRA) construction projects every biennium. Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. This study finds the state of Texas receives $4.8 in economic and financial benefits for every dollar of state funding invested in these projects. This result is based on analysis of the following 15 CEPRA Cycle 7 – 8 projects, which is a representative sampling of the CEPRA program:

- #1516 McFaddin NWR Beach Ridge Restoration (Cycle 7)
- #1520 Bird Island Cove Marsh Restoration (Cycle 7)
- #1521 End of Seawall Beach Nourishment (Cycle 7)
- #1527 Indian Point Shoreline Protection & Marsh Restoration (Cycle 7)
- #1569 Corpus Christi North Beach BMMP Maintenance Renourishment (Cycle 7), performed in accordance with the GLO Beach Monitoring & Maintenance Plan
- #1570 Village of Surfside Beach BMMP Maintenance Renourishment (Cycle 7), performed in accordance with the GLO Beach Monitoring & Maintenance Plan
- #1571 Quintana-Bryan Beach Nourishment (Cycle 78), a Hurricane Ike FEMA repair project
- #1573 Village of Surfside Beach Revetment Emergency Repair (Cycle 7)
- #1576 Arturo Galvan Coastal Park Living Shoreline Restoration (Cycle 8)
- #1577 Keith Lake Fish Pass Baffle Shoreline Protection & Marsh Restoration (Cycle 8)
- #1588 Oyster Lake Habitat Restoration (Cycle 8)
- #1591 Magnolia Inlet Shoreline Protection & Marsh Restoration (Cycle 8)
- #1603 Rockport Beach BMMP Maintenance Renourishment (Cycle 8) performed in accordance with the GLO Beach Monitoring & Maintenance Plan
- #1608 GIWW Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material (BUDM) Fiscal Year 2015 event (Cycle 8)
- #1609 Galveston Seawall 61st to 103rd St. Beach Nourishment with Beneficial Use of Dredged Material (Cycle 8)

The project benefits analyses classified and estimated economic and financial benefits associated with commercial and recreational fishing, tourism and ecotourism (wildlife viewing), improved water quality, carbon sequestration, beach recreation, out-of-state visitor spending, non-Texas project funding, and storm protection. The stream of economic benefits over time varied from project to project depending on a project's durability. The period of analysis for the various projects varied from 1 to 25 years.

This study adopts a Texas accounting perspective. Funding from outside Texas and spending by visitors from outside the state represent financial benefits to the state. A Texas accounting perspective views project contributions normally considered a cost when viewed from a national or world perspective as a financial benefit. Costs funded by non-Texas dollars represent a financial benefit because money flows into the Texas economy. As appropriate, the findings reported here show this adjustment to reflect the Texas accounting perspective for the estimates of benefits and costs. This report serves to estimate the cost-effectiveness of the fifteen projects listed above via benefit-cost ratios and net benefits on an individual project basis, and as a group, or "portfolio."

Table E.1 presents a summary of the assessed projects. The direct and positive net benefits (benefit-to-cost ratios greater than one) from the fifteen evaluated projects combined indicate that these coastal erosion control projects yield high returns on investment for the state of Texas. Preserving Texas' coastal assets proves a worthy public investment strategy for Texas taxpayers and citizens.

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the overwash protection berm at the McFaddin National Wildlife Refuge (NWR) reflects contributions from the U.S. Fish and Wildlife Service (USFWS) and Coastal Impact Assistance Program (CIAP), which covered 98.4% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.67 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Table E.1 Summary of CEPRA Cycles 7 – 8 Projects, Costs, and Benefits

CEPRA Project Number / Name	County	Project Year[1]	Beginning of Project Year		Beginning of 2016[3]		Benefit-to-Cost (B/C) Ratio
			Discounted Cost[2] ($)	Discounted Benefits ($)	Discounted Cost[3] ($)	Discounted Benefits ($)	
#1516 McFaddin NWR Beach Ridge Restoration	Jefferson	2014	415,859	21,671,271	442,557	23,062,535	52.1
#1520 Bird Island Cover Marsh Restoration	Galveston	2014	715,042	2,307,597	760,947	2,455,741	3.2
#1521 End of Seawall Beach Nourishment	Galveston	2015	1,475,049	4,539,140	1,521,661	4,682,577	3.1
#1527 Indian Point Shoreline Protection & Marsh Restoration	San Patricio	2015	899,001	1,296,095	927,409	1,337,052	1.4
#1569 Corpus Christi North Beach BMMP Nourishment	Nueces	2016	2,475,577	10,408,114	2,475,577	10,408,114	4.2
#1570 Village of Surfside Beach BMMP Maintenance Nourishment	Brazoria	2015	2,244,323	925,772	2,315,244	955,026	0.4
#1573 Village of Surfside Beach Revetment Emergency Repair							
#1571 Quintana-Bryan Beach Nourishment	Brazoria	2016	801,380	1,585,708	801,380	1,585,708	2.0
#1576 Arturo Galvan Coastal Park Living Shoreline Restoration	Cameron	2016	608,409	302,393	608,409	302,393	0.5
#1577 Keith Lake Fish Pass Baffle Shoreline Protection & Marsh Restoration	Jefferson	2015	4,109,350	41,459,640	4,239,205	42,769,765	10.1
#1588 Oyster Lake Habitat Restoration	Brazoria	2016	487,947	1,656,822	487,947	1,656,822	3.4
#1591 Magnolia Inlet Shoreline Protection & Marsh Restoration	Calhoun	2015	113,361	12,530,728	116,943	12,926,699	110.5
#1603 Rockport Beach BMMP Maintenance Renourishment	Aransas	2016	409,605	1,835,436	409,605	1,835,436	4.5
#1608 GIWW Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material (BUDM)	Galveston	2015	250,000	47,612	257,900	49,117	0.2
#1609 Galveston Seawall 61st to 103rd St. Beach Nourishment with Beneficial Use of Dredged Material	Galveston	2016	7,990,000	29,020,938	7,990,000	29,020,938	3.6
Total[4]					$23,354,784	$133,047,923	5.7

Notes: [1] Project Year represents the year benefits begin to accrue and may not represent the actual construction year.

[2] Texas portion only; dollar values reflect present worth equivalents at the beginning of Project Year.

[3] Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.16% discount rate.

[4] Total B/C Ratio represents the Total Discounted Benefits divided by the Total Discounted Cost of all five projects combined (i.e., 133,047,923 / 23,354,784 = 5.7).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits, as described by the following examples. The McFaddin NWR Beach Ridge Restoration Project experienced federal spending benefits ($4,796,321 discounted present worth) from USFWS and CIAP funding as mentioned above. Similarly, Bird Island Cove Marsh Restoration experienced federal spending benefits ($1,399,405 discounted present worth) from funding by USFWS Texas Coastal Program and a USFWS National Coastal Wetlands Conservation Grant. Funding provided by the Federal Emergency Management Agency (FEMA) led to significant federal spending benefits for the End of Seawall Beach Nourishment ($4,255,032 discounted present worth) and Quintana-Bryan Beach Nourishment ($1,126,183 discounted present worth).

A discount rate of 3.16% was used in the benefit cost calculations to convert benefits and costs occurring at different points in time to comparable equivalent values ("discounted present worth") for comparison at the beginning of each project's period of analysis. In Table E.1, the discounted present worth of benefits and costs is also converted to equivalent values at a common point in time, 2016. This makes the benefits and costs of the different projects comparable and additive, allowing them to be viewed as a portfolio. The discount rate chosen for this study represents a mid-range average of 20-year AAA corporate bond rates existing at the time of study initiation.

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1.0 INTRODUCTION

1.1 Purpose

Texas' coastal assets, including infrastructure, industry, public and private property, beaches, dunes, wetlands, marshes, and parks, provide significant economic value for the Texas citizenry. Natural and man-made activities, such as storms or cuts in barrier islands, and their subsequent consequences of erosion and increased damage to property and infrastructure adversely affect these coastal assets. To address the significant erosive threat to Texas coastal areas, the 76th Texas Legislature passed the Texas Coastal Erosion Planning and Response Act (CEPRA) in 1999. The CEPRA program, in concert with local and other project partners, invests significant state resources to control coastal erosion. Funded biennially in accordance with the state's budget cycles, the CEPRA program has allocated approximately $97 million combined for Cycle 1 – 8 projects, covering state fiscal years 2000 – 2015. The Texas General Land Office (GLO) has created project partnerships between federal, state, and local entities, which have matched the Cycle 1 – 8 CEPRA funds with an additional $49 million from other state and local resources and $157 million in federal funds, resulting in a total investment of approximately $303 million. The GLO applies CEPRA funds for beach nourishment projects, dune restoration projects, shoreline protection projects, habitat restoration/protection, coastal research and studies, and estuary programs.

The Texas Legislature requires the GLO to report the economic and natural resource benefits derived from CEPRA construction projects every biennium. The GLO contracted Taylor Engineering, Inc. — under GLO Contract No. 13-333-013 and Work Order No. A080 — to perform the benefit-cost analyses for selected Cycles 7 – 8 construction projects. This study analyzed the following five CEPRA projects:

- #1516 McFaddin NWR Beach Ridge Restoration (Cycle 7)
- #1520 Bird Island Cove Marsh Restoration (Cycle 7)
- #1521 End of Seawall Beach Nourishment (Cycle 7)
- #1527 Indian Point Shoreline Protection & Marsh Restoration (Cycle 7)
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These projects represented $11.5 million out of a collective $29.3 million ($15.3 million for Cycle 7 and $14.0 million for Cycle 8) allocated for funding coastal erosion projects and studies during Cycles 7 – 8. Figure 1.2.1 presents a map of the projects' locations along the Texas coast. These projects include seven beach restoration projects, one revetment repair project, six associated with shoreline protection and natural resource protection and/or creation, and one project solely for natural resource protection/creation. This report serves to estimate the cost-effectiveness of the 15 projects listed above via benefit-to-cost ratios.

1.2 Report Scope

This report discusses the methodology and results of the natural resource and economic benefit analyses for select projects constructed during Cycles 7 – 8. Following this introduction, Chapter 2 describes the economic and natural resource benefit methodologies applied in the study. Chapter 3 discusses economic benefits and costs associated with beach restoration and coastal storm risk management. Chapter 4 discusses benefits and costs associated with natural resource protection and/or creation. Chapter 5 summarizes and concludes the report.

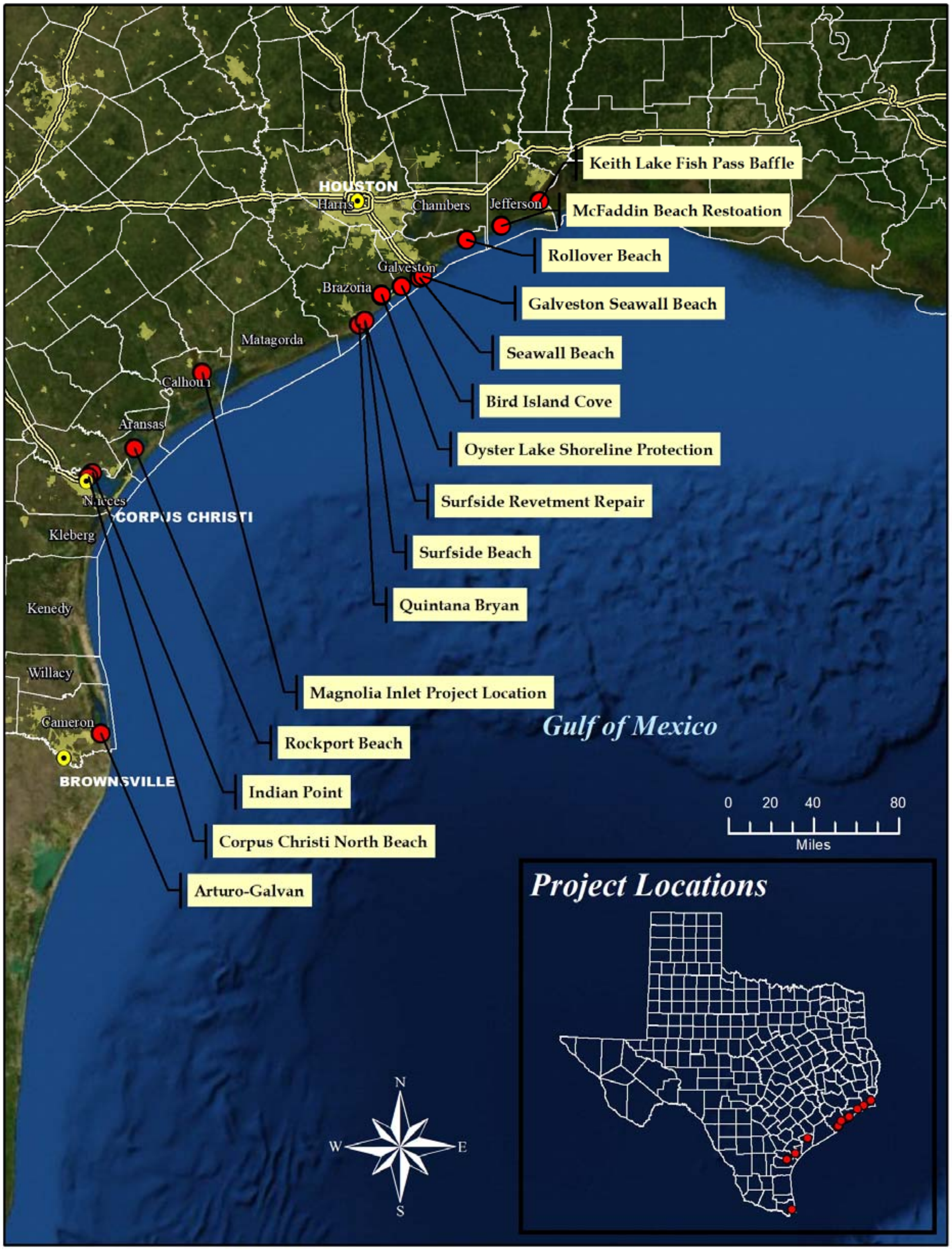


Figure 1.2.1 Location Map of Cycles 7–8 Subject Projects

2.0 ECONOMIC AND NATURAL RESOURCE BENEFITS METHODOLOGY

2.1 General Concepts

Beach restoration and shoreline protection projects result in economic benefits when the projects mitigate for erosion and degradation of beaches and dunes and protect upland property and infrastructure. Natural resource projects result in economic benefits when the projects protect, restore, or create wetlands and other habitats. Beach/dune and natural resource projects' economic benefit methodologies differ in many respects as detailed in Sections 2.2 and 2.3. While each project type requires different methodological steps and procedures, some over-arching concepts apply to all of these projects. This study adopts methodologies similar to those applied in the previous economic benefit studies (Stites et al., 2008; Krecic et al., 2009; Krecic et al., 2011; Trudnak et al., 2013, and Trudnak et al., 2015).

Overall, benefits and costs represent the estimated difference, over the period of analysis, between conditions with the project and conditions without the project. Adjusting each year's benefits and costs reflects then-current price levels with an assumed annual inflation rate derived from the consumer price index (CPI) (http://www.minneapolisfed.org/community_education/teacher/calc/hist1913.cfm) for historical years and long-term forecasts by the Federal Open Market Committee of the U.S. Federal Reserve and the Congressional Budget Office for years beyond 2014. Table 2.1.1 summarizes these rates. An annual discount rate of 3.16% (reflecting a mid-range average of 20-year AAA corporate bond rates at the time of this study) converts values occurring at different points in time to comparable equivalent values, adjusting for the time preference function. The reference point in time for this discounting, or present worth adjustment calculation, is the beginning of the first year of the project life for each project. This point varies among projects (beginning of 2014, 2015, and 2016). After all benefit cost calculations are complete for the different projects included in this study, further present worth adjustments are made to express benefit cost analysis results at the beginning of 2016 (i.e., as of the same point in time). This enables the group of projects in this report to be additive and comparable, enabling them to be viewed as a portfolio.

Table 2.1.1 Price Level Adjustment Information

Year	**Annual Average Consumer Price Index**	**Annual Inflation from Previous Year (%)**
2004	188.9	2.7
2005	195.3	3.4
2006	201.6	3.2
2007	207.3	2.8
2008	215.3	3.9
2009	214.5	-0.4
2010	218.1	1.7
2011	224.9	3.1
2012	229.6	2.1
2013	233.0	1.5
2014	236.7	1.6
2015	237	0.1
2016	--	1.4
2017		2.1
2018		2.1
2019		2.1
2020 & Beyond	--	2.2

Present value factors, based on the 3.16% discount rate, convert values at different points in time to comparable values at the same point in time. In these evaluations, the beginning of the period of analysis represents the point in time used for these discounting calculations. The key to this discounting process, or present value conversion, is equivalence. For example, a benefit accruing in year five is equivalent to its discounted value at the beginning of year one. Discounting reflects the concept that values received or spent in the future are worth less than those received or spent now because of interest. Interest reflects a combination of two effects: (1) changes in prices (inflation), and (2) the time preference function (i.e., even without any inflation an interest rate still exists because a dollar now is preferable to a dollar later). These analyses include inflation in the estimates of benefits accruing and costs occurring over time.

This study assumes most benefits accrue throughout the year. To approximate this effect, the present value calculations apply mid-year discounting (instead of the conventional end-of-period convention) for all benefit calculations.

Regardless of initially estimated price levels, benefits are adjusted (based on historical and forecast inflation estimates previously discussed) to represent price levels existing in the year benefits accrue. For some projects, construction took place early in the year, and even though benefits did not begin to accrue until later in that year, this study treats benefits as though they accrue throughout the same year. For these projects, the authors recognize that this method reflects, if not what really happens, then something very close. The small effect of this calculation method (i.e., the difference between the method and what really happens) on the outcome is insignificant.

This study treats costs as single point-in-time values at the beginning of the period of analysis. The analyses usually exclude a time value adjustment to reflect the actual pattern of project implementation spending that occurred over time because of the relatively short project implementation period (less than a year). The effect of that adjustment would prove insignificant. But for projects with costs spread over a longer period of time, or occurring later in the period of evaluation, appropriate discounting of costs is done.

The stream of economic benefits over time varies from project to project depending on the durability of the project. The period of analysis for the various projects varies from 1 to 20 years.

This study adopted a Texas accounting perspective. Texas taxpayers and citizens likely have the most interest in Texas costs and benefits. Funding from outside Texas and spending by visitors from outside the state represent financial benefits to the state. From a national or world perspective, funding sourced from outside Texas is a cost. A "Texas" accounting perspective, however, views project contributions that originate from outside Texas as a financial benefit to Texas. Costs funded by non-Texas dollars represent a financial benefit because money flows into the Texas economy, including the multiplier effect described below. Along with this effect, this study also properly subtracts this non-Texas part of the project cost from the total implementation cost because it does not represent a state-incurred expense. The estimates of costs and benefits in this study reflect this Texas accounting adjustment.

With respect to spending by out-of-state visitors, this study applies multipliers to estimate the secondary effects of spending by non-Texans visiting project sites within the state. These multiplier factors, when multiplied by out-of-state visitor spending, capture the effects of changes in sales, income, and employment brought about by the initial spending amounts. Two types of such effects exist. One type of multiplier effect takes place within backward-linked industries located within the state. These industries include businesses that supply goods and services to the business operations (e.g., food, gas, and lodging) where visitors/tourists spend their money. The other type of multiplier effect results from the spending by employees of the businesses where visitors spend their money and by employees of the backward-linked businesses and industries involved. The part of this spending that takes place within Texas creates additional sales and economic activity.

Detailed analysis could yield this multiplier effect by applying the results of input-output tables (representing the complex web of economic relationships in the economic system) that exist for states and regions and a myriad of economic sectors of the economy. Conducting such an analysis exceeds the scope of this study. Instead, this study applied a more general approach to determine the multiplier effect for out-of-state visitor spending associated with the various CEPRA projects. For purposes of this evaluation, an overall average multiplier of 1.75 serves as a general average effect representative of conditions in the Texas economy (multipliers often range from 1.5 to 2.0.)

The multiplier value of 1.75 is reasonable in light of the following observations. In the Cycle 3 CEPRA report, Oden and Butler (2006) acknowledge that this multiplier effect is "typically in the range of two times the direct effects." This multiplier effect is generally larger for large regions, such as the state of Texas, and smaller for small areas, such as cities and counties. This tendency relates to the higher population, greater number of industries, and overall higher level of economic integration for a large, diverse, and vigorous economy, such as exists in Texas, than for small intra-state areas. Some (e.g., Horwath Tourism & Leisure Consulting, 1981) have estimated tourism multipliers to range from 1.56 to 2.17 for select counties and regions in Pennsylvania, Wisconsin, Wyoming, and Colorado. In addition, Wiersma et al. (2004) have estimated tourism output multipliers to range from 1.33 to 1.45 for various regions in New Hampshire and 1.51 for the state of New Hampshire. Horváth and Frechtling (1999) report multiplier values of 2.40 for the United States, 2.08 for Puerto Rico, 1.76 for Miami, Florida, 1.63 for Washington, DC, 1.21 for Oregon, and 1.44 for Maryland.

Reducing this multiplier effect reflects that only the retail margins and, in some cases, the wholesale and transportation margins of goods and services purchased by visitors remain in the Texas economy. These margins vary across the economy. For lodging, the margins are very large. Most lodging and related service spending likely remains within Texas. For most items made outside of Texas, the margins likely approach about 50%. The average combined effect of this margining can be expressed as a "capture rate," representing on average the portion of visitor spending that the Texas economy captures. This study adopts a capture rate of 80% (0.8). Combining the capture rate of 0.8 with an overall average multiplier effect of 1.75 results in a net multiplier effect of 1.4 (i.e., 0.8 * 1.75 = 1.4). For example, if non-Texans visiting Texas project sites represent 10% of total visitors who spend, on average, $100/day, then the estimated overall financial economic beneficial impact for Texas of this spending equals total visitation days times 0.1 times $100/visit-day times 1.4.

Estimation of a similar effect can also account for any federal spending that may occur as part of initial project construction or recurring annual operations (e.g., maintenance and inspection), because a major portion of federal spending taking place within Texas represents a net increase inflow of spending for the state economy. However, we must reduce the amount of initial federal spending to account for contributions to federal tax revenues from individuals and businesses in Texas. Applying the ratio of the state of Texas population to the U.S. population total as a proxy for this effect (approaching 10%), an estimated net multiplier effect to apply to any such spending would equal federal spending times 0.9 times 1.4, or federal spending times 1.26. This federal spending and its multiplier effect would represent the estimated net economic financial benefit to the Texas economy.

Many argue that "outside money subsidies," as described in the preceding paragraph, do not really constitute part of a project's intrinsic economic performance. However, this study's purpose is to show the net economic and financial benefit-cost accounting for Texas' citizens, taxpayers, and their representatives. Meeting this objective requires making these net adjustments. Although not "project benefits" in a traditional sense, this outside funding is an important part of the net economic and financial benefit-cost story for Texas.

Comparing the estimated benefits to the project costs reveals the net benefits of the projects evaluated in this report. Dividing the discounted present worth of estimated benefits by the discounted present worth of costs produces the benefit-to-cost (B/C) ratio for each project. B/C ratios greater than one indicate cost-effectiveness for a particular project. Comparing the sum of the benefits of all the projects examined in this study to the sum of the costs of all these projects indicates the economic performance of the suite of projects looked at as a portfolio of CEPRA endeavors.

As a final note, hand calculations may yield different results from those tabulated in this report because of number rounding versus spreadsheet calculations.

2.2 Beach Restoration and Shoreline Protection Projects

The recently constructed beach restoration and shoreline protection projects intend to provide immediate protection to the upland property owners against high frequency storms. Beach restoration generally adds large quantities of sand to the beach; most sand placement occurs on the dry portion of the beach. This process results in a seaward movement of beach elevation contours, typically from the beach berm to the shallow nearshore. Beach nourishment represents a means to turn back time. Because the erosion mechanisms still exist, erosion will return the beach to its original state and continue to erode further. Beach restoration design includes specifications of berm elevations to mimic those of the natural beach, berm extensions to obtain desired beach widths, and beach foreshore slopes, typically steeper than the natural beach, to transition the beach fill to the existing beach. Wave action subsequently reshapes the beach profile to a more natural profile.

“Hard” shoreline protection projects, such as the Surfside revetment, typically limit the landward extent of erosion. These rock or concrete structures, typically sloped, induce wave breaking and loss of wave energy during the wave runup process and, therefore, limit reflection of wave energy from shore. Rock revetments typically consist of two or more layers of rock with the upper, larger rock providing stability against wave attack. A properly-designed revetment must ensure that the lower, smaller rock does not wash out through the upper layers. Should this occur, the revetment may lose elevation, and therefore its protective capabilities, through settlement.

Another purpose of beach restoration projects includes restoring and maintaining public recreational beaches. Beach erosion detrimentally affects public recreational use of the sandy beaches by narrowing the dry beach width along the shoreline. Absent sand placement, the recreational beach would continue to narrow and become less suitable for many types of public recreation. As such, this study identified storm damage reduction and visitation benefits as pertinent to the project areas. The paragraphs below discuss these two types of benefits and the associated methodologies used for their calculation.

Storm Damage Reduction Benefits

Beach restoration and shoreline protection projects protect land, infrastructure, and structures on the landward side against both the ongoing background shoreline erosion and episodic, storm-related erosion. The prevention of land loss and damage to infrastructure and structures form the basis of storm protection benefits to upland properties. Storm damage reduction benefits require estimates of background erosion; storm-related erosion; location of properties, infrastructure, and structures with respect to the shoreline; and value of land, infrastructure, and structures near the shoreline. Similar to the above-mentioned prior economic benefit studies, this study adopted a rigorous engineering approach to develop storm damage reduction benefits. Note that not all the components of the approach discussed below applied to the project evaluations conducted for this study. For example, storm protection benefits to habitable structures may not have occurred for any of the projects. However, for informational purposes, this report discusses all components of the approach, as they have been pertinent to previous studies and will likely apply to future studies.

Background erosion estimates obtained from the University of Texas at Austin, Bureau of Economic Geology (UTBEG) (www.beg.utexas.edu), unless otherwise noted, provide the data for predicting the long-term erosion expected to occur at a beach.

Computing storm-induced beach erosion requires applying a numerical model such as Storm-Induced Beach Change (SBEACH) (Larson and Kraus, 1989). This storm erosion model, developed to simulate beach profile change due to cross-shore transport of sediment under changing water levels and breaking waves, provides short-term erosion and recovery predictions on straight beaches. The model assumes that a beach profile evolves to a new equilibrium profile in response to the elevated water levels associated with the storm surge and increased breaking wave heights associated with the storm wave height. Model application requires information on beach profiles, beach sand size, and wave height and period and water level time series (hydrographs) for the duration of the storm.

The GLO, Texas A&M University, and/or UTBEG provided site-specific beach profile survey data along the project shorelines. The survey data include both pre- and post-construction information. Engineering reports supplied representative sand size information in the project areas.

The U.S. Army Corps of Engineers (USACE) Wave Information Study (WIS) hindcast provides offshore wave conditions (wave height, period, and direction) for the SBEACH model. Other numerical models (e.g., WISWAVE, WAM) driven by climatological wind fields overlaid on grids of the estimated bathymetry generate the WIS hindcast data. The WIS numerical hindcasts supply long-term wave climate information at nearshore locations (stations) of U.S. coastal waters. In some instances, measurements from National Data Buoy Center (NDBC) offshore buoys provided wave information.

Water level (storm surge) information originates from sources such as site-specific Federal Emergency Management Agency (FEMA) flood insurance studies. These studies report peak water level elevations for various return period storms. These reported elevations include astronomical tide in addition to storm effects. In some instances, measured water levels originate from the Texas Coastal Ocean Observation Network (TCOON) stations.

Computation of storm-induced erosion requires selection of representative beach profiles along the various project areas. Delineation of the project shoreline into reaches minimizes the amount of these computations. SBEACH application with the above information and with select model tuning parameters provided beach recession-frequency curves for each examined beach profile in this study.

Analyses necessitated computing damages due to background erosion and storms for each project year. For years 2012 – 2014 and 2016, no tropical storms significantly affected the project areas. In 2015, Tropical Storm Bill made landfall in Matagorda County, causing flooding from storm surge and rainfall; however, the storm's coastal erosion impact on projects selected for this study appears minimal. For 2017 and beyond, this study modeled the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for each future year's shoreline position.

Damage calculations considered the values of land, infrastructure, and structures on the affected properties. For undeveloped properties, this analysis considered the location of the seaward edge of the property from the shoreline, the land area lost due to the corresponding storm-related recession, and the estimated unit land market value for the particular property as obtained from the appropriate property appraisal district. For developed properties, this analysis considered the location of the seaward edge of the property from the shoreline, the distance of the seaward and landward sides of infrastructure and structures from the shoreline, the values of structures for the particular property as obtained from the appropriate property appraisal district, the land area lost due to corresponding storm-related recession, and the unit land value for the particular property as obtained from the appropriate appraisal district.

Following similar USACE methods, this analysis distinguishes between slab-on-grade and pile-supported structures. It assumes damage to slab-on-grade structures occurs when the shoreline recedes landward of the seaward edge of the structure and that total damage occurs when the shoreline recedes halfway through the structure. Note that many post-storm observations (e.g., GEC, 2005) revealed that mid- and high-rise residential buildings with robust structural systems and on deep foundations tend to sustain inundation and wave damage only to the lowest floors, with upper floors remaining intact and undamaged by flood. Accordingly, this study assumes damage occurs to pile-supported structures (with two or more stories that likely have deep foundations) when the shoreline recedes landward of the seaward edge of the structure and that total damage (damage to the lowest two stories only) occurs when the shoreline recedes to the landward edge of the structure. Figure 2.1 presents a typical damage function curve for these two structure types. For example, given erosion extends 35% into a slab-on-grade structure's footprint and the structure appraises at $200,000, this structure sustains 70% damage or $140,000 worth of damage with the above assumptions applied.

Property appraisers usually do not disaggregate structure values by story. Therefore, the present analysis assumes the values divide equally across the number of stories. For example, a five-story, pile-supported structure appraised at $500,000 has a $100,000 per-story value. Therefore, the lowest two stories' total value equals $200,000, the value eligible for damage.

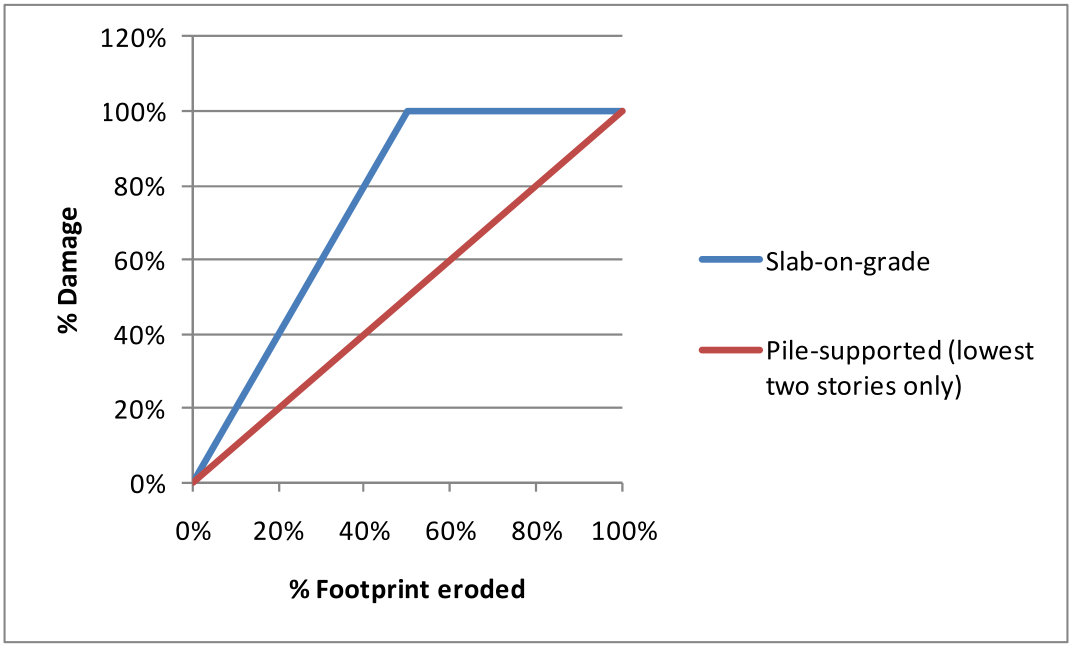


Figure 2.2.1 Structure Damage Functions

The functional relationship between return period and cumulative probability relates damage to cumulative probability. That is, return period relates to the cumulative probability distribution by

$$T_r = \frac{1}{1 - P(X)} \tag{2.1}$$

where T_r is the return period and $P(X)$ is the cumulative probability of X, a storm event. As noted above, this study modeled the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms. Substituting 1 for T_r in Eq. 2.1 and solving for $P(X)$ yields 0 or 0%. Therefore, storms will exceed the 1-year storm, on average, 100% of the time. Similarly, substituting 20 for T_r in Eq. 2.1 and solving for $P(X)$ yields 0.95 or 95%. Therefore, storms will exceed the 20-year storm, on average, 5% of the time.

After modeling the effects of 1-, 2-, 5-, 10-, 20-, 50-, and 100-year return period storms for a particular year's shoreline position, one may develop a damage-cumulative probability curve similar to Figure 2.2. The area under the damage-cumulative probability curve then establishes the expected annual damage for the year. Calculating the area under the curve requires averaging the total damage between adjacent damage points and multiplying by the probability interval between cumulative probabilities corresponding to the damage points (i.e., the trapezoidal integration method). By way of an example, Figure 2.2 shows two labeled points on the damage-cumulative probability curve. The area (valued at $792,000) under the portion of the curve bound by the two points equals the average of \$4,900,000 and \$380,000 (\$2,640,000) times the difference of 0.8 minus 0.5 (0.3). Following this procedure and summing the individual results produces the total area under the curve (i.e., expected annual damage for that year).

Note the expected annual damage will not necessarily occur in a particular year. Rather, over a long time period, the average damage will approach this expected value. The damage-cumulative probability relationship changes every year because background erosion moves the shoreline landward every year. Accounting for this erosive beach behavior requires calculating damage-cumulative probability curves for each project year throughout the period of analysis. Furthermore, this analysis, consistent with USACE practice, assumes the repair of the preceding year's structural damage before each subsequent year. For example, say a total expected annual damage equals \$2,000,000 including \$1,250,000 in structural damage and \$750,000 in land loss in 2015. Before 2016, this analysis assumes repair of the \$1,250,000 structural damage such that the damage could occur again in 2016. Only the land loss (\$750,000) becomes ineligible for future years' damage (or benefit). The total project benefit for a given year represents the difference in the expected value of storm damage between without- and with-project conditions.

Table 2.2.1 presents an example damage-cumulative probability distribution for a given year's without-project conditions. Calculating the expected average interval damage requires three steps. First, average two adjacent total damage estimates of different return period storms. For example, the total damage for 10- and 20-year return period storms equals \$108,009 and \$132,125 based on model simulations. The average of these two values equals \$120,067. Next, determine the interval probability (0.05) by subtracting the cumulative probability value for the 10-year (0.90) from the 20-year (0.95) return period storm. Third, multiply the average interval damage (\$120,067) by the interval probability (0.05) to yield the expected value interval damage (\$6,003). Repeating these calculations for each expected value interval damage calculation and summing produces the expected average annual damage for a given year and project condition. Performing this procedure for each year in the period of evaluation for conditions with and without the project results in expected value annual damages for each year with and without the project. Table 2.2.2 presents an example storm damage reduction benefit calculation, which shows the cumulative present worth of the storm damage reduction benefit for all years in the period of analysis. For the example results shown in Table 2.2.2, no major storms actually impacted the project area during 2016, hence the project did not provide storm damage reduction benefits for that year.

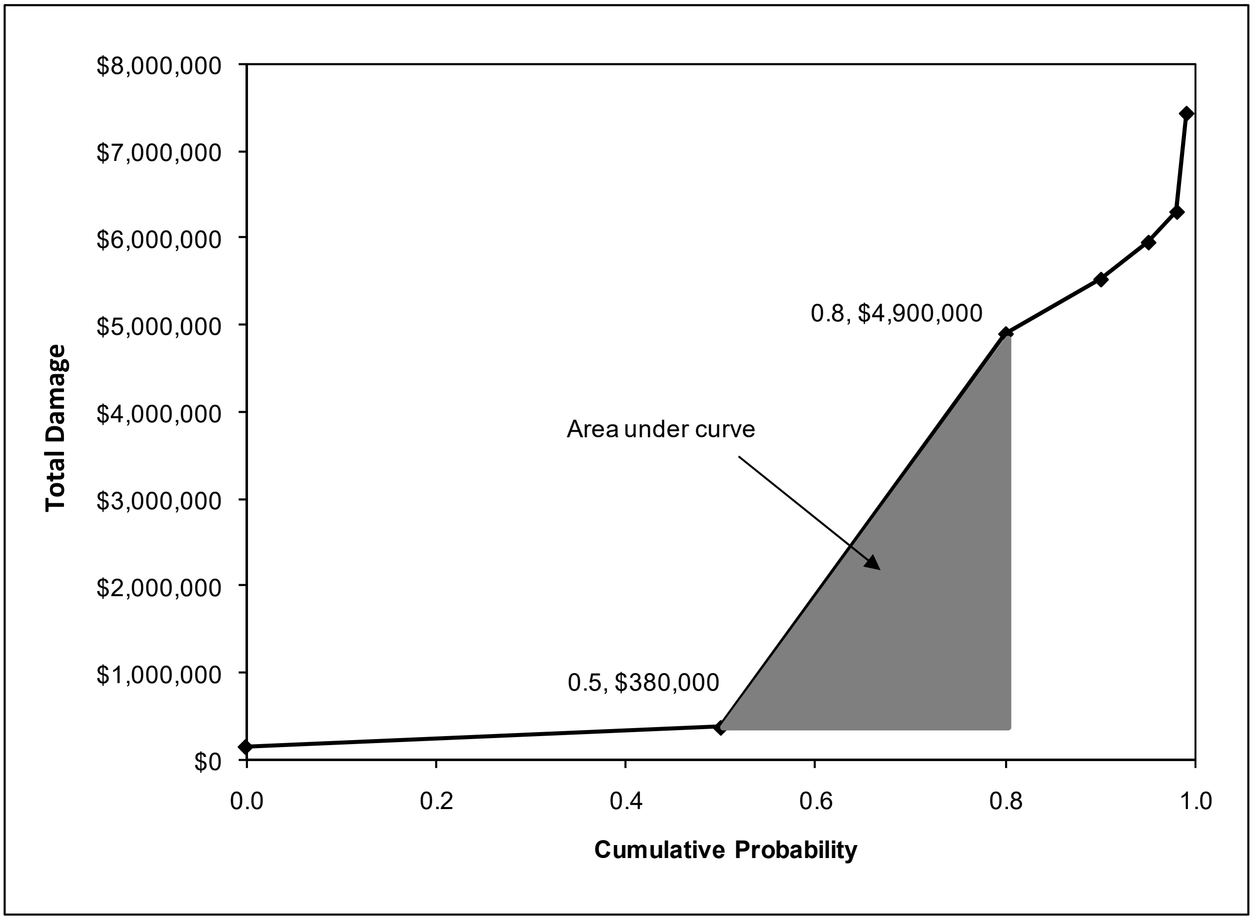


Figure 2.2.2 Example Damage-Cumulative Probability Curve for a Given Year

Table 2.2.1 Example of Total Damage-Cumulative Probability (Year 2, With Project)

Tr[1] (yrs)	**Probability**	**Cumulative Probability**	**Lot Damage**	**Structure Damage**	**Total Damage**	**Average Interval Damage**	**Interval Probability**	**Expected Value Interval Damage**
1	1.00	0.00	$6,681	$0	$6,681	-	-	-
2	0.50	0.50	$7,467	$0	$7,467	$7,074	0.5	$3,537
5	0.20	0.80	$7,598	$0	$7,598	$7,533	0.3	$2,260
10	0.10	0.90	$10,349	$97,660	$108,009	$57,804	0.1	$5,780
20	0.05	0.95	$10,349	$97,660	$108,009	$108,009	0.05	$5,400
50	0.02	0.98	$10,611	$97,660	$108,271	$108,140	0.03	$3,244
100	0.01	0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
>100	<0.01	>0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
Expected Average Annual Damage in 2016 Prices:								$22,387

Table 2.2.2 Example of Storm Damage Reduction Benefit Calculation

Year	**Without Project (2013 Prices)**	**With Project (2013 Prices)**	**Difference (Benefit)**	**Benefit (With Inflation)**	**Discounted Present Worth**	**Cumulative Discounted Present Worth**
2016	$0	$0	$0	$0	$0	$0
2017	$47,517	$22,387	$25,130	$25,658	$24,488	$24,488
2018	$77,113	$24,356	$52,757	$54,996	$50,881	$75,369
2019	$106,892	$25,544	$81,348	$86,581	$77,649	$153,018
2020	$120,404	$44,535	$75,869	$82,526	$71,745	**$224,763**

Notes: [1]Tr = return period; e.g., a 5-yr return period storm has a 20% probability of occurrence in any given year.
Inflation rates: 1.4% for 2015 – 2016, 2.1% annually from 2016 through 2019, and 2.2% annually from 2019 and beyond
Present worth values represent equivalent values, beginning of 2016, 3.16% discount rate (mid-year discounting)

Beach Visitation Benefits

For beach visitation benefits, this study evaluated two categories — spending by out-of-state visitors and recreational enjoyment by all visitors. To develop with- and without-project out-of-state visitor spending estimates requires knowing annual out-of-state visitation, out-of-state visitor spending, and how the with- and without-project conditions affect beach width for each year in the period of analysis. Oden and Butler (2006) report out-of-state visitation by percentage of the total beachgoer population, total number of peak day visitors, and spending for various beach sites throughout Texas — including Galveston Island and South Padre Island beaches — based on site-specific beachgoer surveys. Based on these same surveys, Oden and Butler note that people will visit out-of-state beaches instead of Texas beaches if the Texas beaches become increasingly narrower. Note that Oden et al. (2003) report the number of peak visitor days during the year for South Padre Island. Other project analyses assume a number of peak visitor days based on the traditional Memorial Day to Labor Day period, or no peak period.

New surveys conducted in 2015 revealed updated and enhanced information. Some of the data suggest greater benefits for similar size/scope projects and some suggest reduced benefits, when compared with 2004/2005 survey results. It's hard to say how significant the net result is, or whether the new data revelations tend to offset each other. On the one hand, there is an inherent weakness using data from just one or two days out of a ten-year period to conduct project evaluations. On the other hand, the survey results have enough relative similarity to confirm that we have been using reasonable information for CEPRA project evaluation work. Some relevant key points revealed in the 2015 survey include (a) enhanced beach width sensitivity information, (b) higher levels of visitation than in the 2004/2005 surveys, and (c) lower spending per capita responses than in the 2004/2005 surveys.

All analyses assume beach visitation increases at the same rate as general population growth, approximately 1.4%/year (reflecting a long-term weighted average of Texas and U.S. forecast growth, based on the observation that visitors from outside the state generally approach 10% of all visitors). This growth forecast reflects downward revised projections following the 2010 Census.

This study assumes that out-of-state visitor spending per person is the same for both with- and without-project conditions. Increasing the beach visitation each year by the general population growth rate (1.4%/year) produced estimates of beach population assuming the beach has the capability to accommodate this beach population growth. Because erosion usually reduces beach width, adjustments in beach visitation growth must occur to reflect the effect of narrowing beaches. Calculating the beachgoer population each year (adjusted for beach narrowing) and multiplying by the out-of-state spending times the 1.4 multiplier effect produces the value for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.2.3, in bold italic) over the period of analysis.

Oden and Butler (2006) estimated beach visitation with respect to beach width "elasticity," which measures the percentage change in annual visitation given a percentage change in beach width, at South Padre Island and Galveston and Surfside area beaches. Based on 2015 site-specific beachgoer surveys, Taylor Engineering (2015) updated the elasticity relationship with more detailed survey questions. The survey asked visitors how their beach visitation would change for beach width reductions of 50%, 75%, and 100% (i.e., half as wide, quarter as wide, and completely eroded) as well as a 100% increase in beach width (i.e., twice as wide). The combined results from the Galveston area and South Padre Island indicated that visitation would decrease by 50.4%, 54.9%, and 57.0% for the above beach width reductions and increase by 57.8% for the beach width increase (Figure 2.3). The survey results provide an improved relationship between visitation and beach width changes and validate a prior general assumption that some minimal level of visitation would likely occur for various activities even with a completely eroded beach, as people may, even with no beach, come to the shore to surf, fish, swim, or view wildlife

Table 2.2.3 Example of Out-of-State Beach Visitor Benefit Calculation

Year	Total Visitation		Out-of-State				Difference (2015 Prices)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
			Visitation		Visitor Spending					
	With Project	Without Project	With Project	Without Project	With Project	Without Project				
2016	172,814	74,310	18,318	7,877	$1,536,354	$660,632	$875,722	$875,722	$862,205	$862,205
2017	163,795	75,350	17,362	7,987	$1,456,174	$669,881	$786,293	$802,806	$766,202	$1,628,407
2018	154,490	76,405	16,376	8,099	$1,373,449	$679,259	$694,189	$723,652	$669,501	$2,297,908
2019	144,892	77,475	15,359	8,212	$1,288,122	$688,769	$599,353	$637,910	$572,097	$2,870,005
2020	134,995	78,560	14,309	8,327	$1,200,136	$698,412	$501,724	$545,749	$474,452	**$3,344,457**

Notes: Out-of-state visitation = 10.6% of total visitation
Out-of-state visitor spending = $59.08 per person (2015 prices)
Multiplier effect = 1.4
Inflation rates: 1.4% for 2015 – 2016, 2.1% annually 2016 – 2019, and 2.2%/year from 2019 - 2020 and beyond
Present worth beginning of 2016, 3.16% discount rate, mid-year discounting

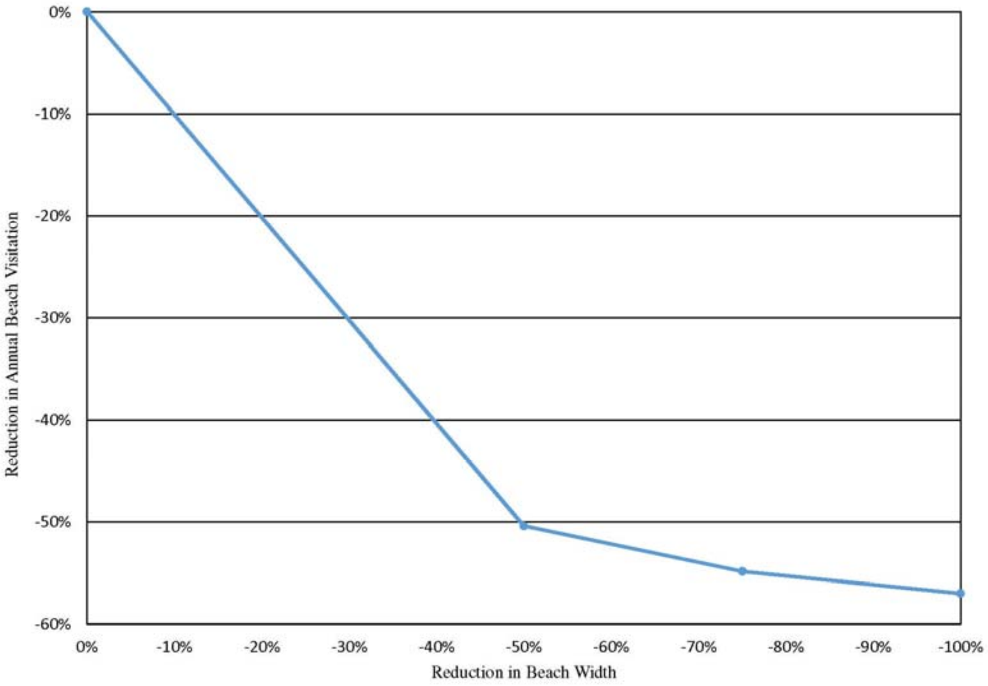


Figure 2.2.3 Relationship between Visitation and Beach Width Change

In addition, ensuring the projected beachgoer population would not exceed the beach's capacity in any given year required estimating the maximum number of visitors per day the beach could accommodate. Studies by USACE and Florida Department of Environmental Protection have determined that the average person needs 100 square feet (sf) of dry beach for normal beach activity. The available dry beach surface area divided by 100 sf and multiplied by 2 (estimated average daily turnover rate) yielded the maximum number of visitors per day. Multiplying this result by 365 days produced an estimated maximum annual number of beach visitors for each area. Projections of beach visitation in this study did not exceed maximum capacity for any of the evaluated areas.

The other category of visitation benefits includes recreation value for all visitors. Estimating this category of benefits requires knowing the total annual beach visitation with and without the project and the unit day value (UDV). The UDV method (USACE, 2016) relies on expert or informed opinion and judgment to approximate the average "willingness to pay" of visitors (per person per visit) to recreational project sites. The UDV method assigns points to general recreation based on five criteria: (1) recreation experience, (2) availability of opportunity, (3) carrying capacity, (4) accessibility, and (5) environmental. One rates an individual site based on a total of 100 points. Table 2.2.4 presents the guidelines for assigning points. Table 2.2.5 facilitates converting points to dollar values for general recreation.

