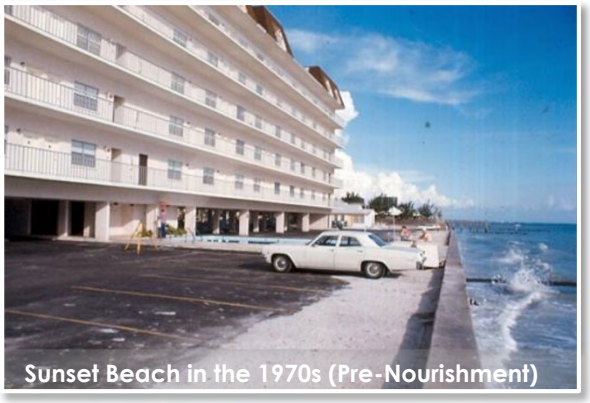
US Army Corps of Engineers ®
Jacksonville District

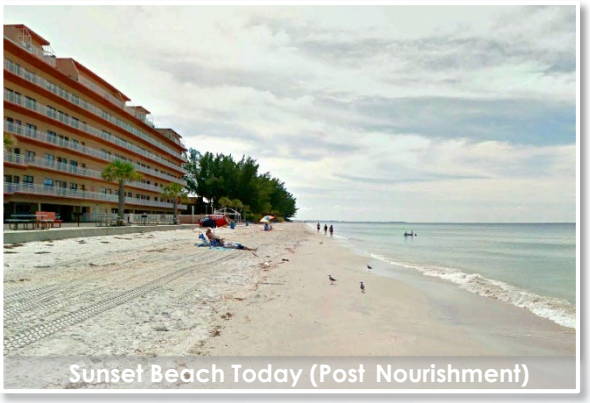
PINELLAS COUNTY, FLORIDA
COASTAL STORM RISK MANAGEMENT STUDY

TREASURE ISLAND AND LONG KEY SEGMENTS

Draft Integrated Feasibility Report and Environmental Assessment

APPENDIX A: ENGINEERING


Sunset Beach in the 1970s (Pre-Nourishment)


Sunset Beach Today (Post Nourishment)

August 2020

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1 Background

Infrastructure along the Pinellas County, Florida shoreline is vulnerable to damage from waves, erosion, and inundation caused by coastal storms. This study investigates alternatives that address these vulnerabilities for two previously authorized Pinellas County Federal project segments, Treasure Island and Long Key.

2 Purpose

The purpose of this report is to assess potential solutions to erosion problems and potential storm damage susceptibility along 7.4 miles of Pinellas County, Florida (**Figure A- 1**). The study area consists of two barrier islands: (1) Treasure Island which extends 3.4 miles between FDEP monuments R-126 and R-143, and (2) Long Key which extends 4.0 miles from R-144 to R-166.

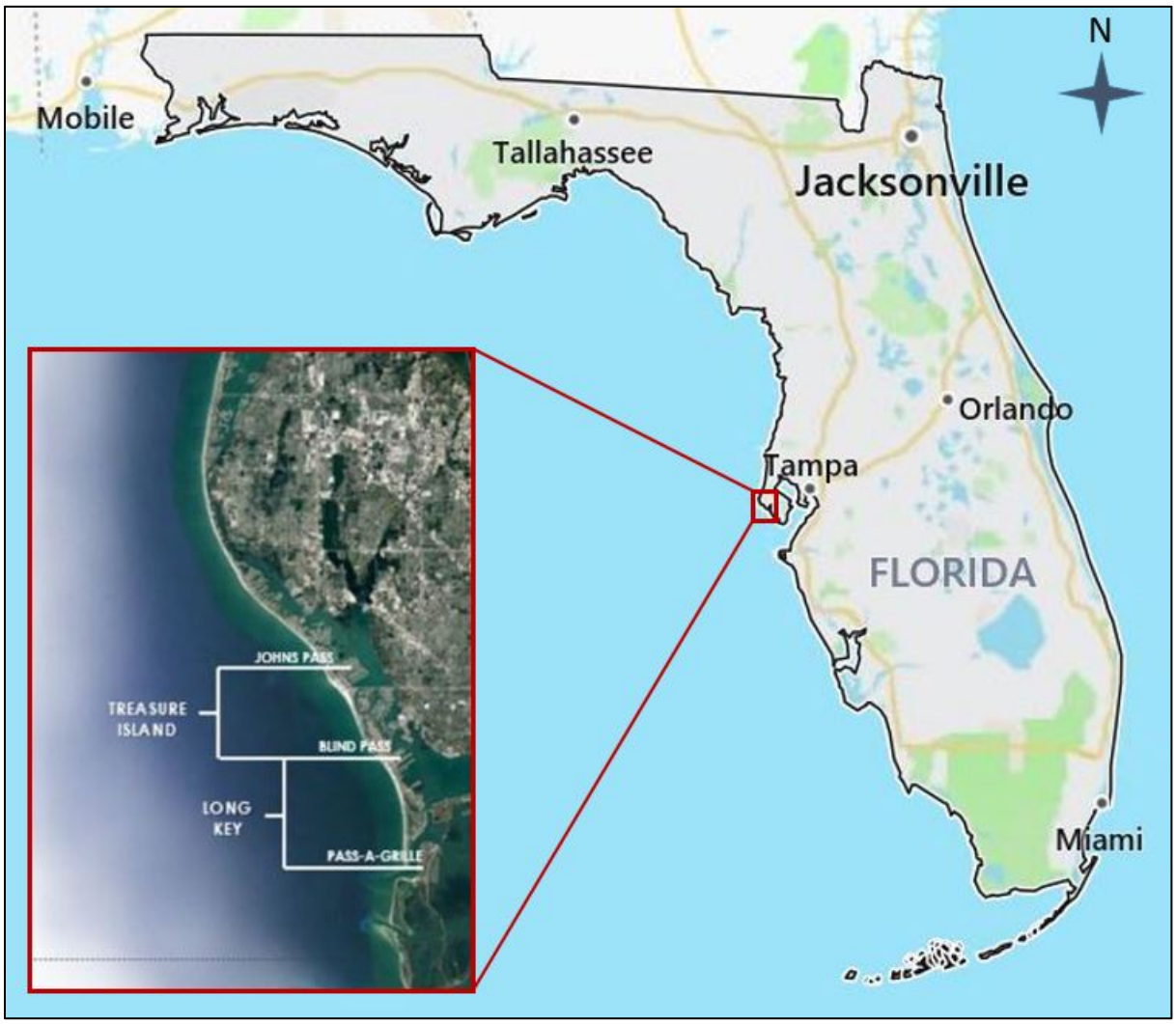


Figure A- 1. Project Site

3 Previous Project History

In 1966, Congress authorized the Pinellas County, Florida Beach Erosion Control Project. This authorization included four project segments: Clearwater Beach Island, Sand Key, Treasure Island, and Long Key. In the current study, Clearwater Beach Island and Sand Key were screened out of the analysis. Clearwater Beach is generally accretional, has never been constructed, and lacks Federal interest. Sand Key still has 15 years of Federal participation remaining under its current authorization, the local sponsor is satisfied to continue with the existing project, and the 14.2 miles of beach would be problematic to study within the current study time and funding constraints. The two remaining segments, Treasure Island and Long Key, are the focus of the analyses described in this appendix.

3.1 History of Treasure Island

The Treasure Island segment was initially constructed in 1969. Current authorization is for a 40 foot design berm at +6.0 ft-MLLW (+4.57 ft-NAVD88) with a renourishment interval of 7 years. The current period of Federal participation is set to expire in 2025. **Figure A- 2** provides a timeline of construction and renourishment events for the Treasure Island Segment. **Figure A- 3** shows graphically the limits of previous placements and provides a table of volumes and sand sources.

3.2 History of Long Key

The Long Key segment was initially constructed in 1980. Current authorization is for a 40 foot design berm at +6.0 ft-MLLW (+4.57 ft-NAVD88) with a renourishment interval of 7 years. The current period of Federal participation is set to expire in 2030. **Figure A- 4** provides a timeline of construction and renourishment events for the Treasure Island Segment. **Figure A- 5** shows graphically the limits of previous placements and provides a table of volumes and sand sources.

4 Natural Forces

4.1 Winds

Local winds are the primary means of generating the small-amplitude, short period waves that are an important mechanism of sand transport along the Florida shoreline. Pinellas County lies between approximately 27.6° and 28.0° degrees latitude, slightly south of the northern boundary of the tropical trade wind zone. Typical prevailing winds are from the east.

Wind data offshore of the project area is available from the USACE Wave Information Study (WIS) Program. WIS hindcast data are generated using the numerical hindcast model WISWAVE (Hubertz, 1992), WAVEWATCH III (Tolman and Chalikov, 1994), and WAM (Komen et al., 1994). WISWAVE is driven by wind fields overlaying a bathymetric grid. Model output includes significant wave height, peak and mean wave period, peak and mean wave direction, wind speed, and wind direction. In the Gulf of Mexico, the WIS hindcast database covers a 35-year period of record extending from 1980 to 2014.

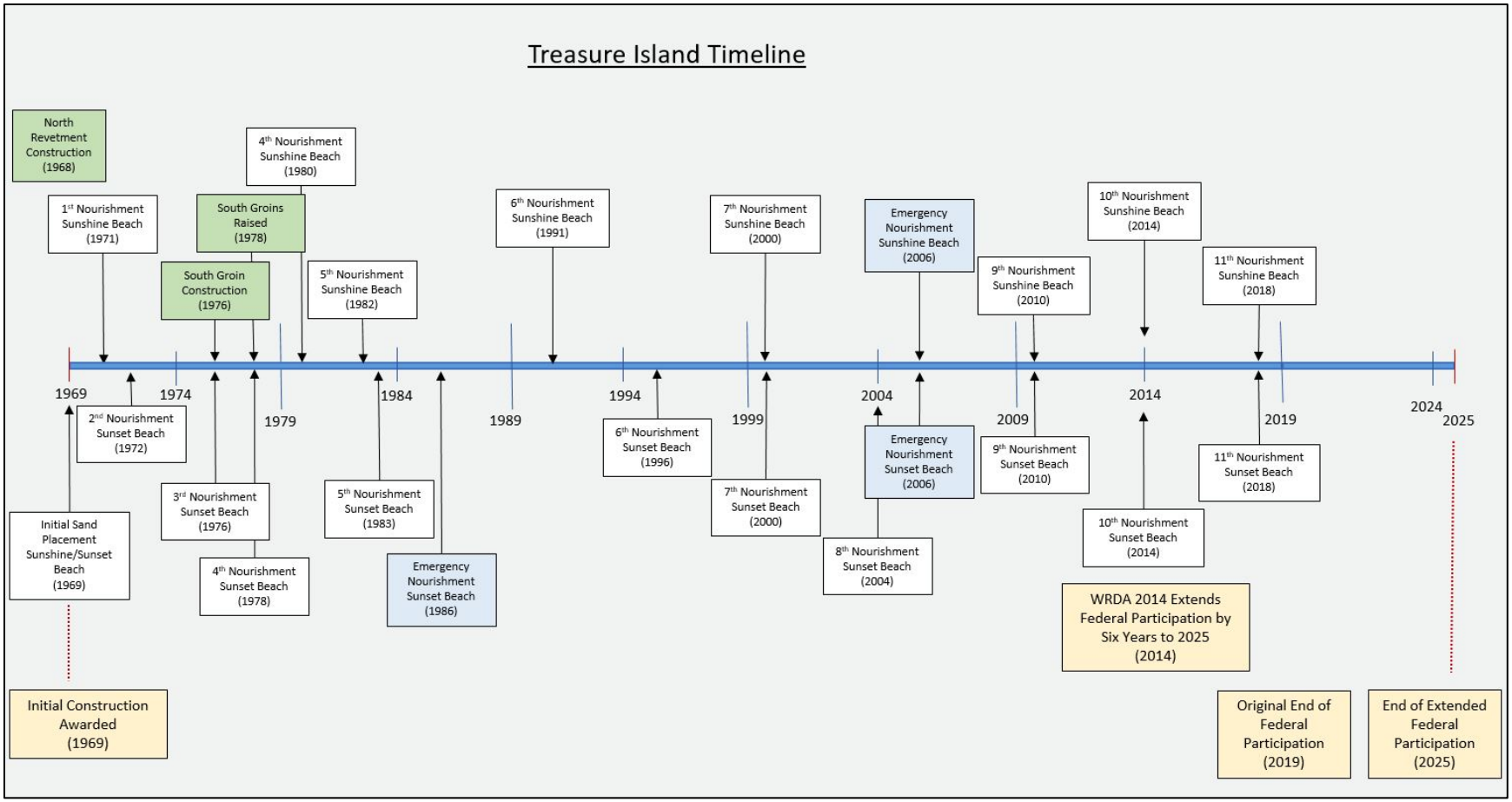
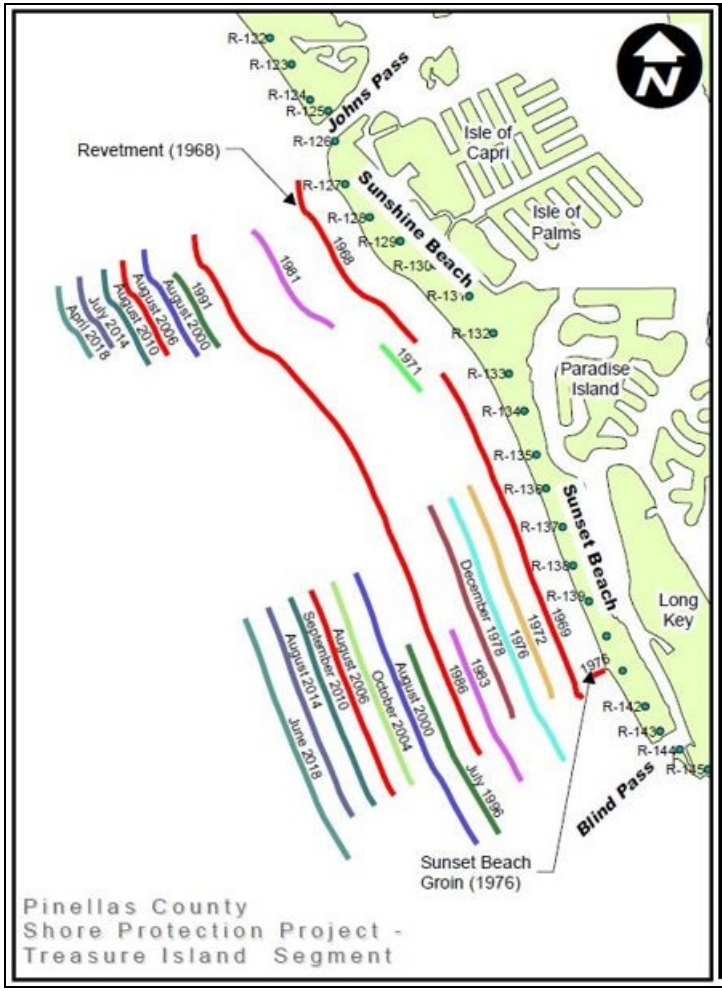


Figure A- 2. Treasure Island History of Federal Participation



Construction Completion Date	Event Type	Location (R-mon)	Volume (CY)	Borrow
1968	Revetment Construction	Sunshine Beach (R126-R131)	n/a	n/a
1969	Initial Restoration	Sunset Beach (R132-R141)	790,000	Blind Pass & Parallel Offshore BA
1971	1st Nourishment	Mid Beach (R131-R132)	75,000	Offshore from R127-R130
1972	2nd Nourishment	Sunset Beach (R141-R142)	155,000	Blind Pass
1976	Groin Construction	Sunset Beach (R141)	n/a	n/a
1976	3rd Nourishment	Sunset Beach (R135-R142)	380,000	Offshore BA
Dec-78	4th Nourishment	Sunset Beach (R135-R142)	32,000	Blind Pass
1981	5th Nourishment	Sunshine Beach (R127-R130)	53,500	John's Pass
1983	5th Nourishment	Sunset Beach (R138-R142)	220,000	Blind Pass
Oct-86	Emergency	Treasure Island (R129-R141)	550,000	Pass-a-Grille shoals
1991	6th Nourishment	Sunshine Beach (R127-R129)	56,000	John's Pass
Jul-96	6th Nourishment	Sunset Beach (R138-R144)	51,300	West Egmont Shoal
Aug-00	7th Nourishment	Sunshine Beach (R126-R129)	40,000	John's and Blind Passes
		Sunset Beach (R136-R144)	348,722	John's and Blind Passes
Sept. 2004	8th Nourishment	Sunset Beach (R136-R141)	225,000	Pass-a-Grille Shoals
Aug-06	Emergency	Sunshine Beach (R126-R128)	77,970	West Egmont Shoal
		Sunset Beach (R136 R141)	106,302	
Oct-10	9th Nourishment	Sunshine Beach (R126-R128)	127,260	John's Pass, Attachment Lobe, Blind Pass
		Sunset Beach (R136 R141)	125,423	
Aug-14	10th Nourishment	Sunshine Beach (R126-R128)	66,892	East Egmont Shoal
		Sunset Beach (R136 R141)	232,407	
Apr-18	11th Nourishment	Sunshine Beach (R126.5-R128)	38,671	John's Pass
Jun-18		Sunset Beach (R136A- R142)	238,981	Johns Pass (R136A -R138.3) East Egmont Shoal (Rem.)

Figure A- 3. Map of Previous Treasure Island Renourishment Events and Tabulated Volumes

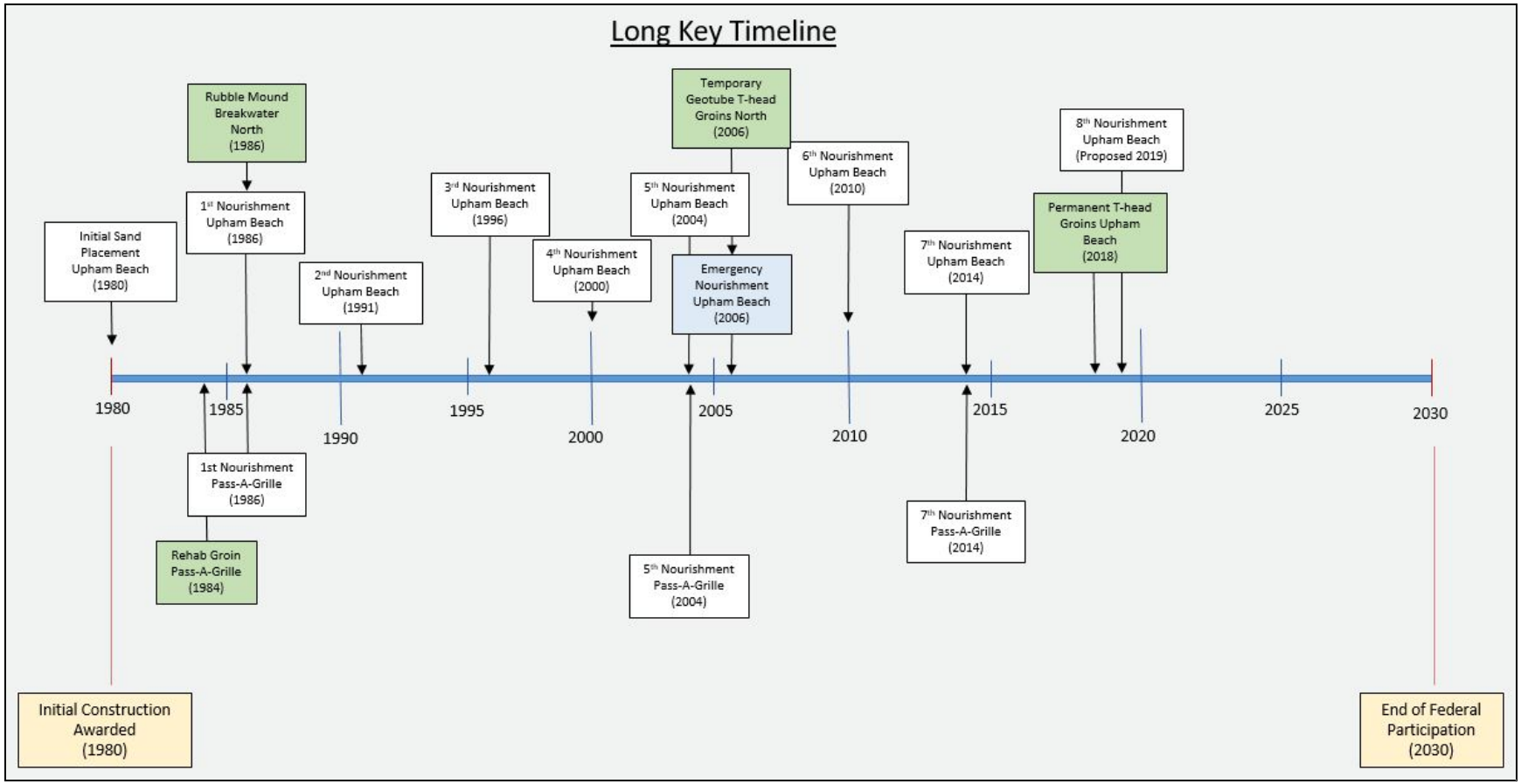
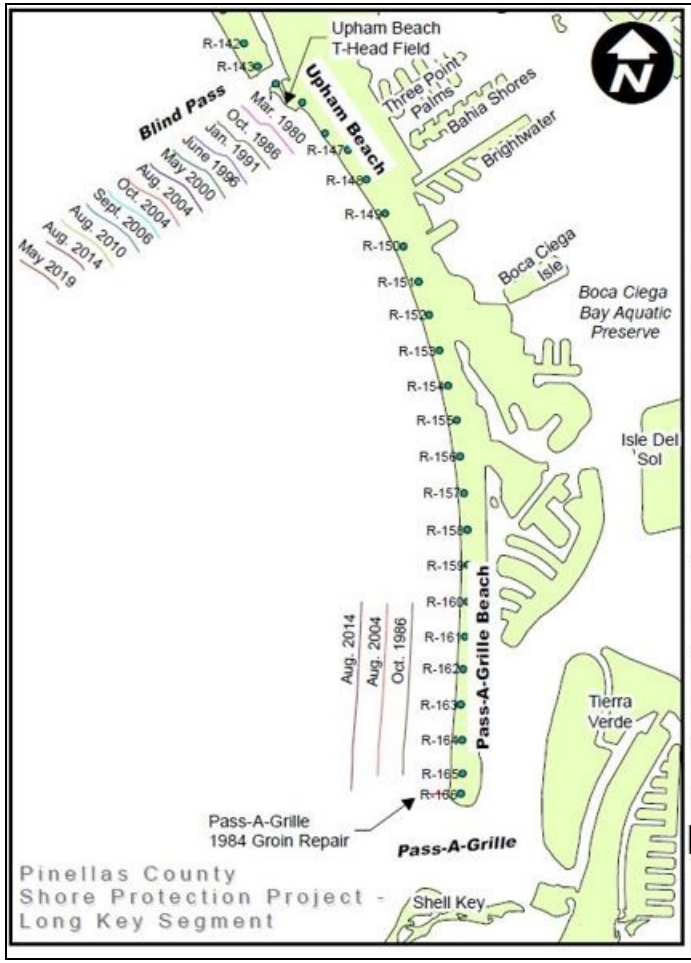


Figure A- 4. Long Key History of Federal Participation



Construction Completion Date	Event Type	Location (R-mon)	Volume (CY)	Borrow Source
Mar-80	Initial Restoration	Upham Beach (R144-R146)	253,760	Blind Pass
1984	Groin Rehabilitation	Pass a Grille (R166)	n/a	n/a
Oct-86	1st Nourishment	Upham Beach (R144-R146)	96,712	Pass a Grille's Ebb Shoal
	Initial Restoration	Pass a Grille (R160 R165)	73,000	
Jan-91	2nd Nourishment	Upham Beach (R144-R146)	229,950	Pass a Grille's Ebb Shoal
Jun-96	3rd Nourishment	Upham Beach (R144-R146)	252,950	West Egmont Shoal
May 2000[1]	4th Nourishment	Upham Beach (R144-R146)	358,900	John & Blind Pass
Aug-04	5th Nourishment	Upham Beach (R144-R146)	366,092	Pass a Grille's Ebb Shoal
	2nd Nourishment	Pass a Grille (R160 R165)	147,000	
May-06[2]	Temporary T-Head Groin Field	Upham Beach (R144-R146)	n/a	n/a - -
Oct-04	Emergency	Upham Beach (R144-R146)	41,670	Pass a Grille's Ebb Shoal
Sep-06	Emergency	Upham Beach (R144-R146)	104,636	West Egmont Shoal
2010	6th Nourishment	Upham Beach (R144-R146)	159,572	Blind Pass
Aug-14	7th Nourishment	Upham Beach (R144-R146)	160,545	East Egmont Shoal
	3rd Nourishment	Pass a Grille (R160 R166)	140,053	
Oct-18[3]	Permanent T-Head Groin Field	Upham Beach (R144-R146)	n/a	n/a
May-19	8th Nourishment	Upham Beach (R144-R146)	150,854	Blind Pass

1. Oil discovered in Blind Pass associated with tanker spill within Tampa Harbor
2. Construction begin to Installed five (5) Temporary Geotextile T-Heads began with 2004 project and completed in May 2006.
3. Construction began on July 2017 to remove all the temporary Geotubes and install four (4) permanent T-Heads on April 2019

Figure A- 5. Map of Previous Long Key Renourishment Events and Tabulated Volumes

There are 365 WIS stations along the Gulf of Mexico shoreline. WIS Station 73268 is representative of offshore wind and wave conditions for the project area. **Table A- 1** provides a summary of wind data from WIS Station 73268, located at latitude 27.75, longitude -82.9 (approximately 8 miles west of the project area). This table contains a summary of average wind speeds and frequency of occurrence broken down into eight 45 degree angle-bands and shows that annual average winds are predominantly from the east. The wind rose presented in **Figure A- 6** provides a further breakdown of winds in the project area.

Table A- 1. Average Wind Conditions

Wind Direction (from)	WIS Station #73268 (1980 – 2014)	
	Percentage Occurrence (%)	Average Wind Speed (mph)
North	12.7	14.9
Northeast	17.9	14.2
East	21.6	12.5
Southeast	14.1	11.8
South	10.3	11.8
Southwest	7.4	11.1
West	7.0	11.4
Northwest	9.0	14.2

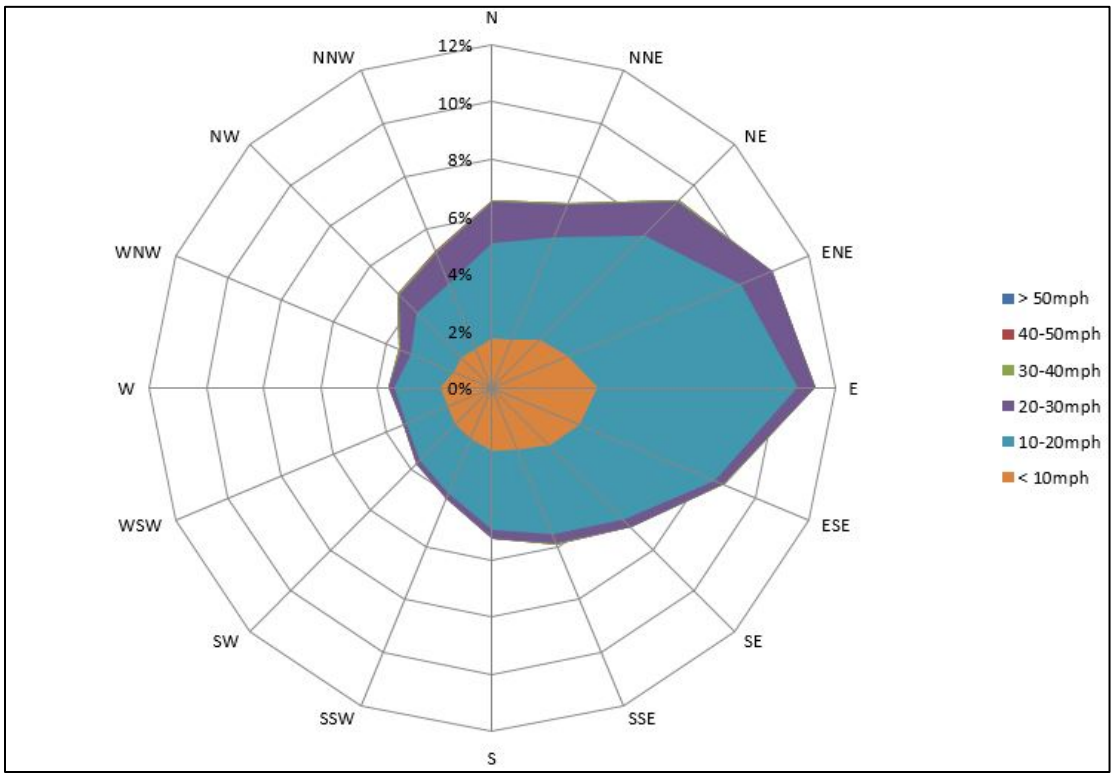


Figure A- 6. Wind Rose – WIS Station 73268

Wind conditions in Coastal Florida are seasonal. A further breakdown of the wind data provides a summary of the seasonal conditions (**Table A- 2**).

Between December and March, frontal weather patterns driven by cold Arctic air masses can extend as far as South Florida. These events (referred to as "Northeasters") generate winds that are predominantly from the northeast quadrant. In the vicinity of Pinellas County, these northeast winter winds are impacted by the Florida land mass but maintain a predominantly northeasterly direction. While Northeasters often result in wave conditions that cause extensive beach erosion on the east coast of Florida, the west coast of Florida experiences little impact from these events.

During summer and fall months (June through November) low pressure systems traversing the region often develop into tropical storms and hurricanes, which can generate devastating winds, waves, and storm surge. These intense seasonal events will be discussed in greater detail under **Section 4.5: Storm Effects**. In the vicinity of Pinellas County, summer winds are predominantly from the east. In the fall, winds shift to the northeast.

In addition to storm winds, the project area also experiences daily breezes. These onshore and offshore winds result from differential heating of land and water masses and typically blow perpendicular to the shoreline. While these breezes play a significant role in local weather patterns, they are not an appreciable cause of sediment movement in the nearshore.

Table A- 2. Seasonal Wind Conditions

Month	WIS Station #73268 (1980 – 2014)	
	Average Wind Speed (mph)	Predominant Direction (from)
January	15.2	NE
February	14.4	N
March	14.0	E
April	12.6	E
May	10.8	E
June	10.2	E
July	9.9	E
August	10.1	E
September	12.2	E
October	14.6	NE
November	15.7	NE
December	15.3	NE

4.2 Waves

Energy dissipation that occurs as waves enter the nearshore zone and break is the principal method of sediment transport. Wave height and period, in combination with tides and storm surge, are the most important factors influencing the behavior of the shoreline. The Pinellas County study area is exposed predominantly to short period wind-waves with occasional exposure to longer period open-ocean storm swells (tropical storm events). However, the limited fetch of the Gulf of Mexico basin and relatively extensive shallow shelf fronting the island limits the size and associated period of significant storm waves.

Wave data for this report were obtained from the USACE WIS hindcast database for the Gulf of Mexico. As previously discussed, WIS station 73268 was selected for the study. Given the relatively shallow depth at this station (23 feet), and the smooth depth contours between the station and shoreline, wave conditions at 73268 are considered to be representative of nearshore wave conditions.

Table A- 3 summarizes the percentage of occurrence and average wave height of the WIS waves by direction. Average wave heights range from 0.8 feet to 1.9 feet, indicating a generally mild wave climate year round. Wave directions are generally from the northwest and south quadrants. This can be seen in greater detail in the wave rose presented in **Figure A- 7**. A seasonal breakdown of wave heights shows that higher wave heights are more frequent in the fall and winter months (November through February) and tend to originate from the northwest quadrant (**Table A- 3**). Spring, summer, and early fall waves (March through October), are smaller and originate predominantly from the south to southeast.

Table A- 4 provides a seasonal breakdown of percent occurrence by wave period. From this table, it can be seen that short period, locally-generated wind waves are common throughout the year. The yellow highlighted values (in this case, entirely in the first row of the table) show the dominant wave period for each month. None of the dominant periods are greater than 4.0 seconds.

Table A- 3. Seasonal Wave Conditions

Month	WIS Station #73285 (1980-2014)	
	Average Wave Height (feet)	Predominant Direction (from)
January	1.9	NW
February	1.8	NW
March	1.7	S
April	1.4	S
May	0.9	S
June	0.8	S
July	0.8	S
August	0.8	S
September	1.0	S
October	0.8	S
November	1.7	NW
December	1.8	NW

4.3 Tides

Astronomical tides are created redominantly by the gravitational pull of the moon and sun and are predictable in magnitude and timing. The National Oceanic and Atmospheric Administration (NOAA) regularly publishes tide tables for selected locations along the coastlines of the Unites States and selected locations around the world. These tables provide times of high and low tides, as well as predicted tidal amplitudes.

Tidal datums were for Treasure Island and Long Key were obtained from NOAA tide stations 8726533 Johns Pass, FL and 8726428 Tierra Verde, FL, respectively. Tidal datums are summarized in **Table A- 5**. The tide range (the difference between Mean High Water and Mean Low Water) is 1.45 feet at Treasure Island and 1.55 feet at Long Key.

