Storm-Induced Beach Change (SBEACH) High-Frequency Storm Erosion Model Study for Escambia County

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1. Background and Objective

The SBEACH (Storm-Induced BEAch CHange) model is used by the Florida Department of Environmental Protection to evaluate coastal erosion from the impact of high-frequency storm events in support of regulatory and beach management programs. The SBEACH model, developed by the U.S. Army Corps of Engineers, is an empirically-based numerical model for predicting short-term profile response to storms. The SBEACH model calculates beach profile changes, with emphasis on beach and dune erosion, bar formation, and movement. It is a cross-shore sediment transport model such that the longshore processes are considered uniform and neglected in the calculation of profile changes. The model was initially formulated using data from prototype-scale laboratory experiments, and further developed and verified based on field measurements and sensitivity testing (Larson and Kraus, 1989).

The present study provides a model calibration of SBEACH for high-frequency erosion analysis of Escambia County. To accurately apply the SBEACH model for a high-frequency storm event, it is essential to have the model calibrated in the project area under similar storm conditions. This calibration requires detailed pre- and post-storm beach profile surveys that represent a storm's effects on cross-shore beach change, and coincident information regarding the wave and water level conditions. This study presents eroded dune and beach profiles due a high-frequency storm event, with a return interval of 15–25 years, in Escambia County using the latest version (4.03) of the SBEACH model. All data resources for analysis and input files required to run the SBEACH model are documented.

2. Model Calibration

Searches for available surveyed beach profiles associated with a tropical storm or hurricane for Escambia County resulted in a limited set of data with enough completeness and quality for model calibration. A set of beach profiles in part of Escambia County were surveyed before and after Hurricane Georges (1998). The model calibration became possible with the help of the Beaches and Shores Resource Center's 2D Storm Surge Model (Beaches and Shores Resource Center, 2009) to make up for the lack of Hurricane Georges measured storm tides on the open coast. The storm surge model domain covers the northeastern Gulf of Mexico with an unstructured grid consisting of 117 cells (total length: 197.7 nautical miles) in the alongshore direction and 80 cells (total length: 123.0 nautical miles) in the cross-shore direction (Figure 1). The grid is rotated at an angle of 78° which orients the model domain along the regional coastline. The unstructured layout of the grid cells permits for fine resolution in the local area of interest, e.g., the grid describes the coastline of Escambia County with cells sized as small as 5000 feet (alongshore distance) by 1000 feet (cross-shore distance).

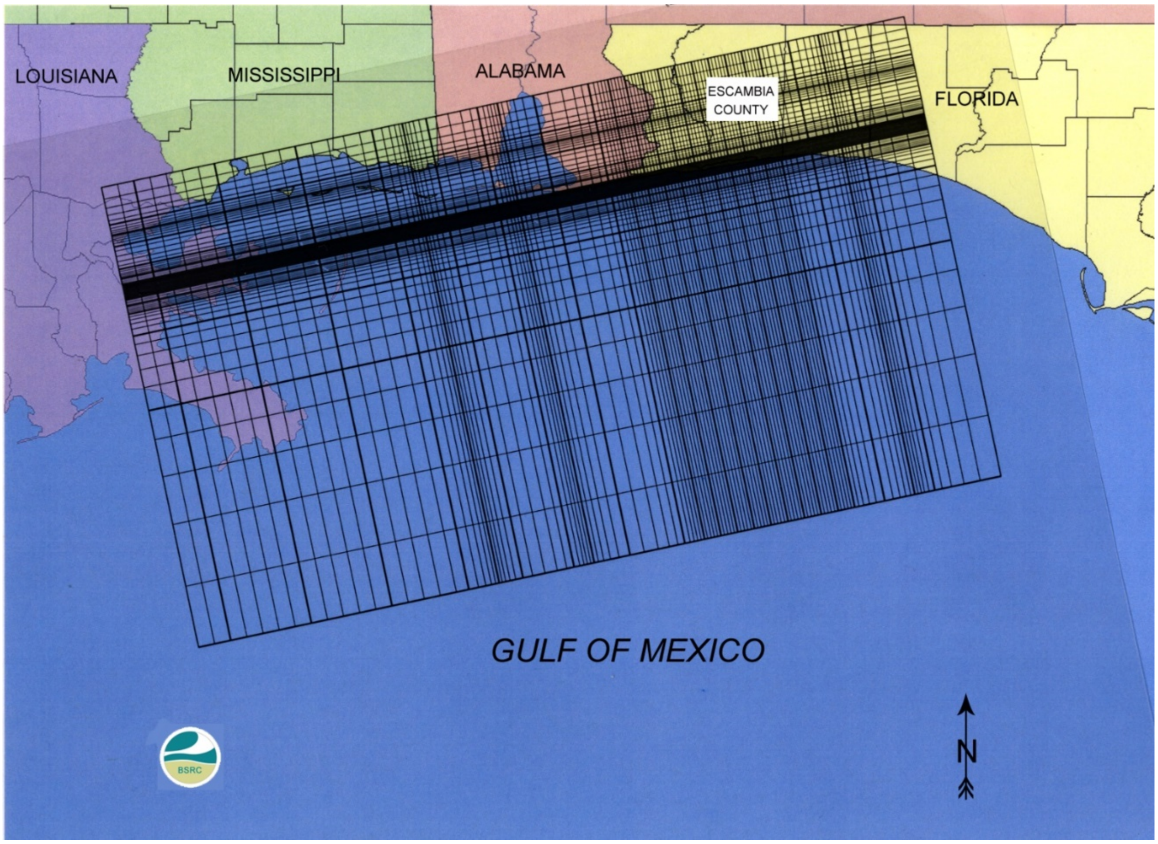


Figure 1. Northeastern Gulf of Mexico model grid (Beaches and Shores Resource Center, 2009).

2.1. Storm Data

Hurricane Georges made landfall in Key West, Florida on the morning of September 25 as a Category 2 hurricane (Figure 2). The hurricane maintained Category 2 status as it tracked through the Gulf of Mexico. Georges made landfall near Biloxi, Mississippi in the early morning hours of September 28 with maximum winds of 110 mph and minimum central pressure of 964 mb (Guiney, 1999). Within 24 hours, Georges had weakened to a tropical depression, looped over southern Mississippi, and began drifting to the east. The weak circulation continued its eastward drift over the interior of the Florida Panhandle, ultimately dissipating on October 1 near the Florida/Georgia border.

Data products available for Hurricane Georges involve the archived storm data from the National Hurricane Center (2018), including storm track and six-hourly measures of barometric pressure, sector-based winds (wind speed-based radii) and forward speed. The legacy HWind archive provides surface wind analysis for Hurricane Georges (HWind, 2018), which contains data-based measures of the radius to maximum winds at six-hour increments through most of the storm's history. Published reporting available for Hurricane Georges include the tropical cyclone report developed by Guiney (1999), which documents a full meteorological narrative of the storm.

Figure 2. Storm track of Hurricane Georges 1998 (National Hurricane Center, 2018).

2.1a. Storm Tide Data

For the model calibration, measured storm tide generated by Hurricane Georges is essential. Two types of data were collected to represent the storm tide along the open coast (Table 1): (1) water levels measured via a tide gauge; and (2) high water marks (HWMs) measured in the field. The National Oceanographic and Atmospheric Administration tide gauge at Pensacola, FL (8729840) afforded time-series data. The remaining data were derived from three tide gauges and nine HWMs (U.S. Army Corps of Engineers – Mobile District, 1998). Figure 3 displays a locator map of the tide gauging stations and HWM locations. Two of the 13 stations (HWM at GEHBAL12 and tide gauge at 8729840) are located within the respective bay systems of Mobile Bay and Pensacola Bay, where there is a dominant sheltering effect of the storm tide and an almost complete absence of wave setup. For the other 11 stations, the three tide gauges are located inside the mouth of the respective bay system, where there is a partial sheltering of the storm tide, and the eight HWMs are located within an enclosed room (e.g., a garage) on the first row of roadway/structures, where the HWM elevation measures are most representative of the total storm tide (i.e., including wave setup) that occurred along the open coast.

Table 1. Data for Hurricane Georges along the Alabama and Florida Panhandle coastlines.

Station	Name	Lat (°N)	Lon (°W)	Description	Peak (feet, NAVD)
GENWAL02	Dauphin Island, AL	30.2489	88.1914	Tide gauge	5.84
GENWAL01	Dauphin Island, AL	30.2494	88.1830	HWM	5.50
GEHBAL10	Dauphin Island, AL	30.2509	88.1709	HWM	6.60
GEHBAL11	Dauphin Island, AL	30.2509	88.1593	HWM	6.46
GEHBAL09	Dauphin Island, AL	30.2515	88.1529	HWM	6.35
GEHBAL12	Dauphin Island, AL	30.3627	88.1439	HWM	6.78
GEGSAL04	Gulf Shores, AL	30.2406	87.7406	HWM	8.51
GEGSAL08	Gulf Shores, AL	30.2478	87.6894	HWM	9.15
GEGSAL10	Gulf Shores, AL	30.2489	87.6833	HWM	10.99
GEGSAL15	Gulf Shores, AL	30.2561	87.6383	HWM	9.62
GEOBFL07	Gulf Shores, AL	30.2786	87.5549	Tide gauge	5.70
8729840	Pensacola, FL	30.4033	87.2117	Tide gauge	4.70
GEFWFL06	Destin, FL	30.3919	86.5258	Tide gauge	4.60

Although the Beaches and Shores Resource Center's 2D Storm Surge Model has been verified throughout the Coastal Construction Control Line (CCCL) studies and various storm events, and has been proven to be an accurate and reliable model (Beaches and Shores Resource Center, 2009), it was reverified using Escambia County bathymetry and Hurricane Georges storm data to generate a storm tide for Pensacola Beach. Figure 4 shows a comparison between model calculated and measured storm tides for the tide gauge at Pensacola (8729840). The model result represents the storm surge only, i.e., no wave setup, since the data are representative of the inside-bay (wave-sheltered) storm tide. The model-calculated storm tide generally agrees well with the measured data, including capturing the shape of the hydrograph and a few of the subtleties therein. The calculated peak storm tide (4.32 feet) is 0.38 feet lower than the measured peak storm tide (4.70 feet), which relates to a relative error of 8%. Figure 5 displays an alongshore plot of peak storm tide (modeled and measured) for the Alabama and Florida Panhandle coastlines. The model result represents the total storm tide, i.e., surge from barometric pressure deficit and wind stress, plus dynamic wave setup and astronomical tide. The model curve compares favorably with the data recorded at the 13 monitoring stations (Figure 3), particularly with replicating the trend of decreasing peak storm tide with greater distance from the landfall location.

Figure 3. Map of monitoring stations for Hurricane Georges surrounding Escambia County.

Based on the successful reverification of the model, the 2D grid system and associated hydrological data of Escambia County from the CCCL study were used to generate storm tide data from Hurricane Georges for Escambia County. Storm track, pressure deficit, and radius to maximum wind for Hurricane Georges (Table 2) were input into the 2D Storm Surge Model. Storm positions (latitude and longitude) and pressure deficits were available at six-hourly intervals (National Hurricane Center, 2018). Radius to maximum wind was derived from time-dependent surface wind analysis maps (HWind, 2018). The model was then run to calculate the total storm tide, i.e., surge from barometric pressure deficit and wind stress plus dynamic wave setup and astronomical tide, for a total of four locations along the study area (see Profiles 1–4 in Figure 5). By comparing the calculated total storm tides with the total storm tide values for various return periods listed in Table 3 (Beaches and Shores Resource Center, 2009), it shows that Hurricane Georges generated total storm tides ranging between 6 and 10 years return period for Escambia County. Therefore, Hurricane Georges was selected as a high-frequency storm, and the hydrograph calculated for Profile 3 was applied for the SBEACH model calibration.

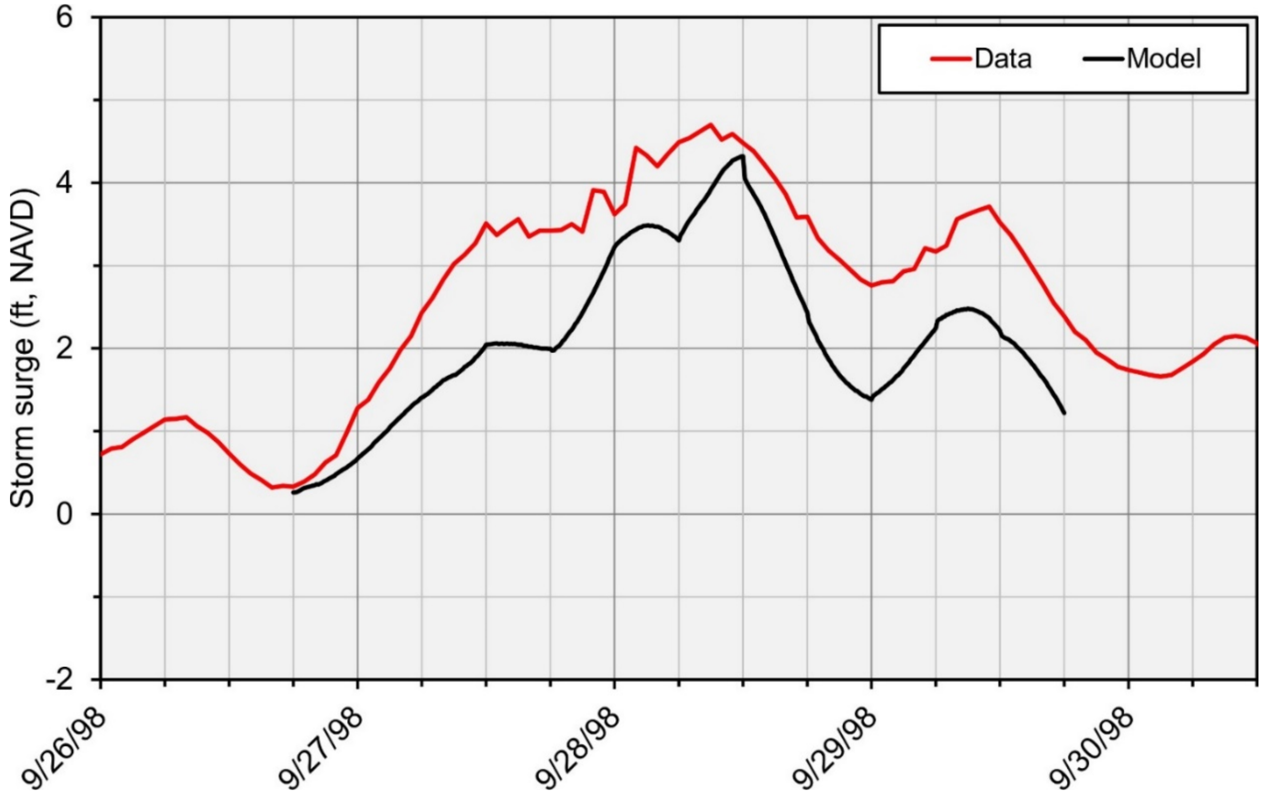


Figure 4. Storm tide recorded and calculated at Pensacola.

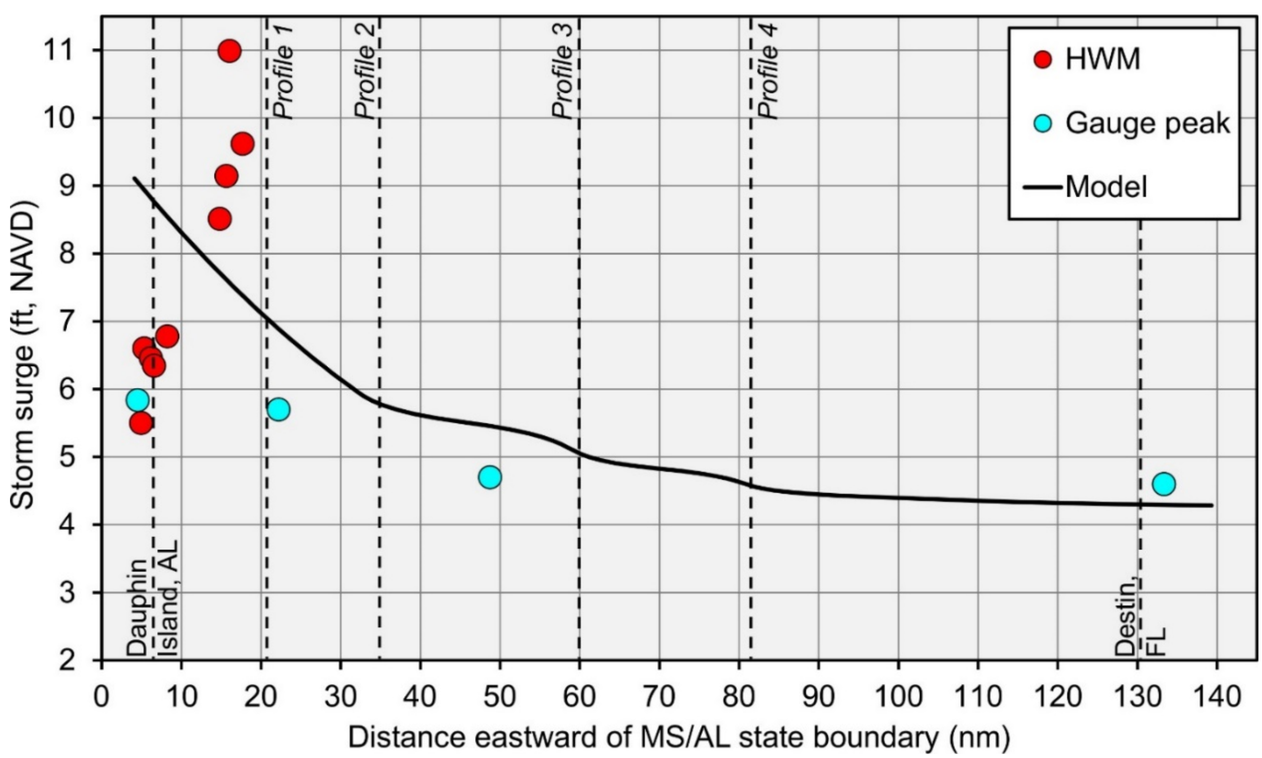


Figure 5. Peak storm tide recorded and calculated along the AL and FL Panhandle coastlines.

Table 2. Storm data for Hurricane Georges as 2D storm surge model input.

Model simulation hour	Date and time (UTC)	Latitude (°N)	Longitude (°W)	Forward speed (nm hour^{-1})	Pressure deficit (in Hg)	Radius to maximum wind (nm)
0	9/26/1998 18:00	26.2	85.9	9.53	1.12	30
6	9/27/1998 00:00	27.0	86.5	8.51	1.30	31
12	9/27/1998 06:00	27.6	87.2	7.93	1.27	24
18	9/27/1998 12:00	28.2	87.8	7.39	1.51	49
24	9/27/1998 18:00	28.8	88.3	5.29	1.51	31
30	9/28/1998 00:00	29.3	88.5	5.29	1.54	32
36	9/28/1998 06:00	29.8	88.7	6.24	1.45	17
42	9/28/1998 12:00	30.4	88.9	2.00	1.42	30
48	9/28/1998 18:00	30.6	88.9	0.86	0.86	25
54	9/29/1998 00:00	30.6	89.0	5.18	0.80	12
60	9/29/1998 06:00	30.6	88.4	4.76	0.62	12
66	9/29/1998 12:00	31.0	88.1	5.27	0.56	12
72	9/29/1998 18:00	30.9	87.5	5.27	0.50	12

Table 3. Total storm tide levels (feet, NAVD) for various return periods and Hurricane Georges.

Return period (years)	Profile 1	Profile 2	Profile 3	Profile 4
50	10.7	10.5	9.8	9.7
40	9.9	9.8	9.3	9.0
25	8.7	8.5	8.2	8.0
20	7.9	7.7	7.6	7.5
15	7.3	7.0	6.9	6.9
10	6.4	6.2	6.0	5.8
5	4.6	4.5	4.3	4.2
Hurricane Georges (1998)	7.0	5.8	5.1	4.6

2.1b. Wave Data

Measured wave data for Hurricane Georges were available from the two nearest offshore NDBC stations (see Figure 3 for respective locations). The first station (42039) is located approximately 115 nautical miles south-southeast of Pensacola (28.788°N 86.008°W) at a nominal water depth of 886 feet. The second station (42040) is located approximately 63 nautical miles south of Dauphin Island (29.208°N 88.226°W) at a nominal water depth of 600 feet. Time-series values of significant wave height and dominant wave period values from the buoy data (NDBC, 2018) are displayed in Figure 6. The data are incremented at an hourly interval, noting there are times leading up to peak storm conditions when recordings were sparse. The time-evolution of the signals is consistent between the two stations, where the waves were higher at station 42040 relative to station 42039 because of the respective proximity to the storm center. To reflect the wave conditions along the coastline of Escambia County caused by Hurricane Georges, a six-hour moving average was applied to an equal-weighted average, i.e., between the two stations, of the time-series data for wave heights and wave periods (Table 4). Wave direction of 0° (shore-normal) was applied as a constant value for input to the SBEACH modeling.

2.1c. Hydrographic Survey Data

The hydrographic survey data utilized in this study were sourced from Florida Department of Environmental Protection (2018). The first set of profile data, collected in July 1998 (file name ES9807_MAE_1), captured the dune and berm features of the beach, as well as the nearshore profile out to approximately 3000 feet offshore at nominal depths of 35–40 feet. The ES9807_MAE_1 dataset provided the profile representation of the pre-Georges beach conditions for the SBEACH modeling input data. The second set of profile data, collected in October 2018 (file name ES9810_PST_1), captured the dune, beach and nearshore condition after the impact of Hurricane Georges. The ES9810_PST_1 dataset provided the profile representation of the post-Georges beach conditions for the SBEACH modeling calibration. The profile datasets (pre- and post-Georges) encompassed R-monuments 110–139, which represents Pensacola Beach (Figure 7). Of the 30 profiles, consistent profile shapes were discerned among a subset of the overall data, including R-monuments 110, 113–117, 119, 120, 124, 126, 128, 129, 131, 132, 135, 137 and 138, which demonstrated a coherent erosional signature at berm elevations of 2–5 feet. Appendix A displays profile plots of the pre- and post-Georges data for the 17 R-monuments of Pensacola Beach used in the SBEACH model calibration.

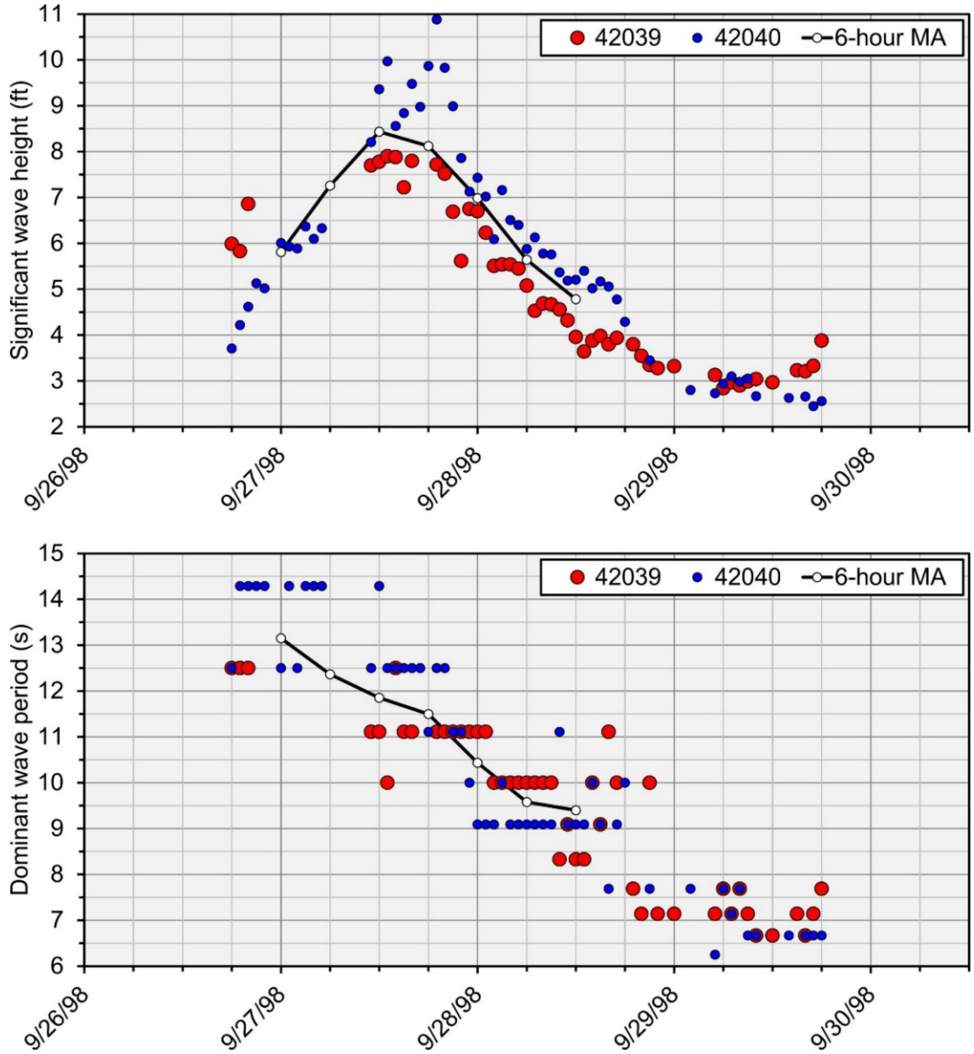


Figure 6. Raw wave data and 6-hour moving-average (MA) at two offshore NDBC buoys.

Table 4. Wave input data for SBEACH modeling.