Assessing both with- and without-project conditions generates the points for each general recreation category in Table 2.2.4. Summing these points and interpolating that point value against the values shown in Table 2.2.5 yields with- and without-project UDVs. Applying the beachgoer population for with- and without-project conditions each year, multiplying by the appropriate UDV, and then taking the difference produces the estimated benefit for any given year. Adjusting these values for inflation and discounting, and summing yields the total benefit (Table 2.2.6, in bold italic) over the period of analysis.

This paragraph presents an example of how to assign points to a typical beach area common to the Texas coast. In this example, a beach can accommodate a variety of activities including swimming, surfing, snorkeling, fishing, picnicking, sunbathing, and other active and passive activities. Further, no high quality value activities, defined as activities not common to the region, exist. Accordingly, one could assign a recreation experience value of 8 points to the beach area. Availability of opportunity assigns points based on travel times to the recreational activity. If visitors have a couple beaches within 45 – 60 minutes travel time to choose from, one could assign a value of 8 points for availability of opportunity. A beach area may possess adequate facilities, such as a relatively wide dry beach, to allow beachgoers to enjoy their recreational experience; these conditions may warrant assigning 6 points for carrying capacity. Accessibility measures the ability of visitors to reach the site. Given people can access the beach via good roads, one may assign 10 points for accessibility. Finally, the environmental category judges the site's aesthetics, such as topography, air and water quality, vegetation, climate, adjacent areas, and pests. In this example, the beach may appear average compared to other area beaches. As such, the beach may warrant 6 points for this category. Summing these assigned points over the five categories yields 38 points. Interpolating between 30 and 40 points in Table 2.2.5 produces a UDV of about $7.13. In this hypothetical example, the same point assignment process would be done for conditions without the project. If the points were to total 21, interpolating between 20 and 30 points in Table 2.2.5 results in a UDV of about $5.27.

Period of Analysis

Note that the period of analysis varies between the examined projects. Reasons for these variations include differences in project scale, presence of hard structures, expected life of the project, and observations of project performance.

Table 2.2.4 Guidelines for Assigning Points to General Recreation Projects (USACE, 2015)

Criteria	Judgment Factors				
Recreation Experience	Two general activities	Several general activities	Several general activities; one high quality value activity	Several general activities; more than one high quality value activity	Numerous high quality value activities; some general activities
Total Points: 30 Point Value:	0 – 4	5 – 10	11 – 16	17 – 23	24 – 30
Availability of Opportunity	Several within 1 hr travel time; a few within 30 min travel time	Several within 1 hr travel time; none within 30 min travel time	One or two within 1 hr travel time; none within 45 min travel time	None within 1 hr travel time	None within 2 hr travel time
Total Points: 18 Point Value:	0 – 3	4 – 6	7 – 10	11 – 14	15 – 18
Carrying Capacity	Minimum facility for development for public health and safety	Basic facility to conduct activities	Adequate facilities to conduct without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site potential	Ultimate facilities to achieve intent of selected alternative
Total Points: 14 Point Value:	0 – 2	3 – 5	6 – 8	9 – 11	12 – 14
Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good road to site; fair access, good roads within site	Good access, high standard road to site; good access within site
Total Points: 18 Point Value:	0 – 3	4 – 6	7 – 10	11 – 14	15 – 18
Environmental	Low aesthetic factors that significantly lower quality	Average aesthetic quality; factors exist that lower quality to minor degree	Above average aesthetic quality; any limiting factors can be reasonably rectified	High aesthetic quality; no factors exist that lower quality	Outstanding aesthetic quality; no factors exist that lower quality
Total Points: 20 Point Value:	0 – 2	3 – 6	7 – 10	11 – 15	16 – 20

Table 2.2.5 Conversion of Points to Dollar Values for Fiscal Year 2017 (USACE, 2016)

Point Values	General Recreation Values UDV (per person per visit)
0	$3.96
10	$4.70
20	$5.20
30	$5.94
40	$7.43
50	$8.42
60	$9.16
70	$9.66
80	$10.65
90	$11.39
100	$11.89

Table 2.2.6 Example of Recreation Benefit for All Beach Visitors

Year	Number of Visitors		Recreation Value (2017 Prices)		Difference (Benefit)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	75,000	75,000	$534,900	$395,550	$139,350	$136,484	$134,377	$134,377
2017	152,100	152,100	$1,084,777	$802,175	$282,602	$282,602	$269,717	$404,094
2018	154,229	154,229	$1,099,964	$813,406	$286,558	$292,576	$270,683	$674,777
2019	156,389	156,389	$1,115,364	$824,794	$290,570	$302,902	$271,652	$946,428
2020	158,578	158,578	$1,130,979	$836,341	$294,638	$313,900	$272,892	$1,219,320

Notes: UDV (with project) = $7.13 (2017 price level)
UDV (without project) = $5.27 (2017 price level)
Inflation rates: 2.1% annually for 2016 – 2019, 2.2% annually for 2019 – 2020 and beyond
Present worth equivalent values at beginning of 2016, mid-year discounting, 3.16% discount rate [mid-year discount factor = $(1/1.0326)^{n+0.5}$, where n = year – 2016]

2.3 Natural Resource Restoration Projects

Natural resource restoration projects generally create or enhance an area's natural resources. Examples of previous GLO natural resource restoration projects include those that created beach and wetland habitat, protected estuarine habitats, and other projects that directly or indirectly created, enhanced, or provided protection for the development and sustainability of natural habitats and the plant and animal communities themselves.

Similar to the prior economic benefits studies, this study quantified natural resource benefits. Estimating these benefits required review of published information on economic benefits of coastal ecosystems, particularly those associated with Texas and other Gulf of Mexico states (e.g., Louisiana). In addition to those over-arching concepts presented in Section 2.1, the economic benefit estimates developed in this study for the natural resource projects rest on the assumptions that the project sites provide economic benefits in a manner similar to those described in the literature. This assumption served as a surrogate for the extensive on-site interviews and natural resource evaluations described in the literature pertinent to this study. Calculations assumed benefits accrue over the entire project benefit period of analysis for natural resource functions.

The GecoServ database (http://www.gecoserv.org/), developed by the Harte Research Institute, Texas A&M University, Corpus Christi, provides a large ecosystem services valuation database with ecosystem economic services unit area dollar values. With the exception of aesthetic valuations (for which there were no Gulf state values reported), this analysis excluded those services values developed from ecosystems in states not bordering on the Gulf of Mexico or not present in the particular water bodies associated with the selected projects. Additionally, this analysis excluded a few early value estimates that recent research has found were less robust than originally assumed.

The services selected for benefit calculations included (in the database terms) *habitat*, *recreation*, *disturbance regulation*, *gas regulation*, *waste regulation*, and *aesthetics*. Table 2.2.7 provides the GecoServ definitions of those terms. Based on the literature for the *habitat* service, this analysis assumed this category provided the basic benefit for commercial and recreational fishing; as a result, the analysis did not use specific commercial and recreational fisheries value estimates. Further, *recreation* included recreational fishing; the database provides 2012 values that this analysis inflated to 2016 dollars using the inflation rates listed in Table 2.1.1. This study applied median ecosystem services values for use in benefit calculations.

Table 2.2.7 Ecosystem Service Values

Ecosystem Service	Definition	Per Acre Value (2016 Price Level)
Habitat	The physical place where organisms reside; refugium for resident and migratory species; spawning and nursery grounds	$54.43
Recreation	Opportunities for rest, refreshment, and recreation Ecotourism; bird-watching; outdoor sports	$88.32
Disturbance Regulation	Dampening of environmental fluctuations and disturbance Storm surge protection; flood protection	$567.62
Gas Regulation	Regulation of the chemical composition of the atmosphere and oceans. Biotic sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds	$565.50
Waste Regulation	Removal or breakdown of non-nutrient compounds and materials Pollution detoxification; abatement of noise pollution	$2,092.13
Aesthetics	Sensory equipment of functioning ecological systems Proximity of houses to scenery; open space	$56.34
Total Ecosystem Services Per Acre Value		$3,424.33

Note: Values provided in 2012 price levels at http://www.gecoserv.org; values converted to 2016 price levels using inflation rates listed in Table 2.1.1

Project benefits to real estate (residential lots and residences immediately adjacent to ecosystem restoration projects) often occur as a one-time increase in the property value. Average property values for the local area around a wetland or natural habitat enhancement project, and in particular those properties immediately adjacent to such a project, will often increase due to the perceived increase in aesthetic value. Fausold and Lilieholm (1999) and Kroeger and Manalo (2006) provide examples of estimating such benefits. The increased value would benefit the present owners. Any subsequent value reassessment or sale would pass along the property amenity. However, the real estate benefit did not apply to any projects selected for this study.

Benefit calculations assume a fixed annual amount of benefit per acre of fully developed habitat created or protected by the project. Table 2.2.8 provides an example calculation of the total value of ecosystem services over a 10-year period resulting from the prevention of 0.5% annual wetland loss on a 9,950-acre wetland ecosystem, with an annual service value of $3,424.33 per acre as defined in Table 2.2.7.

In this example, the difference between the constructed project versus no project results in a total present value benefit of $6,740,178.

Table 2.2.8 Example of Benefit Calculation for Erosion of Newly Created Acreage

Year	Ecosystem Services (Acres)			Ecosystem Services Benefit			
	With Project	Without Project	Difference (Benefit)	Value (2015 Prices) ($)	Value (With Inflation) ($)	Discounted Present Worth ($)	Cumulative Discounted Present Worth ($)
2015	9,950.0	9,950.0	0.0	0	0	0	0
2016	9,950.0	9,900.3	49.8	168,177	167,726	160,079	160,079
2017	9,950.0	9,850.7	99.3	329,824	341,465	315,913	475,992
2018	9,950.0	9,801.5	148.5	493,242	521,374	467,584	943,576
2019	9,950.0	9,752.5	197.5	655,995	707,971	615,481	1,559,057
2020	9,950.0	9,703.7	246.3	818,084	902,327	760,417	2,319,474
2021	9,950.0	9,655.2	294.8	979,176	1,103,768	901,684	3,221,157
2022	9,950.0	9,606.9	343.1	1,139,604	1,312,871	1,039,650	4,260,807
2023	9,950.0	9,558.9	391.1	1,299,036	1,529,466	1,174,069	5,434,876
2024	9,950.0	9,511.1	438.9	1,457,803	1,754,158	1,305,302	**6,740,178**

3.0 BEACH RESTORATION AND SHORELINE PROTECTION BENEFIT ANALYSIS

3.1 Galveston County — #1521 End of Seawall Beach Nourishment

Project Description and Background Information

CEPRA Project #1521 nourished approximately 2,100 ft of shoreline and dunes in Dellanera and Seascape beaches, Galveston County to protect the existing dune and restore recreational access. The project area (Figure 3.1.1) lies west of the western end of the Galveston Seawall, along the Dellanera RV Park and Seascape Condominiums, an area impacted by high erosion rates. Past studies (HDR, 2013a and UTBEG, 2012) estimate historic shoreline erosion rates of roughly 7.2 ft per year on average. The presence of the seawall exacerbates the erosion of the West Island shoreline because it prevents the natural flow of sediment to the west.

Per HDR (2013a), five nourishment and shoreline protection projects have taken place since 2000 in the West Galveston Island end of seawall area. These projects included hauling sand by truck from an upland source and placement of geotextile tubes. In 2008, Hurricane Ike produced catastrophic damages causing the West Galveston Island end of seawall shoreline to retreat up to 100 ft. During the immediate years after the storm, the beach naturally recovered some of its width, but the historic receding trend continued.

GLO had originally planned to build CEPRA Project #1391 in 2010 — a large-scale beach nourishment project (over 1,500,000 cy) to rebuild the area immediately west of the Galveston Seawall. However, a resolution by the Texas Supreme Court over property rights forced GLO to cancel the project. Eventually, GLO reached an agreement with local stakeholders to build a beach nourishment and dune restoration project with 128,000 cy.

HDR's (2015) close-out documentation describes that construction of CEPRA Project #1521 took place from December 2014 to March 2015. The project entailed placement of 69,706 cy of beach berm and 20,941 cy in the dune corridor (a total of 90,647 cy or 43.2 cy/ft, a quantity smaller than the Texas-recommended minimum of 50 cy/ft necessary for an "effective" beach nourishment project [HDR, 2013b]). A visit to the project site in January 2017 and aerial photography show that the sand has disappeared in the area between the end of the seawall and the Seascape Condominiums. The beach widens roughly from 30 ft near the seawall to about 95 ft at the west end of the Dellanera RV Park. This shoreline position is nearly the same as the one prior to the 2015 beach nourishment.

Figures 3.1.2 – 3.1.5 show representative pre-construction conditions, construction photographs, and existing conditions during a January 19, 2017 site visit (roughly 22 months following construction). Figures 3.1.6 – 3.1.8 present aerial photographs of pre-construction (5/15/14), construction (1/28/15) and approximately eight months post-construction (11/21/15) conditions.

Project Funding

Funding for the Seascape-Dellanera beach nourishment and dune restoration project originated from Federal, state, and public and private local sources. Federal funding was available through the FEMA Public Assistance program, on an expense-reimbursement basis. Table 3.1.1 presents the funding breakdown for the project. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $3,273,656 FEMA cost is $327,357. The resulting cost to Texas for Project #1521 amounts to $1,475,049 (present worth, beginning of 2015); this value equals the sum of the CEPRA ($775,000), City of Galveston and Galveston Park Board ($330,312), Seascape Condominium ($42,381), and 10% state share of federal costs ($327,357)

Table 3.1.1 Cost Summary for #1521 End of Seawall Beach Nourishment

Funding Source		Amount
Federal	Federal Emergency Management Agency funding: 73.3% of total cost *(Texas portion)*	$3,273,565 *(327,357)*
Texas	Texas General Land Office, CEPRA: 17.3% of total project cost	*$775,000*
	City of Galveston and Galveston Park Board (8.4% of total project cost)	*$330,312*
	Seascape Condominiums (1% of total project cost)	*$42,381*
Total Project Cost **(*Texas Total*)**		*$4,421,258* *($1,475,049)*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2015.
The project had a balance of $46,590 which was refunded to the Galveston Park Board (this refund is not included in the $330,312 figure).

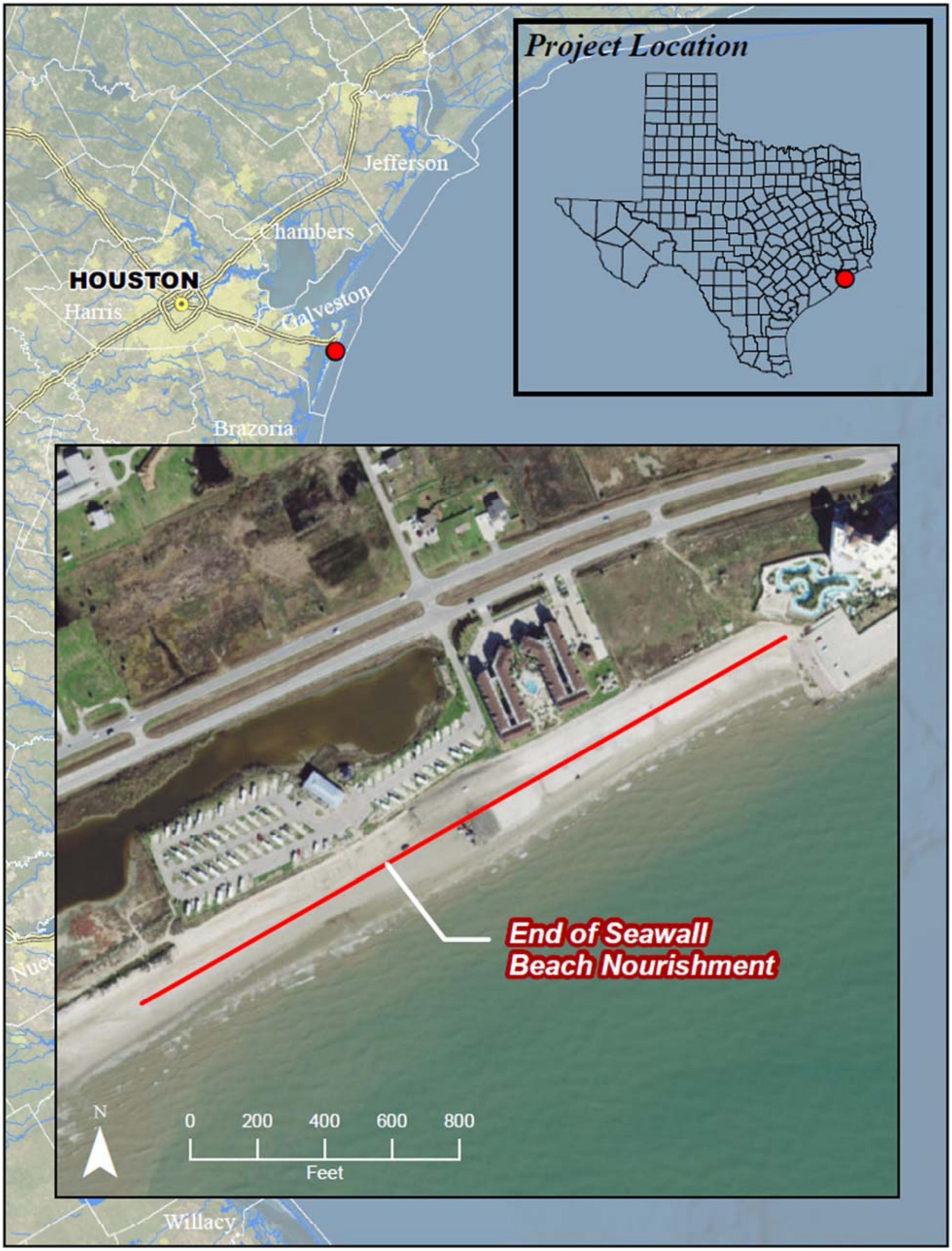


Figure 3.1.1 End of Seawall Beach Nourishment Location

Figure 3.1.2 End of Seawall Beach Nourishment at the Beginning of Construction (12/2/14; Photo provided by GLO) (The arrow shows a point of reference also displayed in Figure 3.1.4)

Figure 3.1.3 Construction of the end of seawall beach nourishment (12/4/14; Photo provided by GLO)

Figure 3.1.4 End of seawall beach nourishment near the construction completion (around March 2015; Photo provided by GLO) (The arrow shows a point of reference also displayed in Figure 3.1.2)

Figure 3.1.5 End of seawall project area 22 months after construction (1/19/17)

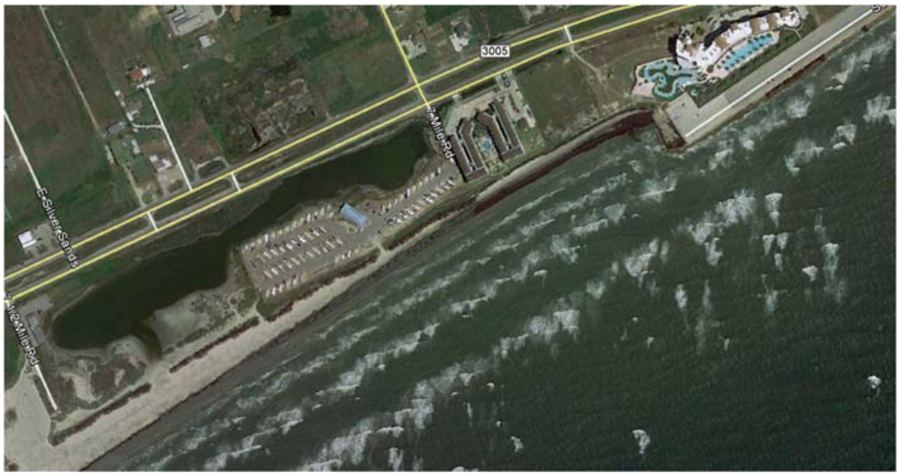


Figure 3.1.6 Pre-construction Aerial 5/15/14 (source: Google Earth)

Figure 3.1.7 During construction Aerial 1/28/15 (source: ESRI Imaging Services)

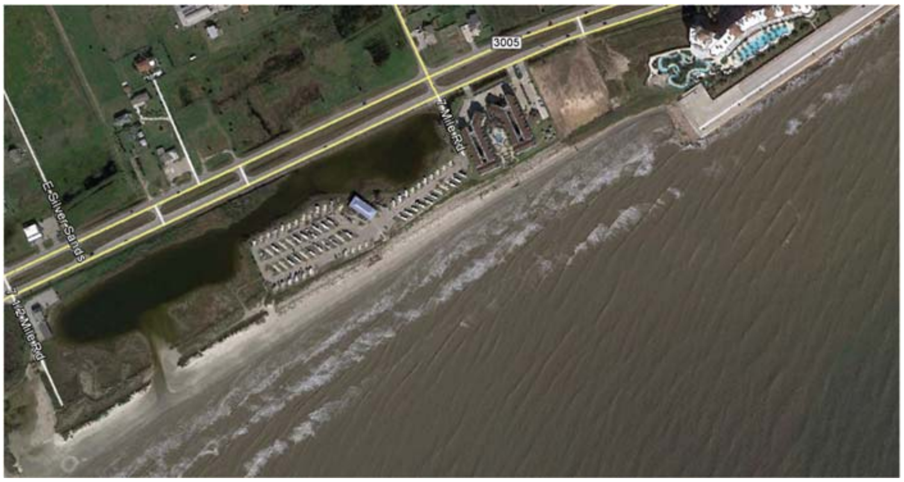


Figure 3.1.8 Post-construction Aerial 11/21/15 (source: Google Earth)

Analysis

This economic benefits analysis considered storm damage reduction, visitation (recreation and out-of-state visitor spending), and federal spending benefits. The area was likely affected by Tropical Storm Bill, which landed in Matagorda Island in June 2015. The storm surge reached 2.5 ft above MHHW (roughly, 3.9 ft above NAVD88) per NOAA (2015). Based on aerial photography, by November 2015 most of the project fill had eroded away (Figure 3.1.8). However, the project may have protected land value by preventing the pre-project shoreline to recede further under T.S. Bill and background erosion conditions in 2015. As such, the project's life was one year.

Storm Damage Reduction Benefits

Estimating storm damage reduction benefits required modeling beach erosion without project conditions in SBEACH. Modeling beach erosion of pre-project conditions provided information on potential loss of land in the absence of CEPRA Project No. 1521. Given that the shoreline returned to its pre-project condition after 2015, the analysis does not require with-project conditions modeling. GLO provided pre-construction beach profile data (Figure 3.1.9) which helped evaluate storm-induced erosion. SBEACH modeling incorporated two representative beach profiles, profile 8+00 in front of the Seascape Condominiums and profile 18+00 in front of the Dellanera RV park. Erosion simulations applied the parameters shown in Table 3.1.2 presented in HDR (2009, 2013).

Table 3.1.2 SBEACH Model Parameters (HDR, 2009, 2013b)

Parameter	Value
Transport Rate Coefficient (K)	2 x 10^{-6} m^4/N
Eps Parameter (ε)	0.002 m^2/s
Transport Rate Decay Factor (λ)	0.5 m^{-1}
Avalanching Angle (ω)	35°
Landward Surf Zone Depth	1.6 ft
Median Grain Size	0.14 mm

Due to unavailability of hourly wave data, this study applied a synthetic storm to simulate T.S. Bill with characteristics corresponding to data collected during the storm (Berg, 2015). The synthetic storm consisted of an associated storm tide, wave height, and wave period based. This analysis applied storm characteristics (Table 3.1.3).

Figure 3.1.9 Representative pre-construction beach profiles (Naismith Marine Services, 2015)

Table 3.1.3 Peak Storm Characteristics for Tropical Storm Bill

Storm Characteristic	Tropical Storm Bill
Storm Tide (ft-NAVD) †	3.9
Offshore Wave Height (ft) ‡	4.5
Offshore Wave Period (s) ‡	6

†Data from National Hurricane Center (NHC) (Berg, 2015)
‡Estimated with Automated Coastal Engineering Software utilizing wind records from NHC (Berg, 2015)

With a typical storm event lasting approximately 36 hours, distributing the peak storm characteristics over a 36-hour period simulates the passage of a storm and provides a realistic storm model. Before the storm period, three normal tide cycles initialized the model. For a diurnal tide typical of this area, three tidal cycles last about 72 hours. Therefore, each simulation covers a 108-hour time period.

To develop synthetic time-varying storm surge hydrographs, many authors (e.g., Kriebel, 1989) have applied sine squared distributions such as

$$S(t) = S_p \sin^2(\pi \frac{t-36}{36}) \tag{3.1}$$

where S is the storm tide (ft MLT), t is time (hours), and S_p is the peak storm tide elevation (ft MLT). The final water surface elevation time series consists of three standard tidal cycles (about 72 hours) developed from a normally varying tide from mean high water (1.23 ft-NAVD) to mean low water (-0.22 ft-NAVD), followed by the return period specific storm surge hydrograph. Generating the normal tidal cycles requires applying the following equation:

$$S(t) = 1.23 \cos^2(\pi \frac{t-24.8}{24.8}) + \left(-0.22\right) \tag{3.2}$$

Minor smoothing at the transition prevented abrupt changes in the water surface elevation. Figure 3.1.10 shows the synthetic T.S. Bill hydrograph.

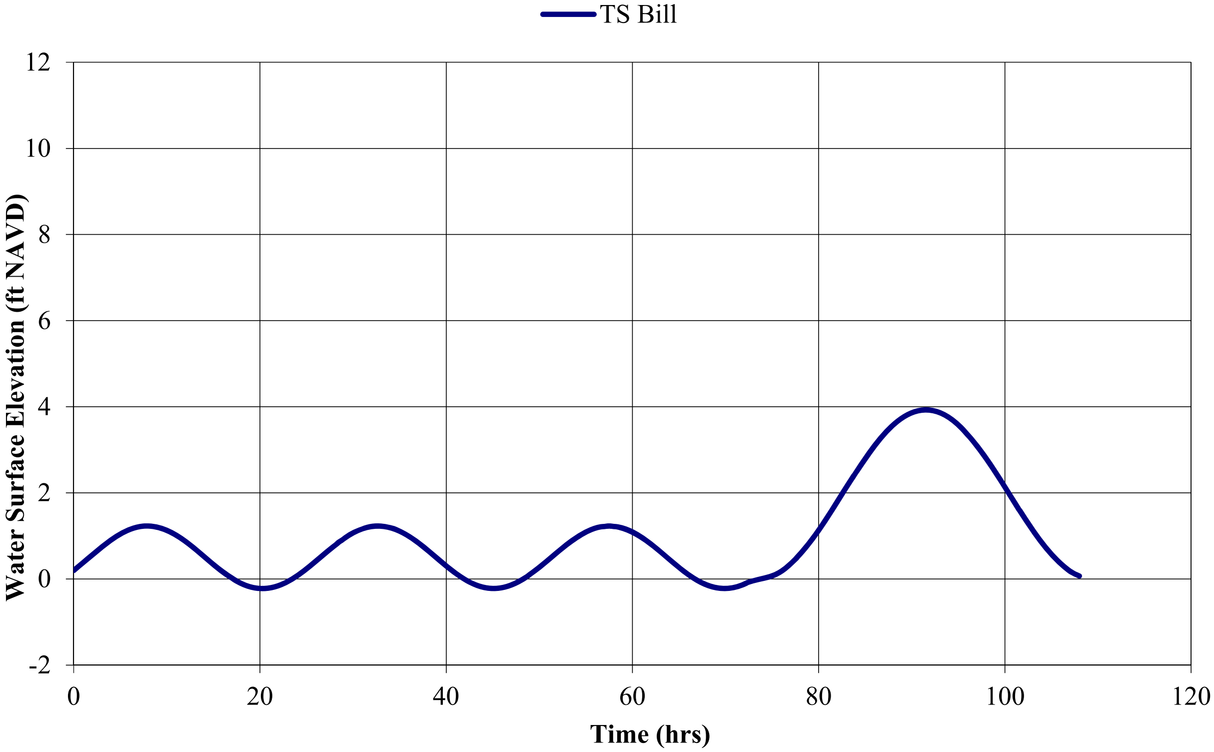


Figure 3.1.10 T.S. Bill, Time-Varying Water Surface Elevation

As with the storm surge, the temporal wave height variation consisted of two parts. A cosine squared distribution (Eq. 3.3) approximated the wave heights during normal conditions over the first 72 hours (3 tidal cycles), followed by a sine squared distribution (Eq. 3.4) which approximated the storm wave heights over 36 hours.

$$H(t) = 1.5\cos^2(\pi\frac{t-24.8}{24.8}) + 1.5 \tag{3.3}$$

and

$$H(t) = (H_p - H_{\min})\sin^2(\pi\frac{t-36}{36}) + H_{\min} \tag{3.4}$$

where H is the wave height (ft), H_p is the peak wave height (ft), and H_{min} is the minimum wave height following a storm.

Each tidal cycle averaged 24.8 hours, and the wave heights varied from 1.5 to 3.0 ft. These conditions represent the relatively calm conditions frequently observed in the Gulf of Mexico. Storm wave heights varied from 3 ft to the peak wave height (Table 3.1.3) and abate to 3 ft after storm passage. The values for H_{min} (minimum wave height following storm) simulate the agitated sea conditions typically found after a storm passes an area. Figure 3.1.11 shows the resulting wave height distributions the model requires.

During the first 72 hours of normal conditions, the wave period varies from three to four seconds according to a cosine-squared distribution with a tidal cycle of 24.8 hours. Similarly, a sine squared distribution approximated the storm wave period over the final 36 hours with a minimum final wave period of three seconds. Figure 3.1.12 shows the resulting wave period distributions the model requires.

Figures 3.1.13 and 3.1.14 show results of simulated beach erosion from T.S. Bill. Because SBEACH modifies an irregular profile to one in “equilibrium,” the rate of erosion varies at different cross section locations. Land loss analyses considered profile retreat at mean high water (MHW) because any land above this elevation is typically dry. At MHW, SBEACH predicts T.S. Bill-induced recession of 7.1 and 36.1 ft. In addition to the retreat from T.S. Bill, the analysis includes a background erosion rate (measured 1950 – 2012) of 10.4 and 11.1 ft/yr at stations 8+00 and 18+00 (Paine, et al., 2014). Of note, given that the Galveston Seawall was completed around 1962, the 1950 – 2012 historical erosion rates already account for the long-term effects the seawall has on the shoreline.

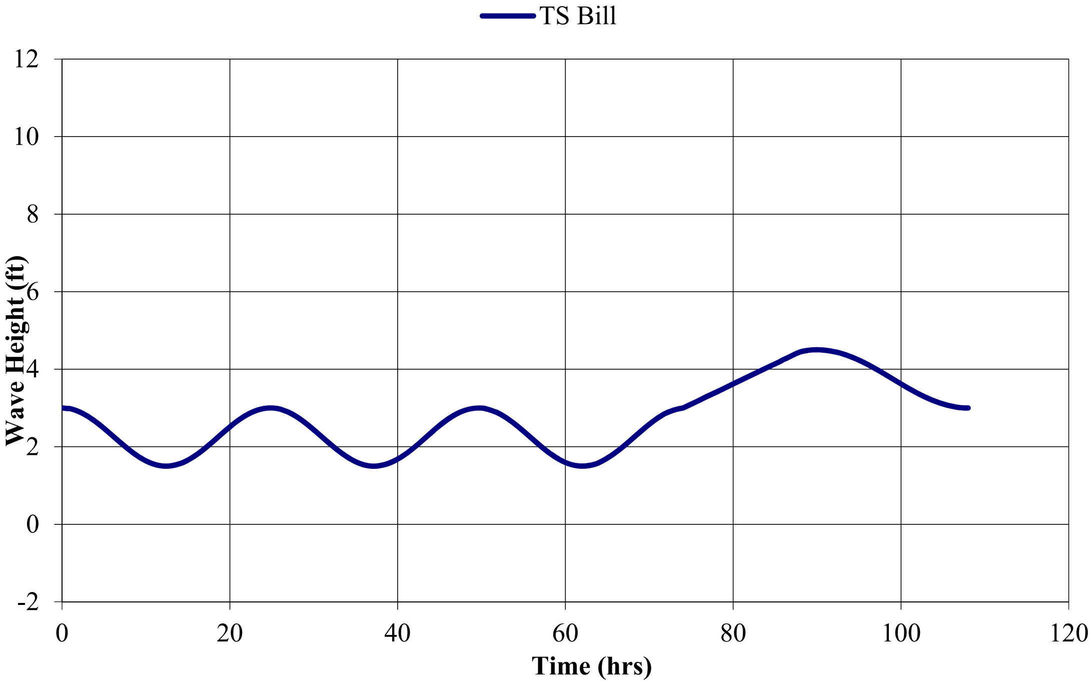


Figure 3.1.11 T.S. Bill, Time-Varying Wave Heights

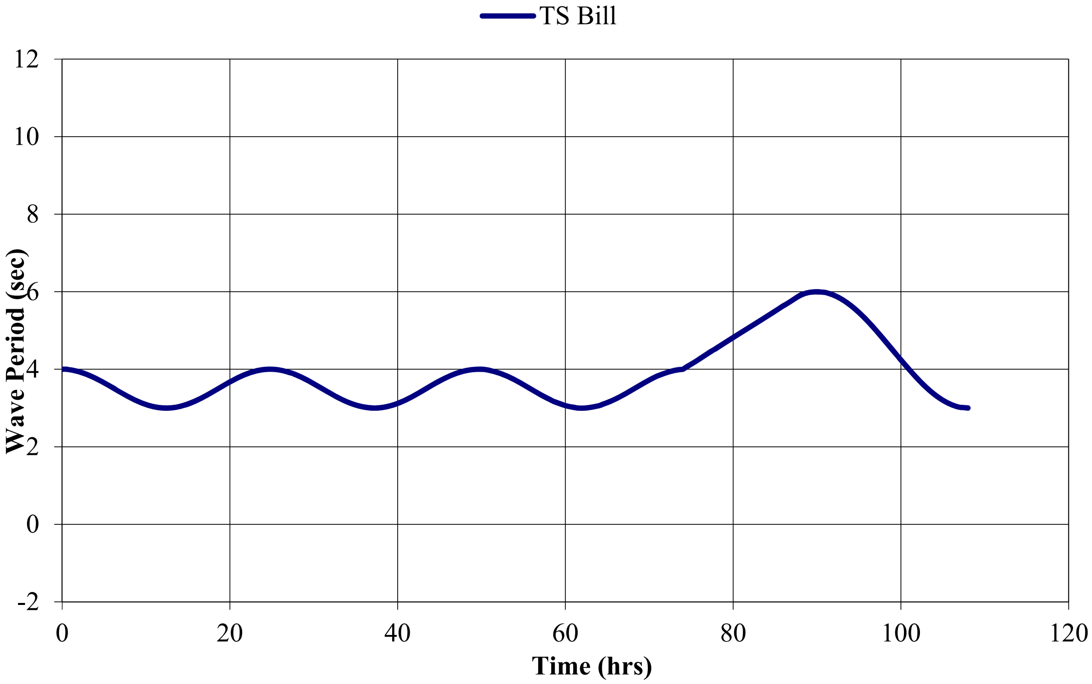
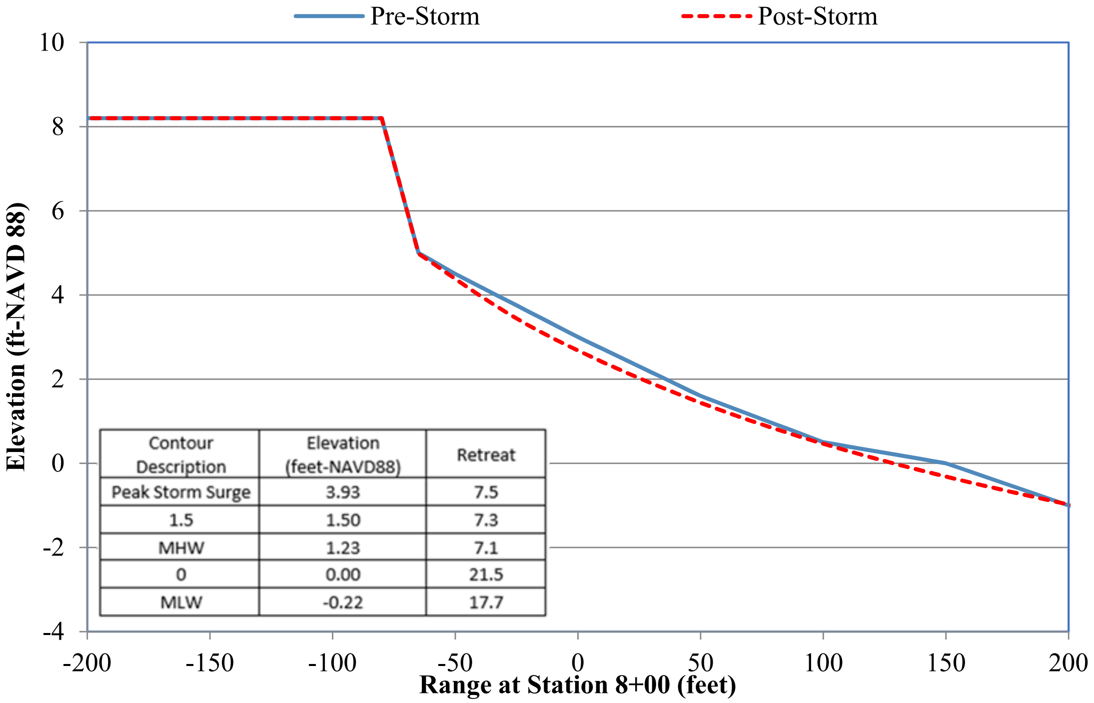
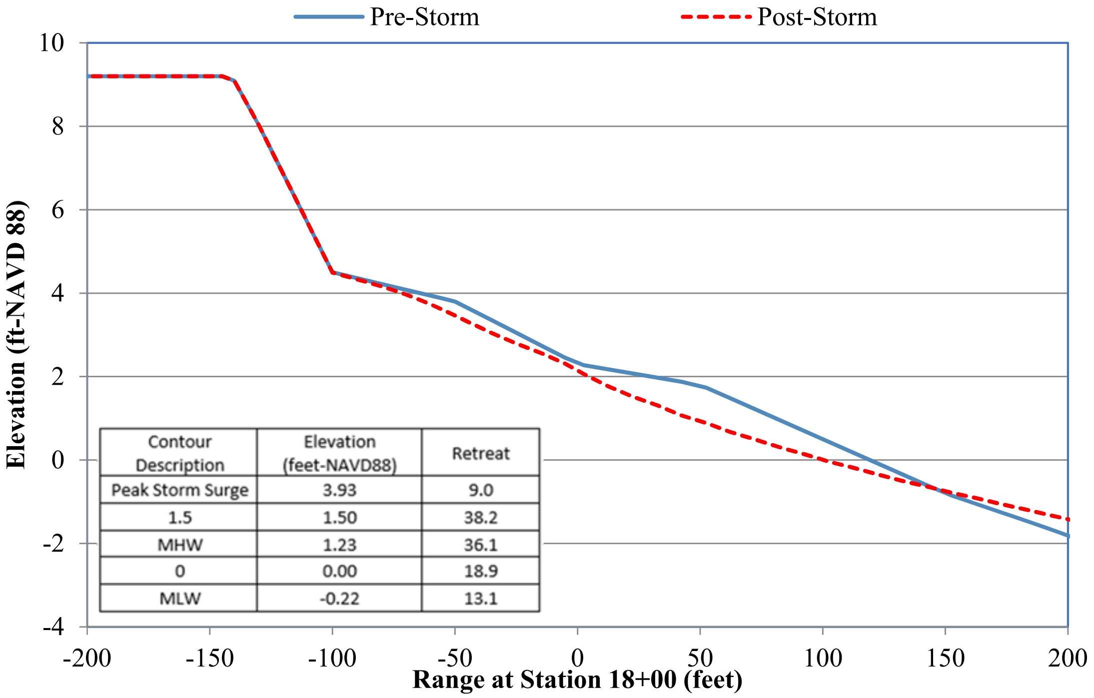


Figure 3.1.12 T.S. Bill, Time-Varying Wave Periods



Contour Description	Elevation (feet-NAVD88)	Retreat
Peak Storm Surge	3.93	7.5
1.5	1.50	7.3
MHW	1.23	7.1
0	0.00	21.5
MLW	-0.22	17.7

Figure 3.1.13 Pre- and Post-T.S. Bill Beach Profiles near Seascape Condominiums (Station 8+00)



Contour Description	Elevation (feet-NAVD88)	Retreat
Peak Storm Surge	3.93	9.0
1.5	1.50	38.2
MHW	1.23	36.1
0	0.00	18.9
MLW	-0.22	13.1

Figure 3.1.14 Pre- and Post-T.S. Bill Beach Profiles near Dellanera RV Park (Station 18+00)

Averaging storm-induced erosion rates at both profiles ([7.1+36.1]/2) the estimated 2015 land loss equals 21.6 ft per unit length. Background erosion occurs at the same rate with or without the beach nourishment. Because background erosion is unable to reach structures or cause more losses than with-project conditions, land losses under with- and without-project project conditions are the same.

SBEACH results do not show erosion beyond the dune toe. This relatively small erosion may show a direct correlation to the size of T.S. Bill. Thus, the without-project conditions do not result in added land loss, and the with-project condition yields no land loss protection benefits.

Visitation Benefits

Based on May 2015 observations, Taylor Engineering (2015) reports about 143 visitors per 1000 ft of shoreline in the Galveston seawall beach near 61st St. Applying this peak season visitation rate for the West End of Seawall beach nourishment area (2,100 ft), the study assumes total peak visitation at 300 visitors per day (143 visitors/1000 ft * 2100 ft). Of note, the study excluded visitation counts at other Galveston Island locations because proximity to the 61st St beach as well as beach characteristics (e.g., beach width, access) of the West End Galveston Seawall best resemble those of the 61st St beach.

Given that the project had a 1-year life, the rapid beach width changes due to natural profile equilibration and T.S. Bill might have affected visitation. The project created a beach berm width of approximately 175 ft, which should have been available to beachgoers for a few months after construction. By the end of 2015, the shoreline retreated roughly to its pre-construction position, i.e., a beach width of 40 ft near the seawall and about 80 ft near Dellanera RV Park, an average width of 60 ft (66% reduction). Using the elasticity relationship (Section 2.2) for visitation change based on beach width reduction, visitation may change -53% (this visitation change applies to the second half of the year).

Assuming an average daily turnover rate of 2, the daily peak season visitation estimate increases to 600. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (120) visit the beach during off days and 285 (i.e., 365 – 80) off peak days exist during a 365-day year. Given the above visitor information, the estimated number of beach visits occurring in 2015 was approximately 82,200 visits ([600 * 80] + [120 * 285]). Based on beachgoer surveys for Galveston's 61st St. and Porretto beaches, Taylor Engineering reports an average of 8.33%, or 6,847 out-of-state visitors (82,200 * 0.0833) in 2015. Applying a -53% visitation change to the second half of 2015 due to changes in beach width, total visitors approximate 60,417 (82,200/2 + 82,200/2*[1-0.53]), where 5,033 (60,417 * 0.0833) visitors originate outside of Texas.

Similarly, the without-project condition assumes that an average beach width of 60 ft is available to beachgoers at the beginning of 2015 and, due to background erosion, about 49.3 ft (60 – [11.1 + 10.4]/2) at the end of the year (55 ft on average). A 55-ft beach width represents a reduction of 70% with respect to a 175-ft wide beach — a width comparable to those near 61st St and Porretto beaches, in Galveston Island. Applying the above-mentioned elasticity relationship to a peak visitation of 82,200, the without-project total visitation results 37,812 (82,200 * [1-0.54]), and the out-of-state visitors total 3,150 (37,812 * 0.0833).

Taylor Engineering found that out-of-state visitors spent $59.08 (2015 dollars) per person per visit to the Galveston area. This translates into a total annual spending of $297,350 (5,033 * $59.08) by out-of-state visitors when the project is present. Without the project, spending by out-of-state visitors approximates $186,102 (3,150 * $59.08), a difference —total out-of-state spending benefit — of $111,248.

Spending by non-Texans visiting the project sites generates secondary economic effects quantified using a multiplier. And because this benefit develops throughout the year, we adjust this value to represent its discounted present worth. Using the multiplier of 1.4 (Section 2.2), the spending benefit by out-of-state visitors increases to $155,747 ($111,248 * 1.4). Using a discount rate of 3.16%, the benefit by out-of-state visitors results $153,343 ($155,747 * 1/1.0316$^{0.5}$).

The study used the Unit Day Value (UDV) point system (Section 2.2, Table 2.5) to estimate a given project's recreational elements' dollar value. The UDV points assigned to the site with- and without project conditions provides an estimate of its economic benefits. Table 3.1.4 presents a summary of the points assigned for with-and without-project conditions. The assignment of points represents the incremental improvement afforded by the wider, renourished beach. Converting UDV points to dollar values with the help of Table 2.6, results in with- and without-project UDVs of $8.12 and $5.72 per person per visit at 2017 price levels. Given inflation values of 1.4 and 2.1% for 2015 and 2016, the UDVs at 2015 price levels result $7.85 ($8.12/1.021/1.014) and $5.52 ($5.72/1.021/1.014) for with and without-project conditions. Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. Table 3.1.5 shows the recreation value benefit for this project $261,105 (present worth, beginning of 2015).

Table 3.1.4 UDV Points Assigned — #1521 End of Seawall Beach Nourishment

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	12	6	30
Availability of Opportunity	3	1	18
Carrying Capacity	8	6	14
Accessibility	14	11	18
Environmental	10	3	20
Total	47	27	100

Table 3.1.5 Recreational Benefit for All Users — #1521 End of Seawall Beach Nourishment

Year	Total Visitation		Recreation Value (2015 Prices)		Difference (2015 Prices)	Beginning of 2015 Discounted Present Worth
	With Project	Without Project	With Project	Without Project		
2015	60,417	37,812	$474,037	$208,838	$265,198	$261,105

Notes:
UDV (with project) = \$8.12 (2017 price levels) = \$7.85 (2015 price levels)
UDV (without project) = \$5.72 (2017 price levels) = \$5.52 (2015 price levels)
Inflation rate 2016 to 2017 = 2.1%; 2017 price level x 1/1.021 = 2016 price level
Inflation rate 2015 to 2016 = 1.4%; 2016 price level x 1/1.014 = 2015 price level
Present worth, beginning of 2015, mid-year discounting, 3.16% discount rate
Discounted present worth = Difference / $1.0316^{(0.5)}$

Federal Spending Benefit

Federal spending that occurs as part of the initial construction represents a net increase inflow of spending for the state economy. Reducing the initial federal funding contribution by 10% (i.e., the estimated amount of federal funds originating from Texas) and applying the multiplier effect (Section 2.1), the estimated federal spending benefit for this project is $4,124,692 (i.e., $3,273,565* 0.9 * 1.4), present worth, beginning of 2015.

Benefit-Cost Summary

The benefit-cost summary for Project #1521 is shown in Table 3.1.6. The modest recreation benefits ($414,448) may be attributed to the short-lived project (1 year). Factors that contribute to Project #1521's life span include the presence of the seawall, the naturally rapid equilibration of a beach nourishment profile during its first year of life, and the erosive effects of Tropical Storm Bill. In addition, per HDR (2013), the amount of sand placed in the area, 43.2 cy/ft, is less than the recommended 50 cy/ft to yield an "effective" beach nourishment project in the state of Texas.

Of note, the evaluation of the beach nourishment as a single, 1-yr project may not show the long-term benefits that several beach nourishment projects could have in preventing land loss. The high erosion rates the seawall creates in this area can be countered with continuous nourishment. Under a multiple nourishment benefit-cost analysis, the without-project condition would likely show the benefits of repetitive sand placement in the area, particularly to the Dellanera RV Park, the Seascape Condominiums, and the Diamond Beach Condominiums.

Table 3.1.6 Benefit-Cost Summary for Project #1521

Benefits and Costs	**Discounted Present Worth (beginning of 2015)**	**Discounted Present Worth (beginning of 2016)**
Federal Spending Benefit	$4,124,692	$4,255,032
Out-of-State Visitor Spending Benefit	$153,343	$158,189
Recreation Benefit	$261,105	$269,356
Total Benefit	$4,539,140	$4,682,577
Total Cost	$1,475,049	$1,521,661
B/C Ratio	**3.1**	**3.1**

3.2 Nueces County — #1569 Corpus Christi North Beach BMMP Maintenance Renourishment

Project Description and Background Information

CEPRA Project #1569 nourished approximately 3,200 ft of bay front shoreline in Corpus Christi North Beach, Nueces County to protect upland structures and restore recreational access. The project area (Figure 3.2.1) lies within Corpus Christi Bay along the southeastern shoreline of Rincon Point, a sand spit that partially separates Nueces and Corpus Christi Bay. The beach is generally characterized by a low elevation berm with no dune feature. Rock structures — the Port of Corpus Christi rock breakwater to the south and a terminal groin to the north — bound the project area. The berth of the USS Lexington, a naval aviation museum, lies immediately south of the nourishment area. A concrete sidewalk spans the landward extent of the North Beach berm, and upland of the sidewalk lie condominiums, hotels, vacant lots, five public beach access parks, and commercial businesses.