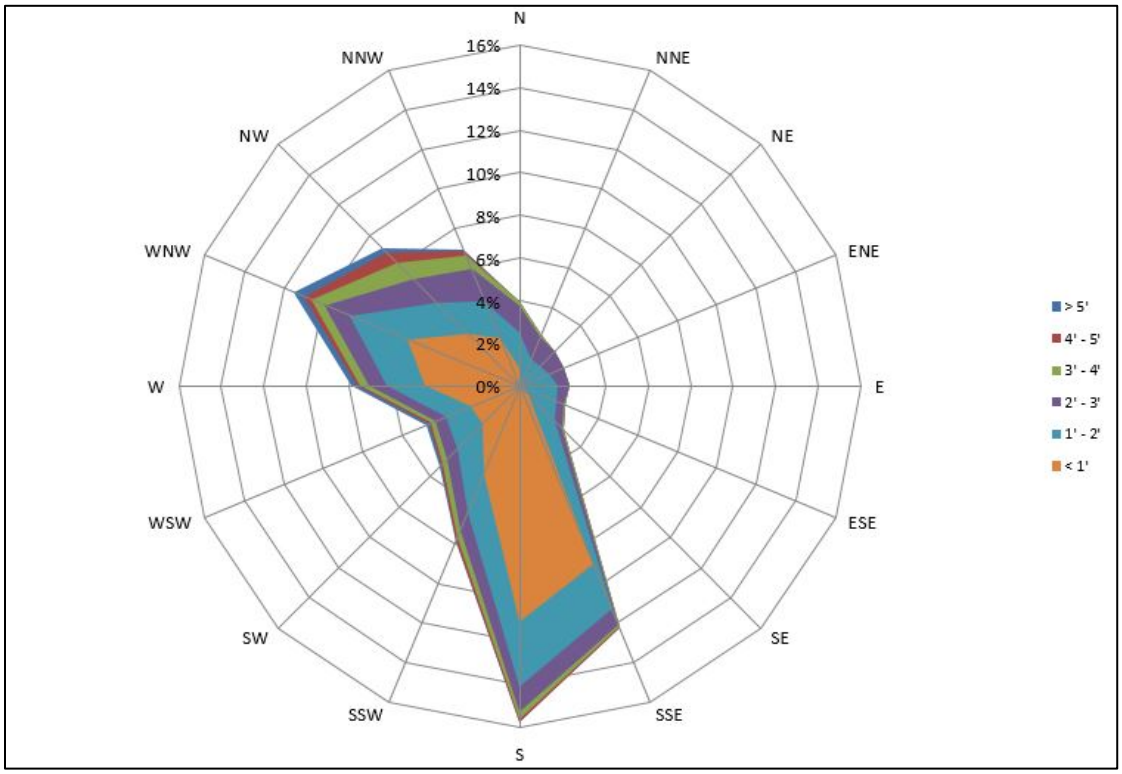


Figure A- 7. Wave Rose – WIS Station 73268

Table A- 4. Wave Period – Percent Occurrence

Wave Period	Percent Occurrence by Wave Period Band											
(Sec)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
< 4.0	53.2	54.3	53.1	57.3	73.0	69.4	68.7	68.8	73.1	76.1	70.0	60.1
4.0 - 4.9	19.4	20.1	22.0	24.3	20.4	24.3	24.8	23.0	15.7	13.3	13.1	17.0
5.0 - 5.9	13.4	12.7	12.2	11.7	5.9	4.5	4.7	4.6	4.9	5.1	8.5	9.8
6.0 - 6.9	5.7	5.4	5.4	4.0	0.5	0.8	0.6	0.9	1.5	2.3	3.8	4.7
7.0 - 7.9	3.5	3.4	3.1	1.1	0.1	0.3	0.3	0.5	1.0	0.9	2.2	3.3
8.0 - 8.9	2.6	2.1	2.1	0.9	0.0	0.4	0.3	0.5	0.9	0.8	1.2	2.7
9.0 - 9.9	1.6	1.2	1.2	0.5	0.0	0.2	0.4	0.7	0.9	0.4	0.8	1.8
10.0 - 10.9	0.6	0.5	0.5	0.1	0.0	0.1	0.1	0.5	0.7	0.3	0.2	0.6
11.0 - 11.9	0.1	0.3	0.3	0.1	0.0	0.0	0.1	0.3	0.7	0.4	0.1	0.2
> 12.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.7	0.5	0.1	0.0

Table A- 5. Tidal Datums

Tidal Datum	Elevation (feet) Relative to NAVD88	
	Station 8726533	Station 8726428
Mean Higher High Water (MHHW)	0.81	0.61
Mean High Water (MHW)	0.46	0.34
North American Vertical Datum (NAVD88)	0.00	0.00
Mean Sea Level (MSL)	-0.28	-0.41
Mean Low Water (MLW)	-0.99	-1.21
Mean Lower Low Water (MLLW)	-1.43	-1.55

4.4 Storm Effects

The shoreline of Pinellas County is influenced by tropical systems during the summer and early fall. Unlike shorelines along the east coast of Florida, Pinellas County is less influenced by northeaster storm activity which typically occurs in months between fall and early spring. However, during the late fall and winter, wave heights do increase slightly, predominantly coming from the northwest. Hurricanes typically generate larger waves and storm surge while winter storms typically have lesser waves, but longer duration and higher frequency.

During intense storm activity, the shoreline is expected to naturally modify its beach profile. Storms erode and transport sediment from the beach into the active zone of storm waves. Once caught in the waves, this sediment is carried along the shore and re-deposited farther down the beach, or is carried offshore and stored temporarily in submerged sand bars. Periodic and unpredictable hurricanes and coastal storms, with their intense breaking waves and elevated water levels, can change the width and elevation of beaches and accelerate erosion. After storms pass, gentle waves usually return sediment from the sand bars to the beach, which is restored gradually to its natural shape. While the beach profile typically recovers from storm energy as described, extreme storm events may cause sediment to leave the beach system entirely, sweeping it into inlets or far offshore into deep water where waves cannot return it to the beach. Therefore, a portion of shoreline recession due to intense storms may never fully recover.

Pinellas County is located in an area of significant storm activity. **Figure A- 8** shows historic tracks of hurricanes and tropical storms from 1852 to 2017 as recorded by the National Hurricane Center (NHC). These hurricane data are available from the National Oceanic and Atmospheric Administration (http://coast.noaa.gov/hurricanes). The shaded circle in the center of this figure indicates a 50-nautical mile radius drawn from the center of the study area (Treasure Island and Long Key). Based on NHC records, 57 tropical storms have passed within this 50-mile radius over the 166-year period of record. The 50-mile radius was chosen for display purposes in **Figure A- 8** because any tropical disturbance passing within this distance, even a weak tropical storm, would be likely to produce some damage along the shoreline. Stronger storms are capable of producing significant damage to the coastline from far greater distances.

In recent years, a number of named storms, passing within the 50 mile radius have significantly impacted the project area, including Tropical Storm Barry (2007), Tropical Storm Emily (2017), Hurricane Irma (2017). Damages from these storms, as well as from more distant storms causing indirect impacts, included substantial erosion and damage from winds, waves, and elevated water levels.

4.5 Storm Surge

Storm surge is defined as the rise of the ocean surface above its astronomical tide level due to storm forces. Surges occur primarily as a result of atmospheric pressure gradients and surface stresses created by wind blowing over a water surface. Strong onshore winds pile up water near the shoreline, resulting in super-elevated water levels along the coastal region and inland waterways. In addition, the lower atmospheric pressure which accompanies storms also contributes to a rise in water surface elevation. Extremely high wind velocities coupled with low barometric pressures (such as those experienced in tropical storms, hurricanes, and very strong northeasters) can produce very high, damaging water levels. In addition to wind speed, direction and duration, storm surge is also influenced by water depth, length of fetch (distance over water), and frictional characteristics of the nearshore sea bottom. An estimate of

storm surge is required for the design of beach fill crest elevations. An increase in water depth may increase the potential for coastal flooding and allow larger storm waves to attack the shore.

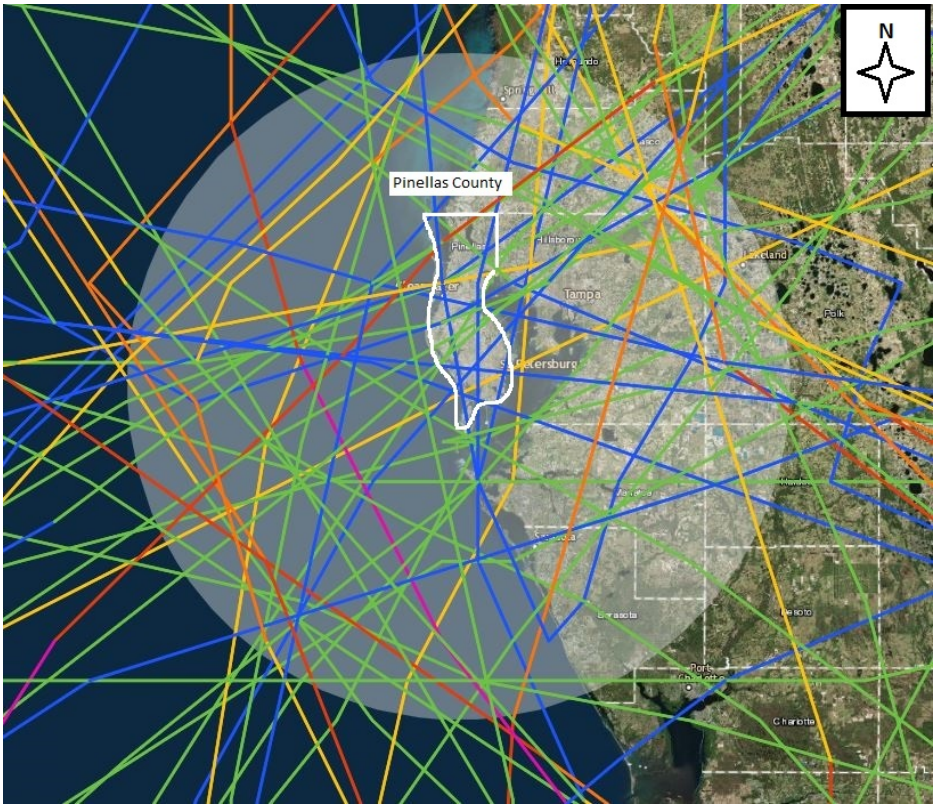


Figure A- 8. Historic storm tracks – Hurricanes and Tropical Storms (1852 – 2017, 50 mile radius)

The dune system along the Treasure Island segment of the study area has an average elevation range of approximately +5 ft-NAVD88 to +9 ft-NAVD88. Along Long Key the average elevation range is approximately +7 ft-NAVD88 to +10 ft-NAVD88. Both project segments are susceptible to overtopping from extreme storm surges. This can be seen from **Table A- 6** which provides surge levels vs storm frequency for both Treasure Island and Long Key, taken from the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) conducted in 2009 (FEMA, 2009). The storm surge elevations presented include the effects of astronomical high tide and wave setup.

Table A- 6. Storm Tide Elevations

Return Period (Years)	Annual Exceedance Probability	Total Storm Tide Level (Feet, NAVD88)	
		Treasure Island	Long Key
10	10%	4.7	4.5
50	2%	8.1	7.5
100	1%	11.2	10.3
500	0.2%	12.7	12.2

4.6 Sea Level Rise

4.6.1 Relative Sea Level Rise

Relative Sea Level Change (RSLC) was calculated using the USACE Sea Level Change Curve Calculator which is available at: http://www.corpsclimate.us/ccaceslcurves.cfm. This Calculator uses the methodology described in Engineer Regulation (ER) 1100-2-8162, *Incorporating Sea Level Changes in Civil Works Programs* (USACE 2013).

Extreme water levels (EWL) incorporated into the calculator are based on statistical probabilities using recorded historic monthly extreme water level values. EWL analysis is described below. *NOAA Technical Report NOS CO-OPS 067 - Extreme Water Levels of the United States 1893-2010* describes the methods and data used in the calculation of the exceedance probability levels using a generalized extreme value (GEV) statistical function (NOAA 2013). The USACE method uses the same NOAA recorded monthly extreme values in a percentile statistical function. Both methods use data recorded and validated by NOAA at the long-term, established tide gauges. The extreme values at the gauge can be significantly different than what may occur at the project site due to differences in site characteristics and complex interactions of physical forces that vary between the locations. The level of confidence in the exceedance probability decreases with longer return periods. Additional information is available at the CO-OPS website at: http://tidesandcurrents.noaa.gov/est/.

Relative sea level (RSL) refers to local elevation of the sea with respect to land, including the lowering or rising of land through geologic processes such as subsidence and glacial rebound. It is anticipated that sea level will rise within the next 100 years. To incorporate the direct and indirect physical effects of projected future sea-level change on design, construction, operation, and maintenance of coastal projects, the USACE has provided guidance in EC 1165-2-212 (USACE, 2012) which has been superseded by ER 1100-2-8162, Engineer Technical Letter (ETL) 1100-2-1 (USACE 2013, 2014), and Engineering Pamphlet 1100-2-1 (USACE, 2019).

ER 1100-2-8162 provides both a methodology and a procedure for determining a range of sea level change estimates based on global sea level change rates, the local historic sea level change rate, the construction (base) year of the project, and the design life of the project. Three estimates are required by the guidance, a Low (Baseline) estimate representing the minimum expected sea level change, an Intermediate estimate, and a High estimate representing the maximum expected sea level change. These estimates are referenced to the midpoint of the latest National Tidal Datum epoch, 1992. The reader is referred to ER 1100-2-8162 for a detailed explanation of the procedure, equations employed and variables included to account for the eustatic change as well as site specific uplift or subsidence to develop corrected rates.

Based on historical sea level measurements taken from NOS gage 8726520 at St. Petersburg, Florida, the historic sea level change rate *(e+M)* was determined from the USACE sea-level change curve calculator (http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html). The economic analysis period for this study begins with a Beach-fx model start date of 2027 (economic base year of 2028) and extends to the end of the project life in 2078. The USACE calculator gives a SLC rate of 2.36 mm/yr from a continuous 60 year record (1947 to 2007). However, NOAA (https://tidesandcurrents.noaa.gov/sltrends) reports that the mean sea level trend is 2.86 mm/year (0.0094 feet/year) with a 95% confidence interval of +/- 0.24 mm/year (0.0008 feet/year) based on monthly mean sea level data over a continuous 72 year

record (1947 to 2019) (**Figure A- 9**). Therefore, SLC curves and extreme water level data generated using the USACE sea-level change curve calculator are likely to under predict when compared with information presented by NOAA.

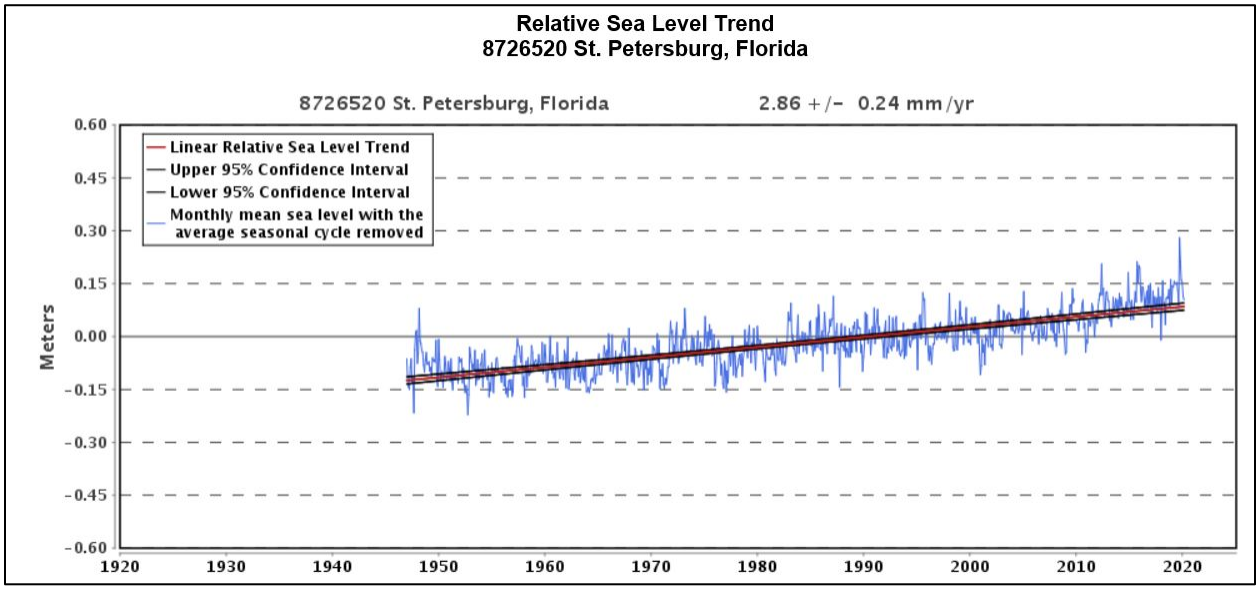


Figure A- 9. Relative Sea Level Trend, NOAA Gauge 8726520 (1947 to 2019)

Applying the USACE SLC curve calculator, the 2.36 mm/yr rate is equivalent to a change of 0.67 feet between 1992 and 2078 or a change of 0.38 feet over the life of the project, beginning in the project start year (2027 to 2078). The USACE Intermediate rate was determined to be 5.64 mm/year (0.0185 feet/year). The USACE High rate was determined to be 16.03 mm/year (0.0526 feet/year). These results in an Intermediate and High change in sea level between the project start year (2027) and the end of the project life (2078) of 0.94 feet and 2.68 feet, respectively. **Figure A- 10** shows RSLC from 1992 and 2078 for all three USACE curves.

The FEMA Base Flood Elevation (BFE), defined as the 1% Annual Exceedance Probability (AEP) Flood, is the regulatory requirement for the elevation or floodproofing of structures and are referenced to FEMA panels (**Figure A- 11**). BFE (relative to NAVD88) at Treasure Island and Long Key is 11.2 feet and 10.3 feet, respectively (Section 4.5: Storm Surge). Using the SLR calculator, the BFE (based on National Tidal Datum Epoch 1992) was plotted relative to relative sea level change for both Treasure Island and Long Key (**Figure A- 12** and **Figure A- 13**). Tidal datums and extreme water levels (including the BFE) are shown in **Figure A- 14** and **Figure A- 15**.

4.7 Storm Tide and Back Bay Flooding

Potential impacts of rising sea level on total water levels experienced at the site include overtopping of waterside structures, increased shoreline erosion, and flooding of low lying areas. Cross-sections were drawn along the Treasure Island and Long Key project segments at each model reach to determine the range of elevations across the barrier island. Elevations were plotted with the BFE (100 year) as well as the 10% (10 Year), 2% (50 Year), and 0.2% (500 Year) AEP water elevations. Transect locations and corresponding cross-sections are shown in Attachment 1. These figures indicate that Treasure Island

and Long Key are susceptible to widespread flooding during a 10% AEP (10 Year) flood event with near total inundation at the 2% AEP (50 Year) flood elevation.

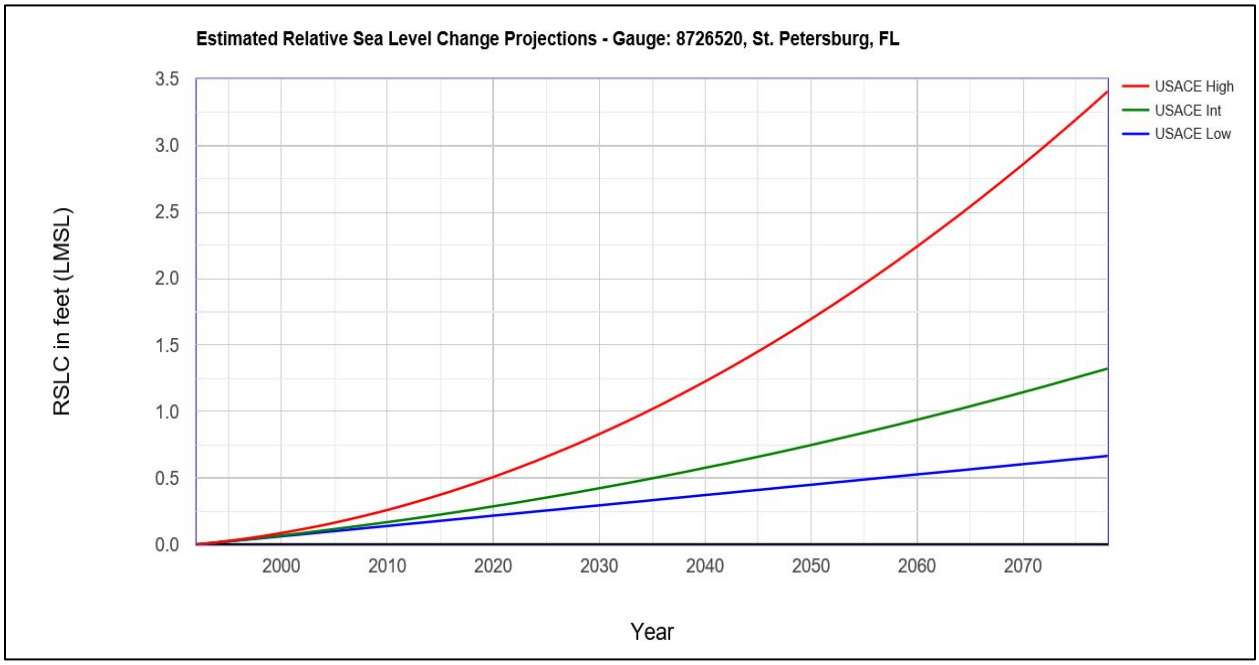


Figure A- 10. USACE Project Sea Level Change

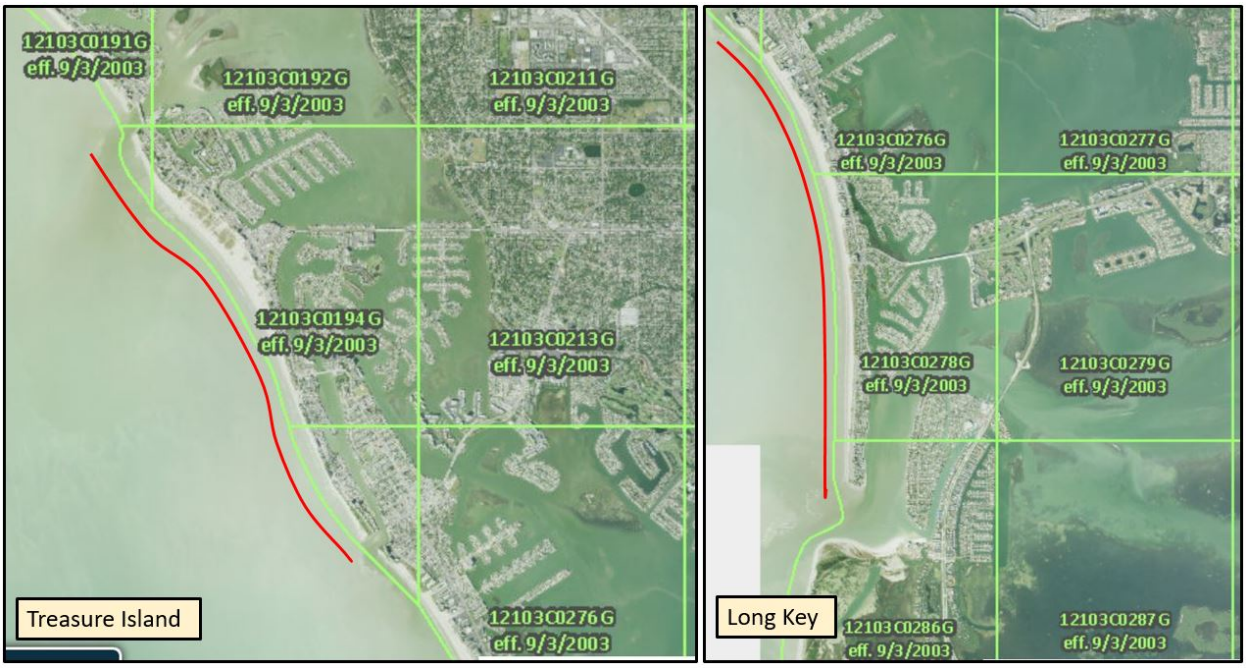


Figure A- 11. FEMA Flood Map Panels for Treasure Island and Long Key
https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html

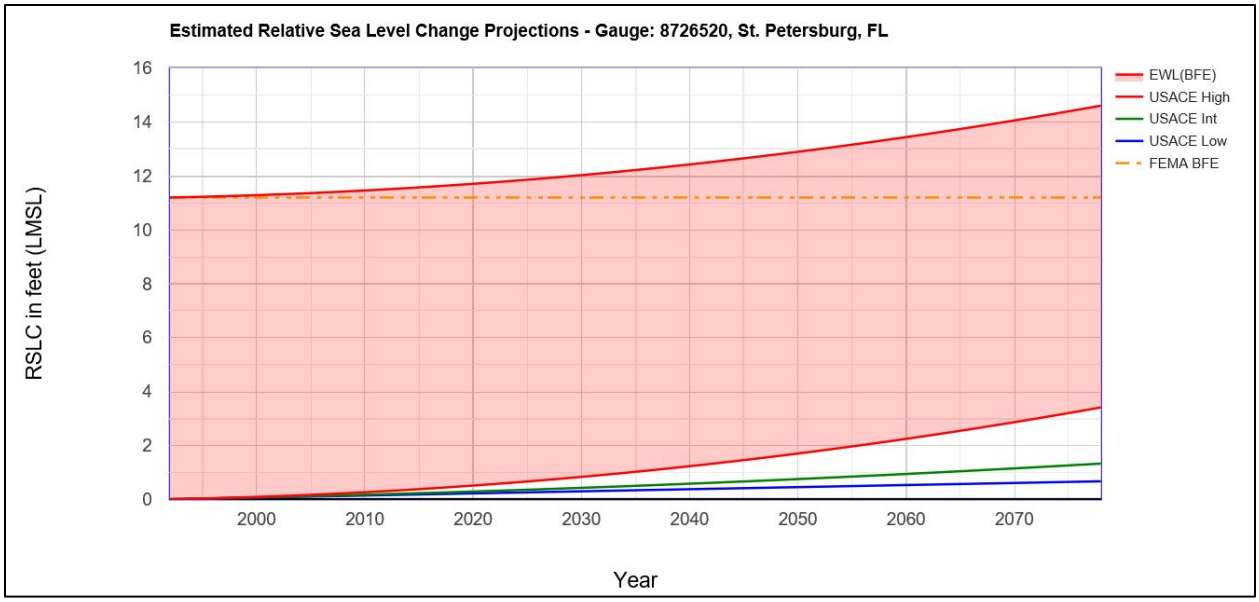


Figure A- 12. Estimated Relative Sea Level Change with Treasure Island BFE

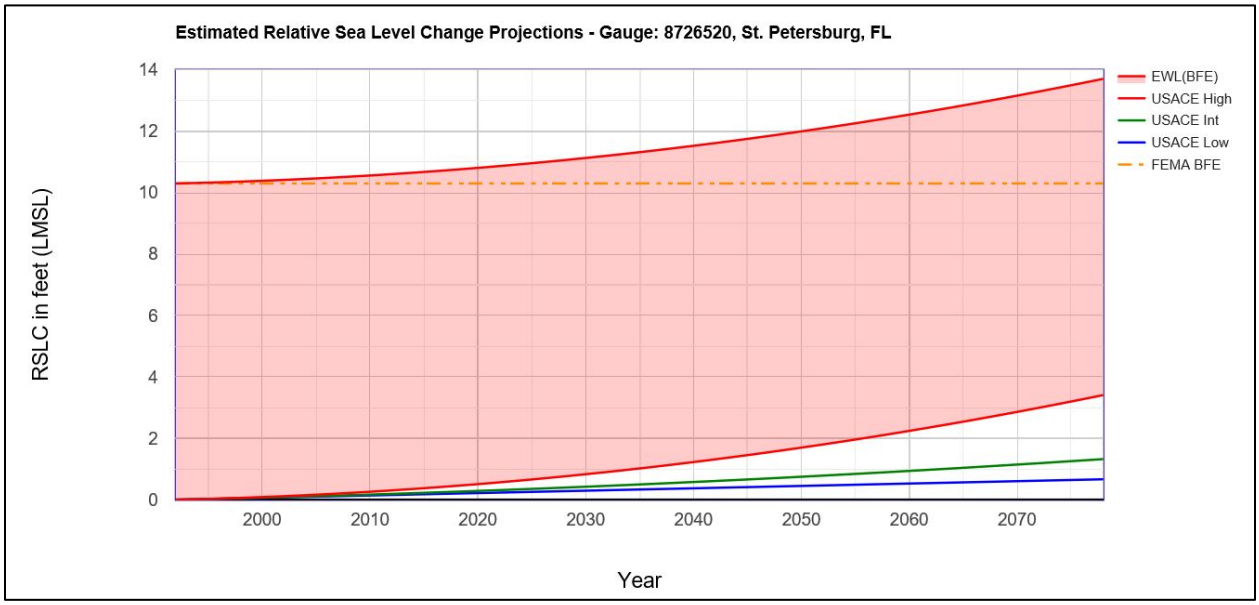


Figure A- 13. Estimated Relative Sea Level Change with Long Key BFE

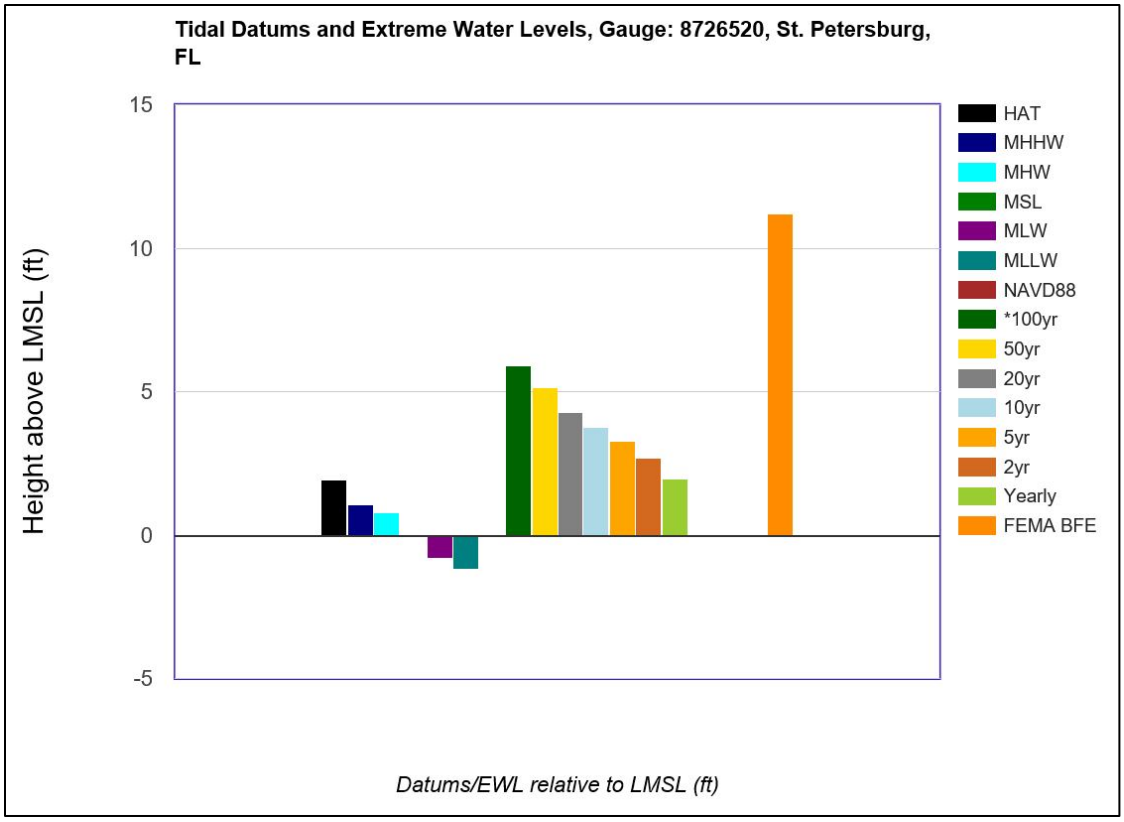


Figure A- 14. Tidal Datums and Extreme Water Levels (Treasure Island)

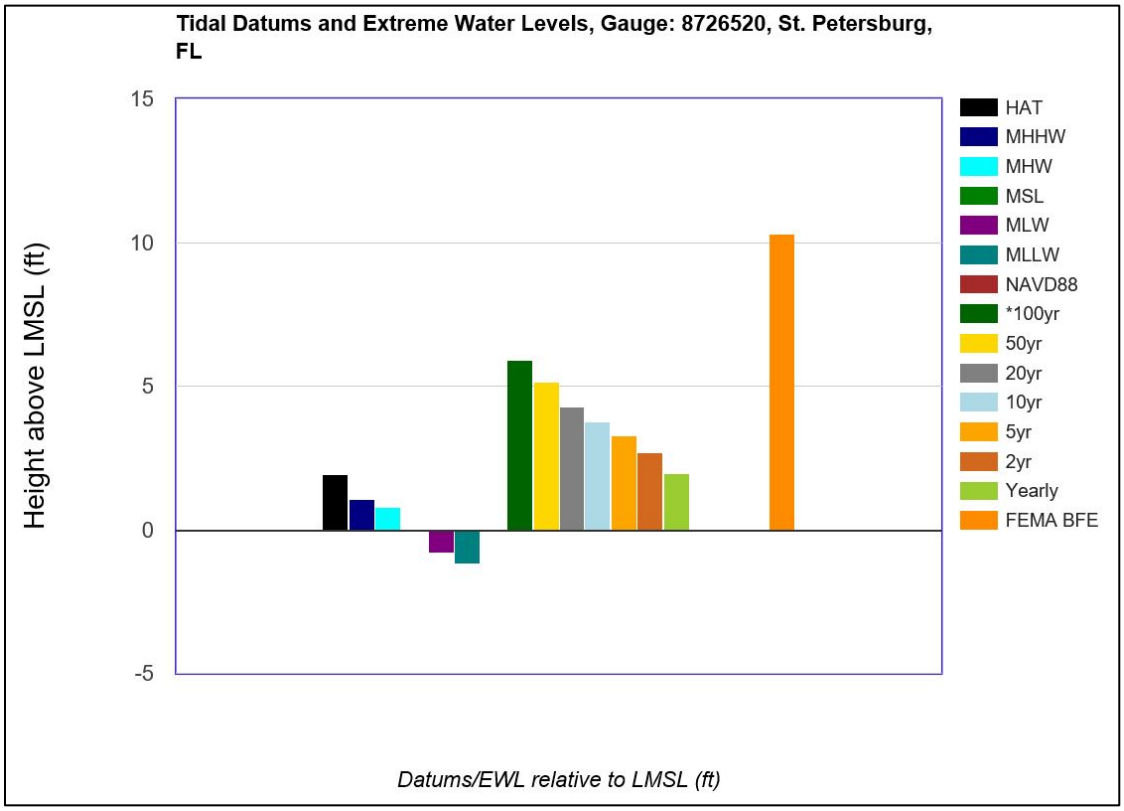


Figure A- 15. Tidal Datums and Extreme Water Levels (Long Key)

In general, RSLC (Baseline, Intermediate, and High) will not affect the overall function of the project. Relative vulnerability to flooding during extreme events is consistent between both with and without project conditions. However, low elevation on the interior sides of the two barrier islands make them highly vulnerable to back bay flooding. Therefore, the primary protection offered by the existing (and possible future) renourishment project is against erosion and wave damages. Increasing sea levels will increase the back bay vulnerability making it more likely that ocean side renourishment will need to be combined with more comprehensive flood management measures than to be implemented as a standalone project.

4.8 Existing Shoreline Armor

Historically, the threat that shoreline erosion has posed to infrastructure has resulted in coastal armoring throughout a portion of the Treasure Island and Long Key segments. For more information on the distribution of armor see Appendix B: Economics.

5 Effects of Adjacent Features

5.1 Inlet Effects

Both Treasure Island and Long Key are significantly influenced by inlets adjacent to the project area. Johns Pass lies immediately to the north of Treasure Island, Blind Pass separates Treasure Island and Long Key, and Pass-a-Grille Inlet lies immediately to the south of Long Key. Tidal currents associated with each inlet impact littoral transport of sediment at the northern and southern tips of both barrier islands leading to high rates of erosion in those areas and resulting in the deposition of littoral sediments within the inlet channels. A detailed description of Johns Pass, Blind Pass, and Pass-a-Grille Inlet, including dredge histories and sediment budgets for adjacent beaches are provided in their respective inlet management plans (FDEP, 2018; FDEP, 2019; and FDEP, 2019).