Model simulation time (hour)	Date and time (UTC)	Wave height (feet)	Wave period (seconds)	Wave direction (°)
0	9/27/1998 00:00	5.81	13.2	0 (shore-normal)
6	9/27/1998 06:00	7.26	12.4	0
12	9/27/1998 12:00	8.44	11.9	0
18	9/27/1998 18:00	8.12	11.5	0
24	9/28/1998 00:00	6.98	10.4	0
30	9/28/1998 06:00	5.64	9.6	0
36	9/28/1998 12:00	4.78	9.4	0

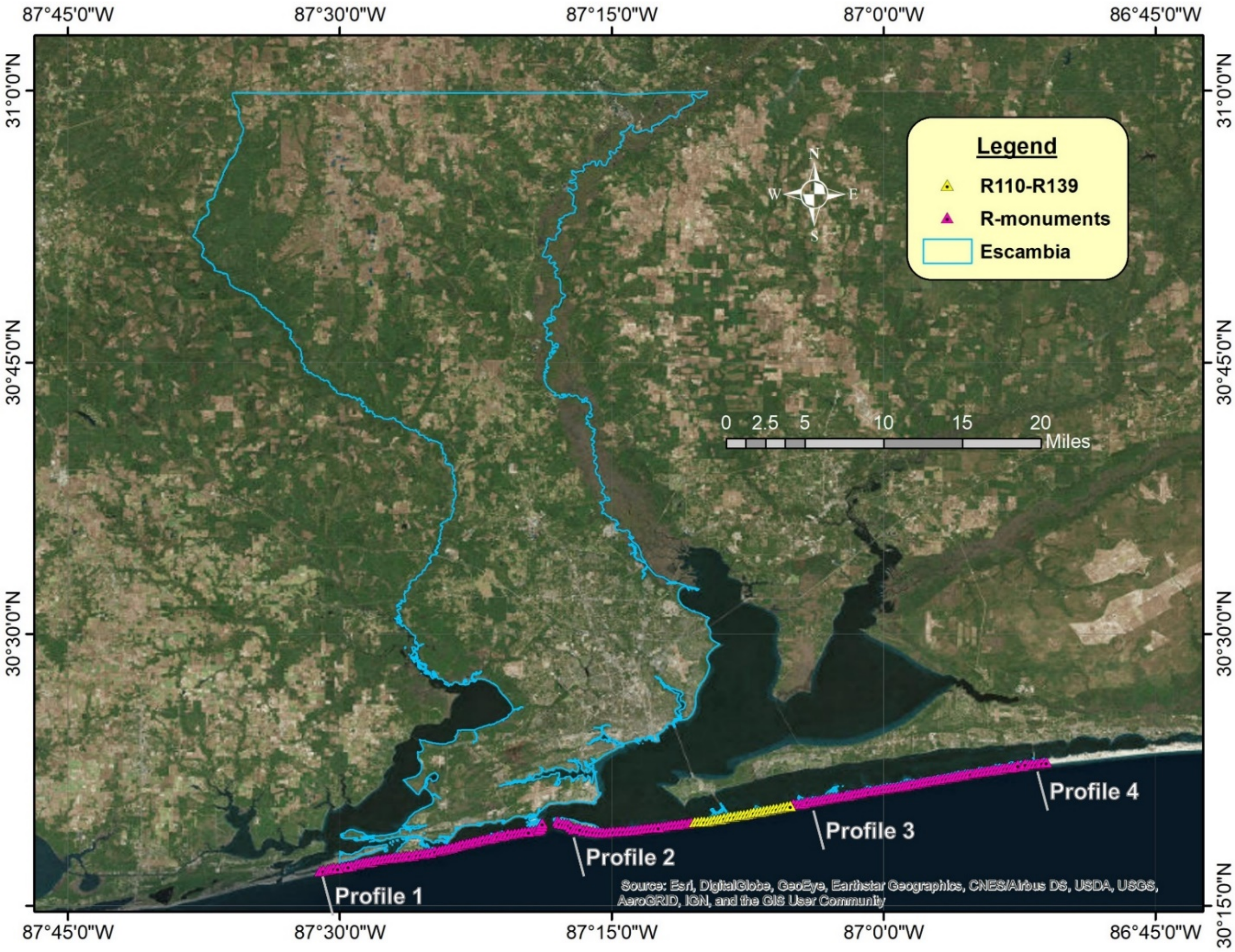


Figure 7. Map of R-monuments and hydrograph output Profiles 1–4 for Escambia County.

2.2. Model Input Parameters

The primary input information for the SBEACH model includes profile, storm and sediment data. Profile data are selected based on the segment of shoreline being modeled. Mean grain size of the beach material is one of the primary sediment data required. Other inputs include model parameters such as grid size, time step and the transport rate coefficient.

The beach profiles were represented in the model using a constant grid scheme with grid cell spacing of 5 feet to generate a detailed result. Each reach was approximately 3000 feet long described by about 600 cells. Sediment data were obtained from the beach sediment survey of Florida's northwest coast (Daniel et al., 2011). For the model calibration area, the average mean grain size was 0.379 mm.

The default values for SBEACH are listed in Table 5. A series of model runs was conducted within the range of recommended values to achieve the best fit between measured and calculated erosion profiles.

Table 5. Default values and range of values for SBEACH model input parameters.

Parameter	**Unit**	**Default value**	**Range of values**
Transport rate coefficient	$m^4\ N^{-1}$	1.75×10^{-6}	$0.25\times10^{-6} - 0.25\times10^{-5}$
Overwash transport parameter	None	0.005	0.002 – 0.008
Coefficient for slope-dependent term	$m^2\ s^{-1}$	0.002	0.001 – 0.005
Transport rate decay coefficient	m^{-1}	0.5	0.1 – 0.5
Landward surf zone depth	feet	1.0	0.5 – 1.6
Effective grain size (D_{50})	mm	0.35	0.15 – 1.0
Maximum slope prior to avalanching	Degree	45	15 – 90
Water temperature	°C	20	0 – 40

2.3. Model Calibration Results

The sensitivity evaluation began with initially setting the model input parameters to the default values (Table 5), except for the effective grain size (D_{50}), which was set to 0.379 mm based on field verification (Daniel et al., 2011), and water temperature, which was set to 27°C. Wind speed and direction, available as options during the model input, were not included due to the insignificant effect on the model results, whereby those terms were zeroed in the model. For each SBEACH run, the hydrograph without wave setup generated from the 2D Storm Surge Model for Escambia County (Profile 3) served as a basis, since the SBEACH model calculates and adds the wave setup internally to reach the desired final water level. Therefore, the hydrograph was adjusted such that the peak water elevation output from SBEACH agreed with the peak storm tide values calculated by the 2D Storm Surge Model for Hurricane Georges. Table 6 presents the SBEACH input hydrograph in tabular format. The peak water level of the input hydrograph is 3.25 feet. Applying the input hydrograph within SBEACH, the peak water level with wave setup predicted by SBEACH was 5.4 feet, which is representative of the total storm tide level caused by Hurricane Georges along the open coast of Escambia County (Table 3).

Table 6. SBEACH input hydrograph values for Hurricane Georges at Escambia County.

Time (hour)	Water level (feet, NAVD)
0	2.54
1	2.48
2	2.41
3	2.45
4	2.51
5	2.63
6	2.79
7	2.85
8	2.87
9	2.76
10	2.69
11	2.69
12	2.71
13	2.76
14	2.87
15	3.08
16	3.25
17	3.19
18	2.96
19	2.62
20	2.33
21	2.07
22	1.81
23	1.59
24	1.43
25	1.31
26	1.24
27	1.22
28	1.24
29	1.27
30	1.32
31	1.40
32	1.56
33	1.75
34	1.93
35	2.01
36	2.06

The average (among the 17 profiles—see Appendix A) erosion distance of the survey measurements versus the SBEACH calculations for contours from 0 to 6 feet above NAVD were used as the principal basis for determining the calibration parameter settings. The lower limit of 0 feet is used because it represents the middle range of the astronomic tide, where a majority of the beach erosion occurred in the elevation contours above this 0-foot level. The upper limit of 6 feet is used because it represents the higher end of the total storm tide levels experienced along the open coast of Escambia County due to Hurricane Georges (Table 3), where most of the beach erosion occurred in the elevation contours below this 6-foot level. Starting with the default values (Table 5), a series of values for each calibration parameter was tested. The transport rate coefficient, the coefficient for the slope-dependent term and the maximum slope prior to avalanching were found to be significant to the calibration results, so they were adjusted individually until reasonable agreement with the measured erosions were achieved.

The final parameter values determined by the calibration procedure are listed in Table 7. These parameter values provided the best replication of the beach erosion observed for Escambia County due to Hurricane Georges. Figure 8 shows comparisons of the average contour recession between the measured (survey) and modeled (SBEACH) beach profiles for the 17 R-monuments based on the final model parameter set. The pattern of SBEACH model-predicted erosion contours using the final calibration values are in general agreement with the pattern of measured erosion contours. For the contour levels within 2–5 feet, which were impacted the most by the storm surge and waves, the average (17 profiles) erosion distance was 58 feet based on the measurements and 53 feet based on the model results, equating to a relative error 9% – an acceptable model approximation of the measured erosion. Plots of measured (pre- and post-Georges) and modeled (SBEACH) beach profiles using the final calibration values for the 17 R-monuments of Escambia County are presented in Appendix A.

Table 7. Final SBEACH model calibration parameters for Escambia County.

Parameter	**Unit**	**Calibration value**
Transport rate coefficient	$m^4\ N^{-1}$	2.5×10^{-6}
Overwash transport parameter	None	0.005
Coefficient for slope-dependent term	$m^2\ s^{-1}$	0.005
Transport rate decay coefficient	m^{-1}	0.5
Landward surf zone depth	feet	1.0
Effective grain size (D_{50})	mm	0.379
Maximum slope prior to avalanching	°	30
Water temperature	°C	27

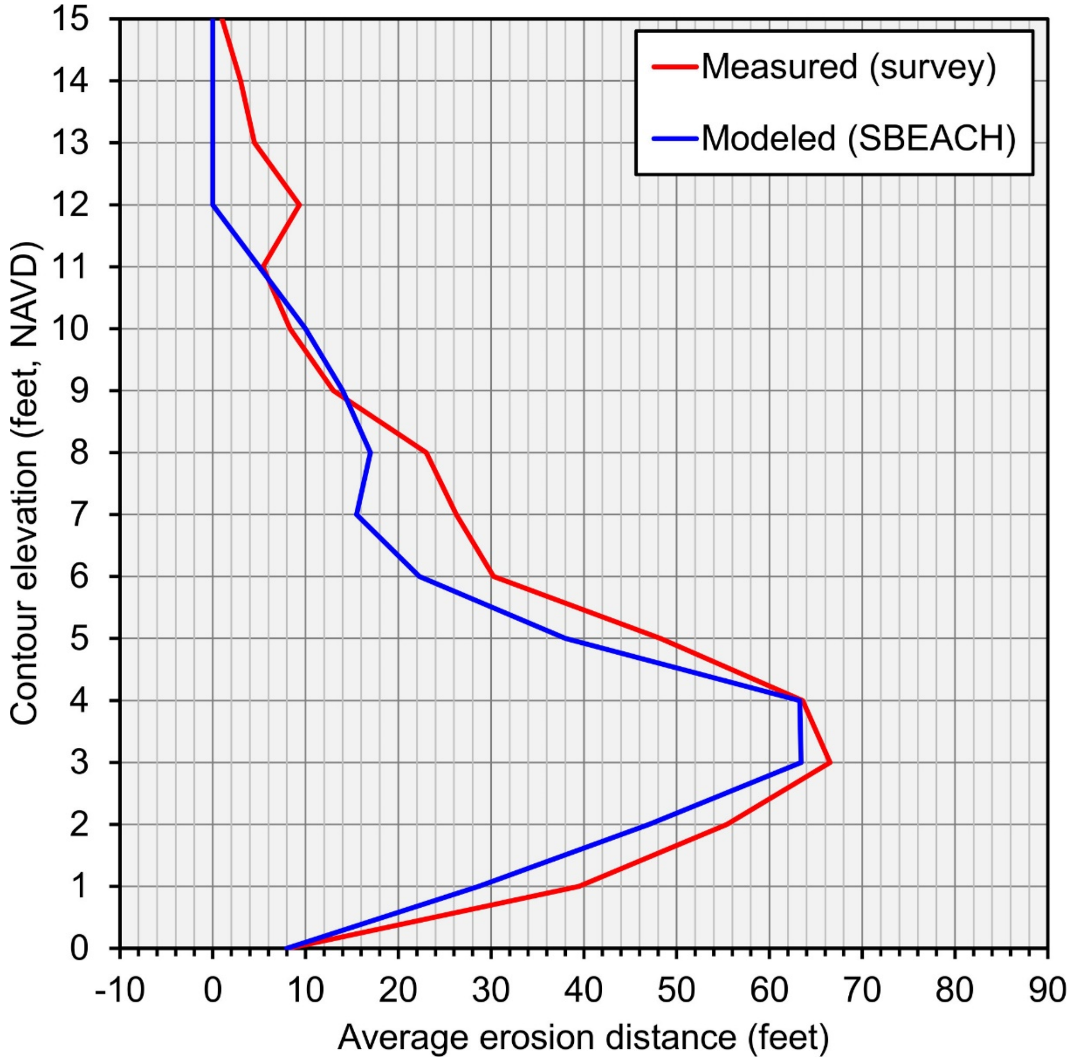


Figure 8. Average contour changes for 17 R-monuments of erosion for Hurricane Georges.

3. Escambia County SBEACH Application

3.1. Model Configuration

Configuration of the SBEACH model in Escambia County for high-frequency storm erosion will be primarily based on the model calibration results, as shown in Table 7. The full county shoreline was partitioned into four reaches: (1) R1–R67, Perdido Key; (2) R68–R156, Pensacola Beach; (3) R157–R186, Gulf Islands National Seashore; and (4) R187–R215, Navarre Beach. Countywide sediment data were obtained from the beach sediment survey for Florida's northwest coast (Daniel et al., 2011). A mean grain size of 0.371 mm was assigned for reach 1, and a mean grain size of 0.379 mm was assigned for reaches 2, 3 and 4 (Table 8). The wave height was set as 10 feet and the wave period was set to 11 seconds, which reflect wave conditions at Pensacola Beach for a 15-/25-year return period (Olsen

Associates, 2014). A 10-foot wave height and an 11-second wave period were chosen as reasonable approximations for a generic high-frequency storm impacting the region. Wave direction, wind speed, and wind direction were applied as a constant zero values for input to the SBEACH model application.

Peak storm tides of 15- and 25-year return periods (Beaches and Shores Resource Center, 2009) for the four reaches in Escambia County are listed in Table 8. As described for the model calibration, the hydrograph without wave setup was applied since the SBEACH model calculates and adds the wave setup internally to reach the desired final water level. Initially, the SBEACH model output water levels do not agree with the 2D model 15- or 25-year storm because the hydrograph generated by the 2D storm surge model includes wave setup. Basically, the wave setup had been incorporated twice (both the 2D storm surge model and the SBEACH model do not include an option to turn off the wave setup routine). Starting with the 2D model hydrograph, the input hydrograph was adjusted in a series of model runs until the resultant SBEACH model peak water levels were equivalent to the predicted 2D model storm tides for each profile. The recommended SBEACH input values to be used in the 15- and 25-year storm erosion calculations are those obtained from the model calibration for Escambia County (Appendix B). Time-series values for the adjusted 15- and 25-year hydrographs without wave setup for each reach are shown in Figures 9 and 10, respectively, and are tabulated in Appendix C.

Table 8. Data characteristics for the four defined reaches of Escambia County.

Reach	**R-monuments**	**Mean grain size (mm)**	**15-year return period storm tide level (feet, NAVD)**	**25-year return period storm tide level (feet, NAVD)**	**Profile date**
1	R1–R67	0.371	7.3	8.7	September 2016
2	R68–R156	0.379	7.0	8.5	September 2016
3	R157–R186	0.379	6.9	8.2	September 2016
4	R187–R215	0.379	6.9	8.0	July 2016

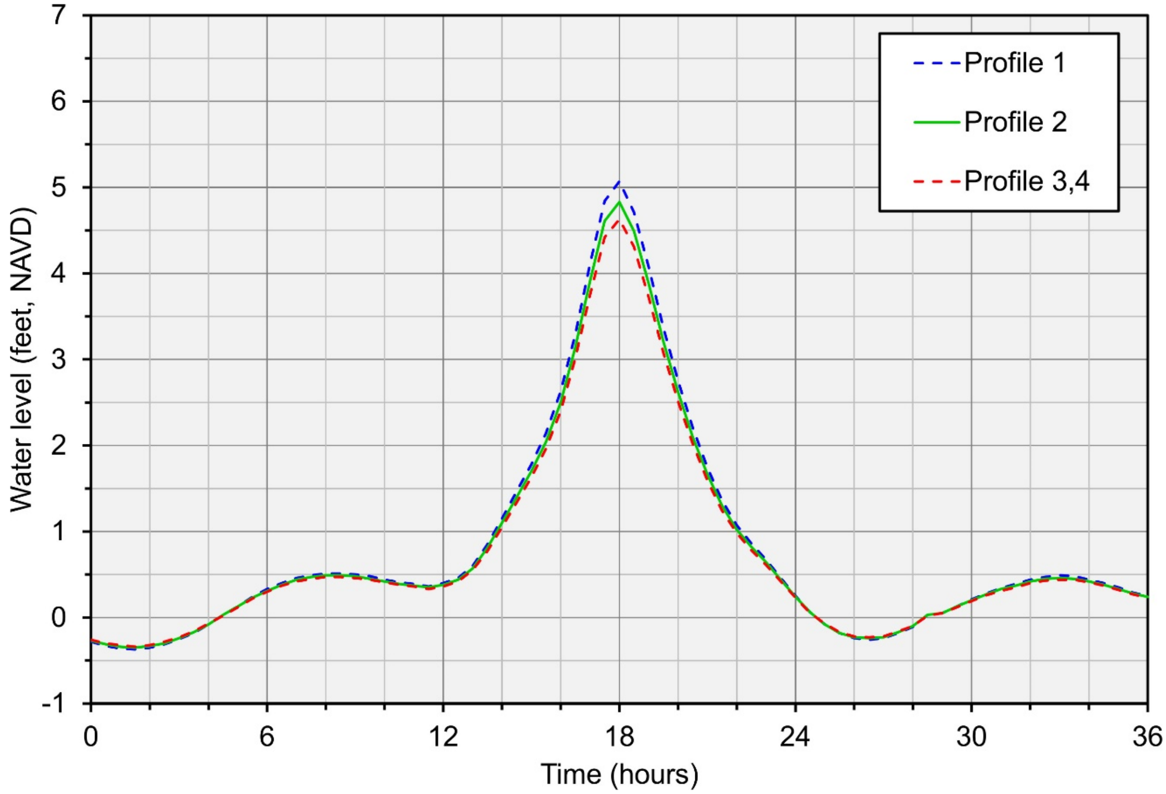


Figure 9. 15-year hydrographs for Escambia County Profiles in SBEACH application.

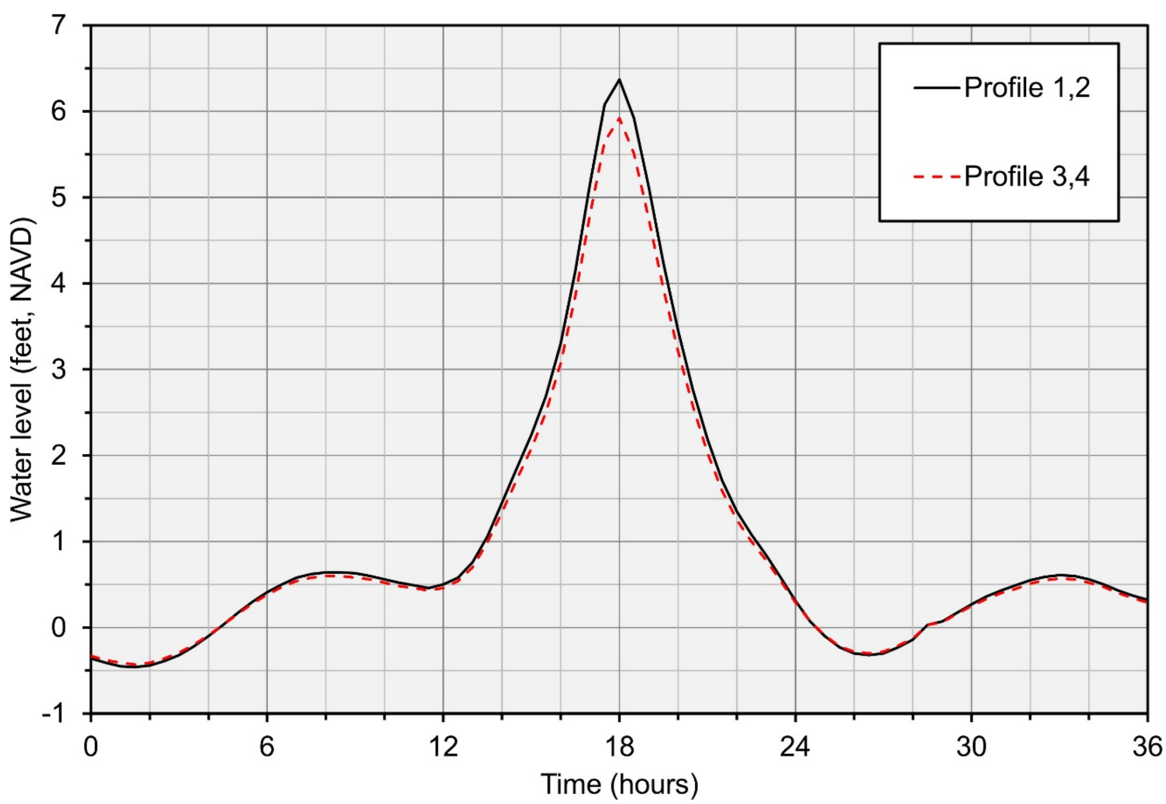


Figure 10. 25-year hydrographs for Escambia County Profiles in SBEACH application.

3.2. Model Application and Results

Representative plots of surveyed profiles and their associated eroded profiles generated from SBEACH for the 15- and 25-year return periods for Escambia County are provided in Appendix D. The most updated profiles available for Escambia County for SBEACH application are listed in Table 8. The profile data included three datasets representative of summer/fall 2016 conditions (FDEP, 2018). The first dataset, file name ES1609_COE_1, encompassed R-monuments 1–101 and 157–186. The second dataset, file name ES1609_TSM_1, encompassed R-monuments 102–156. The third dataset, file name SR1607_MAE_1, encompassed R-monuments 187–215. The profile data captured the dune and berm features of the beach, as well as the nearshore profile out to approximately 3000 feet offshore at nominal depths of 35–40 feet. Figure 11 depicts the DEP range monumentation and Profiles along the open coast of Escambia County.

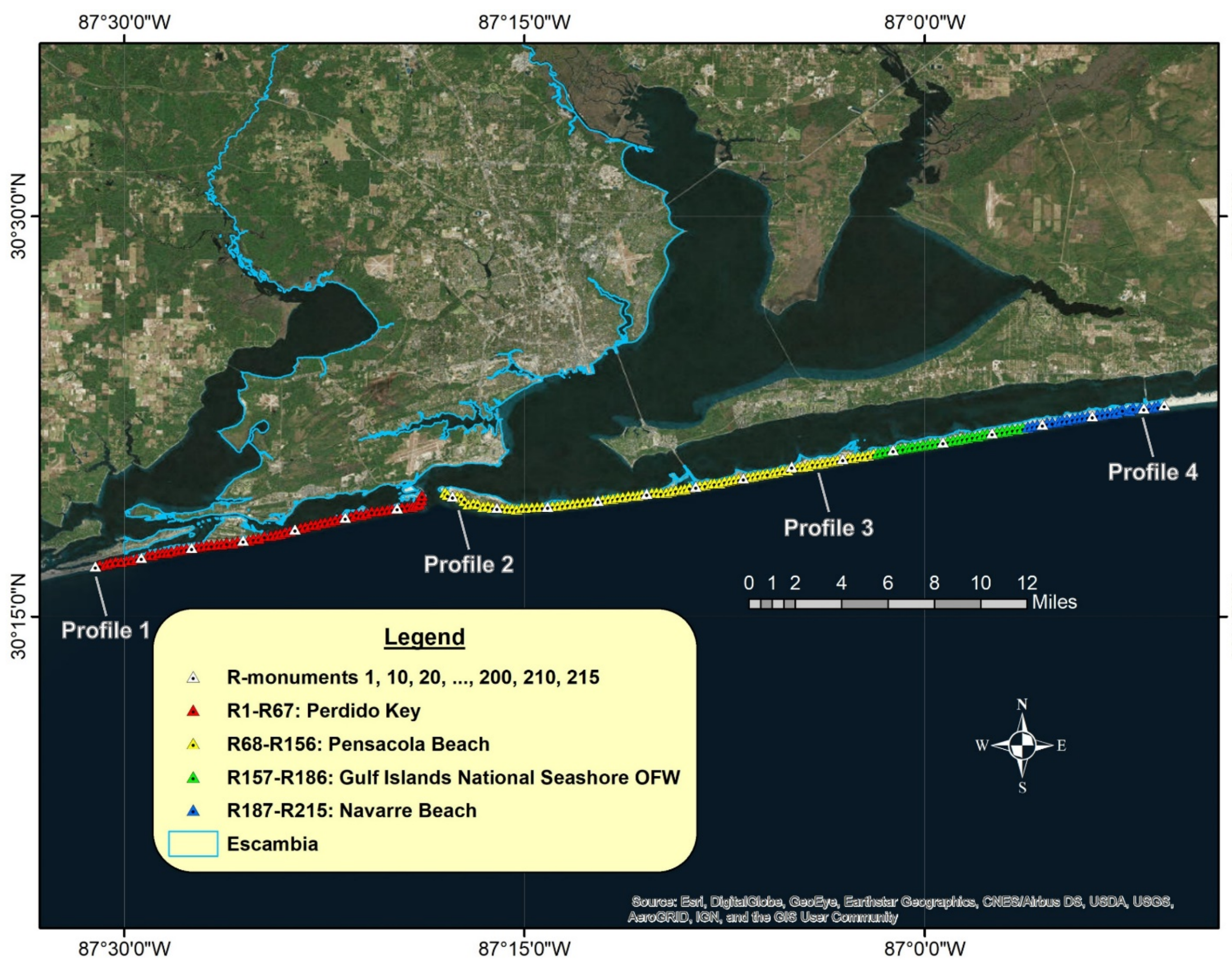


Figure 11. DEP range monumentation and Profiles along the open coast of Escambia County.

REFERENCES

1. Beaches and Shores Resource Center, 2009. Inclusion of tropical storms for the combined total storm tide frequency restudy for Escambia and Santa Rosa counties, Florida. Florida Department of Environmental Protection, 23 p.

2. Daniel, D.C., Ladle, M.M.L., Dabous, A.A., Harrington, E.P., 2011. A sedimentological and granulometric atlas of the beach sediments of Florida's northwest coast and big bend. Florida Geological Survey, 35 p.

3. Florida Department of Environmental Protection, 2018. Public FTP directory. [Accessed online April 17, 2018: ftp://ftp.dep.state.fl.us/pub/water/beaches/HSSD/ProfileData/.]

4. Guiney, J.L., 1999. Preliminary report: Hurricane Georges. National Hurricane Center, 29 p.

5. HWind, 2018. Georges wind analyses. [Accessed online December 7, 2018: https://www.rms.com/perils/hwind/legacy-archive/storms/georges1998.html.]

6. Larson, M., Kraus, N.C., 1989. SBEACH: Numerical model for simulation storm-induced beach change: Empirical foundation and model development. Technical Report CERC-89-9, U.S. Army Corps of Engineers, 134 p.

7. National Data Buoy Center (NDBC), 2018. NOAA's National Data Buoy Center – Center of Excellence in Marine Technology. [Accessed online December 7, 2018: http://www.ndbc.noaa.gov/.]