Documentation of erosion along the project area began with the North Beach Study conducted by Dr. W. Armstrong Price in 1956, which estimated shoreline erosion of approximately -3.3 ft/year between 1880 – 1950 and recommended beach nourishment to abate erosion and protect upland structures. In 1978, USACE and the City of Corpus Christi conducted an initial beach nourishment of approximately 800,000 cy with recreational benefit as a justification of the project (Kraus, 1999). The beach fill eroded relatively rapidly to the north due to spit elongation, which led to construction of the northern terminal groin in 1985 and placement of approximately 30,000 cy along the north end of the beach (Heilman and Shiner, 2002). In 1998, GLO began relocating sand (approximately 23,000 cy) compounded along the northern terminal groin (due to net northerly littoral transport) to eroded areas along the central portion of the beach, a practice referred to as “back-passing”. Following continued erosion, City of Corpus Christi and GLO conducted a truck-haul and back-passing effort in 2001 (CEPRA Cycle 1) with a total beach fill volume of 150,000 cy.

The 2016 nourishment (CEPRA Project #1569), another back-passing effort, relocated approximately 80,000 cy from the northernmost 0.4 miles to the southernmost 0.6 miles of North Beach. The 3,200-ft construction template for the project included two distinct fill sections, transitioned by a 400-ft construction berm taper, with 400-ft tapers on each end. The southernmost fill section, approximately 900-ft long, advanced the seaward edge of the berm approximately 150 – 270 ft compared to baseline conditions. The northern fill section, approximately 1,100 ft long, advanced the seaward edge of the berm approximately 60 – 80 ft. Figure 3.2.2, an excerpt from the project construction drawings, illustrates these distinct fill sections. The Corpus Christi North Beach Nourishment Technical Design Memorandum (HDR,

2014) provides background erosion rates of approximately -10 ft/yr and -7 ft/yr for these southern and northern project fill sections.

Construction of CEPRA Project #1569 occurred from February – June 2016. Figures 3.2.3 – 3.2.9 present representative pre-construction conditions, construction photographs, and existing conditions during an October 20, 2016 site visit approximately four months following construction. Figure 3.2.7 presents an oblique aerial photograph of post-construction condition.

Project Funding

Funding for CEPRA Project #1569 originated solely from Texas agencies; federal funding was not involved. Table 3.2.1 presents the funding breakdown for the project as provided by the GLO expenditure summary. CEPRA Project #1569 incurred engineering costs in 2014 – 2016 and construction costs from February – June 2016. This analysis treats all of the costs as though they were incurred at the beginning of 2016 (i.e., the cost reflects 2016 price levels, and is a present worth equivalent value, beginning of 2016).

Table 3.2.1 Funding for the Corpus Christi North Beach Nourishment Project #1569

Funding Source		**Amount**
State/Local	Texas General Land Office, CEPRA (97% of total project cost)	*$2,400,577*
	City of Corpus Christi (3% of total project cost)	*$75,00*
Total Project Cost ***(Texas Total)***		*$2,475,577* *($2,475,577)*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016

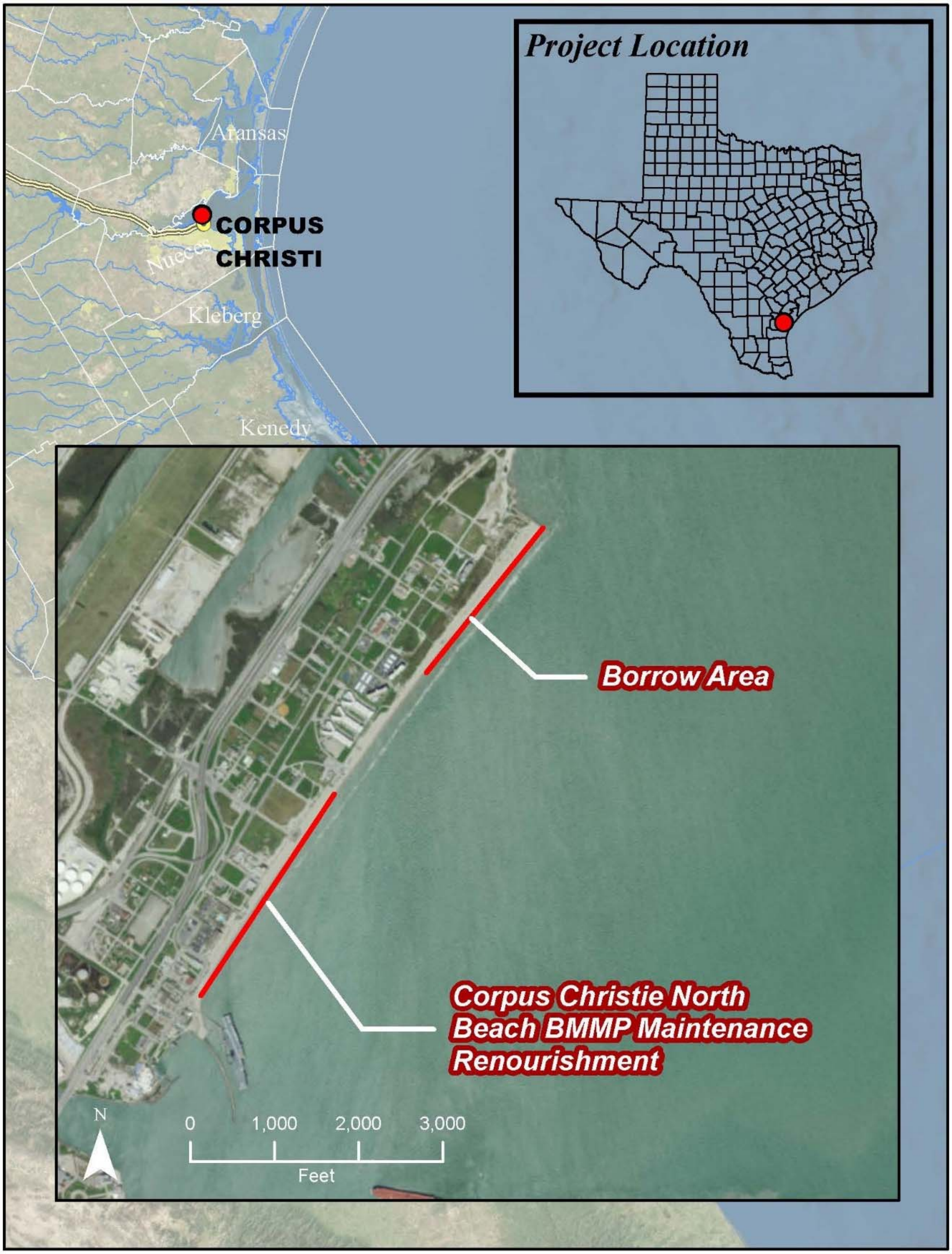


Figure 3.2.1 North Beach Location Map

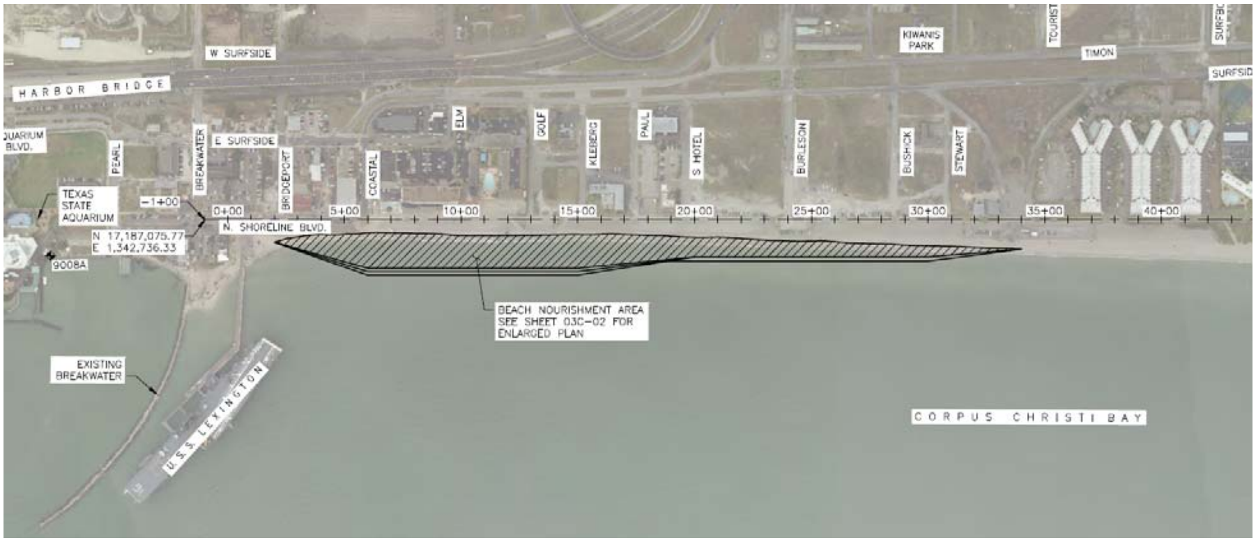


Figure 3.2.2 North Beach Fill Area (Construction Drawings provided by GLO)

Figure 3.2.3 North Beach Pre-Construction Conditions (11/15/15; Photo provided by GLO)

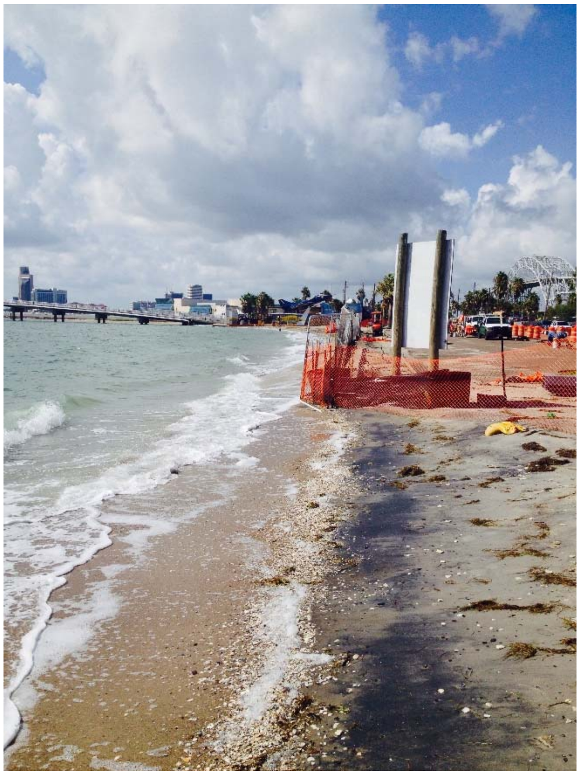


Figure 3.2.4 North Beach Pre-Construction Conditions (9/5/14; Photo provided by GLO)

Figure 3.2.5 Southwestward View of North Beach During Construction (Photo provided by GLO)

Figure 3.2.6 Southwestward View of North Beach Post-Construction (Photo provided by GLO)

Figure 3.2.7 Post-construction Aerial (Photo provided by GLO)

Figure 3.2.8 Northeastward View from Station 13+50, Post-Construction (10/20/2016)

Figure 3.2.9 Southwestward View from Station 13+50, Post-Construction (10/20/2016)

Analysis

Economic benefits from CEPRA Project #1569 result from storm damage reduction and visitation. This analysis assumes a project life of seven years, as estimated in HDR (2014), following project construction, from 2017 – 2023. Estimates of storm damage reduction benefits derived from beach erosion modeling results of pre- and post-storm conditions with and without the project. No overcrowding of the beach occurs with or without the project; thus, the visitation estimates are the same for both cases, and no out-of-state visitor spending benefits accrue as a result of this project (i.e., out-of-state visitor spending is the same with or without the project).

Storm Damage Reduction

Estimating storm damage reduction benefits required modeling with- and without-project conditions in SBEACH. No significant storms impacted the project area during 2016; thus, the project did not provide benefits during the first year of this analysis. This study applied synthetic storms and background erosion rates for years 2017 – 2023 for with- and without-project conditions to develop potential storm damages resulting from land loss, infrastructure damage, and damage to upland structures. The Texas A&M University Conrad Blucher Institute for Surveying and Science provided pre-construction (June 2015) beach profile data along the project area. Taylor Engineering developed representative post-construction profiles utilizing the as-built survey provided by GLO, observations during the October 2016 site visit, and profile slope characteristics of the June 2015 survey. Figure 3.2.10 presents representative pre- and post-construction profiles, which represent the initial without- and with-project condition for SBEACH modeling of the southern fill section. The analysis also developed similar profiles representative of the northern fill section for SBEACH modeling of that stretch of shoreline. This study applied the SBEACH model parameters shown in Table 3.2.2.

Taylor Engineering developed synthetic return period (1-, 2-, 5-, 10-, 20-, 50-, and 100-year) storm events applicable to the project location within Corpus Christi Bay. Taylor Engineering adopted return-period storm surge elevations from the Nueces County Flood Insurance Study (FEMA, 2015) and developed probabilistic wind speeds required to estimate wind-generated waves according to the methodology outlined in ASCE (2011). Using the return period storm surge elevations and wind speeds, Automated Coastal Engineering System (ACES) software (Leenknecht, et. al., 1992) provided estimates of significant wave heights and peak wave periods for each storm event.

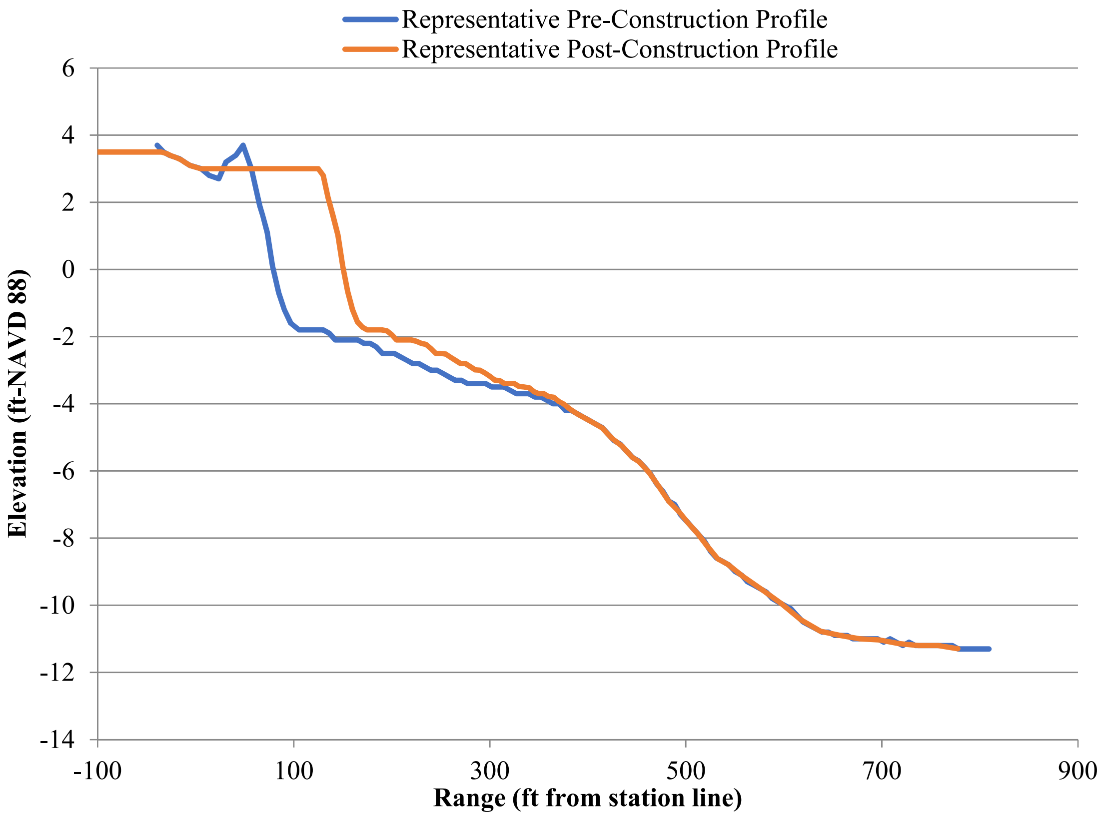


Figure 3.2.10 North Beach Representative Pre- and Post-Construction Profiles

Table 3.2.2 SBEACH Model Parameters

Parameter	**Value**
Transport Rate Coefficient (K)	2.00×10^{-6} m^4/N
Eps Parameter (ϵ)	0.002 m^2/s
Transport Rate Decay Factor (λ)	0.5 m^{-1}
Avalanching Angle (φ)	30°
Landward Surf Zone Depth	1.5 ft
Median Grain Size	0.3 mm

For each year of the project life, beginning in 2017, the analysis adjusted the with- and with-out project representative profiles by the background erosion rate (-10 ft/yr and -7 ft/yr for the southern and northern fill sections) and then applied synthetic storms to these profiles. To simulate 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storm events, the model applied the synthetic storm characteristics shown in Table 3.2.3. Developing synthetic time-varying storm surge hydrographs required applying Eq. 3.1 (page 39). The final water surface elevation time series consists of three standard tidal cycles (about 72 hours) developed from a normally varying tide from mean high water (1.02 ft-NAVD) to mean low water (0.41 ft-NAVD), generated by Eq. 3.2 (page 39), followed by the return period specific storm surge hydrograph. Note that substituting 1.02 for 1.12 and 0.41 for 0.36 in Eq. 3.2 produces the desired normal tide hydrograph. Minor smoothing at the transition prevented abrupt changes in the water surface elevation. Figure 3.2.11 shows the final 1-, 2-, 5-, 10-, 20-, 50-, and 100-year hydrographs.

Table 3.2.3 Peak Storm Characteristics for Various Return Periods

Return Period (yr)	**1**	**2**	**5**	**10**	**20**	**50**	**100**
Storm Tide[†] (feet NAVD)	1.5 [a]	2.5 [a]	3.5 [a]	5	5.9 [a]	6.8	8.4
Wave Height[‡] (feet)	3.8	4.5	5.2	5.9	6.5	7.2	8.1
Wave Period[‡] (seconds)	4.1	4.5	4.8	5	5.2	5.4	5.7

[†] Data from FEMA (2015)
[‡] Developed with ACES utilizing return-period wind events
[a] Assumed value
[*] Interpolated

As with the storm surge, the temporal wave height variation consisted of two parts. A cosine squared distribution (Eq. 3.3, page 40) approximated the wave heights during normal conditions over the first 72 hours (3 tidal cycles), followed by a sine squared distribution (Eq. 3.4, page 40) which approximated the storm wave heights over 36 hours. Each tidal cycle averaged 24.8 hours, and the wave heights varied from 0.4 to 0.8 ft, representing the relatively calm conditions observed in Corpus Christi Bay. Storm wave heights varied from 0.8 ft to the peak wave height (Table 3.2.3) and abate to 1 ft after storm passage. The 1-ft value for H_{min} simulates the agitated sea conditions typically found after a storm passes an area. Figure 3.2.12 shows the resulting wave height distributions the model requires.

During the first 72 hours of normal conditions, the wave period varies from two to three seconds for return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. Similarly, a sine squared distribution approximated the storm wave periods over the final 36 hours with a minimum final wave period of three seconds. Figure 3.2.13 shows the resulting wave period distributions the model requires.

SBEACH produced post-storm profiles for 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storms on eroded with- and without-project profiles from 2017 – 2023. Figure 3.2.14 presents a typical post-storm profile for without- and with-project conditions for the 5-year storm.

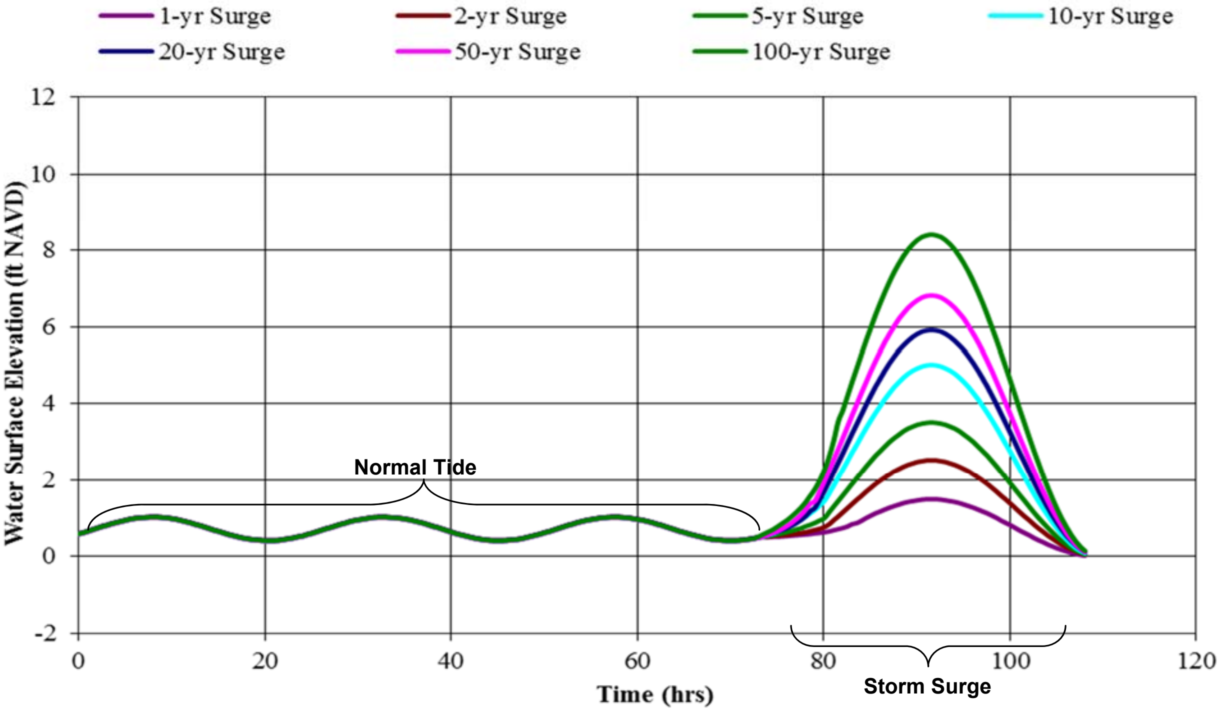


Figure 3.2.11 North Beach Time-Varying Water Surface Elevations

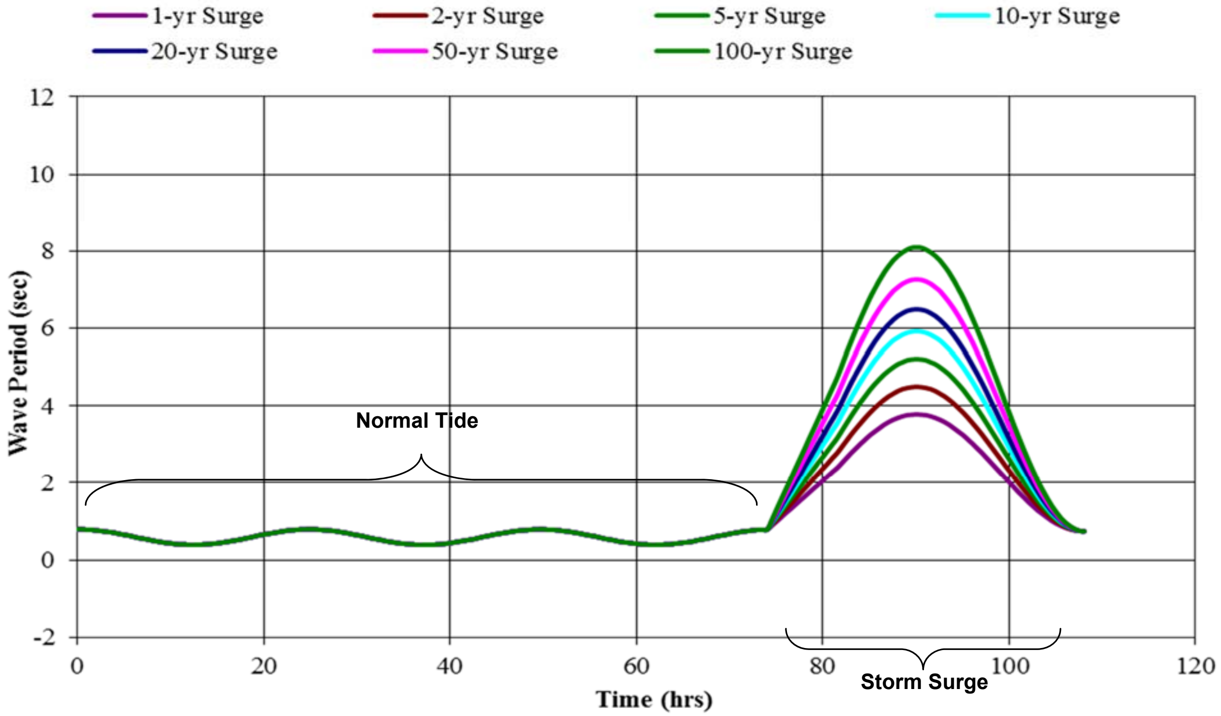


Figure 3.2.12 North Beach Synthetic, Time-Varying Wave Heights

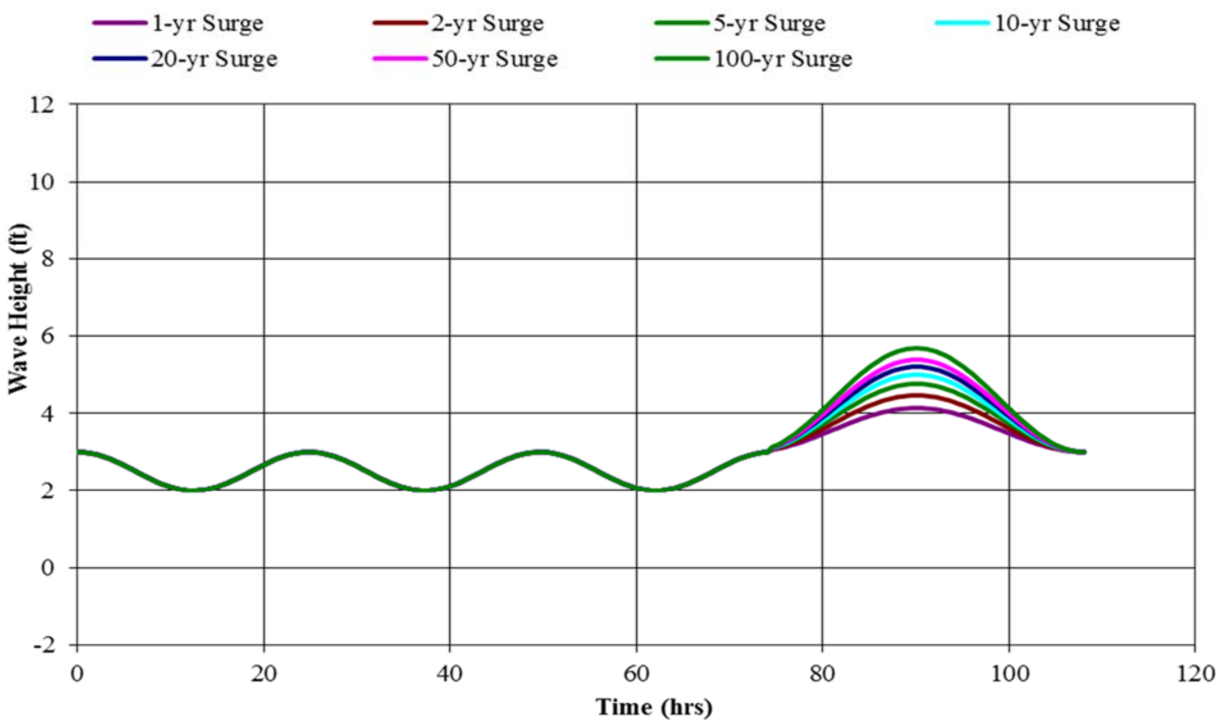


Figure 3.2.13 North Beach Synthetic, Time-Varying Wave Period

The methodology outlined in Section 2.2 and the site-specific information described above produces the damage-cumulative probability distribution from 2017 – 2023 on the with- and without-project representative profiles.

Based on the maximum predicted erosive shoreline condition, the present analysis includes all Bay front properties located approximately 300 feet landward of the shoreline, upland of the original project footprint. Calculations of potential infrastructure damages include erosion within parking lots and the concrete sidewalk that runs along the beachfront. Reconstruction costs calculated per square foot of eroded area, constitute these infrastructure damage values. Table 3.2.4 presents the damage-cumulative probability distribution for 2017 with-project conditions. From the table, the expected annual total damage for this condition averages $36,189 (2016 prices). The same process for conditions without the project results in expected average annual damage of $986,783. Appendix A presents these distributions for the 2017 – 2023 with- and without-project conditions. Of note, the 10-yr return period storm causes the most damage, as larger storms tend to inundate the beach and not batter and erode the berm as drastically.

Table 3.2.5 presents a summary of expected storm damage reduction benefits for CEPRA Project #1569. From the table, the total benefit over the period of analysis equals $9,208,123.

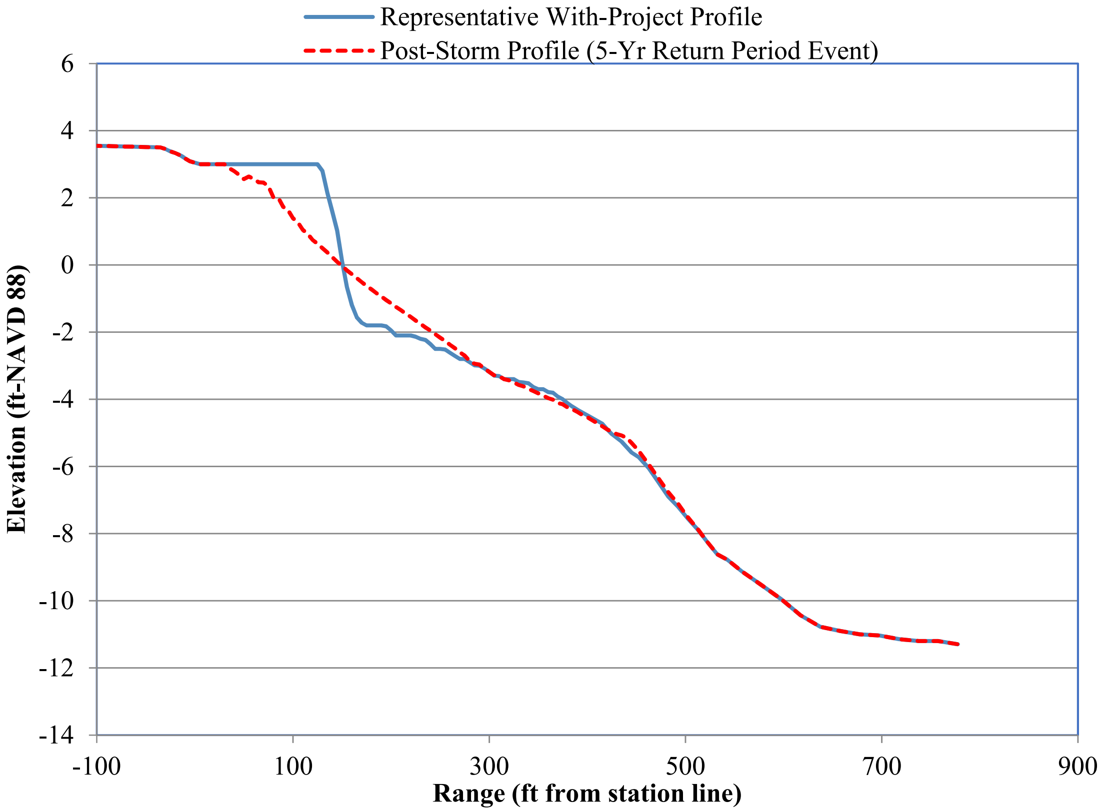


Figure 3.2.14 North Beach With-Project Five-Year Post-Storm Profile

Table 3.2.4 North Beach Total Damage-Cumulative Probability (2017 Conditions, with Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0	$0	$0			
2	0.50	0.50	$0	$27,350	$0	$27,350	$13,675	0.50	$6,837
5	0.20	0.80	$0	$50,705	$0	$50,705	$39,028	0.30	$11,708
10	0.10	0.90	$31,321	$99,421	$959	$131,701	$91,203	0.10	$9,120
20	0.05	0.95	$0	$55,994	$0	$55,994	$93,847	0.05	$4,692
50	0.02	0.98	$0	$61,317	$0	$61,317	$58,655	0.03	$1,760
100	0.01	0.99	$0	$117,642	$0	$117,642	$89,480	0.01	$895
>100	<0.01	>0.99	$0	$117,642	$0	$117,642	$117,642	0.01	$1,176
			Expected Average Annual Damage in Dollars:						$36,189

Notes: 2016 Price Levels

Table 3.2.5 Storm Damage Reduction Benefit — #1569 North Beach Nourishment Project

Year	Without Project (2016 Prices)	With Project (2016 Prices)	Difference (Benefit)	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
2016	$0	$0	$0	$0	$0	$0
2017	$986,783	$36,189	$950,593	$970,556	$926,304	$926,304
2018	$1,094,748	$47,439	$1,047,309	$1,091,758	$1,010,062	$1,936,366
2019	$1,230,566	$62,264	$1,168,303	$1,243,462	$1,115,175	$3,051,540
2020	$1,439,587	$78,435	$1,361,152	$1,480,590	$1,287,164	$4,338,704
2021	$1,668,506	$118,557	$1,549,950	$1,723,045	$1,452,059	$5,790,763
2022	$1,889,370	$156,765	$1,732,605	$1,968,473	$1,608,073	$7,398,836
2023	$2,181,253	$213,540	$1,967,713	$2,284,770	$1,809,287	$9,208,123

Notes: Inflation rate 2016 to 2019 = 2.1%; Inflation rate 2019 to 2023 = 2.2%;
Discount rate = 3.16% (mid-year discounting), present worth as of beginning of 2016

Recreation Benefits

Recreation benefits for the North Beach project derive from the visitation rates and increase in recreational enjoyment. A 2014 Texas A&M University economic study of the tourism to the Corpus Christi metropolitan area estimates a total of 8.1 million visitors from 2012 – 2013, contributing $1.2 billion to the local economy (Lee, 2014). Of that contribution, an estimated $674 million relates to nature and wildlife tourism, which includes beach visitation.

Site-specific visitation estimates are unavailable for North Beach. Use of previous estimates, such as those reported by Oden and Butler (2006) and Taylor Engineering (2015), may not be directly applicable due to the location (within a bay environment), proximity of gulf-front beaches, and the population of Corpus Christi. As a reasonable scale of potential visitors to North Beach, the neighboring Lexington Museum hosts approximately 300,000 annual visitors. Due to the lack of available data, this study assumes that North Beach experiences annual visitation rates equal to the estimate provided by the Lexington museum. The project placement area encompasses approximately half of the length of North Beach, so this study assumes a 2016 visitation rate of 150,000 annual visitors and an annual population growth of 1.4%. Visitation begins following project construction which concluded mid-2016. Accordingly, the 2016 visitation estimate is half of the annual visitation (75,000 visitors).

An additional result of data availability, differences in visitation with and without the project are difficult to predict. Reductions in visitation as a result of the eroded beach carrying capacity are also inadequate, because the capacity — based on the requirement of 100 sf/visitor (Oden, 2006) — exceeds the estimation of annual visitors (i.e. no overcrowding occurs). As such, the estimates of visitation are equal with and without the project. However, this assumption likely under-predicts the total recreational benefit of the project.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the user day values (UDV) (see Section 2.2, Table 2.5) developed for with- and without-project conditions. Table 3.2.6 presents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of $7.63 and $6.54 per person per visit (2017 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project for each year, adjusted for general annual population growth (i.e., 1.4%), yields the benefit for each year. Table 3.2.7 presents the recreation value benefit for this project ($1,199,991 present value, beginning of 2016).

Table 3.2.6 UDV Points Assigned — #1569 North Beach Nourishment Project

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	17	17	30
Availability of Opportunity	3	3	18
Carrying Capacity	9	4	14
Accessibility	8	8	18
Environmental	5	2	20
Total	42	34	100

Benefit-Cost Summary

The storm protection and increase in recreational value of beach visitation result in a combined benefit of $10,408,114, accrued throughout the seven-year project life (Table 3.2.8). With project costs totaling $2,475,577, this project has a 4.20 B/C ratio.

Table 3.2.7 Recreational Benefit for All Users — #1569 North Beach Nourishment Project

Year	Total Visitation		Recreation Value (2017 Prices)		Difference	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	75,000	75,000	$572,250	$490,500	$81,750	$80,069	$78,833	$78,833
2017	152,100	152,100	$1,160,523	$994,734	$165,789	$165,789	$158,230	$237,063
2018	154,229	154,229	$1,176,770	$1,008,660	$168,110	$171,640	$158,797	$395,859
2019	156,389	156,389	$1,193,245	$1,022,782	$170,464	$177,698	$159,365	$555,224
2020	158,578	158,578	$1,209,951	$1,037,100	$172,850	$184,150	$160,092	$715,317
2021	160,798	160,798	$1,226,890	$1,051,620	$175,270	$190,836	$160,823	$876,140
2022	163,049	163,049	$1,244,066	$1,066,343	$177,724	$197,765	$161,557	$1,037,697
2023	165,332	165,332	$1,261,483	$1,081,271	$180,212	$204,946	$162,294	$1,199,991

Notes: UDV (with project) = $7.63 (2017 price levels)
UDV (without project) = $6.54 (2017 price levels)
Inflation rate 2016 to 2019 = 2.1%; Inflation rate 2019 to 2023 = 2.2%;
Present worth, beginning of 2016, mid-year discounting, 3.16% discount rate [mid-year discount factor = (1/1.0316)n+0.5, where n = year – 2016]

Table 3.2.8 Benefit-Cost Summary — #1569 North Beach Nourishment Project

Benefits and Costs	Discounted Present Worth (beginning of 2016)[2]
Storm Damage Reduction	$9,208,123
Recreation Value	$1,199,991
Total Benefit	$10,408,114
Total Cost[1]	$2,475,577
B/C Ratio	**4.20**

[1] Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)

[2] Dollar values represent present worth equivalents at the beginning of 2016 with a 3.16% discount rate

3.3 Brazoria County — #1570 Village of Surfside Beach BMMP Maintenance Renourishment and #1573 Village of Surfside Beach Revetment Emergency Repair

Background Information

The Village of Surfside Beach lies immediately north of the Freeport Ship Channel Entrance along the Gulf of Mexico in Brazoria County, Texas (Figure 3.3.1). Chronic long-term erosion, storm-related episodic erosion, and upland development characterize the area's beaches. Upland development in the project area generally comprises single-family homes with shorefront structures located close to the shoreline. Beach Drive runs parallel to the shoreline immediately seaward of the first row of homes throughout the project area. The most recent long-term erosion rates (1950s – 2012) predicted by the Bureau of Economic Geology (BEG) range from -8.1 ft/yr near the Freeport Jetty to -4.4 ft/yr at Hwy 332. A previous study (Coast and Harbor Engineering [CHE], 2008b) cites recent erosion rates of -30 ft/yr from 2004–2006.

In 2008, an emergency revetment was constructed to protect Beach Drive, upland properties, and infrastructure from high-frequency (i.e., 2-year return period) storm events. Shortly after project completion in 2008, Hurricane Ike severely eroded the beach and damaged the existing revetment along Beach Drive while making landfall in Galveston. Compared to the local statistical distribution of storms, Hurricane Ike had a 30-year return period (CHE, 2008). Designed to protect against a two-year return period storm, the revetment suffered displacement of much of the armor stone yet prevented major damage to the majority of Beach Drive; the revetment and road suffered damage costing approximately $919,050 to repair (CHE, 2008).

In response to the storm-induced damage, the GLO initiated CEPRA project #1471 to repair the revetment damages and #1511 to protect the toe of the revetment and create a wide useable beach. Revetment repairs and enhancements, constructed during winter (January through March) 2011, consisted of installation of large stone blocks, relocating the existing armor stone, and filling voids with grout to fortify the revetment. The two-phased nourishment project involved trucking beach quality fill material from permitted upland borrow sources to the specified placement area. Phase 1 occurred during fall (October–November) 2010 prior to the revetment work; the fill template consisted of a 102-ft wide berm at elevation 5.5 ft relative to the 1988 North American Vertical Datum (NAVD). Phase 2 constructed a dune throughout the project area during winter (January–March) 2012. The Phase 2 fill template consisted of a 20-ft wide dune at elevation 7.5 ft NAVD tying into the existing revetment and sloping (1V:6H) seaward; the southern 2,600 ft of the project also included a 45-ft wide berm at elevation 5.5 ft NAVD tying into the newly constructed dune (i.e., the project filled in eroded areas of the Phase 1 berm). High levels of erosion of the nourishments were observed after construction completion. Previous investigations by CHE have found that most of the eroded material moves northeast away from the Freeport Jetty (CHE 2008b, CHE 2014).

Continued erosion of the nearshore bathymetry prompted the need for another maintenance nourishment project (CEPRA Project #1570), based on analysis of ongoing surveys and criteria established within the Beach Monitoring and Maintenance Plan (BMMP) (CHE, 2010), as well as additional repairs to the revetment (CEPRA Project # 1573) to fix displacement and slumping of the armor stone. This study treats projects #1570 and #1573 as a combined project, as the construction of revetment repairs and the structural integrity of the revetment are intertwined with the beach nourishment. Attempting to conduct the emergency repairs without a dry beach would have been very difficult; the cost for doing so would likely have been at least double the actual cost of Project #1573.

Project Description

Project #1573 consisted of repairing the westernmost 1,275 ft of the existing rock revetment along Beach Drive to protect the roadway and surrounding public infrastructure. The revetment repair was designed to withstand 25-year storm conditions. Project #1570 entailed a maintenance nourishment of the beach immediately seaward of the revetment repair segment, from just west of Texas St. eastward to roughly 400 ft east of Angel Wing St. The project shoreline is classified as a Tier 1 Beach, characterized by widespread erosion or hot spots where infrastructure is threatened (Williams 2014), and the BMMP recommends nourishment when the beach reaches 50% of the target width. The project area authorized in the BMMP extends approximately one mile from near the Freeport Channel eastern jetty to the eastern end of Beach Drive; however, Projects #1570 and #1573 focused on the most critically eroded segment extending from approximately Texas Street eastward to Crab Street. The GLO implemented both projects under a single construction contract, with revetment repairs occurring on dry beach following the maintenance nourishment.

Construction of the nourishment occurred during February–March 2015, and revetment repairs occurred from March–May 2015. The contractor, Apollo Environmental Strategies (AES), placed approximately 26,553 tons of beach fill material within the project area, with the fill template consisting of an approximately 125-ft wide berm at elevation 5.5 ft relative to the 1988 North American Vertical Datum (NAVD). AES placed 2,492 tons of armor stone and 3,427 tons of toe stone during the revetment repairs to fill void space decrease the seaward revetment slope, and repair the dilapidated western terminus of the revetment. These repairs were designed to create a stronger, more resilient structure for coastal erosion protection and increase accessibility to the beach. Figures 3.3.2 – 3.3.5 present pre-construction, during construction, and post-construction conditions. Figures 3.3.6 – 3.3.7 show conditions on January 19, 2017, approximately two years after construction.

Project Funding

Table 3.3.1 presents the funding breakdown and combined total for project #1570 and project #1573. All costs associated with both projects were funded through CEPRA; no federal cost sharing occurred. Projects #1570 and #1573 incurred some costs in mid- to late 2014; however, most of the costs for both projects were incurred in early to mid-2015. This analysis treats all costs for these two projects as though they were incurred at the beginning of 2015 (i.e., present worth, beginning of 2015, in 2015 price levels).