6 Beach-*fx* Life-Cycle Shore Protection Project Evolution Model

Federal participation in Hurricane and Storm Damage Reduction (HSDR) projects is based on a favorable economic justification in which the benefits of the project outweigh the costs. Determining the Benefit to Cost Ratio (BCR) requires both engineering (project performance and evolution) and planning (alternative analysis and economic justification) analyses. The interdependence of these functions has led to the development of the life-cycle simulation model Beach-*fx*. Beach-*fx* combines the evaluation of physical performance and economic benefits and costs of shore protection projects (Gravens et. al., 2007), particularly beach nourishment, to form the basis for determining the justification for Federal participation. This section describes the engineering aspects of the Beach-*fx* model.

6.1 Background & Theory

Beach-*fx* is an event-driven life-cycle model. USACE guidance (USACE, 2017) requires that flood damage reduction studies include risk and uncertainty. The Beach-*fx* model satisfies this requirement by fully incorporating risk and uncertainty throughout the modeling process (input, methodologies, and output).

Over the project life-cycle, typically 50 years, the model estimates shoreline response to a series of historically based storm events. These plausible storms, the driving events, are randomly generated using a Monte Carlo simulation. The corresponding shoreline evolution includes not only erosion due to the storms, but also allows for storm recovery, post-storm emergency dune and/or shore construction, and planned nourishment events throughout the life of the project. Risk based damages to structures are estimated based on the shoreline response in combination with pre-determined storm damage functions for all structure types within the project area. Uncertainty is incorporated not only within the input data (storm occurrence and intensity, structural parameters, structure and contents valuations, and damage functions), but also in the applied methodologies (probabilistic seasonal storm generation and multiple iteration, life cycle analysis). Results from multiple iterations of the life cycle can be averaged or presented as a range of possible values.

The project site itself is represented by divisions of the shoreline referred to as "Reaches". Because this term may also be used to describe segments of the shoreline to which project alternatives are applied, Beach-*fx* reaches will be referred to in this appendix as "Model reaches". Model reaches are contiguous, morphologically homogenous areas that contain groupings of structures (residences, businesses, walkovers, roads, etc…), all of which are represented by Damage Elements (DEs). DEs are grouped within divisions referred to as Lots. **Figure A- 16** shows a graphic depiction of the model setup. For further details about the specifics of Lot extents and DE grouping see the Economics Appendix.

Each model reach is associated with a representative beach profile that describes the cross-shore profile of the reach. While an effort is made to designate model reaches to include a single DNR monument (FDEP R-monument) from which historical survey data can be used to establish a representative profile for that reach, the positioning of the monument within each reach and the length of each reach are variable. Multiple model reaches may share the same representative beach profile and groupings of model reaches may represent a single design reach. For Treasure Island, the project area consists of 14 representative profiles divided between 18 model reaches. For Long Key, the project area consists of 16 representative profiles divided between 22 model reaches. **Table A- 7** provides representative profiles, model reach identifiers, and the FDEP R-monument that falls within the borders of each model reach.

Implementation of the Beach-*fx* model relies on a combination of meteorology, coastal engineering, and economic analyses and is comprised of four basic elements:

- Meteorological driving forces
- Coastal morphology
- Economic evaluation
- Management measures

The subsequent discussion in this section addresses the basic aspects of implementing the Beach-*fx* model. For a more detailed description of theory, assumptions, data input/output, and model implementation, refer to Gravens et al. (2007), Males et al. (2007), and USACE (2009).

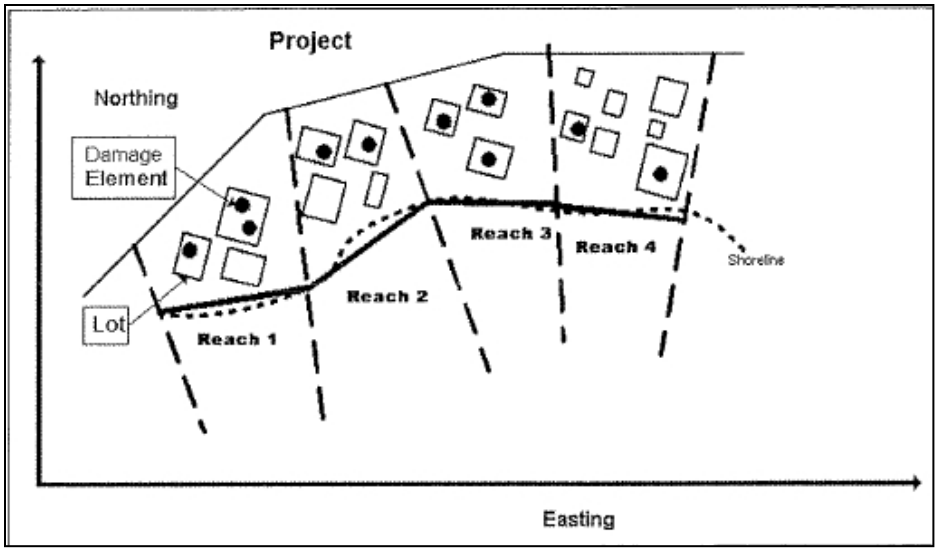


Figure A- 16. Beach-*fx* Model Setup Representation

Table A- 7. Model Reaches

Treasure Island			Long Key		
Representative Profiles	**Model Reaches**	**R-monuments**	**Representative Profiles**	**Model Reaches**	**R-monuments**
TI01	R126	R-126	LK01	R144A	R-144A
TI02	R127	R-127	LK02	R144B	R-144B
TI03	R128	R-128		R144C	R-144C
TI04	R129	R-129	LK03	R145	R-145
TI05	R130	R-130	LK04	R146	R-146
	R131	R-131	LK05	R147	R-147
	R132	R-132	LK06	R148	R-148
TI06	R133	R-133	LK07	R149	R-149
TI07	R134	R-134		R150	R-150
TI08	R135	R-135		R151	R-151, R-152
TI09	R136	R-136	LK08	R153	R-153, R-154
TI10	R137	R-137	LK09	R155	R-155
TI11	R138	R-138	LK10	R156	R-156
TI12	R139	R-139	LK11	R157	R-157
TI13	R140	R-140	LK12	R158	R-158
	R141	R-141		R159	R-159
	R142	R-142	LK13	R160	R-160
TI14	R143	R-143		R161	R-161
				R162	R-162
			LK14	R163	R-163
			LK15	R164	R-164
			LK16	R165	R-165, R-166

6.2 Meteorological Driving Forces

The predominant driving force for coastal morphology and associated damages within the Beach-*fx* model is the historically based set of storms that is applied to the life-cycle simulation. The predominant driving force for erosion, inundation, and wave damages on western coast of Florida is tropical storms (hurricanes) in the summer months. Extra-tropical storms are mild compared to east coast Northeasters and do not significantly impact morphological changes beyond their contribution to the background erosion rate. Obtained from Ocean Weather Incorporated (OWI), the historical wave and water level records resulted in a plausible storm dataset based on 37 tropical storms occurring between 1886 and 2001 and 25 extra-tropical storms covering 1958 to 2017.

Because tropical storm events tend to be of limited duration, passing over a given site within a single portion of the tide cycle, it is assumed that any of the historical storms could have occurred during any combination of tidal phase and tidal range. Therefore, each of the plausible storm hydrographs was combined with possible variations in the astronomical tide. This was achieved by combining the peak of each storm surge hydrograph with the astronomical tide at high tide, mean tide falling, low tide, and mean tide rising for each of three tidal ranges corresponding to the lower quartile, mean, and upper quartile tidal ranges. This resulted in 12 distinct combinations for each historically based tropical storm and a total of 444 tropical storm conditions in the plausible storm dataset.

In addition to the plausible storm dataset, the seasonality of the storms must also be specified. The desired storm seasons are based on the assumption that each plausible storm takes place within the season in which the original historical storm occurred. Probability is defined for each season through the Probability Parameter. The Probability Parameter is determined for each season and storm type by dividing the number of storms by the total number of years in the storm record. Four storm seasons were specified for Treasure Island and Long Key (**Table A- 8**).

Table A- 8. Treasure Island and Long Key Beach-*fx* Storm Seasons

Storm Season	Start Date	End Date	Extra-Tropical		Tropical	
			Number	Probability	Number	Probability
Extratrop Winter/Spring	Dec 1	Apr 31	23	0.38	0	0.00
Tropical Early Summer	May 1	Jul 31	0	0.00	13	0.12
Tropical Peak	Aug 1	Sep 30	1	0.02	15	0.13
Extratrop/Tropical	Oct 1	Nov 30	1	0.02	9	0.08

The combination of the plausible storm dataset and the specified storm season allows the Beach-*fx* model to randomly select from storms of the type that fall within the season currently being processed. For each storm selected, a random time within the season is chosen and assigned as the storm date. The timing of the entire sequence of storms is governed by a pre-specified minimum storm arrival time. A minimum arrival time of 7 days was specified for Pinellas County. Based on this interval the model attempts to place subsequent storm events outside of a 14 day window surrounding the date of the previous storm (i.e. a minimum of 7 days prior to the storm event and a minimum of 7 days following the storm event). The model does allow the user to set different minimum arrival times for extra-tropical and tropical storms. Due to the probabilistic nature of the model the minimum arrival time may be overridden as warranted during the course of the life cycle analysis.

6.3 Coastal Morphology

The Beach-*fx* model estimates changes in coastal morphology through four primary mechanisms:

- Shoreline storm response
- Applied shoreline change
- Project-induced shoreline change
- Post-storm berm recovery

Combined, these mechanisms allow for the prediction of shoreline morphology for both with and without project conditions.

6.3.1 Shoreline Storm Response

Shoreline storm response is determined by applying the plausible storm set that drives the Beach-*fx* model to simplified beach profiles that represent the shoreline features of the project site. For this study, application of the storm set to the idealized profiles was accomplished with the SBEACH coastal processes response model (Larson and Kraus, 1989). SBEACH is a numerical model which simulates storm-induced beach change based on storm conditions, initial profiles, and shoreline characteristics such as beach slope and grain size. Output consists of post-storm beach profiles, maximum wave height and wave period information, and total water elevation including wave setup. Pre- and post-storm profiles, wave data, and water levels can be extracted from SBEACH and imported into the Beach-*fx* Shore Response Database (SRD). The SRD is a relational database used by the Beach-*fx* model to pre-store results of SBEACH simulations of all plausible storms impacting a pre-defined range of anticipated beach profile configurations.

6.3.1.1 Idealized Representative Profiles

In order to develop the idealized SBEACH profiles from which the SRD was derived, it was necessary to first develop representative profiles for the project shoreline. The number of representative profiles developed for any given project depends on the natural variability of shoreline itself. Typically, historical profiles at each FDEP R-monument would be compared over time, aligned, and then averaged into a composite profile representative of the shoreline shape at that given R-monument location. Composite profiles would then be compared and separated into groupings according to the similarity between the following seven dimensions:

- Upland elevation
- Dune slope
- Dune height
- Dune width
- Berm height
- Berm width
- Foreshore slope

6.3.1.2 Future Without Project (FWOP) Profiles

The base year for the present study is 2028. The model start year is required to be 2027. In order to determine the condition of the project shoreline at the model start year, historical surveys were studied. The most recent survey (prior to initiation of this study), was taken by the USACE in 2018 and was considered to be the closest representation of a projected 2027 shoreline.

Using the 2018 survey, fourteen representative profiles were developed for the Treasure Island segment and sixteen representative profiles were developed for Long Key. Using the representative profiles, idealized profiles representing the major dimensions of the profile were defined. **Table A- 9** and **Table A- 10** provide dimensions for each of the idealized pre-storm Beach-*fx* profiles.

6.3.1.3 SBEACH Methodology

SBEACH simulates beach profile changes that result from varying storm waves and water levels. These beach profile changes include the formation and movement of major morphological features such as longshore bars, troughs, and berms. SBEACH is a two-dimensional model that considers only cross-shore sediment transport. The model assumes that simulated profile changes are produced only by cross-shore processes. Longshore wave, current, and sediment transport processes are not included.

Table A- 9. Dimensions of Idealized Representative Profiles – Treasure Island

Profile	Model Reach	Upland Elevation (ft-NAVD88)	Dune Elevation (ft-NAVD88)	Dune Width* (ft)	Berm Elevation (ft-NAVD88)	Berm Width (ft)
TI01	R126	5	7	50	4.57	80
TI02	R127	5	8	20	4.57	45
TI03	R128	5	8	30	4.57	110
TI04	R129	5	5	50	4.57	700
TI05	R130, R131, R132	5	5	50	4.57	800
TI06	R133	5	5	50	4.57	500
TI07	R134	5	5	50	4.57	350
TI08	R135	6	7	80	4.57	100
TI09	R136	6	9	50	4.57	70
TI10	R137	6	6	50	4.57	50
TI11	R138	5	9	40	4.57	0
TI12	R139	5	5	20	4.57	50
TI13	R140, R141, R142	5	9	60	4.57	0
TI14	R143	6	7	60	4.57	150

* Note that the elevation between the upland and the dune may result in a low dune or no berm. In these cases the dune width represents the location on the profile where shoreline characteristics indicate a dune might be placed if included in a FWP project template.

Table A- 10. Dimensions of Idealized Representative Profiles – Long Key

Profile	Model Reach	Upland Elevation (ft-NAVD88)	Dune Elevation (ft-NAVD88)	Dune Width* (ft)	Berm Elevation (ft-NAVD88)	Berm Width (ft)
LK01	R144A	7	7	20	4.57	0
LK02	R144B, R144C	6	6	20	4.57	0
LK03	R145	6	7	60	4.57	220
LK04	R146	6	7	60	4.57	100
LK05	R147	6	9	25	4.57	200
LK06	R148	6	7	80	4.57	150
LK07	R149, R150, R151	5	7	50	4.57	280
LK08	R153	6	7	50	4.57	150
LK09	R155	5	8	100	4.57	100
LK10	R156	6	7	20	4.57	100
LK11	R157	5	9	15	4.57	0
LK12	R158, R159	5	10	40	4.57	0
LK13	R160, R161, R162	5	10	15	4.57	45
LK14	R163	5	10	10	4.57	10
LK15	R164	6	9	20	4.57	10
LK16	R165	5	8	90	4.57	10

* Note that the elevation between the upland and the dune may result in a low dune or no berm. In these cases the dune width represents the location on the profile where shoreline characteristics indicate a dune might be placed if included in a FWP project template.

SBEACH is an empirically based numerical model, which was formulated using both field data and the results of large-scale physical model tests. Input data required by SBEACH describes the storm being simulated and the beach of interest. Basic requirements include time histories of wave height, wave period, water elevation, beach profile surveys, and median sediment grain size.

SBEACH simulations are based on six basic assumptions:

- Waves and water levels are the major causes of sand transport and profile change
- Cross-shore sand transport takes place primarily in the surf zone
- The amount of material eroded must equal the amount deposited (conservation of mass)
- Relatively uniform sediment grain size throughout the profile,
- The shoreline is straight and longshore effects are negligible
- Linear wave theory is applicable everywhere along the profile without shallow-water wave approximations

Once applied, SBEACH allows for variable cross shore grid spacing, wave refraction, randomization of input waves conditions, and water level setup due to wind. Output data consists of a final calculated profile at the end of the simulation, maximum wave heights, maximum total water elevations plus setup, maximum water depth, volume change, and a record of various coastal processes that may occur at any time-step during the simulation (accretion, erosion, over-wash, boundary-limited run-up, and/or inundation).

6.3.1.4 SBEACH Calibration and Verification

Calibration of the SBEACH model was performed using wave height, wave period, and water level information from Tropical Storm Barry (2007) (**Figure A- 17**). Note that SBEACH generated graphics refer to elevations as "ft". However, these elevations (water levels and profiles) are referenced to NAVD88. Calibration of the model is required to ensure that the SBEACH model is tuned to provide realistic shore responses that are representative of the specific project location.

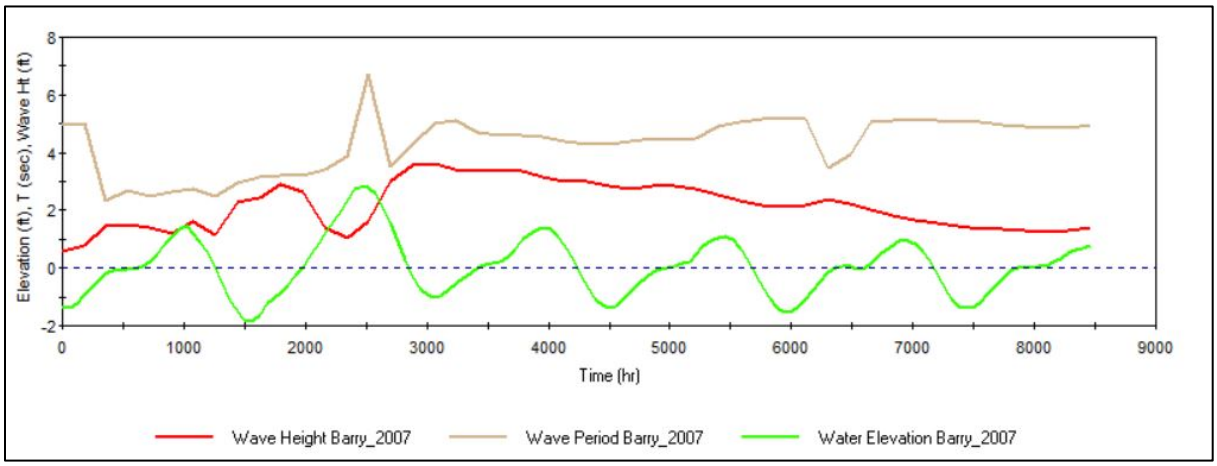


Figure A- 17. Tropical Storm Barry Wave and Water Level Data for SBEACH Calibration

Pre- and post-storm shoreline profiles were obtained from FDEP. Using the pre-storm profiles, SBEACH was then run with a range of values for an array of calibration parameters. **Table A- 11** provides the relevant beach characteristic and sediment transport calibration parameters as well as their final (best fit) calibrated values. Calibration parameters were verified using wave height, wave period, and water level information from Hurricane Irma (2017) (**Figure A- 18**). It should be noted that to calibrate SBEACH a smaller than expected grain size was required. It is believed that the higher erosion this generates in the model helps to reflect inlet effects from Johns Pass, Blind Pass, and Pass-a-Grille that are likely exacerbated during storm events.

Table A- 11. SBEACH Calibrated Beach Characteristic and Sediment Transport Parameters

Beach Characteristic		Sediment Transport	
Parameter	**Calibrated Value**	**Parameter**	**Calibrated Value**
Landward Surf Zone Depth	1.0 ft	Transport Rate Coefficient	2.5e-07 (m4/N)
Effective Grain Size	0.15 mm	Overwash Transport Parameter	0.0
		Coefficient for Slope-Dependent Term	0.005
Maximum Slope Prior to Avalanching	30	Transport Rate Decay Coefficient Multiplier	0.3
		Water Temperature	25degC

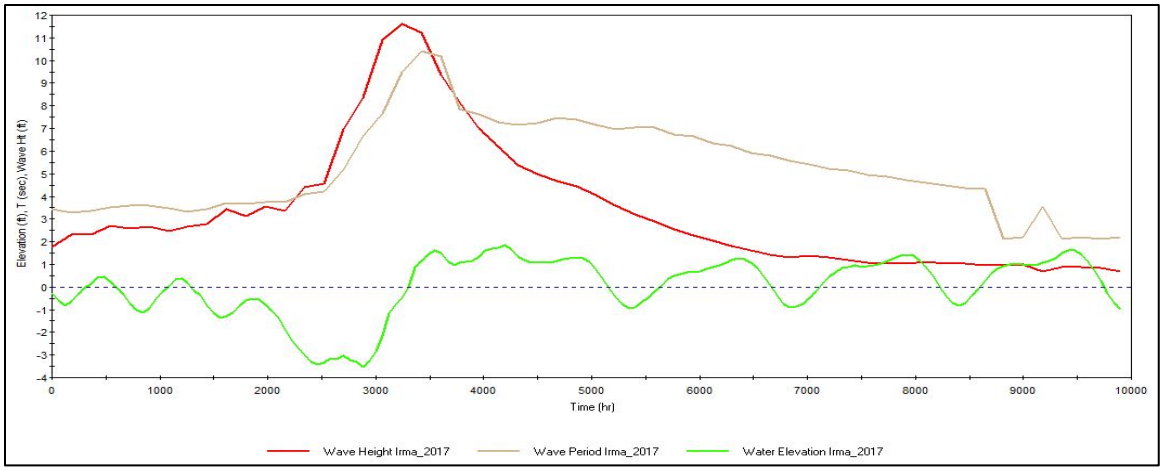


Figure A- 18. Hurricane Irma Wave and Water Level Data for SBEACH Verification

Figure A- 19 to **Figure A- 24** show a sample of calibration and verification SBEACH outputs.

6.3.1.5 SBEACH Simulations

Calibrated Treasure Island and Long Key SBEACH simulations were run for an array of future without project and with project (projected maximum potential dune and berm dimensions) idealized profiles in combination with each of the tropical and extra-tropical storms in the plausible storm database. This resulted in individual storm response profiles. From these profiles, changes in the key profile dimensions were extracted and stored in the combined Treasure Island and Long Key Beach-*fx* SRD.

6.3.2 Applied Shoreline Change

The applied shoreline change rate (in feet per year) is a Beach-*fx* morphology parameter specified at each of the model reaches. It is a calibrated parameter that, combined with the storm-induced change generated internally by the Beach-*fx* model, returns the historical shoreline change rate for that location. Calibration is essential to insure that the morphology behavior is appropriate and representative of the study area.

The target shoreline change rate is an erosion or accretion rate equivalent to the historical background shoreline change rates for the project area. Changes in mean high water (MHW) position typically provide a historical view of the behavior of the shoreline. In Florida profiles are gathered by the FDEP, local sponsors, and USACE. Available beach surveys for Treasure Island and Long Key go back as far as 1873 and the most recent surveys were completed in 2018. Because the Treasure Island and Long Key segments of the Federal HSDR Project was initially completed in 1969 and 1980, respectively, and continues to be periodically renourished, the majority of available surveys do not accurately reflect historical background erosion rates. Inspection of available data prior to initial construction for both segments also found that early surveys did not yield reliable shoreline change rates. Therefore an analytical means of determining background shoreline change was employed. A summary of how these values were determined is provided in Sub-appendix A: Historic Shoreline Change

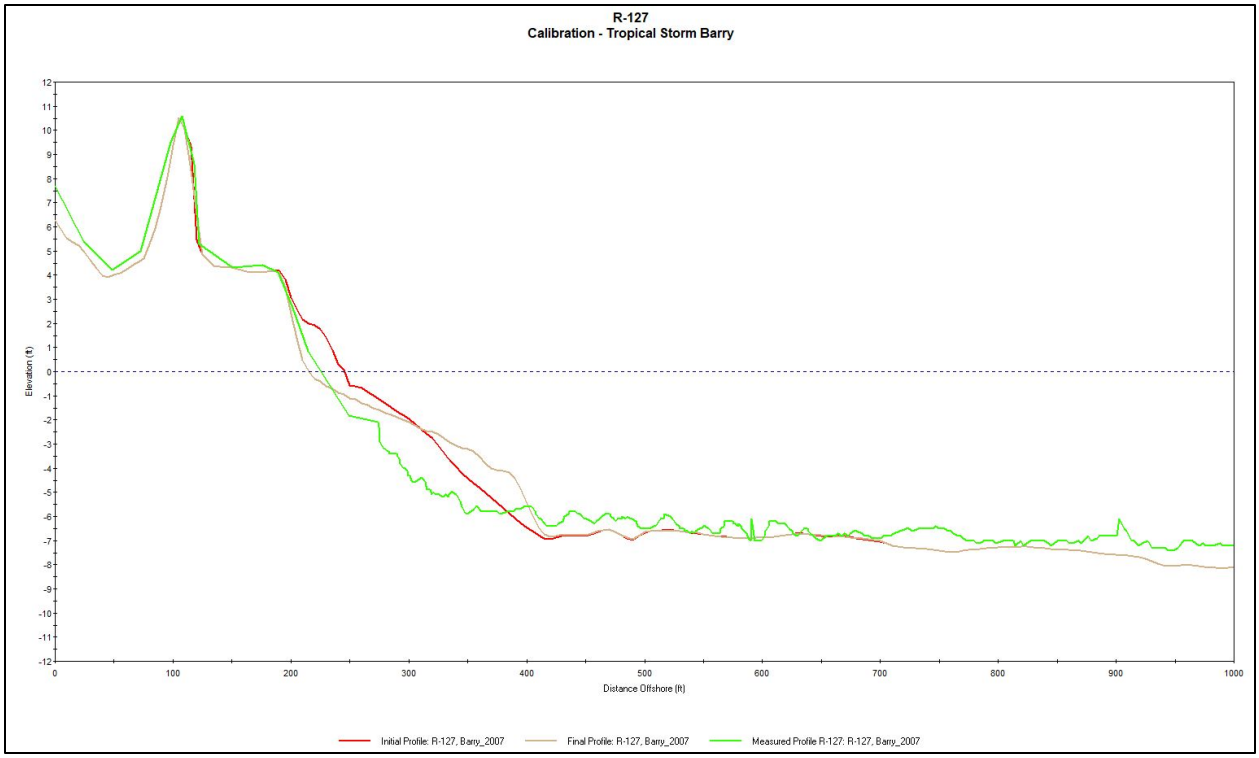


Figure A- 19. SBEACH Calibration at R-127 (Tropical Storm Barry)

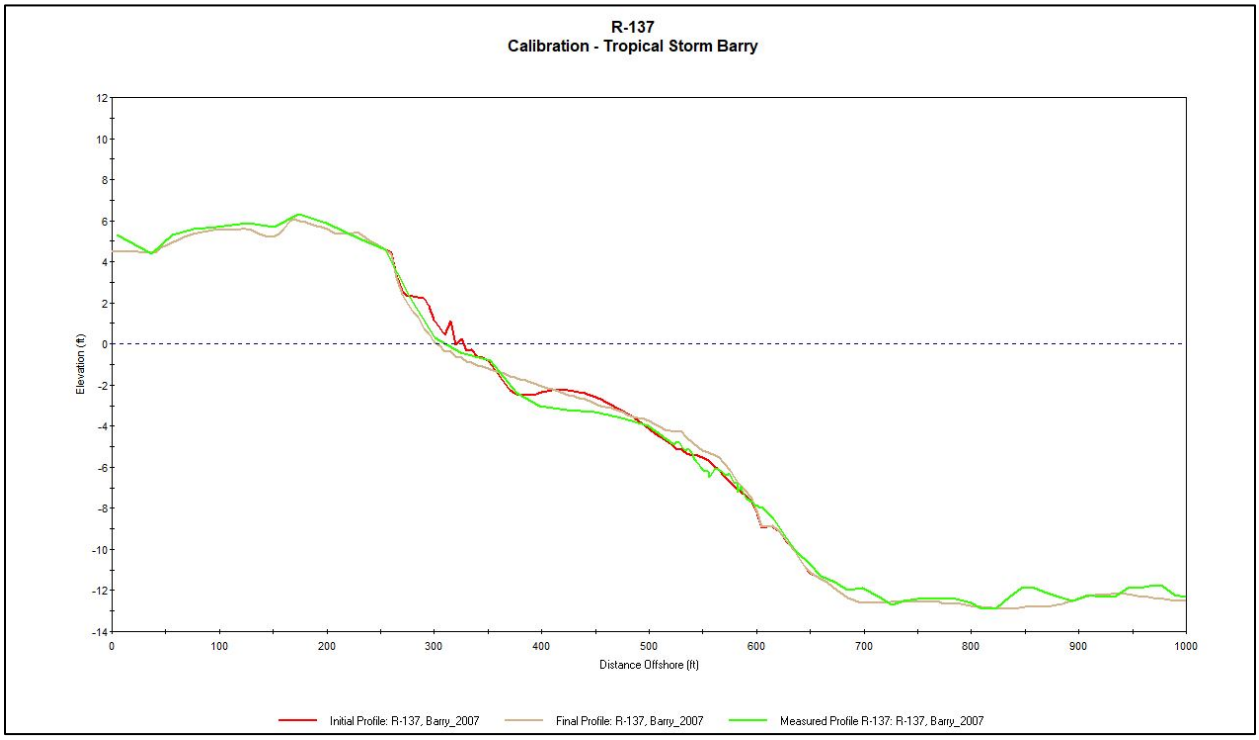


Figure A- 20. SBEACH Calibration at R-137 (Tropical Storm Barry)

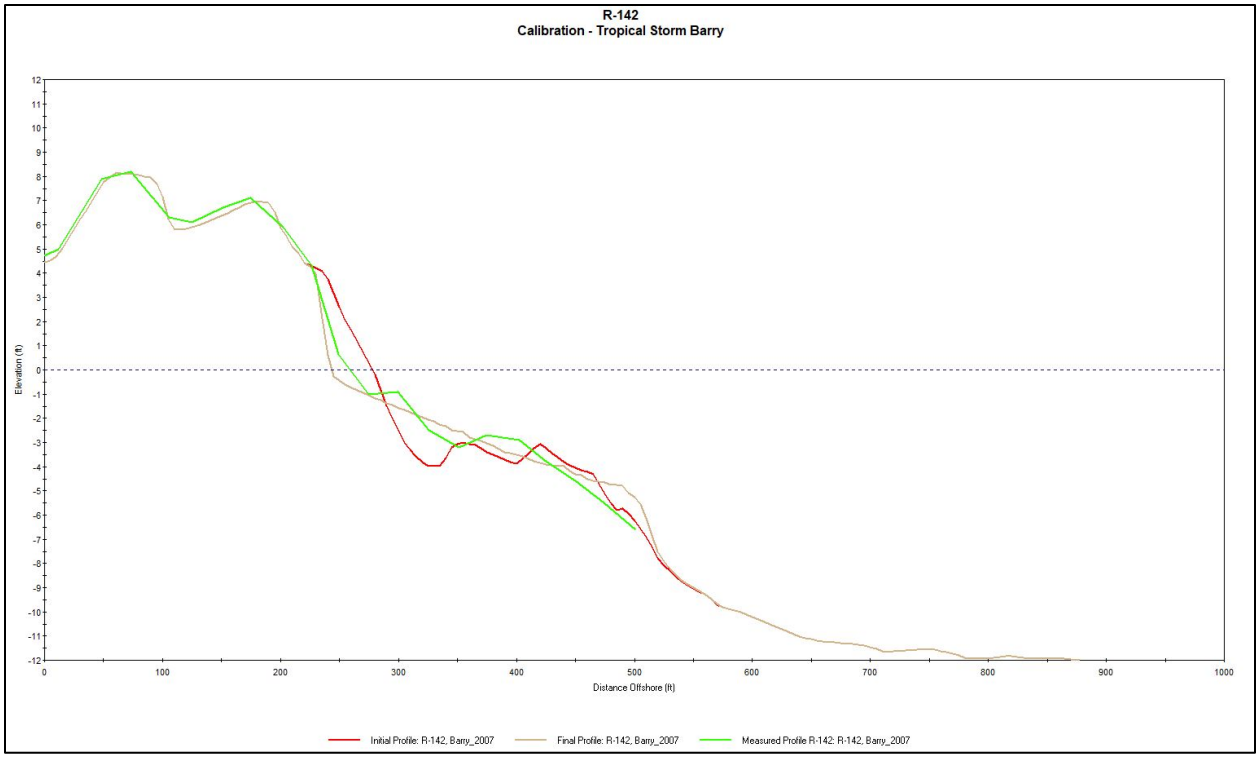


Figure A- 21. SBEACH Calibration at R-142 (Tropical Storm Barry)

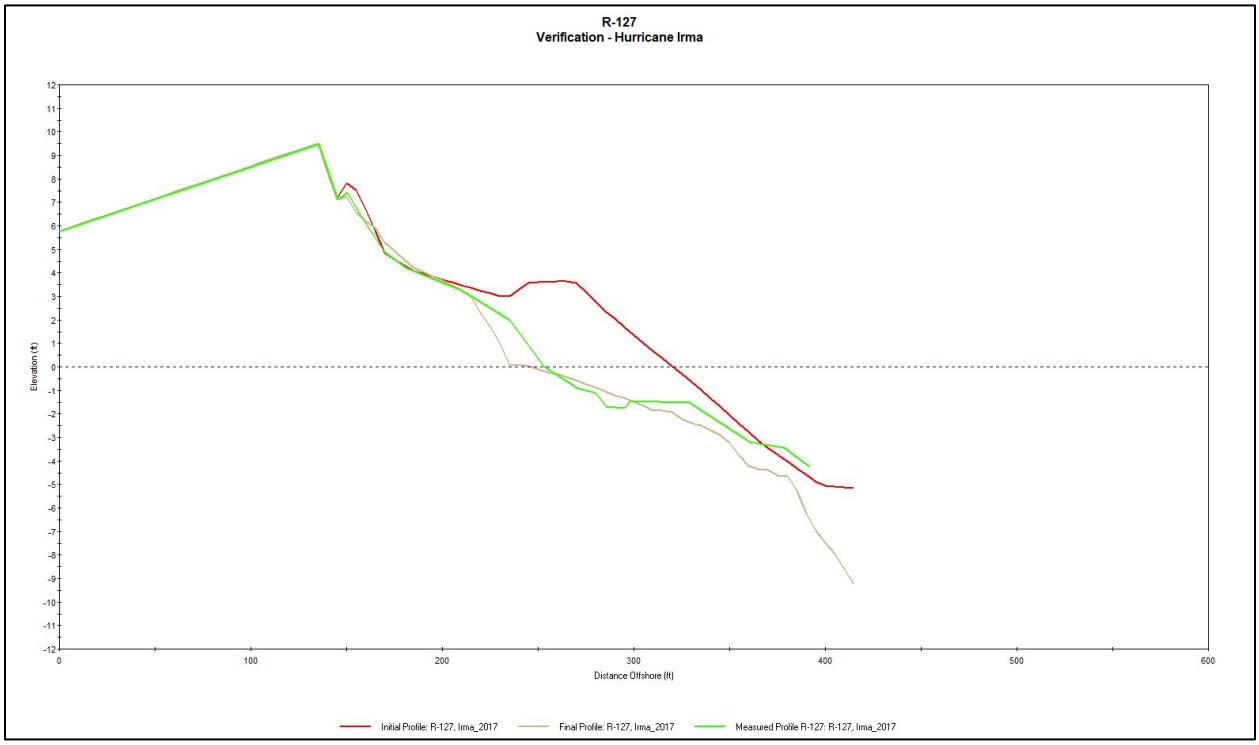


Figure A- 22. SBEACH Verification at R-127 (Hurricane Irma)