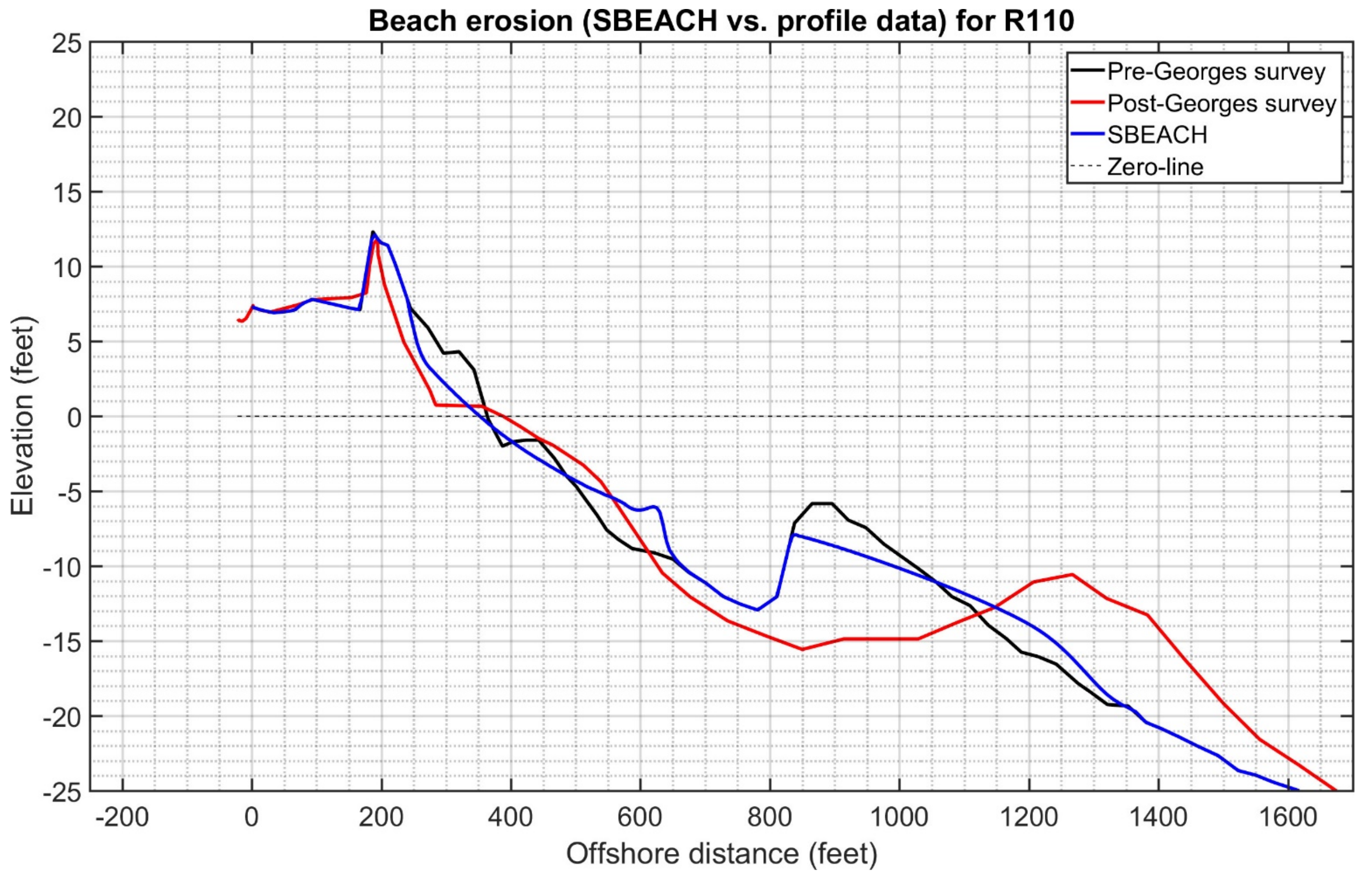
8. National Hurricane Center, 2018. Hurricane Georges Automated Tropical Cyclone Forecast archive. [Accessed online December 7, 2018: ftp://ftp.nhc.noaa.gov/atcf/archive/1998/bal071998.dat.gz.]

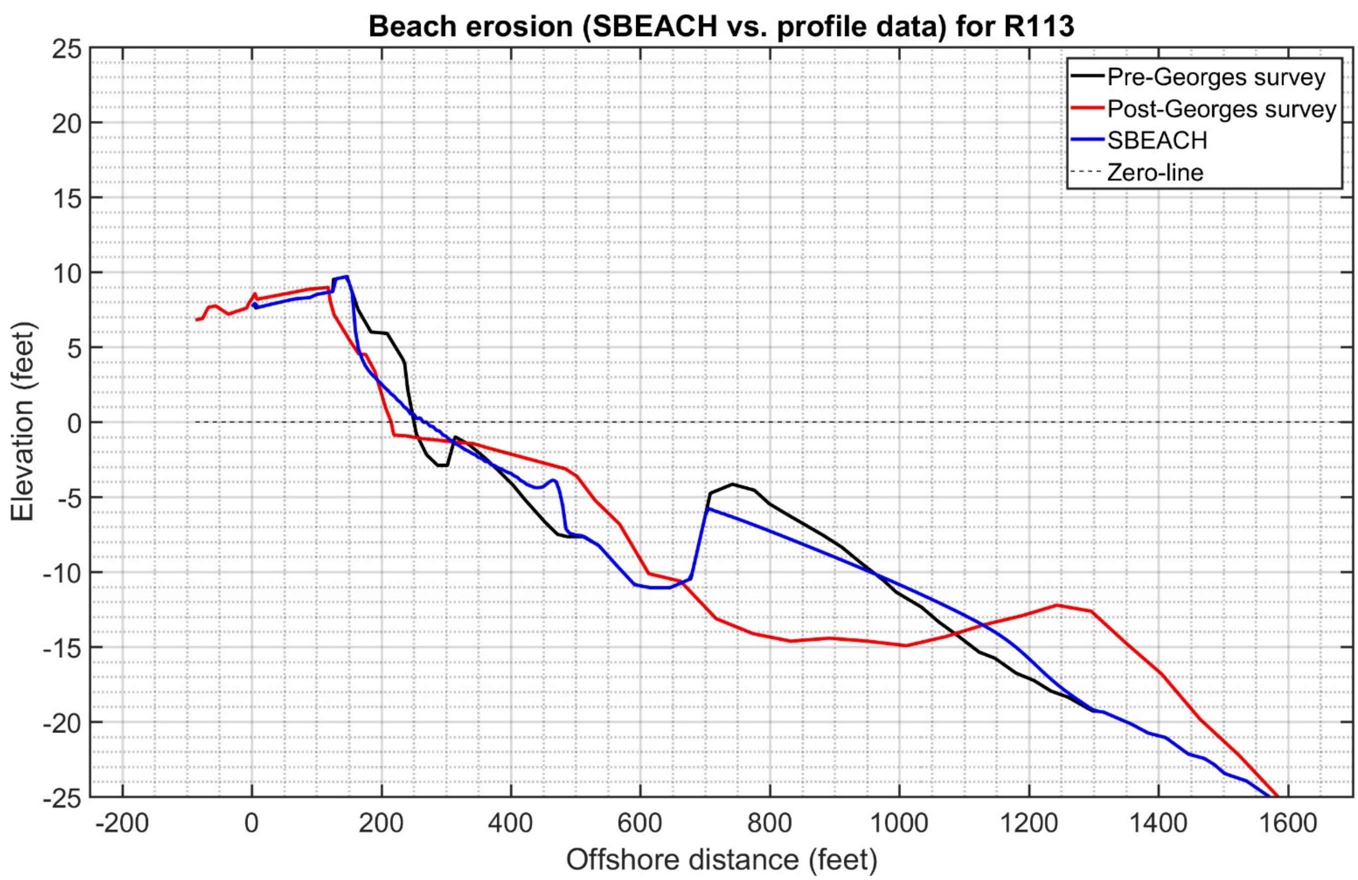
9. Olsen Associates, 2014. SBEACH calibration and erosion analysis in support of maintenance renourishment Pensacola Beach, FL beach restoration project (R-107.5 to R-151) Escambia County, FL. Santa Rosa Island Authority, Pensacola Beach, FL, 104 p.

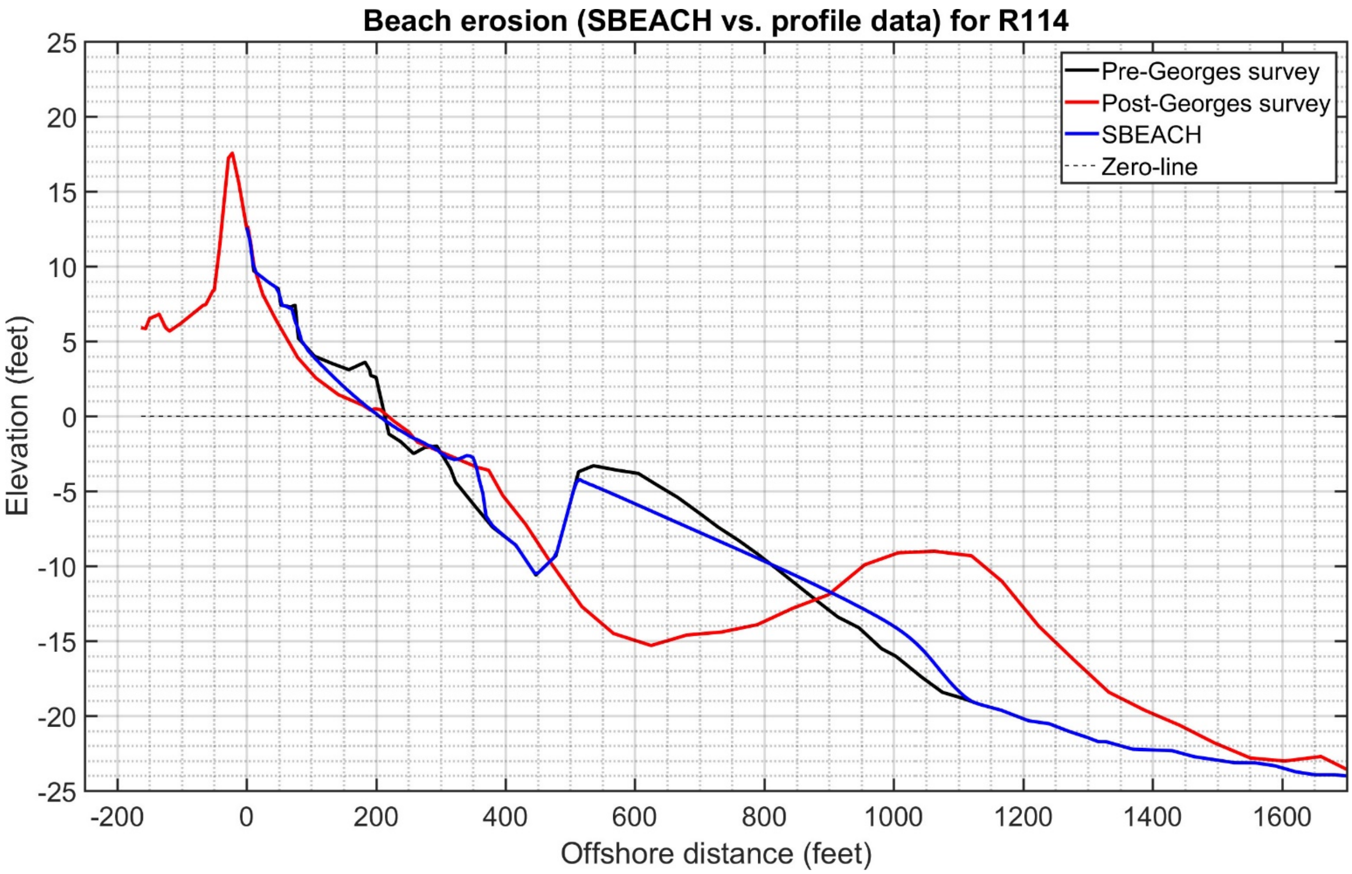
10. U.S. Army Corps of Engineers – Mobile District, 2018. Hurricane Georges storm surge September 1998: Mississippi, Alabama and Florida. Hydrology and Hydraulics Branch, 308 p.

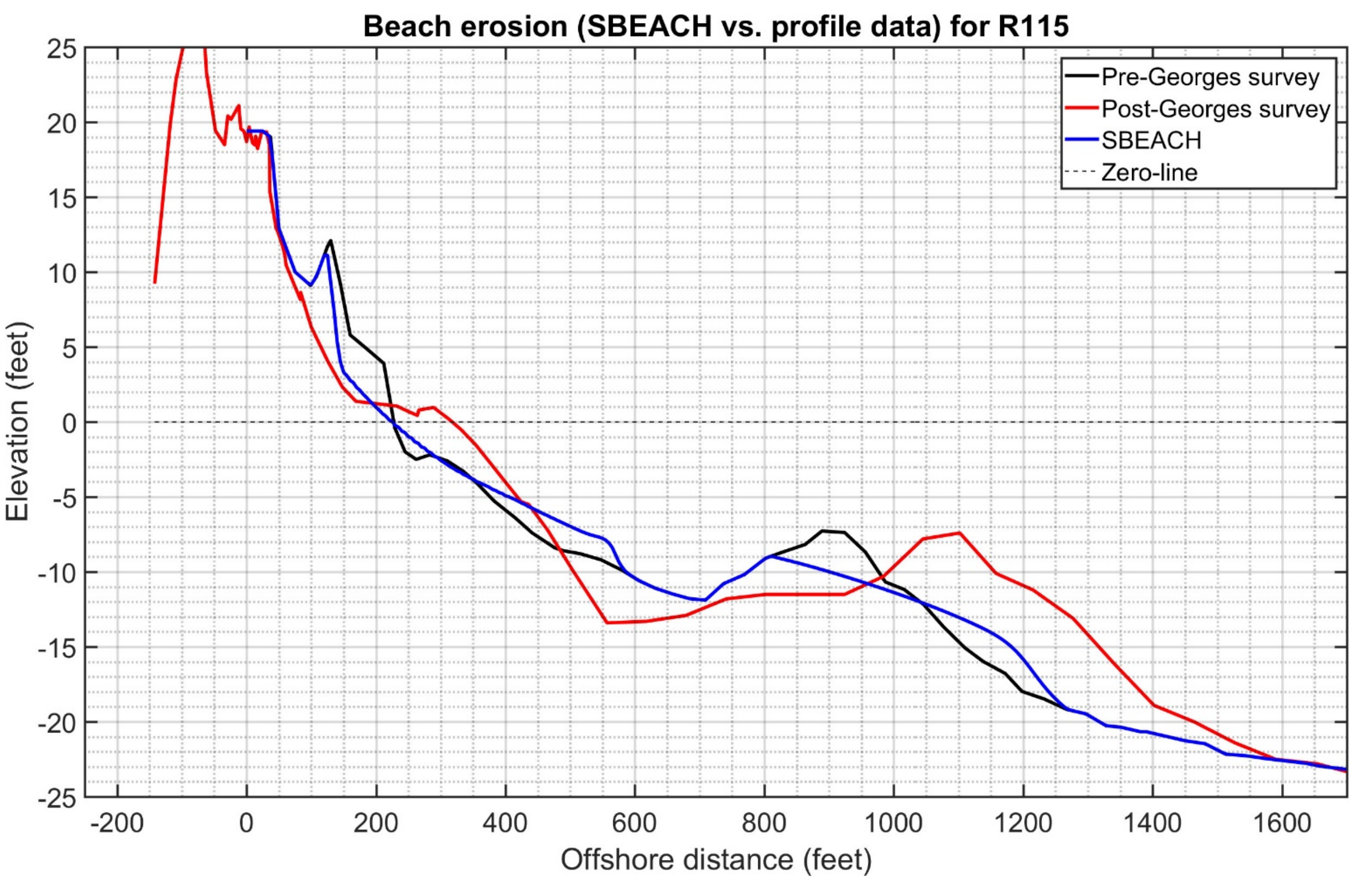
APPENDIX A

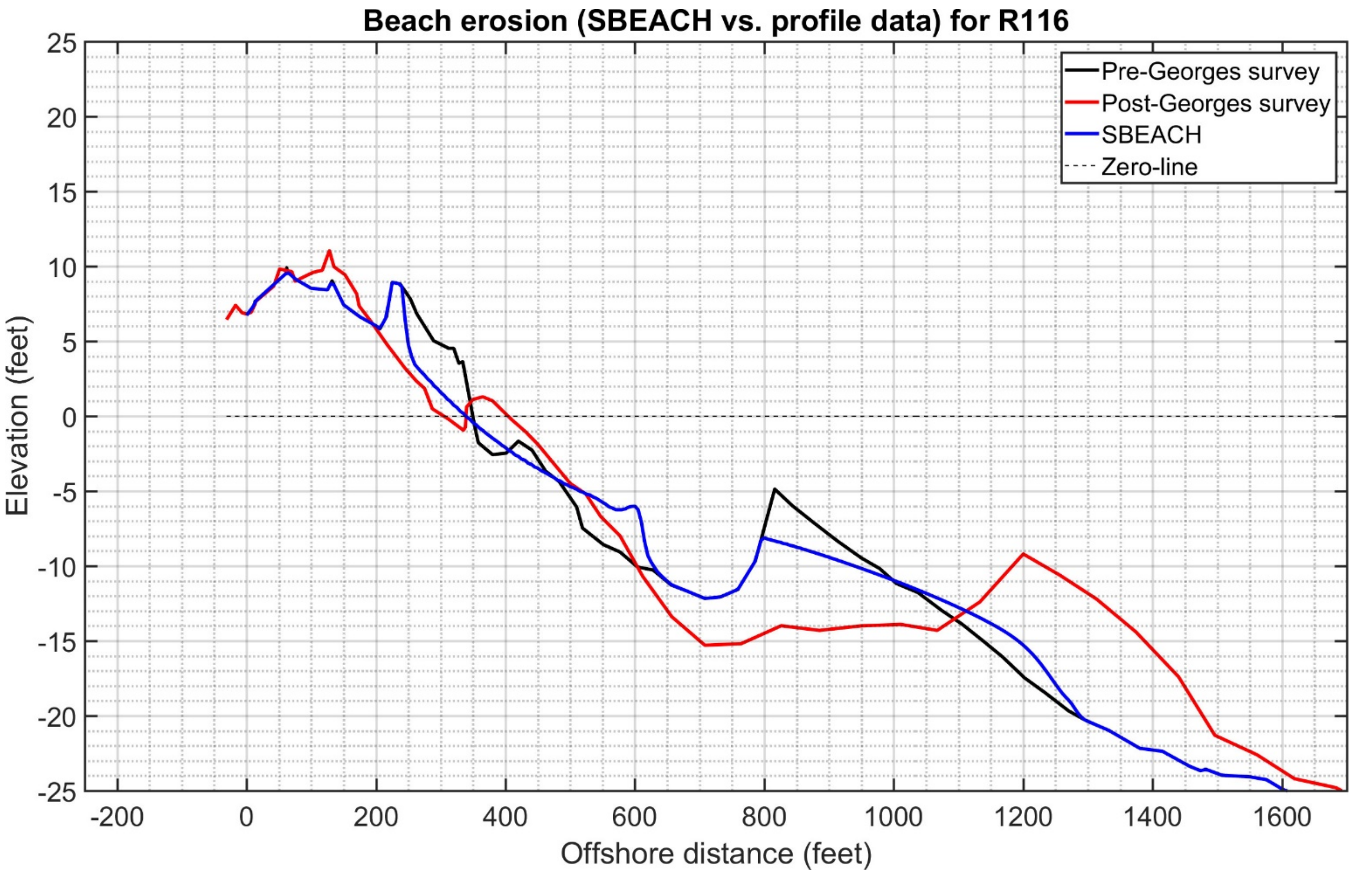
SBEACH Calibration Profiles for Escambia County

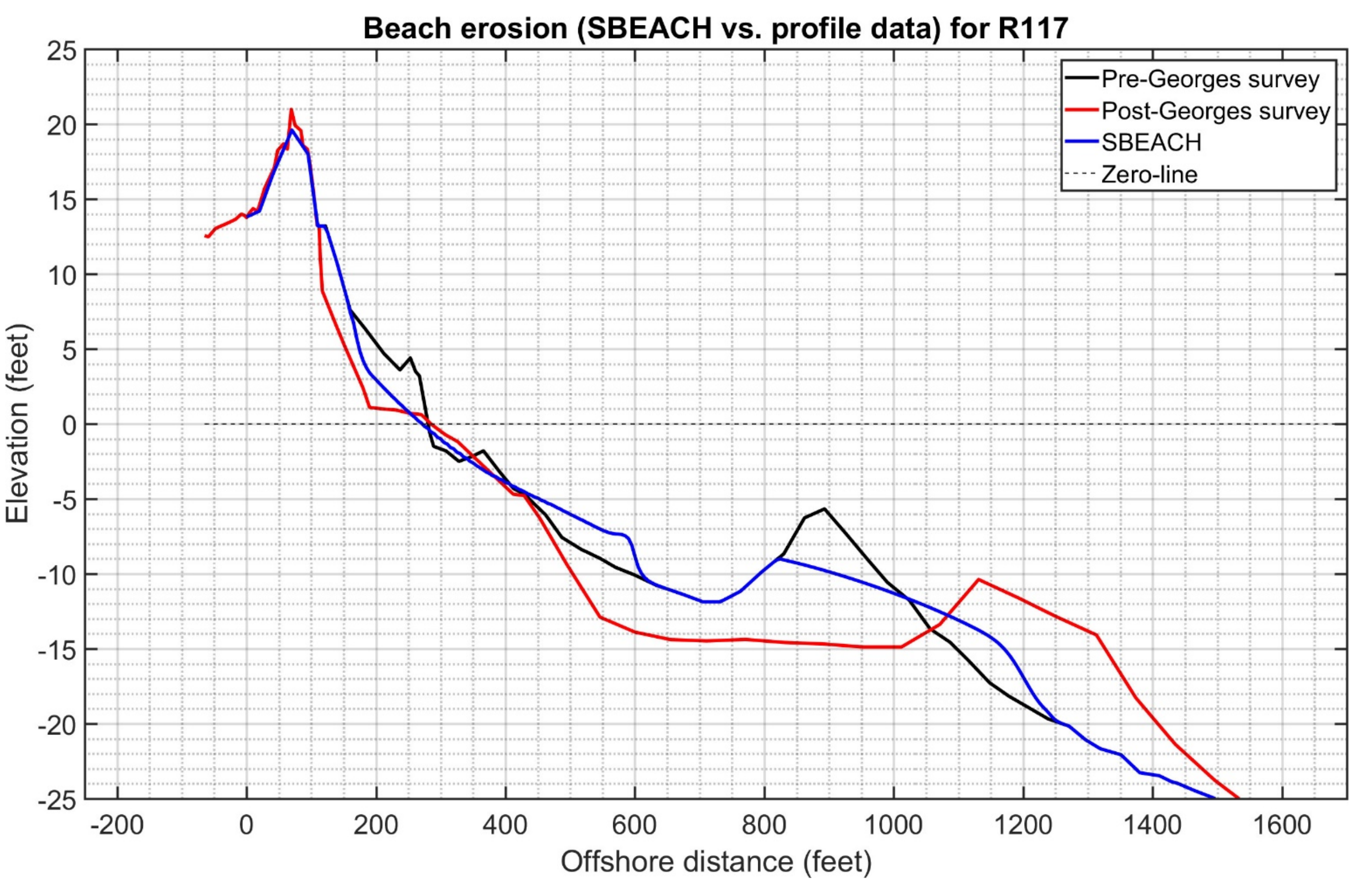

Beach erosion (SBEACH vs. profile data) for R110
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

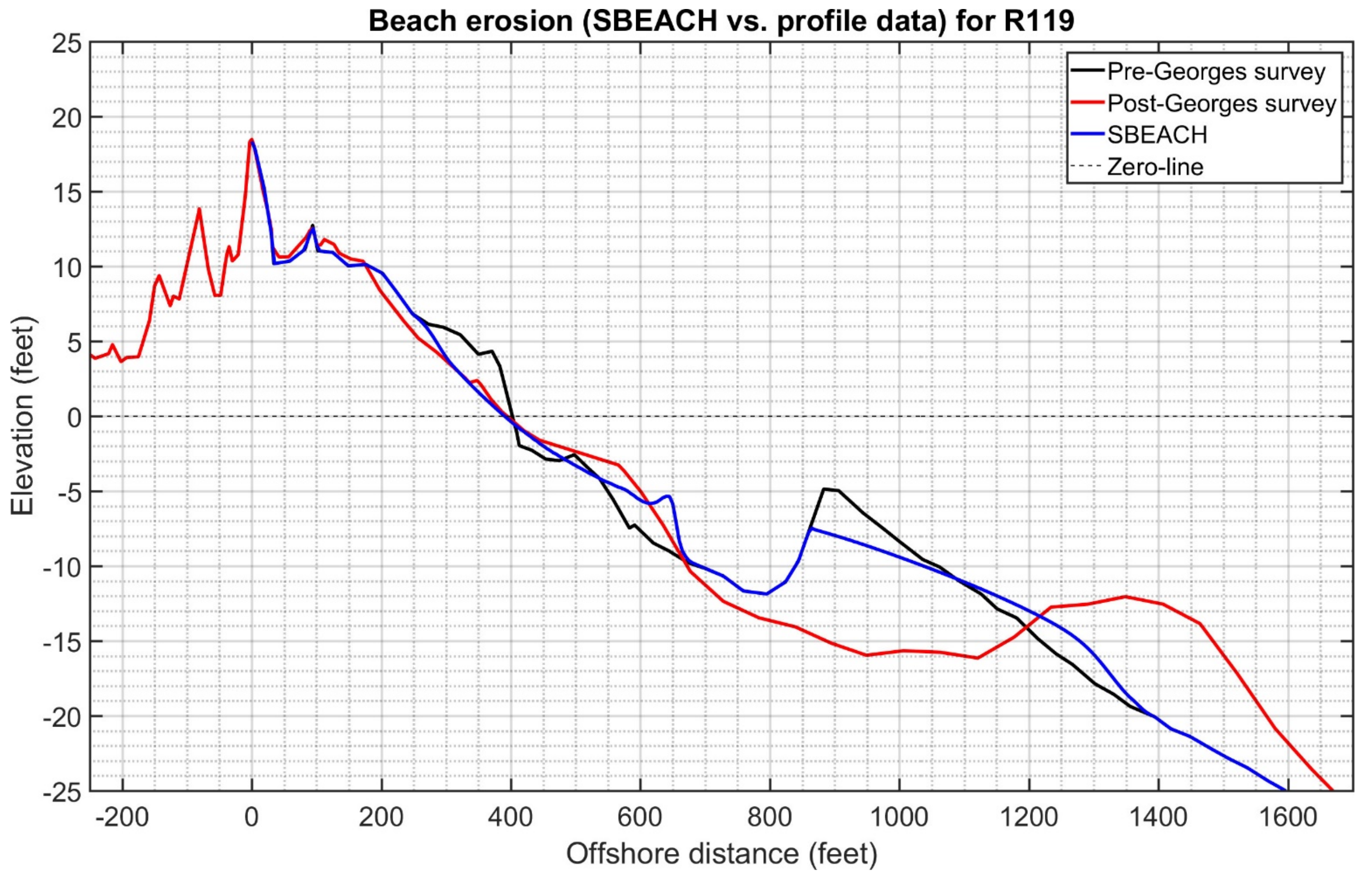

Beach erosion (SBEACH vs. profile data) for R113
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

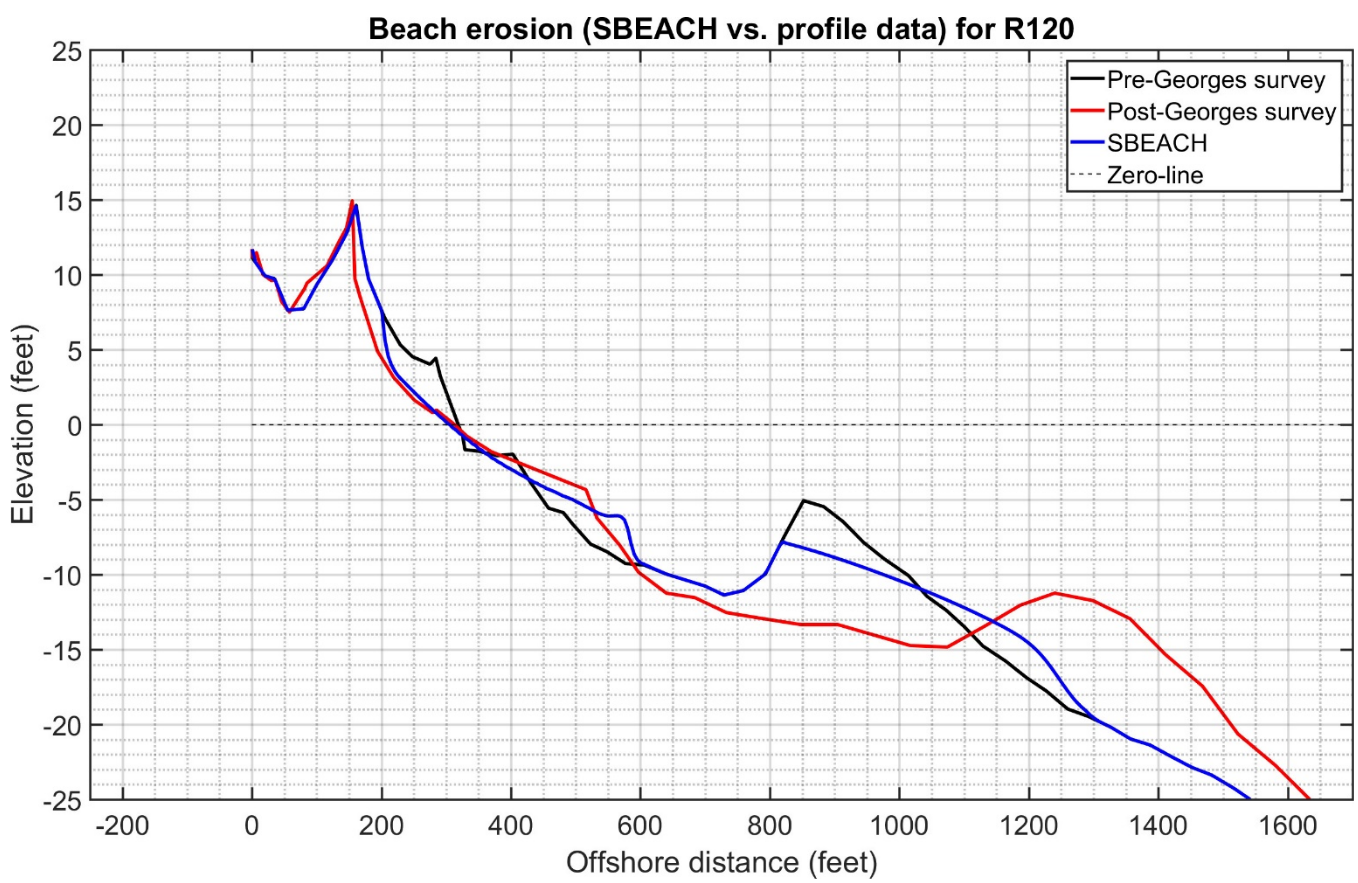

Beach erosion (SBEACH vs. profile data) for R114
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)