Table 3.3.1 Funding for #1570 Village of Surfside Beach BMMP Maintenance Renourishment & #1573 Village of Surfside Beach Revetment Emergency Repair

Project	Funding Source	Amount
Project #1570	Texas General Land Office, CEPRA: 100% of total project cost	*$1,587,467.59*
Project #1573	Texas General Land Office, CEPRA: 100% of total project cost	*$656,855.72*
Combined Total	Texas General Land Office, CEPRA: 100% of total project cost	*$2,244,323.31*

Note: Values in italics are costs to the State of Texas.
Values represent 2015 Prices, Present Worth, Beginning of 2015

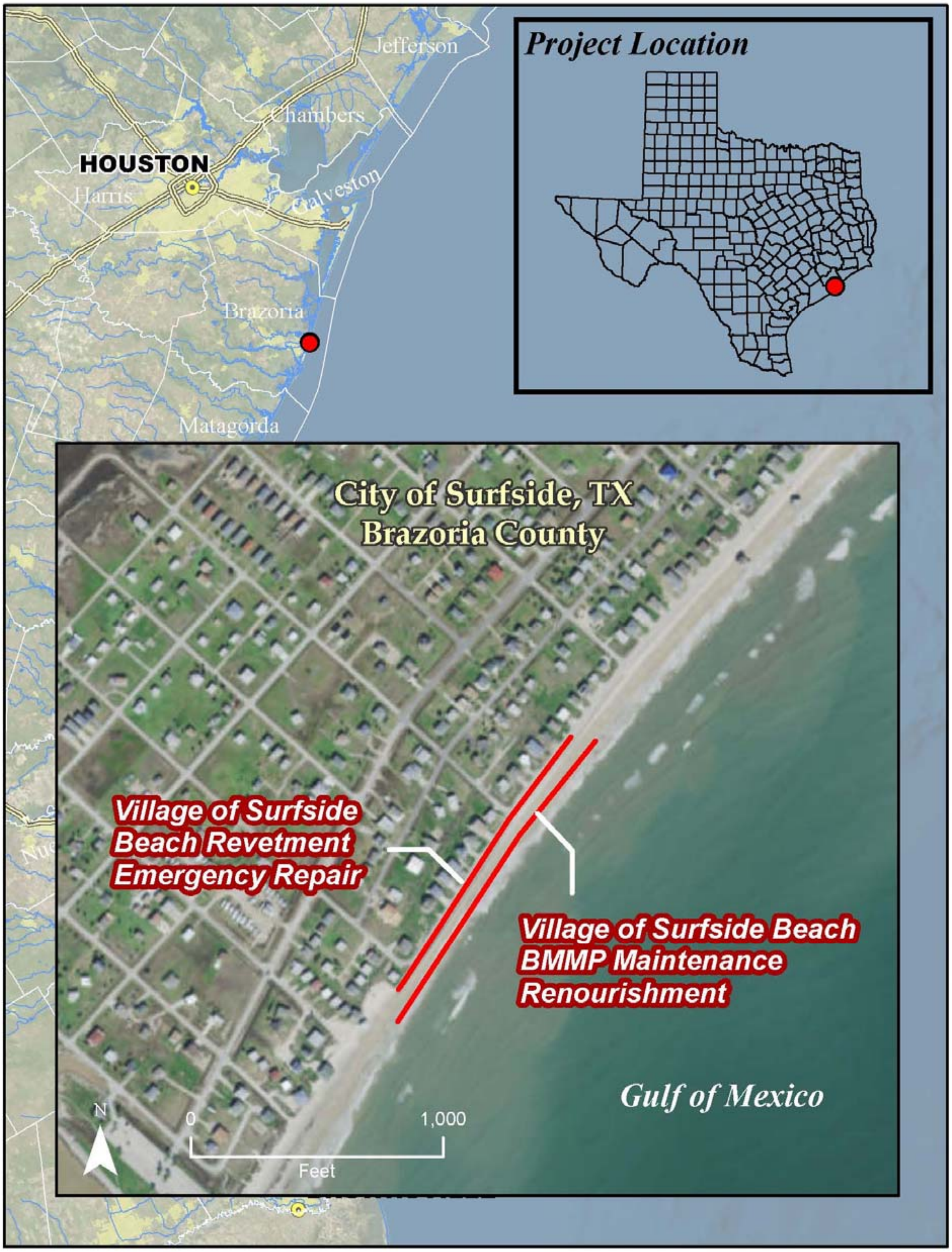


Figure 3.3.1 Surfside Revetment and Beach Nourishment Location Map

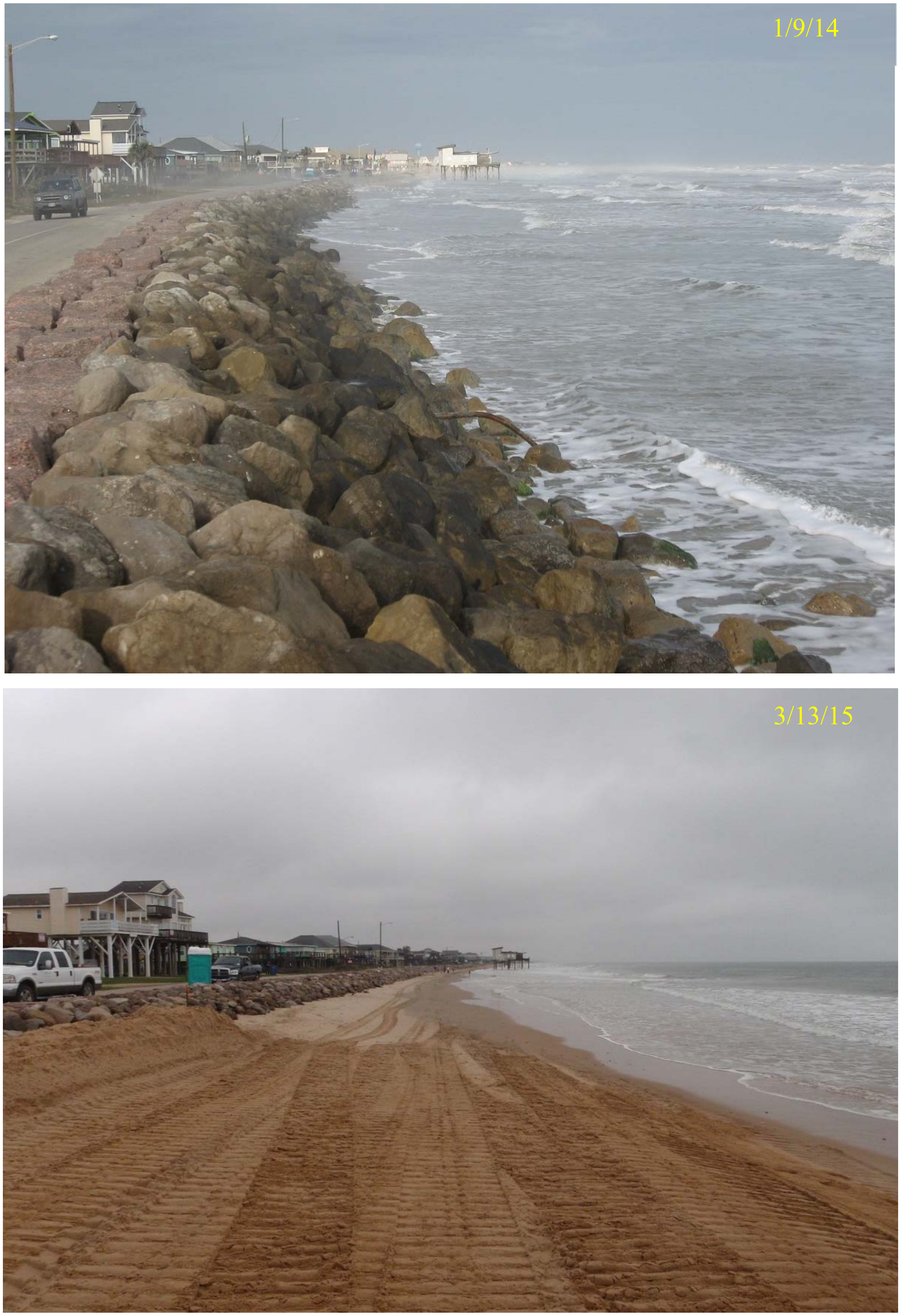


Figure 3.3.2 Eastward View of Project #1570 Pre-and Post-construction (provided by GLO)

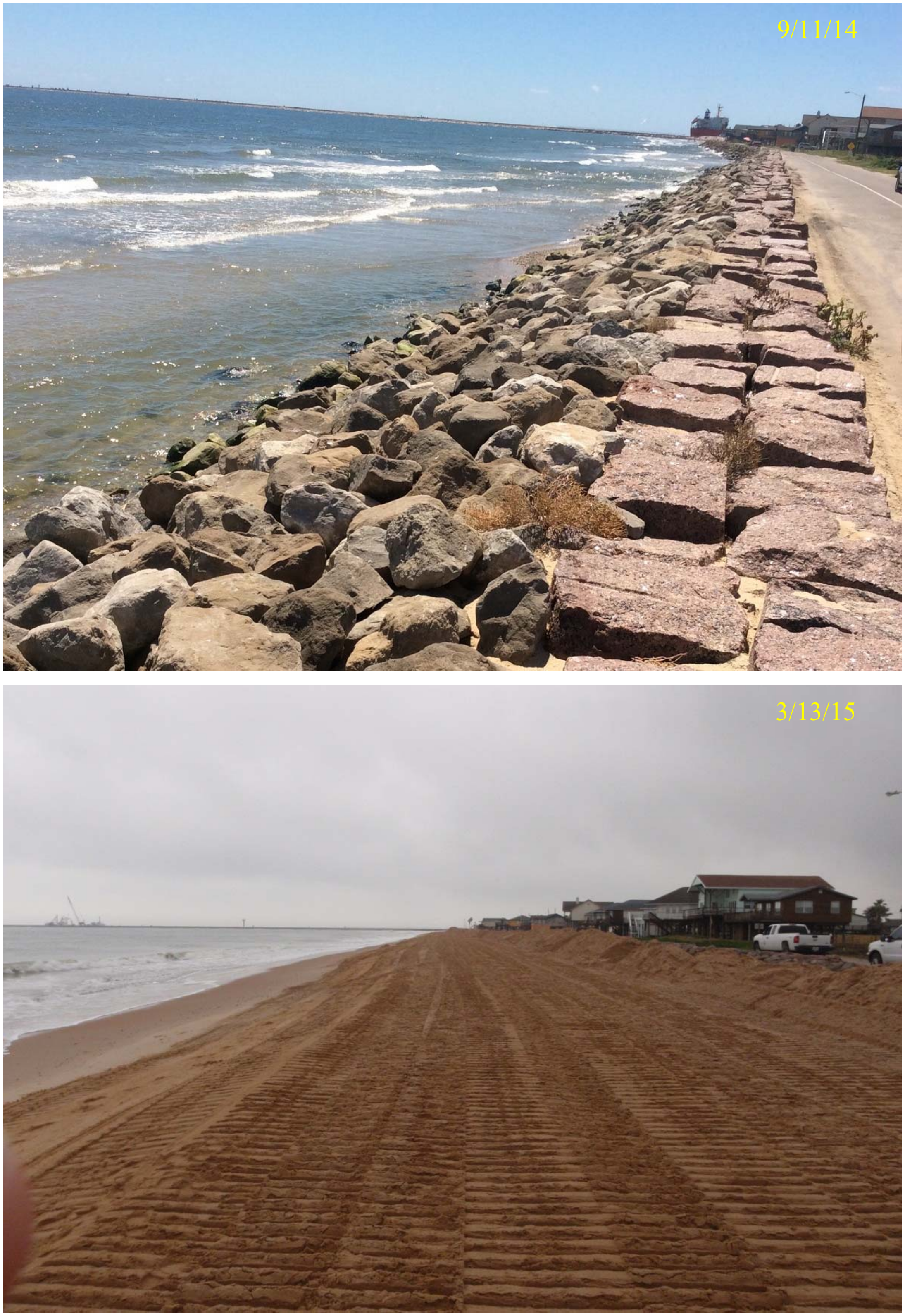


Figure 3.3.3 Westward View of Project #1570 Pre- and Post-construction (provided by GLO)

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Figure 3.3.4 Surfside Revetment Project#1573 During Construction (provided by GLO)

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Figure 3.3.5 Westward Terminus of Revetment During Construction (provided by GLO)

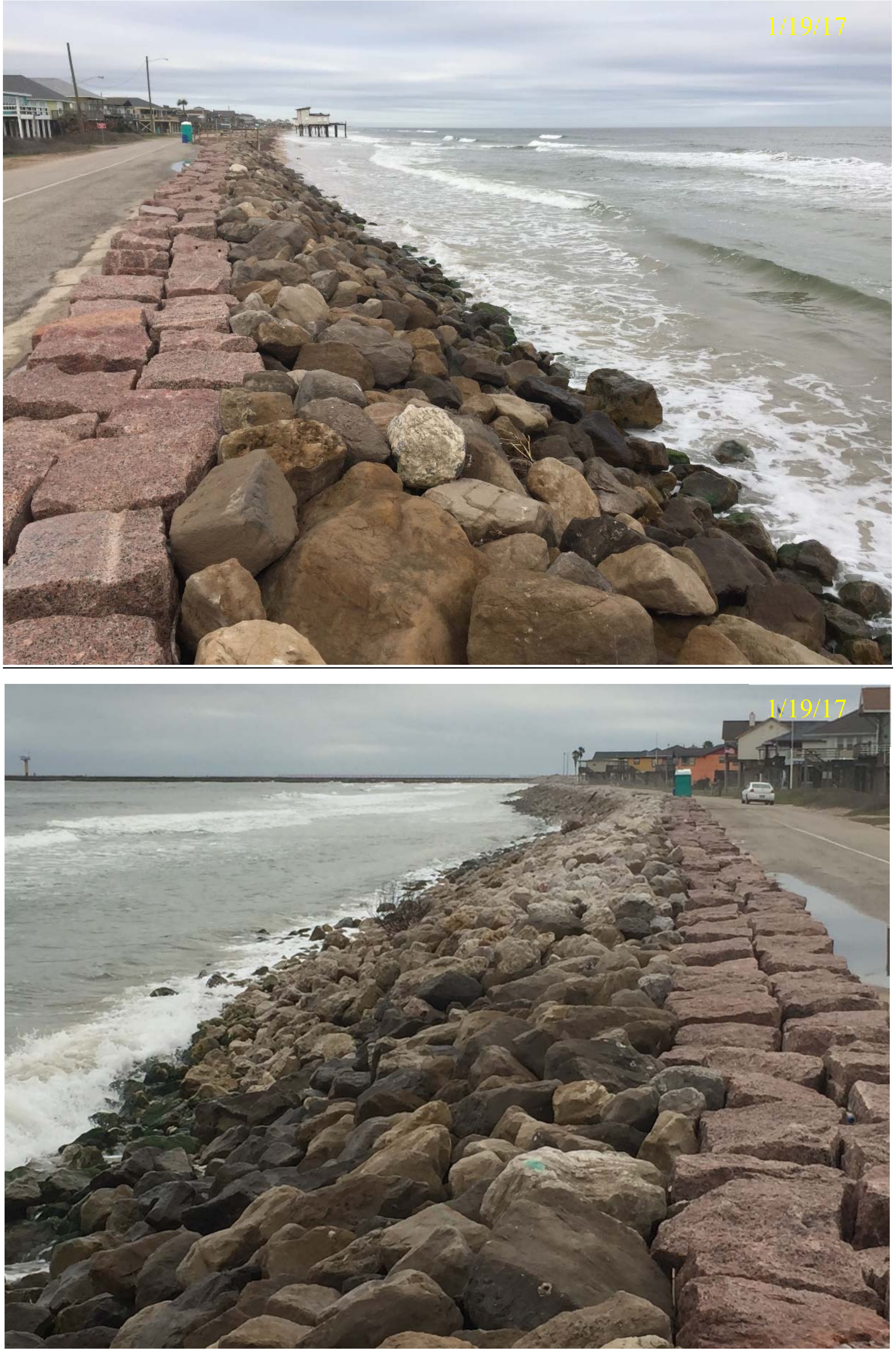

Figure 3.3.6 Eastward (top photo) and Westward (bottom photo) View at East End of Revetment Repair, Present Conditions (1/19/17)

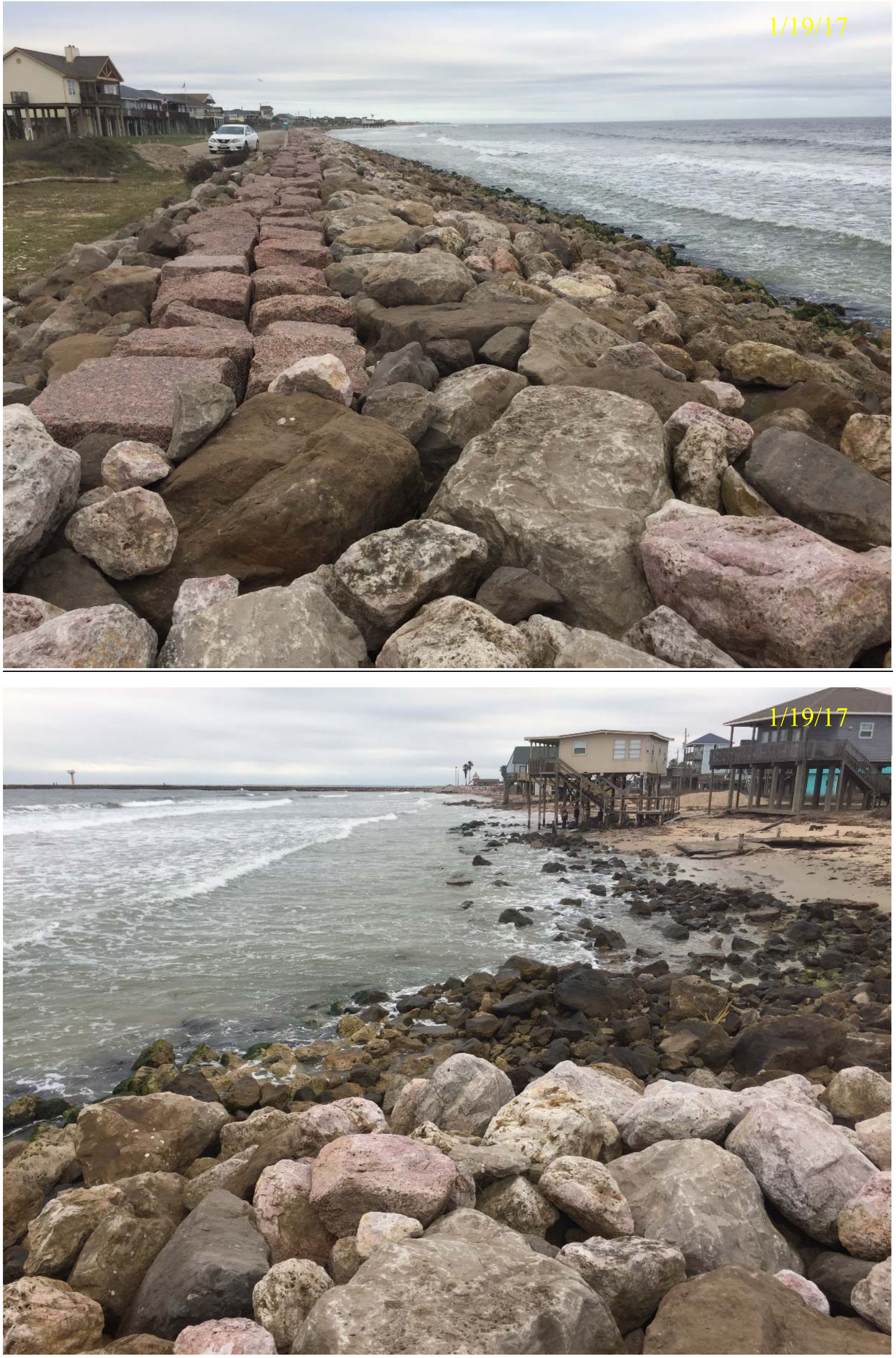

Figure 3.3.7 Eastward (top photo) and Westward (bottom photo) View at West End of Revetment Repair, Present Conditions (1/19/17)

Analysis

Economic benefits from the beach nourishment project includes visitation and storm damage reduction. This analysis adopted two visitation benefit categories — spending by out-of-state visitors and recreational enjoyment by all visitors. Both require estimates of the beachgoer population over the project life, assumed to be 10 years for this analysis. Storm damage reduction benefits were derived from comparisons of pre- and post-storm conditions with and without the project. Known and probabilistic tropical events served as input.

Visitation Benefits

Taylor Engineering (2015) reports about 1,162 peak day visitors to a roughly 1-mile stretch of Surfside Beach based on an afternoon survey in 2015; the results equated to 185 visitors per 1,000 ft of beach. Assuming an average daily turnover rate of 2, the daily visitation estimate equals 370 per 1,000 ft of beach. Based on the roughly 1,300-ft project length, the project area experiences 481 peak day visitors. Assuming 104 peak visitor days occur in the Surfside Beach area, one-fifth (assumed) of the peak day visitors (96) visit the beach during off peak days, and 261 (i.e., 365 – 104) off peak days occur during a 365-day year, then approximately 75,080 visits (50,024 [481 * 104] + 25,056 [96 * 261]) occurred in 2015 in the project area.

The as-built survey (July 29, 2015) indicates that a 50-ft wide berm remained throughout the project area (wider in some spots). Incorporating the above information yields without- and with-project (Table 3.3.2) visitation estimates. In the tables, the first beach visitation column represents beach visitation without any beach width constraint on visitation (i.e., beach visitation grows at an estimated 1.4% annually). One must calculate this beach visitation number as a required starting point for applying the beach width elasticity relationship (Taylor Engineering, 2015) to determine estimated beach visitation with- and without-the project. Given site-specific data, this analysis adopts the elasticity relationship where a 1% visitor reduction occurs for every 1% loss of beach width for the first 50% loss of beach width. Once the beach erodes completely, 43% visitation still occurs (or 57% reduction in beach visitors). Application of the elasticity relationship to estimated visitation growth and to estimated beach width in relevant years since the time of the survey accounts for beachgoers' beach width preferences.

Table 3.3.2 Surfside Beach Nourishment without Project, Total Beach Visitation

Year	Unconstrained Annual Visitation[1]	With-Project Beach Width (ft)	Without-Project Beach Width (ft)[3]	With-Project Constrained Annual Visitation[2]	Without-Project Constrained Annual Visitation
2015	75,080	50	0	75,080	32,284
2016	76,131	25[2]	0	38,066	32,736
2017	77,197	0	0	33,195	33,195

Notes: [1]Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%/year

[2]Assumed beach width (i.e., not surveyed)

[3]Visitation reduced by 1% for every 1% loss of beach width up to 50%; visitation reduced by 57% for complete erosion of the beach (i.e., zero dry beach width)

With- and without-project visitation estimates (Table 3.3.2) serve as input for estimating the benefits from spending by out-of-state visitors and the value of recreation benefits for all visitors. Taylor Engineering (2015) reports that approximately 4.7% of the visitors to Galveston and Surfside beaches originate from outside Texas. These out-of-state visitors spend \$59.08 (2015 dollars) per person per visit in the area. Table 3.3.3 summarizes the benefit to Texas from spending by out-of-state visitors (including the multiplier effect). The present value of this benefit (present value, beginning of 2015) is \$83,848.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers derived in Tables 3.3.2 to the UDV developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.3.4 presents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about \$8.12 and \$5.57 (2017 prices) per person per visit. Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. Table 3.3.5 presents the recreation value benefit for this project. In total, the benefit equals \$528,017 (present value, beginning of 2015).

Table 3.3.3 Surfside Beach Project #1511 Out-of-State Visitor Spending Benefit

Year	Total Visitation		Out of State				Difference (2015 Prices)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
			Visitation		Visitor Spending					
	With Project	Without Project	With Project	Without Project	With Project	Without Project				
2015	75,080	32,284	3,529	1,517	$291,871	$125,504	$166,366	$166,366	$163,798	$163,798
2016	38,066	32,736	1,789	1,539	$147,978	$127,262	$20,717	$21,007	$20,049	$183,848
2017	33,195	33,195	1,560	1,560	$129,043	$129,043	$0	$0	$0	$183,848

Notes: Total visitation estimates are derived from Tables 3.3.2
Out-of-state visitation = 4.7% of total visitation
Out-of-state visitor spending = $59.08 per person (2015 prices)
Multiplier effect = 1.4; inflation 2015-2016 = 1.4%, 2016-2017 = 2.1%
Discount rate = 3.16% (mid-year discounting), present value at beginning of 2015

Table 3.3.4 UDV Points Assigned for Surfside Beach Project #1570

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	10	1	30
Availability of Opportunity	3	3	18
Carrying Capacity	10	1	14
Accessibility	14	14	18
Environmental	10	6	20
Total	47	25	100

Table 3.3.5 Surfside Beach Project #1570 Recreational Benefit for All Users

Year	Total Visitation		Recreation Value (2015 Prices)		Difference (2015 Prices)	Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2015	75,080	32,284	$589,378	$173,688	$415,690	$415,690	$409,274	$409,274
2016	38,066	32,736	$298,818	$176,120	$122,698	$124,416	$118,744	$528,017

Notes: Inflation rates: for 2015 to 2016, 1.4%; for 2016 to 2017, 2.1%
UDV (with project) = $8.12 (2017 prices) = $7.85 (2015 prices) (i.e., $8.12/[1.021*/1.014])
UDV (without project) = $5.57 (2017 prices) = $5.38 (2015 prices) (i.e., $5.57/[1.021*1.014])
Discount rate = 3.16% (mid-year discounting), present value at beginning of 2015

Storm Damage Reduction Benefits

No significant storms impacted the project area during 2015 and 2016, thus the project did not provide benefits for these years. With no dry beach remaining of the nourishment, this analysis assumes no future storm damage reduction benefits will arise from Project #1570. However, the revetment repairs are important to the integrity of the structure and maintaining its significant storm damage reduction benefits. Routine maintenance of the revetment will likely be required over the long-term to maintain the structure's functionality, particularly if a beach is not maintained in front of the revetment. The scope of maintenance costs may vary considerably. This study considers Project #1573 a major maintenance event, and assigns it a project life of 10 years.

Determining the level of storm protection the revetment provided prior to Project #1573 is difficult. Given the slumping of armor stone, exposed under layer, void spaces, and other deficiencies noted in the pre-construction condition, the revetment certainly does not appear to offer the design 25-yr return period storm protection. Failure of the revetment during the early stages of a storm would drastically reduce the revetments effectiveness for the duration of the storm. This analysis assumes the portion of the revetment within the project area (i.e., a 1,275 ft portion of the roughly 3,500-ft long revetment) would have provided a level of protection comparable to the original revetment constructed in 2008. As mentioned, the original revetment prevented major damage to the majority of Beach Drive during Hurricane Ike.

Krecic et al. (2011) evaluated the storm damage reduction benefit of the original revetment by applying the SBEACH storm erosion model. The results of that modeling effort remain valid, as the modeled condition (i.e., no dry beach existing in front of the revetment) resembles 2015 existing conditions prior to the revetment repairs. This study applied the results of Krecic et al. (2011) by prorating the results to the Project #1573's length (1,275 ft/3,500 ft). Of note, CHE (2008) reports a larger proportion of Beach Drive damage from Hurricane Ike occurred at the west end of the revetment; thus, by assuming benefits throughout the project area, the above proration provides a conservative estimate of benefits from Project #1573.

For this study, the storm damages predicted by Krecic et al. (2011) for return period storms of 1, 2, 5, 10, 20, 50, and 100 years represent the without-project case; designed for a 2-yr storm, the results assumed no damages for the 1- and 2-yr return period storms. The with-project case assumes the repaired revetment provides complete protection against a 25-yr storm; thus only 50- and 100-yr storms would causes damages. Tables 3.3.6 and 3.3.7 contain the with-project and without-project damages for 2017, the first year of potential benefits given that no major storms occurred during 2015 and 2016; the dollar values represent discounted present worth beginning of 2015.

Table 3.3.8 presents a summary of expected storm damage reduction benefits for project #1573 at Surfside Beach. From the table, the total benefit over the period of analysis equals $213,907.

Table 3.3.6 Project #1573 Total Damage-Cumulative Probability (2015, With Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0	$0			
2	0.50	0.50	$0	$0	$0	$0	0.50	$0
5	0.20	0.80	$0	$0	$0	$0	0.30	$0
10	0.10	0.90	$0	$0	$0	$0	0.10	$0
20	0.05	0.95	$0	$0	$0	$0	0.05	$0
50	0.02	0.98	$1,103,468	$1,811,627	$2,915,095	$1,457,547	0.03	$43,726
100	0.01	0.99	$1,304,060	$2,146,211	$3,450,271	$3,182,683	0.01	$31,827
>100	<0.01	>0.99	$1,304,060	$2,146,211	$3,450,271	$3,450,271	0.01	$34,503
Expected Average Annual Damage in 2015 Prices:								$110,056

Table 3.3.7 Project #1573 Total Damage-Cumulative Probability (2015, Without Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1.00	0.00	$0	$0	$0			
2	0.50	0.50	$0	$0	$0	$0	0.50	$0
5	0.20	0.80	$0	$45,208	$45,208	$22,604	0.30	$6,781
10	0.10	0.90	$0	$120,554	$120,554	$82,881	0.10	$8,288
20	0.05	0.95	$24,245	$271,246	$295,492	$208,023	0.05	$10,401
50	0.02	0.98	$1,103,468	$1,811,627	$2,915,095	$1,605,293	0.03	$48,159
100	0.01	0.99	$1,304,060	$2,146,211	$3,450,271	$3,182,683	0.01	$31,827
>100	<0.01	>0.99	$1,304,060	$2,146,211	$3,450,271	$3,450,271	0.01	$34,503
Expected Average Annual Damage in 2015 Prices:								$139,959

Table 3.3.8 Surfside Beach Storm Damage Reduction Benefit

Year	Without-Project Annual Expected Value (With Inflation)	With-Project Annual Expected Value (With Inflation)	Difference (Benefit)	Discounted Present Worth	Cumulative Discounted Present Worth
2015	-	-	-	-	-
2016	-	-	-	-	-
2017	$139,959	$110,056	$29,903	$27,665	$27,665
2018	$142,898	$112,367	$30,531	$27,381	$55,046
2019	$145,899	$114,727	$31,172	$27,100	$82,146
2020	$149,108	$117,251	$31,858	$26,847	$108,993
2021	$152,389	$119,830	$32,559	$26,597	$135,590
2022	$155,741	$122,467	$33,275	$26,350	$161,940
2023	$159,168	$125,161	$34,007	$26,105	$188,045
2024	$162,669	$127,914	$34,755	$25,862	$213,907

Notes: Inflation rates: for 2015 to 2016, 1.4%; for 2016–2019, 2.1%/yr; for 2019–2024, 2.2%/yr
Discount rate = 3.16% (mid-year discounting), present worth as of beginning of 2015

Benefit Cost Summary

With a total project cost of $2,244,323, the resulting B/C ratio for projects #1570 and #1573 equal 0.4. Table 3.3.9 summarizes the costs and benefits. Of note, the storm damage reduction benefit is relatively low due to the low probability of occurrence of the lower frequency storms (e.g., 50- and 100-yr storms). Should a storm such as Hurricane Ike impact the project within the assumed 10-year project life, then the storm damage reduction benefits will be realized and the actual B/C ratio would be substantially higher. For example, Krecic et al. (2011) determined that the original revetment prevented $7,138,431 (discounted present worth mid-year 2008) worth of damages, and the B/C ratio for that project equaled 8.23.

Table 3.3.9 Benefit-Cost Summary for Surfside Revetment Project

Benefits and Costs	**Discounted Present Worth (beginning of 2015)**	**Discounted Present Worth (beginning of 2016)[1]**
Storm Damage Reduction Benefit	$213,907	$220,667
Out-of-state Visitor Spending Benefit	$183,848	$189,658
Recreation Benefit	$528,017	$544,702
Total Benefits	$925,772	$955,026
Total Cost	$2,244,323	$2,315,244
B/C Ratio	**0.4**	**0.4**

[1] Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.16% discount rate (i.e., [discounted present worth beginning of 2016] = [discounted present worth beginning of 2015] x 1.0316)

3.4 Brazoria County — #1571 Quintana-Bryan Beach Nourishment

Project Description and Background Information

CEPRA Project #1571 nourished approximately 1,900 ft of shoreline at Bryan Beach, Town of Quintana, Brazoria County (Figure 3.4.1) to protect public property, private property, and infrastructure from storm damage. The project is a FEMA Public Assistance program repair related to beach loss during Hurricanes Ike and Rita; the project fill volume was designed to restore the beach to approximate pre-storm elevations. The Gulf shoreline in this region erodes at a high rate. The most recent long-term erosion rates (1950s – 2012) predicted by the Bureau of Economic Geology (BEG) range from -14.4 ft to -15 ft per year on average; shoreline recession rates have slowed to 4.7 – 6.7 ft/yr from 2000s – 2012, likely a reflection of prior nourishments that have helped offset erosion; GLO completed a beach nourishment and dune restoration project during September 2003 (CEPRA Project #1154) and a subsequent nourishment during March 2005 (CEPRA Project #1175). Additionally, offshore placement of sand dredged from the Freeport Ship Channel may have indirectly benefited Bryan Beach.

Beach fill operations began February 9, 2016, and project construction and demobilization was complete by March 4, 2016. The contractor placed 35,795 cy (in-place volume) within the fill template, which consisted of a berm at elevation 4.2 ft NAVD88 and a 1V:20H foreshore slope (Arcadis, 2016). The berm width extended seaward 90 ft from the project baseline and tied into the existing 4.2 ft contour near the dune vegetation; with the baseline situated roughly 34 ft on average seaward of the existing 4.2 ft NAVD88 contour, the total berm width equaled 124 ft on average. Figures 3.4.2 – 3.4.5 present representative pre-construction conditions, construction photographs, and post-construction conditions. Figures 3.4.6 – 3.4.8 show existing conditions during a January 19, 2017 site visit approximately one year after construction.

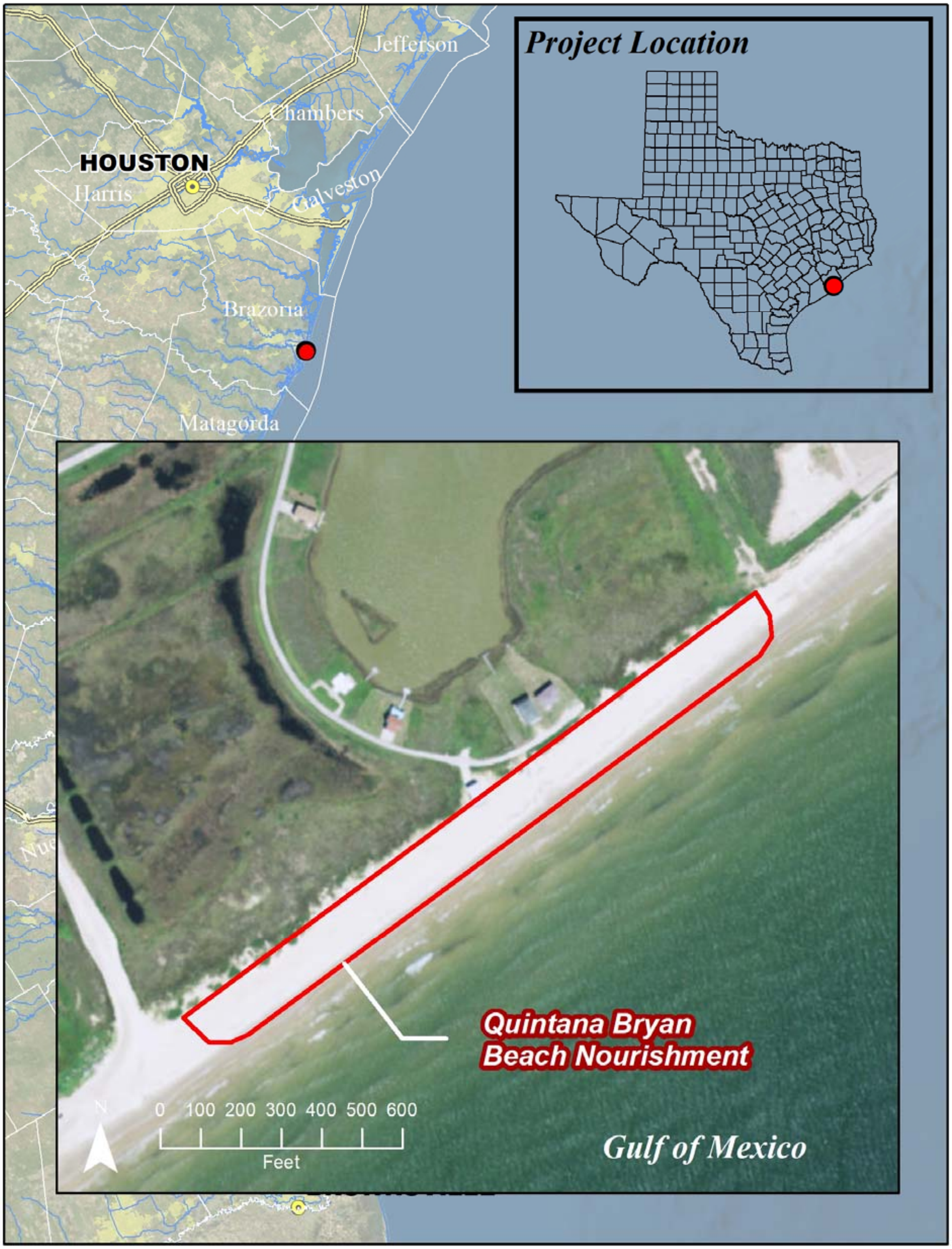

Figure 3.4.1 Bryan Beach BMMP Nourishment (CEPRA Project #1571) Location Map

Figure 3.4.2 Bryan Beach Pre-Construction (11/15/15; Photo provided by Google Earth)

Figure 3.4.3 Bryan Beach during Construction (2016; Photo provided by Google Earth)

Figure 3.4.4 Bryan Beach Post-Construction (3/13/16; Photo provided by GLO)

Figure 3.4.5 Bryan Beach Post-Construction (3/14/16; Photo provided by GLO)

Figure 3.4.6 Present Conditions, Westward (top photo) and Eastward (bottom photo) Views from Eastern End of Project (1/19/17)

Figure 3.4.7 Present Conditions, Westward (top photo) and Eastward (bottom photo) Views from Center of Project (1/19/17)

Figure 3.4.8 Present Conditions, Westward (top photo) and Eastward (bottom photo) Views from Western End of Project (1/19/17)

Project Funding

Funding for the Bryan Beach Nourishment Project originated from Texas agencies and the Federal Emergency Management Agency (FEMA). Table 3.4.1 presents the funding breakdown for the project. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the \$893,796.12 FEMA cost (\$96,418.62 for Ike repairs + \$797,377.50 for Rita repairs) is \$89,379.61. The resulting cost to Texas for Project #1571 amounts to \$801,379.61 (2016 price level); this value equals the sum of the Town of Quintana in-kind contribution (\$10,000.00), CEPRA funding (\$702,000.00), and the 10% state share of federal costs (\$89,379.61). Project construction occurred in early 2016; thus, this analysis treats all costs as though they were incurred at the beginning of 2016 (i.e., the cost reflects 2016 price levels, and is a present worth equivalent value, beginning of 2016).

Table 3.4.1 Funding for the Bryan Beach Nourishment Project #1571 (2016 Prices)

Funding Source		**Amount**
Federal	Federal Contribution (FEMA Ike) (*Texas portion*)	\$96,418.62 (\$*9,641.86*)
	Federal Contribution (FEMA Rita) (*Texas portion*)	\$797,377.50 (\$*79,737.75*)
State/Local	Town of Quintana In-Kind Commitment	\$*10,000.00*
	Texas General Land Office, CEPRA	\$*702,000.00*
Total Project Cost **(*Texas Total*)**		\$1,605,796.12 (\$*801,379.61*)

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016

Analysis

Economic benefits from the 2016 project result from storm damage reduction and recreational enjoyment. A site visit conducted January 19, 2017 documented a relatively consistent berm approximately 60-ft wide throughout the project area. A fill taper was evident at the northeast end of the project area and the berm widened towards the southwest end, indicating net southwesterly littoral transport towards Bryan Beach Park. Conservatively applying the above-mentioned 15 ft/yr background erosion rate, this analysis assumes the remaining fill will completely eroded from the project area within 4 years. Accordingly, this analysis assumes a 5-year project life, from 2016 – 2021. As discussed below, no overcrowding of the beach occurs with or without the project; thus, the visitation estimates are the same for both cases, and no out-of-state visitor spending benefits accrue as a result of this project (i.e., out-of-state visitor spending is the same with or without the project).

Recreation Benefits

Site-specific visitation estimates are unavailable for Bryan Beach. With minimal tourist accommodations in Town of Quintana, which has a population of less than 100 residents, this analysis assumes Bryan Beach predominantly provides a recreational outlet for the nearby City of Freeport and other inland Texas residents. Taylor Engineering (2015) reports visitation estimates for a nearby project area in Surfside Beach, Given the lack of data, this study assumes that Bryan Beach experiences 50 percent of the Surfside Beach visitation estimates. Taylor Engineering (2015) reports about 1,162 peak day visitors to a roughly 1-mile stretch of Surfside Beach based on an afternoon survey in 2015; the results equated to 185 visitors per 1,000 ft of beach. Assuming an average daily turnover rate of 2, the daily visitation estimate equals 370 per 1,000 ft of beach. Increasing this number to a 2016 (i.e., the project base year) value by the rate of general population growth (1.4%) and accounting for the 1,900-ft length of Project #1571, the above visitation assumption suggests the project area experiences 356 peak day visitors (370*1900/1000*1.014*0.5). Provided that 104 peak visitor days occur in the project area, one-fifth of the peak day visitors (71) visit the beach during off peak days, and 261 (i.e., 365 – 104) off peak days occur during a 365-day year, approximately 55,555 visits (37,024 [356 * 104] + 18,531 [71 * 261]) occurred in 2016 in the project area.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV-developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.4.2 presents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about $5.87 and $5.00 per person per visit (2017 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project for each year, adjusted for general annual population growth (i.e., 1.4%), yields the benefit for each year. Table 3.4.3 presents the recreation value benefit for this project ($234,762 present value, beginning of 2016).

Table 3.4.2 UDV Points Assigned — #1571 Bryan Beach Nourishment Project

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	10	5	30
Availability of Opportunity	0	0	18
Carrying Capacity	6	2	14
Accessibility	6	6	18
Environmental	7	3	20
Total	29	16	100

Table 3.4.3 Recreational Benefit for All Users — #1571 Bryan Beach Nourishment Project

Year	Total Visitation		Recreation Value		Difference (Benefit in 2016 Prices)	Benefit (with Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	55,555	55,555	$326,108	$277,775	$48,333	$47,339	$46,608	$46,608
2017	56,333	56,333	$330,673	$281,664	$49,010	$49,010	$46,775	$93,383
2018	57,121	57,121	$335,303	$285,607	$49,696	$50,739	$46,942	$140,325
2019	57,921	57,921	$339,997	$289,606	$50,391	$52,530	$47,111	$187,436
2020	58,732	58,732	$344,757	$293,660	$51,097	$54,437	$47,326	$234,762

Notes: UDV (with project) = $6.34 (2017 price levels)
UDV (without project) = $5.05 (2017 price levels)
Inflation rate 2016 - 2019 = 2.1%/year; 2019-2020 = 2.2%
Present worth, beginning of 2016, mid-year discounting, 3.16% discount rate [mid-year discount factor = $(1/1.0316)^{n+0.5}$, where n = year – 2016]

Storm Damage Reduction Benefits

Estimating storm damage reduction benefits required modeling with- and without-project conditions in SBEACH. No significant storms impacted the project area during 2016, thus the project did not provide benefits for that year. This study applied synthetic storms and background erosion rates for years 2017 – 2020 for with- and without-project conditions. The GLO provided pre-construction (December 2015) and post-construction (March 2016) beach profile data along the project area. Taylor Engineering developed representative 2017 existing profiles utilizing the post-construction survey provided by GLO, observations during the January 2017 site visit, and profile slope characteristics of the pre-construction survey. This analysis applied a single pre-construction profile and single existing profile representative of the entire project area for SBEACH simulations of the without- and with-project conditions; Figure 3.4.9 presents the representative profiles for 2017. The modeling effort applied the model parameters shown in Table 3.4.4, as presented in Krecic et al. for the nearby Surfside Beach area.

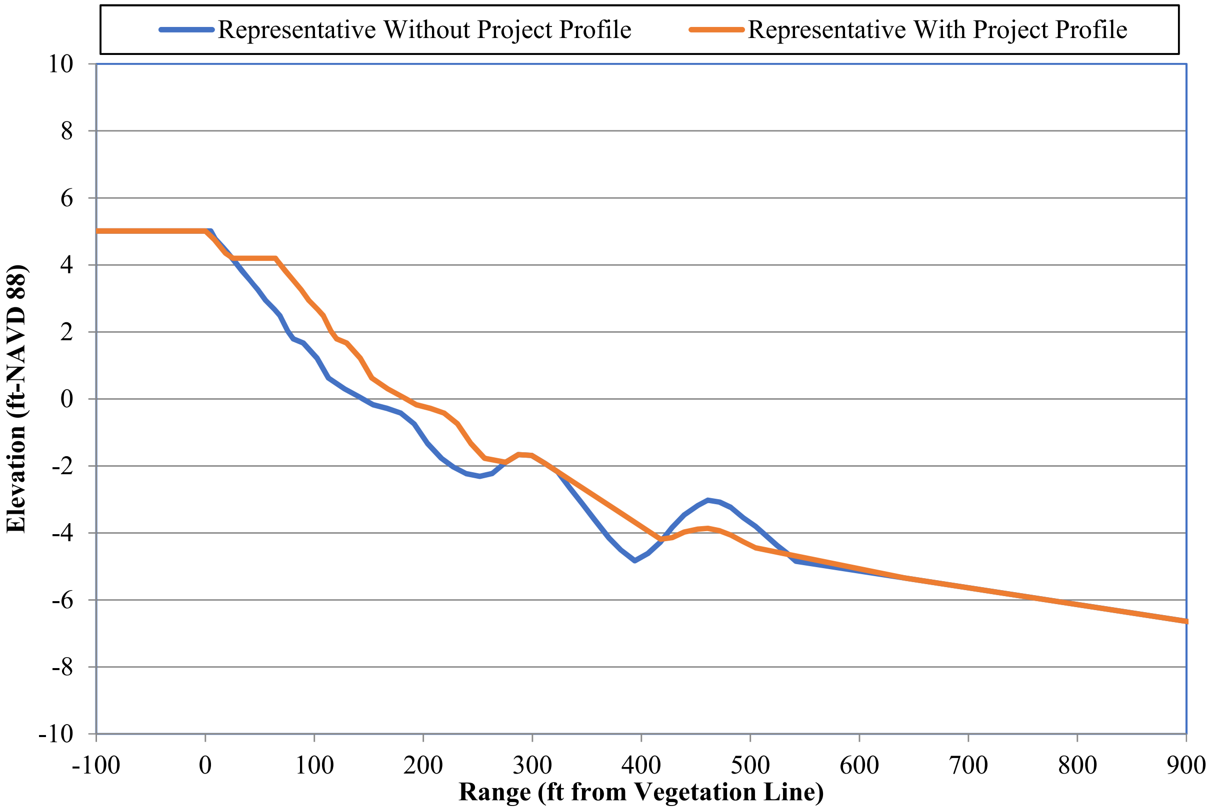

Figure 3.4.9 Bryan Beach Representative Pre- and Post-Construction Profiles

Table 3.4.4 SBEACH Model Parameters (HDR, 2009c)

Parameter	Value
Transport Rate Coefficient (K)	2.25×10^{-6} m^4/N
Eps Parameter (ϵ)	0.002 m^2/s
Transport Rate Decay Factor (λ)	0.5 m^{-1}
Avalanching Angle (φ)	35°
Landward Surf Zone Depth	1.6 ft
Median Grain Size	0.14 mm

As mentioned, Bryan Beach experienced no major storms in 2016. To account for background erosion, this analysis eroded the without-project representative profile (initially the Dec 2015 pre-construction condition) 15 feet landward per year for 2017 – 2020 to account for the historical long-term erosion at the site, while the with-project representative profile (initially the January 2017 observed condition) was eroded 15 feet landward per year for 2018 – 2020. To simulate 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storm events, this study applied a synthetic storm with characteristics (Table 3.4.5) corresponding to the return period under consideration. Developing synthetic time-varying storm surge hydrographs required applying Eq. 3.1 (page 40). The final water surface elevation time series consists of three standard tidal cycles (about 72 hours) developed from a normally varying tide from mean high water (1.23 feet NAVD) to mean low water (-0.22 feet NAVD), generated by Eq. 3.2 (page 40), followed by the return period specific storm surge hydrograph. Note that substituting 1.45 for 1.12 and -0.22 for 0.36 in Eq. 3.2 produces the desired normal tide hydrograph. Minor smoothing at the transition prevented abrupt changes in the water surface elevation. Figure 3.4.10 shows the final 1-, 2-, 5-, 10-, 20-, 50-, and 100-year hydrographs.

Table 3.4.5 Peak Storm Characteristics for Various Return Periods

Return Period (yr)	**1**	**2**	**5**	**10**	**20**	**50**	**100**
Storm Tide[†] (feet NAVD)	2.1 [a]	2.4 [a]	3.2	4.4	6.6[*]	9.4	10.9
Offshore Wave Height[‡] (feet)	11.6	13.3	15.8	17.3	19.2	21.5	23.2
Offshore Wave Period[‡] (seconds)	10.1	10.7	11.0	11.8	12.3	12.9	13.4

[†] Data from HDR (2009c)

[‡] Data from Lockwood, Andrews, and Newman, Inc. (2006)

[a] Assumed value

[*] Interpolated

As with the storm surge, the temporal wave height variation consisted of two parts. A cosine squared distribution (Eq. 3.3, page 41) approximated the wave heights during normal conditions over the first 72 hours (3 tidal cycles), followed by a sine squared distribution (Eq. 3.4, page 41) which approximated the storm wave heights over 36 hours. Each tidal cycle averaged 24.8 hours, and the wave heights varied from 1.5 to 3.0 ft, representing the relatively calm conditions frequently observed in the Gulf of Mexico. Storm wave heights varied from 5 ft to the peak wave height (Table 3.4.5) and abate to 5 ft after storm passage. The 5-ft value for H_{min} simulates the agitated sea conditions typically found after a storm passes an area. Figure 3.4.11 shows the resulting wave height distributions the model requires.

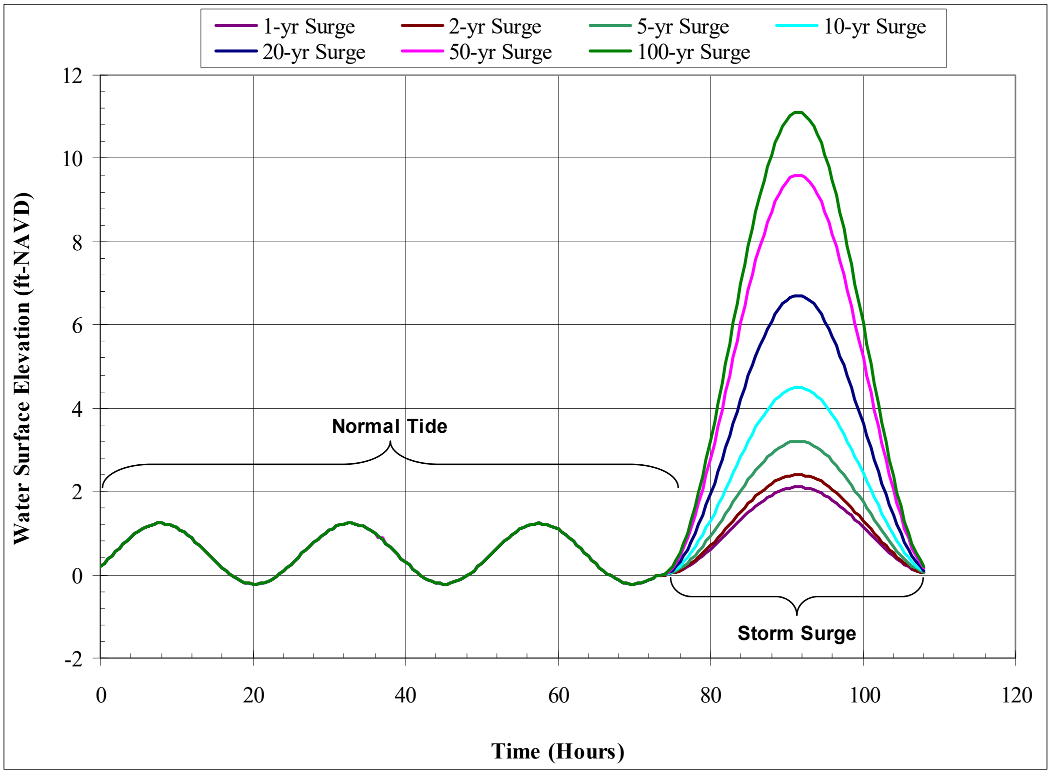

Figure 3.4.10 Bryan Beach Time-Varying Water Surface Elevations

During the first 72 hours of normal conditions, the wave period varies from five to six seconds for 1-, 2-, and 5-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. The wave period varies from seven to eight seconds for 10-, 20-, 50-, and 100-year return period storms according to a cosine-squared distribution with a tidal cycle of 24.8 hours. Similarly, a sine squared distribution approximated the storm wave periods over the final 36 hours with a minimum final wave period of seven (1-, 2-, and 5-year return period storms) and nine (10-, 20-, 50-, and 100-year storms) seconds. Figure 3.4.12 shows the resulting wave period distributions the model requires.

SBEACH produced post-storm profiles for 1-, 2-, 5-, 10-, 20-, 50-, and 100-year storms on eroded with- and without-project profiles between 2017 and 2020. Figure 3.4.13 presents a typical post-storm profile for without- and with-project conditions for the 5-year storm.

The methodology outlined in Section 2.2 and the site-specific information described above produces the damage-cumulative probability distribution between 2017 and 2020 on the with- and without-project representative profiles.