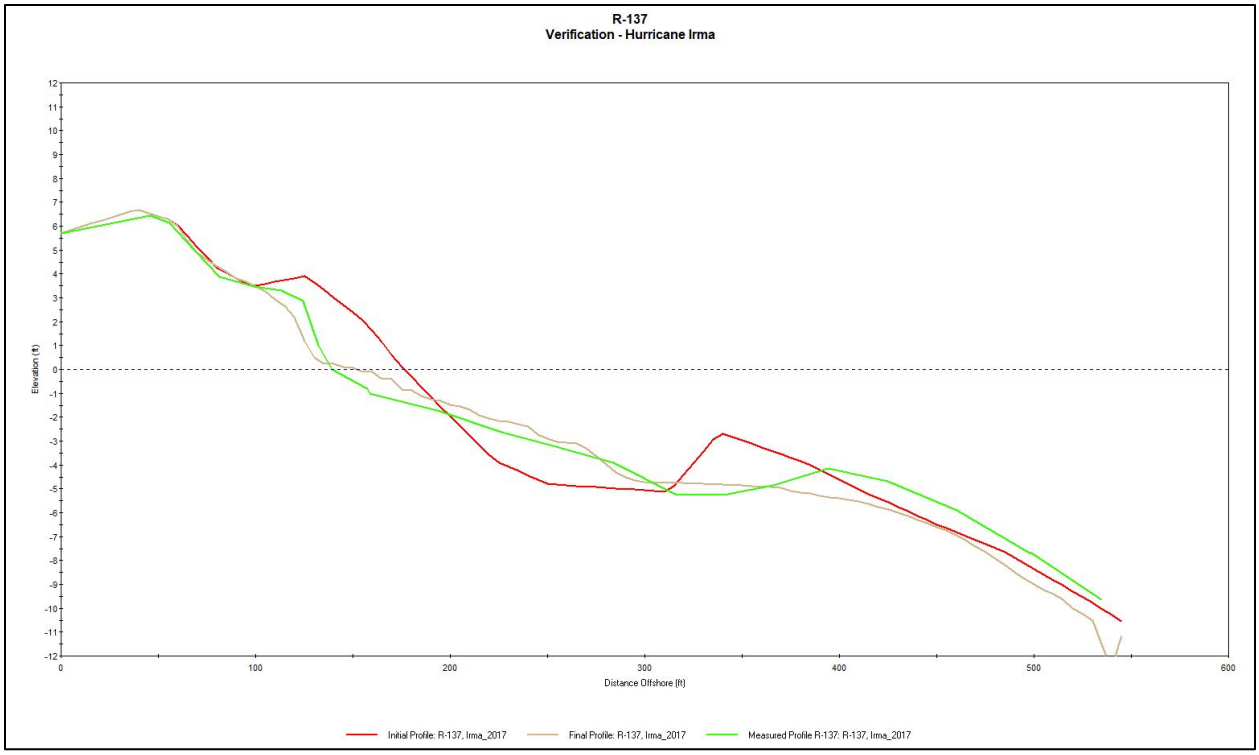


Figure A- 23. SBEACH Verification at R-137 (Hurricane Irma)

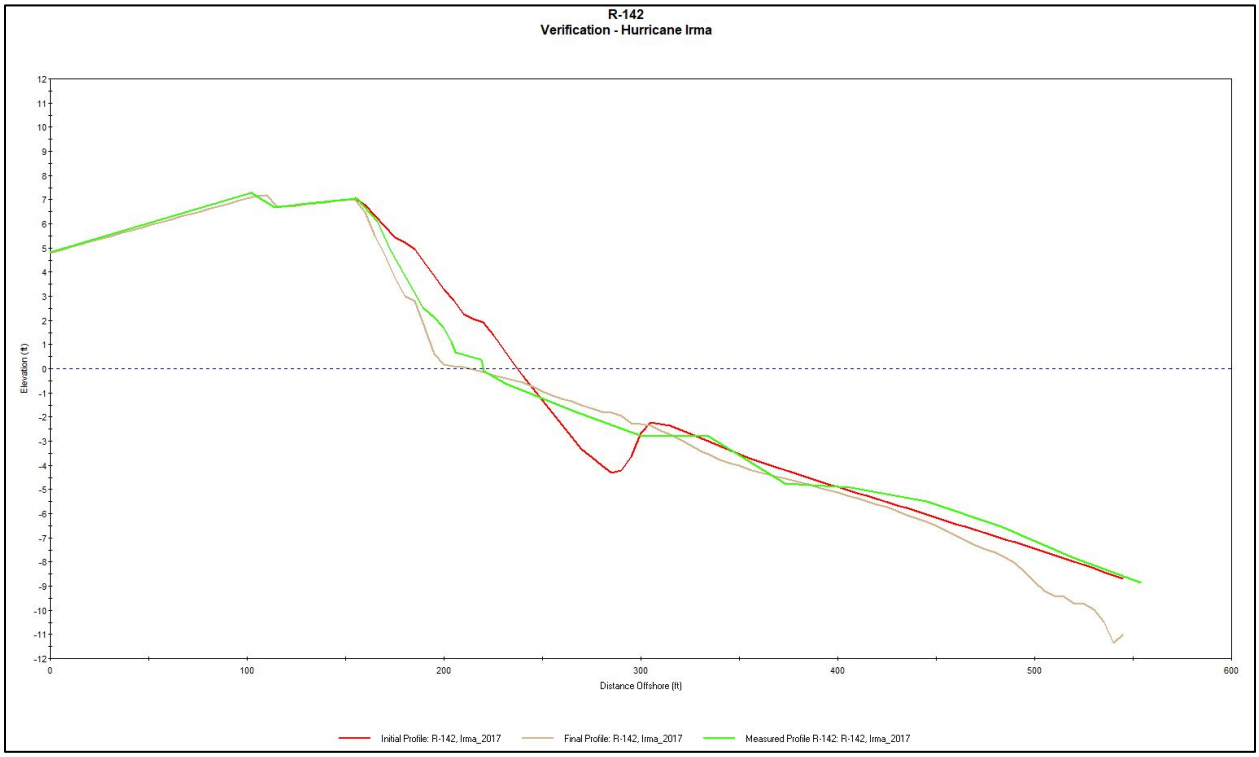


Figure A- 24. SBEACH Verification at R-142 (Hurricane Irma)

During Beach-*fx* calibration, applied erosion rates were adjusted for each model reach and the Beach-*fx* model was run for repeatedly for 300 iterations over a 50-year project life cycle. Calibration is achieved when the rate of shoreline change, averaged over hundreds of life cycle simulations, is equal to the background (target) shoreline change rate. **Table A- 12** provides the historical background erosion rates, storm-induced change rates (isolated by running the model with applied rates set to zero), and the calibrated Beach-fx applied erosion rates for Treasure Island and Long Key.

Table A- 12. Historical Background Change Rates and Calibrated Beach-fx Applied Erosion Rates

Treasure Island				Long Key			
Model Reach	**Historical Background Change Rate (ft/year)**	**Storm Induced Change Rate (ft/year)**	**Calibrated Beach-fx Applied Erosion Rates (ft/year)**	**Model Reach**	**Historical Background Change Rate (ft/year)**	**Storm Induced Change Rate (ft/year)**	**Calibrated Beach-fx Applied Erosion Rates (ft/year)**
R126	-18.207	-1.430	-16.777	R144A	-42.116	-2.974	-38.774
R127	-15.199	-1.588	-13.613	R144B	-36.984	-2.984	-33.613
R128	-10.401	-1.586	-8.815	R144C	-39.550	-2.984	-36.179
R129	-6.532	-1.399	-5.133	R145	-30.414	-1.610	-28.442
R130	-3.639	-1.416	-2.223	R146	-22.473	-1.611	-20.501
R131	-1.707	-1.416	-0.291	R147	-16.170	-1.519	-14.333
R132	-0.736	-1.416	0.680	R148	-9.703	-1.520	-7.858
R133	-0.295	-1.416	1.121	R149	-5.012	-1.525	-3.184
R134	-0.158	-1.436	1.278	R150	-2.414	-1.525	-0.585
R135	-0.213	-1.433	1.220	R151	-1.008	-1.525	0.820
R136	-0.949	-1.516	0.873	R152	-0.434	-1.610	1.543
R137	-2.245	-1.455	-0.564	R153	-0.156	-1.525	1.690
R138	-4.696	-1.564	-2.807	R154	-0.058	-1.614	1.916
R139	-8.672	-1.409	-7.034	R155	-0.138	-1.524	1.386
R140	-15.057	-1.526	-13.216	R156	-0.346	-1.524	1.178
R141	-23.403	-1.526	-21.562	R157	-0.791	-1.524	0.733
R142	-34.750	-1.526	-32.911	R158	-1.862	-1.525	-0.337
R143	-43.268	-1.263	-42.984	R159	-3.047	-1.525	-1.522
				R160	-4.938	-1.525	-3.413
				R161	-8.060	-1.525	-6.535
				R162	-12.137	-1.542	-10.595
				R163	-16.940	-1.525	-15.416
				R164	-42.116	-2.974	-38.774
				R165	-36.984	-2.984	-33.613

6.3.3 Post Storm Berm Recovery

Post storm recovery of eroded berm width after passage of a major storm is a recognized process. Although present coastal engineering practice has not yet developed a predictive method for estimating this process, it is an important element of post-storm beach morphology. Within Beach-*fx*, post-storm recovery of the berm is represented in a procedure in which the user specifies the percentage of the

estimated berm width loss during the storm that will be recovered over a given recovery interval. It is important to note that the percentage itself is not a "stand alone" parameter that is simply applied during the post storm morphology computations. The percentage of berm recovery is estimated prior to model calibration and becomes a tunable calibration parameter to ensure model convergence (when the model reproduces the target erosion rates as discussed in Section 6.3.2: Applied Shoreline Change).

Based on recommendations by the model developer regarding Florida shorelines, review of available historical FDEP profiles that would qualify as pre- and post- storm, and successful model calibration a recovery percentage of 90% over a recovery interval of 21 days was determined to be appropriate for Pinellas County.

6.4 Economic Evaluation

The Beach-*fx* model analyzes the economics of coastal storm risk management projects based on the probabilistic nature of storm associated damages to structures in the project area. Damages are treated as a function of structure location and construction, the intensity and timing of the storms, and the degree of protection that is provided by the natural or constructed protection elements. Within the model, damages are attributed to three mechanisms:

- Erosion (through structural failure or undermining of the foundation)
- Flooding (through structure inundation levels)
- Waves (through the force of impact)

Although wind may also cause shoreline damage, coastal storm risk management projects are not designed to mitigate for impacts due to wind. Therefore, the Beach-*fx* model does not include this mechanism. Damages are calculated for each model reach, lot, and damage element following each storm that occurs during the model run. Erosion, water level, and maximum wave height profiles are determined for each individual storm from the lookup values in the previously stored SRD. These values are then used to calculate the damage driving parameters (landward excursion, erosion depth, inundation level, and wave height) for each damage element.

The relationship between the value of the damage driving parameter and the percent damage incurred from it is defined in a user-specified "damage function". Two damage functions are specified for each damage element, one to address the structure and the other to address its contents. Damages due to erosion, inundation, and wave attack are determined from the damage functions and then used to calculate a combined damage impact that reduces the value of the damage element. The total of all FWOP damages is the economic loss that can be mitigated by the coastal storm risk management project.

A thorough discussion of the economic methodology and processes of Beach-*fx* can be found in the Appendix B: Economics.

6.5 Management Measures

Shoreline management measures that are provided for in the Beach-*fx* model are emergency nourishment and planned nourishment.

6.5.1 Emergency Nourishment

Emergency nourishments are generally limited beach fill projects conducted by local governments in response to storm damage. The Treasure Island and Long Key Segments of Pinellas County does not have a consistent history of emergency nourishment in response to storm related erosion. Therefore, no emergency management measure was included in the Beach-*fx* analysis.

6.5.2 Planned Nourishment

Planned nourishments are handled by the Beach-*fx* model as periodic events based on nourishment templates, triggers, and nourishment cycles. Nourishment templates are specified at the model reach level and include all relevant information such as order of fill, dimensions, placement rates, unit costs, and borrow-to-placement ratios. Planned nourishments occur when user defined nourishment triggers are exceeded and a mobilization threshold volume is met. At a pre-set interval, all model reaches which have been identified for planned nourishment are examined. In reaches where one of the nourishment threshold triggers is exceeded, the required volume to restore the design template is computed. If the summation of individual model reach level volume requirements (to fill the given nourishment template) exceeds the mobilization threshold volume established by the user, then a nourishment is triggered and all model reaches identified for planned nourishment are restored to the nourishment template.

6.5.2.1 Nourishment Distance Triggers and Mobilization Threshold

Beach-*fx* planned nourishment templates have three nourishment distance triggers (1) berm width, (2) dune width, and (3) dune height. Each distance trigger is a fractional amount of the corresponding nourishment template dimension. When the template dimensions fall below the fraction specified by the trigger, a need for renourishment is indicated. For any project template, the berm width trigger can be set such that a minimum berm width (what has been traditionally referred to as a “design berm”) can be maintained, allowing the remainder of the template to act as sacrificial fill (traditional “advance fill”), or the berm trigger can be set to allow minimal erosion of the berm allowing the project interval and mobilization threshold volume to govern the renourishment cycle. For the Pinellas study, the latter method was employed and the berm trigger was set to 0.99 (1% loss). The dune width and dune height triggers were similarly set to allow minimal erosion to the dune. The dune width and dune height triggers were set to 0.99 (1% loss of width) and 0.90 (10% loss of height), respectively.

6.5.2.2 Project Interval Setting and Mobilization Threshold

The project interval (set in years) is the interval at which the Beach-fx model will determine if a renourishment is required. At the set interval, if nourishment triggers have been met, the model will then determine the volume in each reach designated to receive fill that would be necessary to restore the full nourishment template for that reach. If the sum of the individual reach volumes exceeds the user specified mobilization threshold a renourishment event is initiated. If the total volume falls below the mobilization threshold no event is initiated and the model will not evaluate the nourishment triggers again until the next interval increment. For example a project interval of 4 years will cause the model to evaluate nourishment distance triggers in year 4 of the project life and if the triggers or volume threshold are not met, the model will not evaluate the triggers again until year 8.

The mobilization threshold (minimum nourishment volume required to initiate a nourishment cycle) is specified in cubic yards. It is often set to be approximately the same volume (or slightly less) than the

volume of the sacrificial portion of the nourishment template. This allows the berm width trigger and mobilization threshold to act together to maintain a desired project dimension.

While both the project interval and the mobilization threshold are variable, one or the other will be the dominate parameter in determining the characteristics of the renourishment event. By setting the project interval to the minimum of 1 year, it allows the volume threshold to control when an event will be initiated by causing the model to check reach volume requirements on an annual basis. Renourishment events over the lifecycle may then occur during any given year should volumetric losses require it. Due to the random generation of storms, this can result in a range of renourishment intervals over the life of the project. In defining the project, an average renourishment interval is determined based on events occurring over multiple iterations of the project lifecycle.

When the project interval is set to a value greater than 1 and the volume threshold is set low (in the range of 10,000 cubic yards), it is the interval that will determine the characteristics of the renourishment event. In this case, the model will return volumetric requirements for the specified interval. Due to the random generation of storms within the model, these requirements will vary between renourishment events. In defining the project, the average renourishment volume is determined based on events occurring over multiple iterations of the project lifecycle.

It is the nature of the Beach-fx model that if the project volume is relatively fixed (volume threshold governs) then the renourishment interval becomes more variable. Conversely, if the renourishment cycle is fixed (project interval governs) then the renourishment volume becomes more variable. In practice, the best way to optimize a project is to allow either the project interval or the threshold volume to govern. Once the project alternatives have been screened (using either approach) based on performance and economic benefit, the project returning the highest net benefits may be further refined as necessary by making incremental adjustments to either the threshold volume (in cases where the project interval governs) or the project increment (in cases where the volume threshold governs). Attempting to vary the project interval and the threshold volume simultaneously during the initial screening process is not recommended as it will lead to an unreasonably large array of alternatives.

The choice of screening process is determined by the user and may be influenced by a number of factors. At project sites where frequent high intensity storms dominate erosional impacts, it may be preferred to determine volume losses on an annual basis. The project interval would then be set to one year and the volume threshold would be determined based on the dimensions of fill (roughly equivalent the “sacrificial” portion of the fill). At project sites where storms are less frequent or less intense and erosional impacts are dominated by relatively constant conditions, including inlet effects, it may be preferred to evaluate project performance based on a fixed interval. The volume threshold would be set low (10,000 cubic yards as a general rule) and the project interval would be set based on factors such as borrow site recharge estimates or anticipated funding cycles. Note that the choice of process and specified parameters are project specific and may vary from location to location.

Pinellas County lies on the west coast of Florida. Historically, storm frequency and intensity have been relatively low (compared to the east coast of Florida) and extra-tropical storms lack the high energy wave conditions that characterize the northeaster storms that impact the eastern seaboard. Erosional losses throughout Pinellas County, including at both Treasure Island and Long Key, are dominated by localized (non-storm generated) sediment transport processes. At Treasure Island and Long Key, the north and south regions of the barrier islands experience the highest erosion levels due to effects from

the inlets that they are adjacent to. It was therefore concluded that a fixed interval screening approach was warranted.

The project interval for Treasure Island and Long Key was set to six years based on existing frequency of fills and inlet recharge rates. Initial evaluation runs indicated that the presence of armor influenced project benefits by reducing the impacts of erosion on infrastructure. This reduced the variability of benefits between various project alternatives. Therefore, project costs became a governing factor in the economic analysis. One of the most significant project costs is the mobilization and demobilization of dredging equipment. Increasing the project interval significantly reduces project costs (due to reduced mobilization events). While theoretically the project interval can be increased up to the analyzed life of the project, in practice this is not feasible. Placing large volumes of sand at infrequent intervals can easily exceed the expected capacity of available sand sources and may lead to distortions of the shoreline that will negatively alter natural shoreline behavior in unanticipated ways, require alteration of existing jetty and groin structures, and increase the environmental impacts of sand placement on the species that utilize this habitat.

For Treasure Island and Long Key, primary sand sources are the adjacent inlets with occasional supplement coming from the Egmont Shoal north of the Tampa Harbor channel. Sand from the inlets comes from periodic maintenance events ranging from 4 to 10 years in frequency. Additionally, based on inlet management plans for each of the three adjacent inlets (FDEP, 2018; FDEP, 2019, and FDEP, 2019), the average recharge rate of these sand sources is approximately 6 years. As the project is expected to include placement at both Treasure Island and Long Key simultaneously (to minimize project costs and maintain historic placement patterns) using sand from all three of these sources, the maximum interval was set to 6 years in order to avoid either excessive over dredging or under dredging of any given inlet. Egmont Shoal was considered as a source that would allow for longer intervals. However, its distance from the project makes it a less economical sand source except in a supplemental capacity or when combined with other placements outside of the present study area such as Sand Key. Additionally, taking substantial volumes of material from the Egmont Shoal could potentially have negative impacts to the local sediment transport system in the vicinity of Tampa Bay.

With little variability in benefit due to the presence of armor, the cost effectiveness and minimal localized impact of using maintenance material from adjacent inlets, and the high cost of mobilization and demobilization of dredging equipment, an interval of 6 years was considered optimal for the screening of project alternatives.

6.6 Beach-*fx* Project Alternatives

6.6.1 Nourishment Templates

Beach-*fx* planned nourishment templates are defined by three dimensions, the template dune height, template dune width, and template berm width. Berm elevations and dune and foreshore slopes remain constant based on the existing profiles. For Pinellas County, each model reach template was developed based on combinations of dune raising (to an elevation of 10 ft-NAVD88), dune extension (20 foot extension of the existing dune and profile to depth of closure), and twelve berm extensions (profile extensions to depth of closure): 20-foot to 130-foot by increments of 10 feet.

The future without project Beach-fx model runs indicated that little to no damages were expected in the central portions of either Treasure Island or Long Key. It was found that based on expected damages, the optimal placement areas were the same as those presently being filled as part of the current period of Federal participation:

- Sunshine Beach – Model reaches R126 to R128
- Sunset Beach – Model Reaches R138 to R142
- Upham Beach – Model Reaches R144A to R146
- Pass-a-Grille – Model Reaches R160 to R165

It should be noted that tapers are not included as part of the modeled fill and may extend several hundred feet beyond the physical limits covered by these model reaches.

Nourishment templates were developed for an array of alternatives which are presented in **Table A- 13**.

Table A- 13. Project Alternatives

Primary Template Dimensions			Treasure Island	Long Key	Alternative
Berm Width (ft)	Dune Elevation (ft-NAVD88)	Dune Width (ft)	Alternative ID	Alternative ID	Description
Berm Only					
20	Existing	Existing	TI_Ends_20ft	LK_Ends_20ft	20ft Berm at Ends
30	Existing	Existing	TI_Ends_30ft	LK_Ends_30ft	30ft Berm at Ends
40	Existing	Existing	TI_Ends_40ft	LK_Ends_40ft	40ft Berm at Ends
50	Existing	Existing	TI_Ends_50ft	LK_Ends_50ft	50ft Berm at Ends
60	Existing	Existing	TI_Ends_60ft	LK_Ends_60ft	60ft Berm at Ends
70	Existing	Existing	TI_Ends_70ft	LK_Ends_70ft	70ft Berm at Ends
80	Existing	Existing	TI_Ends_80ft	LK_Ends_80ft	80ft Berm at Ends
90	Existing	Existing	TI_Ends_90ft	LK_Ends_90ft	90ft Berm at Ends
100	Existing	Existing	TI_Ends_100ft	LK_Ends_100ft	100ft Berm at Ends
110	Existing	Existing	TI_Ends_110ft	LK_Ends_110ft	110ft Berm at Ends
120	Existing	Existing	TI_Ends_120ft	LK_Ends_120ft	120ft Berm at Ends
130	Existing	Existing	TI_Ends_130ft	LK_Ends_130ft	130ft Berm at Ends
Dune Raising					
0	10	Existing	TI_Ends_DH_0ft	LK_Ends_DH_0ft	0ft Berm at Ends + Added 10ft Dune Height Addition
30	10	Existing	TI_Ends_DH_30ft	LK_Ends_DH_30ft	30ft Berm at Ends + Added 10ft Dune Height Addition
100	10	Existing	TI_E_DH_100ft	LK_E_DH_100ft	100ft Berm + 10ft Dune Height
Dune Widening					
0	Existing	Existing + 20	TI_Ends_DW_0ft	LK_Ends_DW_0ft	0ft Berm at Ends + 20ft Dune Width Extension
30	Existing	Existing + 20	TI_Ends_DW_30ft	LK_Ends_DW_30ft	30ft Berm at Ends + 10ft Dune Width Extension
100	Existing	Existing + 20	TI_E_DW_100ft	LK_E_DW_100ft	100ft Berm + Added 20ft Dune Width
Dune Raising + Widening					
0	10	Existing + 20	TI_E_DWDH_0ft	LK_E_DWDH_0ft	0ft Berm at Ends + Added 20ft Dune Width + 10ft Dune Height
30	10	Existing + 20	TI_E_DWDH_30ft	LK_E_DWDH_30ft	30ft Berm at Ends + Added 20ft Dune Width + 10ft Dune Height
100	10	Existing + 20	TI_E_DWDH_100ft	LK_E_DWDH_100ft	100ft Berm +10ft Dune Height +Added 20ft Dune Width

6.7 Recommendation for TSP

Screening of the project alternatives using the Beach-fx model indicated that templates in which the dune was raised to a uniform +10 ft-NAVD88 elevation and then extended by 20 feet seaward (from dune crest to depth of closure) provided the maximum net benefits of the full array. These included the TI_E and LK_E DWDH_0ft, the TI_E and LK_E DWDH_30ft, and TI_E and LK_E DWDH_100ft alternatives.

Typically, one of these alternatives would definitively return the highest net benefits for the lowest cost and would be established as the Tentatively Selected Plan (TSP). However, due to uncertainty in the reliability of FWOP damage tabulations within the model, no definitive TSP was determined from this final array. While the relative screening of FWP alternatives resulted in high confidence that the

"DWDH" (dune raising and widening) alternatives provide the most benefit, uncertainty in the FWOP model results would not allow for reliable screening to identify the most beneficial and cost effective berm condition. Therefore, the TSP, which includes elevation of the dune to 10 ft-NAVD88 and extension of the elevated dune and profile by 20 feet seaward, is presented as a berm extension with a range of 0 feet (no berm in the equilibrated profile) to 100 feet. Efforts to refine this range to a single berm template is ongoing.

7 Project Design

7.1 Project Length

The Treasure Island and Long Key each contain two segments that will receive renourishment under the TSP. Sunshine Beach and Sunset Beach are located at the north and south ends of Treasure Island. Sunshine Beach to the north has a project length of approximately 0.5 miles. Sunset Beach to the south has project length of approximately 1.0 miles. Upham Beach and Pass-a-Grille Beach are located at the north and south ends of Long Key and have similar dimension to Treasure Island beaches. Upham Beach to the north has a project length of approximately 0.5 miles. Pass-a-Grille Beach to the south has a project length of approximately 1.0 mile.

7.2 Project Baseline

The project baseline (referenced to R-monuments) will be in the general vicinity of the landward toe of the existing dune for the final recommended plan. In regions where the existing dune is ill defined, extrapolation from adjacent areas with dunes, consideration of localized topography, and position infrastructure will be considered. Due to the complexity of the shoreline, involving residential and commercial structures as well as instances of shoreline armor, the exact baseline will not be fully determined until the Planning, Engineering, and Design (PED) phase of the study.

7.3 Project Cross-shore Dimensions

Despite uncertainty in precise positioning of the combined dune and berm TSP profile, the general cross-shore dimensions will be as described in the following sections.

Note that project elevations are presented in the NAVD88 datum. This is consistent with Beach-fx model inputs. However, as sea levels change, the natural cross-shore dimension will equilibrate to those changes resulting in an elevated berm relative to the NAVD88 datum modeled. Therefore, relevant elevations will also be noted in the MLW datum to allow for future adjustment of cross-shore dimensions due to sea level change. Relative difference between NAVD88 to MLW differs slightly between Treasure Island and Long Key (see Section 4.3: Tides). Therefore, an average conversion of MLW = -1.1 ft-NAVD88 was applied.

7.4 Project Dune

The TSP includes raising the dune to a uniform elevation of +10 ft-NAVD88 (11.1 ft-MLW). The existing Treasure Island and Long Key shorelines in the vicinity of the project has a predominantly variable, low elevation dune system. Treasure Island existing dune heights relative to the upland elevation range

from 2 to 3 feet in Sunshine Beach and 0 feet to 4 feet in Sunset Beach. Long Key dune heights relative to the upland range from 0 feet to 1 foot in Upham Beach and 3 feet to 5 feet in Pass-a-Grille Beach. Raising the dunes to a uniform elevation of +10 ft-NAVD88 (11.1 ft-NAVD88) would result in dune heights relative to the upland of 5 feet in Sunshine Beach, 4 feet to 5 feet in Sunset Beach, 3 feet to 4 feet in Upham Beach and 4 feet to 5 feet in Pass-a-Grille Beach.

In addition to raising the elevation of the existing dune (creating dunes as necessary where the existing dune elevation is 0 feet), the TSP includes extending the existing width of the dune seaward by 20 feet. The seaward extension of the dune includes the dune and the foreshore down to the depth of closure. In reaches where the existing dune has a height of 0 feet, an "existing width" was assigned based on localized shoreline characteristics (where a dune might naturally fall if included in the cross-section profile) and informed by adjacent areas. Existing widths ranged from 20 feet to 50 feet at Sunshine Beach, 20 feet to 60 feet at Sunset Beach, 20 feet to 60 feet at Upham Beach, and 15 feet to 90 feet at Pass-a-Grille Beach.

Table A- 14 and **Table A- 15** summarize the cross-shore dune dimensions for the existing and TSP profiles for Treasure Island and Long Key, respectively. Note that dune width will likely become more uniform between adjacent reaches than shown in the individual idealized Beach-fx model profiles. This is due to constructability and performance as well as aesthetics.

7.5 Project Berm

The berm elevation for the TSP is +4.57 ft-NAVD88 (+5.67 ft-MLW), which is consistent with the previously authorized Pinellas County project and approximates the natural berm elevation. Restricting the design berm elevation to the natural berm elevation minimizes scarping of the beach fill as it undergoes readjustment. Vertical scarps can hinder the beach access of nesting sea turtles, and may also pose safety problems related to recreational beach use. Other reasons for mimicking the natural berm elevation are related to storm damage protection. A berm constructed at a lower elevation would increase the probability of overtopping by relatively frequent storms, thereby offering less protection to upland development and/or existing dunes. A higher berm elevation could result in problems related to backshore flooding due to excessive rainfall or wave overtopping. A higher berm may also be more susceptible to wind-induced erosion.

The TSP berm has a minimum width of 0 feet and maximum width of 100 feet.

7.6 Project Beach Slopes

After adjustment and sorting of the placed material by wave action, the material is expected to adjust to an equilibrium beach slope, similar to the existing beach. In southern Pinellas County, the existing beach slopes in the project area are approximately 1 (vertical) on 10 (horizontal) at the dune, 1 on 15 from the berm to MLW (approximately -1.1 ft-NAVD88), and 1 on 30 below MLW. The estimate of the slope of the material after adjustment is based on averaging the beach profile slopes of the native beach from the mean low water datum to the approximate location of the 15 foot depth contour. Sand from the project borrow site was determined to be a near match to the gradation and shell content of the existing beach (which is dominated by previous fills from the same borrow sources). This will allow the beach fill to equilibrate to a shape similar to the existing profile.

Table A- 14. Existing and TSP Cross-shore Dune Dimensions – Treasure Island

Model Profile	Model Reach	Upland Elevation (ft-NAVD)	Existing Dune			TSP Dune			Dune Slope	TSP Berm	
			Elevation (ft-NAVD)	Height (ft)	Width (ft)	Elevation (ft-NAVD)	Height (ft)	Width (ft)		Elevation (ft-NAVD)	Max Width (ft)
TI01	R126	5	7	2	50	10	5	70	0.1	4.57	100
TI02	R127	5	8	3	20	10	5	40	0.1	4.57	100
TI03	R128	5	8	3	30	10	5	50	0.1	4.57	100
TI04	R129	5	5	0	50	---	---	---	---	4.57	100
TI05	R130, R131, R132	5	5	0	50	---	---	---	---	4.57	100
TI06	R133	5	5	0	50	---	---	---	---	4.57	100
TI07	R134	5	5	0	50	---	---	---	---	4.57	100
TI08	R135	6	7	1	80	---	---	---	---	4.57	100
TI09	R136	6	9	3	50	---	---	---	---	4.57	100
TI10	R137	6	6	0	50	---	---	---	---	4.57	100
TI11	R138	5	9	4	40	10	5	60	0.1	4.57	100
TI12	R139	5	5	0	20	10	5	40	0.1	4.57	100
TI13	R140, R141, R142	5	9	4	60	10	5	80	0.1	4.57	100
TI14	R143	6	7	1	60	10	4	80	0.1	4.57	100

Table A- 15. Existing and TSP Cross-shore Dune Dimensions – Long Key

Model Profile	Model Reach	Upland Elevation (ft-NAVD)	Existing Dune			TSP Dune			Dune Slope	Berm	Max
			Elevation (ft-NAVD)	Height (ft)	Width (ft)	Elevation (ft-NAVD)	Height (ft)	Width (ft)		Elevation (ft-NAVD)	Width (ft)
LK01	R144A	7	7	0	20	10	3	40	0.1	4.57	100
LK02	R144B, R144C	6	6	0	20	10	4	40	0.1	4.57	100
LK03	R145	6	7	1	60	10	4	80	0.1	4.57	100
LK04	R146	6	7	1	60	10	4	80	0.1	4.57	100
LK05	R147	6	9	3	25	---	---	---	---	4.57	100
LK06	R148	6	7	1	80	---	---	---	---	4.57	100
LK07	R149, R150, R151	5	7	2	50	---	---	---	---	4.57	100
LK08	R153	6	7	1	50	---	---	---	---	4.57	100
LK09	R155	5	8	3	100	---	---	---	---	4.57	100
LK10	R156	6	7	1	20	---	---	---	---	4.57	100
LK11	R157	5	9	4	15	---	---	---	---	4.57	100
LK12	R158, R159	5	10	5	40	---	---	---	---	4.57	100
LK13	R160, R161, R162	5	10	5	15	10	5	35	0.1	4.57	100
LK14	R163	5	10	5	10	10	5	30	0.1	4.57	100
LK15	R164	6	9	3	20	10	4	40	0.1	4.57	100
LK16	R165	5	8	3	90	10	5	110	0.1	4.57	100

It is unnecessary and impractical to artificially grade beach slopes below the low water elevation since they will be shaped by wave action. For this reason, the foreshore slope of the beach fill placed at the time of construction or future renourishment may differ from that of the natural profile. The angle of repose of the hydraulically placed material depends on the characteristics of the fill material and the wave climate in the project area. With steep initial slopes, the material will quickly adjust to the natural slopes. For design purposes it is assumed that that construction berm will have an approximate slope of 1:10.

7.7 Project Construction

As previously discussed, the foreshore slope of the beach fill placed at the time of construction or future renourishment may differ from that of the natural profile. This reflects the capabilities of the construction equipment that will be used to build the shore protection project. Within the first year or two after placement of the beachfill, the construction profile will be reshaped by waves into an

equilibrium profile, causing the berm to retreat to a position more characteristic of the project design template.

Based on the approximated initial fill volume and constructability considerations, construction templates applicable to the TSP enhanced dune template with minimum (0 foot) equilibrated berm and maximum (100 foot) equilibrated berm were determined. The construction templates (shown in **Figure A- 25** and **Figure A- 26**) consist of a uniform dune elevation, a 20 foot seaward extension of the dune and profile, and the equilibrated berm and corresponding construction berm. The construction template for the 0 foot berm is approximated to be 70 feet in width (at the existing berm elevation from the seaward toe of the dune). The construction template for the 100 foot berm is approximated to be 225 feet in width. Both of these construction templates will equilibrate into the project template. The volume of material in the equilibrated profile (between the template and the "existing" condition) represents the material that is expected to erode between successive nourishment events including portions of the dune.

7.8 Project Volumes and Renourishment Interval

Each complete Beach-*fx* model run consists of 100 iterations, each iteration representing the life of the project (50 years). Based on the enhanced dune TSP, both minimum and maximum berm widths were modeled (100 iteration runs) and a range of average volumes was determined for each initial fill event and each subsequent renourishment event. Model runs were made for each of the three sea level rise cases: Base, Intermediate, and High. **Table A- 16** and **Table A- 16** provide minimum, maximum, and average fill volumes (for both initial and renourishment events) and renourishment intervals over the life of the project for the TSP with minimum and maximum berm, respectively for the combined Treasure Island segments (Sunshine Beach and Sunset Beach).