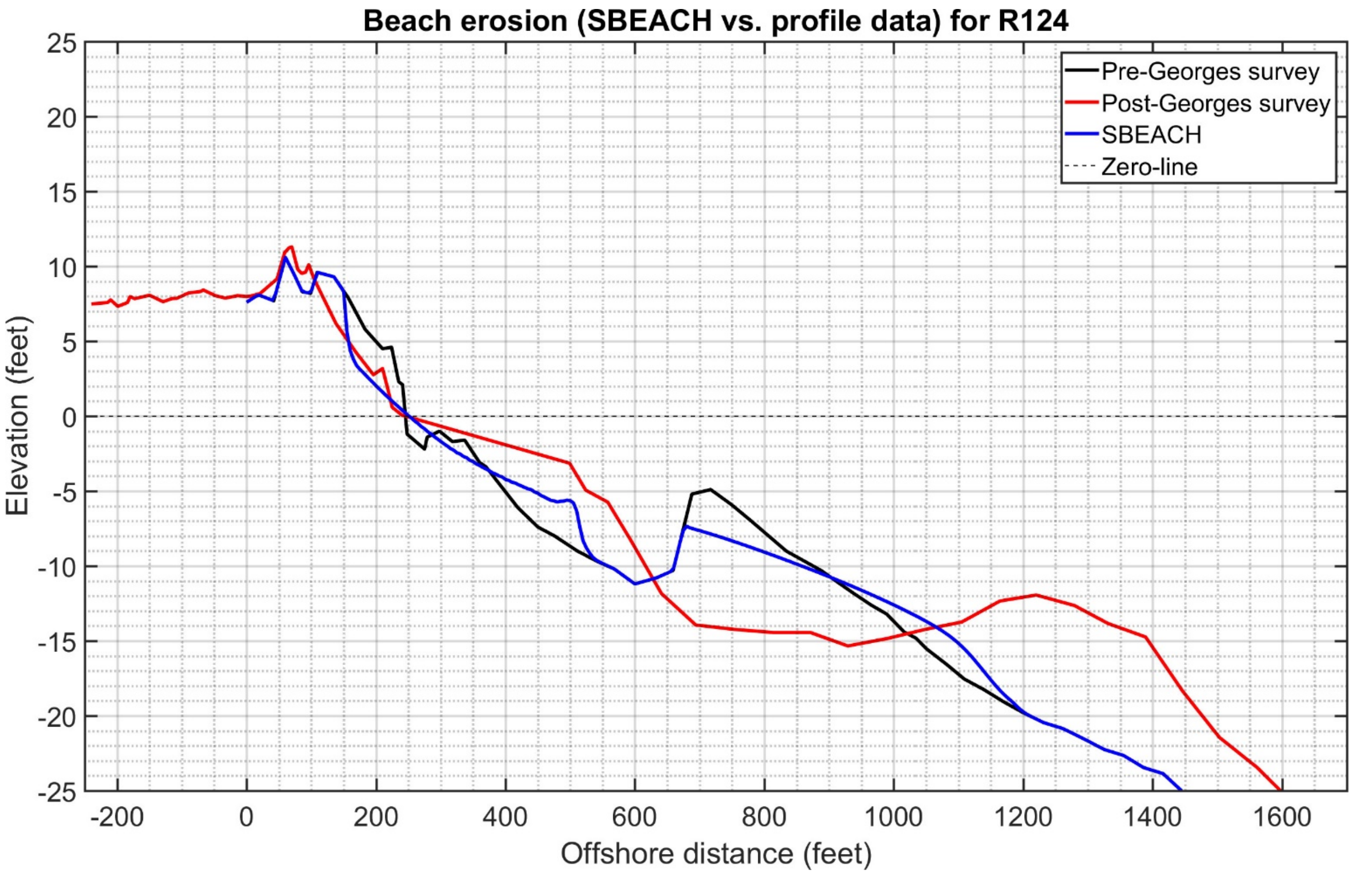

Beach erosion (SBEACH vs. profile data) for R115
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)

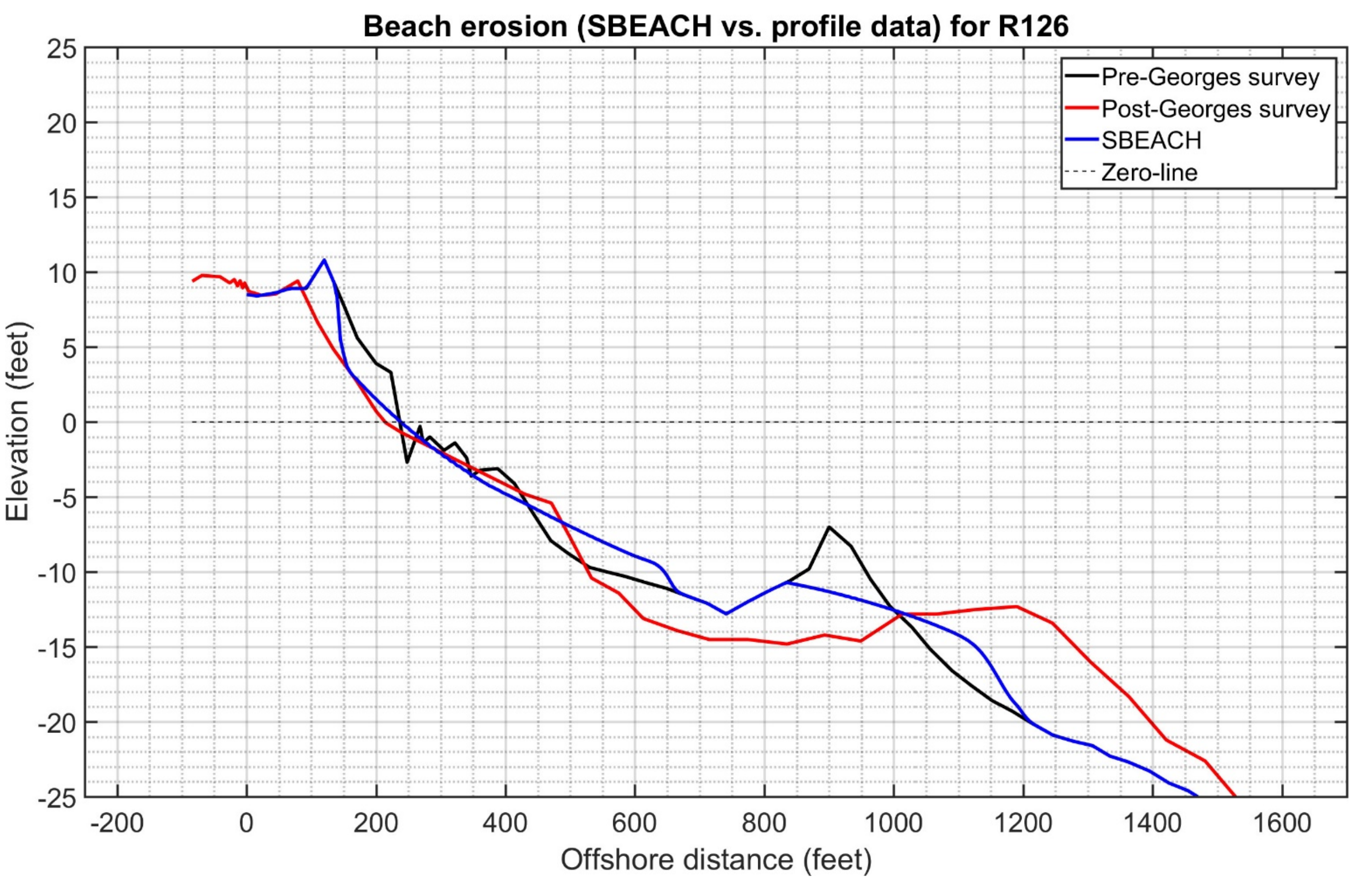

Beach erosion (SBEACH vs. profile data) for R116
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)

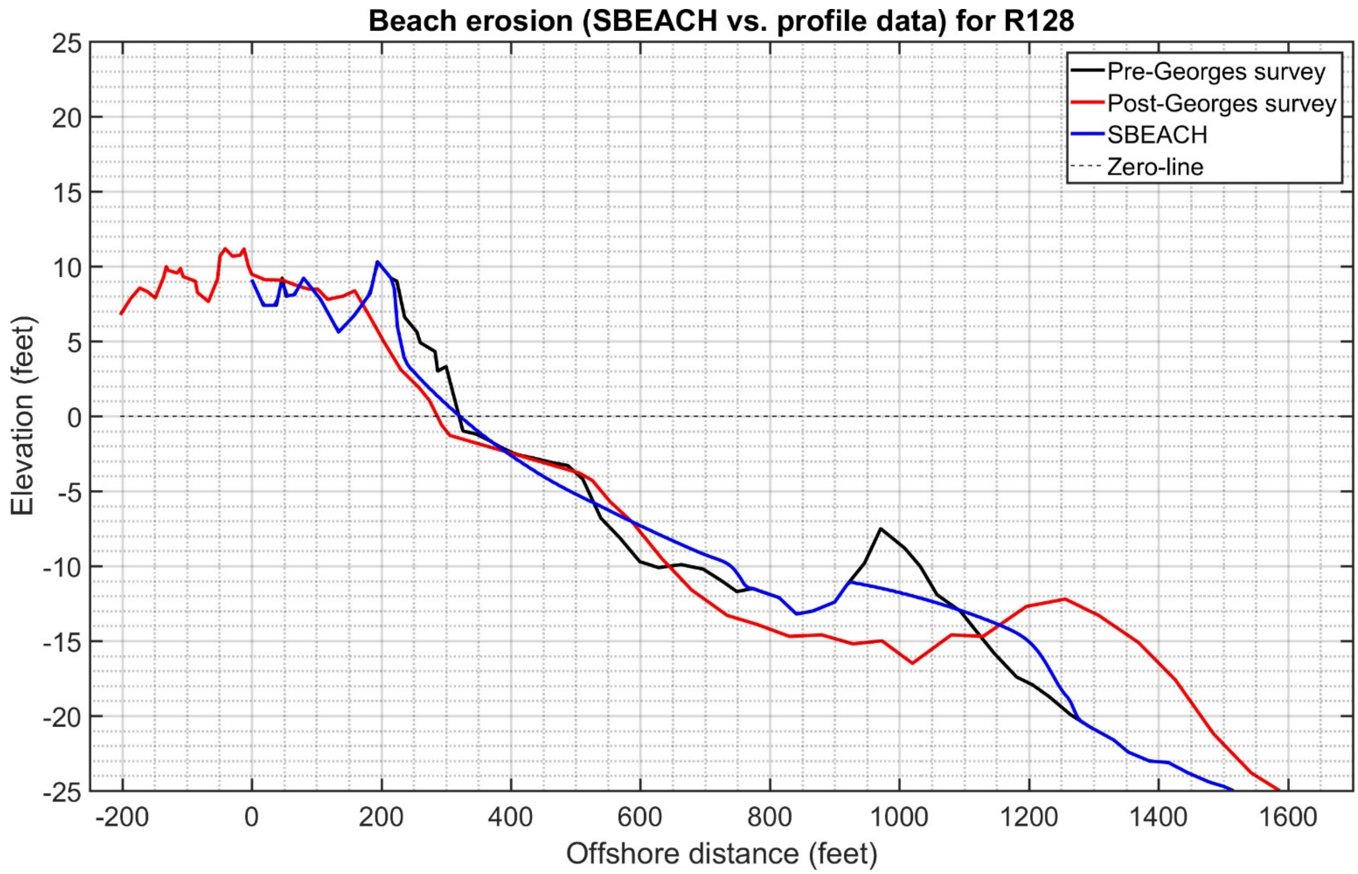

Beach erosion (SBEACH vs. profile data) for R117
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)

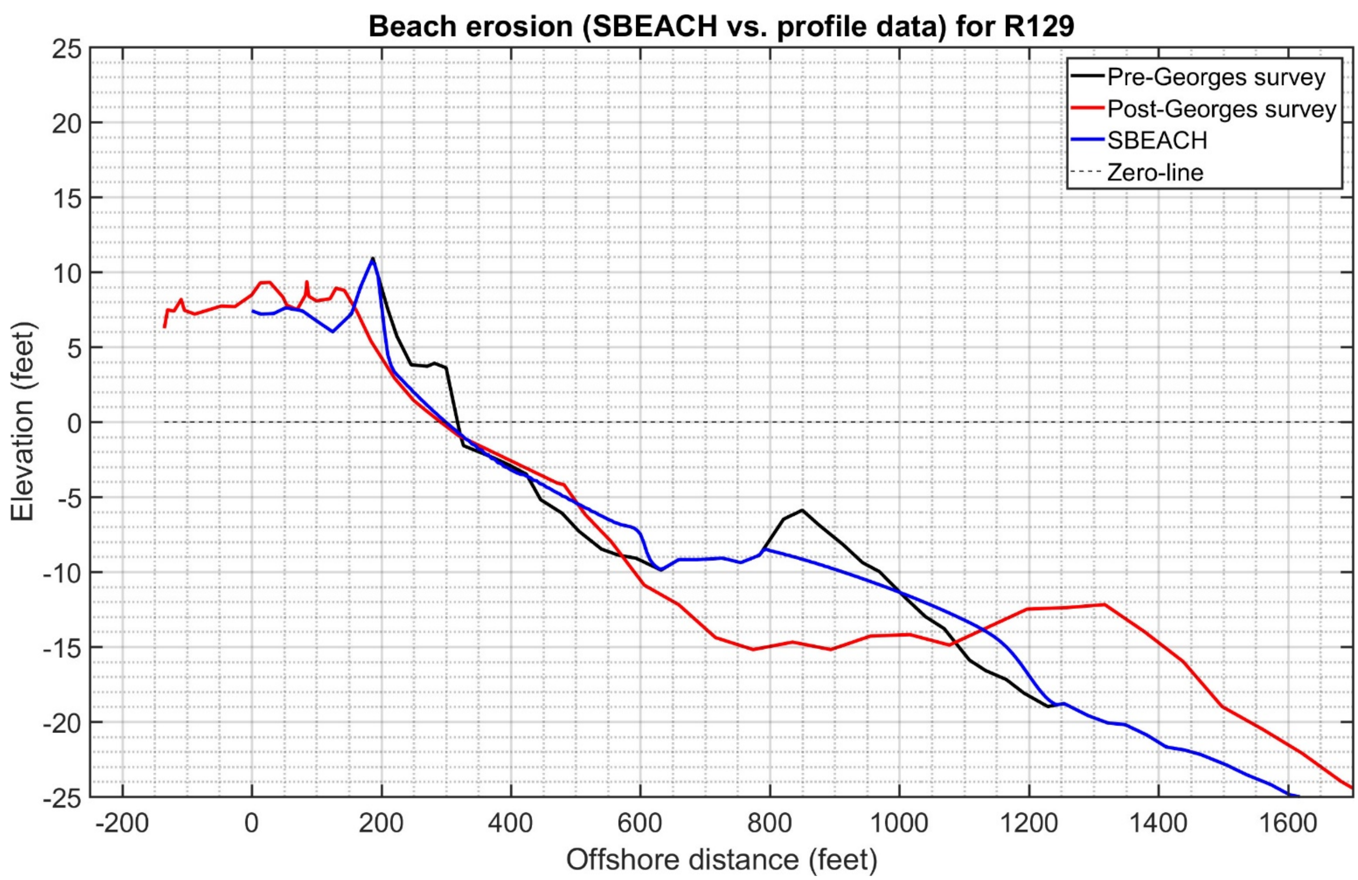

Beach erosion (SBEACH vs. profile data) for R119
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

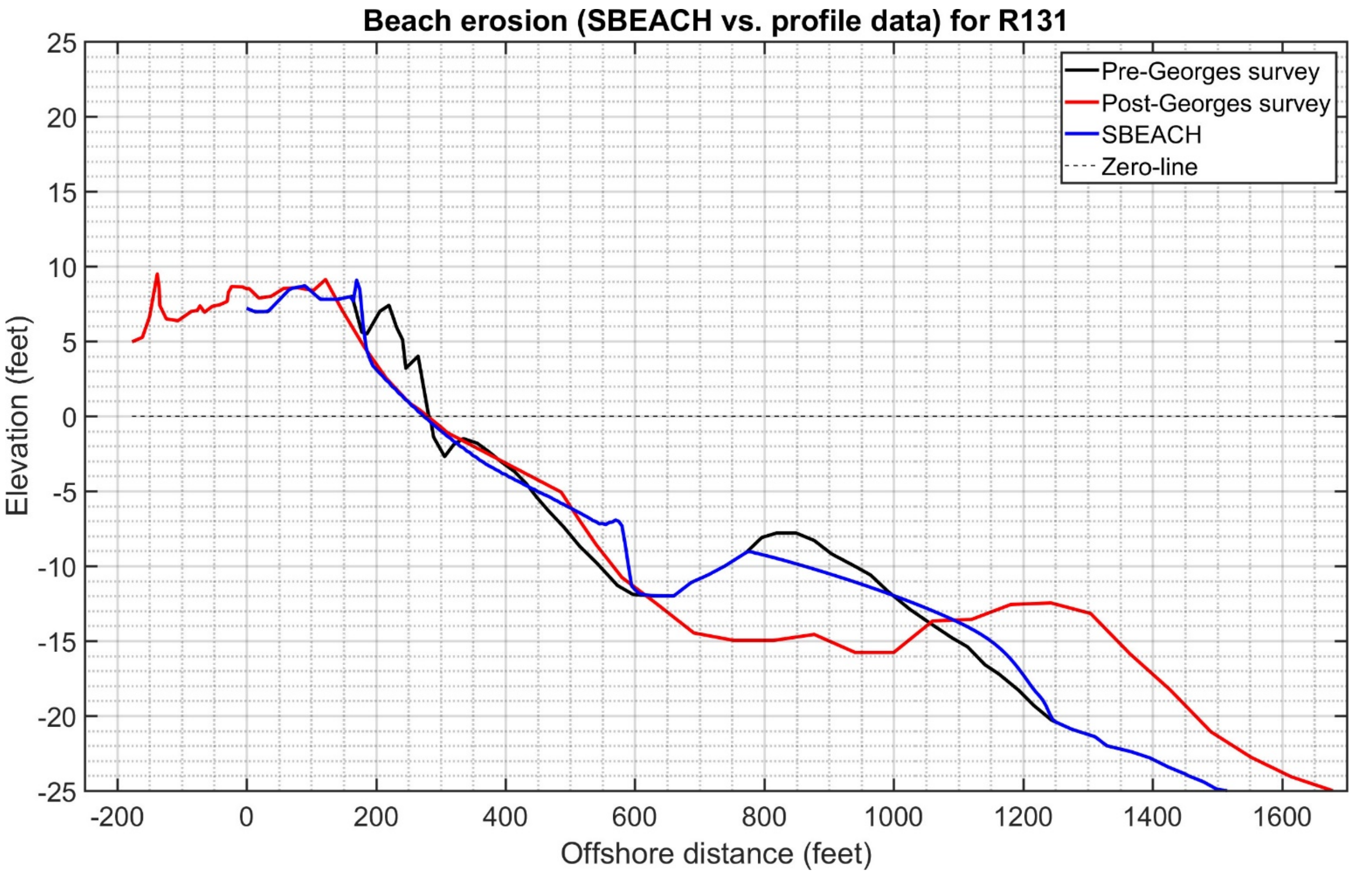

Beach erosion (SBEACH vs. profile data) for R120
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

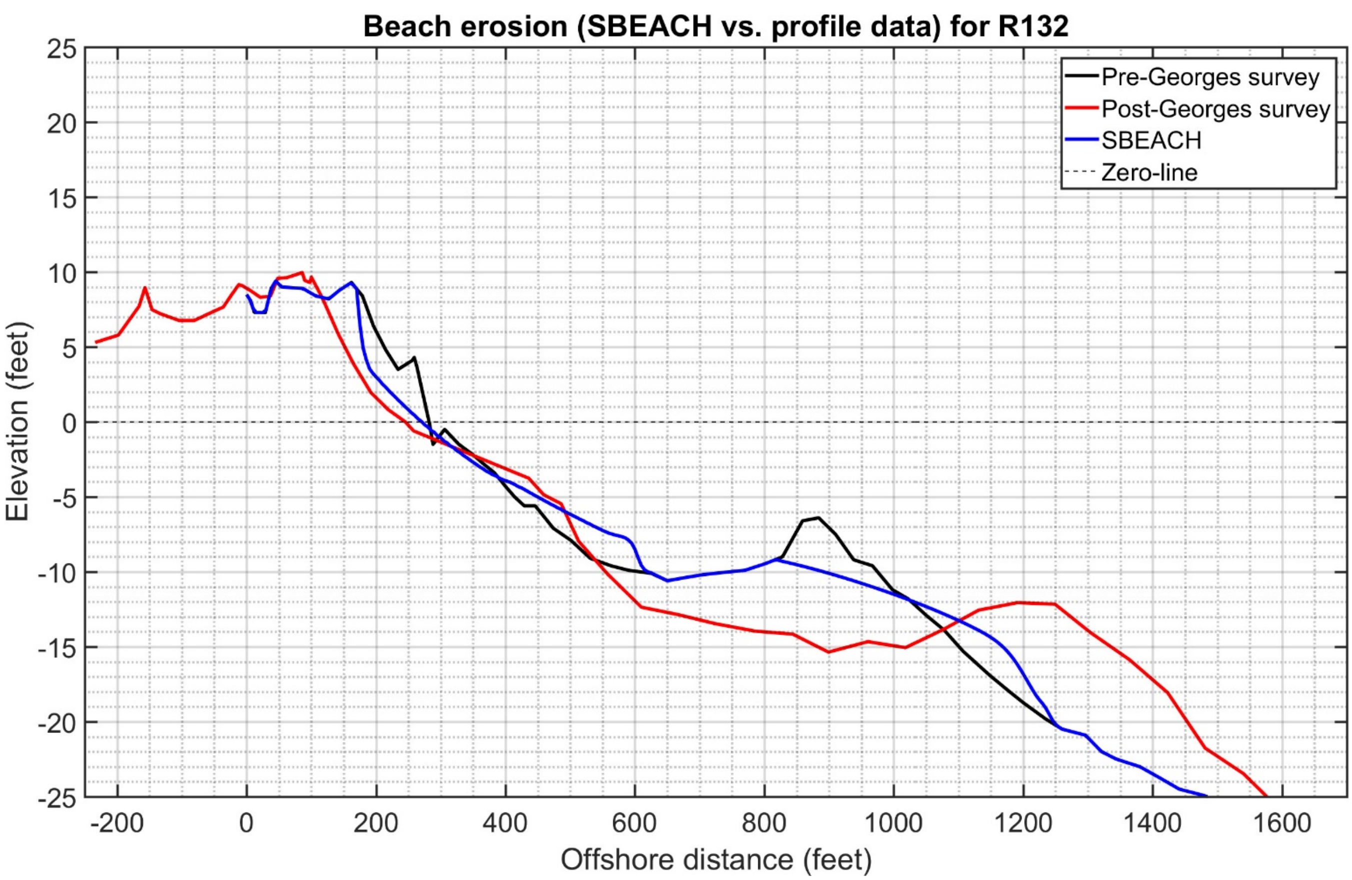

Beach erosion (SBEACH vs. profile data) for R124
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

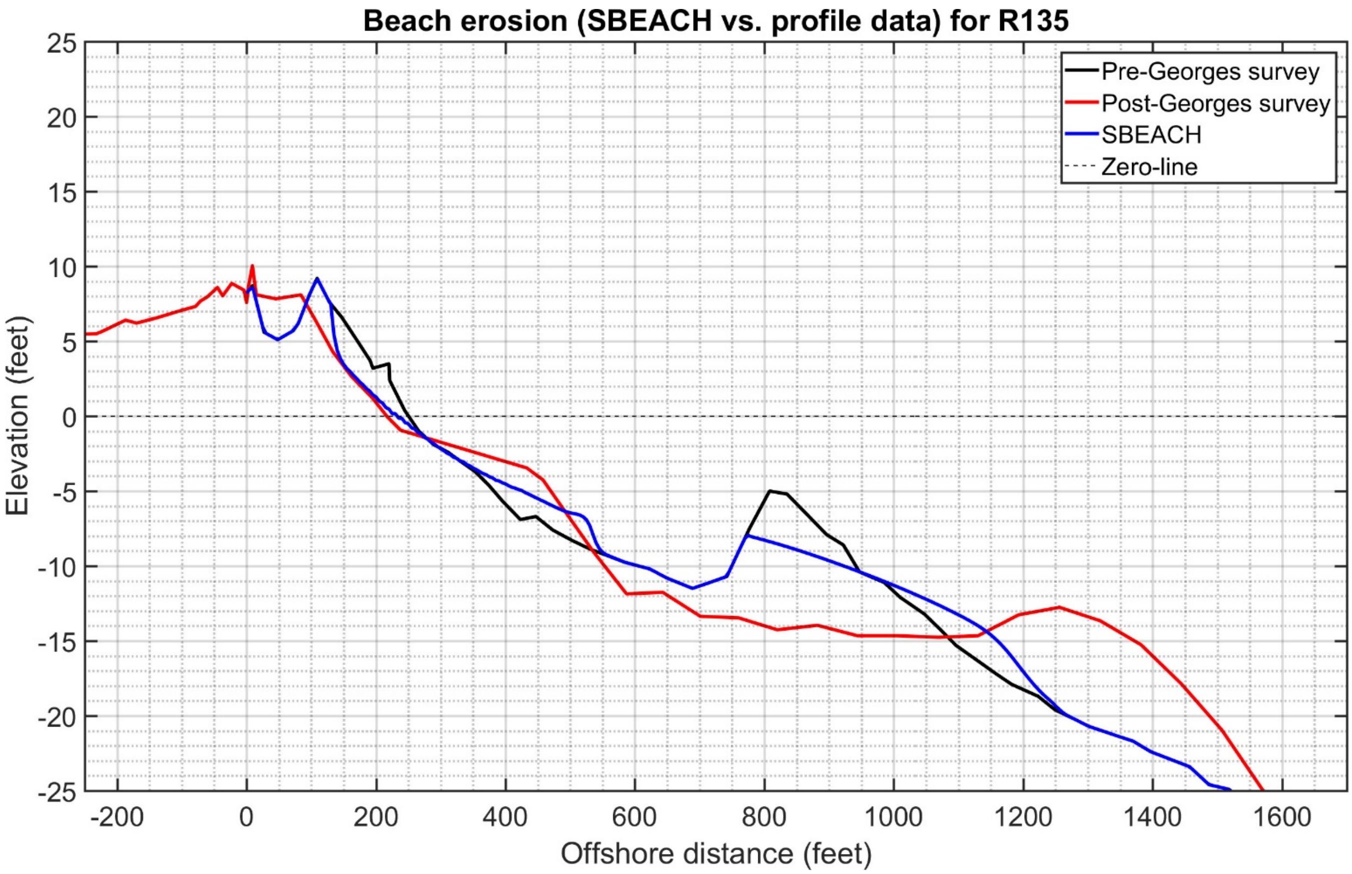

Beach erosion (SBEACH vs. profile data) for R126
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