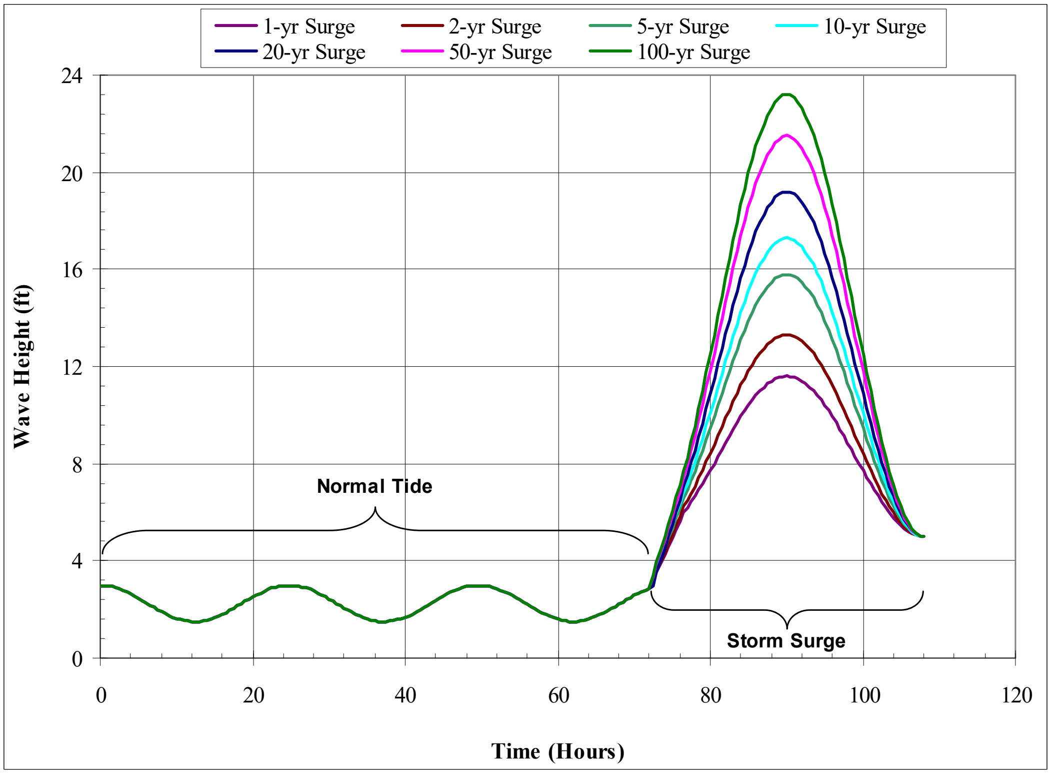

Figure 3.4.11 Bryan Beach Synthetic, Time-Varying Wave Heights

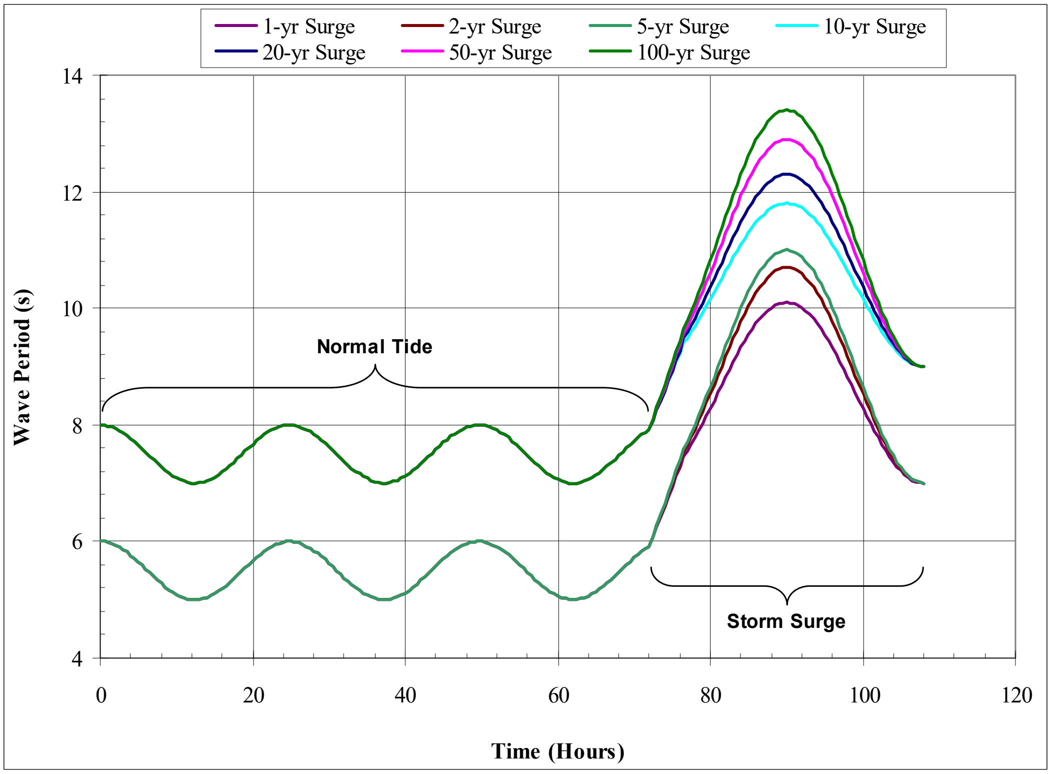

Figure 3.4.12 Bryan Beach Synthetic, Time-Varying Wave Period

Based on the maximum predicted erosive shoreline condition, the present analysis includes all Gulf front properties located about 150 feet landward of the dune vegetation line. Tables 3.4.6 and 3.4.7 present the damage-cumulative probability distribution for 2017 with-project and without-project conditions. From the table, the expected annual total damage for this condition averages $22,387(2016 prices). Appendix A presents these distributions for the 2017–2020 with- and without-project conditions.

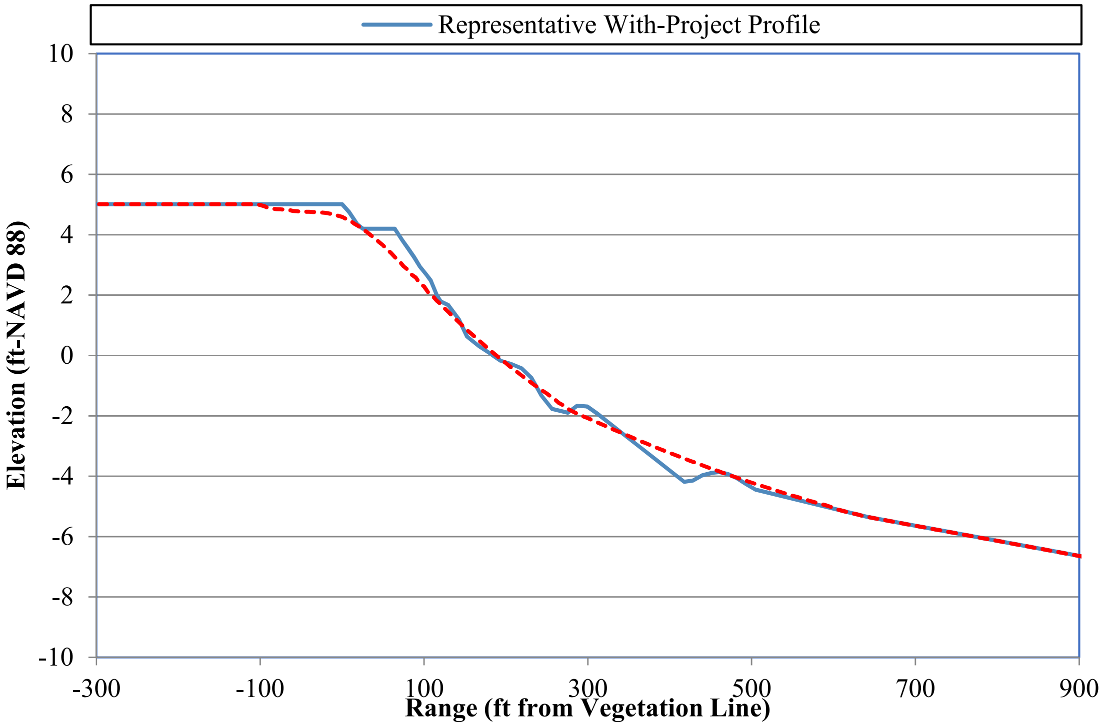

Figure 3.4.13 Bryan Beach with- and without-Project Five-Year Post-Storm Profile

Table 3.4.6 Bryan Beach Total Damage-Cumulative Probability (2017, With Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	$6,681	$0	$6,681	-	-	-
2	0.5	0.5	$7,467	$0	$7,467	$7,074	0.5	$3,537
5	0.2	0.8	$7,598	$0	$7,598	$7,533	0.3	$2,260
10	0.1	0.9	$10,349	$97,660	$108,009	$57,804	0.1	$5,780
20	0.05	0.95	$10,349	$97,660	$108,009	$108,009	0.05	$5,400
50	0.02	0.98	$10,611	$97,660	$108,271	$108,140	0.03	$3,244
100	0.01	0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
>100	<0.01	>0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083
Expected Average Annual Damage in 2016 Prices:								$22,387

Table 3.4.7 Bryan Beach Total Damage-Cumulative Probability (2017, Without Project)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage
1	1	0	$8,122	$0	$8,122			
2	0.5	0.5	$8,515	$0	$8,515	$8,319	0.5	$4,159
5	0.2	0.8	$10,349	$97,660	$108,009	$58,262	0.3	$17,479
10	0.1	0.9	$10,349	$97,660	$108,009	$108,009	0.1	$10,801
20	0.05	0.95	$21,734	$110,391	$132,125	$120,067	0.05	$6,003
50	0.02	0.98	$31,671	$148,582	$180,253	$156,189	0.03	$4,686
100	0.01	0.99	$33,039	$199,504	$232,543	$206,398	0.01	$2,064
>100	<0.01	>0.99	$33,039	$199,504	$232,543	$232,543	0.01	$2,325
Expected Average Annual Damage in 2016 Prices:								$47,517

Table 3.4.8 presents a summary of expected storm damage reduction benefits for project #1571 at Bryan Beach. From the table, the total benefit over the period of analysis equals $224,763. Of note, this analysis does not include prevention of land loss due to background erosion as a benefit, as the minimal land values (roughly $1000/acre on average for the shore-front lots) do not amount to significant damages.

Table 3.4.8 Bryan Beach Storm Damage Reduction Benefit

Year	Without Project (2016 Prices)	With Project (2016 Prices)	Difference (2016 Prices)	Benefit (With Inflation)	Discounted Present Worth	Cumulative Discounted Present Worth
2016	$0	$0	$0	$0	$0	$0
2017	$47,517	$22,387	$25,130	$25,658	$24,488	$24,488
2018	$77,113	$24,356	$52,757	$54,996	$50,881	$75,369
2019	$106,892	$25,544	$81,348	$86,581	$77,649	$153,018
2020	$120,404	$44,535	$75,869	$82,526	$71,745	$224,763

Notes: Inflation rates: 2.1%/yr for 2016 – 2019; 2.2% for 2019 - 2020
Discount rate = 3.16% (mid-year discounting), present worth as of beginning of 2016

Federal Spending Benefit

Federal spending that occurs as part of the initial construction represents a net increase inflow of spending for the state economy. Reducing the initial federal funding contribution by 10% (i.e., the estimated amount of federal funds originating from Texas) and applying the multiplier effect (Section 2.1), the estimated federal spending benefit for this project is $1,126,183 (i.e., $893,796 * 0.9 * 1.4) in 2016 prices.

Benefit Cost Summary

Adding the federal spending benefit to the visitation and storm damage reduction benefits results in a total estimated benefit for this project of $1,585,708. With a total project cost of $801,380, the resulting B/C ratio for project #1571 equals 2.0. Table 3.4.9 summarizes the costs and benefits.

Table 3.4.9 Benefit-Cost Summary for Bryan Beach Nourishment Project

Benefits and Costs	**Discounted Present Worth (beginning of 2016)[2]**
Storm Damage Reduction	$224,763
Recreation Value	$234,762
Federal Spending	$1,126,183
Total Benefit	$1,585,708
Total Cost[1]	$801,380
B/C Ratio	**2.0**

[1] Texas costs only, assumed incurred at the beginning of the first year of project construction (i.e., not discounted)

[2] Dollar values represent present worth equivalents at the beginning of 2016 with a 3.16% discount rate

3.5 Aransas County — #1603 Rockport Beach BMMP Maintenance Renourishment

Project Description and Background Information

Rockport Beach lies along the Aransas Bay shoreline within the City of Rockport Beach in Aransas County, Texas (Figure 3.5.1). The Aransas County Navigation District (ACND) owns and maintains the beach, which consists of approximately 4,700 ft of shoreline. The park resides along a small peninsula that partially separates Little Bay from Aransas Bay and extends east to Legget Light Channel. Terminal groins bound the western and eastern limits of the beach. Rockport Beach is primarily characterized by a relatively low elevation berm and a low-profile dune feature. The beach is a vital economic engine to the area, and maintaining its quality is critical to the continued success of not just the beach itself but also the surrounding area.

The original beach restoration project occurred in 1988, along with construction of the terminal groins. In 2004, the first nourishment project placed 33,255 cubic yards of sand trucked from a commercial upland facility (CEPRA Project #1063). The ends of the beach have historically eroded at a faster rate than the central section of the beach. Coastal Planning and Engineering (2002) reported an average shoreline recession rate of -4.2 ft/yr from 1988–2002, with a maximum rate of -8.4 ft/yr occurring along the eastern end where erosion had depleted the subaerial beach. More recent monitoring results (CB&I, 2014) indicate shoreline recession rates have slowed, with the west, center, and east ends averaging -0.4, -0.2, and -2.6 ft/yr from 2007–2014. However, significant erosion had occurred at the east and west ends immediately after the 2004 project, possibly a result of wave interaction with the groins (CB&I, 2014).

A beach assessment conducted by the GLO in 2014 found the erosion hotspots at the east and west ends had reached a threshold that warranted nourishment. Additionally, despite the relative shoreline stability, the berm generally decreased in elevation slightly across the project area. CEPRA Project #1603 targeted these problem areas to restore the recreational beach to its full capacity. Constructed from November – December 2015, the project placed 6,571 cy along the western and eastern “base-proposal” areas that span roughly 1,460 ft and 1,600 ft in length. Figures 3.5.2 – 3.5.6 show pre-construction, during-construction, and post-construction conditions of Rockport Beach.

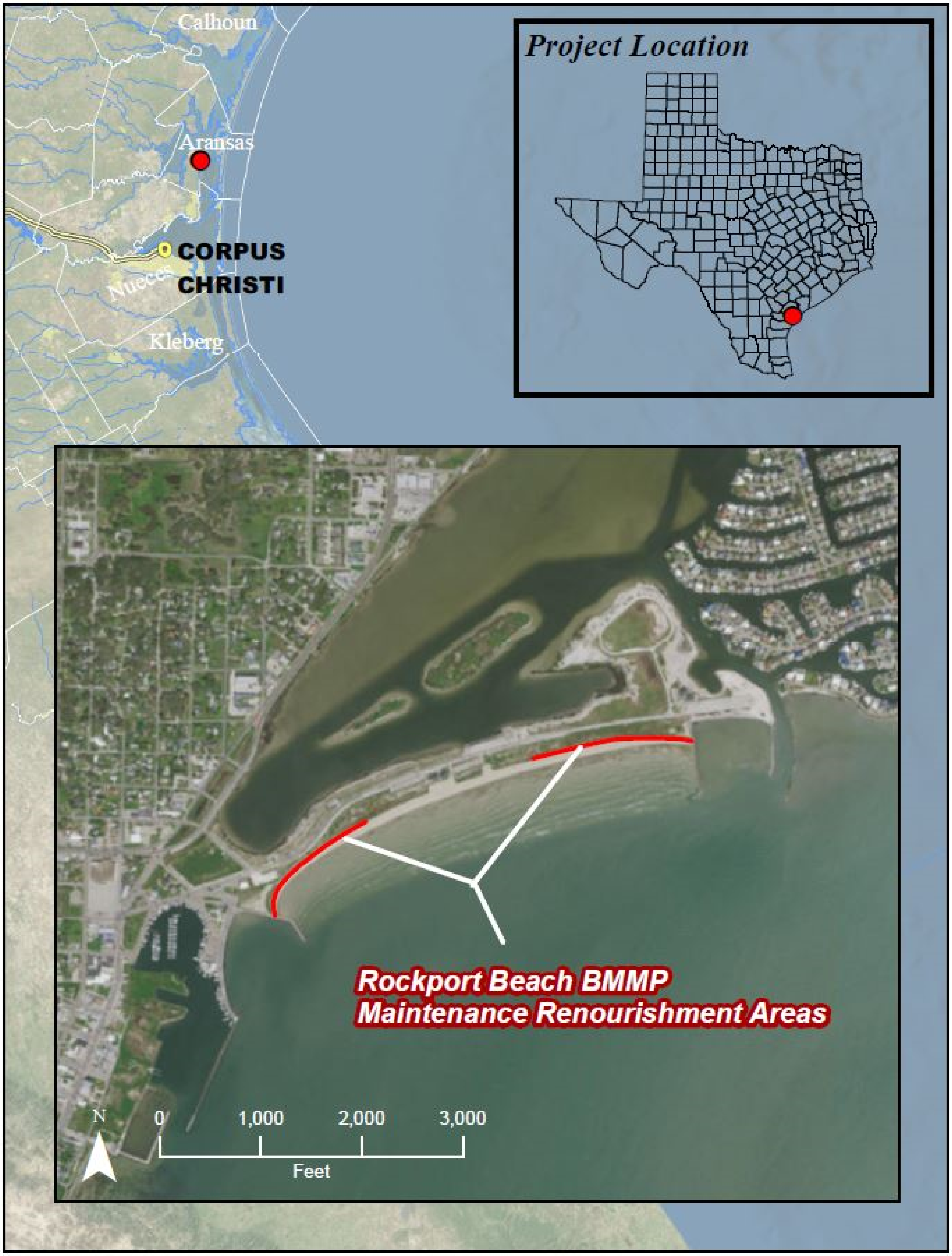

Figure 3.5.1 Rockport Beach Location Map

Figure 3.5.2 Rockport Beach #1603 Pre-construction Near East End (6/12/14; provided by GLO)

Figure 3.5.3 Rockport Beach #1603 During Construction Near East End (12/11/15; provided by GLO)

Figure 3.5.4 East End of Rockport Beach Project #1603 Post-construction (10/20/16)

Figure 3.5.5 Center of Rockport Beach Project #1603 Post-construction (10/20/16)

Figure 3.5.6 West End of Rockport Beach Project #1603 Post-construction (10/20/16)

Project Funding

Funding for CEPRA Project #1603 derived solely from state agencies. CEPRA funds covered 88.4% of project costs, and ACND contributed the remaining 11.6%. Table 3.5.1 presents the funding breakdown as provided by the 2016 GLO expenditure summary. Because the costs were incurred close to the end of 2015, no discounting was necessary for the economic evaluation and the costs are considered to be an equivalent present worth amount, beginning of 2016.

Table 3.5.1 Funding for the Rockport Beach Nourishment Project #1603

Funding Source		Amount*
State/Local	Texas General Land Office/CEPRA (88.4% of total project cost)	*$361,921*
	Aransas County Navigation District (11.6% of total project cost)	$47,684
Total Project Cost ***(Texas Total)***		**$409,605** ***($409,605)***

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016

Analysis

Economic benefits from CEPRA Project #1603 are based on recreational enjoyment. With an estimated 210,000 annual visitors (ACND chairman Malcolm Dieckow, as reported in The Rockport Pilot, 2/15/16), visitation benefits to Rockport Beach are important to the community. A record of beach passes sold during 2015 and 2016 — 17,463 day passes and 4,618 annual passes in 2015 and 14,480 day passes and 43,223 annual passes in 2016 (personal communications with ACND — does not show an increase after project construction; thus, the visitation estimates are the same for the with- and without-project cases, and no out-of-state visitor spending benefits accrue as a result of this project (i.e., out-of-state visitor spending is the same with or without the project). Additionally, no overcrowding of the beach occurs with or without the project. The entire beach and upland area is ACND property with no value listed in the Aransas County Property Appraiser database; thus, this analysis does not consider storm damage reduction benefits.

Recreation Benefits

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV-developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.5.2 presents a summary of the points assigned for with- and without-project conditions in the project area. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about \$8.25 and \$7.37 per person per visit (adjusted for inflation to 2016 price levels, i.e., the first year of the project). Taking the difference between the estimated recreation value for all visitors with- and without-project for each year, adjusted for general annual population growth (i.e., 1.4%), yields the benefit for each year. Table 3.5.3 presents the recreation value benefit for this project (\$1,835,436 present value, beginning of 2016).

Table 3.5.2 UDV Points Assigned — #1603 Rockport Beach Nourishment Project

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	10	9	30
Availability of Opportunity	7	7	18
Carrying Capacity	10	6	14
Accessibility	14	14	18
Environmental	9	5	20
Total	50	41	100

Table 3.5.3 Recreational Benefit for All Users — #1603 Rockport Beach Nourishment Project

Year	Total Visitation		Recreation Value (2017 Prices)		Difference (Benefit)	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	210,000	210,000	$1,768,200	$1,581,300	$186,900	$183,056	$180,230	$180,230
2017	212,940	212,940	$1,792,955	$1,603,438	$189,517	$189,517	$180,876	$361,106
2018	215,921	215,921	$1,818,056	$1,625,886	$192,170	$196,205	$181,523	$542,629
2019	218,944	218,944	$1,843,509	$1,648,649	$194,860	$203,130	$182,173	$724,803
2020	222,009	222,009	$1,869,318	$1,671,730	$197,588	$210,506	$183,005	$907,808
2021	225,117	225,117	$1,895,489	$1,695,134	$200,354	$218,149	$183,840	$1,091,648
2022	228,269	228,269	$1,922,025	$1,718,866	$203,159	$226,069	$184,679	$1,276,327
2023	231,465	231,465	$1,948,934	$1,742,930	$206,004	$234,277	$185,522	$1,461,849
2024	234,705	234,705	$1,976,219	$1,767,331	$208,888	$242,783	$186,369	$1,648,217
2025	237,991	237,991	$2,003,886	$1,792,074	$211,812	$251,598	$187,219	$1,835,436

Notes: UDV = $8.42 with project and $7.53 without project (2017 prices)
Inflation rates: for 2016 – 2019, 2.1%/yr; for 2019 to 2025, 2.2%/yr
2016 benefit with inflation = (2016 benefit in 2017 prices)/1.021
Discount rate = 3.16% (mid-year discounting), present worth as of beginning of 2016

Benefit-Cost Summary

With total benefits of $1,835,436 and a total project cost of $409,605, the resulting B/C ratio for project #1603 equals 4.5. Table 3.5.4 summarizes the costs and benefits.

Table 3.5.4 Benefit-Cost Summary for the Rockport Beach Nourishment Project

Benefits and Costs	Discounted Present Worth (beginning of 2016)
Recreation Value	$1,835,436
Total Benefit	$1,835,436
Total Cost	$409,605
B/C Ratio	**4.5**

3.6 Galveston County — #1608 GIWW Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material (BUDM) Fiscal Year 2015 event

Project Description and Background Information

Rollover Pass, a man-made inlet at the eastern end of the Bolivar Peninsula in Galveston County, links the Gulf of Mexico with Rollover Bay and East Bay. Chronic long-term erosion, storm-related episodic erosion, and low-density upland development characterize the beaches near the Pass. During February 2015, the GLO, in cooperation with USACE and Galveston County, nourished Caplen Beach, west of the Pass, with beach-quality material dredged from the Gulf Intracoastal Waterway Rollover Bay segment. This project is part of a long-term effort involving other CEPRA projects to manage the severe erosion problems affecting the Bolivar Peninsula, particularly the erosion caused by Rollover Pass.

The 2015 project placed approximately 150,000 cy of sand (Jones, 2015) along approximately 2,100 ft of shoreline (Figure 3.6.1), beginning about 1,900 ft west of the Pass, widening the dry beach by roughly 57 ft on average (per comparison of pre- and post-construction surveys). Figure 3.7.2 represents post-construction conditions. Based on information obtained from UTBEG, the study area's shoreline erodes about 5.7 ft/year. Upland development in the project area, generally comprised of elevated single-family homes, lies a fair distance from the shoreline. Based on the maximum predicted erosive shoreline condition, this analysis includes the first row of Gulf front properties and lots. Of note, Hurricane Ike devastated the study area in September 2008, destroying a very large percentage of structures on the peninsula and dramatically affecting the shoreline.

Project Funding

Table 3.6.1 presents the funding breakdown for the project. The USACE cost represents the federal cost to dredge the Gulf Intracoastal Waterway (GIWW) and place the material in a dredge material placement area (DMPA). The state and county costs represent the total incremental cost of placing the dredged material on the beach as opposed to a DMPA. This analysis uses the summation of the CEPRA and Galveston County costs, $250,000, as the total project cost; it excludes the federal cost, because USACE's maintenance dredging of the GIWW would still occur without CEPRA's support for the nourishment project. This analysis treats all costs as though they were incurred at the beginning of 2015 (i.e., the cost reflects 2015 price levels, and is a present worth equivalent value, beginning of 2015).

Figure 3.6.1 Location Map for #1608 GIWW Rollover Bay Reach BN with BUDM (FY 2015 event)

Figure 3.6.2 Caplen Beach after the 2015 Nourishment (February 18, 2015; Photo Provided by GLO)

Table 3.6.1 Funding for Project #1608 GIWW Rollover Bay Reach BN with BUDM

Funding Source		**Amount**
Federal	U.S. Army Corps of Engineers (In-kind dredging contribution, 95.96% of total project costs)	$5,545,020
State/Local	Texas General Land Office, CEPRA (85% of incremental cost, 3.41% of total project cost)	*$197,500*
	Galveston County (15% of incremental cost, 0.90% of total project cost)	*$52,500*
Total Project Cost **(*Texas Total*)**		$5,795,020 *($250,000)*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2015

Analysis

Taylor Engineering visited the site on January 20, 2017, almost two-years post-construction. This visit, however, occurred after the 2016 beach nourishment with BUDM event and, thus, did not allow for observations of the 2015 project performance. Based on performance of the prior projects (Taylor Engineering, 2013), this study assumes that no significant amount of beach fill remained on the dry beach prior to the 2016 project and, thus, adopts a one-year project life for the 2015 project. With the short project length, rapid erosion of the beach fill is expected. Fill material may remain offshore, but lack of data prohibits verification of this. Figures 3.6.3 and 3.6.4 show conditions during the January 20, 2017 site visit.

Economic benefits from the 2015 project include land value protection and recreational enjoyment. Storm damage protection did not occur, because no major storms impacted the project area during 2015 (i.e., the one-year project life). Nevertheless, the project did offset the background erosion during this period and thus preserved land values. Given the 2015 Galveston Central Appraisal District information, these property values equal $1,667,927. Dividing the total property value by the average lot depth (approximately 300 ft) and multiplying by the background erosion (5.7 ft) yields a benefit of $31,691.

Based on July 2004 observations, Oden and Butler report about 90 peak day visitors to Rollover Pass. Given that Taylor Engineering's 2015 survey does not cover the Rollover Pass area, the Oden and Butler beach visitation estimate provides a more accurate count. Assuming an average daily turnover rate of 2, the daily visitation estimate increases to 180. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (36) visit the beach during off peak days and 285 (i.e., 365 – 80) off peak days exist during a 365-day year. Given the above visitor information, the estimated number of beach visits occurring in 2004 was approximately 24,660 visits ([180 * 80] + [36 * 285] = 24,660). Increasing this number to a 2015 (i.e., the project base year) value by the rate of general population growth (1.4%), as discussed in Section 2.1, yields 28,735 (i.e., 24,660 * 1.014^{11}). Because of the modest levels of beach use, no overcrowding occurs with or without project (the number of visitors is the same).

Based on 2015 beachgoer surveys, Taylor Engineering (2015) report that out-of-state visitors concentrate in areas with access to transportation, lodging, and other touristic amenities, such as the city of Galveston. The survey did not identify any out-of-state visitors to locations such as Jamaica Beach and Surfside Beach, though budget constraints and adverse weather during implementation of the survey limited the survey duration (i.e., one holiday weekend Saturday). Given the lack of commercial development and recreational amenities, this study did not include out-of-state visitor spending as a benefit for this project.

Figure 3.6.3 Conditions near East End of Project Area (January 20, 2017)

Figure 3.6.4 Conditions near West End of Project Area (January 20, 2017)

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers mentioned above to the UDV analysis developed (see Section 2.2, Table 2.5) for with- and without-project conditions. Table 3.6.2 presents a summary of the points assigned for with- and without-project conditions in the project area. This assignment of points reflects the incremental improvement afforded by the wider re-nourished beach. Converting the points to dollar values with the help of Table 2.6 (Section 2.2) results in with- and without-project UDVs of about $5.94 and $5.35 per person per visit (2015 price levels). Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. Table 3.6.3 presents the recreation value benefit for this project ($10,160 present value, mid-year 2015).

Table 3.6.2 UDV Points Assigned — #1608 GIWW Rollover Bay Reach BN with BUDM

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	8	6	30
Availability of Opportunity	3	3	18
Carrying Capacity	5	2	14
Accessibility	7	6	18
Environmental	7	5	20
Total	30	22	100

Table 3.6.3 Recreational Benefit for All Users — #1608 GIWW Rollover Bay Reach BN with BUDM

Year	Total Visitation		Recreation Value (2015 Prices)		Present Worth (Difference; 2015 Prices)	Discounted Present Worth
	With Project	Without Project	With Project	Without Project		
2015	28,735	28,735	$168,100	$151,433	$16,667	$16,410

Notes:
UDV (with project) = $5.94 (2017 price levels) = $5.85 (2015 price levels)
UDV (without project) = $5.35 (2017 price levels) = $5.27 (2015 price levels)
Inflation rate 2016 to 2017 = 1.4%; 2017 price level x 1/1.014 = 2016 price level
Inflation rate 2015 to 2016 = 0.1%; 2016 price level x 1/1.001 = 2015 price level
Present worth, beginning of 2015, mid-year discounting, 3.16% discount rate
Discounted present worth = Difference / $1.0316^{(0.5)}$

Benefit-Cost Summary

Because of the limited visitation and inexpensive land values in the project area, the total project benefits are relatively low (Table 3.6.4). The estimated benefits occur throughout the year. Using mid-year discounting, the present worth of the $31,691 land value benefit equates to $31,202 (i.e., $31,691 x $1/1.0316^{0.5}$ = $31,202). Combined with the recreational benefit, $16,410, the total project benefit is $47,612.

With project costs totaling $250,000, this project has a 0.19 benefit/cost ratio. Although the benefit/cost ratio is low, the project represents a very low cost alternative (with a unit cost of $1.67 per cubic yard of beach fill) for mitigating Rollover Pass' erosive effects on Caplen Beach.

Table 3.6.4 Benefit-Cost Summary — #1608 GIWW Rollover Bay Reach BN with BUDM

Benefits and Costs	**Discounted Present Worth (beginning of 2015)[1]**	**Discounted Present Worth (beginning of 2016)[1]**
Prevention of Land Loss Benefit	$31,202	$32,188
Recreation Benefits	$16,410	$16,929
Total Benefits	$47,612	$49,117
Total Cost	$250,000	$257,900
B/C Ratio	**0.2**	**0.2**

[1] Dollar values reflect present worth equivalents with a 3.16% discount rate

3.7 Galveston County — #1609 Galveston Seawall 61st to 103rd St. Beach Nourishment with Beneficial Use of Dredged Material

Project Description and Background Information

The Galveston Seawall, built approximately between 1902 and 1962, is a large waterfront structure that protects the City of Galveston from coastal inundation. The seawall extends from Fort San Jacinto to roughly 3 miles west of the 61st St fishing pier. The section east of 61st St includes a groin field designed to retain sand for recreational purposes. A riprap revetment protects the seawall's foundation from scour. Since the completion of the first segment in 1904, the seawall has withstood several large storms — including Hurricane Ike in 2008 — without any significant damage. Large storms deplete the sand located between groins; otherwise, the beaches within the groin fields erode slowly, providing space for recreational enjoyment. The 61st St groin and fishing pier interrupts the flow of sand west, so no dry beach exists in front of the seawall west of this groin.

Between late September – November 2015, the GLO, in cooperation with USACE and the Galveston Park Board, built a beach west of the 61st St groin with material dredged from the Galveston Ship Channel. Figure 3.7.1 shows the location of the project. This project is part of the state and local authorities' efforts to create space for recreational enjoyment.

Per GLO information, CEPRA Project #1609 placed approximately 629,188 cy of sand. The length of the project was roughly 4900 ft (between 61st St and 75th St) with a flat berm elevation at 4 ft (NAVD88) that buries the seawall's protective rip rap. Of the total placement length, 3800 ft reached the full design width of 275 – 300 ft. According to contractor surveys, the beach "retained" 357,000 cy after it equilibrated in the immediate time post-construction. USACE draft project drawings show plans to build beaches further west, apparently as part of CEPRA Project #1609. However, none of these two additional areas have been built yet. Figures 3.7.2 and 3.7.3 show aerial views of pre- and post-construction conditions.

Because updrift groins interrupt most flow of sand, and because no beach has existed in the project area since the construction of the seawall, erosion rates measured directly at the site are unavailable. UTBEG's Shoreline Change Rate Atlas shows a shoreline position envelope — that is, the range of shoreline positions —between 1930 – 2012. Given that virtually no beach has existed since the construction of the Galveston Seawall, one can assume that the shoreline's recession occurred in its entirety within the 30 years prior to the construction of the seawall. As such, the background erosion rate for this site was estimated at approximately 8.7 ft/yr (262 ft / 30 yr). Purple lines in Figure 3.7.4 show the shoreline envelope since 1930 (UTBEG, accessed February 2017).

Substantial development characterizes the upland area, which features access to transportation, hotels and condominiums, and many touristic amenities. The area nourished with CEPRA Project #1609 is an extension of Galveston's beaches east of the 61st St groin.

Project Funding

Table 3.7.1 presents the funding breakdown for the project. The USACE cost represents the Federal cost to dredge the Galveston Ship Channel and place the material in a dredge material placement area (DMPA). The state costs represent the total incremental cost of placing the dredged material on the beach as opposed to a DMPA. This analysis uses the summation of the GLO costs, $8,990,000, as the total project cost; it excludes the federal cost, because USACE's maintenance dredging of the ship channel would still occur without GLO's (and CEPRA) support for the nourishment project. Of note, the GLO provided documentation showing that the project had a balance of roughly $1 million, refundable to the state. Absent exact information about this refund, the study assumed that the cost to Texas was reduced by exactly $1 million, or $7,990,000).

Table 3.7.1 Funding for Project #1609 Galveston Seawall 61st to 103rd St. Beach Nourishment

Funding Source		***Amount***
Federal	U.S. Army Corps of Engineers (In-kind dredging contribution, 62% of total project costs)	$14,953,358
State/Local	Qualified Project Partner (QPP) (78% of non-Federal incremental cost	*$6,990,000*
	Texas General Land Office, CEPRA (22% of non-Federal incremental cost; 9% of total project cost)	*$2,000,000*
Total Project Funding (100%) *(Texas Total)*		$23,943,358 *($8,990,000)*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2016

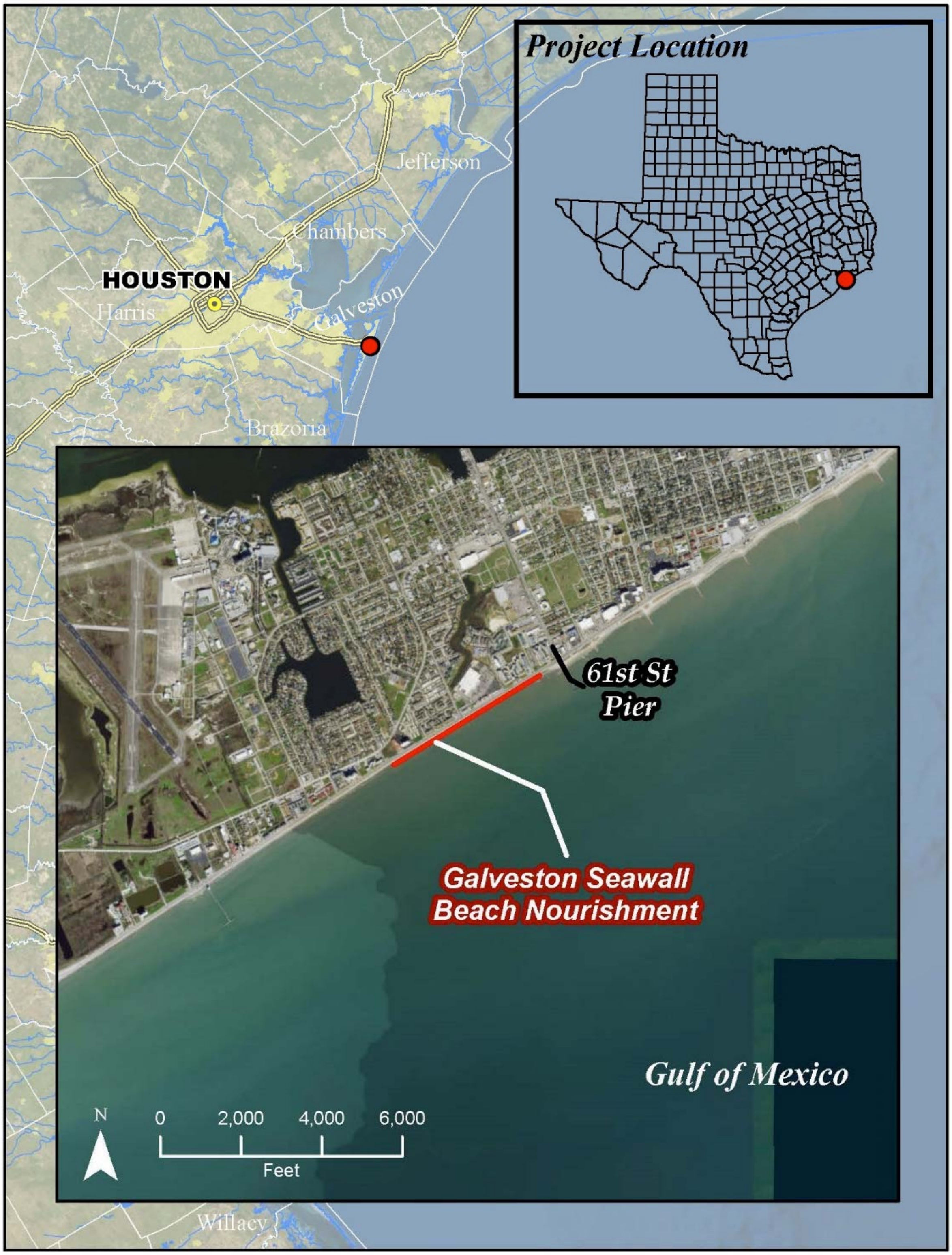

Figure 3.7.1 Location Map for #1609 Galveston Seawall BN with BUDM (FY 2015 event)

Figure 3.7.2 Pre-Construction Conditions for the Galveston Seawall BN with BUDM (Source: Google Earth Imagery, 1/17/2014)

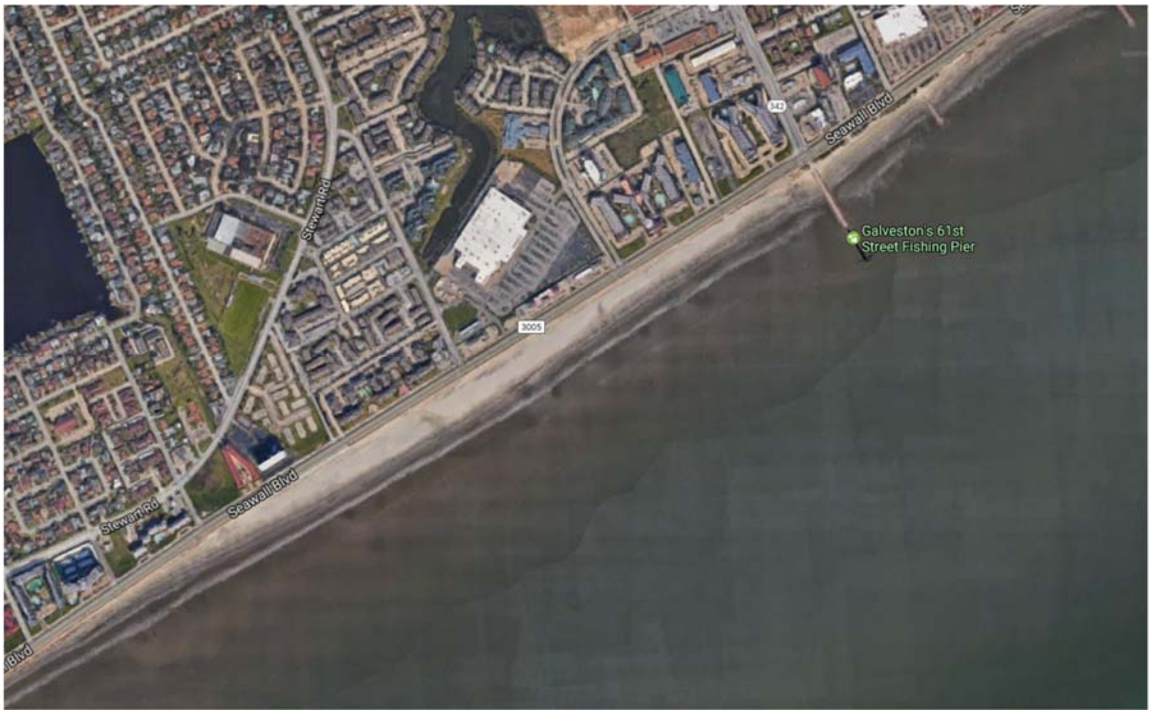

Figure 3.7.3 Post-Construction Conditions for the Galveston Seawall BN with BUDM (Source: Google Maps Imagery, Exact Date Unknown)

Figure 3.7.4 Post-Construction Conditions for the Galveston Seawall BN with BUDM (Source: UTBEG, Atlas of Texas Gulf Shoreline Change Rates)

Analysis

Taylor Engineering visited the project area on January 20, 2017, roughly 14 months post-construction. Figures 3.7.5 and 3.7.6 show project conditions during the site visit. Figure 3.7.5 shows the beach berm near its widest point. Figure 3.7.6 shows the project near its "tapering" area. The line of seaweed (wrack line) gives an idea of the location of recent high-tides.

The visit showed that most of the beach nourishment width has been preserved. The site visit photos show a significant and consistent beach width throughout much of the project area, and fill remained as far west as 80th St. Some of the beach fill has likely spread into the nearshore region to the west, but the 61st St groin has impounded a substantial amount of fill dispersed to the east. During the visit, Taylor Engineering staff measured approximately the distance from seawall to wrack line. Between 61st St and 75th St — the project limits — the beach had an average berm width (seawall to wrack line) of approximately 130 ft. Absent site-specific data about beach fill evolution and accumulation of offshore sand, this economic benefits study assumed a life-span of seven years, which appears reasonable based on the current beach width and above-mentioned background erosion rate.

Even though the absence of a beach results in waves lapping permanently at the rip rap, historically, this has not represented a major structural problem to the seawall. Naturally, the project helps protect the rip rap from waves; however, the assumption that a relatively small beach nourishment such as this one — susceptible to complete erosion under hurricane conditions — may protect a structure the size and importance of the Galveston Seawall would yield an unrealistically high benefit-cost ratio. Therefore, the study did not quantify any potential storm damage protection to the seawall.

As mentioned above, the project's goal is to expand Galveston Island's beach availability for recreational enjoyment. As such, this study quantified the economic benefits to the state of Texas from beach visitation (recreational benefits and out-of-state visitor spending benefits) starting at the beginning of 2016.

Recreational Benefits

The study assumed a project length of 4,350 ft (full beach width length [3,800 ft] plus half the tapering length [550ft]). Based on May 2015 observations, Taylor Engineering (2015) reports 443 peak visitors per 1,000 ft of shoreline on average at Porretto Beach in Galveston, an area with a relatively wide beach width, similar to the project area. Applying this visitation rate, the study estimates a peak visitation of 1,927 (443 / 1000 * 4350). Assuming a daily turnover rate of 2, the daily peak visitation estimate increases to 3,854. This analysis assumes the peak season runs from Memorial Day to three weeks before Labor Day (approximately 80 days). One-fifth (assumed) of the peak day visitors (546) visit the beach during off days, and 285 (i.e., 365 – 80) off peak days exist during a 365-day year. Given the above information, approximately 527,770 (3,854 * 80 + 770 * 285) visits occurred based on the 2015 visitation estimates. Increasing this beach visitation estimate by the general population growth rate (1.4%/year), 535,159 (527,770 * 1.014) visits occurred in 2016 after project construction. Anecdotally, the nourished beach has attracted many visitors, resulting in greatly increased hotel occupancy rates in the project vicinity; thus, above estimate appear reasonable.

To estimate the effect of beach width "elasticity" (Section 2.2), this analysis reduced the beach width to account for background erosion over the 7-year project life (beginning in 2016). Given the current

Figure 3.7.5 Galveston Seawall Beach Nourishment 14 months after completion (65th St)

Figure 3.7.6 Galveston Seawall Beach Nourishment 14 months after completion (77th St)

beach width of 130 ft, this analysis applied an erosion rate of 20 ft/yr, which completely erodes the beach after 7 years. Of note, this erosion rate is greater than the above-mentioned 8.7 ft/yr background erosion rate calculated from historical data. However, applying the 8.7 ft/yr erosion rate on the 130-ft wide berm would lead to a 15-year project life, which may not be realistic without additional fill or groin west of the project area to help retain fill. Thus, using the greater erosion rate provides a more conservative estimate of project benefits. Given that visitation occurs throughout the year, the beach width for each year was considered mid-year (e.g., 2017 mid-year width = 130 – 20 / 2 = 120 ft).

Some pre-2015 aerial photography indicates potential availability of beach within 1,500 ft of the 61st St groin and fishing pier. However, the beach berm does not appear completely dry in most areas and the rip rap revetment is completely exposed, making beach access unsafe. Any incipient beach was considered too small to be included in the without-project conditions. Nevertheless, the elasticity relationship assumes that under a beach reduction of 100%, the annual visitation change is approximately -57%. However, this value is based on beach user surveys conducted on unarmored beaches, where the 100% berm erosion case may still provide access to a sandy shoreline that may provide recreational opportunities, albeit at a limited capacity. At the Galveston seawall, where the shoreline is not available for recreation if no dry beach remains, such visitation is unrealistic. Accordingly, this analysis assumes a visitation reduction of 80% for a completely eroded beach, as some visitation will still occur for sightseeing or other similar activities. The elasticity relationship described in Section 2.2 was applied for the first 50% loss of beach width (i.e., approximately 1% reduction in visitation for every 1% loss of beach width); thereafter, visitation reduced by 0.6% for every 1% loss of beach width such that an 80% reduction occurs with 100% loss of beach. Tables 3.7.2 and 3.7.3 show total with-project and without-project visitation.

Calculating recreation enjoyment benefits for all visitors involved applying the visitation numbers derived in Tables 3.7.2 and 3.7.3 to the UDV developed (see section 2.2) for with- and without-project conditions. The UDV points assigned to the site with- and without project conditions provides an estimate of its economic benefits. Table 3.7.4 shows a summary of the points assigned for with- and without-project conditions in the project area. Converting the points (54 and 19) to dollars requires interpolating values from Table 2.6. The resulting with- and without-project UDVs are $8.72 and $5.15 (2017 dollars) per person per visit. Deflating at a rate of 2.1%, the 2016 UDVs result $8.54 and $5.04. Taking the difference between the estimated recreation value for all visitors with- and without-project estimates yields the benefit for the year. For the first year of analysis (2016, at 2016 price levels), the recreation value for with-project conditions equals $4,568,505 (535,159 * $8.54), and the without-project value equals $539,876 (107,032 * $5.04). The difference ($4,028,629) yields the recreational benefit for 2016 (assumed mid-year). Table

3.7.5 shows the total recreation value benefit for this project compounding benefits for the life of the project (7 years). In total, using a mid-year discounting rate of 3.16%, the benefit equals $15,545,790 (present value, beginning of 2016).