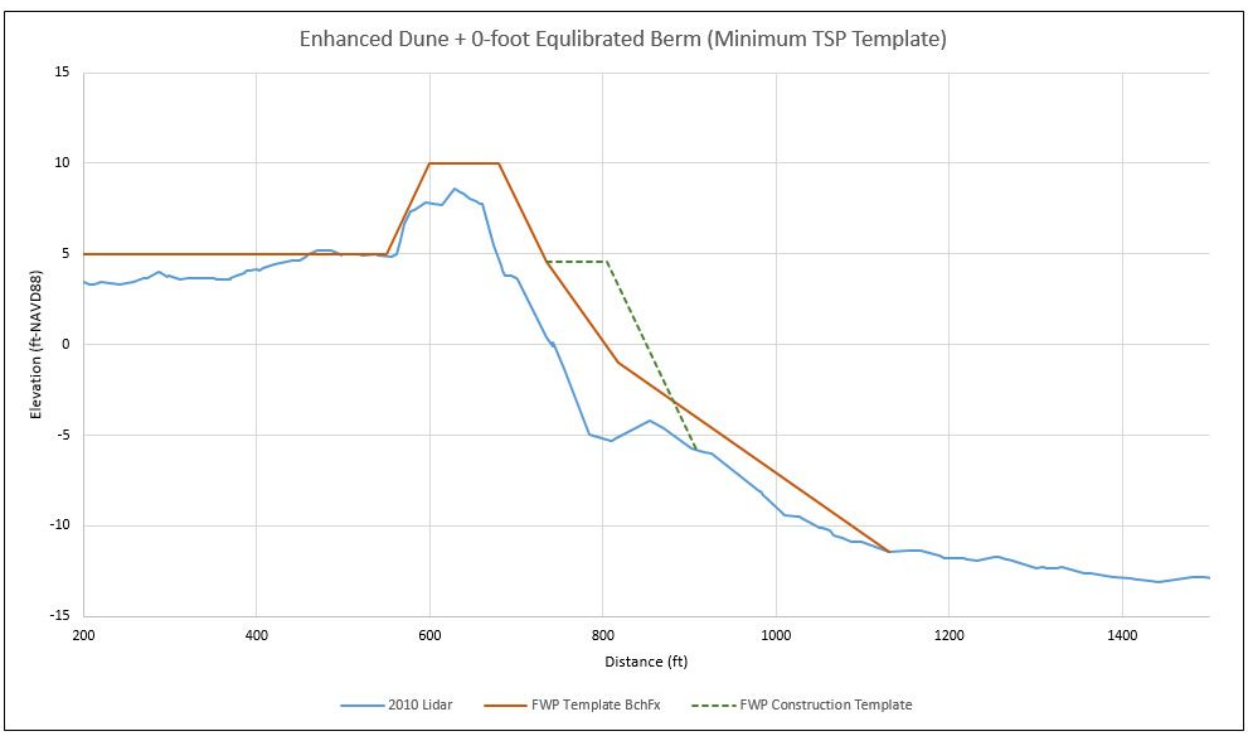


Figure A- 25. Conceptual Cross-shore Profile and Construction Berm for TSP Dune with 0-foot Berm

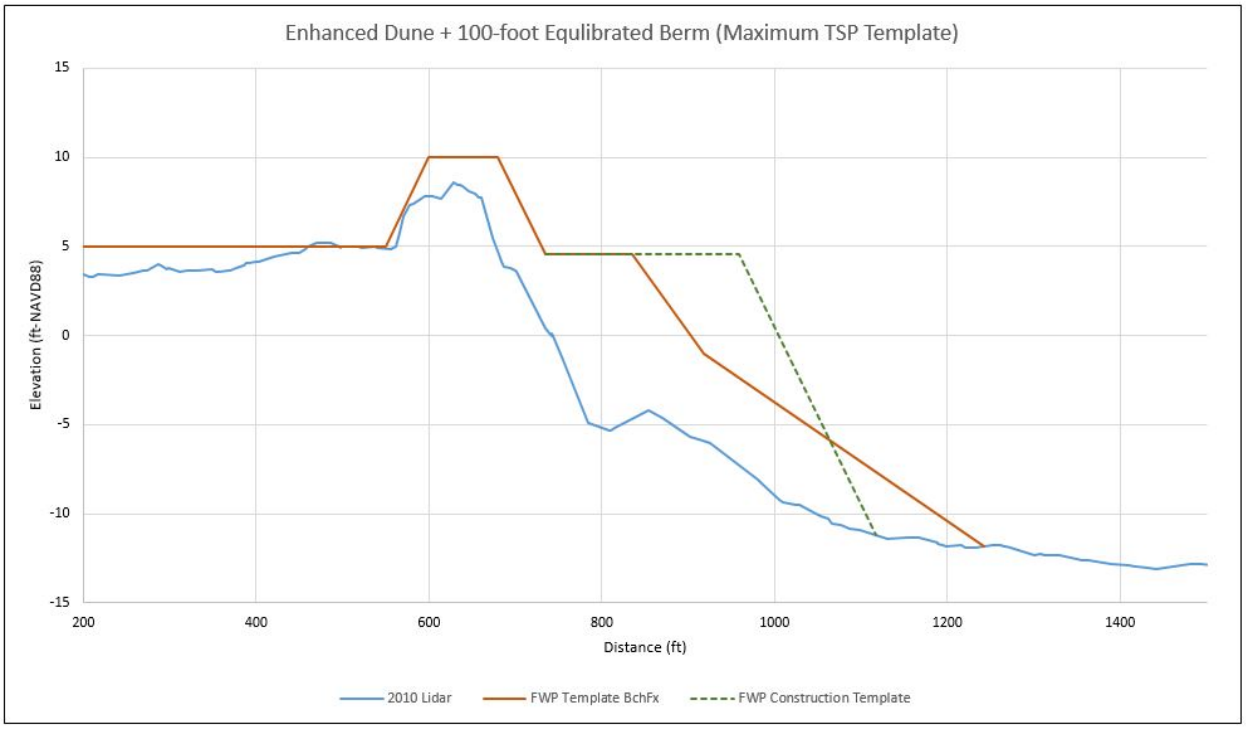


Figure A- 26. Conceptual Cross-shore Profile and Construction Berm for TSP Dune with 100-foot Berm

Table A- 16. Project Volumes for Minimum (0 foot) TSP Berm (Treasure Island Segment)

Project Volumes (Over 100 Beach-*fx* Life-cycle Iterations)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	174,500 – 179,200	5.9 - 6.2	123,800 – 558,900
	Average	174,650	6.0	409,250
Intermediate	Min - Max	174,600 – 179,300	5.9 - 6.2	154,150 – 589,100
	Average	174,700	6.0	444,100
High	Min - Max	174,700 – 179,650	5.9 - 6.2	127,200 – 731,800
	Average	174,900	6.0	547,900

Table A- 17. Project Volumes for Maximum (100 foot) TSP Berm (Treasure Island Segment)

Project Volumes (Over 100 Beach-*fx* Life-cycle Iterations)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	741,000 – 772,300	5.7 - 6.2	328,000 – 588,250
	Average	743,400	6.0	413,650
Intermediate	Min - Max	741,350 – 773,050	5.7 - 6.2	366,100 – 610,600
	Average	743,800	6.0	447,650
High	Min - Max	742,550 – 775,400	5.7 - 6.2	437,200 – 725,900
	Average	745,100	6.0	557,400

Table A- 18 and **Table A- 19** provide minimum, maximum, and average fill volumes (for both initial and renourishment events) and renourishment intervals over the life of the project for the TSP with minimum and maximum berm, respectively for the combined Treasure Island segments (Upham Beach and Pass-a-Grille Beach).

Final optimization of the TSP may include variable berm widths (between 0 foot and 100 foot) between the project segments. These tables represent a bracket of minimum and maximum anticipated volumes.

Table A- 18. Project Volumes for Minimum (0 foot) TSP Berm (Long Key Segment)

Project Volumes (Over 100 Beach-*fx* Life-cycle Iterations)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	153,500 – 155,400	5.8 - 6.2	97,200 – 433,800
	Average	153,550	6.0	238,860
Intermediate	Min - Max	153,550 – 155,500	5.8 - 6.2	100,250 – 417,500
	Average	153,600	6.0	265,200
High	Min - Max	153,600 – 155,700	5.8 - 6.3	131,800 – 520,200
	Average	153,700	6.0	354,850

Table A- 19. Project Volumes for Maximum (100 foot) TSP Berm (Long Key Segment)

Project Volumes (Over 100 Beach-*fx* Life-cycle Iterations)				
Sea level change Case	Volume Description	Initial Fill Volume (cubic yards)	Renourishment Interval (years)	Average Volume per Interval (cubic yards)
Base	Min - Max	683,650 – 705,500	5.7 - 6.2	232,300 – 505,650
	Average	685,350	6.0	316,300
Intermediate	Min - Max	683,950 – 706,000	5.7 - 6.2	252,100 – 492,350
	Average	685,700	6.0	348,000
High	Min - Max	684,900 – 707,600	5.8 - 6.2	318,550 – 608,152
	Average	686,750	6.0	450,600

7.9 Project Monitoring

Physical monitoring of the project is necessary to assess project performance and to ensure that project functionality is maintained throughout the 50-year project life. The monitoring plan will be directed primarily toward accomplishing systematic measurements of the beach profile shape. Profile surveys should provide accurate assessments of dune and beach fill volumes and a basis for assessing post-construction dune and beach fill adjustments, as well as variation in the profile shape due to seasonal changes and storms. Monitoring will play a vital role in determining if the project is preforming as predicted and if project renourishment is necessary. Post construction monitoring activities include topographic and bathymetric surveys of the placement area on an annual basis following construction. The cost for this post construction monitoring is included in the cost shared total project cost.

Other monitoring efforts include bathymetric mapping of the borrow sites to ensure sand availability, which will be done as part of the pre-construction engineering and design (PED) phase prior to each nourishment.

Measured wind, wave, and water level information will be obtained from the best available existing data sources. This data will be applied in support of previously discussed monitoring efforts. It will also be used to periodically assess the state of sea level rise and to determine if reassessment of the project volumes and/or renourishment intervals.

8 Project Summary

This appendix summarizes the engineering design of a shore protection project proposed for construction in Pinellas County, Florida (Treasure Island and Long Key Segments). The project consists of beach nourishment/renourishment along the north and south portions of Treasure Island and Long Key as follows:

- Sunshine Beach – Model reaches R126 to R128
- Sunset Beach – Model Reaches R138 to R142
- Upham Beach – Model Reaches R144A to R146
- Pass-a-Grille – Model Reaches R160 to R165

The design beach fill template is characterized by enhancement/construction of a uniform dune to a +10 ft-NAVD88 (+11.1 ft-MLW) elevation, a 20 foot extension of the dune (from crest to Depth of Closure), and 0 foot to 100 foot extension of the berm at +4.57 ft-NAVD88 (+5.67 ft-MLW). Beach fill material required under the High SLR case includes an average of 328,600 to 1,431,850 cubic yards for initial construction of all project segments and eight renourishment events averaging 902,750 to 1,008,000 cubic yards every six years. The final renourishment event is expected to occur eight years prior to the end of Federal participation. This will require proration of the final renourishment volume (increase by approximately a third) to ensure protection for the remaining two years of the project. It should be noted that in practice, renourishment requirements are influenced by storm events and long term erosion and may experience some variability due to the uncertainty inherent in natural phenomena.

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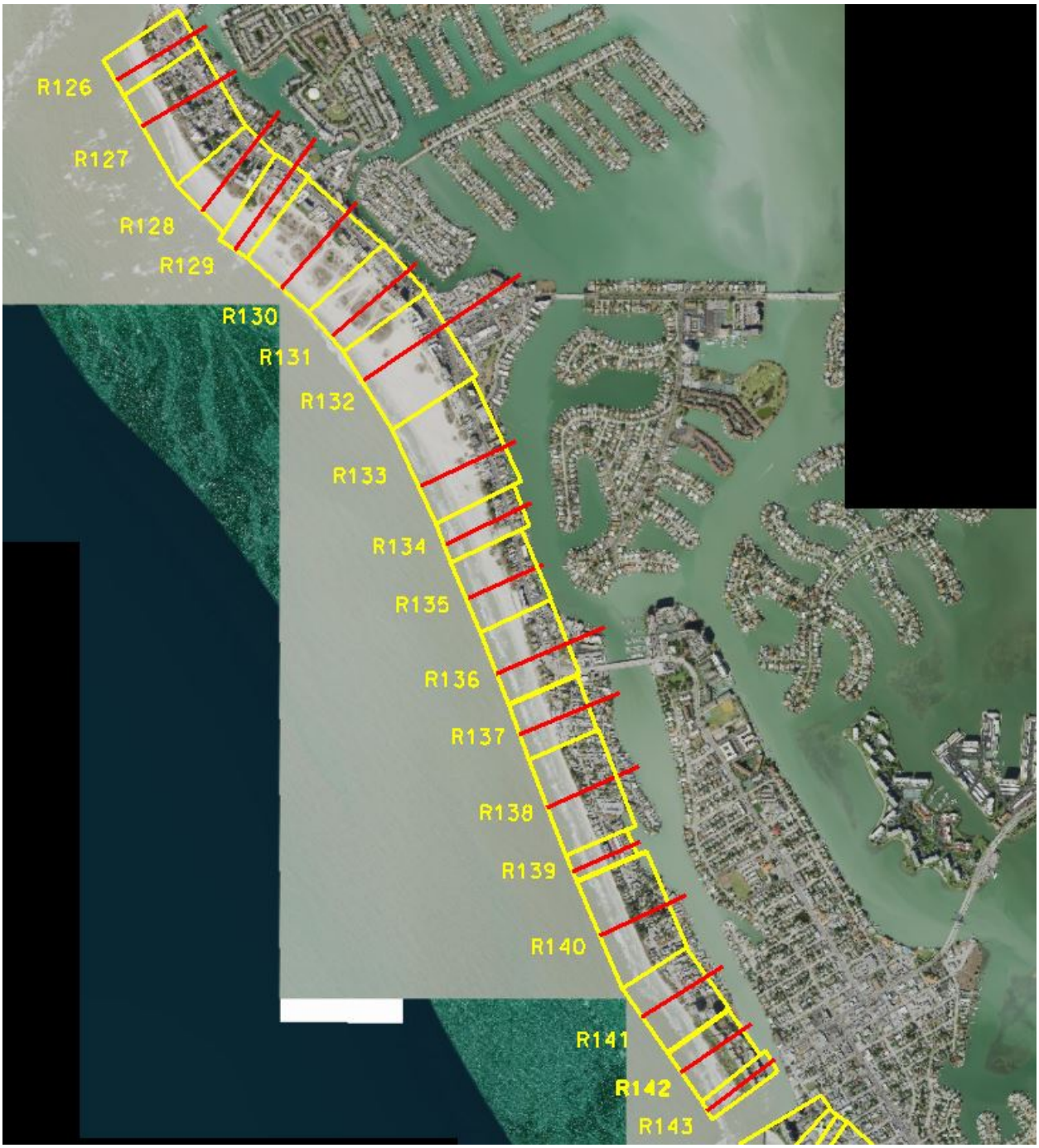
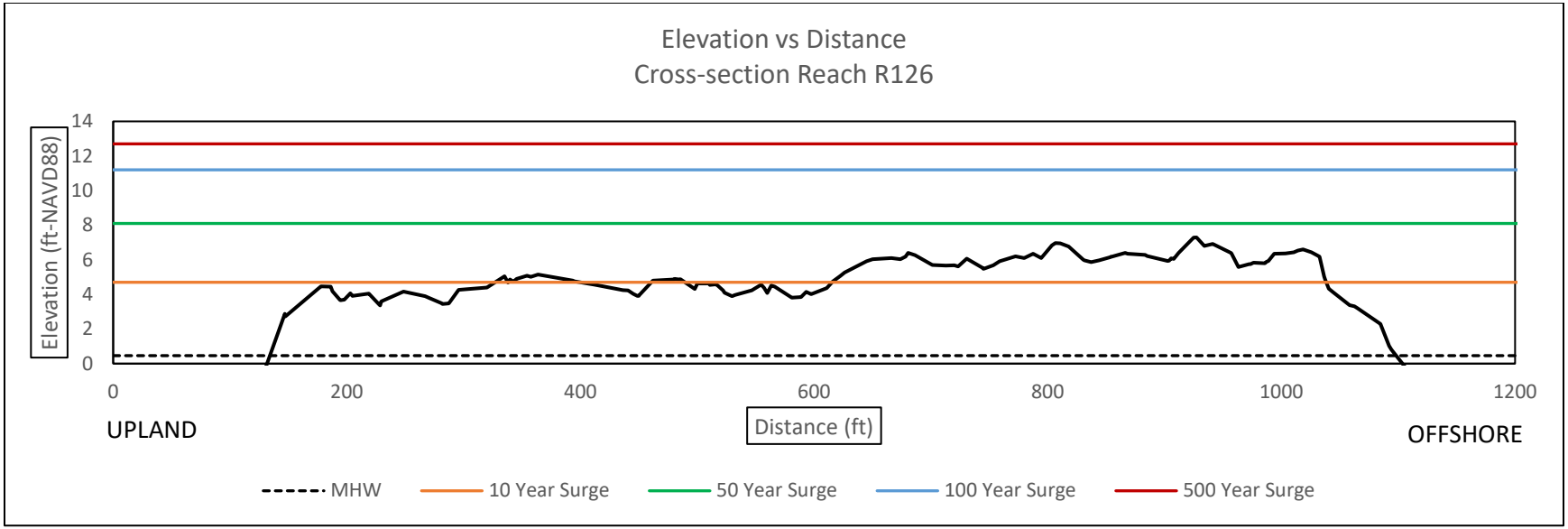
Attachment 1

Treasure Island and Long Key Cross-sections

Treasure Island – Transects and Cross-sections

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Elevation (ft-NAVD88)
14
12
10
8
6
4
2
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0
200
400
600
800
1000
1200
Distance (ft)
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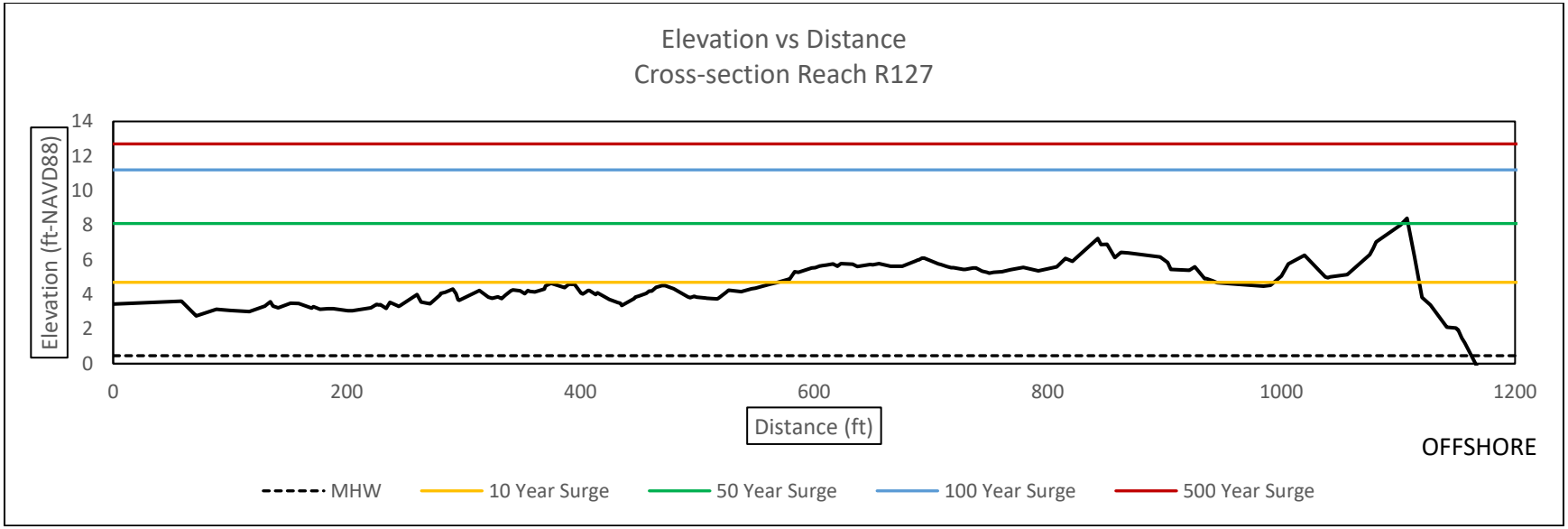
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge


Elevation vs Distance
Cross-section Reach R127
Elevation (ft-NAVD88)
14
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10
8
6
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2
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800
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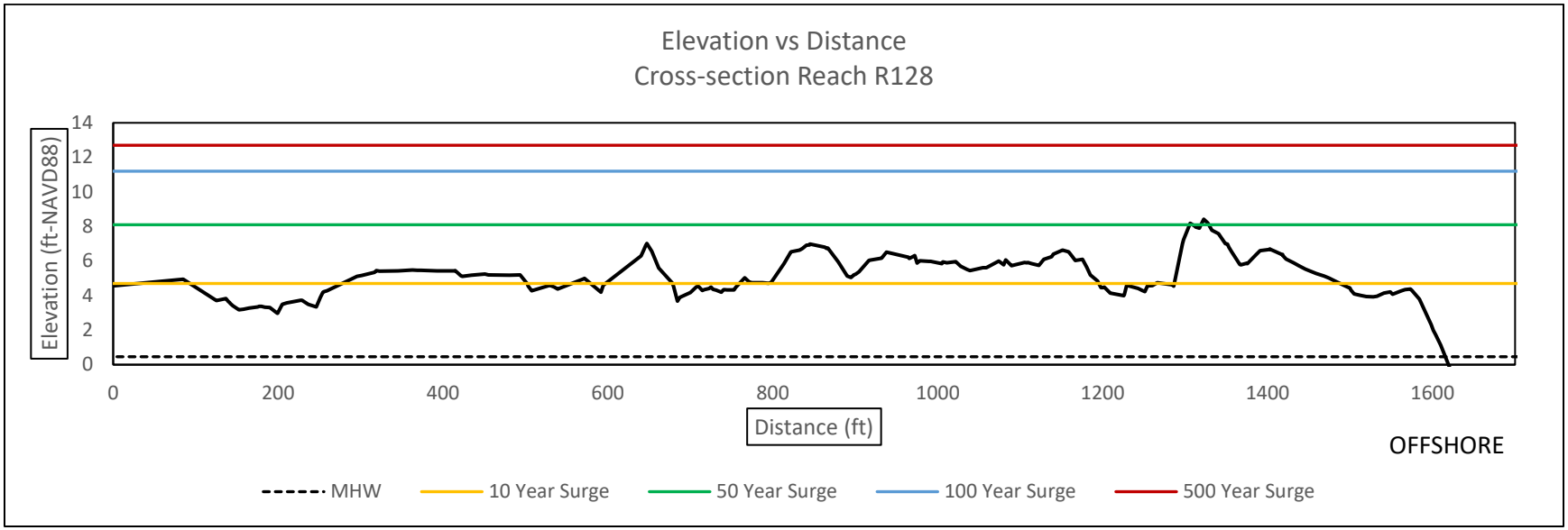
1200
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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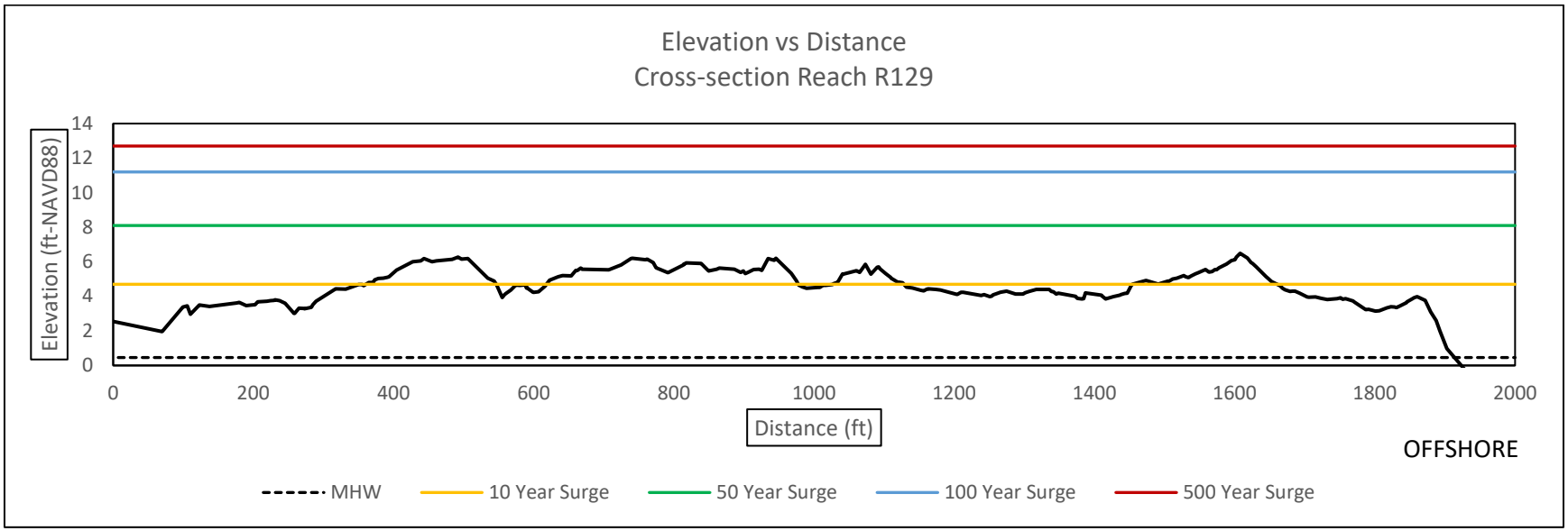
1600
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Cross-section Reach R129
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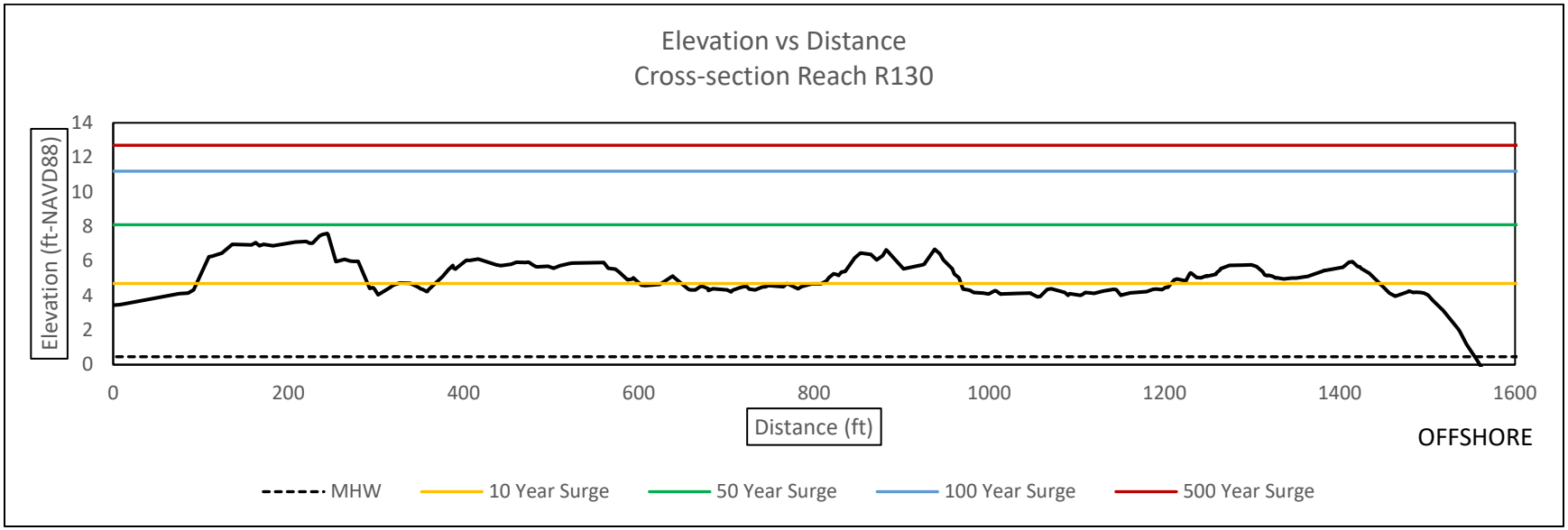
1200
1400
1600
1800
2000
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Cross-section Reach R130
Elevation (ft-NAVD88)
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10
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800
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1200
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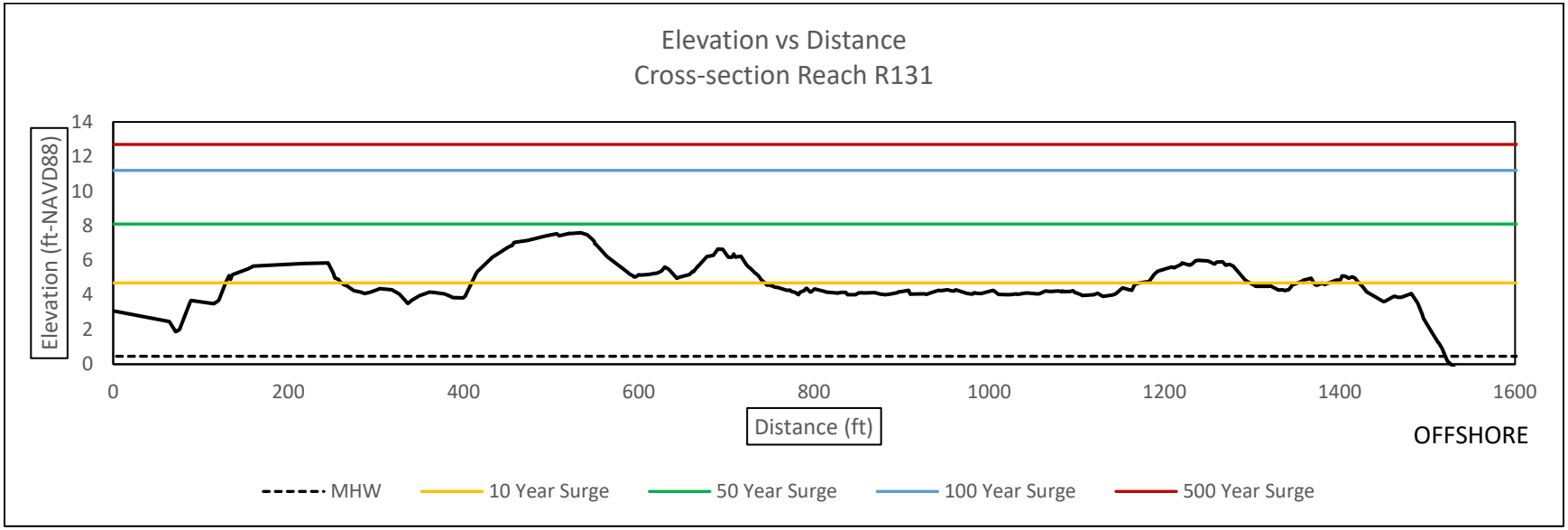
1600
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Cross-section Reach R131
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12
10
8
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2
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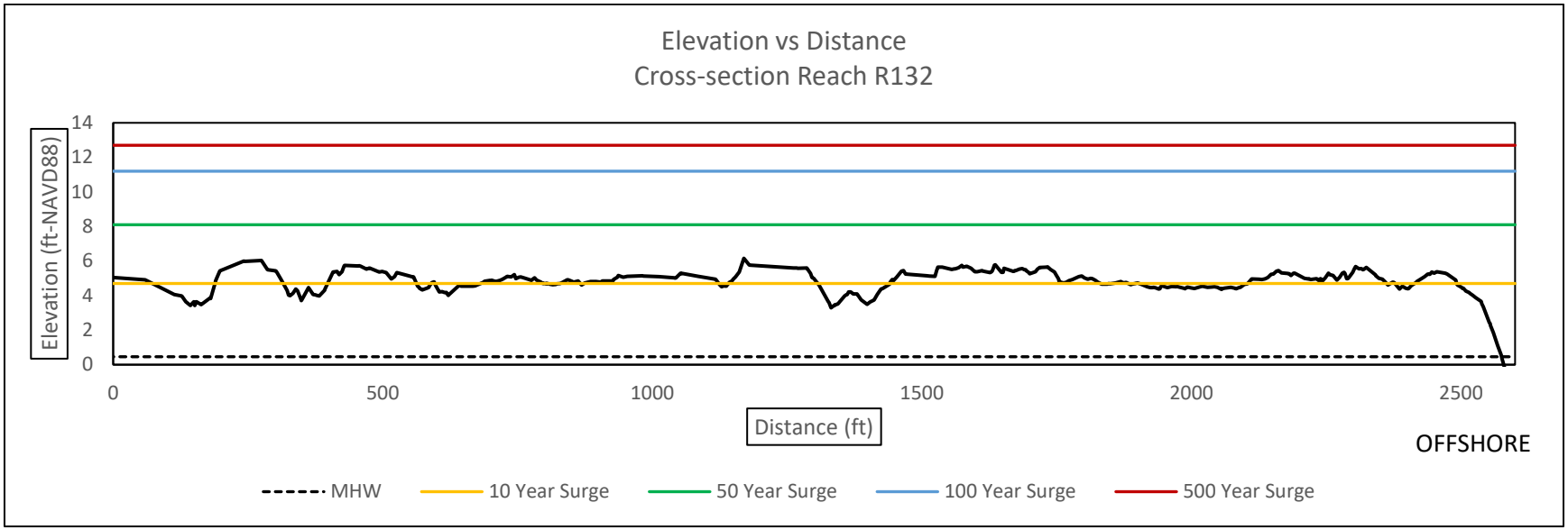
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Distance (ft)
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100 Year Surge
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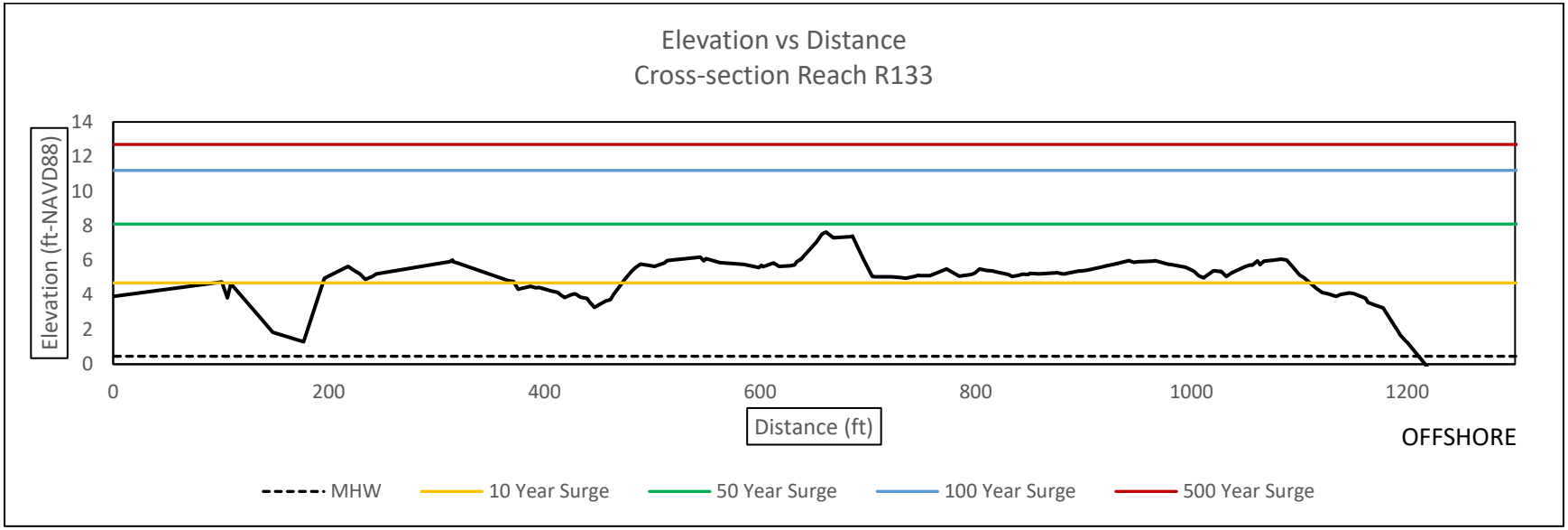
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Distance (ft)
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MHW
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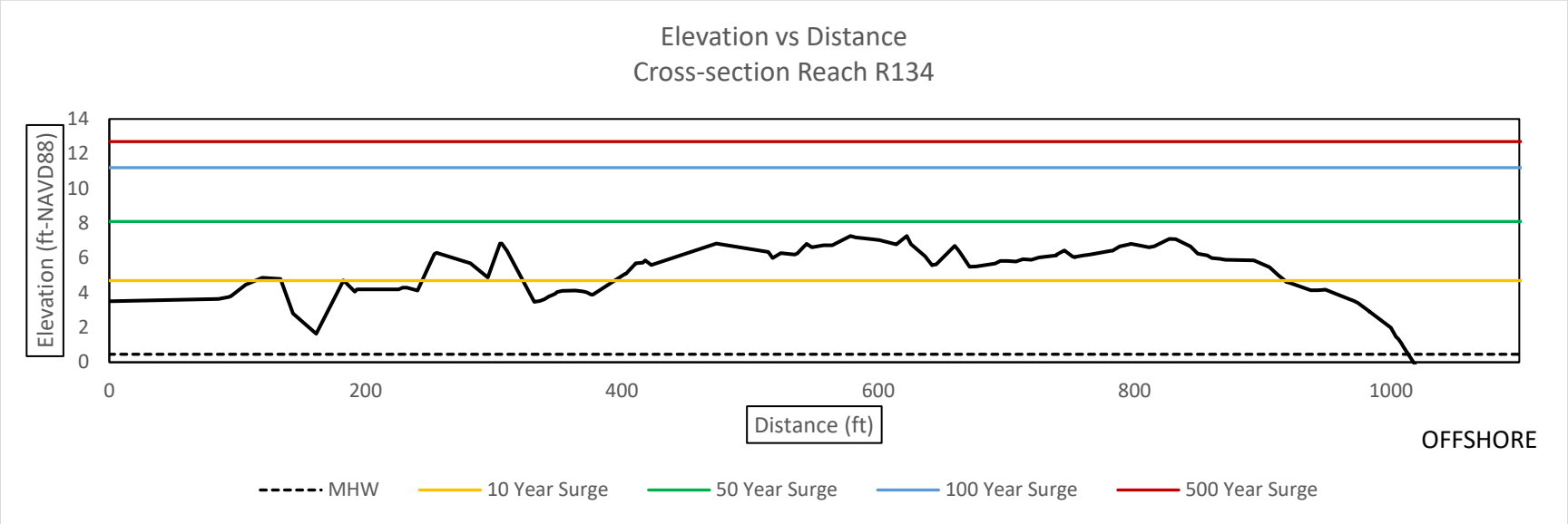
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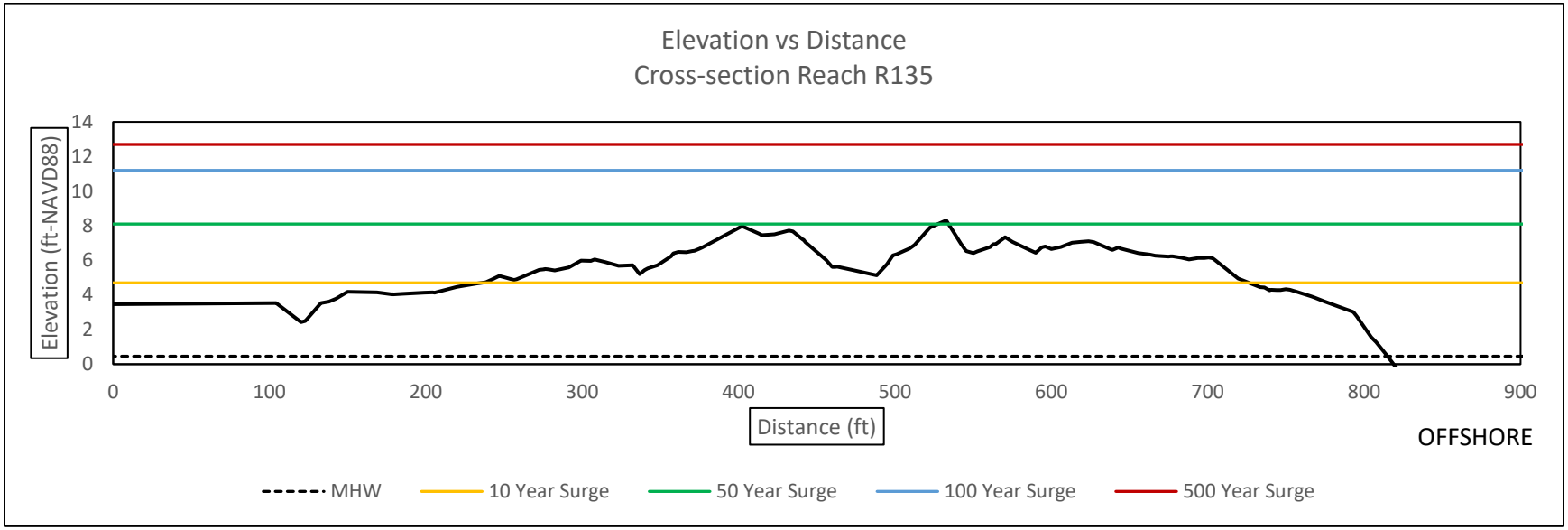
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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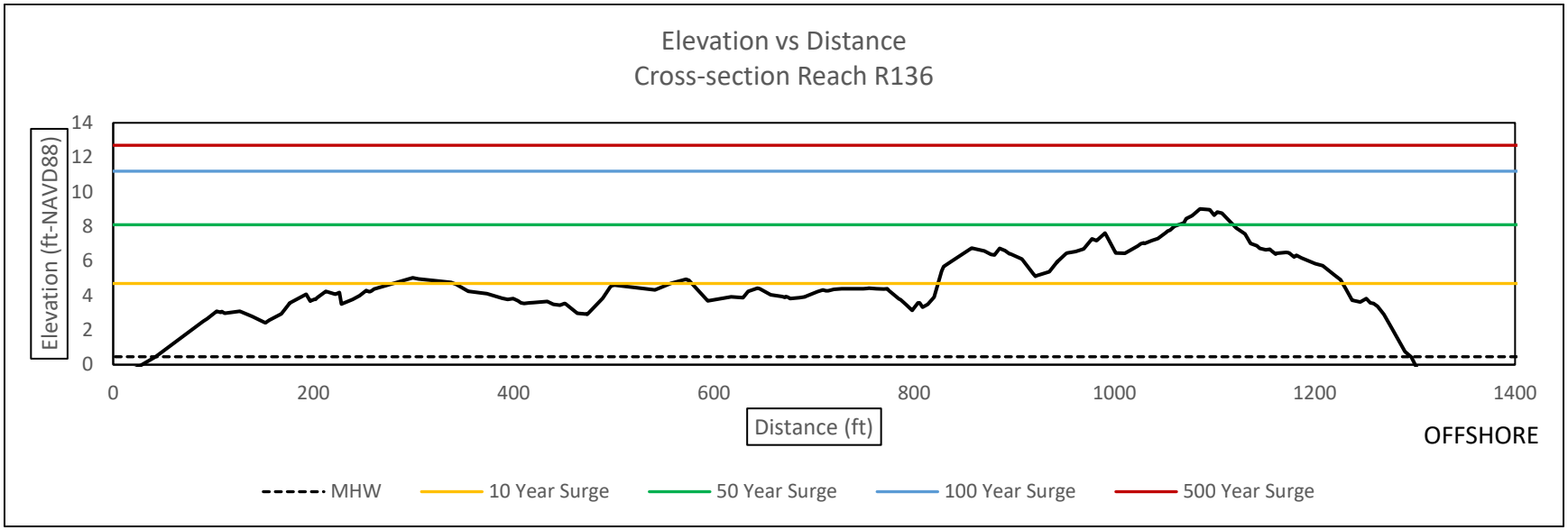
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Cross-section Reach R136
Elevation (ft-NAVD88)
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8
6
4
2
0
0
200
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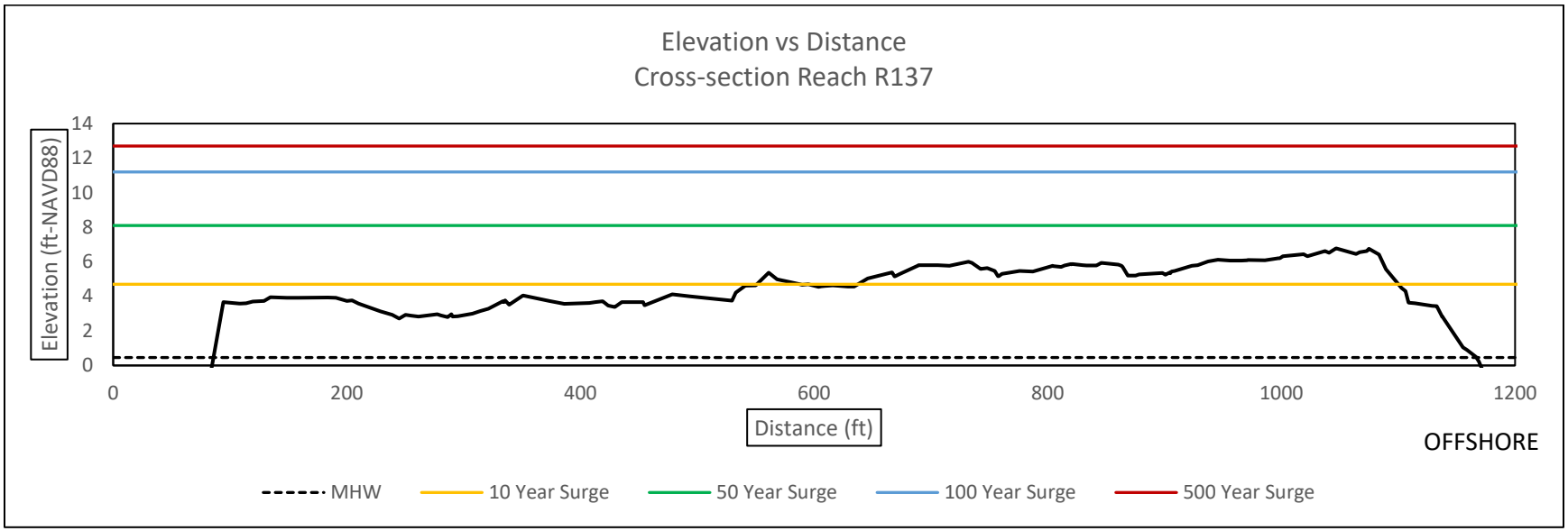
1000
1200
1400
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge