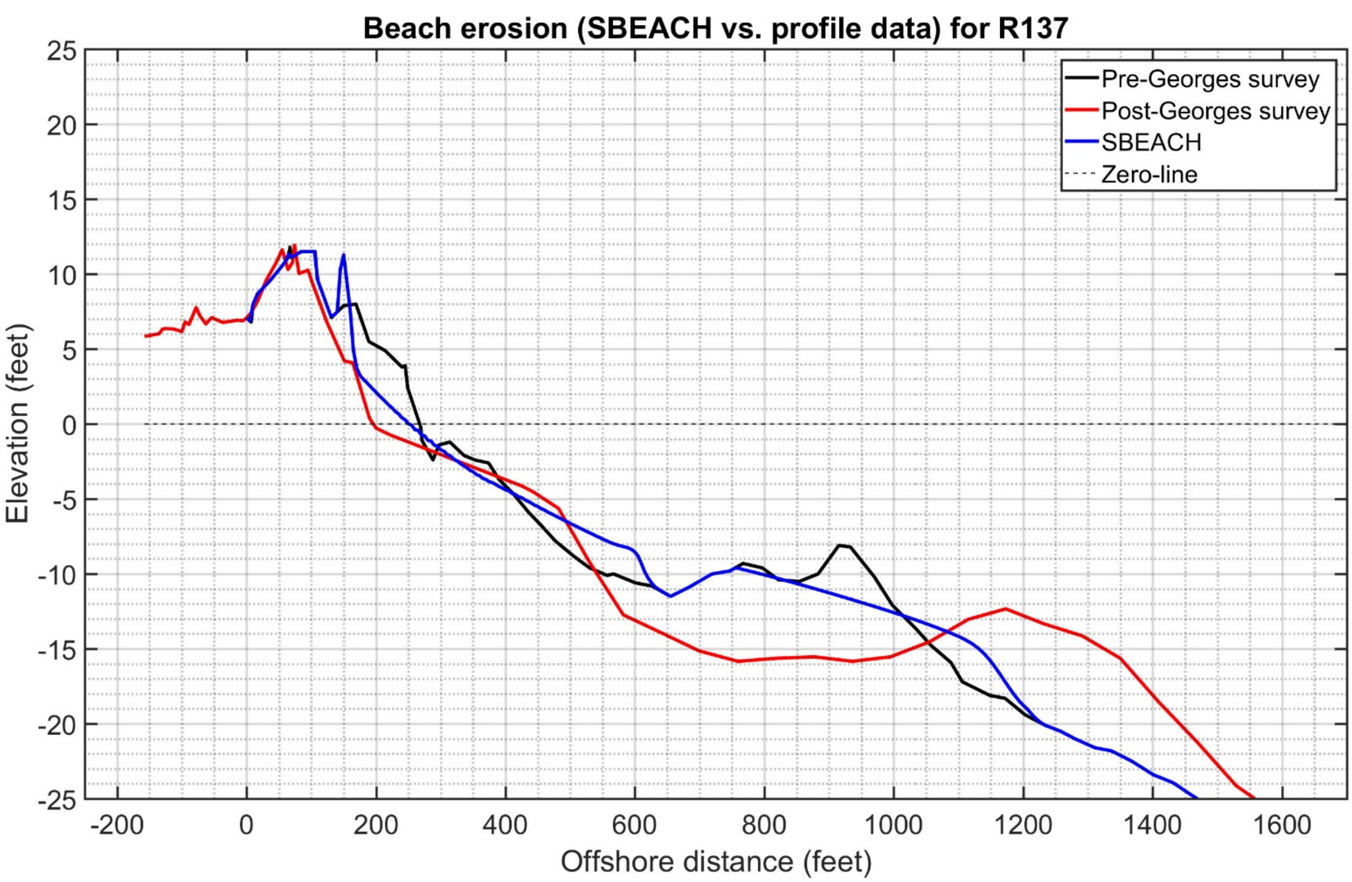

Beach erosion (SBEACH vs. profile data) for R128
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

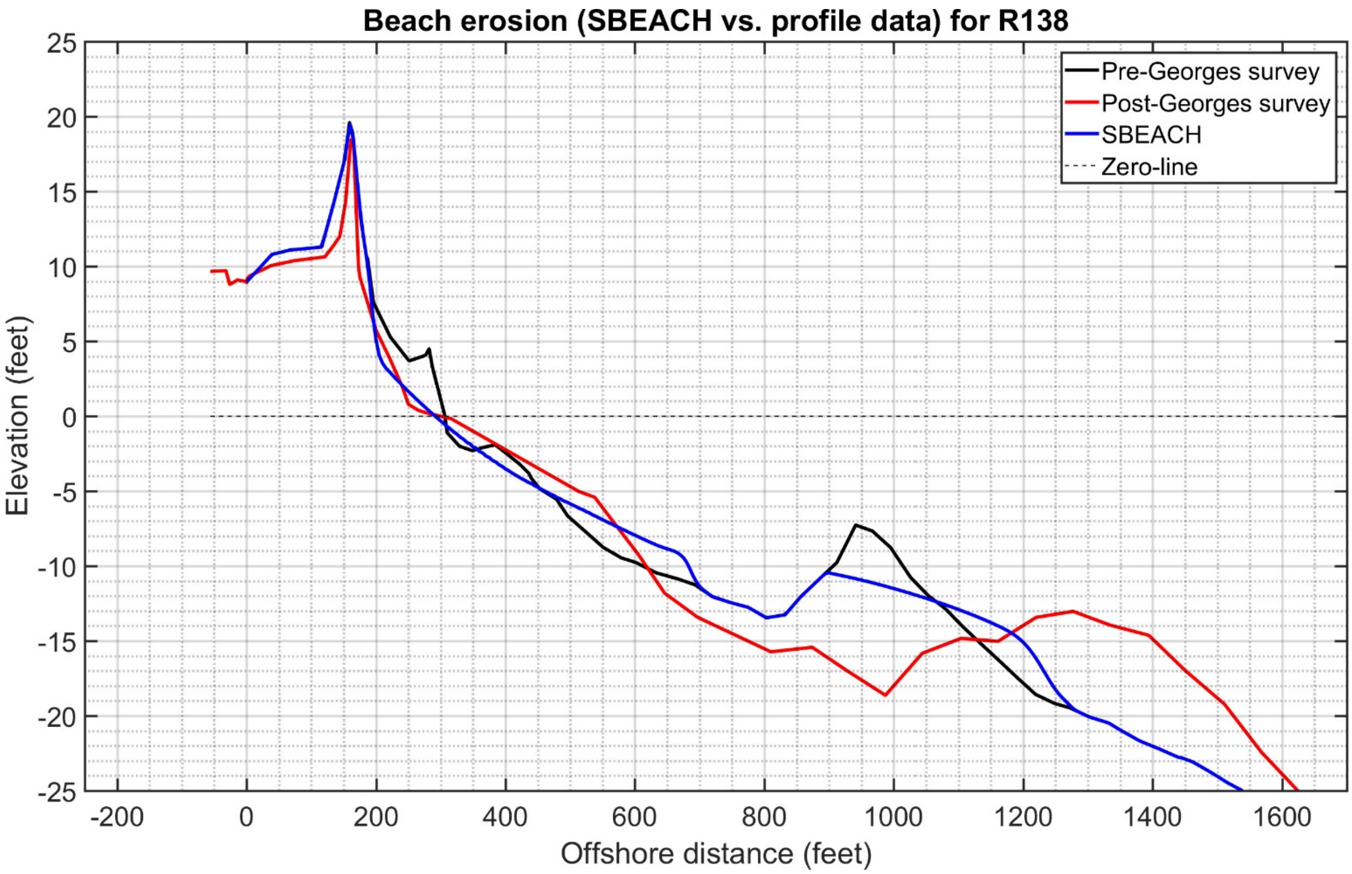

Beach erosion (SBEACH vs. profile data) for R129
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600


Beach erosion (SBEACH vs. profile data) for R131
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600


Beach erosion (SBEACH vs. profile data) for R132
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600


Beach erosion (SBEACH vs. profile data) for R135
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600


Beach erosion (SBEACH vs. profile data) for R137
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600


Beach erosion (SBEACH vs. profile data) for R138
Elevation (feet)
Offshore distance (feet)
Pre-Georges survey
Post-Georges survey
SBEACH
Zero-line
25
20
15
10
5
0
-5
-10
-15
-20
-25
-200
0
200
400
600
800
1000
1200
1400
1600

APPENDIX B

Recommended SBEACH Input Values for Escambia County

Final SBEACH Input Settings – 15- and 25-year storm erosions in Escambia County:

For all storm tide hydrographs, use 15- and 25-year hydrographs without wave setup and adjusted proportionally to peak elevation shown for each range monumentation segment shown below, and the storm duration for all cases is 36 hours. All elevations listed below are relative to NAVD. All wave input depth values are set as deep water with no wave randomization. All storm time steps are set at 5 minutes. Water temperature is 27 degrees centigrade. Grid cell width is 5 feet.

Parameter	R1–R67	R68–R156	R157–R186	R187–R215
Transport rate coefficient ($m^4\ N^{-1}$)	2.5×10^{-6}	2.5×10^{-6}	2.5×10^{-6}	2.5×10^{-6}
Overwash transport parameter (unitless)	0.005	0.005	0.005	0.005
Coefficient for slope-dependent term ($m^2\ s^{-1}$)	0.005	0.005	0.005	0.005
Transport rate decay coefficient (m^{-1})	0.5	0.5	0.5	0.5
Landward surf zone depth (feet)	1.0	1.0	1.0	1.0
Effective grain size (D_{50}) (mm)	0.371	0.379	0.379	0.379
Maximum slope prior to avalanching (°)	30	30	30	30
Water temperature (°C)	27	27	27	27
Constant wave height (feet)	10	10	10	10
Constant wave period (seconds)	11	11	11	11
15-year hydrograph peak elevation (feet)	5.1	4.8	4.6	4.6
25-year hydrograph peak elevation (feet)	6.4	6.4	5.9	5.9

APPENDIX C

Adjusted 15- and 25-Year Hydrograph Tables for Escambia County

Escambia County – Adjusted 15-Year Hydrograph (feet, NAVD) for SBEACH:

Time (hour)	R1–R67	R68–R156	R157–R215
0.0	-0.28	-0.27	-0.26
0.5	-0.33	-0.31	-0.30
1.0	-0.36	-0.34	-0.32
1.5	-0.37	-0.35	-0.34
2.0	-0.35	-0.33	-0.32
2.5	-0.31	-0.30	-0.28
3.0	-0.25	-0.24	-0.23
3.5	-0.18	-0.17	-0.16
4.0	-0.08	-0.08	-0.07
4.5	0.03	0.03	0.02
5.0	0.13	0.13	0.12
5.5	0.24	0.23	0.22
6.0	0.33	0.31	0.30
6.5	0.40	0.38	0.37
7.0	0.46	0.44	0.42
7.5	0.49	0.47	0.45
8.0	0.51	0.49	0.47
8.5	0.51	0.49	0.47
9.0	0.50	0.48	0.46
9.5	0.48	0.45	0.44
10.0	0.44	0.42	0.41
10.5	0.41	0.39	0.38
11.0	0.39	0.37	0.36
11.5	0.36	0.35	0.33
12.0	0.40	0.38	0.36
12.5	0.46	0.44	0.42
13.0	0.60	0.57	0.55
13.5	0.85	0.81	0.77
14.0	1.15	1.10	1.05
14.5	1.47	1.40	1.34
15.0	1.78	1.70	1.63
15.5	2.14	2.04	1.96
16.0	2.63	2.50	2.40
16.5	3.29	3.14	3.01
17.0	4.11	3.91	3.75
17.5	4.84	4.61	4.42
18.0	5.07	4.83	4.63
18.5	4.71	4.49	4.31

Time (hour)	R1–R67	R68–R156	R157–R215
19.0	4.07	3.88	3.72
19.5	3.37	3.21	3.08
20.0	2.75	2.62	2.51
20.5	2.21	2.10	2.02
21.0	1.74	1.66	1.59
21.5	1.36	1.30	1.24
22.0	1.07	1.02	0.98
22.5	0.86	0.82	0.78
23.0	0.67	0.64	0.61
23.5	0.46	0.44	0.42
24.0	0.25	0.24	0.23
24.5	0.06	0.06	0.05
25.0	-0.08	-0.08	-0.07
25.5	-0.18	-0.18	-0.17
26.0	-0.24	-0.23	-0.22
26.5	-0.26	-0.24	-0.23
27.0	-0.24	-0.23	-0.22
27.5	-0.18	-0.17	-0.16
28.0	-0.11	-0.10	-0.10
28.5	0.03	0.03	0.02
29.0	0.05	0.05	0.05
29.5	0.13	0.13	0.12
30.0	0.21	0.20	0.19
30.5	0.28	0.27	0.26
31.0	0.34	0.33	0.31
31.5	0.39	0.37	0.35
32.0	0.44	0.42	0.40
32.5	0.47	0.45	0.43
33.0	0.49	0.46	0.44
33.5	0.48	0.45	0.44
34.0	0.44	0.42	0.41
34.5	0.40	0.38	0.37
35.0	0.35	0.33	0.32
35.5	0.29	0.28	0.27
36.0	0.25	0.24	0.23

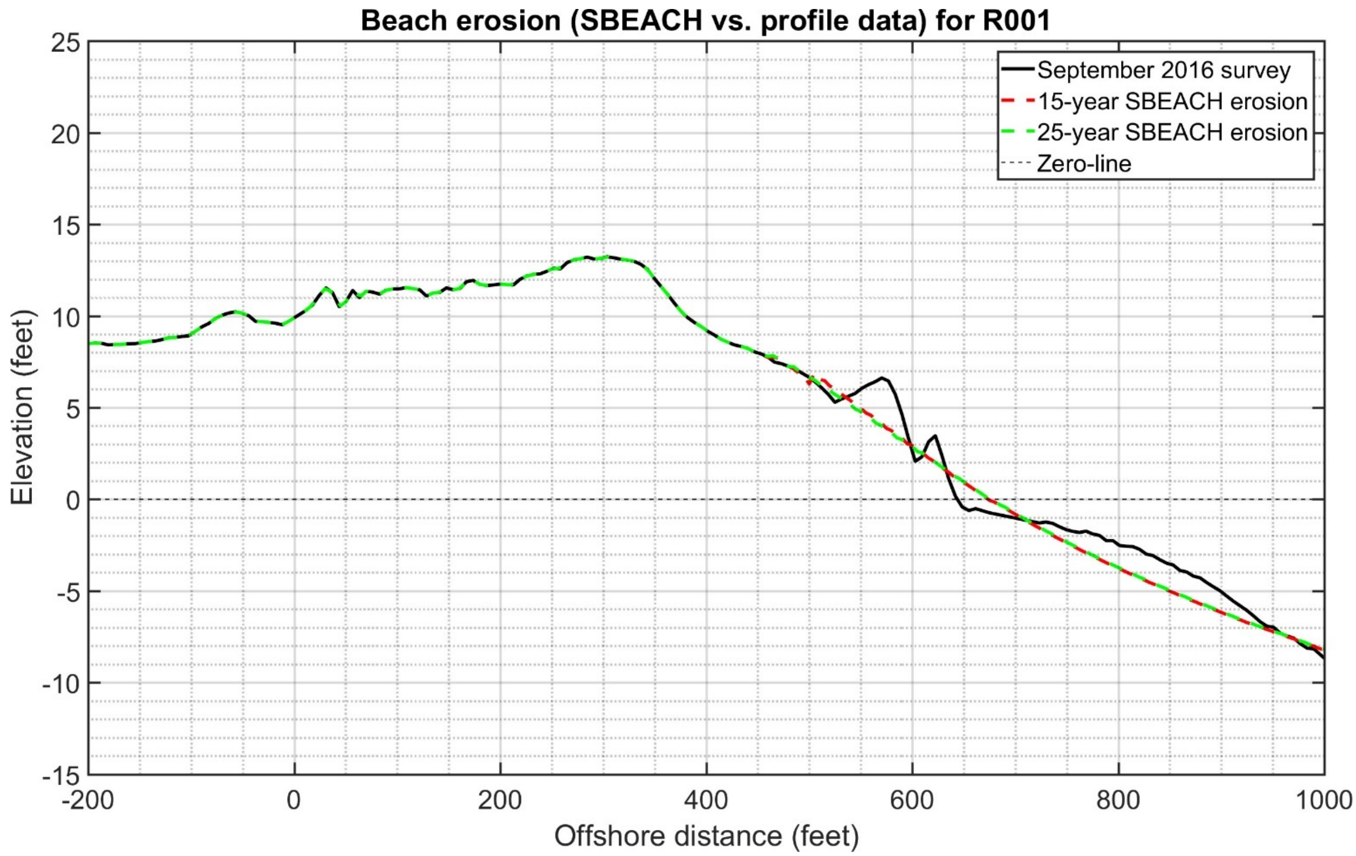
Escambia County – Adjusted 25-Year Hydrograph (feet, NAVD) for SBEACH:

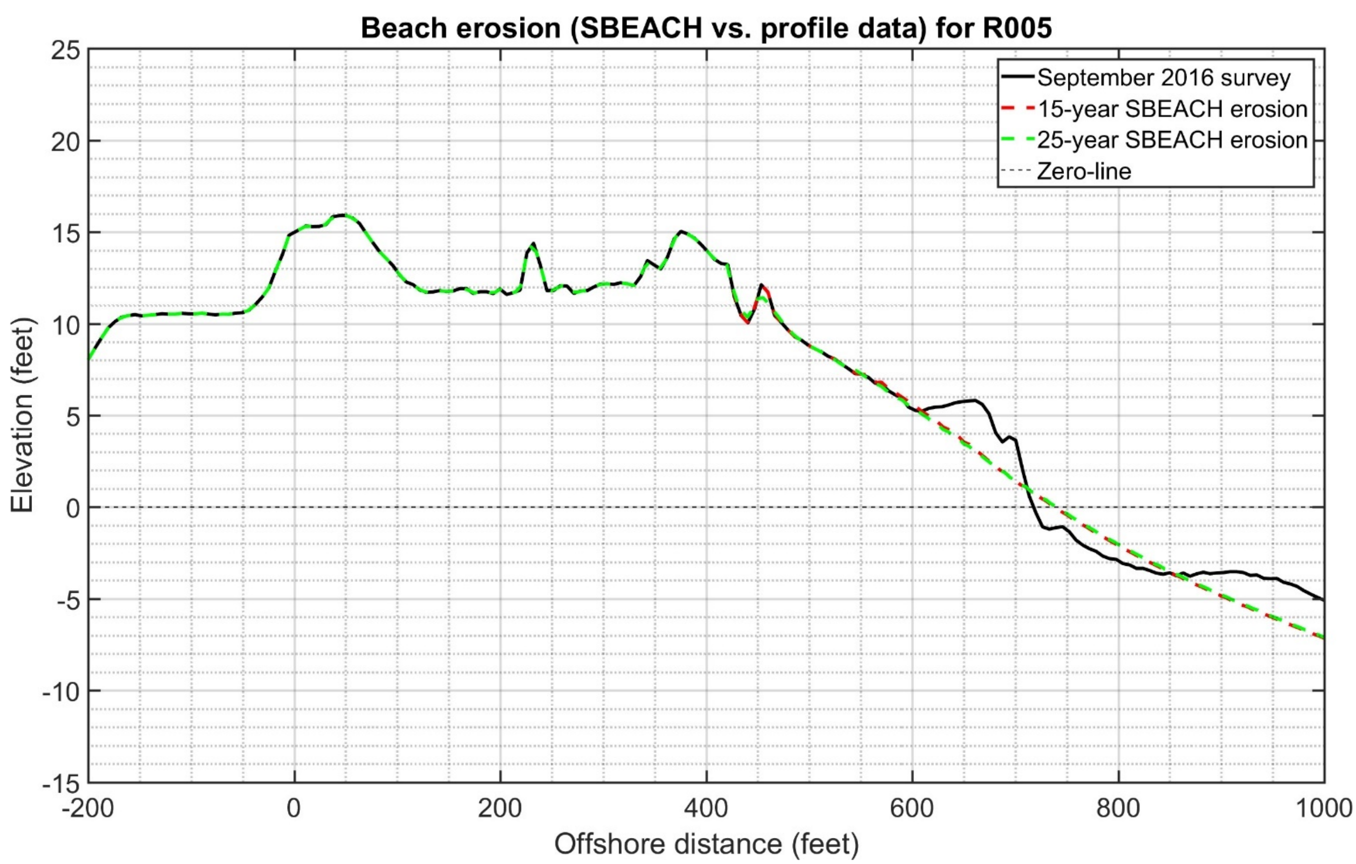
Time (hour)	R1–R156	R157–R215
0.0	-0.36	-0.33
0.5	-0.41	-0.38
1.0	-0.45	-0.41
1.5	-0.46	-0.43
2.0	-0.44	-0.41
2.5	-0.39	-0.36
3.0	-0.32	-0.29
3.5	-0.22	-0.20
4.0	-0.10	-0.09
4.5	0.03	0.03
5.0	0.17	0.16
5.5	0.30	0.28
6.0	0.41	0.38
6.5	0.50	0.47
7.0	0.58	0.54
7.5	0.62	0.58
8.0	0.64	0.60
8.5	0.64	0.60
9.0	0.63	0.58
9.5	0.60	0.56
10.0	0.56	0.52
10.5	0.52	0.48
11.0	0.49	0.46
11.5	0.46	0.43
12.0	0.50	0.46
12.5	0.58	0.54
13.0	0.76	0.70
13.5	1.06	0.99
14.0	1.45	1.34
14.5	1.85	1.72
15.0	2.24	2.08
15.5	2.69	2.50
16.0	3.30	3.07
16.5	4.14	3.85
17.0	5.16	4.80
17.5	6.08	5.65
18.0	6.37	5.92
18.5	5.92	5.51

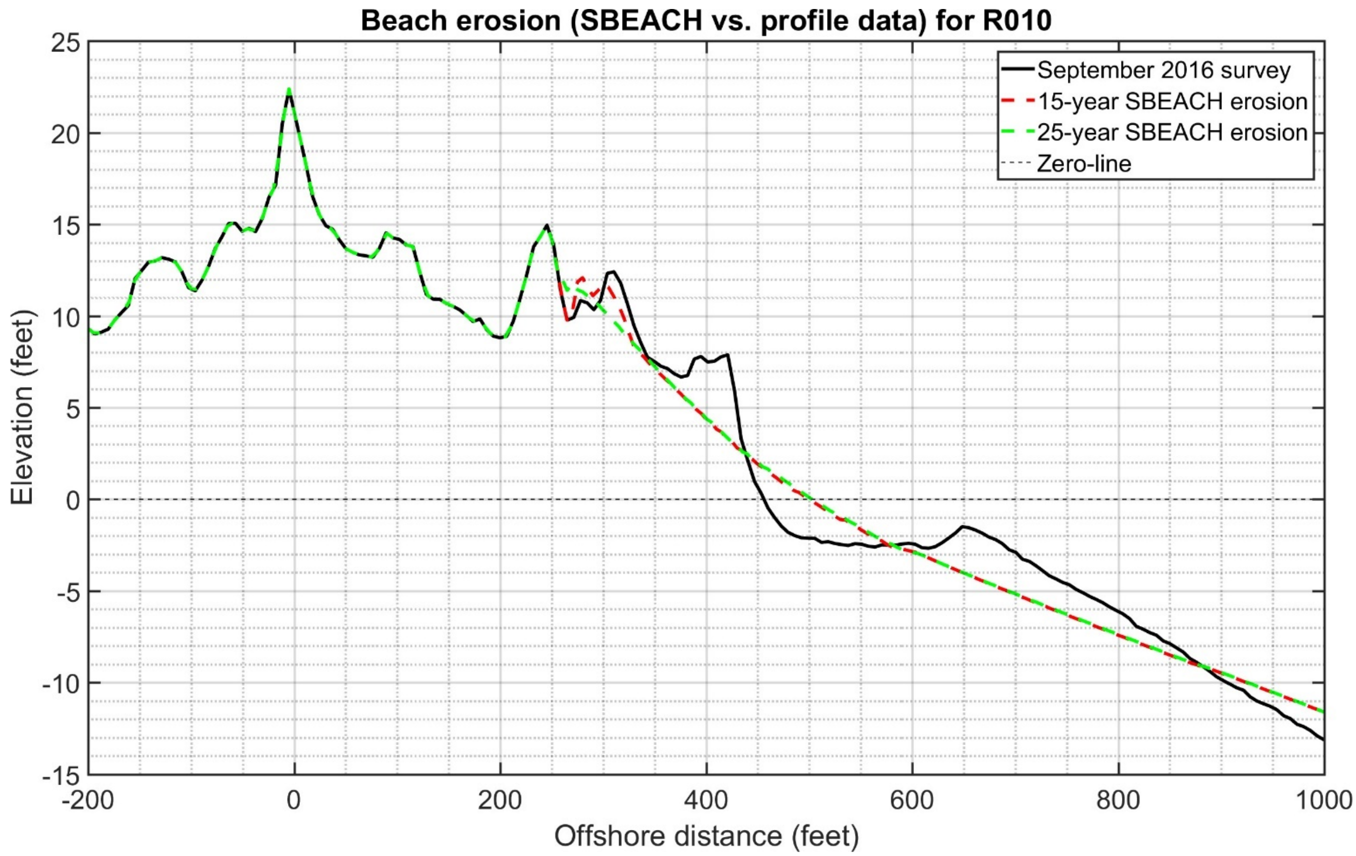
Time (hour)	R1–R156	R157–R215
19.0	5.12	4.75
19.5	4.24	3.94
20.0	3.45	3.21
20.5	2.77	2.58
21.0	2.19	2.03
21.5	1.71	1.59
22.0	1.35	1.25
22.5	1.08	1.00
23.0	0.84	0.78
23.5	0.58	0.54
24.0	0.31	0.29
24.5	0.07	0.07
25.0	-0.10	-0.09
25.5	-0.23	-0.22
26.0	-0.30	-0.28
26.5	-0.32	-0.30
27.0	-0.30	-0.28
27.5	-0.23	-0.21
28.0	-0.14	-0.13
28.5	0.03	0.03
29.0	0.07	0.06
29.5	0.17	0.16
30.0	0.27	0.25
30.5	0.36	0.33
31.0	0.43	0.40
31.5	0.49	0.45
32.0	0.55	0.51
32.5	0.59	0.55
33.0	0.61	0.57
33.5	0.60	0.56
34.0	0.56	0.52
34.5	0.50	0.47
35.0	0.43	0.40
35.5	0.37	0.34
36.0	0.32	0.29