Table 3.7.2 Annual Visitation for the 61st St – 75th St Area with CEPRA Project #1609

Year	Unconstrained annual visitation	Beach width	Beach width change	Elasticity (Visitation change)	Constrained annual visitation
2016	535,159	140	0%	0%	535,159
2017	542,651	120	-14%	-14%	465,129
2018	550,248	100	-29%	-29%	393,034
2019	557,952	80	-43%	-43%	318,829
2020	565,763	60	-57%	-54%	258,634
2021	573,684	40	-71%	-63%	213,082
2022	581,715	20	-86%	-71%	166,204

Notes: Estimated at mid-year.
Background erosion, -20 ft/yr.
Starting daily peak visitation, 3854.
Out-of-State visitation, 10.6% of total visitation
Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.7.3 Annual Visitation for the 61st St – 75th St Area without CEPRA Project #1609

Year	Unconstrained annual visitation	Beach width	Beach width change	Elasticity (Visitation change)	Constrained annual visitation
2016	107,032	0	100%	0%	107,032
2017	108,530	0	100%	0%	108,530
2018	110,050	0	100%	0%	110,050
2019	111,590	0	100%	0%	111,590
2020	113,153	0	100%	0%	113,153
2021	114,737	0	100%	0%	114,737
2022	116,343	0	100%	0%	116,343

Notes: Starting daily peak visitation, 20% of with-project visitation.
Out-of-State visitation, 10.6% of total visitation
Weighted population growth rate (proxy for unconstrained visitation growth) = 1.4%

Table 3.7.4 UDV Points Assigned — #1609 Galveston Seawall Beach Nourishment

Criteria	Points Assigned (With Project)	Points Assigned (Without Project)	Total Possible Points
Recreation Experience	16	1	30
Availability of Opportunity	3	1	18
Carrying Capacity	9	1	14
Accessibility	16	14	18
Environmental	10	2	20
Total	54	19	100

Table 3.7.5 Galveston Seawall Beach Nourishment Project Recreation Benefit for All Visitors

Year	Total Visitation		Recreation Value (2016 Prices)		Difference (2016 Prices)	With Inflation	Discounted Present Worth	Cumulative Discounted Present Worth
	With Project	Without Project	With Project	Without Project				
2016	535,159	107,032	$4,568,505	$539,876	$4,028,629	$4,028,629	$3,966,447	$3,966,447
2017	465,129	108,530	$3,970,684	$547,434	$3,423,249	$3,495,138	$3,335,779	$7,302,226
2018	393,034	110,050	$3,355,228	$555,098	$2,800,129	$2,918,970	$2,700,544	$10,002,770
2019	318,829	111,590	$2,721,761	$562,870	$2,158,891	$2,297,777	$2,060,717	$12,063,486
2020	258,634	113,153	$2,207,892	$570,750	$1,637,142	$1,780,798	$1,548,152	$13,611,638
2021	213,082	114,737	$1,819,027	$578,741	$1,240,287	$1,378,800	$1,161,954	$14,773,592
2022	166,204	116,343	$1,418,841	$586,843	$831,998	$945,262	$772,198	**$15,545,790**

Notes: Total visitation estimates derive from Tables 3.7.2 and 3.7.3.
With-project, UDV dollar value (2016 Prices) = $8.54
Without-project, UDV dollar value (2016 Prices) = $5.04
Multiplier effect = 1.4
Inflation rates: 1.4% (2016), 2.1% (2017 – 2019), 2.2% (2020 and beyond)
Present worth beginning of 2016, 3.16% discount rate, mid-year discounting

Out-of-State Visitor Spending Benefit

Taylor Engineering (2015) reported that 10.6% of the visitors in the project vicinity (i.e., near 61st Street) come from out-of-state. Applying this value to the total annual visitation estimates (Tables 3.7.2 and 3.7.3) yields the number of annual out-of-state. Taylor Engineering (2015) also reports that out-of-state visitors spent $59.08 (2015 dollars) per person per visit to the Galveston area. Inflating this value to 2016 prices yields $59.91 ($59.08 * 1.014). Table 3.7.4 summarizes the benefit to Texas from spending by out-of-state visitors. The present value of this benefit (beginning of 2016) is $13,475,148.

Table 3.7.6 Galveston Seawall Beach Nourishment Project Out-Of-State Visitor Spending Benefit

Year	**Out-of-State**				**Difference (2016 prices)**	**With Inflation**	**Beginning of 2016 Discounted Present Worth**	**Beginning of 2016 Cumulative Discounted Present Worth**
	Visitation		**Visitor Spending (2016 prices)**					
	With Project	**Without Project**	**With Project**	**Without Project**				
2016	56,727	11,345	$4,757,677	$951,535	$3,806,142	$3,806,142	$3,747,394	$3,747,394
2017	49,304	11,504	$4,135,101	$964,857	$3,170,244	$3,236,820	$3,089,239	$6,836,632
2018	41,662	11,665	$3,494,161	$978,365	$2,515,796	$2,622,569	$2,426,322	$9,262,955
2019	33,796	11,829	$2,834,463	$992,062	$1,842,401	$1,960,927	$1,758,619	$11,021,574
2020	27,415	11,994	$2,299,317	$1,005,951	$1,293,366	$1,406,855	$1,223,062	$12,244,636
2021	22,587	12,162	$1,894,349	$1,020,034	$874,315	$971,957	$819,096	$13,063,731
2022	17,618	12,332	$1,477,593	$1,034,315	$443,278	$503,623	$411,417	**$13,475,148**

Notes: Out-of-state visitation = 10.6% of total visitation estimates derive from Tables 3.7.2 and 3.7.3.
Out-of-state spending = $59.91 per person (2016 prices)
Multiplier effect = 1.4
Inflation rates: 1.4% (2016), 2.1% (2017 – 2019), 2.2% (2020 and beyond)
Present worth beginning of 2016, 3.16% discount rate, mid-year discounting

Benefit-Cost Summary

With total benefits of $29,020,938 and a total project cost of $7,990,000, the resulting B/C ratio for project #1609 equals 3.6. Table 3.7.7 summarizes the results

Table 3.7.7 Benefit-Cost Summary — #1609 Galveston Seawall BN with BUDM

Benefits and Costs	**Discounted Present Worth (beginning of 2016)**
Out-of-state Visitor Spending Benefit	$13,475,148
Recreation Benefit	$15,545,790
Total Benefit	$29,020,938
Total Cost	$7,990,000
B/C Ratio	**3.6**

Notes: Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.16% discount rate.
Assumes a $1 million refund to the state took place near the beginning of 2016, per GLO.
Costs considered as taking place at the beginning of 2016 (discount factor = 1).
Benefits include mid-year discounting.

4.0 NATURAL RESOURCE RESTORATION BENEFIT ANALYSIS

4.1 Jefferson County — #1516 McFaddin NWR Beach Ridge Restoration

Project Description and Background Information

The McFaddin National Wildlife Refuge (NWR) occupies about 57,000 acres on the Chenier Plain along the Texas Gulf Coast in western Jefferson, Chambers, and eastern Galveston County (Figure 4.1.1). The NWR extends from the coast inland to or beyond the Gulf Intracoastal Waterway (GIWW). Most of the NWR habitat is brackish marsh. Rapid coastline erosion, as much as 40 ft per year, has occurred along the NWR section of the Texas coast. Erosion (exacerbated by Hurricane Ike) removed the beach dune system that historically protected interior wetlands from inundation with saline Gulf waters during episodic high water levels, typically occurring more frequently than tropical storm or hurricane storm surges (Salt Bayou Marsh Work Group, 2013; LJA, 2016).

Because of shoreline erosion, the McFaddin NWR, historically a predominately brackish wetland system, now experiences more frequent Gulf overwash and longer periods of marsh exposure to high salinity water. The resulting changes in marsh salinity have caused an annual average conversion of up to 0.69% of the marsh community to open water in the Salt Bayou marsh system (Salt Bayou Marsh Work Group, 2013). This occurs because the saline water alters sediment chemistry, increasing sulfide-driven bacterial digestion of organic wetland soils which results in lowered land surface and increased water depths. These changes degrade and destroy the historic brackish marsh.

CEPRA project #1516 McFaddin NWR Beach Ridge Restoration constructed a 10-mile long overwash protection berm from Perkins levee west to a point about two miles west of White's levee. The project objective was to prevent high frequency episodic salt water overwash and thereby minimize or eliminate wetland loss due to increased salinity in the marsh.

Figure 4.1.1 McFaddin NWR beach ridge restoration location

The overwash protection berm was completed in August 2015 after about a year and a half construction period. The berm (Figure 4.1.2) typically comprises a series of 800-ft long by 36-ft wide sand-covered clay embankments separated by 300-ft wide gaps. The gaps allow a return path to the Gulf for water overtopping the structure during extreme storms. The berm restricts saline water penetration into the marsh and subsequent movement through the marsh towards discharges at the east end of the Salt Bayou system.

Figure 4.1.2 McFaddin NWR overwash protection berm under construction (Photo from GLO)

Project Funding

Funding for the McFaddin NWR beach ridge restoration originated from federal and Texas sources, as listed in Table 4.1.1. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the total federal cost ($3,690,000) is $369,000. The resulting cost to Texas for Project #1571 amounts to $429,000 (present worth, beginning of 2015); this value equals the sum of the CEPRA funding ($60,000) and the 10% state share of federal costs ($369,000). The largest part of the project budget funded construction that occurred from mid-2014 through the latter half of 2015; this analysis therefore assumes that project costs were incurred at the beginning of 2015 (i.e., the approximate mid-point of this construction period). Converting to a present worth equivalent value, beginning of 2014 (i.e., for a direct comparison with the benefit estimates) using a 3.16% discount rate, the total cost incurred by Texas becomes $3,635,130 (i.e., 1.0316 x $3,750,000).

Table 4.1.1 Funding for the McFaddin NWR Beach Ridge

Funding Source		**Amount[1]**	**Beginning of 2014 Discounted Present Worth[2]**
Federal	USFWS (*Texas portion*)	$3,200,000 *($320,000)*	$3,101,978 *($310,198)*
	CIAP to Jefferson County, in kind (*Texas portion*)	$134,000 *($13,400)*	$129,895 *($12,990)*
	CIAP to Jefferson County, cash (*Texas portion*)	$266,000 *($26,600)*	$257,852 *($25,785)*
	CIAP to State (*Texas portion*)	$90,000 *$9,000*	$87,243 *$357,697*
State/Local	Texas GLO, CEPRA	*$50,000*	*$48,468*
	Texas GLO, in kind	*$10,000*	*$9,694*
Total Project Cost		$3,750,000	$3,635,130
Texas Total		*$429,000*	*$415,859*

Note: Values in italics are costs to the State of Texas.
[1]Values represent present worth, beginning of 2015
[2]Beginning of 2014 present worth = Amount/1.0316 (i.e., 3.16% discount rate)

Analysis

Project construction began mid-year in 2014 and was completed in August 2015. We therefore considered project effects beginning in 2014. As typical for analyses of other similar projects, we assumed a 20-yr project lifetime for this analysis, with 2015 (the construction completion year) as the first year of the project life. The berm is situated about 600-ft inland of the beach, landward of shoreline erosion over the assumed 20-yr project life.

Taylor Engineering estimated McFaddin NWR beach ridge restoration project benefit as the value of emergent wetland acreage protected from conversion to open water due to the project's minimization of saline water intrusion into the marsh system. The benefit estimate required determination of the amount of wetland that would be lost with and without the overwash protection berm. To estimate wetland loss, we delineated the wetland area likely influenced by overwash salinity increases, determined the amount of emergent wetland converted to open water during the berm's project life, and estimated the economic value of wetlands based on per acre ecosystem services values.

Taylor Engineering applied a geographic information system (GIS) analysis of National Wetlands Inventory (NWI) data to delineate and quantify the area of emergent wetland vegetation likely influenced by saline overwash entering the marsh. We assumed that overwash moved north and east through the marsh, bounded on the south by the newly-constructed berm, on the west by the unpaved road extending from the end of the project to the GIWW, on the north by the GIWW, and on the east by Perkins levee. We obtained NWI Texas wetlands data for this area as a shapefile from the Texas Natural Resources Information System[1]. The NWI wetlands data are based on interpretation of 2010 aerial images (we did not attempt to account for any wetland loss occurring between the 2010 image date and project construction).

We refined the resulting wetlands shapefile by removing wetland areas likely unaffected by Gulf overwash. These included wetlands identified as:

- deepwater tidal habitats
- high energy shorelines or beaches, bars, and flat, and having < 30% vegetative cover
- marine (>30 ppt salinity)
- lacustrine and having <30% persistent vegetative cover
- palustrine (<0.5 ppt salinity)

We removed palustrine wetlands, reasoning that these wetlands have remained fresh without the berm and have not been substantially altered by past exposure to saline water. The final shapefile for the wetlands potentially protected from Gulf water overwash by the protection berm contained 18,550 acres of emergent vegetation wetlands, classified as marine and estuarine emergent wetlands (NWI codes E2EM1P, E2EM1Ps and E2EM1Px) and distributed as shown in Figure 4.1.3.

Citing 2002 Texas Parks and Wildlife Department information, the Salt Bayou Watershed Restoration Plan (2013) reports an emergent vegetation to open water conversion rate of up to 0.69% per year due to salinity stress in the Salt Bayou marsh system. Updated information about marsh loss rates in the western part of the Salt Bayou system (which includes the area protected by the overwash berm) from

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[1] Accessed January 1, 2017 at: https://tnris.org/data-catalog/entry/national-wetlands-inventory-vector/

2001 – 2012 (M. Rezsutek, Texas Parks and Wildlife, personal communication, January 11, 2017) indicated an annual marsh to open water conversion rate of 0.24% per year. Taylor Engineering assumed a 0.24% annual marsh to open water conversion rate for this evaluation.

Comparison of the ecosystem value differences between the with-project and without-project conditions provides the project benefit value. For the without-project condition, we assumed that the annual wetland loss rate given above remains unchanged for the analysis period. The with-project condition assumed that ecosystem services benefits would begin the year following construction completion, as the reduction of salt water entering the system and displacement of residual salt water with fresh water during the wet season would eliminate emergent vegetation loss due to salinity effects.

In addition to ecosystem services benefits accruing to wetland preservation, we also recognized that some ecosystem value would be permanently lost due to berm construction over existing wetlands. To estimate wetland loss, we overlaid a 36-ft wide continuous berm footprint over the NWI wetlands shapefile to obtain a shapefile of potentially affected wetlands. After excluding deepwater wetlands (the berm typically avoids these areas), we assumed that 73% of the remaining wetlands would be covered by the berm (given the typical 800-ft long berm followed by 300-ft gap project configuration). This method resulted in an estimated 100 acres of wetland lost due to direct impact from berm construction. We assumed that 50 acres were lost during 2014 construction and 50 additional acres were lost during 2015 construction.

We estimated the economic services value of the emergent vegetation marsh (expressed as dollars/acre) as the sum of habitat, recreation, disturbance regulation, gas regulation, and waste regulation values discussed in Section 2.3. We did not include the aesthetics value because most of the area benefitting from the project is remote and offers only limited human aesthetic experience. Marsh ecosystem services values, at 2014 prices, totaled $3,318 per acre.

Based on the above assumptions and analyses, we calculated the annual acreage of emergent wetlands lost for with- and without-project conditions. Subtracting the wetland acreage lost with the project (i.e., salinity-related loss during construction and permanent loss due to direct berm impact) from the acreage lost without the project (i.e., salinity-related loss) provided the net project benefit in terms of protected wetland acreage. Table 4.1.2 shows the benefit calculation steps. Net acreage protected in each year is multiplied by the wetland ecosystem services per acre value (2014 prices). This value is then converted to an inflation-adjusted amount, reflecting the price levels estimated to exist in each year. This amount is then converted to a present value, at the beginning of 2014. Finally, the annual benefit present values are accumulated for the 21-year evaluation period.

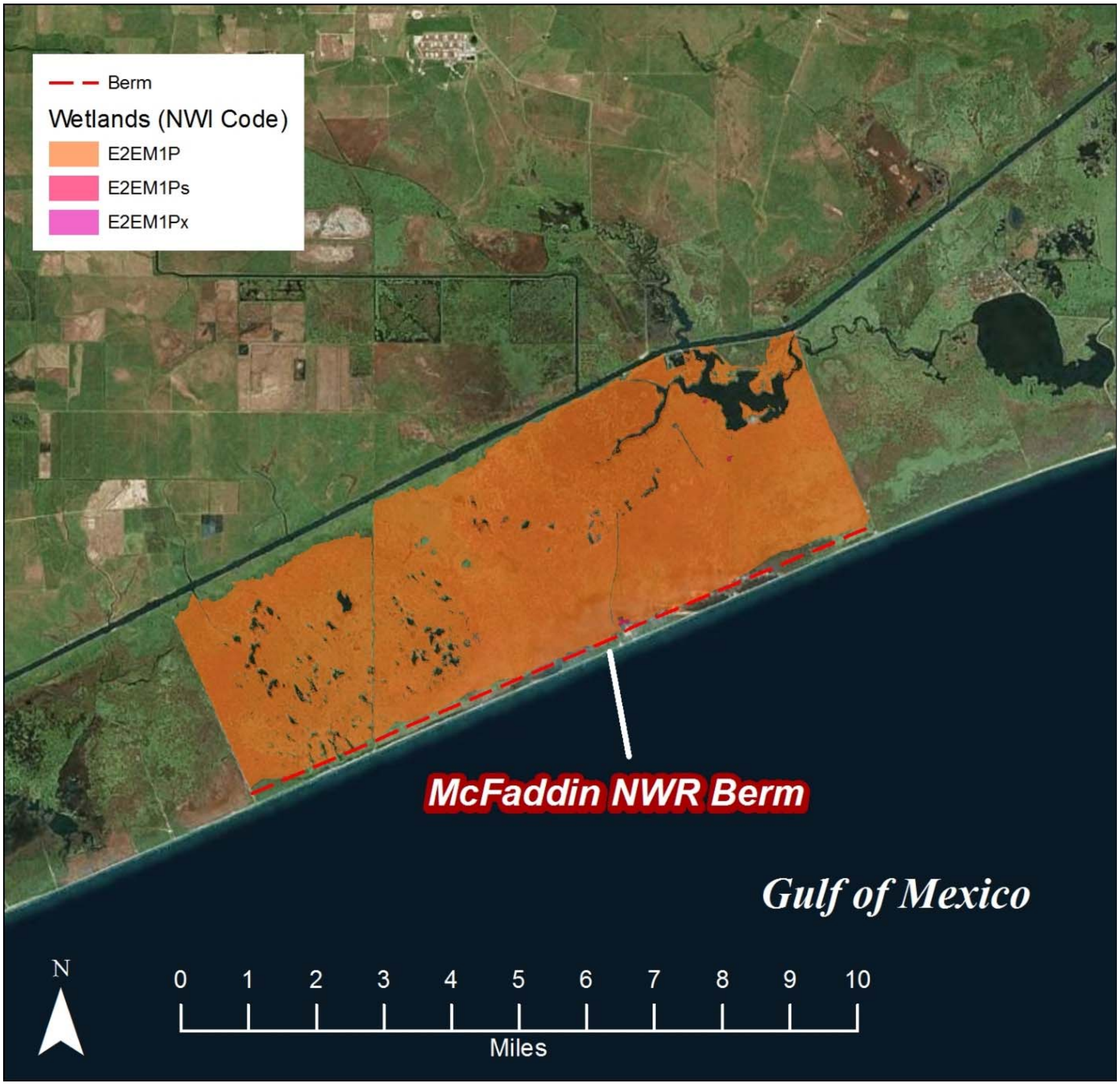

Figure 4.1.3 Wetlands Protected by Overwash Berm

Table 4.1.2 McFaddin NWR Ridge Economic Benefits

Year	Emergent Wetland Lost (acres)				Emergent Wetland Preserved with Project (acres)	Annual Value of Wetlands Preserved			
	With-project		Without-project			2014 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2014 Discounted Present Worth[1] ($)	Beginning of 2014 Cumulative Discounted Present Worth ($)
	Annual Loss	Cumulative	Annual	Cumulative					
2014	94.5	94.5	44.5	44.5	-50.0	-165,909	-165,909	-163,348	-163,348
2015	94.3	188.8	44.4	88.9	-99.9	-331,419	-331,751	-316,625	-479,973
2016	0.0	188.8	44.3	133.2	-55.6	-184,402	-187,171	-173,165	-653,138
2017	0.0	188.8	44.2	177.4	-11.4	-37,738	-39,109	-35,074	-688,212
2018	0.0	188.8	44.1	221.5	32.7	108,574	114,881	99,873	-588,339
2019	0.0	188.8	44.0	265.5	76.7	254,535	274,977	231,731	-356,608
2020	0.0	188.8	43.9	309.4	120.6	400,145	441,792	360,906	4,298
2021	0.0	188.8	43.8	353.2	164.4	545,407	615,420	487,345	491,643
2022	0.0	188.8	43.7	396.9	208.0	690,319	796,071	611,090	1,102,733
2023	0.0	188.8	43.6	440.4	251.6	834,884	983,963	732,186	1,834,919
2024	0.0	188.8	43.5	483.9	295.1	979,102	1,179,320	850,673	2,685,591
2025	0.0	188.8	43.4	527.2	338.4	1,122,973	1,382,369	966,593	3,652,184
2026	0.0	188.8	43.3	570.5	381.7	1,266,500	1,593,348	1,079,988	4,732,173
2027	0.0	188.8	43.2	613.6	424.8	1,409,682	1,812,498	1,190,898	5,923,070
2028	0.0	188.8	43.0	656.7	467.9	1,552,520	2,040,067	1,299,362	7,222,432
2029	0.0	188.8	42.9	699.6	510.8	1,695,015	2,276,312	1,405,420	8,627,852
2030	0.0	188.8	42.8	742.5	553.7	1,837,169	2,521,495	1,509,111	10,136,963
2031	0.0	188.8	42.7	785.2	596.4	1,978,981	2,775,886	1,610,473	11,747,436
2032	0.0	188.8	42.6	827.9	639.0	2,120,453	3,039,762	1,709,543	13,456,978
2033	0.0	188.8	42.5	870.4	681.6	2,261,586	3,313,407	1,806,358	15,263,336
2034	0.0	188.8	42.4	912.8	724.0	2,402,379	3,597,115	1,900,955	17,164,292

[1] Present worth beginning of 2014 applying a mid-year discount factor [$(1/1.0316)^{n+0.5}$, where n = ((year - 2014) + 0.5)] to the inflation-adjusted value

Federal Spending Benefit

This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.2). A multiplier of 1.26 applied to the federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy. Thus, the federal spending benefit for Project #1516 is $4,649,400 ($3,690,000*1.26), present worth, beginning of 2015. Converting this value to present worth at the beginning of 2014 (i.e., for a direct comparison with the benefit estimates) based on a 3.16% discount rate yields $4,506,979.

Benefit-Cost Summary

Adding the ecosystem services benefit to the federal spending benefit yields a total project benefit of $21,671,271. Dividing the total project benefits value by the total Texas project cost results in a B/C ratio of 52.1 (Table 4.1.3).

Table 4.1.3 Benefit-Cost Summary for McFaddin NWR Beach Ridge Restoration

Benefits and Costs	**Discounted Present Worth (beginning of 2014)**	**Discounted Present Worth (beginning of 2016)**
Ecosystem Services Benefits	$17,164,292	$18,266,215
Federal Spending Benefits	$ 4,506,979	$4,796,321
Total Benefits	$21,671,271	$23,062,535
Total Texas Costs	$415,859	$442,557
B/C Ratio	**52.1**	**52.1**

4.2 Galveston County — #1520 Bird Island Cove Marsh Restoration

Project Description and Background Information

A combination of regional land subsidence, both natural and human-induced, as well as sea level rise have contributed to erosion of marshes in Galveston Bay (Coplin and Galloway, 1999). As cessation of groundwater withdrawal has slowed regional subsidence, several marsh creation projects in Galveston Bay have begun to restore marsh along the bay side of Galveston Island. The Bird Island Cove marsh restoration project is a continuation of these restoration efforts.

The Bird Island Cove marsh restoration (Figures 4.2.1 and 4.2.2) used a design similar to those of successful marsh creation projects in nearby areas of Galveston Bay. The project built a geotextile tube breakwater to protect the eroding north shoreline of Shell Island Point and created marsh habitat by constructing emergent mounds behind the breakwater and Shell Island Point. The geotextile tube was filled and the mounds created with material hydraulically dredged from a nearby borrow area in West Galveston Bay. The restoration project began construction in mid-2014 and was completed by the end of the year.

Project Funding

Funds for project execution included direct and in-kind support from the federal and Texas sources listed in Table 4.2.1. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $1,162,522 total federal costs — including the USFWS Texas Coastal Program contribution ($60,000), USFWS National Coastal Wetlands Conservation Grant ($1,000,000), and NOAA grant ($102,522) — equals $116,252. The resulting cost to Texas for Project #1520 amounts to $726,252 (2014 price level); this value equals the sum provided by the state and private agencies ($610,000) listed in Table 2.1 and the 10% state share of federal costs ($116,252). Projects costs were incurred throughout 2014; thus, this analysis assumes all costs represent a present worth equivalent value, mid-year 2014. Converting to a present worth equivalent value, beginning of 2014 (i.e., for a direct comparison with the benefit estimates) using a 3.16% discount rate, the total cost incurred by Texas becomes $715,042 (i.e., 1.0316 x $726,252).

Table 4.2.1 Funding for the Bird Island Marsh Restoration

Funding Source		**Amount[1] ($)**	**Discounted Present Worth Beginning of 2014 ($)**
Federal	USFWS Texas Coastal Program	60,000	59,074
	(Texas Portion)	*6,000*	*5,907*
	USFWS National Coastal Wetlands Conservation Grant	1,000,000	984,565
	(Texas Portion)	*100,000*	*98,456*
	NOAA Estuary Restoration Act Grant (to GLO)	102,522	*100,939*
	(Texas Portion)	*10,252*	*10,094*
State/Local/ Private	Texas Parks and Wildlife Department (in-kind)	*10,000*	*9,846*
	Texas GLO, CEPRA	*350,000*	*344,598*
	Texas GLO, CEPRA (in-kind)	*10,000*	*9,846*
	Galveston Bay Estuary Program	*150,000*	*147,685*
	Coastal Conservation Association	*50,000*	*49,228*
	NRG Texas Power LLC (in kind)	*40,000*	*39,383*
Total Project Cost		1,772,522	1,745,163
Texas Total		*726,252*	*715,042*

Note: Values in italics are costs to the State of Texas.

[1] Values represent present worth, mid-year of 2014

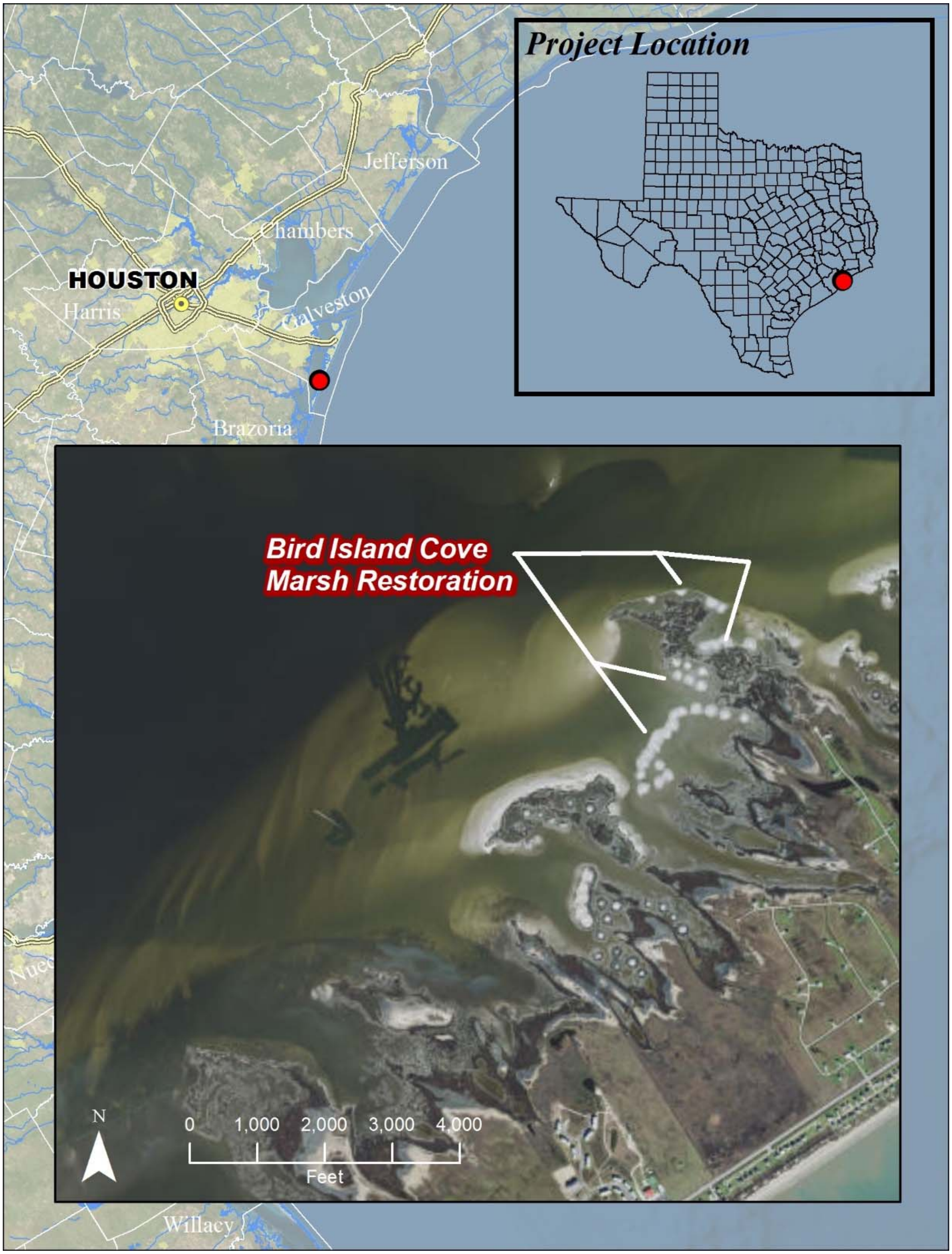

Figure 4.2.1 Bird Island Cove Marsh Restoration, Galveston County, Texas

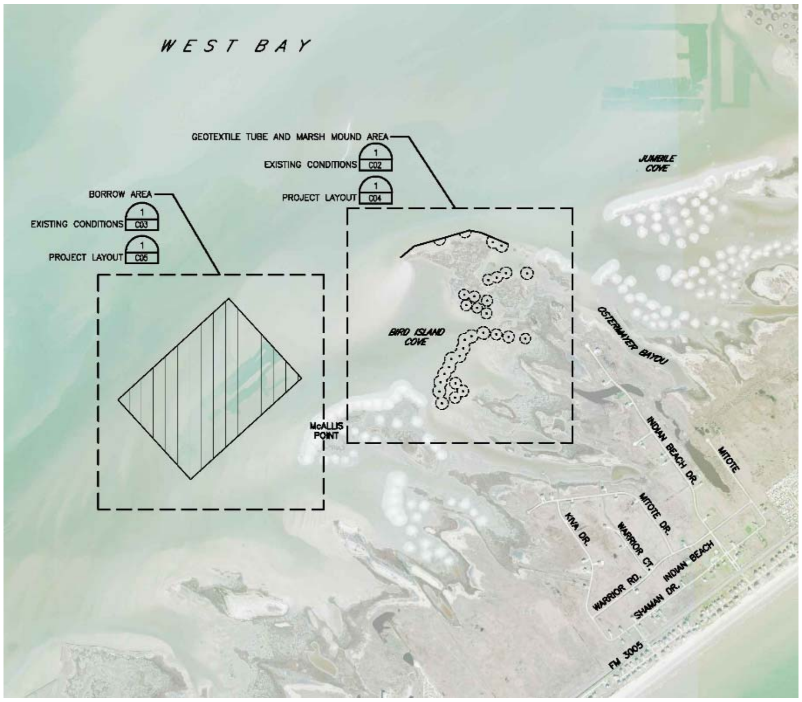

Figure 4.2.2 Bird Island Cove Marsh Restoration Plan View Drawing (Detail from HDR project record drawing dated 02/10/15)

Analysis

Ecosystem Services Benefits

The ecosystem services benefits analysis for the Bird Island Cove marsh restoration rests on several assumptions:

- The breakwater will prevent further erosion of Shell Island Point and of marsh mounds created behind the breakwater;
- Marsh mounds will evolve (i.e., settle, erode, and become vegetated) in a manner and time frame similar to those created in nearby areas in the past;
- Marsh evolution will differ depending on whether marshes were constructed in protected (i.e., behind the breakwater or other marsh) or exposed areas;
- Full ecosystem value benefits occur when the marsh mounds have settled and developed a vegetation community as well as a full benthic community and marsh soil column;
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015). In addition, analysis of potential effects of sea level rise on marshes in

Galveston Bay (Feagin et al., 2010) has indicated that (at least for existing rates of sea level rise) marshes will most likely migrate and remain viable;

- We evaluated the projects effects over a 21-yr period. The breakwater began to have some effect during construction in 2014 but, because the project was completed near the end of the year, we considered 2015 as the first year of the 20-yr project life.
- ecosystem services benefits will accrue from 1) the breakwater's prevention of marsh erosion and 2) development of new marsh on the mounds;
- While open water areas occur within the project area, the ecosystem services values for changes in open water are negligible relative to marsh values; we did not attempt to account for open water services value gained from erosion or lost by marsh creation.

The project built a 2,000-ft long geotextile tube breakwater on the north side of Shell Island Point to provide protection to the point and to marsh mounds created behind the breakwater. The ecosystem services value of the breakwater can be calculated as the value of marsh protected from erosion. Our examination of aerial imagery from 1954 and 2014 showed substantial erosion of the point at an annual erosion rate of about 6.2 ft/yr. Applying that erosion rate to the shoreline visible in a May 2014 aerial image indicated that, without the breakwater, 5.1 acres of marsh would be lost over a 21-year period.

Examination of the marsh created in Jumbile Cove immediately west of Jamaica Beach allows estimation of marsh evolution. From aerial images available in Google Earth, numerous marsh mounds were created in 2003 and early 2004 (a dredge appears working in a 01/31/2004 image). Some of the mounds were created in sheltered areas behind a breakwater or older marsh islands while others were created in relatively exposed locations. Our comparison of a 11/21/2015 image with the 2004 image indicated that ten mounds built in sheltered locations expanded in area at a median annual rate of 3%. Eight mounds built in exposed locations decreased in size at a 5% median annual rate. For the Bird Island Cove marsh, we considered islands build immediately behind the breakwater, Shell Island Point, or newly created mounds as occurring in sheltered locations. We considered the relatively contiguous chain of nine mounds with a northwest exposure as occurring in an exposed location. We estimated the initial area of each mound, as visible in a 03/27/2015 aerial image, and then applied the annual area change rates above to the area of each mound for each year of the project life. This study calculated the annual value of created marsh by multiplying the total marsh acreage by the ecosystem services values for habitat, recreation, disturbance regulation, gas regulation, waste regulation, and aesthetics ($3,374 per acre in 2014 prices) as discussed in Section 2.3. Tables 4.2.2 – 4.2.4 detail the annual ecosystem services benefits occurring from marsh erosion prevention, marsh creation in sheltered areas, and marsh creation in exposed areas.

Table 4.2.2 Bird Island Marsh Economic Benefits - Erosion Prevention

Year	Marsh Lost (acres)				Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2014 Cumulative Discounted Present Worth ($)
	With Project		Without Project			2014 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2014 Discounted Present Worth[1] ($)	
	Annual Loss	Cumulative	Annual	Cumulative					
2014	0.08	0.08	0.244	0.244	0.16	548	548	540	540
2015	0.00	0.08	0.244	0.488	0.41	1,371	1,372	1,310	1,850
2016	0.00	0.08	0.244	0.731	0.65	2,193	2,226	2,060	3,909
2017	0.00	0.08	0.244	0.975	0.89	3,016	3,126	2,803	6,712
2018	0.00	0.08	0.244	1.219	1.14	3,838	4,061	3,531	10,243
2019	0.00	0.08	0.244	1.463	1.38	4,661	5,035	4,243	14,487
2020	0.00	0.08	0.244	1.707	1.63	5,484	6,054	4,946	19,433
2021	0.00	0.08	0.244	1.950	1.87	6,306	7,116	5,635	25,067
2022	0.00	0.08	0.244	2.194	2.11	7,129	8,221	6,310	31,378
2023	0.00	0.08	0.244	2.438	2.36	7,951	9,371	6,973	38,351
2024	0.00	0.08	0.244	2.682	2.60	8,774	10,568	7,623	45,974
2025	0.00	0.08	0.244	2.926	2.84	9,596	11,813	8,260	54,234
2026	0.00	0.08	0.244	3.170	3.09	10,419	13,108	8,884	63,118
2027	0.00	0.08	0.244	3.413	3.33	11,241	14,454	9,497	72,615
2028	0.00	0.08	0.244	3.657	3.58	12,064	15,852	10,097	82,712
2029	0.00	0.08	0.244	3.901	3.82	12,886	17,306	10,685	93,396
2030	0.00	0.08	0.244	4.145	4.06	13,709	18,815	11,261	104,657
2031	0.00	0.08	0.244	4.389	4.31	14,531	20,383	11,826	116,483
2032	0.00	0.08	0.244	4.632	4.55	15,354	22,011	12,379	128,861
2033	0.00	0.08	0.244	4.876	4.79	16,177	23,700	12,920	141,782
2034	0.00	0.08	0.244	5.120	5.04	16,999	25,453	13,451	155,233

[1] Present worth at beginning of 2014, applying a mid-year discount factor $[(1/1.0316)^{n+0.5}$, where n = (year - 2014)] to the inflation-adjusted value

Table 4.2.3 Bird Island Marsh Economic Benefits - Protected Marsh Development

Year	Marsh Area Created		Annual Value of Created Marsh			Beginning of 2014 Cumulative Discounted Present Worth ($)
	Total (acres)	Net Marsh Service (acres)	2014 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2014 Discounted Present Worth[1] ($)	
2014	10.28	0.00	0	0	0	0
2015	10.63	1.06	3,586	3,589	3,426	3,426
2016	10.99	1.81	6,091	6,182	5,720	9,145
2017	11.36	2.60	8,762	9,080	8,143	17,288
2018	11.75	3.44	11,606	12,281	10,676	27,965
2019	12.15	4.34	14,634	15,810	13,323	41,288
2020	12.56	5.29	17,854	19,713	16,103	57,391
2021	12.98	6.31	21,276	24,007	19,011	76,402
2022	13.42	7.38	24,909	28,725	22,050	98,452
2023	13.88	8.53	28,764	33,900	25,226	123,678
2024	14.35	9.74	32,852	39,570	28,543	152,221
2025	14.84	11.02	37,184	45,773	32,006	184,227
2026	15.34	12.38	41,772	52,553	35,621	219,848
2027	15.86	13.82	46,629	59,953	39,392	259,240
2028	16.40	15.34	51,767	68,024	43,326	302,566
2029	16.95	16.95	57,200	76,817	47,428	349,993
2030	17.53	17.53	59,141	81,170	48,580	398,574
2031	18.12	18.12	61,147	85,770	49,760	448,334
2032	18.74	18.74	63,221	90,630	50,970	499,304
2033	19.38	19.38	65,365	95,765	52,208	551,512
2034	20.03	20.03	67,582	101,192	53,477	604,988

[1] Present worth at beginning of 2014, applying a mid-year discount factor [$(1/1.0316)^{n+0.5}$, where n = (year - 2014)] to the inflation-adjusted value

Table 4.2.4 Bird Island Marsh Economic Benefits - Unprotected Marsh Development

Year	Marsh Area Created		Annual Value of Created Marsh			Beginning of 2014 Cumulative Discounted Present Worth ($)
	Total (acres)	Net Marsh Service (acres)	2014 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2014 Discounted Present Worth[1] ($)	
2014	5.25	0.00	0	0	0	0
2015	4.99	0.50	1,682	1,684	1,607	1,607
2016	4.73	0.78	2,624	2,663	2,464	4,071
2017	4.50	1.03	3,467	3,593	3,222	7,293
2018	4.27	1.25	4,218	4,463	3,880	11,173
2019	4.05	1.45	4,885	5,277	4,447	15,620
2020	3.85	1.62	5,474	6,043	4,937	20,557
2021	3.66	1.78	5,991	6,760	5,353	25,910
2022	3.47	1.91	6,442	7,429	5,703	31,613
2023	3.30	2.03	6,832	8,052	5,992	37,604
2024	3.13	2.12	7,167	8,633	6,227	43,831
2025	2.97	2.21	7,451	9,172	6,413	50,245
2026	2.82	2.28	7,688	9,672	6,556	56,800
2027	2.68	2.34	7,882	10,134	6,658	63,459
2028	2.55	2.38	8,037	10,561	6,726	70,185
2029	2.42	2.42	8,156	10,953	6,763	76,948
2030	2.30	2.30	7,745	10,630	6,362	83,310
2031	2.18	2.18	7,355	10,317	5,985	89,295
2032	2.07	2.07	6,984	10,012	5,631	94,926
2033	1.97	1.97	6,633	9,717	5,297	100,224
2034	1.87	1.87	6,298	9,431	4,984	105,207

[1] Present worth at beginning of 2014, applying a mid-year discount factor [$(1/1.0316)^{n+0.5}$, where n = (year - 2014)] to the inflation-adjusted value

Federal Spending Benefit

This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.2). A multiplier of 1.26 applied to the total federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy. Thus, the federal spending benefit for Project #1520 is $1,464,777 ($1,162,522*1.26), mid-year 2014. Converting to present worth, beginning of 2014, the federal spending benefit equals $1,442,168.

Benefit-Cost Summary

Table 4.2.5 summarizes project benefits and costs. All costs and benefits are listed in terms of beginning of 2014 present worth, applying mid-year discounting. Dividing the total project benefits value by the total Texas project cost results in a B/C ratio of 3.2.

Table 4.2.5 Benefit-Cost Summary for Bird Island Cove Marsh Restoration

Benefits and Costs	**Discounted Present Worth (beginning of 2014)**	**Discounted Present Worth (beginning of 2016)**
Ecosystem Services Benefit	$865,428	$920,987
Federal Spending Benefit	$1,442,168	$1,534,753
Total Benefits	$2,307,597	$2,455,741
Total Costs	$715,042	$760,947
B/C Ratio	**3.2**	**3.2**

4.3 San Patricio County — #1527 Indian Point Shoreline Protection & Marsh Restoration

Project Description and Background Information

CEPRA Project #1527 constructed a rock revetment and segmented breakwater along the Corpus Christi Bay shoreline of Indian Point Peninsula, Portland, San Patricio County (Figure 3.4.1) to protect existing habitat from persistent shoreline erosion. The Indian Point Feasibility Study (McPherson, 2012) found, through analysis of historical aerial photography, that shoreline retreat rates ranged from 8.9 ft/yr – 17.4 ft/yr for different periods. Between 2005 and 2011, erosion proceeded at an average rate of 14.2 ft/yr. McPherson (2012) stated that ongoing maintenance has stabilized the point itself (Figure 4.3.2), but that shoreline retreat on either side was ongoing and "progressive (occurring steadily over time) and not episodic (occurring during a major storm)." Long-term impacts of continued erosion are severe: "If the shoreline is breached and the lagoons become connected to the open bay, a new shoreline may form on the landward side of the lagoons, posing greater risk to the roadway and resulting in significant wetland loss (potentially 4 to 5 acres in single event)."

To achieve the project objectives to protect existing wetlands, promote seagrass expansions, and protect and/or maintain existing infrastructure, CEPRA Project #1527 constructed approximately 700 ft of rock revetment around the Indian Point Pier parking lot and approximately 500 ft of segmented rock breakwater extending northeast of the point into Corpus Christi Bay. The breakwater is intended to protect wetlands and lagoons close to the shoreline. Project construction was completed December 15, 2014 per the Sealed Engineering Record Drawings submitted to The Texas General Land Office. Figure 4.3.2 – 4.3.3 show pre- and post-construction conditions.

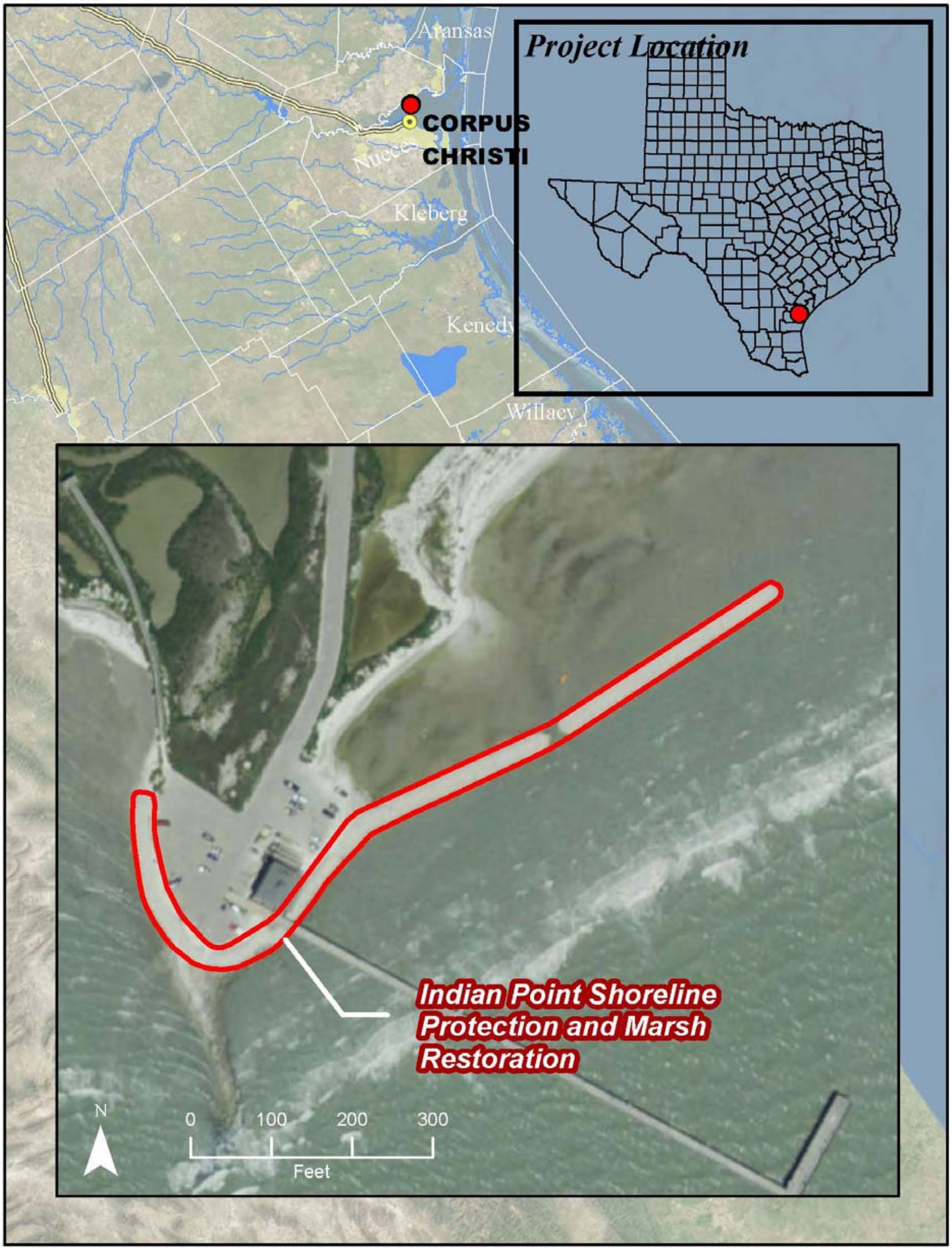

Figure 4.3.1 Indian Point Shoreline Protection and Marsh Restoration Location Map

Figure 4.3.2 Pre-Construction Shoreline of Indian Point (Photo provide by GLO)

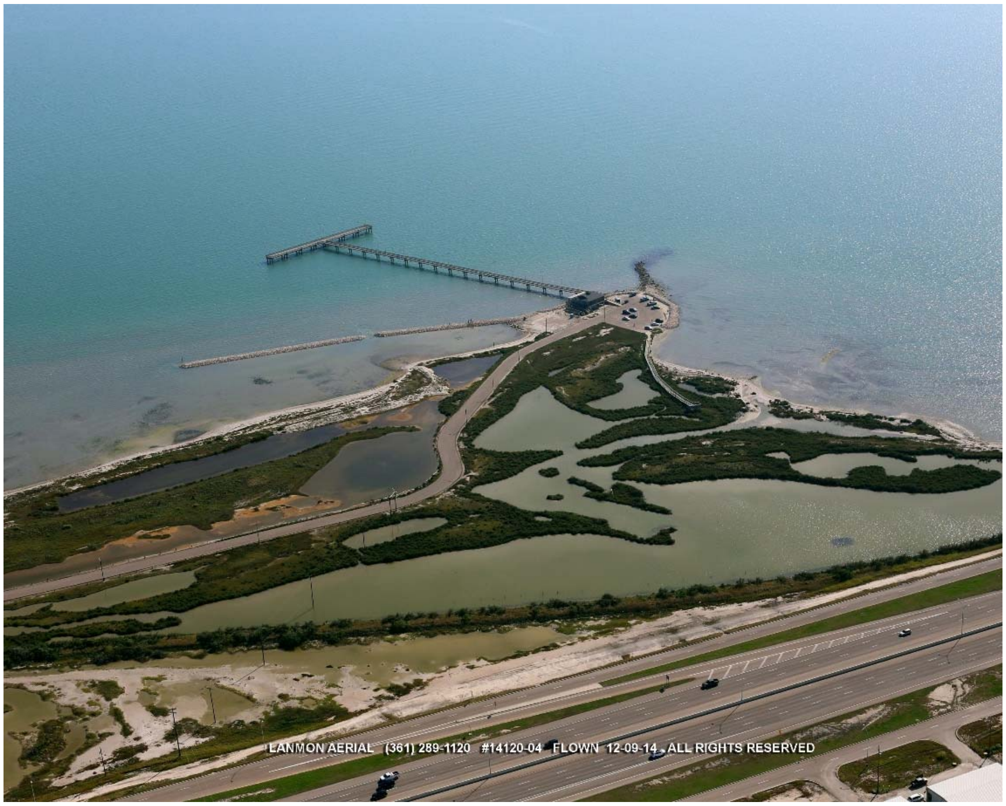

Figure 4.3.3 Post-Construction Conditions (Photo Provided by GLO)

Project Funding

Funding for Project #1527 derived solely from state funding sources. Cost sharing included 32.4% from City of Portland, 7.6% from Coastal Bend Bays and Estuaries Program, and 60% from CEPRA (Table 4.3.1) Actual project expenditures totaled \$899,000.51, leaving \$25,999.49 of the available funding unspent. Costs are assumed to be incurred at the beginning of 2015 for purposes of the economic evaluation.