Elevation vs Distance
Cross-section Reach R137
Elevation (ft-NAVD88)
14
12
10
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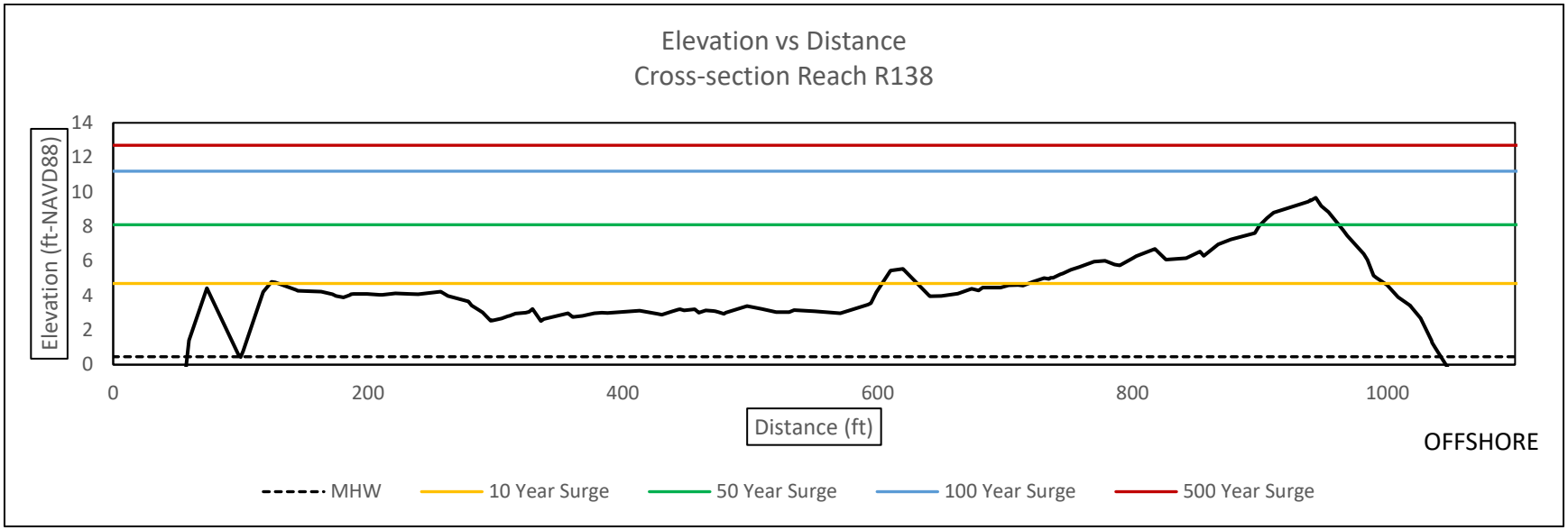
1000
1200
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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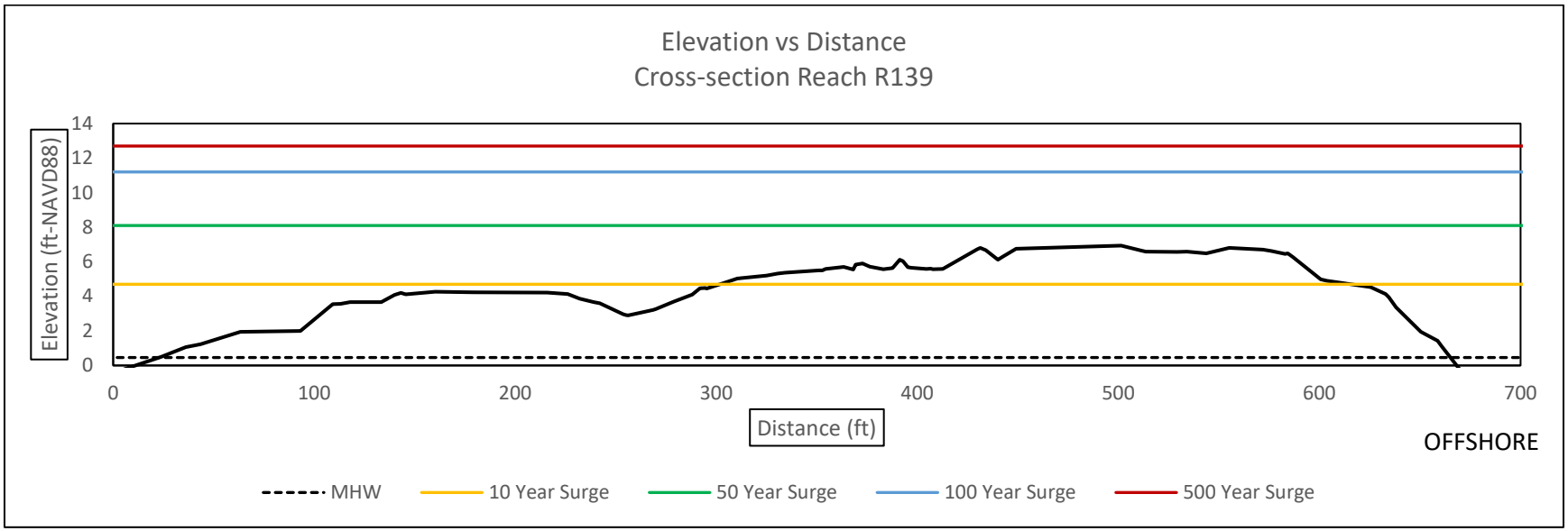
1000
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge


Elevation vs Distance
Cross-section Reach R139
Elevation (ft-NAVD88)
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12
10
8
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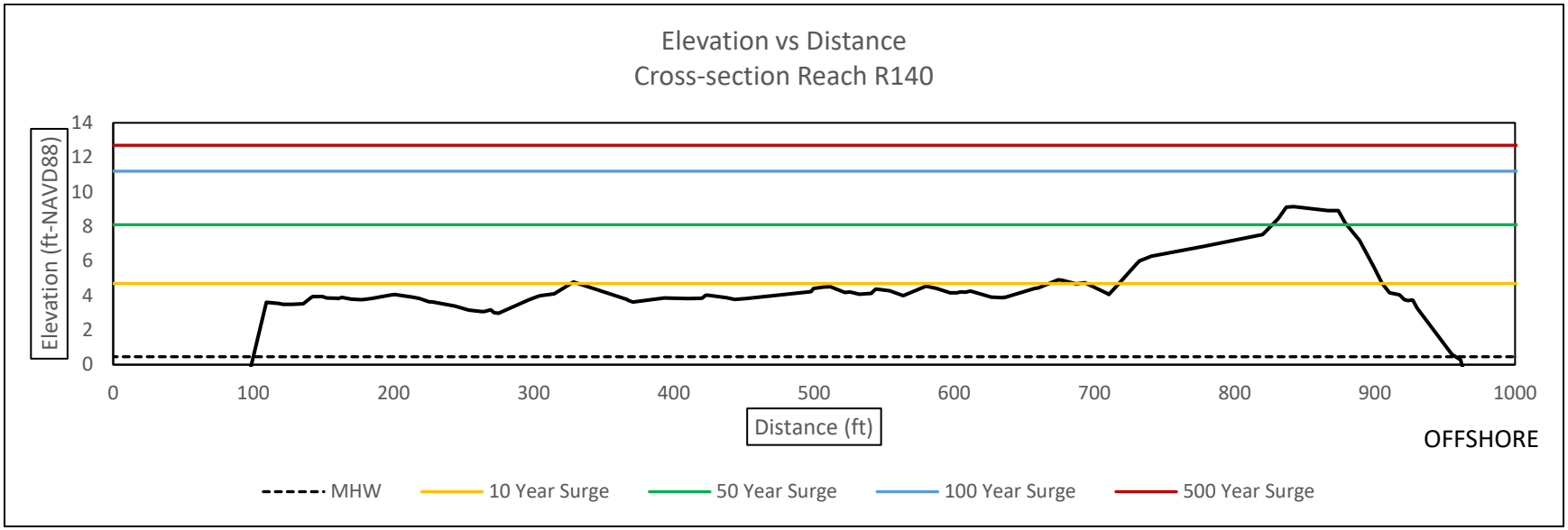
500
600
700
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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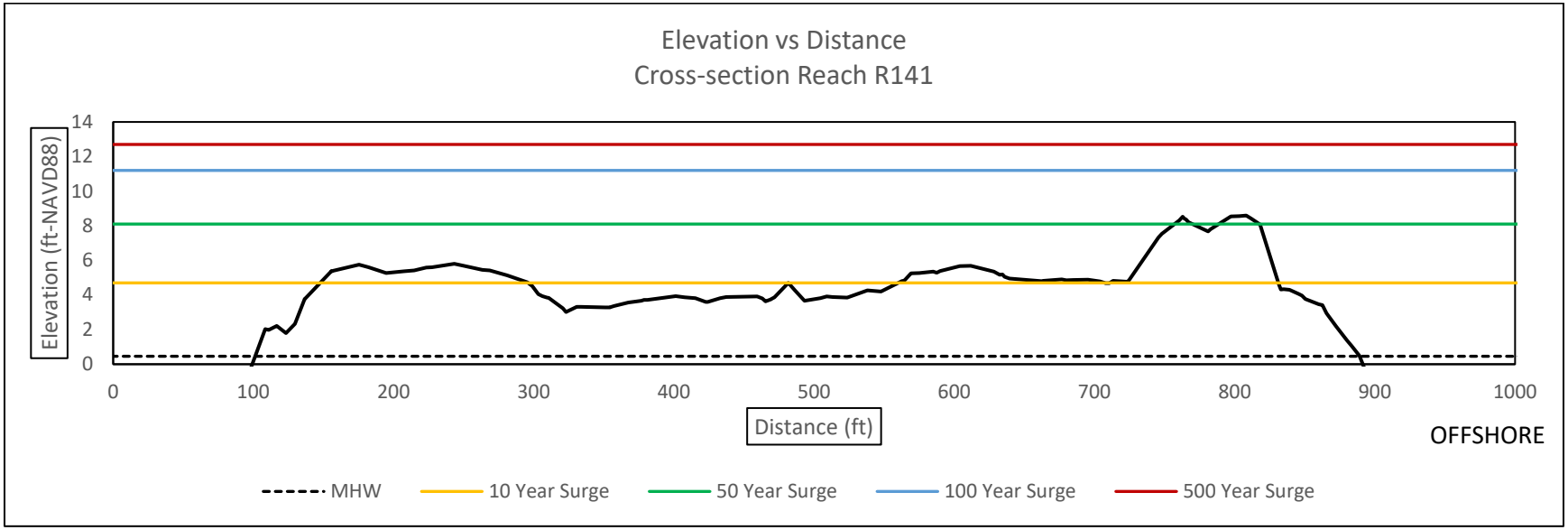
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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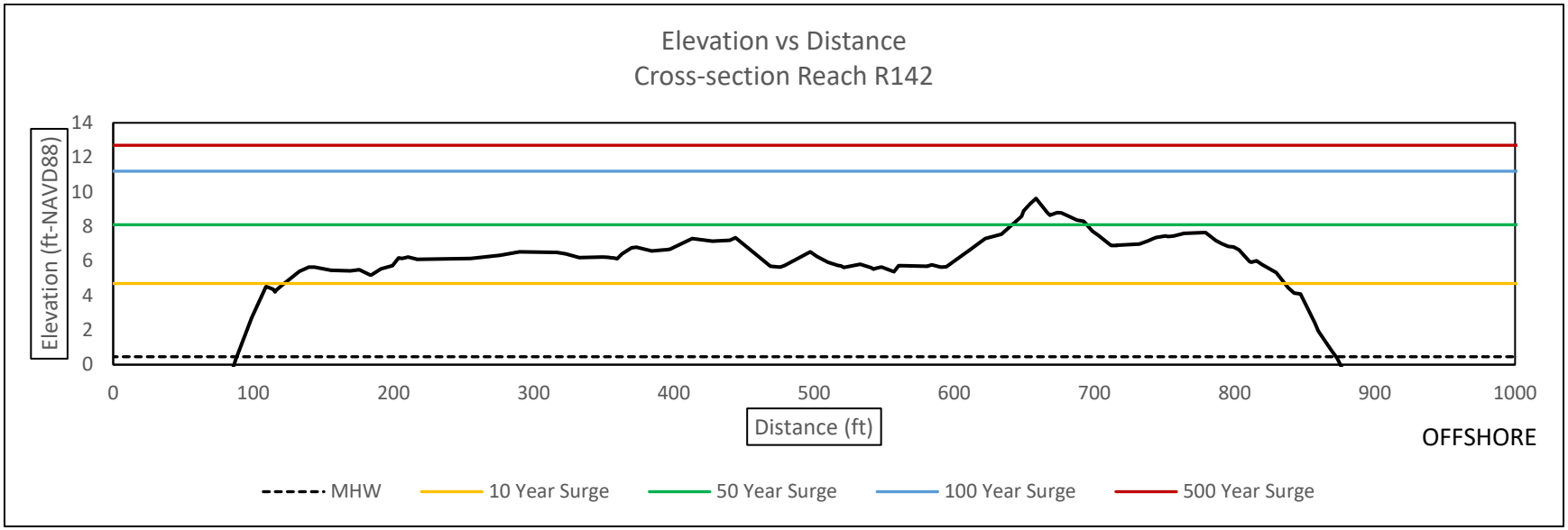
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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8
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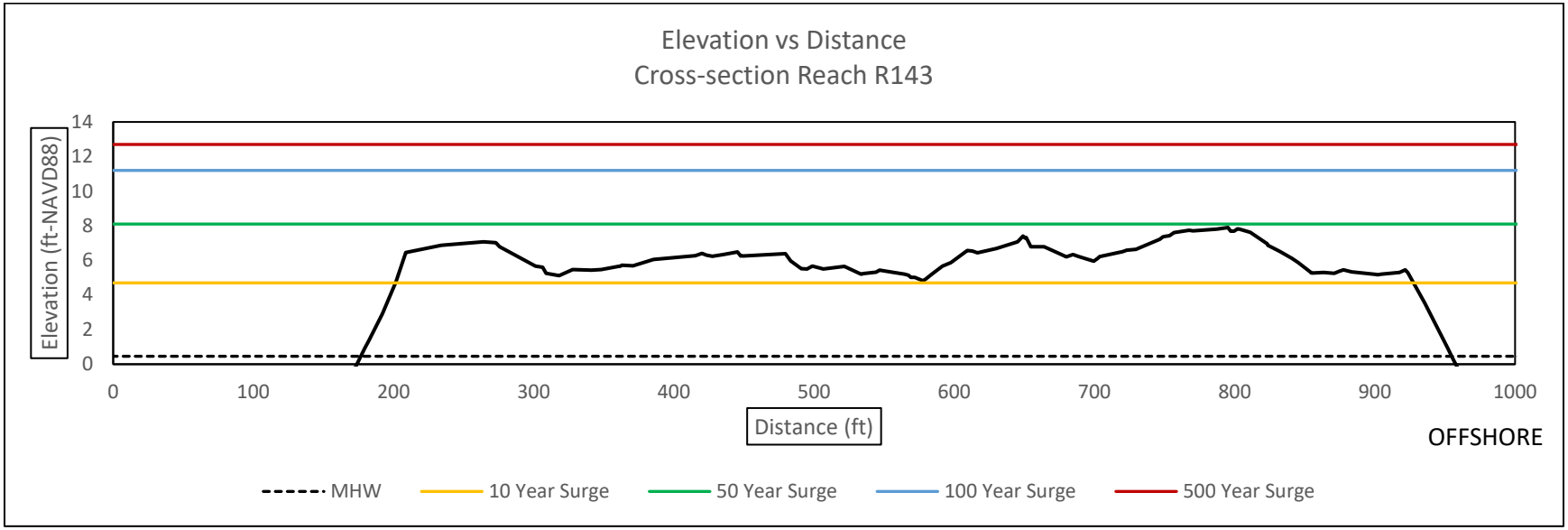
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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400
500
600
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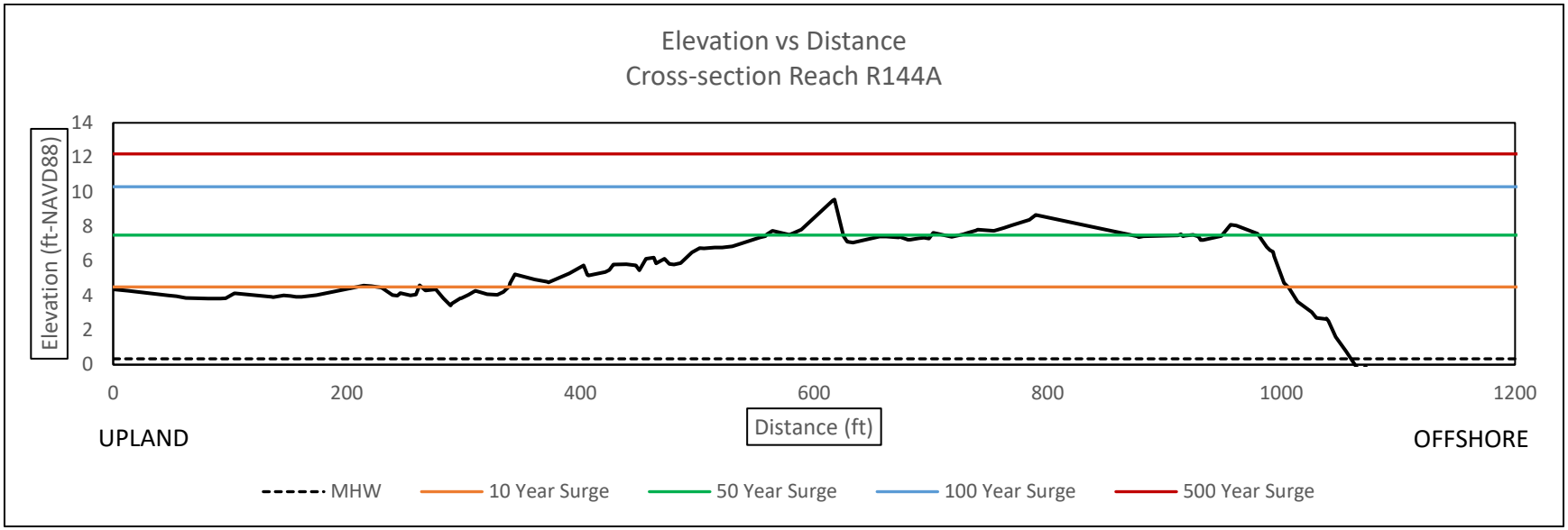
Distance (ft)
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge