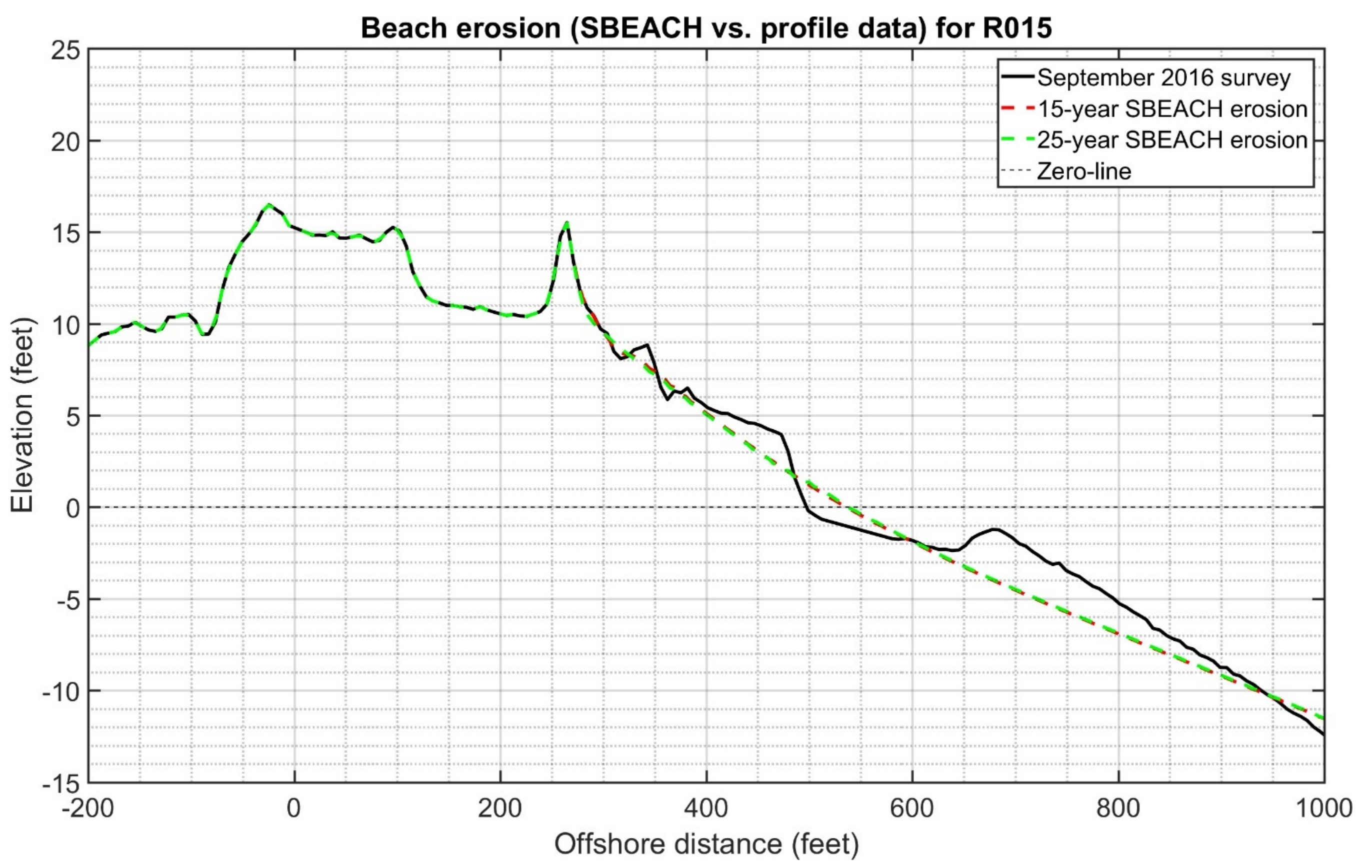
APPENDIX D

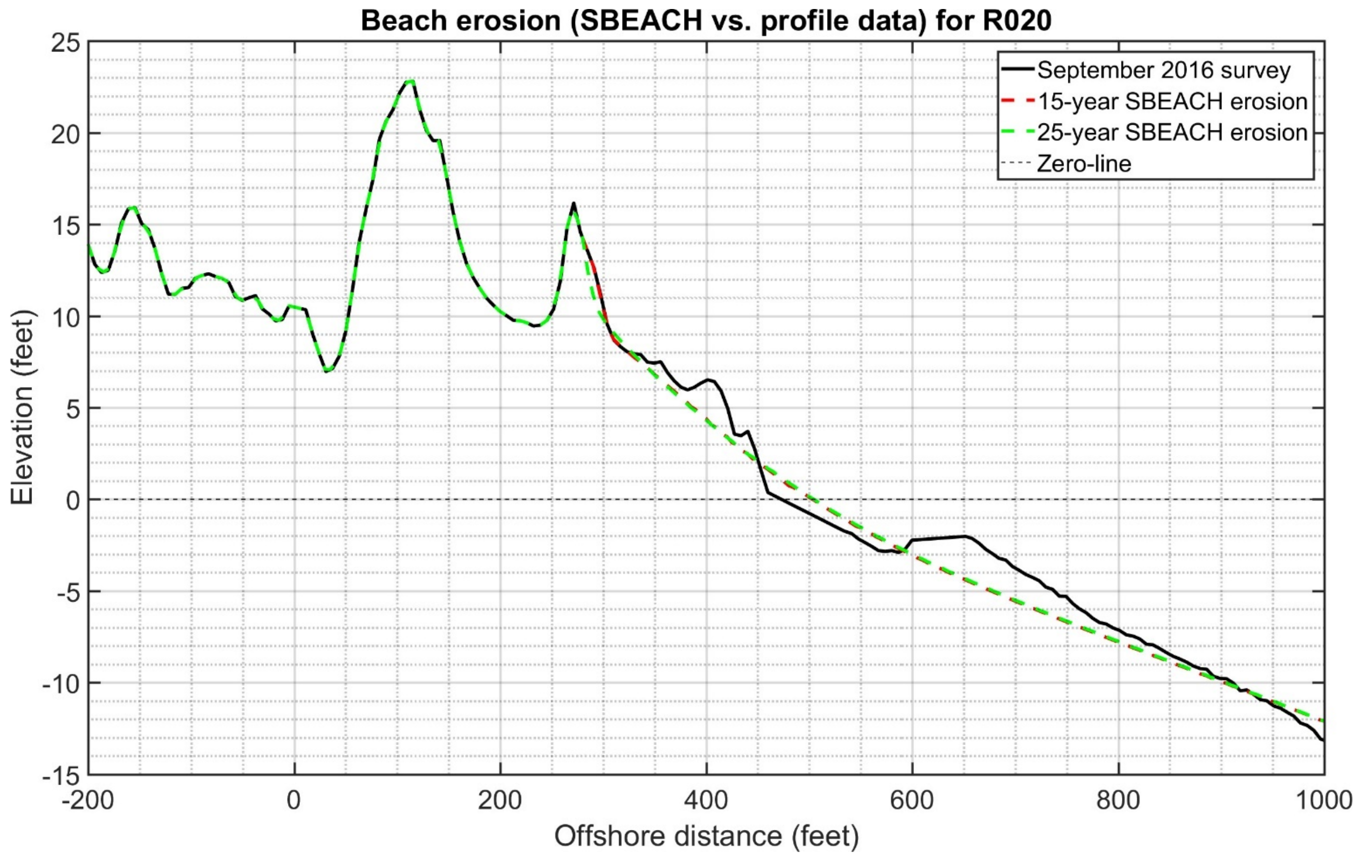
Escambia County SBEACH 15- and 25-Year Storm Erosion Profiles

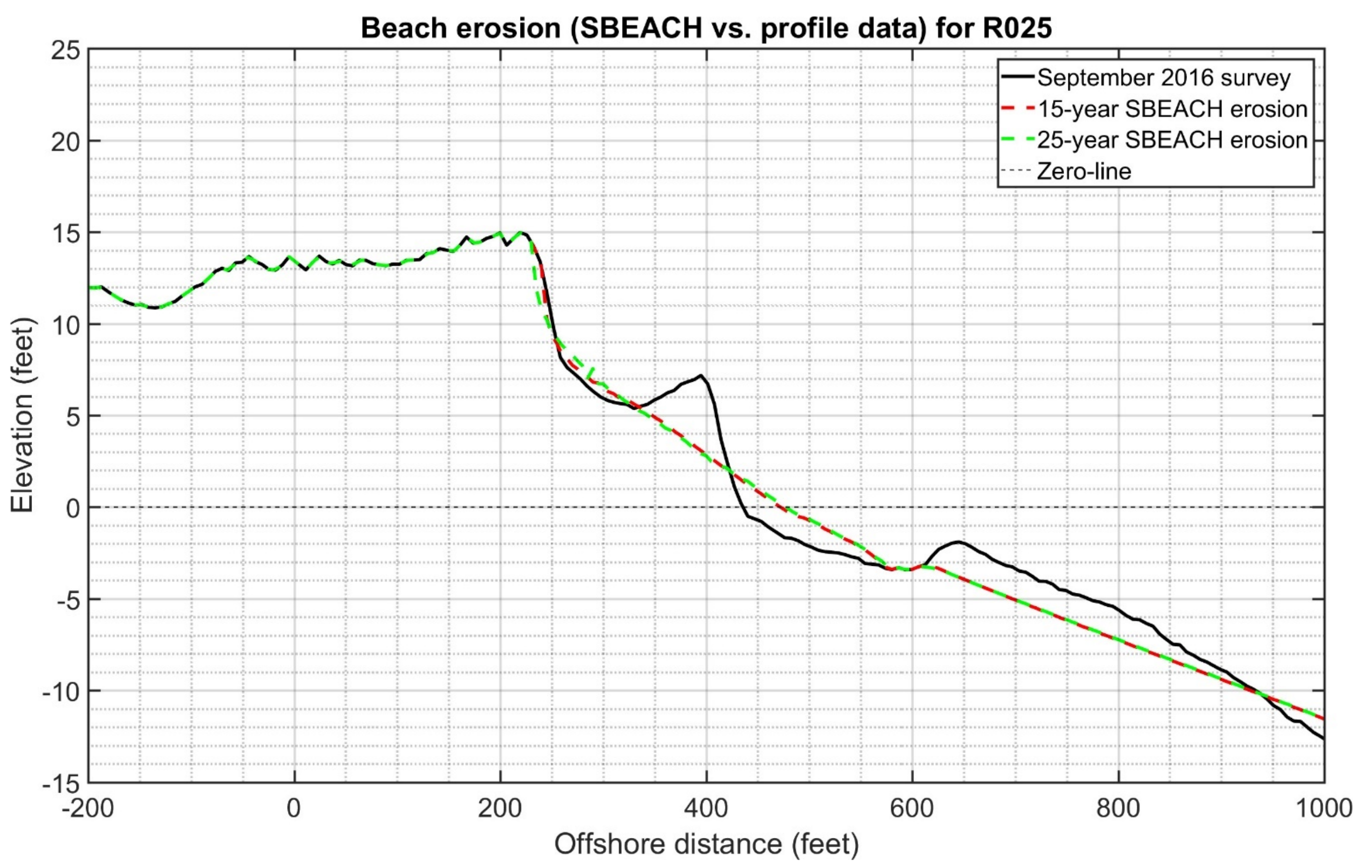

Beach erosion (SBEACH vs. profile data) for R001
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000

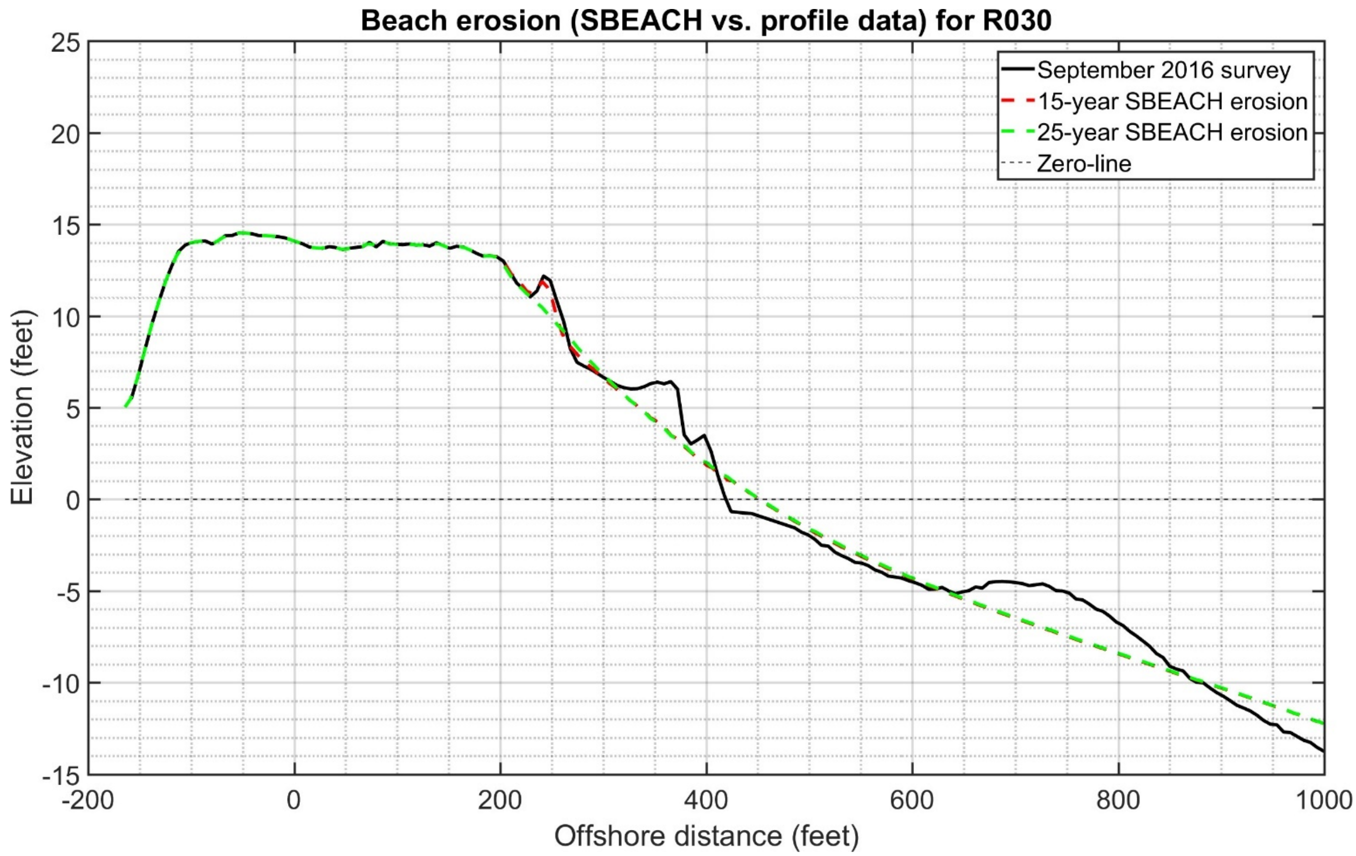

Beach erosion (SBEACH vs. profile data) for R005
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000