Table 4.3.1 Funding for the Indian Point Shore Protection and Marsh Restoration

Funding Source		Amount (2015 Prices)
State/Local	City of Portland (cash – 32.4% of total)	*\$300,000*
	Coastal Bend Bays and Estuaries Program (cash – 7.6% of total)	*\$70,000*
	CEPRA (cash – 60% of total)	*\$555,000*
Total Project Cost		\$925,000
Texas Total		*\$925,000*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2015
Actual project expenditures totaled \$899,000.51

Analysis

The economic benefits defined in this analysis include protection of part of the Indian Point Pier access road and avoidance of the conversion of a higher services estuarine community to a lower services estuarine community. This analysis assumes the constructed breakwater extending into Corpus Christi Bay protects the leeward shoreline and prevents estuarine marshes from eroding to subtidal vascular plant (seagrass) habitat, a community type with lower ecosystem services values. If the erosion were to continue unchecked, the shoreline would retreat to the roadway, which would then require a protective revetment. For purposes of this analysis, the protected area includes the approximate wave shadow created by the breakwater (Figure 4.3.4). As mentioned, McPherson (2012) described the armored point itself as stable. While the constructed revetment is a design improvement over the existing revetment and may reduce future maintenance costs, we have no means to assess the benefit of that improvement. This analysis assumes the point would remain stable in the without-project case; thus, benefits from the revetment improvement are excluded from this analysis. This analysis assumes a 20-year project life.

Ecosystem Services Benefit

A single erosion rate was presumed for uplands and wetlands within the project area of influence. The upland areas and the emergent wetlands were presumed to erode at the same annual rate. The rate of conversion of communities to subtidal seagrass habitat was based on the 2005 – 2011 erosion rate (14.2 ft/yr) provided in McPherson (2012). Aerial photographs of the site taken within the last decade and the National Wetland Inventory wetland shapefiles for the site (NWI, 2016) were used to estimate 2015 upland and wetland areas that would erode without the project. Any area that was eroded was assumed to convert to submersed habitat (E1AB3 – Estuarine subtidal aquatic bed rooted vascular – i.e., seagrass bed). When erosion of uplands or emergent wetlands reached "irregularly exposed" ("usually" flooded wetland habitat), the erosion was presumed to be translated across that typically open water area to the next emergent marsh shoreline within the same year that the erosion reached that habitat. This analysis applied the ecosystem service values obtained from the GecoServ (Harte Research Institute, 2016), as discussed in Section 2.3. This analysis assumed submersed habitat and emergent wetland aesthetics are equivalent and, thus, excluded aesthetics from the benefits analysis. Adjusting the values for inflation to 2015 (i.e., the year benefits begin accruing), this analysis used $3,321.49 per acre for emergent wetlands. Multiple regional studies provided the basis for the emergent wetland services values. A single economic study (Francis, 2012) performed in Corpus Christi Bay provided the value for seagrass bed ($1,265.75) used in this analysis. The net ecosystem benefits equal the difference between the with-project preserved marshes and the sum of the without project eroding marsh area and newly created submersed habitat. (Table 4.3.2).

Roadway Protection Benefit

Over the 20-year project life, erosion without the project would expose 1,994 ft of the roadway east of the parking lot. The cost of constructing a revetment to protect the roadway is based on the approximate per foot total construction cost ($674.24) of the revetment around the point and the breakwater constructed for the Indian Point Project. We assumed that such a revetment would be built at one time and assumed the construction would occur in in 2021, the year in which the ongoing erosion would have eliminated the shoreline and associated uplands that the project breakwater protects. No attempt was made to estimate an annual cost over the 20-yr period of evaluation. Based on the above-mentioned exposed roadway length and unit construction cost, the revetment has a total estimated construction cost of $1,344,435 (2015 price level). Adjusting this value for inflation through 2021 ($1,515,502) and then converting to a present worth equivalent amount, the revetment required in the without-project case would cost $1,257,444 (discounted present worth, beginning of 2015).

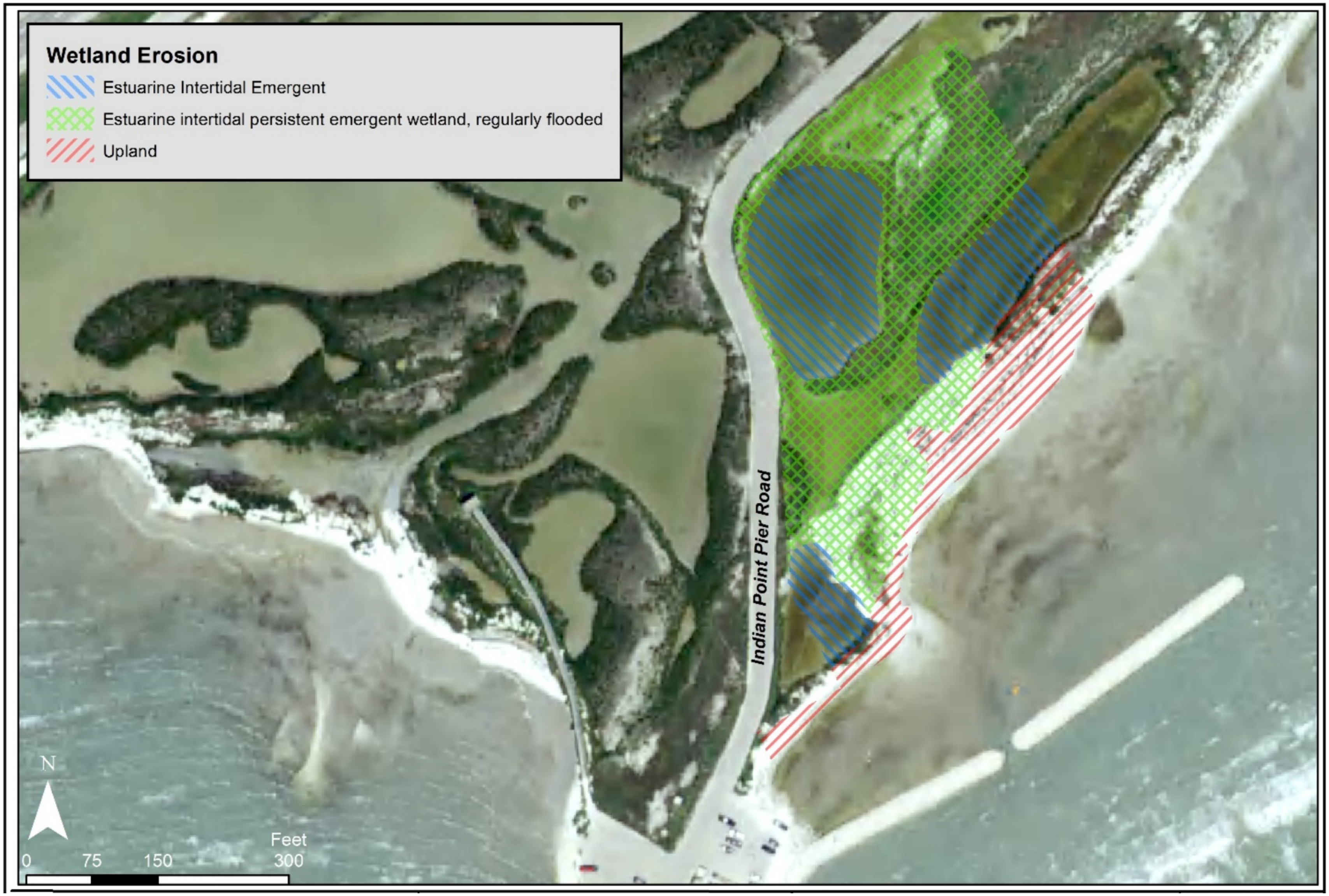

Figure 4.3.4 Upland and Wetland Area of Without Project Impact

Table 4.3.2 Indian Point Revetment Ecosystem Services Benefits

Year	Emergent Wetland With Project acres	Emergent Wetland Without Project acres	Submersed Habitat Gained Without Project acres	Annual Value With Project Wetlands (2015 $)	Annual Value Without Project Wetlands (2015 $)	Annual Value Without Project Submersed Habitat Gained (2015 $)	Net Project Habitat Services Value (2015 $)	Inflation-Adjusted Value ($)	2015 Discounted Present Worth[1] ($)	2015 Discounted Cumulative Value of Wetlands Preserved ($)
2015	4.04	4.04	0.05	$13,202	$13,202	$59	-$59	-$59	-$59	-$59
2016	4.04	4.03	0.14	$13,202	$13,176	$178	-$152	-$156	-$148	-$208
2017	4.04	3.82	0.52	$13,202	$12,473	$659	$69	$71	$65	-$142
2018	4.04	3.71	0.70	$13,202	$12,130	$885	$187	$191	$171	$29
2019	4.04	3.61	0.88	$13,202	$11,787	$1,111	$304	$310	$270	$299
2020	4.04	3.53	1.03	$13,202	$11,529	$1,308	$366	$374	$315	$613
2021	4.04	3.26	1.47	$13,202	$10,643	$1,862	$697	$712	$582	$1,195
2022	4.04	2.74	2.00	$13,202	$8,960	$2,525	$1,716	$1,754	$1,389	$2,584
2023	4.04	2.62	2.12	$13,202	$8,555	$2,682	$1,965	$2,008	$1,541	$4,126
2024	4.04	1.75	2.99	$13,202	$5,725	$3,778	$3,698	$3,780	$2,813	$6,938
2025	4.04	1.65	3.09	$13,202	$5,379	$3,912	$3,911	$3,997	$2,883	$9,821
2026	4.04	1.57	3.17	$13,202	$5,137	$4,006	$4,059	$4,148	$2,901	$12,722
2027	4.04	1.52	3.22	$13,202	$4,954	$4,077	$4,171	$4,263	$2,889	$15,611
2028	4.04	1.14	3.60	$13,202	$3,732	$4,550	$4,920	$5,028	$3,304	$18,915
2029	4.04	1.06	3.68	$13,202	$3,451	$4,659	$5,092	$5,204	$3,315	$22,229
2030	4.04	0.96	3.78	$13,202	$3,127	$4,785	$5,290	$5,407	$3,338	$25,567
2031	4.04	0.87	3.87	$13,202	$2,836	$4,897	$5,468	$5,589	$3,345	$28,912
2032	4.04	0.79	3.94	$13,202	$2,591	$4,992	$5,618	$5,742	$3,331	$32,243
2033	4.04	0.75	3.99	$13,202	$2,444	$5,049	$5,709	$5,834	$3,281	$35,525
2034	4.04	0.70	4.19	$13,202	$2,287	$5,302	$5,612	$5,736	$3,127	$38,651

[1] Emergent Wetland value = $3,267.81 per acre (2015 prices); Submersed Habitat value = $1265.75 per acre (2015 prices)

[2] Present worth in 2015 dollars applying a mid-year discount factor [(1/1.0316)n+0.5, where n = ((year - 2015) + 0.5)] to the inflation-adjusted value

Benefit Cost Summary

Summing the above estimates for erosion reduction and preserved ecosystem services benefits yielded a total project benefit of $1,296,095. Dividing the total benefits by the Texas project cost results in a B/C ratio of 1.4 (Table 4.3.3).

Table 4.3.3 Benefit-Cost Summary for Indian Point Project

Benefits and Costs	**Discounted Present Worth (beginning of 2015)**	**Discounted Present Worth (beginning of 2016)**
Erosion Reduction Benefit	$1,257,444	$1,297,179
Ecosystem Services Benefit	$38,651	$39,872
Total Benefits	$1,296,095	$1,337,052
Total Costs	$899,001	$927,409
B/C Ratio	**1.4**	**1.4**

4.4 Cameron County — #1576 Arturo Galvan Coastal Park Living Shoreline Restoration

Project Description and Background Information

CEPRA Project #1576 lies along the western shoreline of Laguna Madre, Texas, near the Queen Isabella Causeway in Port Isabel (Figure 4.4.1). The purpose of the project was to restore a 2,000-ft long living shoreline at the Arturo Galvan Park. The pre-existing condition included concrete rubble riprap in a wide band along the shoreline (Figure 4.4.2). The project removed the existing riprap, graded the bank to achieve elevations conducive to natural recruitment of salt marsh plants (Figure 4.4.3), and constructed a breakwater at the approximate location of the pre-construction waterward edge of riprap. About 3,000 cy of material were removed during grading, and about 2,800 cy of stone were placed over a 0.805-acre area (1,950 ft x 18 ft maximum width) for breakwater construction. The remaining area (0.695 acres) landward of the breakwater was replanted with *Spartina alterniflora* (smooth cordgrass), a common and widespread estuarine wetland species.

Project construction occurred throughout 2015, with *Spartina alterniflora* planting performed on August 13, 2015. A post-planting survival survey in late 2015 identified less than 50% plant survival; thus, a subsequent planting effort in early 2016 was required to satisfy contract specifications (minimum 75% survival). The planting contactor noted the following in its plant survival report (Belaire Environmental, Inc. 2015): “seasonal high tides had inundated the entire shoreline, planting area, and breakwater and had begun to erode erosion control blanket on the shoreline, up to approximately +2.5 ft NAVD88”. Figure 4.4.4 captures the eroded shoreline conditions in December 2015, and the eroded conditions remained evident during an October 2016 site visit (Figure 4.4.5)

Project Funding and Costs

Project funding originated from the National Oceanographic and Atmospheric Administration (NOAA) and CEPRA, as listed in Table 4.4.1. All project costs totaled $787,515 according to the expenditure summary provided by GLO. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas’ share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the NOAA costs is $21,972. The resulting cost to Texas for Project #1576 amounts to $589,772; this includes the QPP ($100,000) and CEPRA ($467,800) cost shares and the 10%

state share of federal costs ($21,972). Since construction began in early 2015, this analysis assumes all costs represent a present worth equivalent value as of beginning of 2015. Converting to a present worth equivalent value, beginning of 2016 (i.e., for a direct comparison with the benefit estimates) using a 3.16% discount rate, the total cost incurred by Texas becomes $608,409 (i.e., 1.0316 x $589,772).

Table 4.4.1 Funding and Costs for Arturo Galvan Coastal Park Living Shoreline Restoration

Funding Source		**Amount[1] ($)**
Federal	NOAA Award No. NA12NOS4190164 (28% of total Cost Share) *(Texas portion)*	$219,715 *($21,972)*
State/Local	QPP (City of Port Isabel) (Cash, 13% of Total Project Cost Share)	$100,000
	CEPRA (59% of total cost share)	$467,800
Total Project Costs ***(Texas total)***		$787,515 *($589,772)*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2015

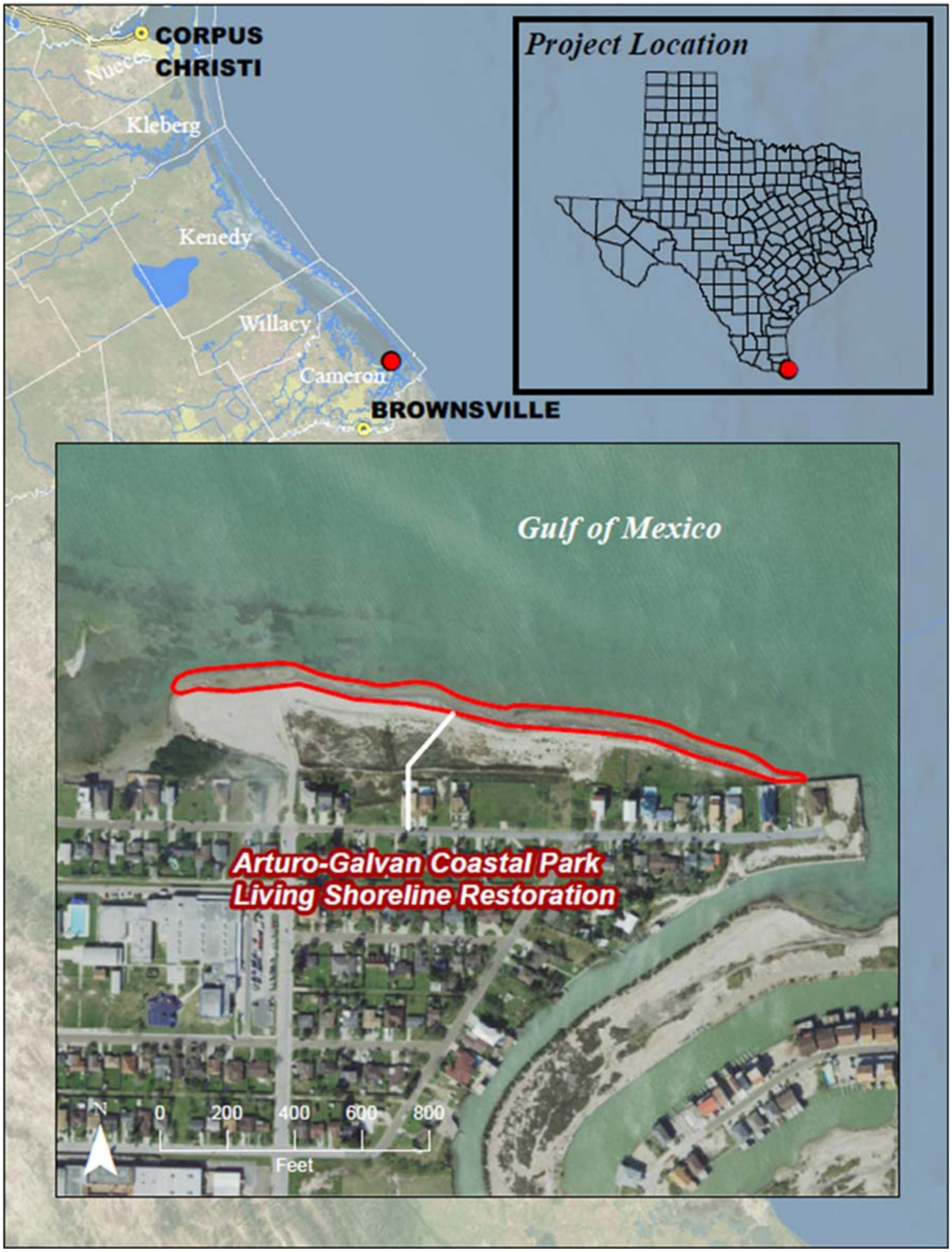

Figure 4.4.1 Location of Arturo Galvan Coastal Park Living Shoreline Restoration, Port Isabel, Texas

Figure 4.4.2 Pre-Project Shoreline of Arturo Galvan Coastal Park, Port Isabel, Texas. From HDR (2011)

Figure 4.4.3 CEPRA Project #1576 during Construction (provided by GLO)

Figure 4.4.4 Post-construction Shoreline Erosion observed as observed in December 2015 (Belaire Environmental 2015)

Figure 4.4.5 October 2016 Site Conditions

Analysis

Ecosystem Services Benefits

The living shoreline project was nominally complete in late 2015. However, available data indicate only partial ecosystem services were being provided during 2016. Ecosystem services might be expected to develop more slowly than initially expected due to slow wetland development on the site through 2016. We have assumed that a fully functional marsh will develop by project year 6 (Table 4.4.2) and continue to function fully for five years. However, further continued erosion of adjacent uplands appears likely. This erosion would slowly damage and ultimately would bury the marsh, reducing and finally eliminating ecosystem services. Therefore, the levels of service provided by the project were projected to initially develop over a 5-year period, sustain service for about 5 years, and then decline over the remaining 5 years of the projected 15-year project life. This analysis applied the ecosystem service values presented in Section 2.3. Because of the ongoing erosion of the bank that has occurring following construction, the benefits analysis excluded values for Disturbance Regulation. The resulting ecosystem services value used in this analysis equals $2,856.72 per acre. The annual value of the ecosystem services (Table 4.4.3) varies with the development of the marsh, maximum marsh services period, and declining marsh period.

Table 4.4.2 Estimated Project Life Ecosystem Services Levels, CEPRA Project #1576

Year	Project Year	Service Level (%)	Service Area (acres)
2016	1	10%	0.07
2017	2	20%	0.14
2018	3	40%	0.28
2019	4	60%	0.42
2020	5	80%	0.56
2021	6	100%	0.70
2022	7	100%	0.70
2023	8	100%	0.70
2024	9	100%	0.70
2025	10	100%	0.70
2026	11	80%	0.56
2027	12	60%	0.42
2028	13	40%	0.28
2029	14	20%	0.14
2030	15	10%	0.07

Table 4.4.3 Ecosystem Services Benefit Summary, CEPRA Project #1576

Year	With Project Created Wetland Acres	Annual Value of Wetlands Created			Discounted Cumulative Value of Wetland Created ($)
	Annual (acres)	2016 Price Levels ($)	Inflation-Adjusted Value ($)	Discounted Present Worth[1] ($)	
2016	0.07	199	199	195	195
2017	0.14	397	405	387	582
2018	0.28	794	828	766	1,348
2019	0.42	1,191	1,268	1,137	2,485
2020	0.56	1,588	1,728	1,502	3,987
2021	0.70	1,985	2,207	1,860	5,847
2022	0.70	1,985	2,256	1,843	7,690
2023	0.70	1,985	2,305	1,826	9,516
2024	0.70	1,985	2,356	1,809	11,324
2025	0.70	1,985	2,408	1,792	13,116
2026	0.56	1,588	1,969	1,420	14,536
2027	0.42	1,191	1,509	1,055	15,591
2028	0.28	794	1,028	697	16,288
2029	0.14	397	525	345	16,633
2030	0.07	199	268	171	16,804

Federal Spending Benefit

Federal funding is considered an economic benefit because money flows into the Texas economy. A multiplier of 1.26 applied to the federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy (see Section 2.1). As mentioned above, NOAA, a federal agency, contributed $219,715 to the project. Thus, the federal spending benefit equals $276,841 (present worth, beginning of 2015). Converting to a present worth equivalent value, beginning of 2016 using a 3.16% discount rate, the federal spending benefit becomes $285,589 (i.e., 1.0316 x $276,841).

Benefit-Cost Summary

The benefit cost ratio for the project (Table 4.4.4) is less than one because the constructed wetland is impacted by the erosion of the shoreline, which is predicted to shorten the project services life and to make the marsh less than fully functional for most of the project period. All amounts in Table 4.4.4 are adjusted to 2016 dollars to reflect the starting date for benefits of the completed project.

Table 4.4.4 Arturo Galvan Coastal Park Living Shoreline Restoration Benefit Cost Summary

Benefits and Costs	**Discounted Present Worth (Beginning of 2016)**
Ecosystem Services Benefits	$16,804
Federal Spending Benefit	$285,589
Total Benefits	$302,393
Total Texas Costs	$608,409
B/C Ratio	**0.50**

4.5 Jefferson County — #1577 Keith Lake Fish Pass Baffle Shoreline Protection & Marsh Restoration

Project Description and Background Information

The Salt Bayou ecosystem complex occupies about 139,000 acres west of Sabine Pass and Sabine Lake (Figure 4.5.1). Historically a predominately freshwater or brackish wetland system, human activities beginning in the 1860s have substantially altered the system, resulting in increased salinities and transition of much of the system to an estuarine condition. Increased salinities have caused changes in marsh vegetation and conversion of marsh to open water as organic soils degenerate on exposure to increasingly saline conditions. The Keith Lake Fish Pass, constructed in 1977 to allow water from the Sabine River to enter Keith Lake, has substantially contributed to the increased salinity in the Salt Bayou system, increasing salinity in marshes near Keith Lake as well as Fence Lake, Johnson Lake, Knight Lake, Salt Bayou, Salt Lake, Shell Lake and areas to the west (Salt Bayou Marsh Workgroup, 2013; TWBD, 2009). The objective of the Keith Pass Fish Baffle project is to reduce the volume of salt water entering Keith Lake and the upstream lakes and marshes, thereby minimizing and avoiding loss of soil and emergent wetland communities.

Jefferson County completed construction of the Keith Lake Fish Pass Baffle in March 2015. The stone structure (Figures 4.5.2 and 4.5.3) reduces the cross section of the fish pass and restricts the flow of salt water into Keith Lake. The reduced saltwater inflow will allow freshwater to displace saltwater in the Salt Bayou system and stop further marsh deterioration.

Figure 4.5.1 Keith Lake Fish Pass Baffle Location

Figure 4.5.2 Keith Lake Fish Pass Baffle Under Construction (Photo provide by GLO)

Figure 4.5.3 Completed Keith Lake Fish Pass Baffle (Photo provided by GLO)

Project Funding

Funding for the Keith Pass Fish Pass Baffle originated entirely from Texas sources. GLO and Jefferson County provided funding as listed in Table 4.5.1. GLO project payments to Jefferson County occurred from February through May 2015. This analysis assumes all costs reflect a present worth equivalent as of the beginning of 2015.

Table 4.5.1 Funding for the Keith Lake Fish Pass Baffle

Funding Source		Amount
State/Local	CEPRA (Texas GLO; 37% of project construction cost)	*$1,041,226*
	Jefferson County (63% of project construction cost)	*$2,814,124*
	Jefferson County - paid to USACE for project design	*$254,000*
Total Project Cost		*$4,109,350*
Texas Total		*$4,109,350*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, beginning of 2015

Analysis

Taylor Engineering estimated Keith Lake Fish Pass Baffle benefit as the value of emergent wetland acreage protected from conversion to open water due to the reduction in system salinity effected by the baffle. The benefit estimate required determination of the amount of wetland that would be lost with and without the fish pass baffle. To estimate wetland loss, we delineated the wetland area likely influenced by fish pass-related salinity increases, determined the amount of emergent wetland converted to open water during the fish pass project life, and estimated the economic value of wetlands based on per acre ecosystem services values. As typical for analyses of other similar projects, we assumed a 20-yr project lifetime for this analysis.

Taylor Engineering applied a geographic information system (GIS) analysis of National Wetlands Inventory (NWI) data to delineate and quantify the area of emergent wetland vegetation likely influenced by saline water entering the system from the fish pass. We obtained NWI Texas wetlands data as shapefiles from the Texas Natural Resources Information System[2]. The Natural Resources Conservation Service's

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[2] Accessed January 1, 2017 at: https://tnris.org/data-catalog/entry/national-wetlands-inventory-vector/

Watershed Boundary Dataset provided a Salt Bayou basin boundary shapefile[3]. From these shapefiles, we extracted wetlands distribution and classifications within the Salt Bayou basin. No single NWI analysis was available, so NWI data from 1993 (covering about 25% of the study area) and 2010 (covering about 75% of the area) were composited to provide a single layer for assessment purposes. We did not attempt to account for wetland loss between those dates and the 2015 project start date. An informal analysis concluded that doing so would have only a minor effect on the B/C ratio, and the final calculations would not have been significantly changed by estimates of the difference between 1993 and 2010 conditions.

We further refined the resulting Salt Bayou system shapefile by removing wetlands not likely affected by salinity from the fish pass. These wetlands occurred in areas:

- north of the GIWW
- along the Sabine Pass shoreline
- west of a ditch running from about west end of Salt Lake NW to GIWW
- west of a ditch running from about west end of Fence Lake south to boat ramp
- along gulf shoreline (these wetlands are more likely influenced by washovers from Gulf than from water originating in Keith Lake)
- southeast of the "ridges" southeast of Keith Lake
- any other areas outside of the Salt Bayou study area boundary shown in the Salt Bayou management plan

We also removed NWI-classified freshwater wetlands (i.e., wetlands characterized by salinity < 0.5 ppt), reasoning that these wetlands remain fresh nearly 40 years after the fish pass was opened and therefore are not likely affected by saline water from the pass. The final shapefile for the Keith Lake Fish Pass Baffle project analysis contained 15,750 acres of emergent vegetation wetlands, distributed as shown in Figure 4.5.4.

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[3] Accessed January 1, 2017 at: https://datagateway.nrcs.usda.gov/

Figure 4.5.4 Brackish, Emergent Vegetation Wetlands Likely Influenced by Saline Water from the Keith Lake Fish Pass

Citing 2002 Texas Parks and Wildlife Department information, the Salt Bayou Watershed Restoration Plan (2013) reports an emergent vegetation to open water conversion rate of up to 0.69% per year due to salinity stress in the Salt Bayou marsh system. Updated information about marsh loss rates from 2001 – 2012 (M. Rezsutek, Texas Parks and Wildlife Department, personal communication, January 11, 2017) indicated an annual marsh to open water conversion rate of 0.5% per year in the east part of the Salt Bayou system. Taylor Engineering assumed a 0.5% marsh to open water conversion rate for this evaluation.

Comparison of with and without-project conditions determined wetland preservation benefits. For the without project condition, we assumed that the annual wetland loss rate estimated above remained unchanged for the analysis period. The with-project condition assumed that wetland loss would continue during the project construction year. After the construction year (year 1) the reduced volume of salt water entering the system and displacement of salt water with fresh water during the wet season would eliminate emergent vegetation loss due to salinity effects.

We estimated the economic services value of the emergent vegetation marsh (expressed as dollars/acre) as the sum of habitat, recreation, disturbance regulation, gas regulation, and waste regulation values described in Section 2.3. We did not include the aesthetics value, because most of the area benefitting from the fish pass baffle project is remote and offers only limited human aesthetic experience. Marsh ecosystem services values, at 2015 prices, totaled $3,321 per acre.

Based on the above assumptions and estimated annual economic service values, we calculated the amounts of emergent wetlands that would exist for with- and without-project conditions. Subtracting these values provided the project benefit in terms of emergent wetland vegetation acreage protected by the project. We then calculated the total annual benefits value, in terms of 2015 dollars, by multiplying the acres protected by the project by the wetland ecosystem services per acre value. Table 4.5.2 summarizes the benefits estimate.

Table 4.5.2 Keith Lake Fish Pass Baffle Economic Benefits

Year	Emergent Wetland Existing (acres)		Emergent Wetland Preserved with Project (acres)	Annual Value of Wetlands Preserved			Beginning of 2015 Cumulative Discounted Present Worth ($)
	With Project	Without Project		2015 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2015 Discounted Present Worth[1] ($)	
2015	15671.3	15671.3	0.0	0	0	0	0
2016	15671.3	15592.9	78.4	260,260	263,903	251,871	251,871
2017	15671.3	15514.9	156.3	519,218	537,544	497,319	749,190
2018	15671.3	15437.4	233.9	776,882	821,191	736,469	1,485,660
2019	15671.3	15360.2	311.1	1,033,257	1,115,125	969,444	2,455,103
2020	15671.3	15283.4	387.9	1,288,351	1,421,020	1,197,534	3,652,637
2021	15671.3	15207.0	464.3	1,542,169	1,738,397	1,420,120	5,072,758
2022	15671.3	15130.9	540.3	1,794,718	2,067,588	1,637,303	6,710,061
2023	15671.3	15055.3	616.0	2,046,004	2,408,936	1,849,179	8,559,239
2024	15671.3	14980.0	691.3	2,296,034	2,762,790	2,055,844	10,615,084
2025	15671.3	14905.1	766.2	2,544,813	3,129,511	2,257,394	12,872,478
2026	15671.3	14830.6	840.7	2,792,349	3,509,467	2,453,922	15,326,400
2027	15671.3	14756.4	914.8	3,038,647	3,903,036	2,645,519	17,971,919
2028	15671.3	14682.6	988.6	3,283,713	4,310,608	2,832,275	20,804,195
2029	15671.3	14609.2	1062.0	3,527,555	4,732,579	3,014,280	23,818,474
2030	15671.3	14536.2	1135.1	3,770,177	5,169,359	3,191,619	27,010,093
2031	15671.3	14463.5	1207.8	4,011,585	5,621,367	3,364,379	30,374,473
2032	15671.3	14391.2	1280.1	4,251,787	6,089,033	3,532,645	33,907,118
2033	15671.3	14319.2	1352.0	4,490,788	6,572,798	3,696,499	37,603,617
2034	15671.3	14247.6	1423.6	4,728,594	7,073,114	3,856,023	41,459,640

Benefit-Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a B/C ratio of 10.1 (Table 4.5.3).

Table 4.5.3 Benefit-Cost Summary for Keith Lake Fish Pass Baffle

Benefits and Costs	Discounted Present Worth (beginning of 2015)	Discounted Present Worth (beginning of 2016)
Total Benefits (Ecosystem Services)	$41,459,640	$42,769,765
Total Costs	$ 4,109,350	$4,239,205
B/C Ratio	**10.1**	**10.1**

4.6 Brazoria County — #1588 Oyster Lake Habitat Restoration

Project Description and Background Information

Oyster Lake is an estuarine tidal lake situated on the northwest side of West Galveston Bay in Brazoria County. Situated between the bay and the Gulf Intracoastal Waterway, Oyster Lake is separated from the bay by tidal wetlands. Since the 1940's, the bay shoreline has eroded nearly 1,000 ft towards the lake, and continued erosion would breach the remaining tidal wetlands, resulting in loss of wetlands and allowing erosion of the interior shoreline of Oyster Lake.

Phase I of the Oyster Lake habitat restoration placed reef-ball breakwaters along a 450-ft length of shoreline on both the lake and bay sides of the most critically eroded bay shoreline. The breakwaters appear effective in allowing sediment accumulation along the shoreline and development of a marsh community. CEPRA project #1588 implemented Phase II of the Oyster Lake habitat restoration, placing 2,500-ft long rock breakwaters along the Galveston Bay shoreline north and south of the Phase I breakwater (Figures 4.6.1 and 4.6.2). The breakwaters are designed to prevent further erosion of the shoreline and provide an area between the breakwater and shoreline in which sediment deposition and marsh development will occur.

Project Funding

The QPP, Galveston Bay Foundation, received project funding from NOAA and the Coastal Conservation Association in the amounts listed in Table 4.6.1. CEPRA funding comprised the remainder of the project funding. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $30,000 NOAA cost is $3,000. The resulting cost to Texas for Project #1588 amounts to $473,000; this value equals the sum of the CEPRA funding ($270,000), Coastal Conservation Association funding ($200,000), and 10% state share of federal costs ($3,000). This analysis assumes all costs were incurred near the middle of the construction period (beginning of 2015); thus, the costs reflect a present worth at the beginning of 2015. Converting to 2016 price levels (i.e., for a direct comparison with the benefit estimates) using a 3.16% discount rate, the total cost incurred by Texas becomes $487,947, present worth as of beginning of 2016.

Table 4.6.1 Funding for Oyster Lake Habitat Restoration

Funding Source		**Amount[1] ($)**
Federal	NOAA	30,000
	(Texas Portion)	*3,000*
State/Private	Texas GLO, CEPRA	270,000
	Coastal Conservation Association	200,000
Total Project Cost		500,000
Texas Total		*473,000*

Note: Values in italics are estimated costs to the State of Texas, and took place over a two-year period, 2014 - 2015.
Values represent present worth, beginning of 2015

Analysis

Ecosystem Services Benefits

The ecosystem services benefits analysis for the Oyster Lake habitat restoration rest on several assumptions:

- The breakwater will prevent further erosion of the West Galveston Bay shoreline behind the breakwater;
- Marsh will develop between the breakwaters and the shoreline;
- Ecosystem services benefits will accrue from 1) the breakwater's prevention of marsh erosion and 2) development of new marsh;
- Full ecosystem value benefits for new marsh occur when the marsh has developed a vegetation community as well as a full benthic community and marsh soil column;
- While open water areas occur within the project area, the ecosystem services values for open water are much smaller than marsh values. We did not attempt to account for open water services value gained from erosion or lost by marsh creation;
- The project has a 20-year life as has been assumed for the economic evaluation of similar projects (Taylor, 2015).

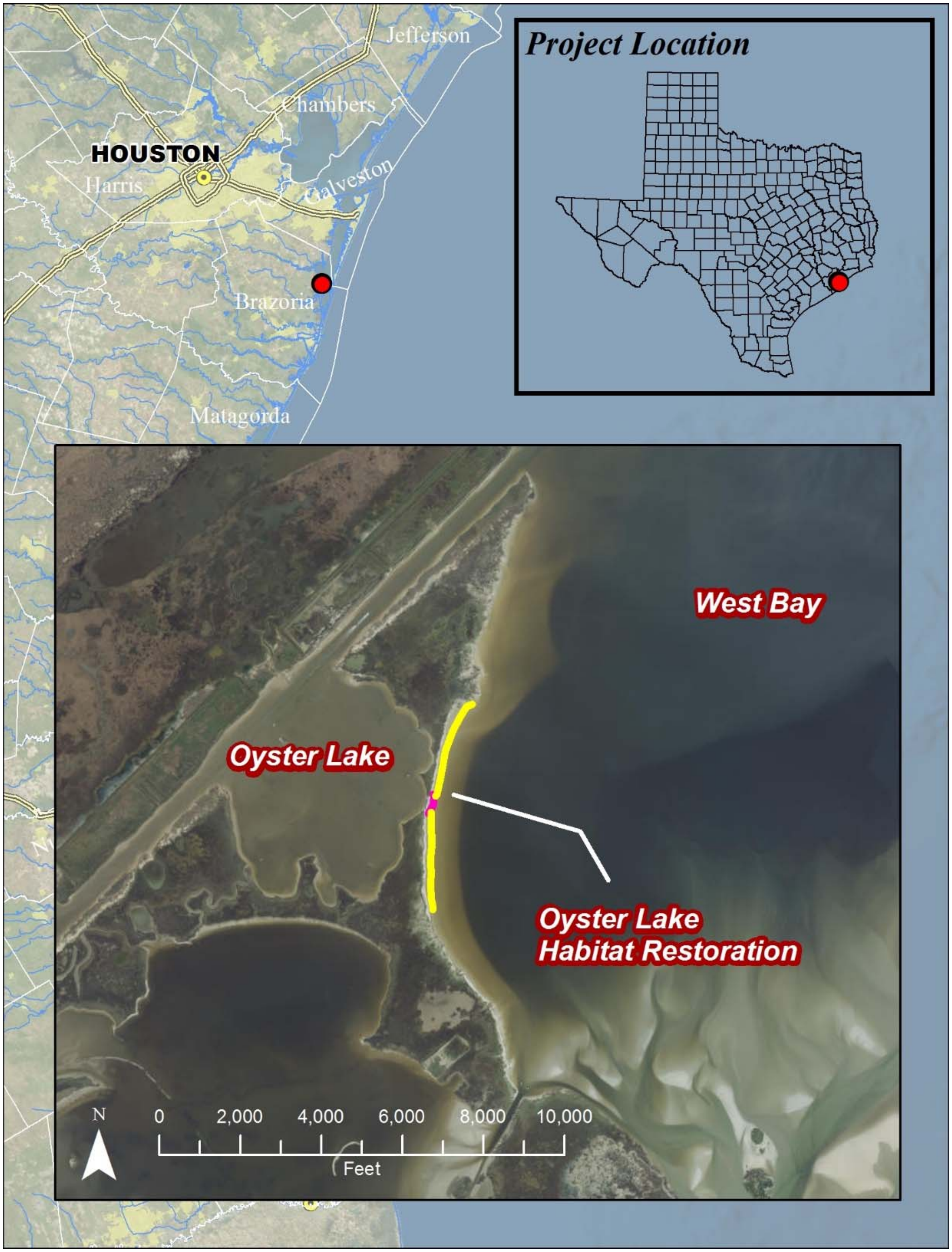

Figure 4.6.1 Oyster Lake Habitat Restoration, Brazoria County, Texas

Figure 4.6.2 Oyster Lake Habitat Restoration Rock Breakwater

We estimated the ecosystem services value of the marsh (expressed as dollars/acre) as the sum of habitat, recreation, disturbance regulation, gas regulation, and waste regulation values described in Section 2.3. We did not include the aesthetics value, because most of the area benefitting from the restoration project is remote and offers only limited human aesthetic experience. Because the breakwaters were completed in early 2016, we considered 2016 as the first year of the project life and the year in which ecosystem services benefits began to accrue. Marsh ecosystem services values, at 2016 prices, totaled $3,368 per acre.

The ecosystem services value for prevention of marsh loss from erosion requires calculation of a project area specific erosion rate and determination of the number of acres of marsh that would be lost without the breakwater over the project lifetime. Our examination of aerial imagery[4] from 12/31/1943 and 3/27/2015 showed shoreline erosion at an annual erosion rate of about 9.6 ft/yr. Applying that erosion rate to the shoreline visible in a 11/21/2015 (shortly before completion of the breakwaters) aerial image, and bounded by roughly shore-perpendicular lines drawn from each end of the revetment, indicated the area that would be lost to erosion over the project life. National Wetland Inventory data[5] showed 25.9 acres of marsh in the area lost to erosion. Applying a uniform amount of wetland loss over the 20-year project life gave 1.30 acres of wetland loss per year. With the breakwaters in place, we assumed zero wetland loss. Multiplying the annual ecosystem services value (adjusted for inflation) by the cumulative acreage lost

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[4] Images available in Google Earth

[5] Accessed January 1, 2017 at: https://tnris.org/data-catalog/entry/national-wetlands-inventory-vector/

gives the annual ecosystem services benefit for wetland loss prevention. Finally, we converted the annual benefit to an equivalent present value amount, beginning of 2016. Table 4.6.2 lists the results of these calculations. The wetland loss prevention benefits amount to $799,584 (discounted present worth, beginning of 2016).

The ecosystem services value for marsh development behind the breakwater requires calculation of the wetland acreage between the breakwaters and the shoreline, estimation of the length of time necessary for marsh to develop in that area, and determination of annual economic value based on marsh acreage and state of development. Calculating the area between the breakwaters and the shoreline visible in the 11/21/2015 aerial image, we determined that 22.7 acres of wetland are available for marsh development. The marsh ecosystem requires time to develop its full ecosystem services value. We assumed that ecosystem services value would develop over a 15-year period, achieving 10% of its full value during the first year and increasing by 6.4% of the remaining 90% service value for each of the next 14 years (i.e., (90/14)/100 = 6.4%) (Taylor, 2013). Ecosystem services value remained at 100% thereafter. Multiplying the total marsh acreage by the percentage of services value for each year provided the annual net marsh service benefit in acres. We then obtained the annual economic value by multiplying the net services acres by the annual, inflation-adjusted ecosystem services value. Finally, we converted the annual benefit to an equivalent present value amount, beginning of 2016. Table 4.6.3 lists the results of these calculations. The marsh development benefits amount to $818,244 (discounted present worth, beginning of 2016).

Table 4.6.2 Oyster Lake Economic Benefits – Wetland Loss Prevention

Year	Marsh Lost (acres)				Marsh Preserved with Project (acres)	Annual Value of Marsh Preserved			Beginning of 2016 Cumulative Discounted Present Worth ($)
	With Project		Without Project						
	Annual	Cumulative	Annual	Cumulative		2016 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	0.00	0.00	1.295	1.30	1.30	4,362	4,362	4,294	4,294
2017	0.00	0.00	1.295	2.59	2.59	8,723	8,906	8,500	12,794
2018	0.00	0.00	1.295	3.89	3.89	13,085	13,640	12,619	25,414
2019	0.00	0.00	1.295	5.18	5.18	17,446	18,569	16,653	42,067
2020	0.00	0.00	1.295	6.48	6.48	21,808	23,721	20,622	62,689
2021	0.00	0.00	1.295	7.77	7.77	26,169	29,092	24,517	87,205
2022	0.00	0.00	1.295	9.07	9.07	30,531	34,687	28,336	115,542
2023	0.00	0.00	1.295	10.36	10.36	34,892	40,515	32,083	147,625
2024	0.00	0.00	1.295	11.66	11.66	39,254	46,582	35,758	183,383
2025	0.00	0.00	1.295	12.95	12.95	43,616	52,896	39,361	222,744
2026	0.00	0.00	1.295	14.25	14.25	47,977	59,466	42,894	265,638
2027	0.00	0.00	1.295	15.54	15.54	52,339	66,299	46,358	311,996
2028	0.00	0.00	1.295	16.84	16.84	56,700	73,404	49,754	361,750
2029	0.00	0.00	1.295	18.13	18.13	61,062	80,790	53,083	414,833
2030	0.00	0.00	1.295	19.43	19.43	65,423	88,465	56,345	471,178
2031	0.00	0.00	1.295	20.72	20.72	69,785	96,438	59,542	530,720
2032	0.00	0.00	1.295	22.02	22.02	74,146	104,720	62,675	593,394
2033	0.00	0.00	1.295	23.31	23.31	78,508	113,319	65,744	659,138
2034	0.00	0.00	1.295	24.61	24.61	82,869	122,246	68,750	727,889
2035	0.00	0.00	1.295	25.90	25.90	87,231	131,511	71,695	799,584

[1] Present worth beginning of 2016, using a mid-year discount factor [$(1/1.0316)^{n+0.5}$, where n = (year - 2016)] to the inflation-adjusted value

Table 4.6.3 Oyster Lake Economic Benefits – Marsh Development

Year	Marsh Area Created		Annual Value of Created Marsh			Beginning of 2016 Cumulative Discounted Present Worth ($)
	Total (acres)	Net Marsh Service (acres)	2016 Prices ($)	Inflation-Adjusted Value ($)	Beginning of 2016 Discounted Present Worth[1] ($)	
2016	22.70	0.00	0	0	0	0
2017	22.70	2.27	7,645	7,806	7,450	7,450
2018	22.70	3.73	12,560	13,093	12,114	19,564
2019	22.70	5.19	17,475	18,599	16,680	36,244
2020	22.70	6.65	22,390	24,355	21,173	57,417
2021	22.70	8.11	27,305	30,354	25,580	82,997
2022	22.70	9.57	32,220	36,606	29,904	112,901
2023	22.70	11.03	37,135	43,118	34,145	147,046
2024	22.70	12.49	42,049	49,899	38,304	185,350
2025	22.70	13.94	46,964	56,957	42,383	227,733
2026	22.70	15.40	51,879	64,302	46,383	274,116
2027	22.70	16.86	56,794	71,943	50,304	324,420
2028	22.70	18.32	61,709	79,888	54,149	378,569
2029	22.70	19.78	66,624	88,149	57,918	436,487
2030	22.70	21.24	71,539	96,734	61,612	498,099
2031	22.70	22.70	76,453	105,654	65,232	563,331
2032	22.70	22.70	76,453	107,978	64,625	627,955
2033	22.70	22.70	76,453	110,354	64,023	691,979
2034	22.70	22.70	76,453	112,781	63,428	755,406
2035	22.70	22.70	76,453	115,263	62,837	818,244

[1] Present worth at beginning of 2016, using a mid-year discount factor $[(1/1.0316)^{n+0.5}$, where n = (year - 2016)] to the inflation-adjusted value

Federal Spending Benefit

This study considers costs funded by non-Texas dollars as financial benefit because money flows into the Texas economy (Section 2.1). A multiplier of 1.26 applied to the federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy. Accordingly, the $30,000 NOAA cost share (assumed present worth, beginning of 2015) represents a project benefit. Applying the 1.26 multiplier and converting to a 2016 present worth value using a 3.16% discount rate, the estimated federal spending benefit for this project is $38,994 (i.e., $30,000*1.0316* 1.26).

Benefit-Cost Summary

Dividing the total project benefits value by the total Texas project cost results in a B/C ratio of 3.40 (Table 4.6.4).

Table 4.6.4 Benefit-Cost Summary for Oyster Lake Habitat Restoration

Benefits and Costs	**Beginning of 2016 Discounted Present Worth**
Wetland Loss Prevention Benefit	$799,584
Marsh Development Benefit	$818,244
Federal Spending Benefit	$38,994
Total Benefits	$1,656,822
Total Texas Costs	$487,947
B/C Ratio	**3.40**

Note: Present worth conversion assumes costs were incurred middle of 2-yr construction period (2014 – 2015), or beginning of 2015 (i.e., cost x 1.0316 = present worth, beginning of 2016

4.7 Calhoun County — #1591 Magnolia Inlet Shoreline Protection & Marsh Restoration

Project Description and Background Information

CEPRA Project #1591 lies within the inlet of Old Town Lake at Magnolia Beach (Figure 4.7.1). The objective of this project was to restore tidal conveyance within Old Town Lake by removing accumulated sediments and shell from the inlet. Prior to the project, hypersalinity and fish kills occurred during summer and drought periods. Texas A&M University researchers have reported loss and conversion of estuarine plant communities to open water due to these conditions. Restoring tidal conveyance eliminated or minimized episodes of hypersalinity and stabilized estuarine marshes in the affected areas. Additionally, some of the accumulated sediments and shell were relocated to protect an eroding shoreline.

The existing condition of the inlet included several barriers (shoals) blocking the exchange of tidal flow to upstream marshes which adversely impacted water quality over a large area. The daily tidal range upstream of the barriers was less than one inch. Background information provided by GLO described pre-project conditions: “The resulting high salinities and low dissolved oxygen levels were lethal to fish and aquatic organisms; fish kills were routine and the local community and businesses that rely on this resource had declined for decades. Resident marsh bird species were negatively impacted, including the endangered Whooping Cranes. Birdwatchers and businesses were adversely impacted, including those frequenting and servicing the Magic Ridge Marsh Preserve, owned by the Texas Ornithological Society/Audubon Society. Public access to public lands were disrupted, preventing kayaking over the man- made barriers and disrupting travel by water to available fishing within large portions of the marsh. The tidal inlet barriers increased upstream flooding during storms and hurricanes.”