Long Key – Transects and Cross-sections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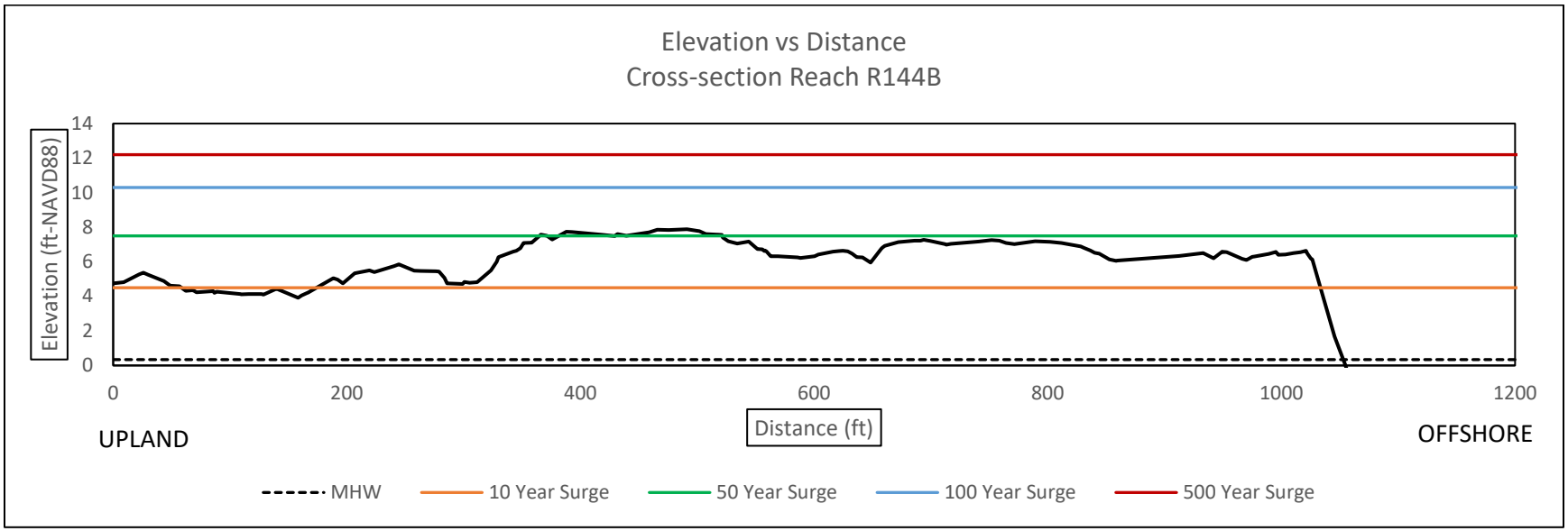
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Distance (ft)
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MHW
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50 Year Surge
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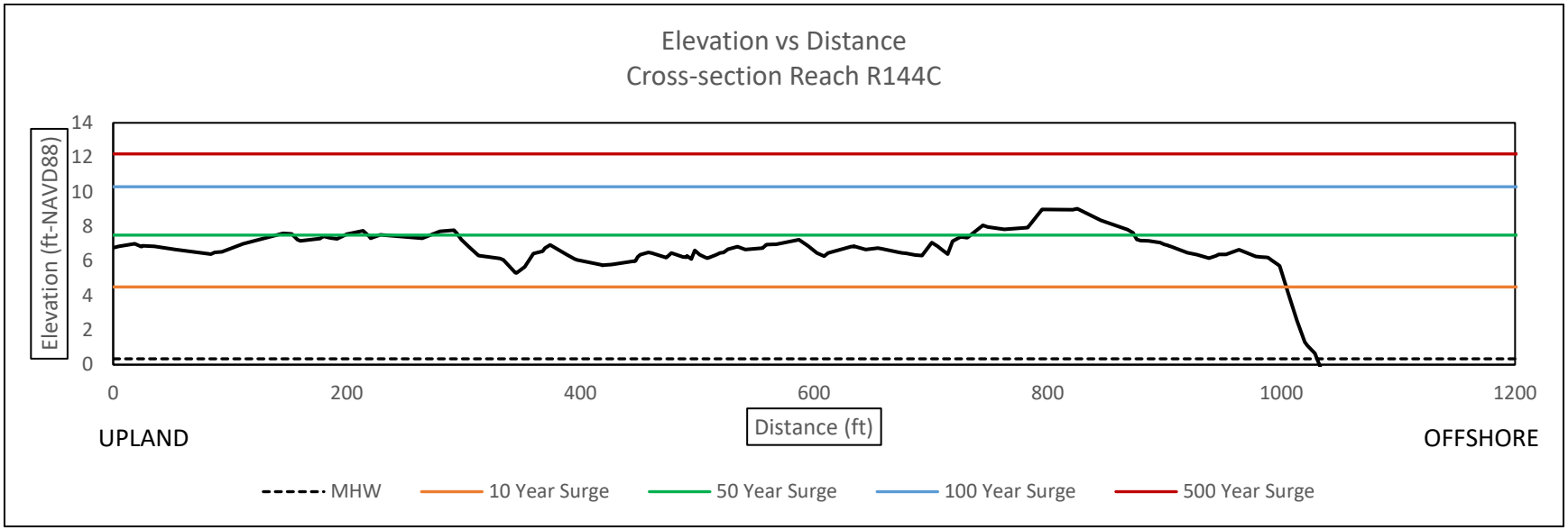
500 Year Surge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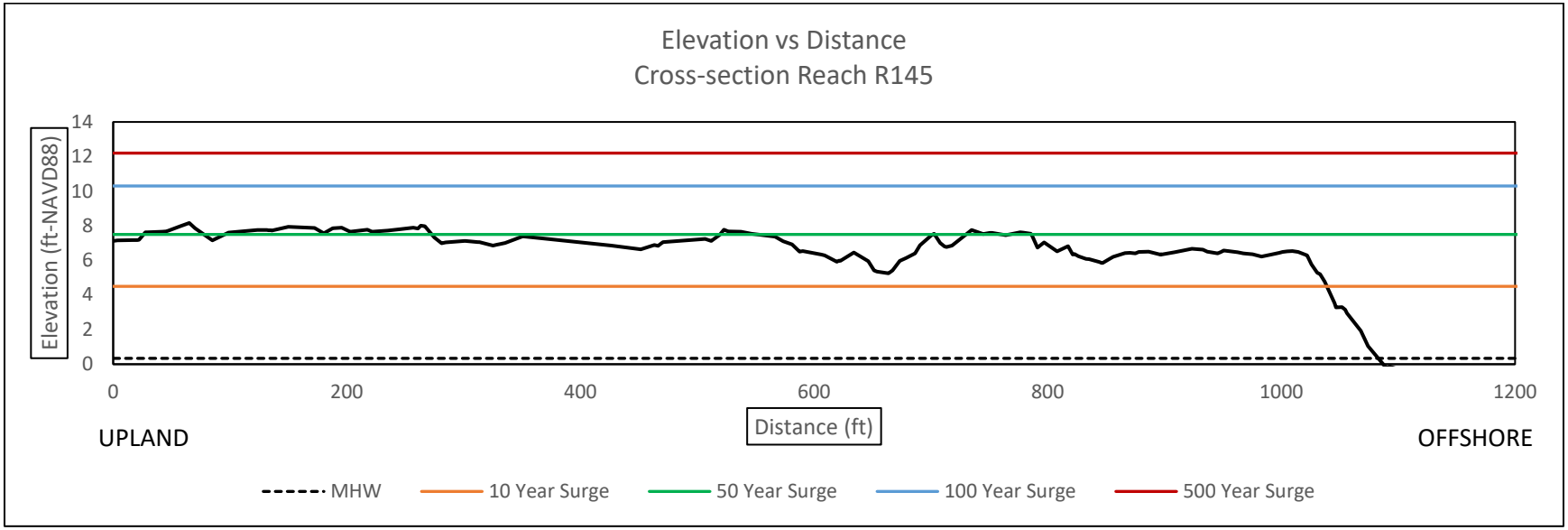
500 Year Surge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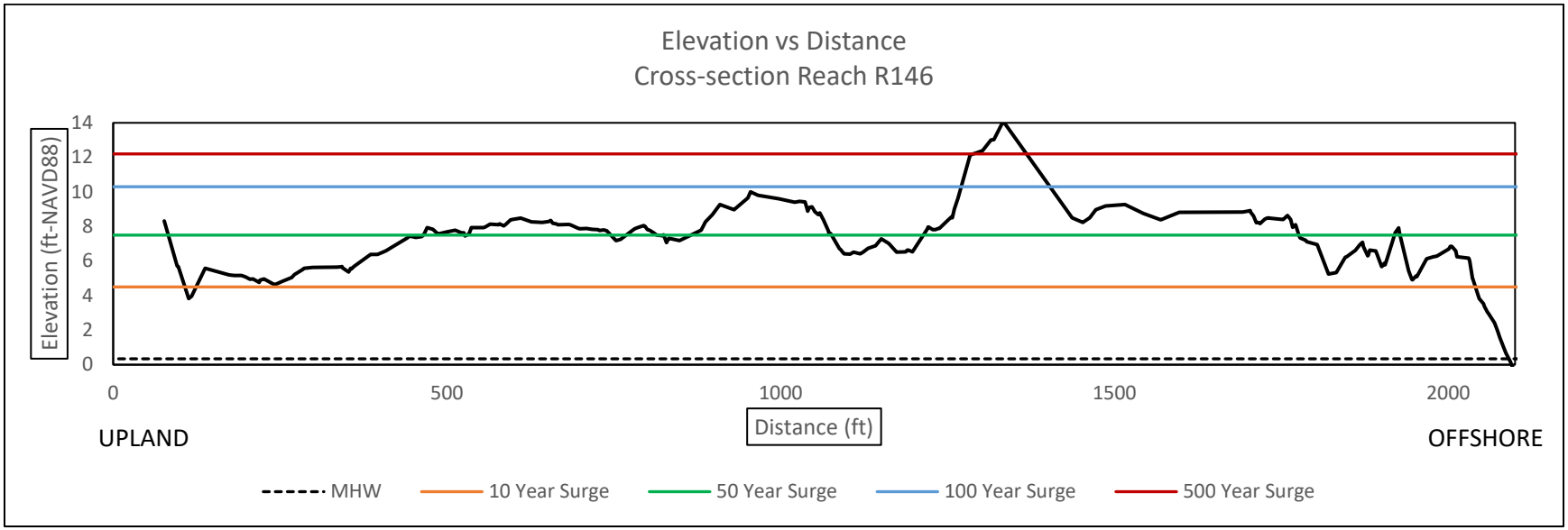
500 Year Surge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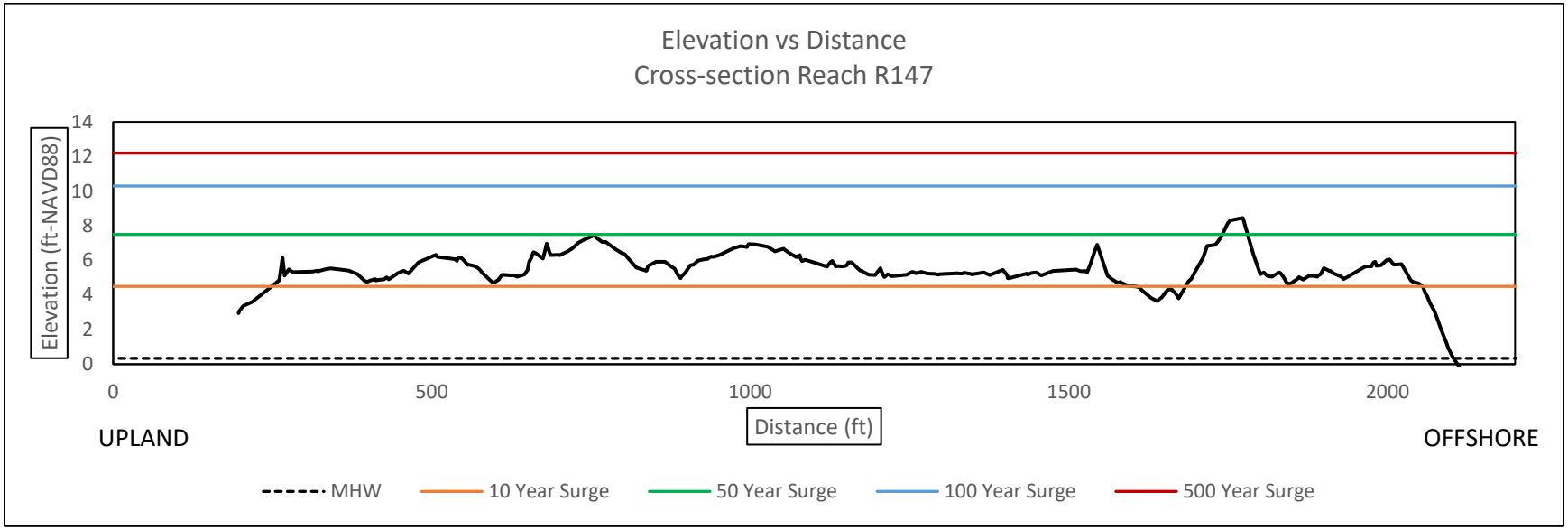
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Distance (ft)
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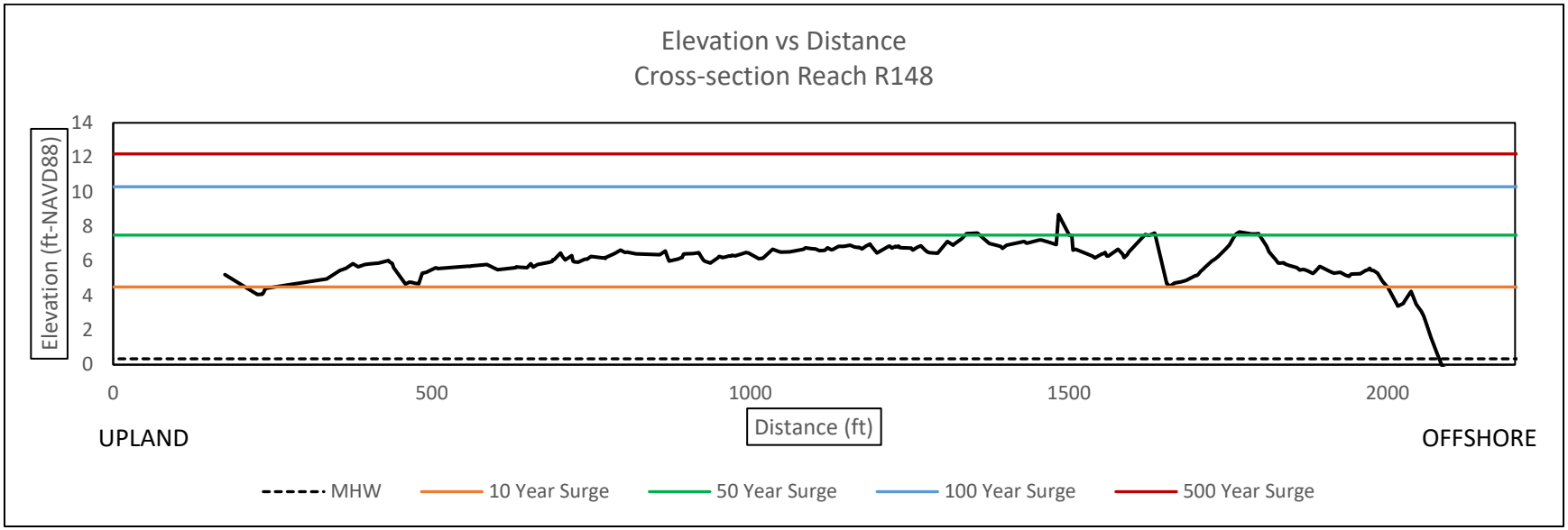
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Distance (ft)
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MHW
10 Year Surge
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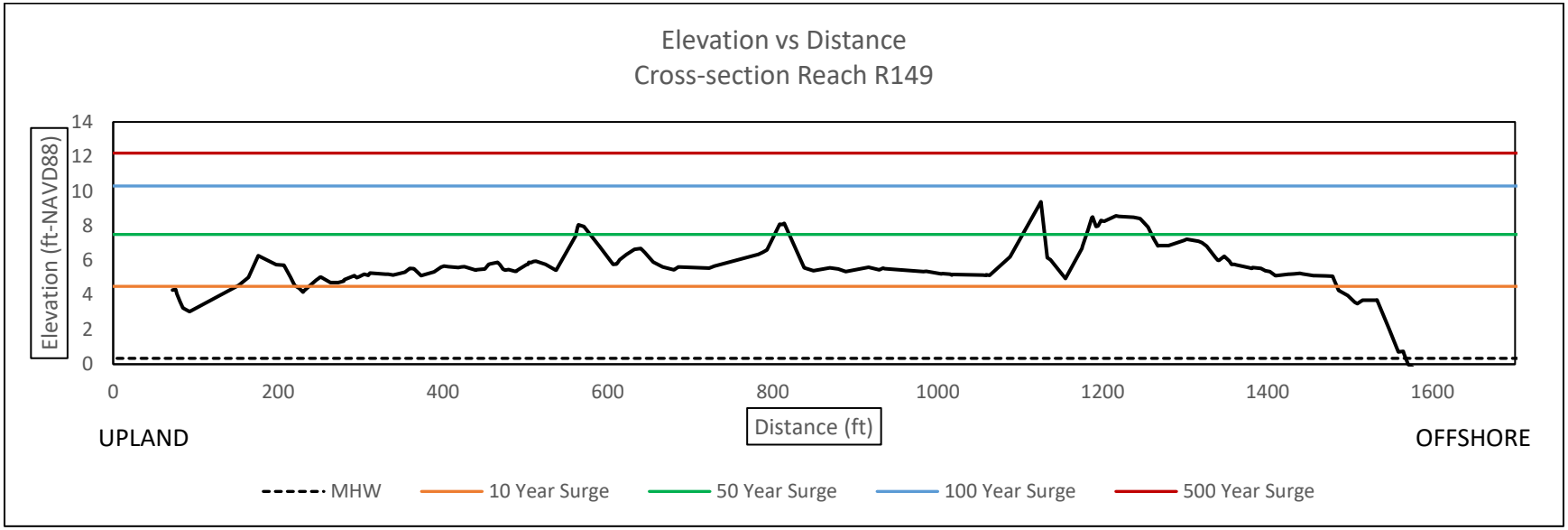
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Distance (ft)
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OFFSHORE
MHW
10 Year Surge
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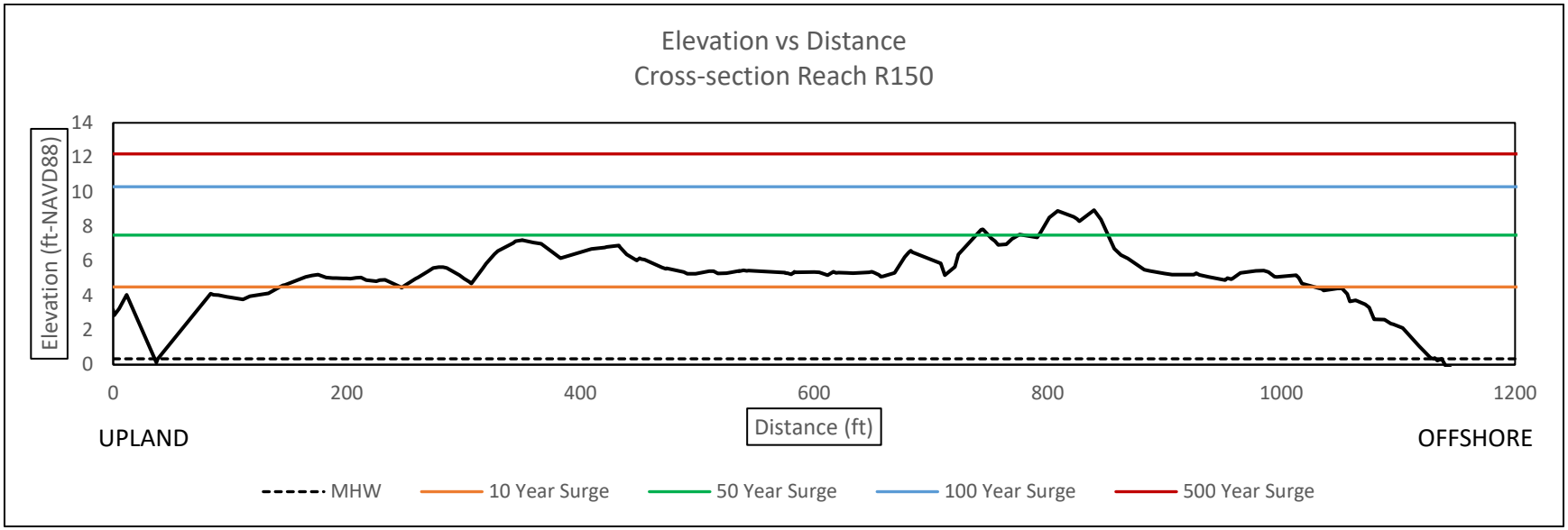
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Cross-section Reach R150
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Distance (ft)
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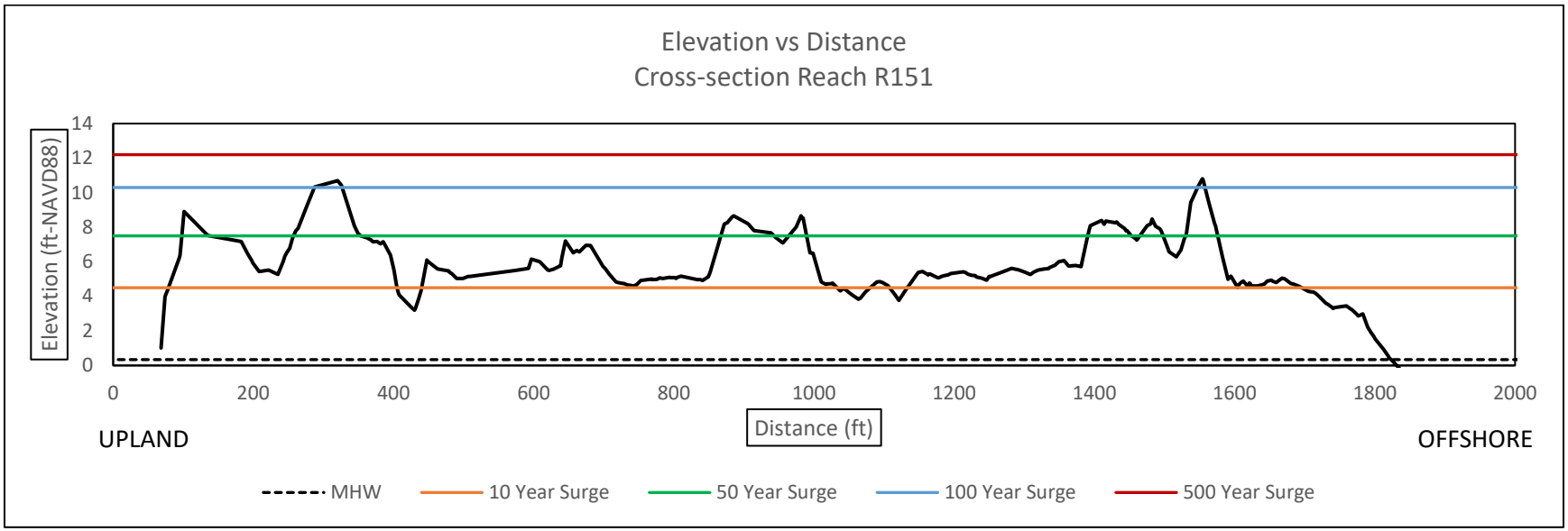
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
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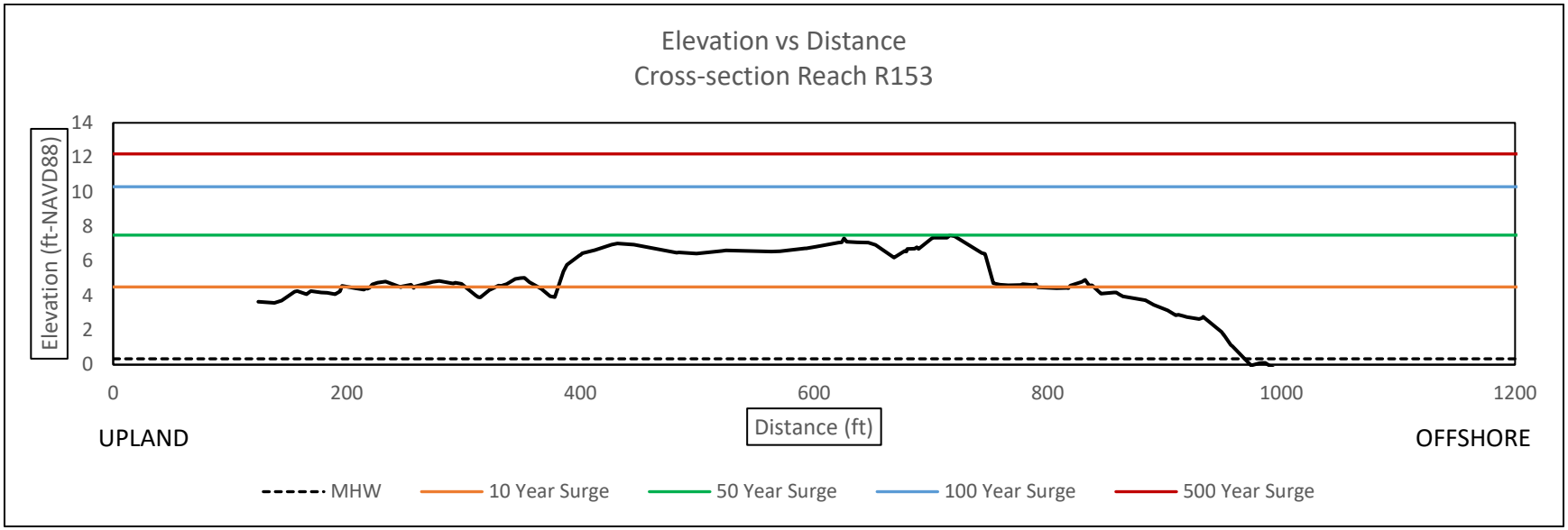
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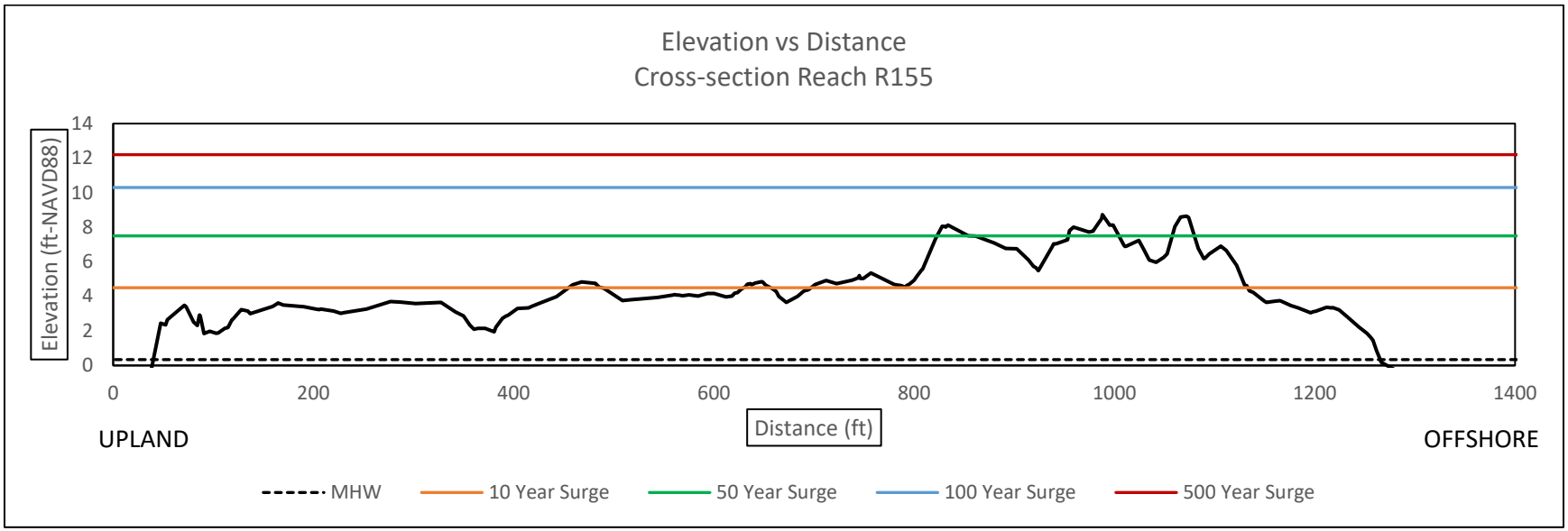
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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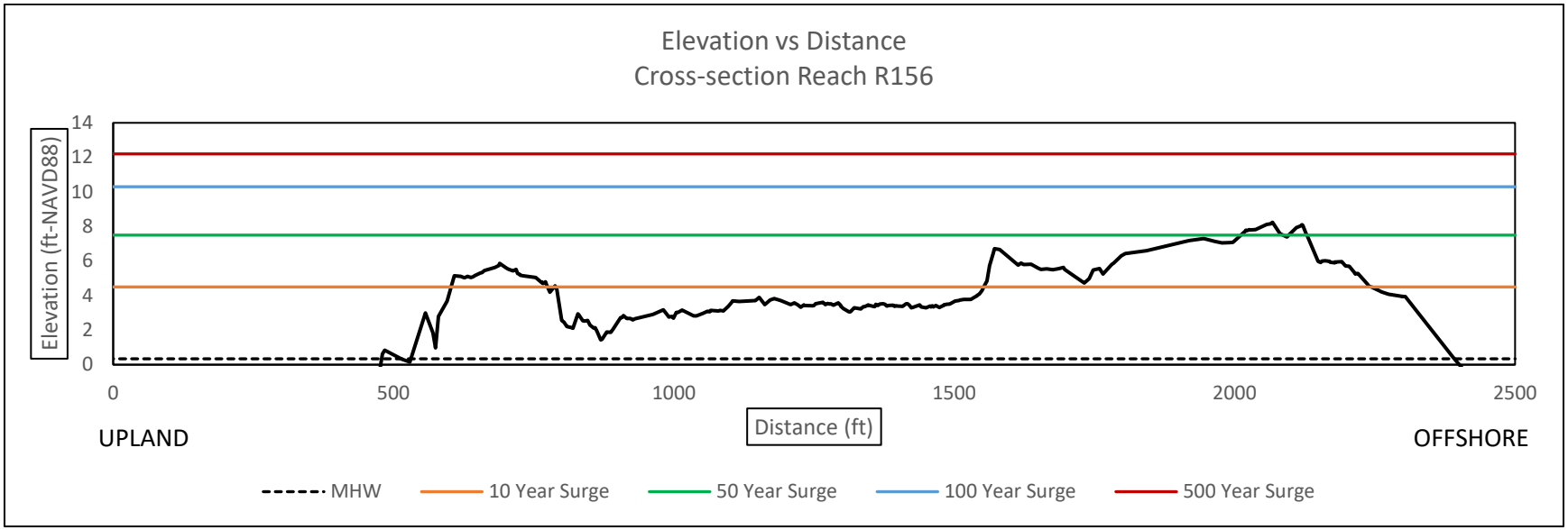
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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10
8
6
4
2
0
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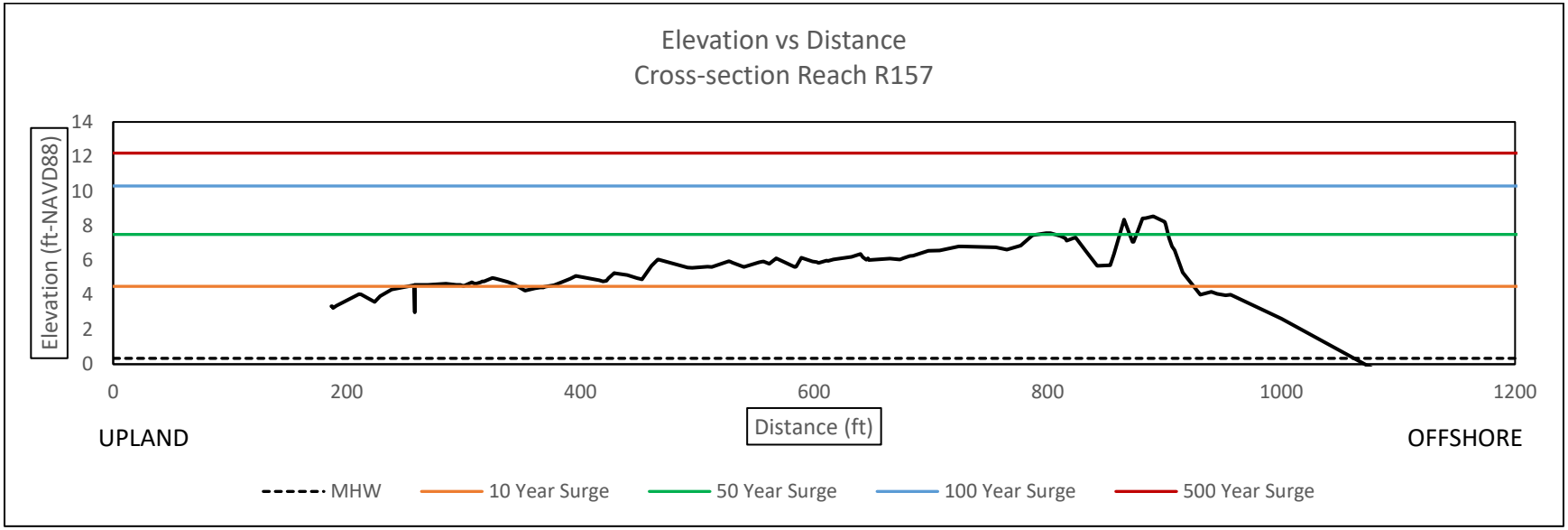
1500
2000
2500
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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2
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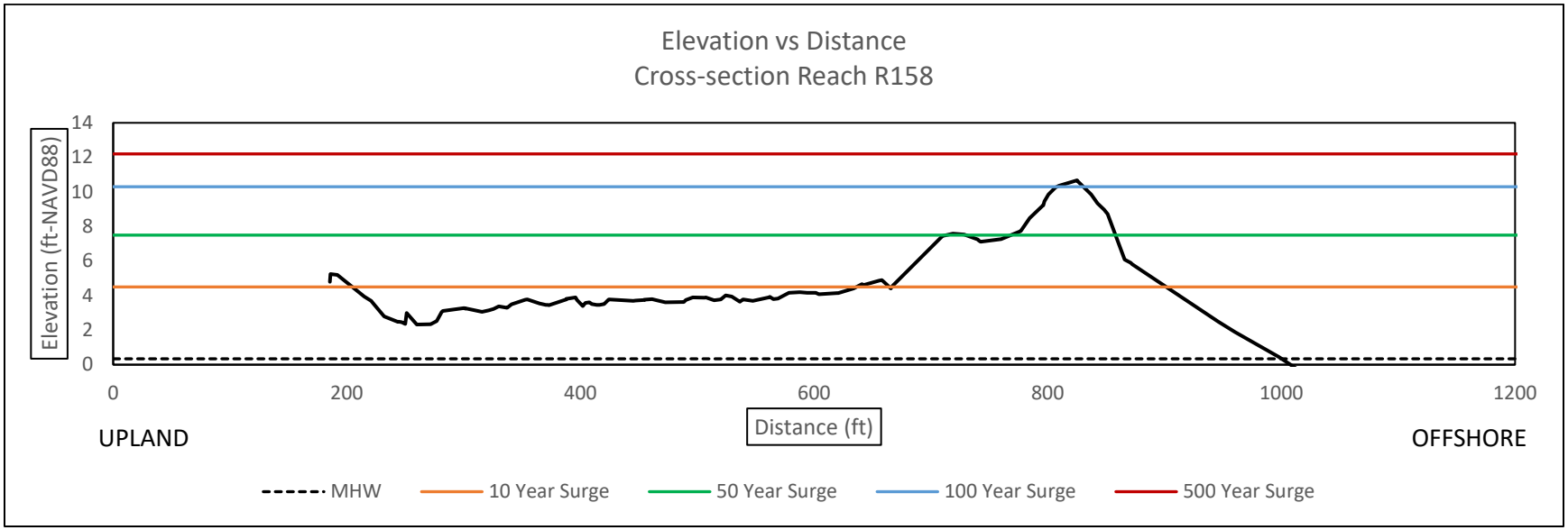
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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Distance (ft)
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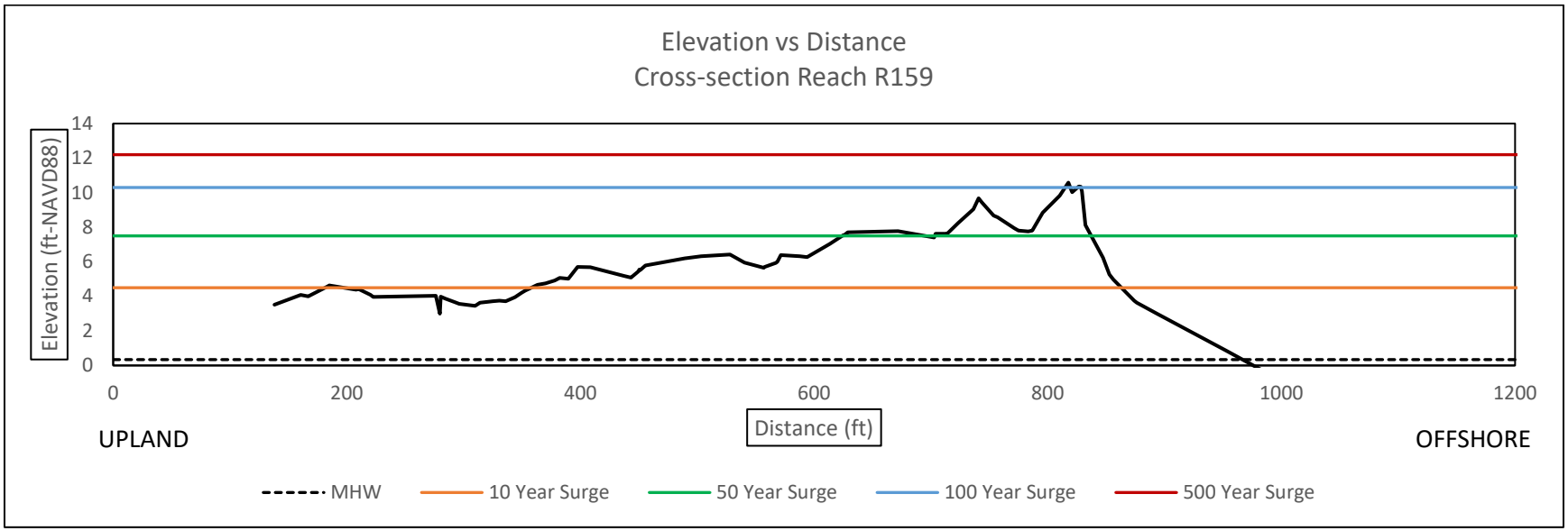
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge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OFFSHORE
MHW
10 Year Surge
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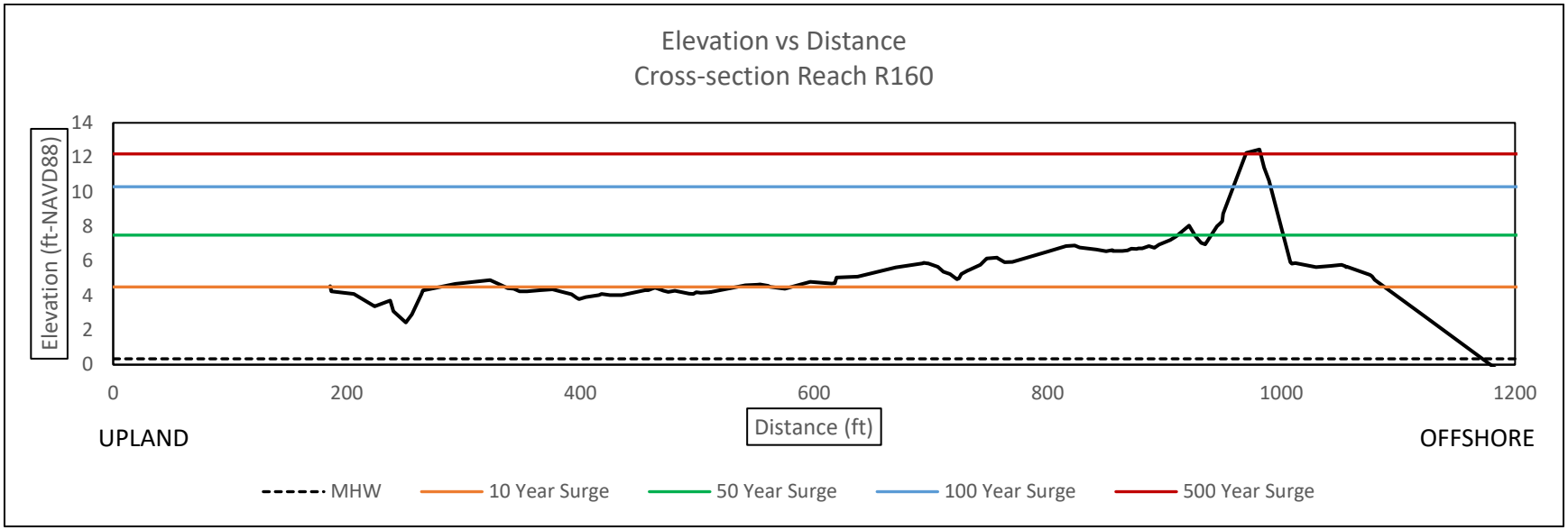
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MHW
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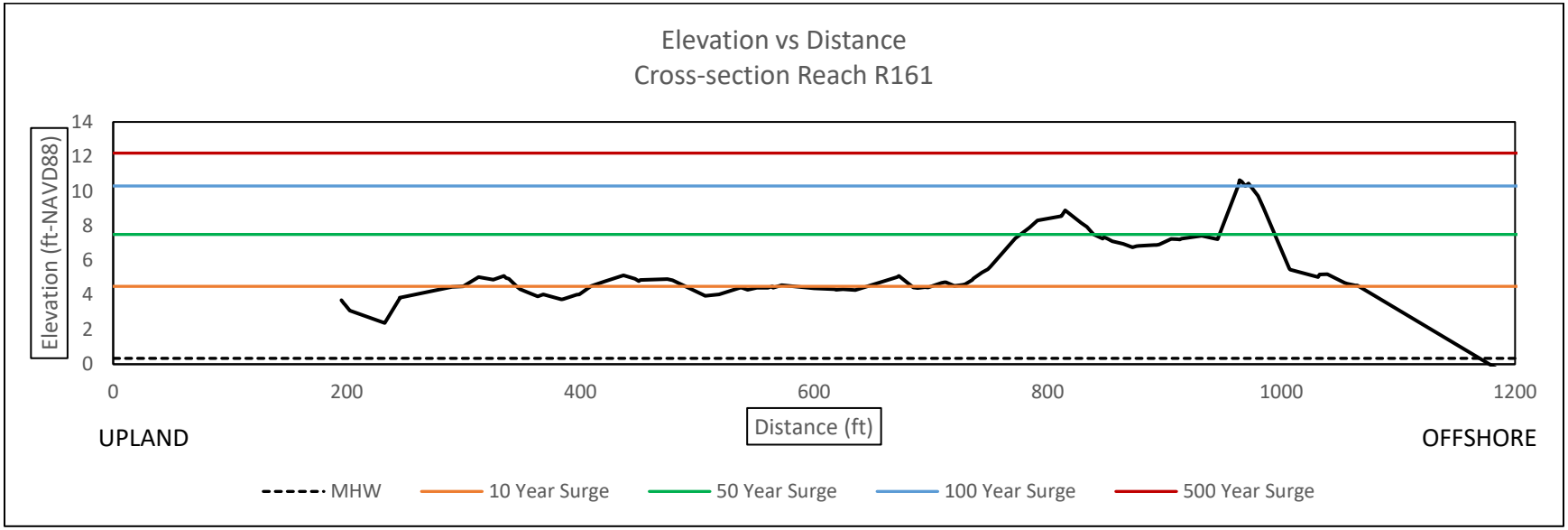
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Distance (ft)
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OFFSHORE
MHW
10 Year Surge
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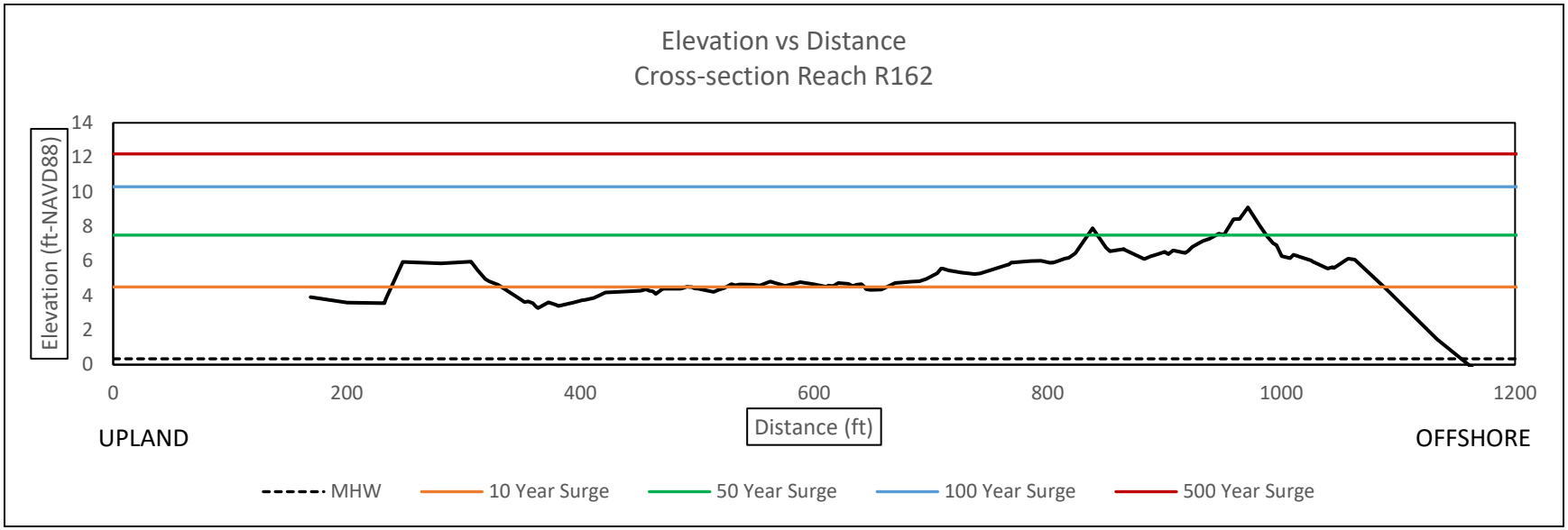
500 Year Surge