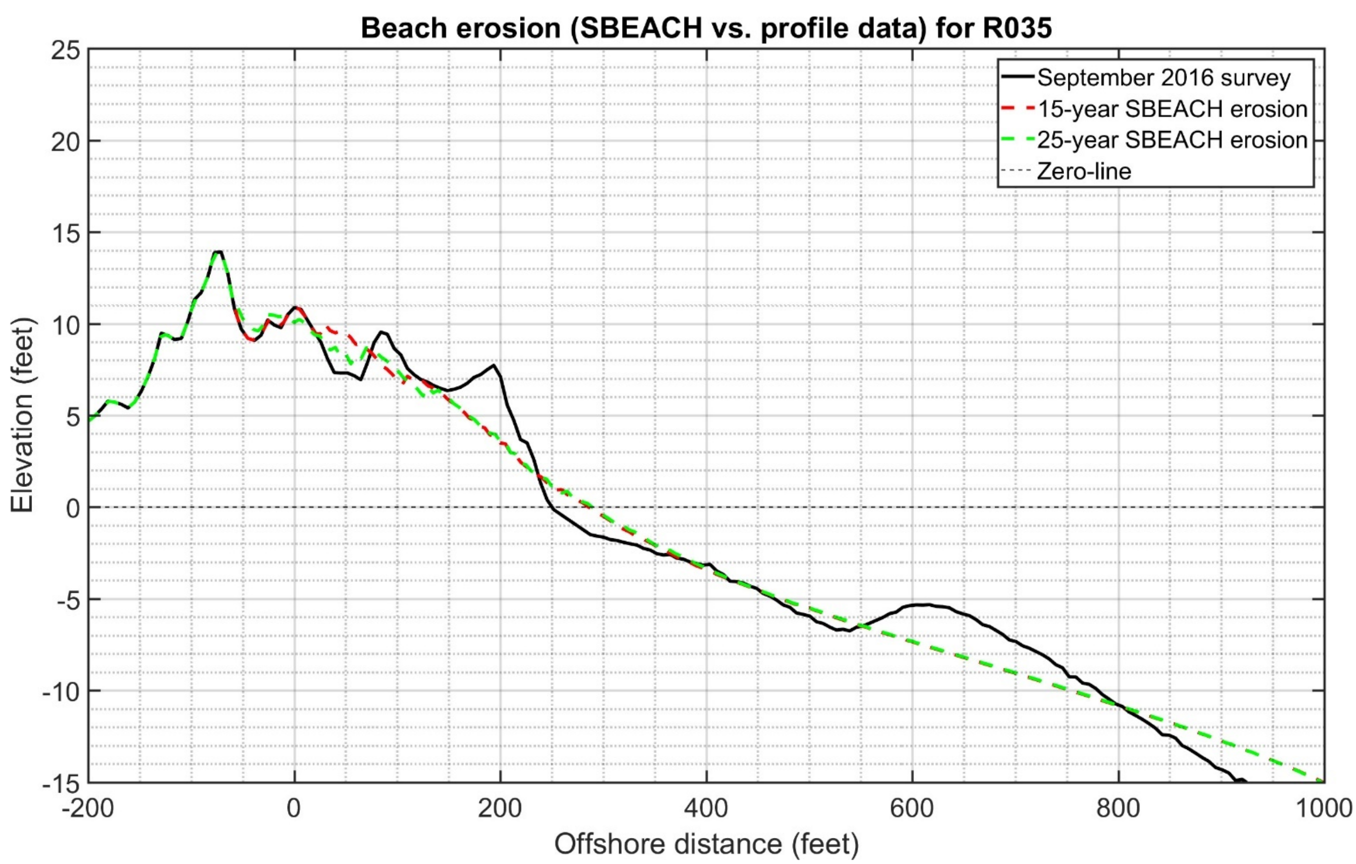

Beach erosion (SBEACH vs. profile data) for R010
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R015
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R020
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R025
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R030
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R035
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
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-15
-200
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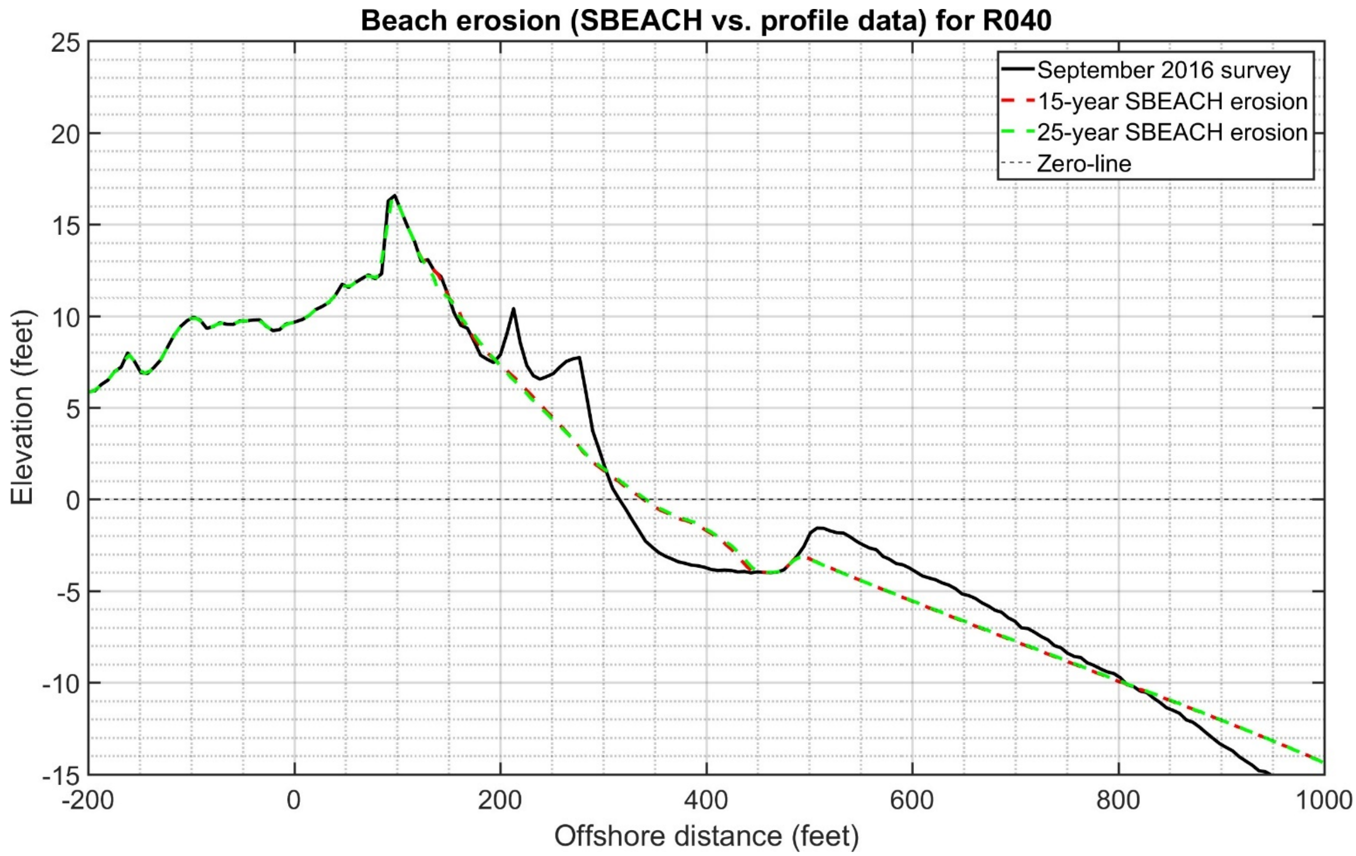
Beach erosion (SBEACH vs. profile data) for R040
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
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-5
-10
-15
-200
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800
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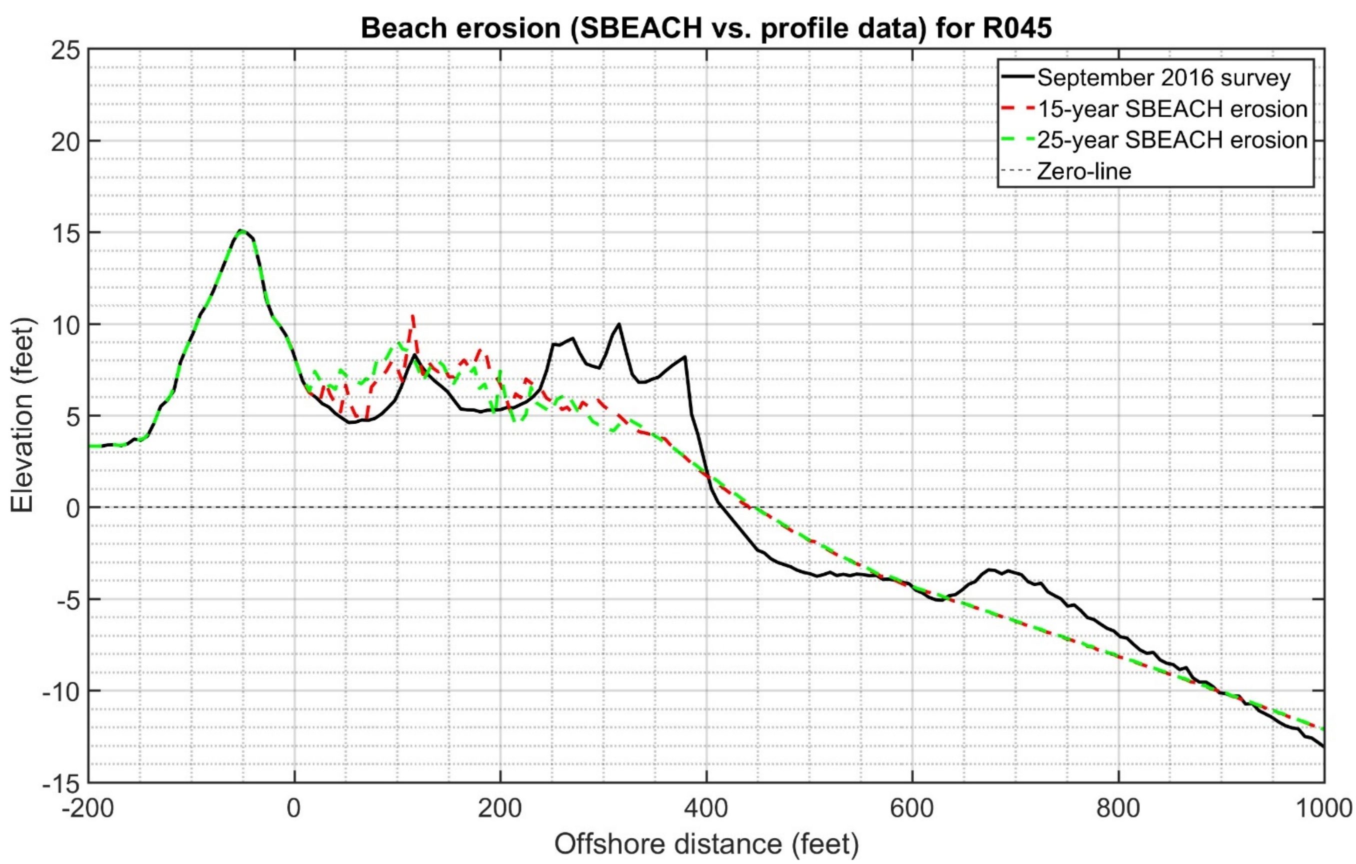
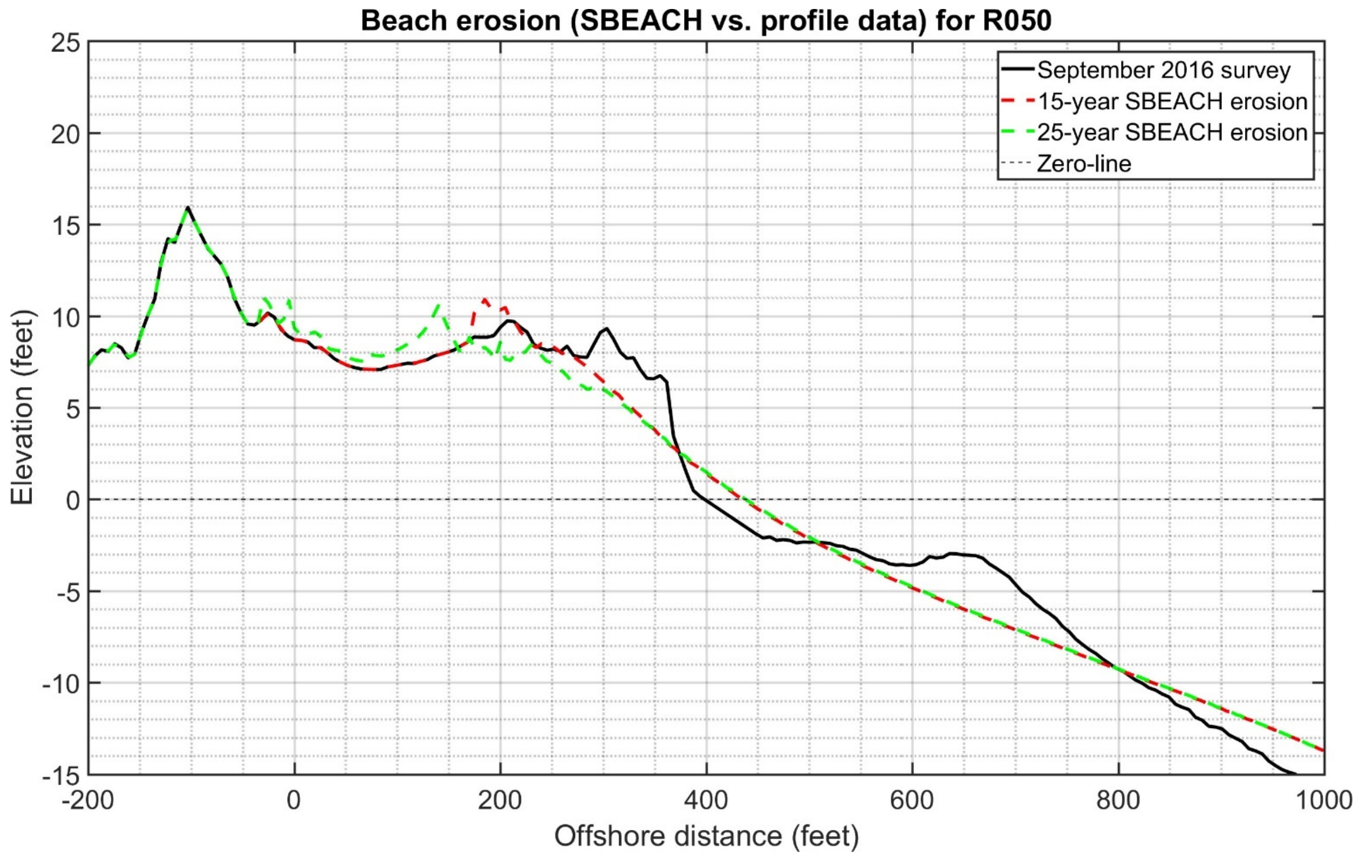
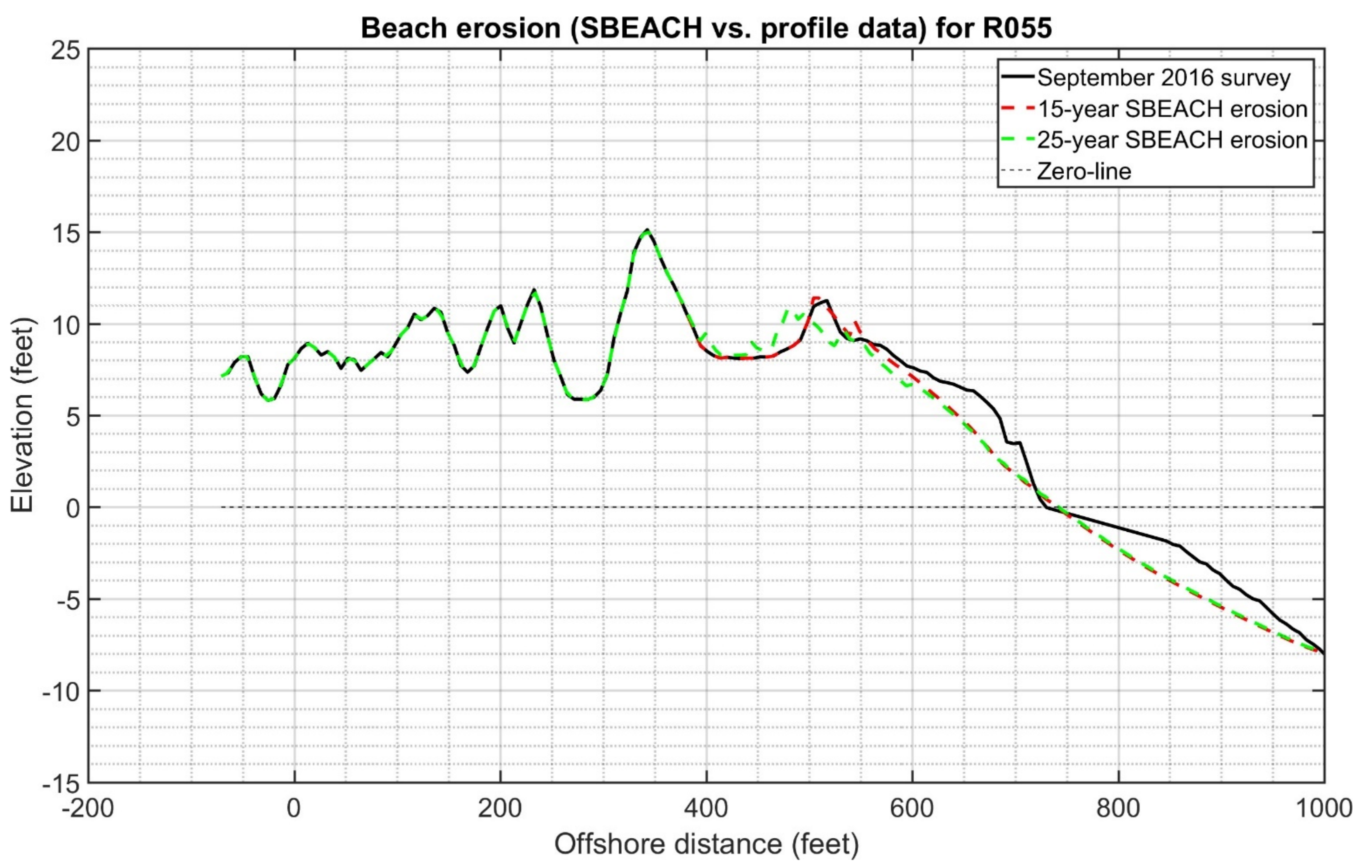
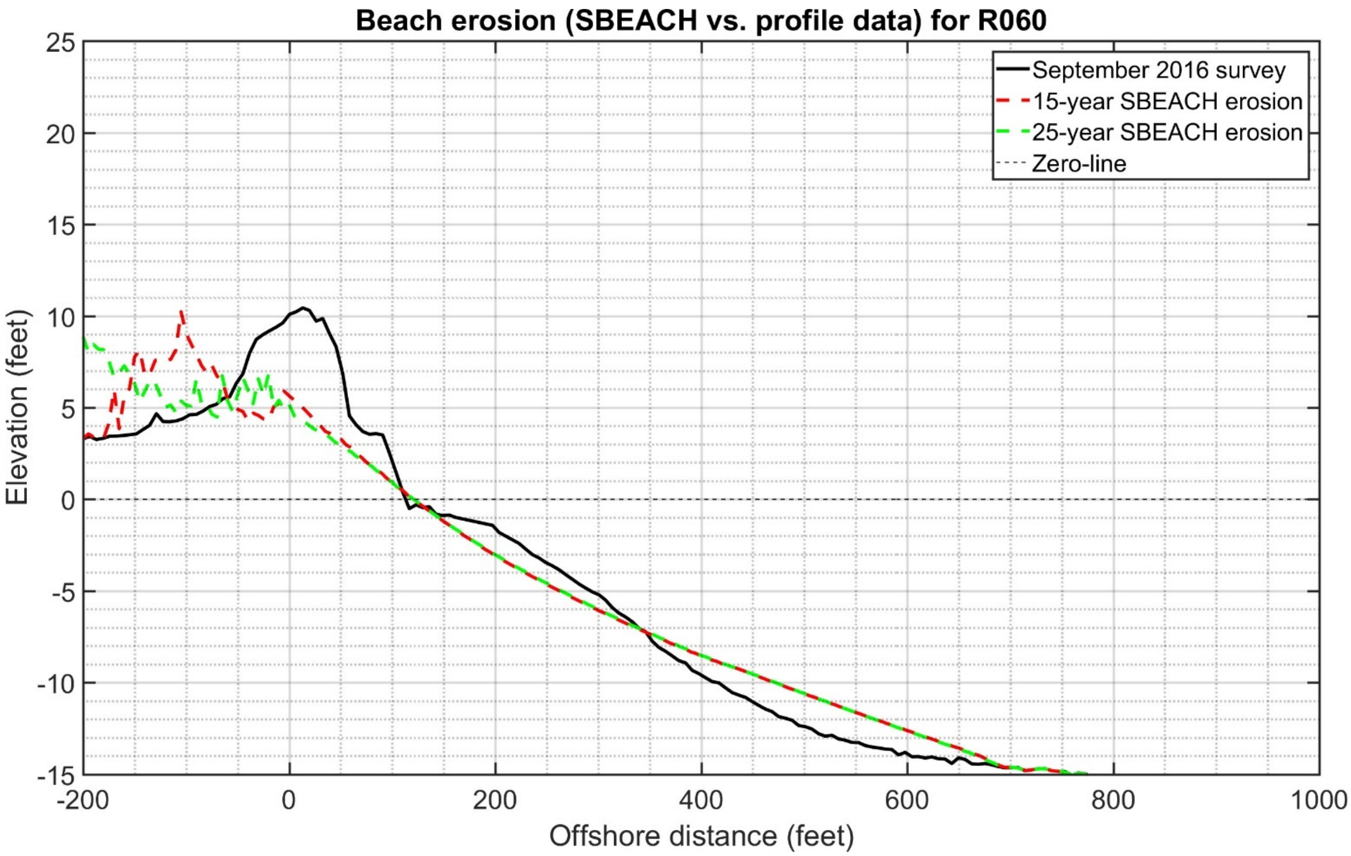

Beach erosion (SBEACH vs. profile data) for R045
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
1000


Beach erosion (SBEACH vs. profile data) for R050
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)


Beach erosion (SBEACH vs. profile data) for R055
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)