The project removed shell and mud debris from the inlet at Magnolia Beach and a four-foot high shell-hash berm (about 0.29 acres, 586 cubic yards of material) near Highway 316, restoring flow to 770 acres of marsh and salt flats from Old Town Lake down to Powderhorn Lake. The project also resulted in reconnecting over five miles of tidal channel networks to Lavaca Bay and the Gulf of Mexico ecosystems (Figure 4.7.2). Shelly components of the dredged material were used to create 0.03 acre of intertidal shell habitat on the south side of Old Town Lake over unvegetated bottom along 113 ft of shoreline. (Figure 4.7.3). Following construction, fish access in the project area has improved as has the fishing, which has induced more visitors to the local community. With the project in place, the tides are flowing appropriately (GLO, 2015).

Project Funding and Costs

Project funding was provided by NOAA and CEPRA as summarized in Table 4.7.1. Any costs that originate from national agencies or organizations are decreased by 90% (see Section 2.1) to account for the fact that some entity other than the State of Texas incurs those costs. This is based on the assumption that Texas contributes, roughly in proportion to Texas' share of the national population, about 10% of federal spending through individual and corporate taxes. Accordingly, the Texas share of the $160,746 NOAA cost is $16,075. The resulting cost to Texas for Project #1591 amounts to $115,139; this value equals the sum of the CEPRA contribution ($99,064) and the 10% state share of federal costs ($16,075). Texas incurred its share of the costs over the course of 2015; thus, this analysis assumes the costs in Table 4.7.1 reflect a present worth equivalent mid-year 2015. Converting to equivalent present worth equivalent at the beginning of 2015 (i.e., for a direct comparison with the benefit estimates), assuming mid-year discounting and the project discount rate of 3.16%, the total cost to the state of Texas equals $113,361.

Table 4.7.1 Funding Sources for CEPRA Project #1591

Funding Sources		**Amount**[1]
Federal	NOAA Restoration Center (Cash) *(Texas portion)*	$160,746 *($16,075)*
State	CEPRA	*$99,064*
Total Project Cost		$259,810
Texas Total		*$115,139*

Note: Values in italics are costs to the State of Texas.
Values represent present worth, mid-year 2015

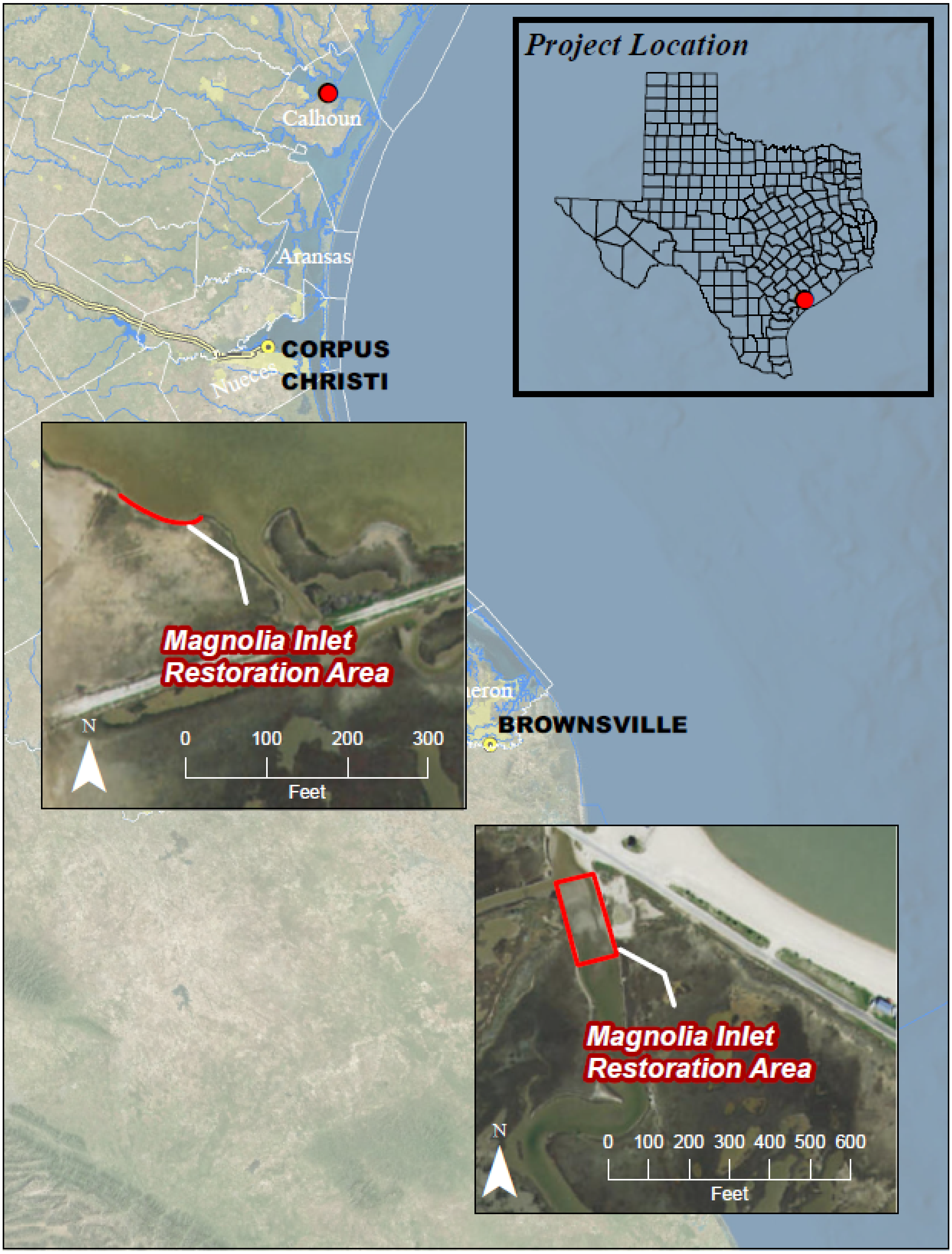

Figure 4.7.1 Location of Magnolia Inlet Restoration, Calhoun County, Texas

Figure 4.7.2 Magnolia Inlet Before and After Removal of the Shoal Blocking Tidal Exchange (Photos from Feagin (2016))

Figure 4.7.3 Shore Protection Measure on the South Side of Old Town Lake. (Photo from Feagin (2016))

Analysis

The economic benefits identified for this project include those associated with restoration of appropriate tidal exchange and stabilization of existing marsh areas. Benefits to the estuarine marshes upstream of the channel obstructions include habitat, recreation, disturbance regulation, gas regulation, and waste regulation. Marine open water benefits include habitat, recreation, and aesthetics. Aesthetics was not included in the estuarine marsh calculations because the marsh, while functioning poorly, was largely visibly intact; the channel and open water areas were blocked and non-flowing. The project visibly altered the open water areas while greatly improving the functions of both the marsh and open waters.

Project benefit acres identified by GLO formed the basis of the ecosystems services valuation. We assumed that the restoration of flows by the removal of the plugs represented a one-time, per-acre benefit applied to the estuarine marsh and the open water occurring in 2016, the year after project completion. While the project area was referred to in GLO provided documents as losing wetland area to open water, review of 25 years of aerial photography revealed no apparent (visible, large scale) changes in wetland areas or open water areas. The available documentation did not include specific information on wetland losses (i.e., conversion to open water). Therefore, we assumed the removal of the channel plugs stopped any loss that might have been occurring, stabilizing and preserving the marshes present at the time the project was completed. Because there are no available services valuation data on salt flats, we did not include these areas in the benefits analysis, presuming that they would probably remain as salt flats, a persistent aspect of many estuarine marshes.

The shoreline creation was not valued for this analysis. The creation of 0.03 acres of shoreline intertidal berm (113 ft x 10 ft wide, as described in the project Department of the Army permit issued in 2015) with shelly material removed from the channel was likely a benefit, but we were unable to confidently assign dollar benefits. The berm was not planted and no further information was available on that aspect of the project other than a photograph (Figure 4.7.3). We assumed that the small berm continued to function like the unvegetated bottom it was placed over. The short length of the berm and the available information suggested that it would have minimal shoreline protection benefit and unknown ecological benefits.

We estimated economic services value for the restored estuarine wetlands functions as the sum of habitat, recreation, disturbance regulation, gas regulation, and waste regulation values described in Section 2.3. We did not include the aesthetics value because most of the area benefitting from the project is remote and offers only limited human aesthetic experience as defined in the GecoServ database (Harte Research

Institute, 2017) used to determine the unit area valuations. Marsh values, at 2015 prices, totaled $3,321 per acre.

We used the same GecoServ database to estimate values for open water areas improved by the project, identifying benefits to habitat, recreation and aesthetics (included due to the fundamental change from still to moving water for those accessing the site). Open water values, at 2015 prices, totaled $1,817 per acre.

Because the marsh and open water were present and functioning to some (albeit greatly reduced) level prior to the project, we assumed that the pre-restoration conditions provided one-half the level of ecosystem services provided after the restoration. We therefore reduced the ecosystem services value per acre to 50% of the values determined in Section 2.3. Table 4.7.2 lists the marsh and open water benefits values for the 20-year project evaluation period.

Federal Spending Benefit

This study considers costs funded by non-Texas dollars as a financial benefit because money flows into the Texas economy (Section 2.1). A multiplier of 1.26 applied to the total federal cost accounts for the spending and re-spending multiplier, or ripple, effect of the federal contribution as the monetary inflow circulates throughout the Texas economy. NOAA contributed $160,746 (Table 4.7.1). Converting this value to equivalent present worth (beginning of 2015), assuming mid-year discounting and the project discount rate of 3.16%, NOAA's contribution equals $158,265 (i.e., $160,746/1.0316$^{0.5}$). Thus, the federal spending benefit is $199,414 (i.e., $158,365*1.26).

Benefit Cost Summary

Summing the project ecosystem services and federal spending benefits and dividing by Texas costs, expressed as beginning of 2015 values with mid-year discounting, results in a B/C ratio of 110.5 (Table 4.7.3). Table 4.7.3 provides the benefits and cost summary in terms of beginning of 2016 present worth with mid-year discounting.

Table 4.7.2 Magnolia Inlet Economic Benefits

Year	Benefit						Annual Value of Marsh and Open Water Benefits			
	Marsh		Open Water		Marsh Value (2015 $)	Open Water Value (2015 $)	Summed Values (2015 $)	Inflation-Adjusted Summed Value ($)	Beginning of 2015 Discounted Present Worth[1] ($)	Beginning of 2015 Cumulative Discounted Present Worth ($)
	Annual Gain (acres)	Cumulative Gain (acres)	Annual Gain (acres)	Cumulative Gain (acres)						
2016	185.0	185.0	429.0	429.0	307,238	389,852	697,090	706,849	674,621	674,621
2017	0.0	185.0	0.0	429.0	307,238	389,852	697,090	721,693	667,689	1,342,309
2018	0.0	185.0	0.0	429.0	307,238	389,852	697,090	736,848	660,828	2,003,137
2019	0.0	185.0	0.0	429.0	307,238	389,852	697,090	752,322	654,038	2,657,175
2020	0.0	185.0	0.0	429.0	307,238	389,852	697,090	768,873	647,951	3,305,126
2021	0.0	185.0	0.0	429.0	307,238	389,852	697,090	785,788	641,922	3,947,048
2022	0.0	185.0	0.0	429.0	307,238	389,852	697,090	803,076	635,948	4,582,995
2023	0.0	185.0	0.0	429.0	307,238	389,852	697,090	820,743	630,030	5,213,025
2024	0.0	185.0	0.0	429.0	307,238	389,852	697,090	838,800	624,167	5,837,192
2025	0.0	185.0	0.0	429.0	307,238	389,852	697,090	857,253	618,358	6,455,550
2026	0.0	185.0	0.0	429.0	307,238	389,852	697,090	876,113	612,604	7,068,154
2027	0.0	185.0	0.0	429.0	307,238	389,852	697,090	895,387	606,903	7,675,057
2028	0.0	185.0	0.0	429.0	307,238	389,852	697,090	915,086	601,255	8,276,312
2029	0.0	185.0	0.0	429.0	307,238	389,852	697,090	935,218	595,660	8,871,972
2030	0.0	185.0	0.0	429.0	307,238	389,852	697,090	955,793	590,117	9,462,089
2031	0.0	185.0	0.0	429.0	307,238	389,852	697,090	976,820	584,625	10,046,714
2032	0.0	185.0	0.0	429.0	307,238	389,852	697,090	998,310	579,185	10,625,899
2033	0.0	185.0	0.0	429.0	307,238	389,852	697,090	1,020,273	573,795	11,199,694
2034	0.0	185.0	0.0	429.0	307,238	389,852	697,090	1,042,719	568,455	11,768,149
2035	0.0	185.0	0.0	429.0	307,238	389,852	697,090	1,065,659	563,165	12,331,314

[1] Present worth, beginning of 2015, applying a mid-year discount factor [(1/1.0316)$^{n+0.5}$, where n = ((year - 2015) + 0.5)] to the inflation-adjusted value

Table 4.7.3 Benefit-Cost Summary for Magnolia Inlet

Benefits and Costs	Discounted Present Worth (beginning of 2015)	Discounted Present Worth (beginning of 2016)
Ecosystem Services Benefit	$12,331,314	$12,720,984
Federal Spending Benefit	$199,414	$205,715
Total Benefits	$12,530,728	$12,926,699
Total Texas Costs	$113,361	$116,944
B/C Ratio	**110.5**	**110.5**

5.0 CONCLUSIONS

This study finds the state of Texas receives $5.70 in economic and financial benefits for every Texas dollar invested in these projects. Table 5.1 presents a summary of the assessed CEPRA Cycles 7 – 8 projects, which is a representative sampling of the CEPRA program.

The leveraging of federal participation plays a substantial role for several projects. For example, the low Texas cost of the overwash protection berm at the McFaddin National Wildlife Refuge (NWR) reflects contributions from the U.S. Fish and Wildlife Service (USFWS) and Coastal Impact Assistance Program (CIAP), which covered 98.4% of the total project costs. As another example, the low Texas cost of the beach nourishment near Rollover Pass reflects the substantial cost savings from partnership with the U.S. Army Corps of Engineers (USACE) for the beneficial use of dredged material. This project placed beach fill at an effective unit cost of $1.67 per cubic yard (cy) of beach fill, far below typical industry costs. However, even with this low beach fill unit cost, the benefit-to-cost ratio is still low, mainly because of the project area's relatively low property values and low visitation rates compared to more popular tourist destinations (e.g., Galveston Island and South Padre Island beaches). Furthermore, the benefit-to-cost ratio of this beach nourishment project does not include federal spending as a benefit, because federal spending would be the same with or without the project (because the federal dredging project would occur with or without the beach nourishment).

Federal spending on CEPRA projects is also important from a Texas point of view because it reflects financial inflows to the state economy and lowers project costs to Texas. Several of the evaluated projects realized these benefits, as described by the following examples. The McFaddin NWR Beach Ridge Restoration Project experienced federal spending benefits ($4,796,321 discounted present worth) from USFWS and CIAP funding as mentioned above. Similarly, Bird Island Cove Marsh Restoration experienced federal spending benefits ($1,399,405 discounted present worth) from funding by USFWS Texas Coastal Program and a USFWS National Coastal Wetlands Conservation Grant. Funding provided by the Federal Emergency Management Agency (FEMA) led to significant federal spending benefits for the End of Seawall Beach Nourishment ($4,255,032 discounted present worth) and Quintana-Bryan Beach Nourishment ($1,126,183 discounted present worth).

Overall, the direct and positive net benefits (B/C ratios greater than one) from the 15 evaluated projects combined indicate that these coastal erosion control projects yield high returns on investment for the state of Texas. Preserving Texas' coastal assets proves a worthy public investment strategy for the Texas taxpayers and citizens.

Table 5.1.1 Summary of CEPRA Cycles 7 – 8 Projects, Costs, and Benefits

CEPRA Project Number / Name	**County**	**Project Year**[1]	**Beginning of Project Year**		**Beginning of 2016**[3]		**Benefit-to-Cost (B/C) Ratio**
			Discounted Cost[2] **($)**	**Discounted Benefits ($)**	**Discounted Cost**[3] **($)**	**Discounted Benefits ($)**	
#1516 McFaddin NWR Beach Ridge Restoration	Jefferson	2014	415,859	21,671,271	442,557	23,062,535	52.1
#1520 Bird Island Cover Marsh Restoration	Galveston	2014	715,042	2,307,597	760,947	2,455,741	3.2
#1521 End of Seawall Beach Nourishment	Galveston	2015	1,475,049	4,539,140	1,521,661	4,682,577	3.1
#1527 Indian Point Shoreline Protection & Marsh Restoration	San Patricio	2015	899,001	1,296,095	927,409	1,337,052	1.4
#1569 Corpus Christi North Beach BMMP Nourishment	Nueces	2016	2,475,577	10,408,114	2,475,577	10,408,114	4.2
#1570 Village of Surfside Beach BMMP Maintenance Nourishment	Brazoria	2015	2,244,323	925,772	2,315,244	955,026	0.4
#1573 Village of Surfside Beach Revetment Emergency Repair							
#1571 Quintana-Bryan Beach Nourishment	Brazoria	2016	801,380	1,585,708	801,380	1,585,708	2.0
#1576 Arturo Galvan Coastal Park Living Shoreline Restoration	Cameron	2016	608,409	302,393	608,409	302,393	0.5
#1577 Keith Lake Fish Pass Baffle Shoreline Protection & Marsh Restoration	Jefferson	2015	4,109,350	41,459,640	4,239,205	42,769,765	10.1
#1588 Oyster Lake Habitat Restoration	Brazoria	2016	487,947	1,656,822	487,947	1,656,822	3.4
#1591 Magnolia Inlet Shoreline Protection & Marsh Restoration	Calhoun	2015	113,361	12,530,728	116,943	12,926,699	110.5
#1603 Rockport Beach BMMP Maintenance Renourishment	Aransas	2016	409,605	1,835,436	409,605	1,835,436	4.5
#1608 GIWW Rollover Bay Reach Beach Nourishment with Beneficial Use of Dredged Material (BUDM)	Galveston	2015	250,000	47,612	257,900	49,117	0.2
#1609 Galveston Seawall 61st to 103rd St. Beach Nourishment with Beneficial Use of Dredged Material	Galveston	2016	7,990,000	29,020,938	7,990,000	29,020,938	3.6
Total[4]					$23,354,784	$133,047,923	5.7

Notes: [1] Project Year represents the year benefits begin to accrue and may not represent the actual construction year.

[2] Texas portion only; dollar values reflect present worth equivalents at the beginning of Project Year.

[3] Dollar values reflect present worth equivalents at the beginning of 2016 with a 3.16% discount rate.

[4] Total B/C Ratio represents the Total Discounted Benefits divided by the Total Discounted Cost of all five projects combined (i.e., 133,047,923 / 23,354,784 = 5.7).

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APPENDIX A

Storm Damage Reduction Benefits—Damage-Cumulative Probabilities

North Beach Maintenance Nourishment CEPRA #1569

Without Project Conditions, Year 1 (2017)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$35,216	$0	$35,216									
2	0.50	0.50	$0	$63,269	$0	$63,269	$49,243	0.50	$24,621	$0	$0	$49,243	$24,621	$0	$0
5	0.20	0.80	$1,053,754	$164,067	$682,167	$1,899,988	$981,629	0.30	$294,489	$526,877	$158,063	$113,668	$34,100	$341,084	$102,325
10	0.10	0.90	$2,355,803	$223,440	$3,400,473	$5,979,717	$3,939,852	0.10	$393,985	$1,704,779	$170,478	$193,753	$19,375	$2,041,320	$204,132
20	0.05	0.95	$711,559	$164,280	$354,444	$1,230,283	$3,605,000	0.05	$180,250	$1,533,681	$76,684	$193,860	$9,693	$1,877,459	$93,873
50	0.02	0.98	$1,241,047	$169,502	$716,629	$2,127,178	$1,678,731	0.03	$50,362	$976,303	$29,289	$166,891	$5,007	$535,536	$16,066
100	0.01	0.99	$1,039,012	$177,615	$946,002	$2,162,630	$2,144,904	0.01	$21,449	$1,140,030	$11,400	$173,559	$1,736	$831,315	$8,313
>100	<0.01	>0.99	$1,039,012	$177,615	$946,002	$2,162,630	$2,162,630	0.01	$21,626	$1,039,012	$10,390	$177,615	$1,776	$946,002	$9,460
			Expected Average Annual Damage in 2016 Prices:						$986,783		$456,304		$96,309		$434,169

With Project Conditions, Year 1 (2017)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$0	$0	$0									
2	0.50	0.50	$0	$27,350	$0	$27,350	$13,675	0.50	$6,837	$0	$0	$13,675	$6,837	$0	$0
5	0.20	0.80	$0	$50,705	$0	$50,705	$39,028	0.30	$11,708	$0	$0	$39,028	$11,708	$0	$0
10	0.10	0.90	$31,321	$99,421	$959	$131,701	$91,203	0.10	$9,120	$15,660	$1,566	$75,063	$7,506	$480	$48
20	0.05	0.95	$0	$55,994	$0	$55,994	$93,847	0.05	$4,692	$15,660	$783	$77,707	$3,885	$480	$24
50	0.02	0.98	$0	$61,317	$0	$61,317	$58,655	0.03	$1,760	$0	$0	$58,655	$1,760	$0	$0
100	0.01	0.99	$0	$117,642	$0	$117,642	$89,480	0.01	$895	$0	$0	$89,480	$895	$0	$0
>100	<0.01	>0.99	$0	$117,642	$0	$117,642	$117,642	0.01	$1,176	$0	$0	$117,642	$1,176	$0	$0
			Expected Average Annual Damage in 2016 Prices:						$36,189		$2,349		$33,768		$72

North Beach Maintenance Nourishment CEPRA #1569

Without Project Conditions, Year 2 (2018)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$39,396	$0	$39,396									
2	0.50	0.50	$0	$91,410	$0	$91,410	$65,403	0.50	$32,701	$0	$0	$65,403	$32,701	$0	$0
5	0.20	0.80	$1,247,255	$168,246	$682,167	$2,097,669	$1,094,539	0.30	$328,362	$623,628	$187,088	$129,828	$38,948	$341,084	$102,325
10	0.10	0.90	$2,559,187	$227,619	$3,520,427	$6,307,234	$4,202,451	0.10	$420,245	$1,903,221	$190,322	$197,933	$19,793	$2,101,297	$210,130
20	0.05	0.95	$905,673	$168,459	$469,556	$1,543,688	$3,925,461	0.05	$196,273	$1,732,430	$86,622	$198,039	$9,902	$1,994,991	$99,750
50	0.02	0.98	$1,444,431	$173,682	$904,202	$2,522,315	$2,033,001	0.03	$60,990	$1,175,052	$35,252	$171,070	$5,132	$686,879	$20,606
100	0.01	0.99	$1,242,396	$181,794	$1,480,174	$2,904,364	$2,713,339	0.01	$27,133	$1,343,414	$13,434	$177,738	$1,777	$1,192,188	$11,922
>100	<0.01	>0.99	$1,242,396	$181,794	$1,480,174	$2,904,364	$2,904,364	0.01	$29,044	$1,242,396	$12,424	$181,794	$1,818	$1,480,174	$14,802
			Expected Average Annual Damage in 2016 Prices:						$1,094,748		$525,142		$110,072		$459,534

With Project Conditions, Year 2 (2018)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$0	$0	$0									
2	0.50	0.50	$0	$30,561	$0	$30,561	$15,280	0.50	$7,640	$0	$0	$15,280	$7,640	$0	$0
5	0.20	0.80	$0	$59,285	$0	$59,285	$44,923	0.30	$13,477	$0	$0	$44,923	$13,477	$0	$0
10	0.10	0.90	$103,223	$117,781	$7,823	$228,827	$144,056	0.10	$14,406	$51,611	$5,161	$88,533	$8,853	$3,912	$391
20	0.05	0.95	$0	$60,173	$0	$60,173	$144,500	0.05	$7,225	$51,611	$2,581	$88,977	$4,449	$3,912	$196
50	0.02	0.98	$0	$94,837	$0	$94,837	$77,505	0.03	$2,325	$0	$0	$77,505	$2,325	$0	$0
100	0.01	0.99	$4,323	$121,821	$0	$126,144	$110,490	0.01	$1,105	$2,161	$22	$108,329	$1,083	$0	$0
>100	<0.01	>0.99	$4,323	$121,821	$0	$126,144	$126,144	0.01	$1,261	$4,323	$43	$121,821	$1,218	$0	$0
			Expected Average Annual Damage in 2016 Prices:						$47,439		$7,807		$39,046		$587

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Without Project Conditions, Year 3 (2019)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$62,157	$0	$62,157									
2	0.50	0.50	$0	$95,589	$0	$95,589	$78,873	0.50	$39,436	$0	$0	$78,873	$39,436	$0	$0
5	0.20	0.80	$1,450,640	$172,425	$798,381	$2,421,445	$1,258,517	0.30	$377,555	$725,320	$217,596	$134,007	$40,202	$399,190	$119,757
10	0.10	0.90	$2,762,571	$231,798	$3,622,854	$6,617,224	$4,519,334	0.10	$451,933	$2,106,606	$210,661	$202,112	$20,211	$2,210,617	$221,062
20	0.05	0.95	$1,109,057	$172,638	$706,727	$1,988,423	$4,302,823	0.05	$215,141	$1,935,814	$96,791	$202,218	$10,111	$2,164,790	$108,240
50	0.02	0.98	$1,647,816	$177,861	$1,314,643	$3,140,320	$2,564,371	0.03	$76,931	$1,378,436	$41,353	$175,249	$5,257	$1,010,685	$30,321
100	0.01	0.99	$1,445,780	$185,973	$1,959,396	$3,591,150	$3,365,735	0.01	$33,657	$1,546,798	$15,468	$181,917	$1,819	$1,637,020	$16,370
>100	<0.01	>0.99	$1,445,780	$185,973	$1,959,396	$3,591,150	$3,591,150	0.01	$35,911	$1,445,780	$14,458	$185,973	$1,860	$1,959,396	$19,594
			Expected Average Annual Damage in 2016 Prices:						$1,230,566		$596,326		$118,897		$515,343

With Project Conditions, Year 3 (2019)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$5,868	$0	$5,868									
2	0.50	0.50	$0	$34,533	$0	$34,533	$20,201	0.50	$10,100	$0	$0	$20,201	$10,100	$0	$0
5	0.20	0.80	$0	$67,866	$0	$67,866	$51,199	0.30	$15,360	$0	$0	$51,199	$15,360	$0	$0
10	0.10	0.90	$195,375	$121,960	$17,317	$334,652	$201,259	0.10	$20,126	$97,687	$9,769	$94,913	$9,491	$8,658	$866
20	0.05	0.95	$0	$88,313	$0	$88,313	$211,482	0.05	$10,574	$97,687	$4,884	$105,136	$5,257	$8,658	$433
50	0.02	0.98	$0	$107,818	$0	$107,818	$98,065	0.03	$2,942	$0	$0	$98,065	$2,942	$0	$0
100	0.01	0.99	$42,782	$130,401	$1,642	$174,825	$141,322	0.01	$1,413	$21,391	$214	$119,110	$1,191	$821	$8
>100	<0.01	>0.99	$42,782	$130,401	$1,642	$174,825	$174,825	0.01	$1,748	$42,782	$428	$130,401	$1,304	$1,642	$16
			Expected Average Annual Damage in 2016 Prices:						$62,264		$15,295		$45,645		$1,323

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Without Project Conditions, Year 4 (2020)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$70,737	$0	$70,737									
2	0.50	0.50	$21,337	$121,773	$0	$143,110	$106,923	0.50	$53,462	$10,668	$5,334	$96,255	$48,127	$0	$0
5	0.20	0.80	$1,654,024	$176,604	$1,187,066	$3,017,694	$1,580,402	0.30	$474,121	$837,680	$251,304	$149,189	$44,757	$593,533	$178,060
10	0.10	0.90	$2,965,956	$235,978	$3,646,627	$6,848,560	$4,933,127	0.10	$493,313	$2,309,990	$230,999	$206,291	$20,629	$2,416,846	$241,685
20	0.05	0.95	$1,312,442	$176,817	$1,191,037	$2,680,296	$4,764,428	0.05	$238,221	$2,139,199	$106,960	$206,397	$10,320	$2,418,832	$120,942
50	0.02	0.98	$1,851,200	$182,040	$1,734,987	$3,768,227	$3,224,261	0.03	$96,728	$1,581,821	$47,455	$179,429	$5,383	$1,463,012	$43,890
100	0.01	0.99	$1,649,164	$190,153	$2,487,473	$4,326,790	$4,047,508	0.01	$40,475	$1,750,182	$17,502	$186,096	$1,861	$2,111,230	$21,112
>100	<0.01	>0.99	$1,649,164	$190,153	$2,487,473	$4,326,790	$4,326,790	0.01	$43,268	$1,649,164	$16,492	$190,153	$1,902	$2,487,473	$24,875
			Expected Average Annual Damage in 2016 Prices:						$1,439,587		$676,045		$132,978		$630,564

With Project Conditions, Year 4 (2020)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$11,242	$0	$11,242									
2	0.50	0.50	$0	$38,712	$0	$38,712	$24,977	0.50	$12,489	$0	$0	$24,977	$12,489	$0	$0
5	0.20	0.80	$0	$76,446	$0	$76,446	$57,579	0.30	$17,274	$0	$0	$57,579	$17,274	$0	$0
10	0.10	0.90	$288,967	$130,540	$26,811	$446,318	$261,382	0.10	$26,138	$144,483	$14,448	$103,493	$10,349	$13,405	$1,341
20	0.05	0.95	$0	$111,074	$0	$111,074	$278,696	0.05	$13,935	$144,483	$7,224	$120,807	$6,040	$13,405	$670
50	0.02	0.98	$0	$129,601	$0	$129,601	$120,337	0.03	$3,610	$0	$0	$120,337	$3,610	$0	$0
100	0.01	0.99	$123,116	$156,586	$9,752	$289,453	$209,527	0.01	$2,095	$61,558	$616	$143,093	$1,431	$4,876	$49
>100	<0.01	>0.99	$123,116	$156,586	$9,752	$289,453	$289,453	0.01	$2,895	$123,116	$1,231	$156,586	$1,566	$9,752	$98
			Expected Average Annual Damage in 2016 Prices:						$78,435		$23,519		$52,759		$2,157

North Beach Maintenance Nourishment CEPRA #1569

Without Project Conditions, Year 5 (2021)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$94,476	$0	$94,476									
2	0.50	0.50	$87,331	$145,512	$0	$232,843	$163,659	0.50	$81,830	$43,665	$21,833	$119,994	$59,997	$0	$0
5	0.20	0.80	$1,857,408	$180,783	$1,611,398	$3,649,589	$1,941,216	0.30	$582,365	$972,369	$291,711	$163,148	$48,944	$805,699	$241,710
10	0.10	0.90	$3,169,340	$240,157	$3,658,282	$7,067,779	$5,358,684	0.10	$535,868	$2,513,374	$251,337	$210,470	$21,047	$2,634,840	$263,484
20	0.05	0.95	$1,515,826	$180,996	$1,633,021	$3,329,843	$5,198,811	0.05	$259,941	$2,342,583	$117,129	$210,577	$10,529	$2,645,651	$132,283
50	0.02	0.98	$2,054,584	$186,219	$2,111,301	$4,352,104	$3,840,973	0.03	$115,229	$1,785,205	$53,556	$183,608	$5,508	$1,872,161	$56,165
100	0.01	0.99	$1,852,549	$194,332	$2,720,668	$4,767,549	$4,559,826	0.01	$45,598	$1,953,566	$19,536	$190,275	$1,903	$2,415,984	$24,160
>100	<0.01	>0.99	$1,852,549	$194,332	$2,720,668	$4,767,549	$4,767,549	0.01	$47,675	$1,852,549	$18,525	$194,332	$1,943	$2,720,668	$27,207
			Expected Average Annual Damage in 2016 Prices:						$1,668,506		$773,627		$149,872		$745,008

With Project Conditions, Year 5 (2021)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$28,091	$0	$28,091									
2	0.50	0.50	$0	$61,474	$0	$61,474	$44,782	0.50	$22,391	$0	$0	$44,782	$22,391	$0	$0
5	0.20	0.80	$27,422	$102,630	$0	$130,052	$95,763	0.30	$28,729	$13,711	$4,113	$82,052	$24,616	$0	$0
10	0.10	0.90	$385,133	$156,724	$71,833	$613,690	$371,871	0.10	$37,187	$206,277	$20,628	$129,677	$12,968	$35,916	$3,592
20	0.05	0.95	$0	$128,456	$0	$128,456	$371,073	0.05	$18,554	$192,566	$9,628	$142,590	$7,130	$35,916	$1,796
50	0.02	0.98	$858	$155,785	$0	$156,644	$142,550	0.03	$4,276	$429	$13	$142,121	$4,264	$0	$0
100	0.01	0.99	$262,392	$160,765	$19,245	$442,403	$299,523	0.01	$2,995	$131,625	$1,316	$158,275	$1,583	$9,623	$96
>100	<0.01	>0.99	$262,392	$160,765	$19,245	$442,403	$442,403	0.01	$4,424	$262,392	$2,624	$160,765	$1,608	$19,245	$192
			Expected Average Annual Damage in 2016 Prices:						$118,557		$38,322		$74,558		$5,676

North Beach Maintenance Nourishment CEPRA #1569

Without Project Conditions, Year 6 (2022)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$5,105	$120,660	$0	$125,766									
2	0.50	0.50	$184,503	$154,092	$0	$338,596	$232,181	0.50	$116,090	$94,804	$47,402	$137,376	$68,688	$0	$0
5	0.20	0.80	$2,060,792	$184,963	$1,969,488	$4,215,242	$2,276,919	0.30	$683,076	$1,122,648	$336,794	$169,527	$50,858	$984,744	$295,423
10	0.10	0.90	$3,372,724	$244,336	$3,669,937	$7,286,997	$5,751,120	0.10	$575,112	$2,716,758	$271,676	$214,649	$21,465	$2,819,712	$281,971
20	0.05	0.95	$1,719,210	$185,176	$1,992,847	$3,897,232	$5,592,114	0.05	$279,606	$2,545,967	$127,298	$214,756	$10,738	$2,831,392	$141,570
50	0.02	0.98	$2,257,968	$190,398	$2,532,575	$4,980,942	$4,439,087	0.03	$133,173	$1,988,589	$59,658	$187,787	$5,634	$2,262,711	$67,881
100	0.01	0.99	$2,055,933	$198,511	$2,906,165	$5,160,609	$5,070,775	0.01	$50,708	$2,156,950	$21,570	$194,455	$1,945	$2,719,370	$27,194
>100	<0.01	>0.99	$2,055,933	$198,511	$2,906,165	$5,160,609	$5,160,609	0.01	$51,606	$2,055,933	$20,559	$198,511	$1,985	$2,906,165	$29,062
			Expected Average Annual Damage in 2016 Prices:						$1,889,370		$884,957		$161,312		$843,101

With Project Conditions, Year 6 (2022)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$31,400	$0	$31,400									
2	0.50	0.50	$0	$65,653	$0	$65,653	$48,526	0.50	$24,263	$0	$0	$48,526	$24,263	$0	$0
5	0.20	0.80	$96,089	$106,809	$0	$202,899	$134,276	0.30	$40,283	$48,045	$14,413	$86,231	$25,869	$0	$0
10	0.10	0.90	$526,179	$160,903	$147,897	$834,979	$518,939	0.10	$51,894	$311,134	$31,113	$133,856	$13,386	$73,948	$7,395
20	0.05	0.95	$5,538	$132,635	$0	$138,173	$486,576	0.05	$24,329	$265,858	$13,293	$146,769	$7,338	$73,948	$3,697
50	0.02	0.98	$62,769	$159,964	$669	$223,403	$180,788	0.03	$5,424	$34,153	$1,025	$146,300	$4,389	$335	$10
100	0.01	0.99	$436,737	$164,944	$28,739	$630,420	$426,911	0.01	$4,269	$249,753	$2,498	$162,454	$1,625	$14,704	$147
>100	<0.01	>0.99	$436,737	$164,944	$28,739	$630,420	$630,420	0.01	$6,304	$436,737	$4,367	$164,944	$1,649	$28,739	$287
			Expected Average Annual Damage in 2016 Prices:						$156,765		$66,709		$78,519		$11,537

North Beach Maintenance Nourishment CEPRA #1569

Without Project Conditions, Year 7 (2023)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$67,160	$124,839	$0	$191,999									
2	0.50	0.50	$292,962	$171,474	$89,619	$554,056	$373,028	0.50	$186,514	$180,061	$90,030	$148,157	$74,078	$44,810	$22,405
5	0.20	0.80	$2,264,176	$189,142	$2,426,537	$4,879,854	$2,716,955	0.30	$815,087	$1,278,569	$383,571	$180,308	$54,092	$1,258,078	$377,423
10	0.10	0.90	$3,576,108	$248,515	$3,681,592	$7,506,215	$6,193,035	0.10	$619,303	$2,920,142	$292,014	$218,828	$21,883	$3,054,065	$305,406
20	0.05	0.95	$1,922,594	$189,355	$2,446,003	$4,557,952	$6,032,084	0.05	$301,604	$2,749,351	$137,468	$218,935	$10,947	$3,063,798	$153,190
50	0.02	0.98	$2,461,352	$194,577	$2,732,413	$5,388,343	$4,973,147	0.03	$149,194	$2,191,973	$65,759	$191,966	$5,759	$2,589,208	$77,676
100	0.01	0.99	$2,259,317	$202,690	$3,045,241	$5,507,248	$5,447,795	0.01	$54,478	$2,360,334	$23,603	$198,634	$1,986	$2,888,827	$28,888
>100	<0.01	>0.99	$2,259,317	$202,690	$3,045,241	$5,507,248	$5,507,248	0.01	$55,072	$2,259,317	$22,593	$202,690	$2,027	$3,045,241	$30,452
			Expected Average Annual Damage in 2016 Prices:						$2,181,253		$1,015,039		$170,773		$995,442

With Project Conditions, Year 7 (2023)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Infrastructure Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Infrastructure Damage	Expected Value Interval Infrastructure Damage	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1.00	0.00	$0	$35,566	$0	$35,566									
2	0.50	0.50	$0	$74,233	$0	$74,233	$54,900	0.50	$27,450	$0	$0	$54,900	$27,450	$0	$0
5	0.20	0.80	$194,463	$130,548	$0	$325,011	$199,622	0.30	$59,887	$97,231	$29,169	$102,391	$30,717	$0	$0
10	0.10	0.90	$701,745	$165,083	$198,730	$1,065,558	$695,284	0.10	$69,528	$448,104	$44,810	$147,815	$14,782	$99,365	$9,937
20	0.05	0.95	$65,628	$158,820	$1,833	$226,280	$645,919	0.05	$32,296	$383,686	$19,184	$161,951	$8,098	$100,282	$5,014
50	0.02	0.98	$206,034	$164,143	$7,003	$377,181	$301,730	0.03	$9,052	$135,831	$4,075	$161,481	$4,844	$4,418	$133
100	0.01	0.99	$632,763	$169,123	$94,224	$896,111	$636,646	0.01	$6,366	$419,399	$4,194	$166,633	$1,666	$50,614	$506
>100	<0.01	>0.99	$632,763	$169,123	$94,224	$896,111	$896,111	0.01	$8,961	$632,763	$6,328	$169,123	$1,691	$94,224	$942
			Expected Average Annual Damage in 2016 Prices:						$213,540		$107,761		$89,248		$16,532

Quintana-Bryan Beach Nourishment CEPRA #1571

Without Project Conditions, Year 1 (2017)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$8,122	$0	$8,122							
2	0.5	0.5	$8,515	$0	$8,515	$8,319	0.5	$4,159	$8,319	$4,159	$0	$0
5	0.2	0.8	$10,349	$97,660	$108,009	$58,262	0.3	$17,479	$9,432	$2,830	$48,830	$14,649
10	0.1	0.9	$10,349	$97,660	$108,009	$108,009	0.1	$10,801	$10,349	$1,035	$97,660	$9,766
20	0.05	0.95	$21,734	$110,391	$132,125	$120,067	0.05	$6,003	$16,042	$802	$104,025	$5,201
50	0.02	0.98	$31,671	$148,582	$180,253	$156,189	0.03	$4,686	$26,703	$801	$129,486	$3,885
100	0.01	0.99	$33,039	$199,504	$232,543	$206,398	0.01	$2,064	$32,355	$324	$174,043	$1,740
>100	<0.01	>0.99	$33,039	$199,504	$232,543	$232,543	0.01	$2,325	$33,039	$330	$199,504	$1,995
			Expected Average Annual Damage in 2016 Prices:					$47,517		$10,281		$37,236

With Project Conditions, Year 1 (2017)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$6,681	$0	$6,681							
2	0.5	0.5	$7,467	$0	$7,467	$7,074	0.5	$3,537	$7,074	$3,537	$0	$0
5	0.2	0.8	$7,598	$0	$7,598	$7,533	0.3	$2,260	$7,533	$2,260	$0	$0
10	0.1	0.9	$10,349	$97,660	$108,009	$57,804	0.1	$5,780	$8,974	$897	$48,830	$4,883
20	0.05	0.95	$10,349	$97,660	$108,009	$108,009	0.05	$5,400	$10,349	$517	$97,660	$4,883
50	0.02	0.98	$10,611	$97,660	$108,271	$108,140	0.03	$3,244	$10,480	$314	$97,660	$2,930
100	0.01	0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083	$10,611	$106	$97,660	$977
>100	<0.01	>0.99	$10,611	$97,660	$108,271	$108,271	0.01	$1,083	$10,611	$106	$97,660	$977
			Expected Average Annual Damage in 2016 Prices:					$22,387		$7,738		$14,649

Quintana-Bryan Beach Nourishment CEPRA #1571

Without Project Conditions, Year 2 (2018)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$8,515	$0	$8,515							
2	0.5	0.5	$9,039	$26,368	$35,407	$21,961	0.5	$10,981	$8,777	$4,389	$13,184	$6,592
5	0.2	0.8	$10,218	$95,707	$105,925	$70,666	0.3	$21,200	$9,629	$2,889	$61,038	$18,311
10	0.1	0.9	$33,039	$199,504	$232,543	$169,234	0.1	$16,923	$21,628	$2,163	$147,605	$14,761
20	0.05	0.95	$38,831	$224,965	$263,796	$248,169	0.05	$12,408	$35,935	$1,797	$212,235	$10,612
50	0.02	0.98	$46,098	$273,341	$319,439	$291,617	0.03	$8,749	$42,464	$1,274	$249,153	$7,475
100	0.01	0.99	$48,988	$301,348	$350,336	$334,887	0.01	$3,349	$47,543	$475	$287,344	$2,873
>100	<0.01	>0.99	$48,988	$301,348	$350,336	$350,336	0.01	$3,503	$48,988	$490	$301,348	$3,013
			Expected Average Annual Damage in 2016 Prices:					$77,113		$13,476		$63,637

With Project Conditions, Year 2 (2018)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$6,943	$0	$6,943							
2	0.5	0.5	$7,860	$0	$7,860	$7,402	0.5	$3,701	$7,402	$3,701	$0	$0
5	0.2	0.8	$8,122	$0	$8,122	$7,991	0.3	$2,397	$7,991	$2,397	$0	$0
10	0.1	0.9	$18,415	$97,660	$116,075	$62,099	0.1	$6,210	$13,269	$1,327	$48,830	$4,883
20	0.05	0.95	$17,228	$97,660	$114,888	$115,482	0.05	$5,774	$17,822	$891	$97,660	$4,883
50	0.02	0.98	$20,813	$97,660	$118,473	$116,681	0.03	$3,500	$19,021	$571	$97,660	$2,930
100	0.01	0.99	$22,262	$123,121	$145,383	$131,928	0.01	$1,319	$21,538	$215	$110,391	$1,104
>100	<0.01	>0.99	$22,262	$123,121	$145,383	$145,383	0.01	$1,454	$22,262	$223	$123,121	$1,231
			Expected Average Annual Damage in 2016 Prices:					$24,356		$9,325		$15,031

Quintana-Bryan Beach Nourishment CEPRA #1571

Without Project Conditions, Year 3 (2019)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$8,515	$0	$8,515							
2	0.5	0.5	$9,039	$26,368	$35,407	$21,961	0.5	$10,981	$8,777	$4,389	$13,184	$6,592
5	0.2	0.8	$10,218	$95,707	$105,925	$70,666	0.3	$21,200	$9,629	$2,889	$61,038	$18,311
10	0.1	0.9	$33,039	$199,504	$232,543	$169,234	0.1	$16,923	$21,628	$2,163	$147,605	$14,761
20	0.05	0.95	$38,831	$224,965	$263,796	$248,169	0.05	$12,408	$35,935	$1,797	$212,235	$10,612
50	0.02	0.98	$46,098	$273,341	$319,439	$291,617	0.03	$8,749	$42,464	$1,274	$249,153	$7,475
100	0.01	0.99	$48,988	$301,348	$350,336	$334,887	0.01	$3,349	$47,543	$475	$287,344	$2,873
>100	<0.01	>0.99	$48,988	$301,348	$350,336	$350,336	0.01	$3,503	$48,988	$490	$301,348	$3,013
			Expected Average Annual Damage in 2016 Prices:					$77,113		$13,476		$63,637

With Project Conditions, Year 3 (2019)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$6,943	$0	$6,943							
2	0.5	0.5	$7,860	$0	$7,860	$7,402	0.5	$3,701	$7,402	$3,701	$0	$0
5	0.2	0.8	$8,122	$0	$8,122	$7,991	0.3	$2,397	$7,991	$2,397	$0	$0
10	0.1	0.9	$18,415	$97,660	$116,075	$62,099	0.1	$6,210	$13,269	$1,327	$48,830	$4,883
20	0.05	0.95	$17,228	$97,660	$114,888	$115,482	0.05	$5,774	$17,822	$891	$97,660	$4,883
50	0.02	0.98	$20,813	$97,660	$118,473	$116,681	0.03	$3,500	$19,021	$571	$97,660	$2,930
100	0.01	0.99	$22,262	$123,121	$145,383	$131,928	0.01	$1,319	$21,538	$215	$110,391	$1,104
>100	<0.01	>0.99	$22,262	$123,121	$145,383	$145,383	0.01	$1,454	$22,262	$223	$123,121	$1,231
			Expected Average Annual Damage in 2016 Prices:					$24,356		$9,325		$15,031

Quintana-Bryan Beach Nourishment CEPRA #1571

Without Project Conditions, Year 4 (2020)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$8,515	$0	$8,515							
2	0.5	0.5	$9,039	$26,368	$35,407	$21,961	0.5	$10,981	$8,777	$4,389	$13,184	$6,592
5	0.2	0.8	$10,218	$95,707	$105,925	$70,666	0.3	$21,200	$9,629	$2,889	$61,038	$18,311
10	0.1	0.9	$33,039	$199,504	$232,543	$169,234	0.1	$16,923	$21,628	$2,163	$147,605	$14,761
20	0.05	0.95	$38,831	$224,965	$263,796	$248,169	0.05	$12,408	$35,935	$1,797	$212,235	$10,612
50	0.02	0.98	$46,098	$273,341	$319,439	$291,617	0.03	$8,749	$42,464	$1,274	$249,153	$7,475
100	0.01	0.99	$48,988	$301,348	$350,336	$334,887	0.01	$3,349	$47,543	$475	$287,344	$2,873
>100	<0.01	>0.99	$48,988	$301,348	$350,336	$350,336	0.01	$3,503	$48,988	$490	$301,348	$3,013
			Expected Average Annual Damage in 2016 Prices:					$77,113		$13,476		$63,637

With Project Conditions, Year 4 (2020)

Tr (yrs)	Probability	Cumulative Probability	Lot Damage	Structure Damage	Total Damage	Average Interval Damage	Interval Probability	Expected Value Interval Damage	Average Interval Land Loss	Expected Value Interval Land Loss	Average Interval Structural Damage	Expected Value Interval Structural Damage
1	1	0	$6,943	$0	$6,943							
2	0.5	0.5	$7,860	$0	$7,860	$7,402	0.5	$3,701	$7,402	$3,701	$0	$0
5	0.2	0.8	$8,122	$0	$8,122	$7,991	0.3	$2,397	$7,991	$2,397	$0	$0
10	0.1	0.9	$18,415	$97,660	$116,075	$62,099	0.1	$6,210	$13,269	$1,327	$48,830	$4,883
20	0.05	0.95	$17,228	$97,660	$114,888	$115,482	0.05	$5,774	$17,822	$891	$97,660	$4,883
50	0.02	0.98	$20,813	$97,660	$118,473	$116,681	0.03	$3,500	$19,021	$571	$97,660	$2,930
100	0.01	0.99	$22,262	$123,121	$145,383	$131,928	0.01	$1,319	$21,538	$215	$110,391	$1,104
>100	<0.01	>0.99	$22,262	$123,121	$145,383	$145,383	0.01	$1,454	$22,262	$223	$123,121	$1,231
			Expected Average Annual Damage in 2016 Prices:					$24,356		$9,325		$15,031