Elevation vs Distance
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Distance (ft)
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OFFSHORE
MHW
10 Year Surge
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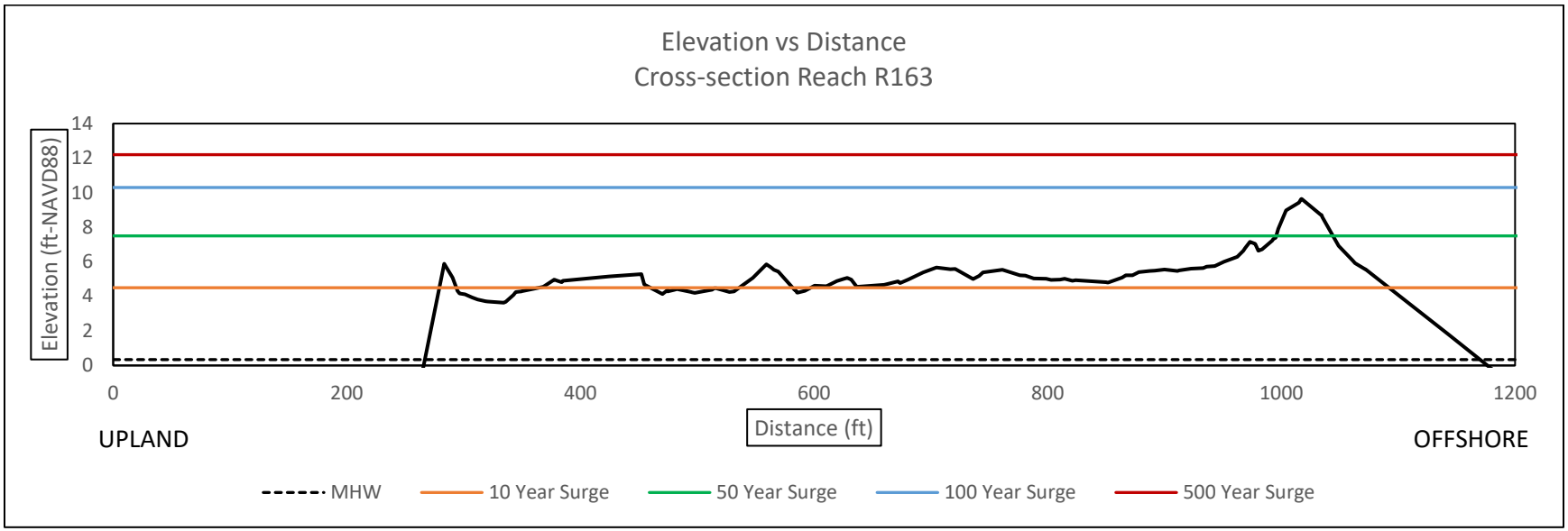
Elevation vs Distance
Cross-section Reach R163
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Distance (ft)
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MHW
10 Year Surge
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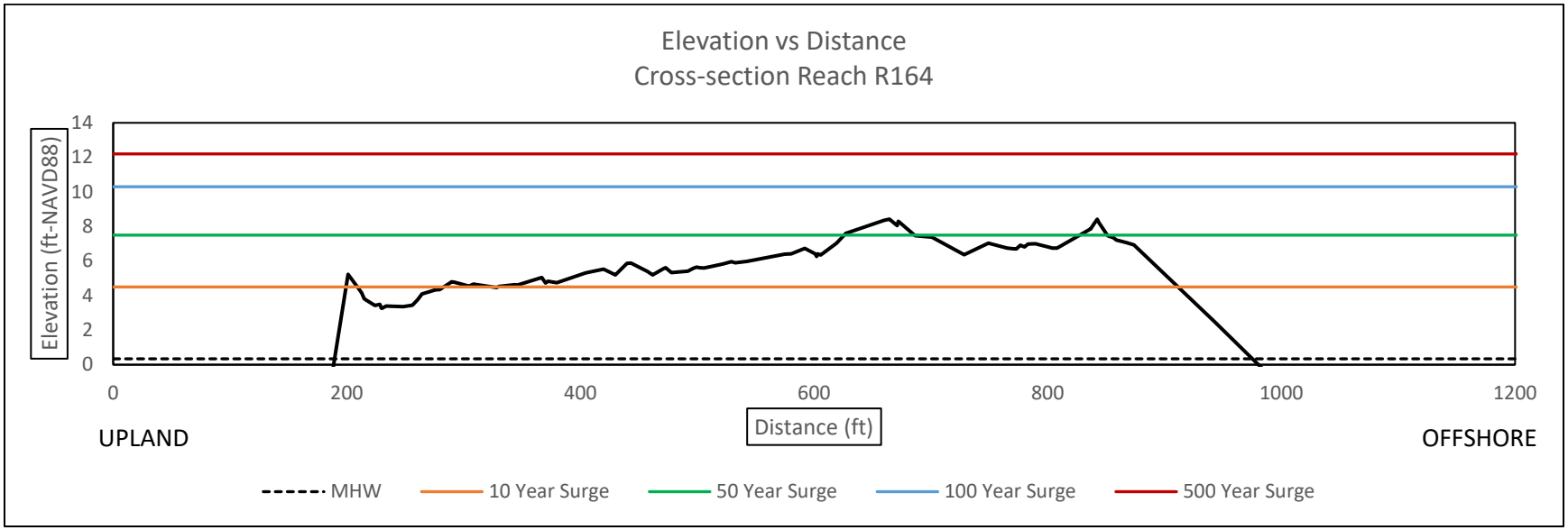
500 Year Surge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Cross-section Reach R164
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Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
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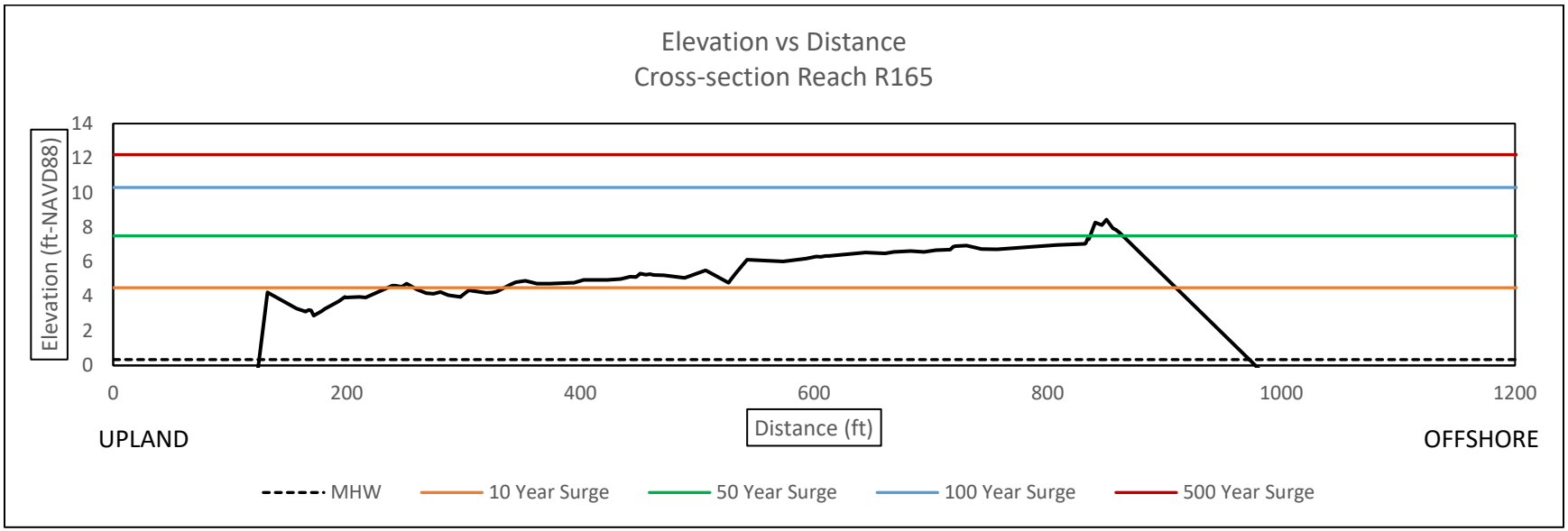
500 Year Surge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Cross-section Reach R165
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800
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1200
Distance (ft)
UPLAND
OFFSHORE
MHW
10 Year Surge
50 Year Surge
100 Year Surge
500 Year Surge

Engineering Sub-appendix A

Pinellas Applied Shoreline Change

Determination of Background Shoreline Change from Project Induced Shoreline Change
Pinellas County, Treasure Island and Long Key, Florida

1 Project Induced Shoreline Change

The project induced shoreline change rate accounts for the alongshore dispersion of placed beach nourishment material. Beach-*fx* requires the use of shoreline change rates in order to represent the planform diffusion of the beach fill alternatives after placement. Traditionally the one-dimensional shoreline change model GENESIS (Hanson and Kraus, 1989), a PC-based program capable of simulating long term spatial changes in longshore transport, has been employed for USACE feasibility studies. However, model setup, calibration, verification, and application to an array of beach renourishment alternatives can be complex and time consuming.

In order to bring the analysis more in line with the accelerated schedules required under SMART Planning guidelines, an alternative methodology was employed. Engineering Manual EM 1110-2-3301 Design of Beach Fills (USACE, 1995) provides guidance on the selection of shoreline change models. Four acceptable alternatives are discussed:

- GENESIS – One-dimensional model (PC based)
- Dean and Yoo (1992) – One line analytical model (spreadsheet/calculator based)
- Multi-contour 3D – Three dimensional model with variable profile and longshore capabilities (PC based)
- Fully 3D Model – Three dimensional model that calculate waves and currents in addition to sediment transport (PC based)

Of the alternatives, the one line analytical model is simplest to apply and produces valid planform diffusion estimates for variable fill widths and lengths. It should be noted that the governing equation within the GENESIS and GenCade models is a one line analytical solution.

1.1 One Line Analytical Model

While Dean and Yoo provides the basic governing formulations for assessing shoreline change rates, it does not specify a discrete analytical solution. These governing formulations, based on the conservation of sand combined with sediment transport, have existed for several decades. In that time, many analytical solutions have been developed to solve them. Because the analytical solution presented by Larson et al. (1987) is the closest in formulation to the GENESIS model traditionally used in more complex USACE applications, it was selected as the one-line model for use with the Pinellas County, Treasure Island and Long Key Segment project.

1.2 One Line Analytical Solution

The analytical solution for shoreline evolution derived by Larson et al. can be described by:

$$y(x,t) = \frac{1}{2} y_o \left[erf\left(\frac{a-x}{2\sqrt{\varepsilon t}}\right) + erf\left(\frac{a+x}{2\sqrt{\varepsilon t}}\right) \right]$$

Where

a = one half of the length of the fill
y_o = original cross-shore width of the fill
x = long-shore distance (where x = 0 is the center point of the fill)
t = time (where t = 0 is initial placement)
ε = diffusion coefficient

The diffusion coefficient is defined as:

$$\varepsilon = \frac{2Q}{(h_* + B)}$$

Where Q can be computed using the CERC equation, given as:

$$Q = \frac{KH_b^{\frac{5}{2}}\sqrt{\frac{g}{\lambda}}\sin(2\theta)}{16(s-1)(1-p)}$$

Where

K = non-dimensional sediment transport proportionality factory (see Section 1.1.2.3.3)
H_b = breaker height
g = acceleration due to gravity
λ = breaking wave height proportionality factor
θ = angle of wave approach
s = specific gravity of sediment
p = porosity of sediment

1.3 Input Parameters

1.3.1 Breaker Wave Height

The breaker wave height is an estimate of the height of waves as they arrive and break on a given beach. This parameter is typically calculated analytically based on deep-water wave characteristics (USACE, 1984). However, for the Treasure Island and Long Key shorelines, only an estimated value for this parameter was required. This is due to the fact that measured shoreline change rates were available to calibrate the analytical solution. The value of H_b becomes independent of the analytical results during the calibration process.

1.3.2 Wave Angle

Wave angle like the breaker wave height is normally a value determined from measured data. This parameter also becomes independent of analytical results during the calibration process. Therefore, the wave angle was set to 45deg, which results in maximum dispersion.

1.3.3 Non-dimensional Sediment Transport Coefficient, K

The sediment transport coefficient *K* can be highly variable. It is dependent on sediment characteristics, properties of the suspension medium, and local wave climate. Small changes in any of the environmental or sediment factors can have a significant impact on the value of *K*. Given its variability, *K* can be set initially based on known or generally accepted parameter values, and then fine-tuned using measured or historical data for the project site. The one line model is calibrated in just this manner, where *K* is adjusted to maximize replication of measured shoreline change rates.

1.4 Calibration

In order to apply a one-line model it is necessary to calibrate the model using the available data. For Treasure Island and Long Key the best available data are post-fill dispersion rates associated with the existing project. Shoreline change rates for the existing project at Treasure Island were calculated as MHW recession using post-fill monitoring surveys taken annually following the 2006 renourishment event. Shoreline change rates for the existing project at Long Key were calculated as MHW recession using post-fill monitoring surveys taken annually following the 2015 renourishment event. For each project segment the one-line model was applied only to those model reaches that correspond to the limits of the fill. Measured rates were then compared to recession rates calculated with the one line model using the project berm widths for each fill segment and variable K values. Because of consistent environments between Treasure Island and Long Key, a single K value for all segments was needed. The K value that most closely reproduced the measured shoreline recession for all project segments was 0.85.

Model reaches are shown graphically in **Figure 1** and corresponding project induced shoreline change rates are provided in **Table 1**. Note that **Table 1** provides a single value averaged over the entire project segment. This is due to the fact that survey data shows considerable variability between monitoring survey profiles, fluctuating significantly from year to year as sediment "waves" move (predominantly south) along the islands. These fluctuations in annual rates tend to drown out the long term erosional trends unless there is a sufficient long term record to smooth them out. Long term records were not available due to the relatively short interval between fills as well as the variability in consecutive fill volumes and dimensions for each event. It was determined that in the absence of long term data, average values within each monitoring period would best capture associated erosional trends. Additionally, the Beach-fx model was developed with the assumption of relatively smooth transitions in erosions rates between model reaches. Past experience has shown that significant changes in erosion between consecutive model reaches results in model instability and questionable outputs. Model developers recommend using averaged or otherwise smoothed values if measured erosion rates show significant variance.

2 Background Shoreline Change Rates

Past applications of the one line model have shown that as a fill equilibrates, the dispersion rate decreases until it approximates the background erosion rate when the project berm width reaches approximately 20 feet in width. Using the calibrated one line model, the background shoreline change rates for the full extent of both Treasure Island and Long Key project segments were calculated. In order to determine erosion for the entire length of each island, all model reaches were included in the analysis. **Table 2** provides the calculated background shoreline change rates representative of the

project. As the values are determined analytically with a consistent fill width there is no significant variability in the values.

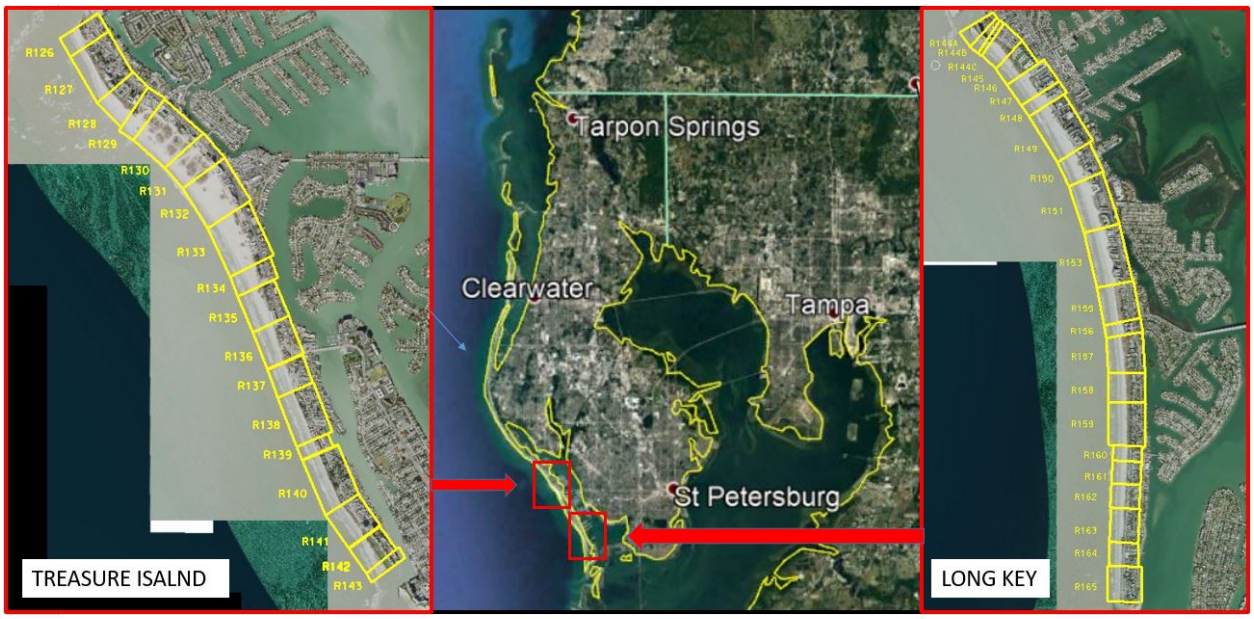

Figure 1. Beach-fx Model Reaches for Treasure Island and Long Key

Table 1. Project Induced Shoreline Change Rates

Project Segment	Model Reaches	Average Berm Width* (feet)	Optimized K	Measured Average Shoreline Change Rate (feet/year)	Calculated Average Shoreline Change Rate (feet/year)
Sunshine Beach North Treasure Island	R126 – R127	40	0.85	-18.0	-17.5
Sunset Beach South Treasure Island	R138 – R143	30	0.85	-8.0	-9.0
Upham Beach North Long Key	R144A – R146	125	0.85	-46.0	-40.0
Pass-a-Grille Beach South Long Key	R160 – R166	40	0.85	-11.0	-11.0
* Berm width measured from the seaward toe of the dune					

Table 2. Calculated Background Shoreline Change Rates

Treasure Island Model Reach	Shoreline Change Rate (feet/year)	Long Key Model Reach	Shoreline Change Rate (feet/year)
R126	-9.104	R144A	-9.359
R127	-7.599	R144B	-8.219
R128	-5.201	R144C	-8.219
R129	-3.266	R145	-6.759
R130	-1.820	R146	-4.994
R131	-0.853	R147	-3.593
R132	-0.368	R148	-2.156
R133	-0.147	R149	-1.114
R134	-0.079	R150	-0.536
R135	-0.106	R151	-0.224
R136	-0.211	R153	-0.035
R137	-0.499	R155	-0.010
R138	-1.044	R156	-0.023
R139	-1.927	R157	-0.069
R140	-3.346	R158	-0.173
R141	-5.201	R159	-0.396
R142	-7.722	R160	-0.853
R143	-9.615	R161	-1.524
		R162	-2.469
		R163	-4.030
		R164	-6.068
		R165	-8.470

3 Verification of Calculated Background Erosion

Current renourishment intervals for Sunshine, Sunset, and Upham Beaches is 4 years. The interval for Pass-a-Grille Beach is 10 years. For study purposes it can be assumed that in the final year of the renourishment period each project segment will be in a nearly or fully eroded condition. As the fill berm associated with the placement diminishes the dispersive (planform) erosion rates also diminish. By the end of the fill interval the berm will be nearly or entirely eroded and localized erosion rates should approach the background erosion rates for that segment. Note that these rates, determined at each FDEP R-monument, could not be directly applied to the Beach-fx modeling due to significant variability. Additionally, given the project length and the steady decrease in erosion moving toward the island centers from the inlets, a single or set of averaged values that might be suitable for a general comparison with the one-line model was not considered suitable for Beach-fx modeling purposes.

In order to verify the calculated background rates, averaged background erosion rates were compared to the average erosion determined from the final post-fill survey (fourth year for Sunrise, Sunset, and Upham Beaches and tenth year for Pass-a-Grille Beach) for each of the fill events previously identified. Only previously filled segments were included in the comparison as dispersion from these fills will affect adjacent areas such that conditions would not represent true background rates for those areas. Comparison results are shown in **Table 3**.

Table 3. Project Induced Shoreline Change Rates

Project Segment	Model Reach	Fourth Year Average Shoreline Change Rate (feet/year)	Calculated Average Shoreline Change Rate (feet/year)
Sunrise Beach	R126 – R127	-19.0	-7.3
Sunset Beach	R138 – R143	-18.0	-3.7
Upham Beach	R144A – R146	-32.0	-6.8
Pass-a-Grille Beach	R160 – R166	-7.0	-3.9

As can be seen in **Table 3** there is a significant difference between the calculated and expected (fourth year and tenth year) averaged erosion rates. That they do not show better agreement is likely due to the fact that the project segments are heavily dominated by inlet effects which are not accounted for in the one-line model. In an attempt to fully capture those effects on the background erosion (inlet effects are also not intrinsically part of the Beach-fx methodology and therefore can only be introduced through erosion rates) the berm width in the one-line solution was reset from 20 feet to 40 feet. **Table 4** provides the comparison for the adjusted average background erosion rates.

Table 4. Project Induced Shoreline Change Rates

Project Segment	Model Reach	Monitored Average Shoreline Change Rate (feet/year)	Calculated Average Shoreline Change Rate (feet/year)
Sunrise Beach	R126 – R127	-15.0	-17.0
Sunset Beach	R138 – R143	-18.0	-10.0
Upham Beach	R144A – R146	-32.0	-14.0
Pass-a-Grille	R160 – R166	-7.0	-8.0

While there is now good agreement between erosion rates for Sunshine Beach and Pass-a-Grille Beach, the one-line model still significantly under predicts the expected erosion rates measured for Sunshine Beach and particularly Upham Beach.

The averaged erosion rates with the “best fit” to measured data were obtained through incremental (10 foot) adjustments to the modeled berm width. The best fit berm width for both Sunset Beach and Upham Beach was found to be 90 feet. Average erosion rates for each are shown in **Table 5**

Table 5. Project Induced Shoreline Change Rates

Project Segment	Model Reach	Monitored Average Shoreline Change Rate (feet/year)	Calculated Average Shoreline Change Rate (feet/year)
Sunset Beach	R138 – R143	-18.0	-17.0
Upham Beach	R144A – R146	-32.0	-31.0

Based on adjusted model settings for all project segments the final calculated background erosion rates for both Treasure Island and Long Key are presented in **Table 6** and are shown graphically in **Figure 2** and **Figure 3**. Note that the erosion rate shown graphically for R144 is an average of R144A, R144B, and R144C.

Table 6. Calculated Background Shoreline Change Rates

Treasure Island Model Reach	Shoreline Change Rate (feet/year)	Long Key Model Reach	Shoreline Change Rate (feet/year)
R126	-18.207	R144A	-42.116
R127	-15.199	R144B	-39.550
R128	-10.401	R144C	-36.984
R129	-6.532	R145	-30.414
R130	-3.639	R146	-22.473
R131	-1.707	R147	-16.170
R132	-0.736	R148	-9.703
R133	-0.295	R149	-5.012
R134	-0.158	R150	-2.414
R135	-0.213	R151	-1.008
R136	-0.949	R153	-0.434
R137	-2.245	R155	-0.156
R138	-4.696	R156	-0.058
R139	-8.672	R157	-0.138
R140	-15.057	R158	-0.346
R141	-23.403	R159	-0.791
R142	-34.750	R160	-1.862
R143	-43.268	R161	-3.047
		R162	-4.938
		R163	-8.060
		R164	-12.137
		R165	-16.940

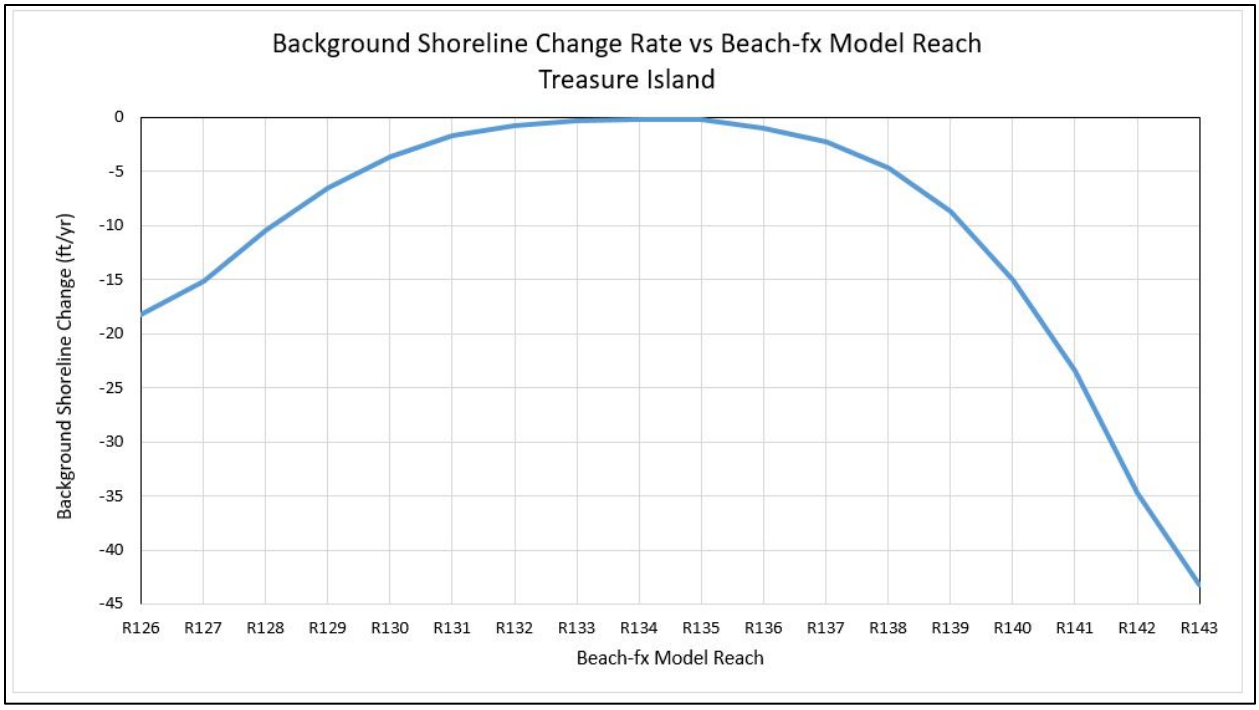

Figure 2. Calculated Background Erosion Rates – Treasure Island

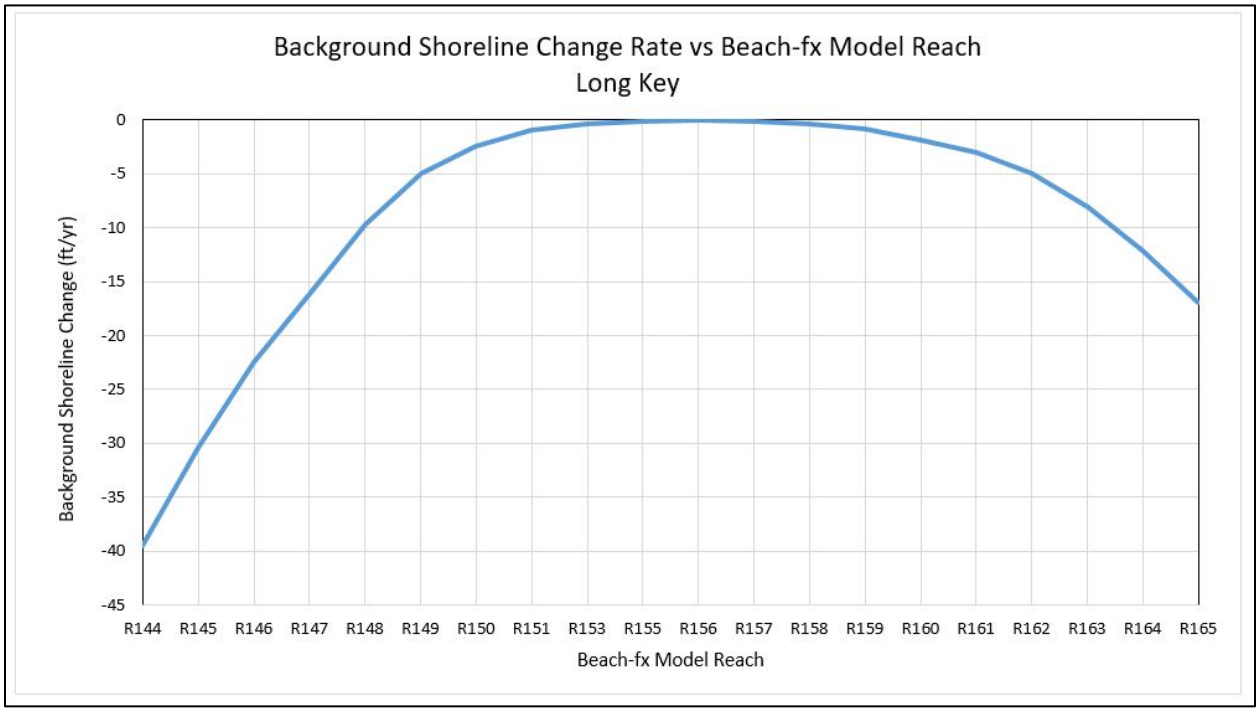

Figure 3. Calculated Background Erosion Rates – Long Key