Beach erosion (SBEACH vs. profile data) for R060
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
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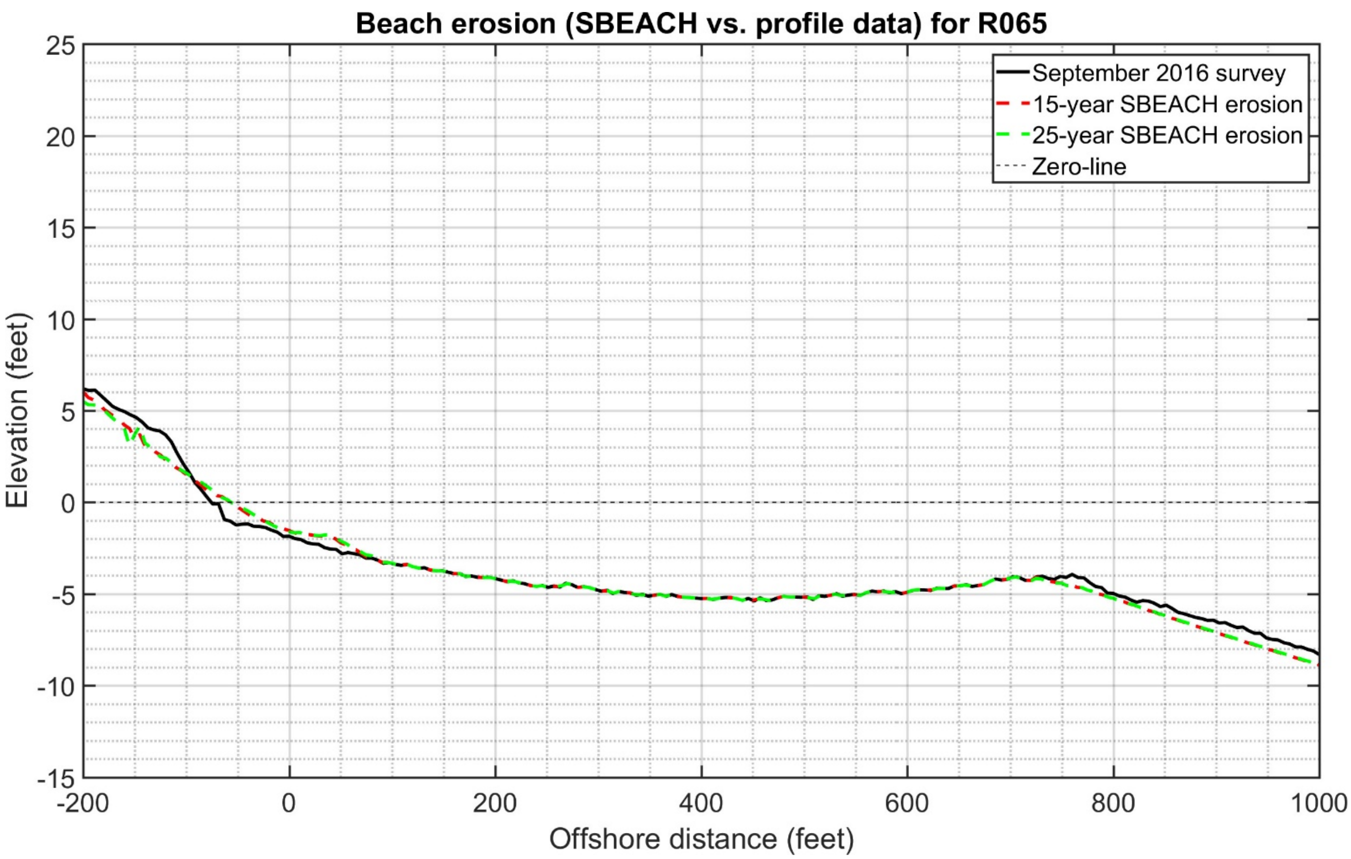
Beach erosion (SBEACH vs. profile data) for R065
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
0
-5
-10
-15
-200
0
200
400
600
800
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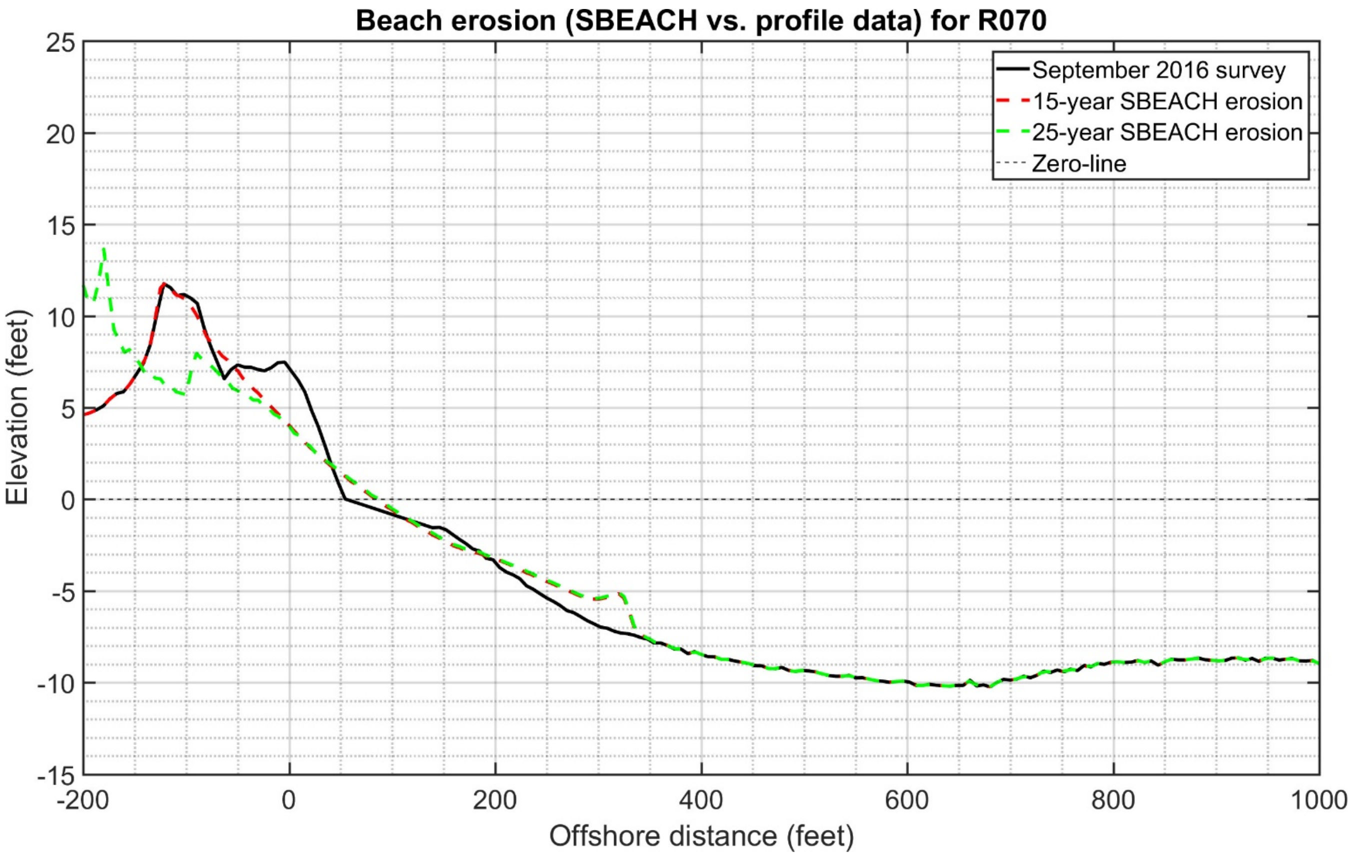
Beach erosion (SBEACH vs. profile data) for R070
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
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5
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-5
-10
-15
-200
0
200
400
600
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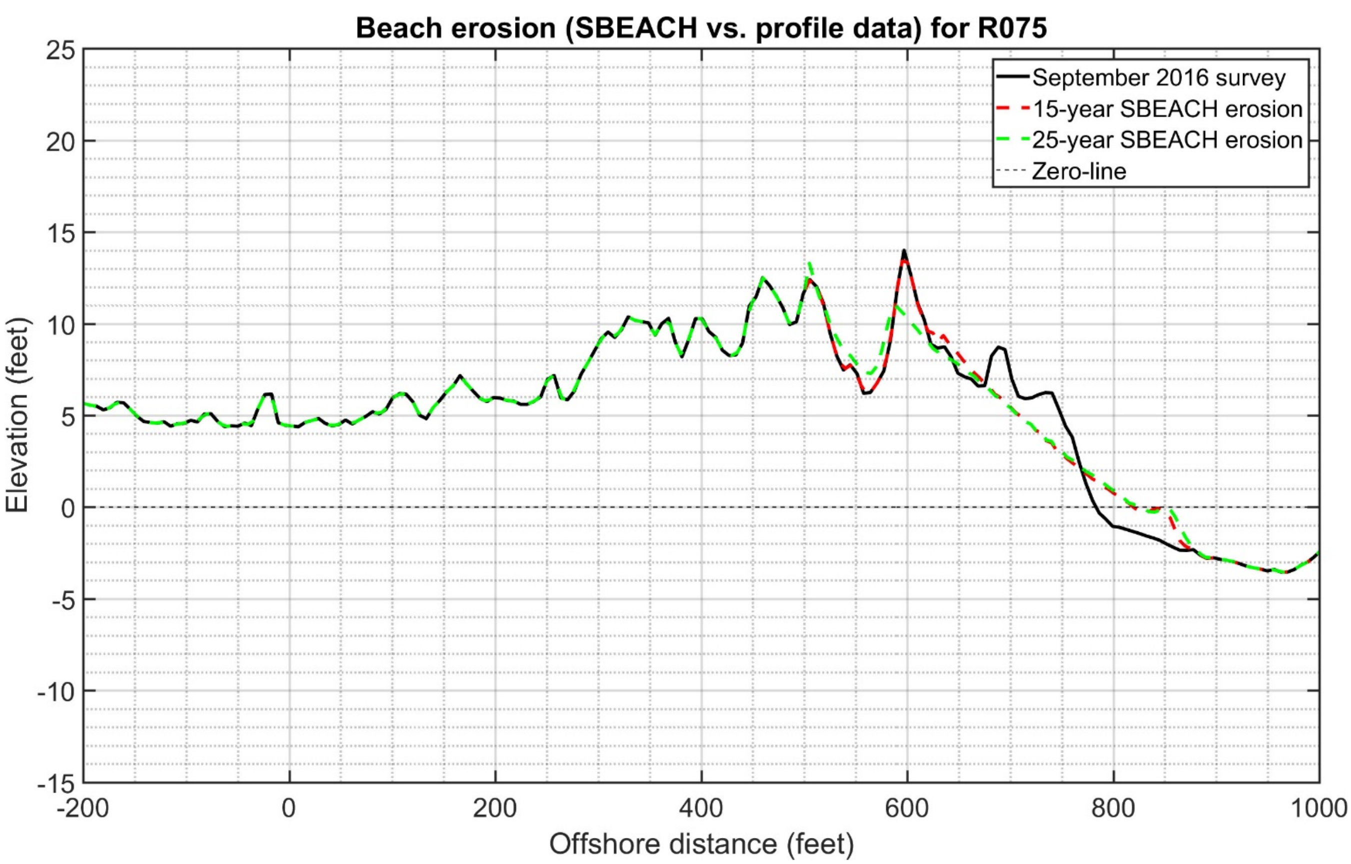
Beach erosion (SBEACH vs. profile data) for R075
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
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-5
-10
-15
-200
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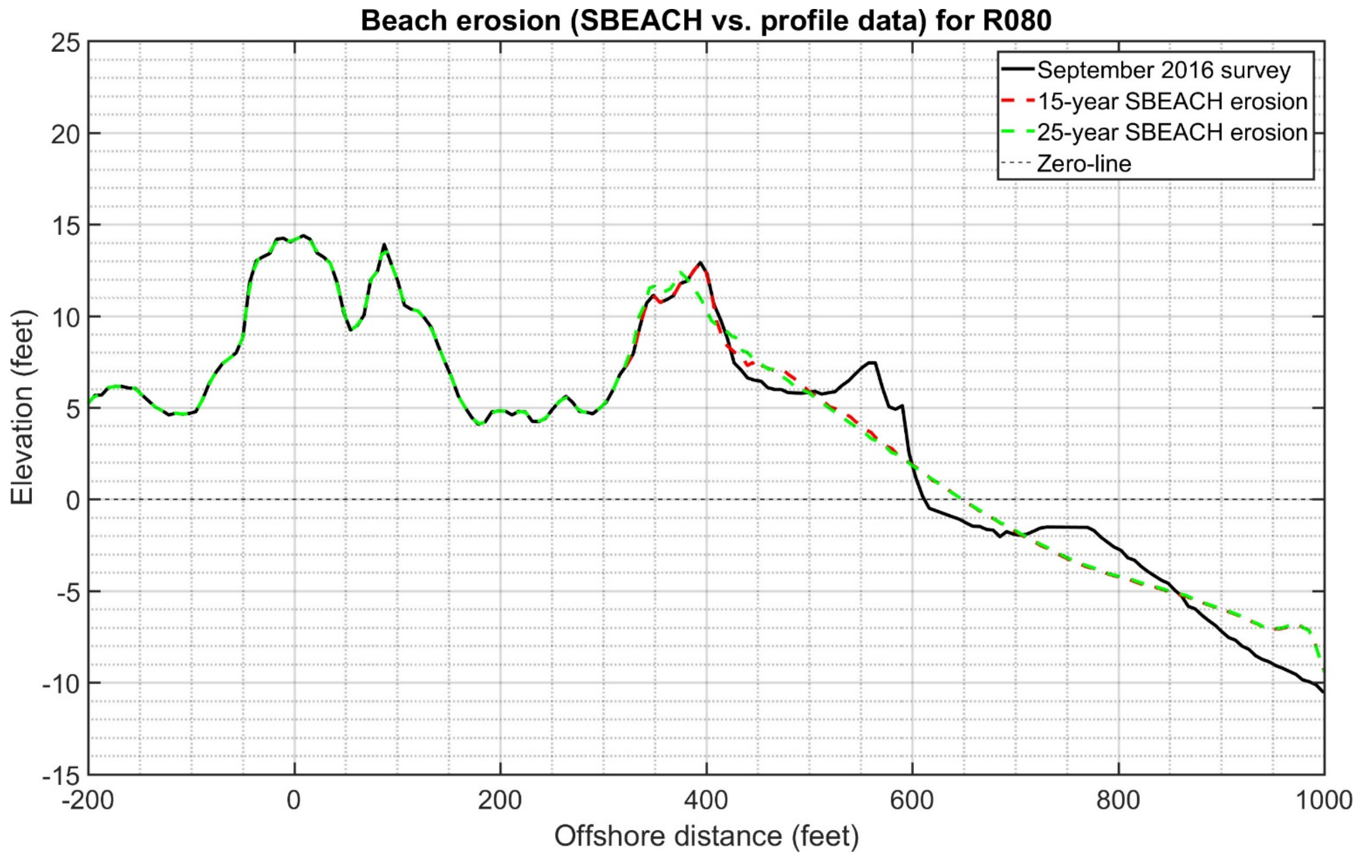
Beach erosion (SBEACH vs. profile data) for R080
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
-10
-15
-200
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200
400
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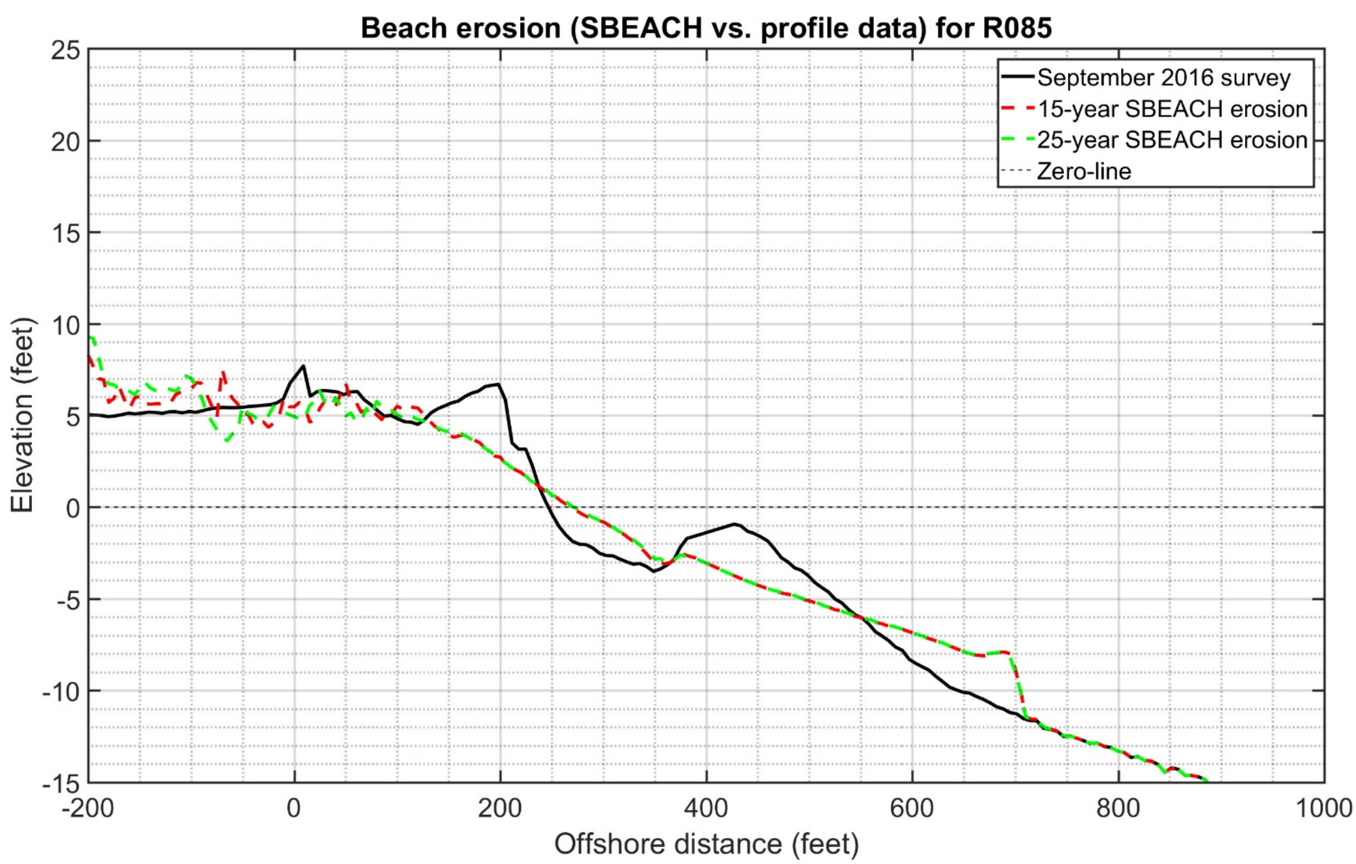
Beach erosion (SBEACH vs. profile data) for R085
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
5
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-5
-10
-15
-200
0
200
400
600
800
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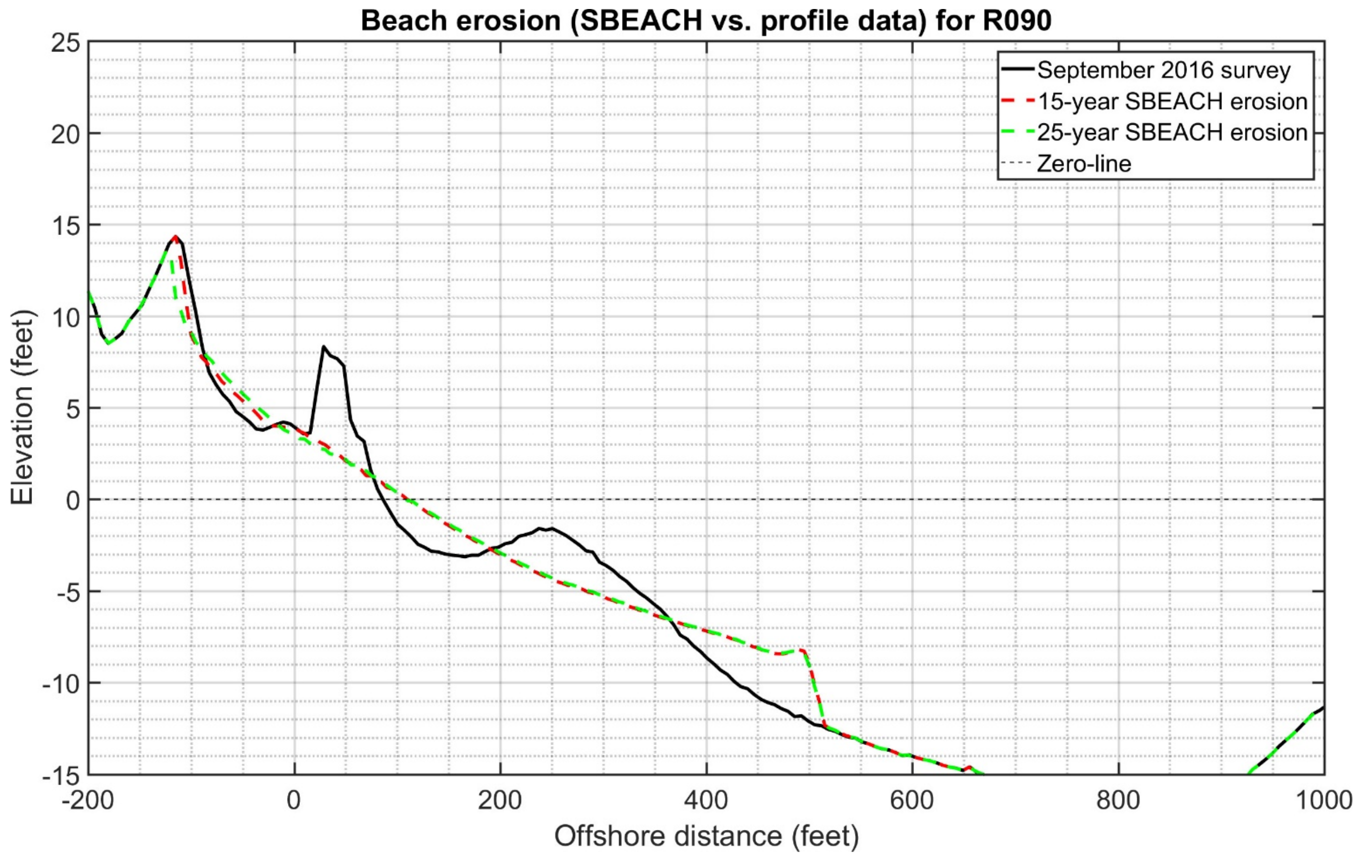
Beach erosion (SBEACH vs. profile data) for R090
Elevation (feet)
Offshore distance (feet)
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
25
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-10
-15
-200
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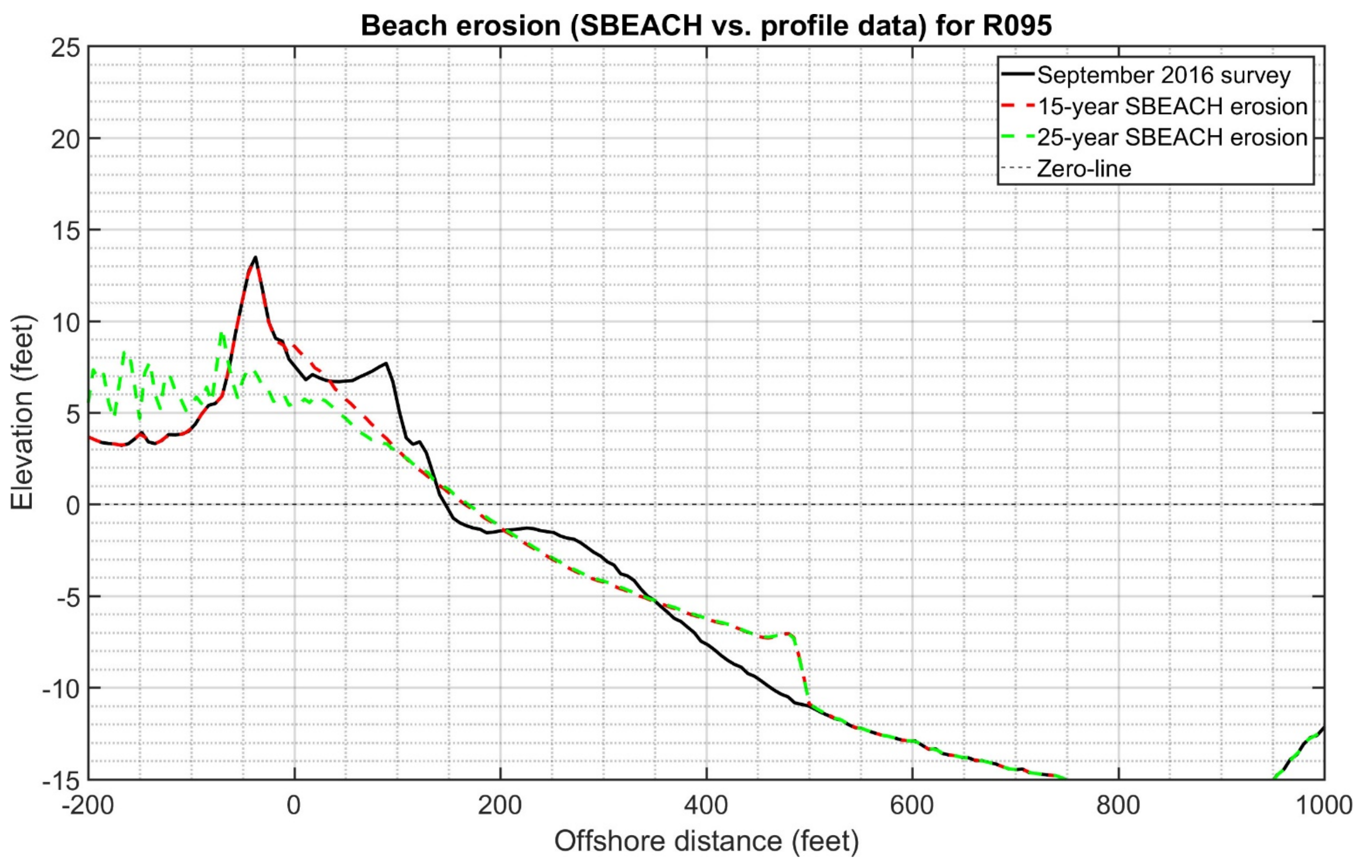
Beach erosion (SBEACH vs. profile data) for R095
Elevation (feet)
Offshore distance (feet)
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
25
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-10
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-200
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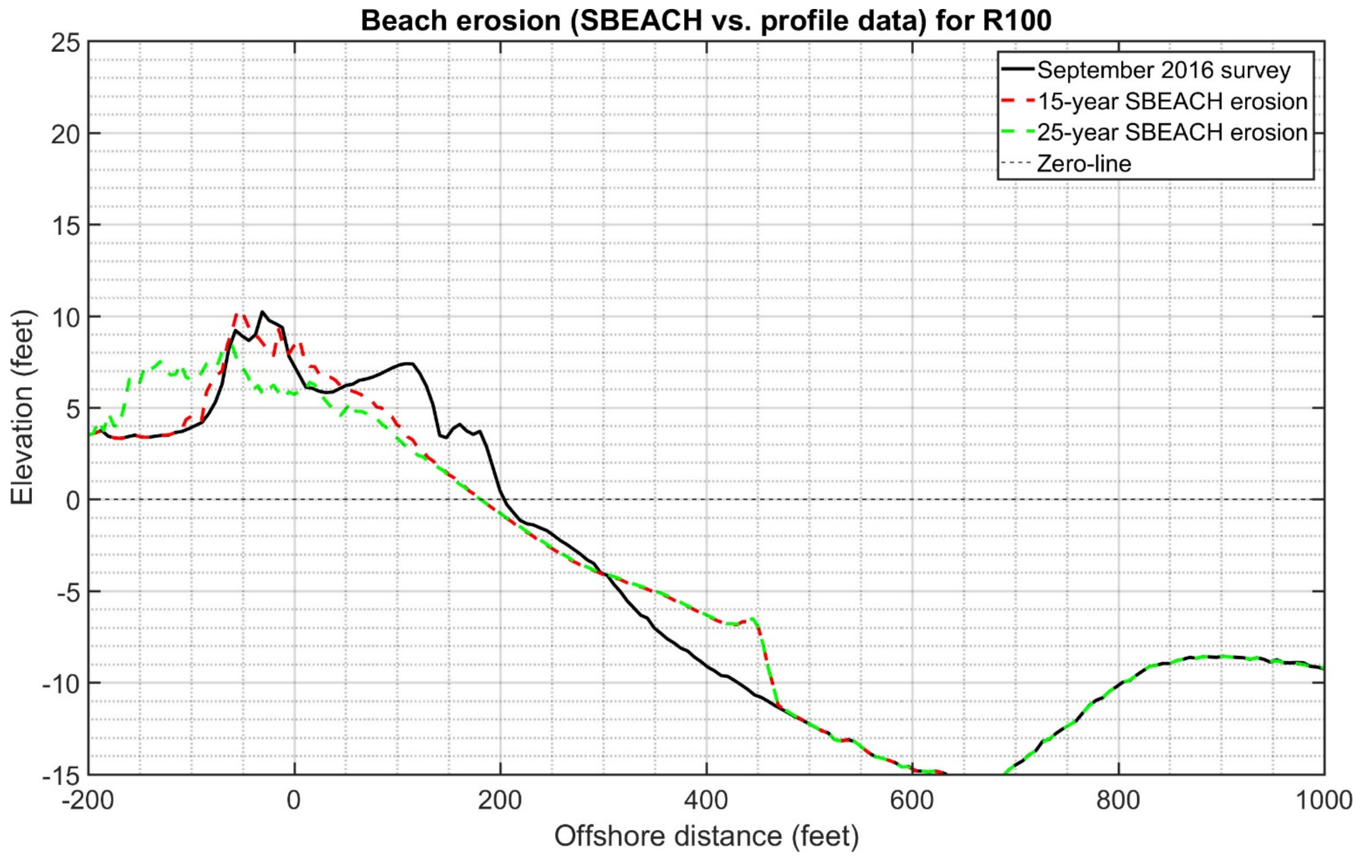
Beach erosion (SBEACH vs. profile data) for R100
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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-5
-10
-15
-200
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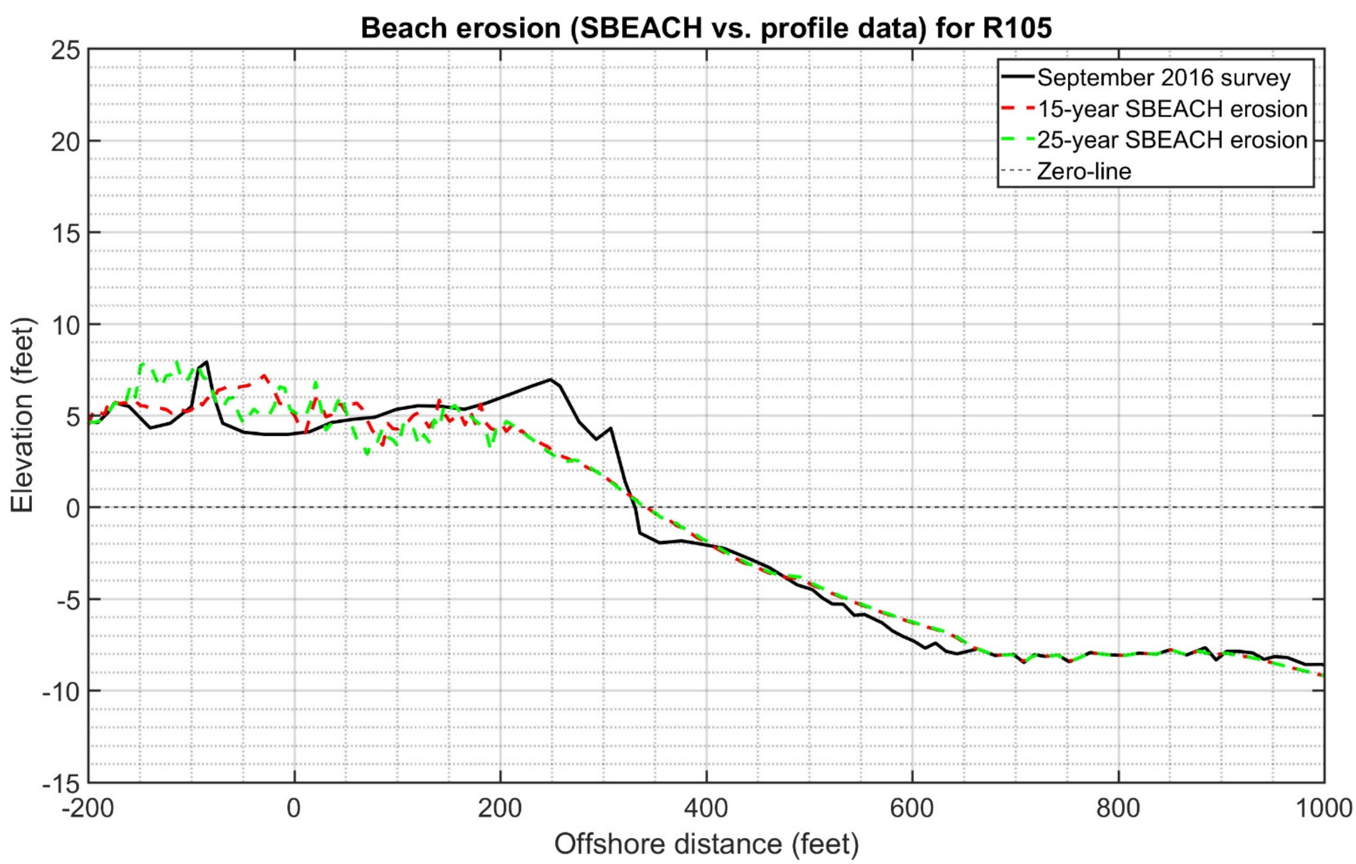
Beach erosion (SBEACH vs. profile data) for R105
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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-200
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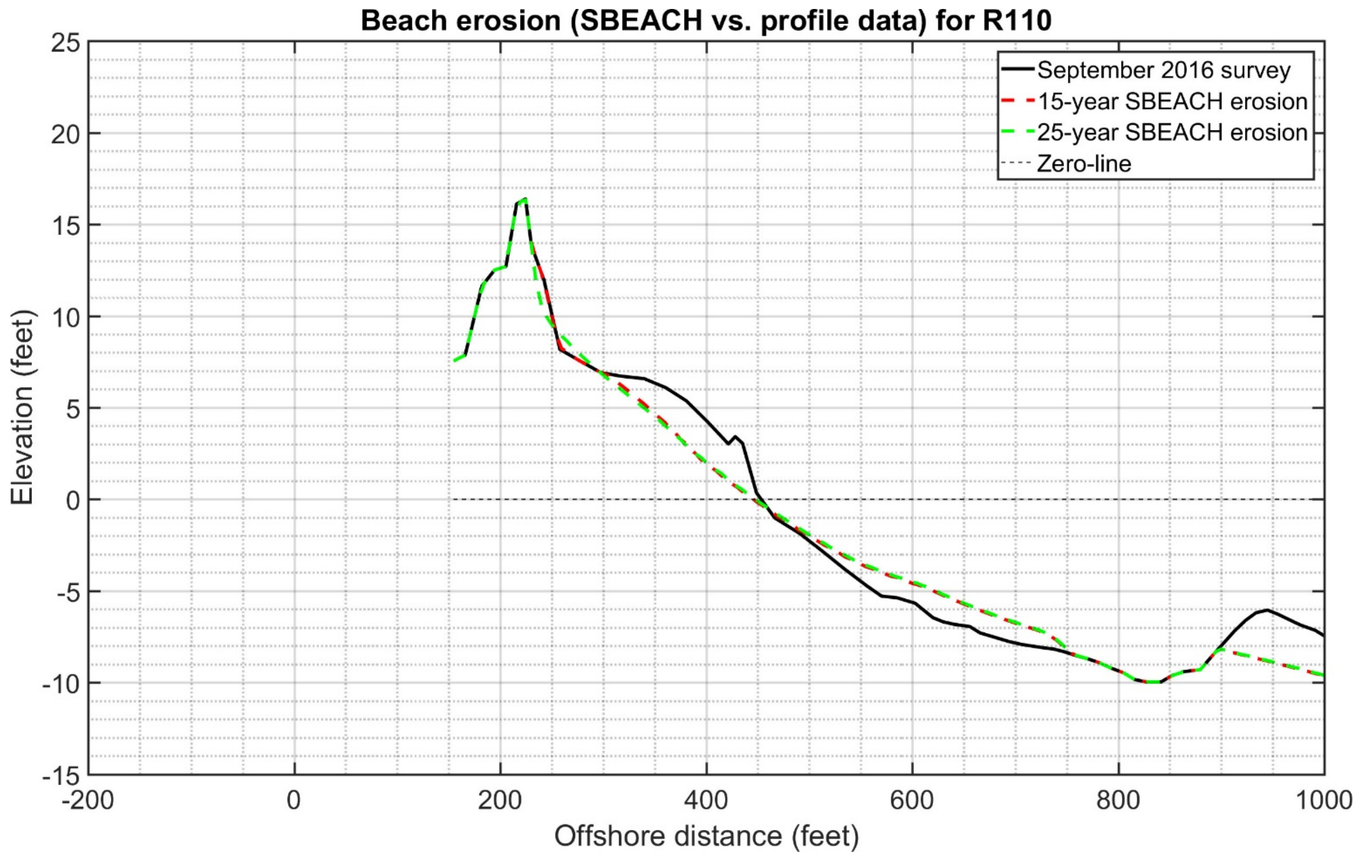
Beach erosion (SBEACH vs. profile data) for R110
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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-200
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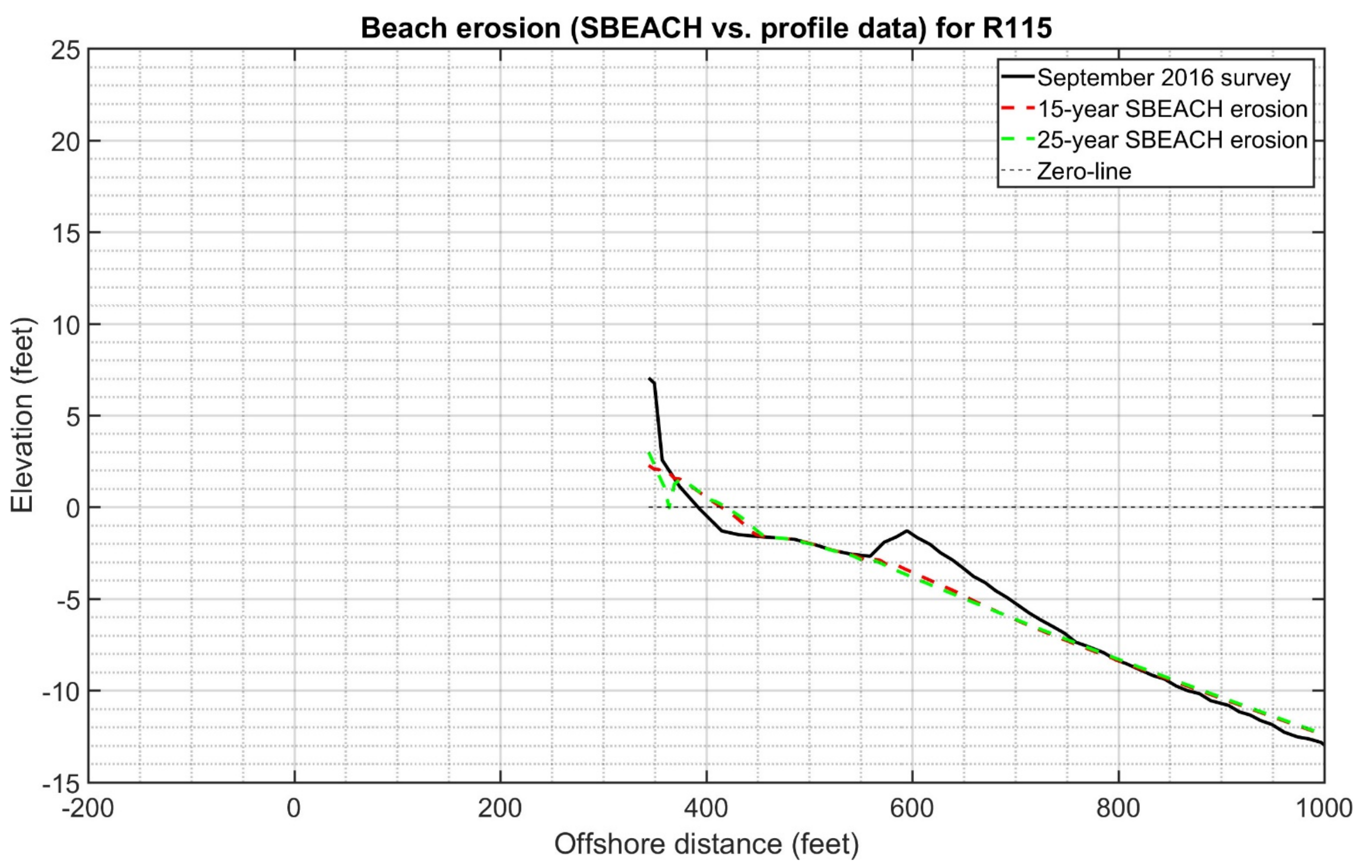
Beach erosion (SBEACH vs. profile data) for R115
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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-15
-200
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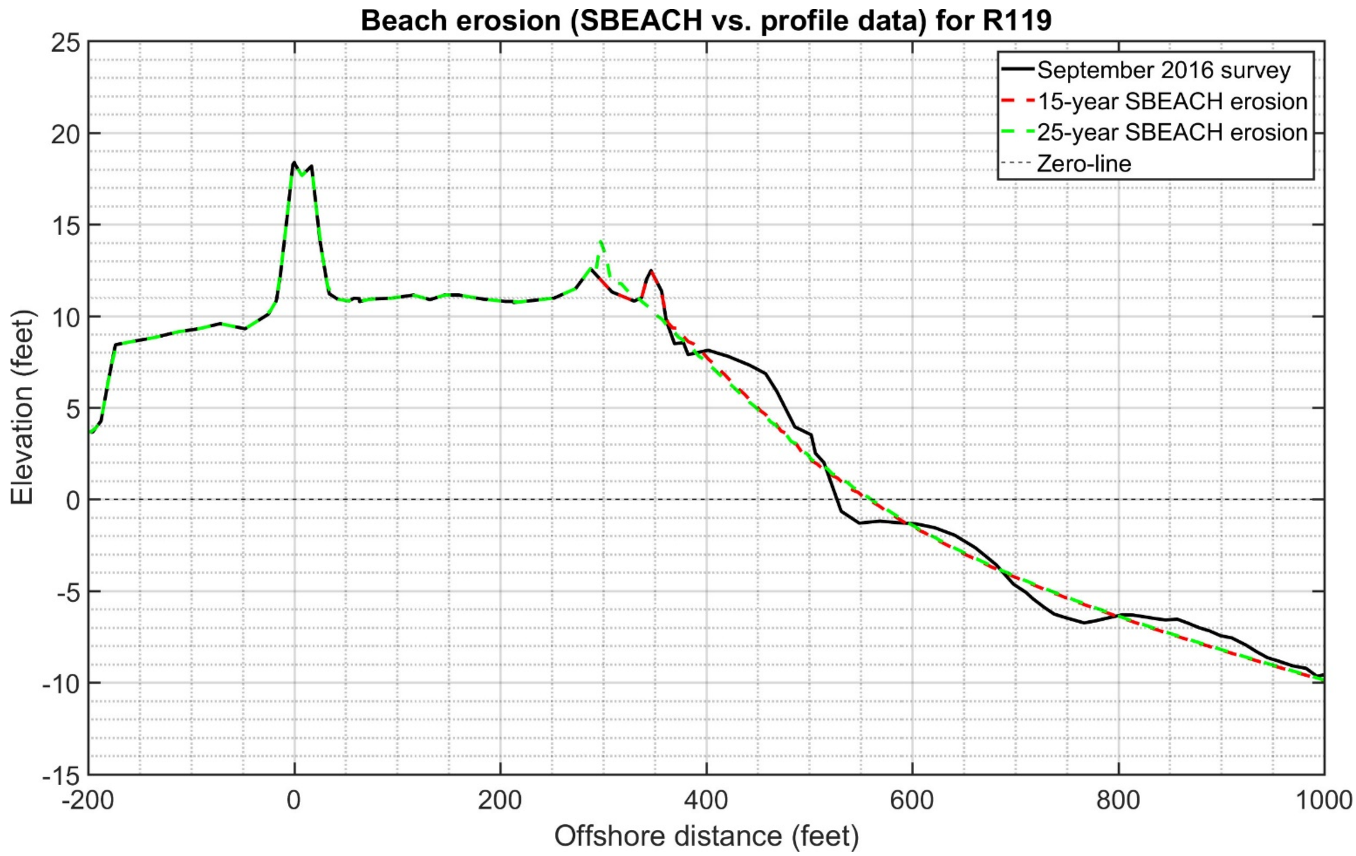
Beach erosion (SBEACH vs. profile data) for R119
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
-10
-15
-200
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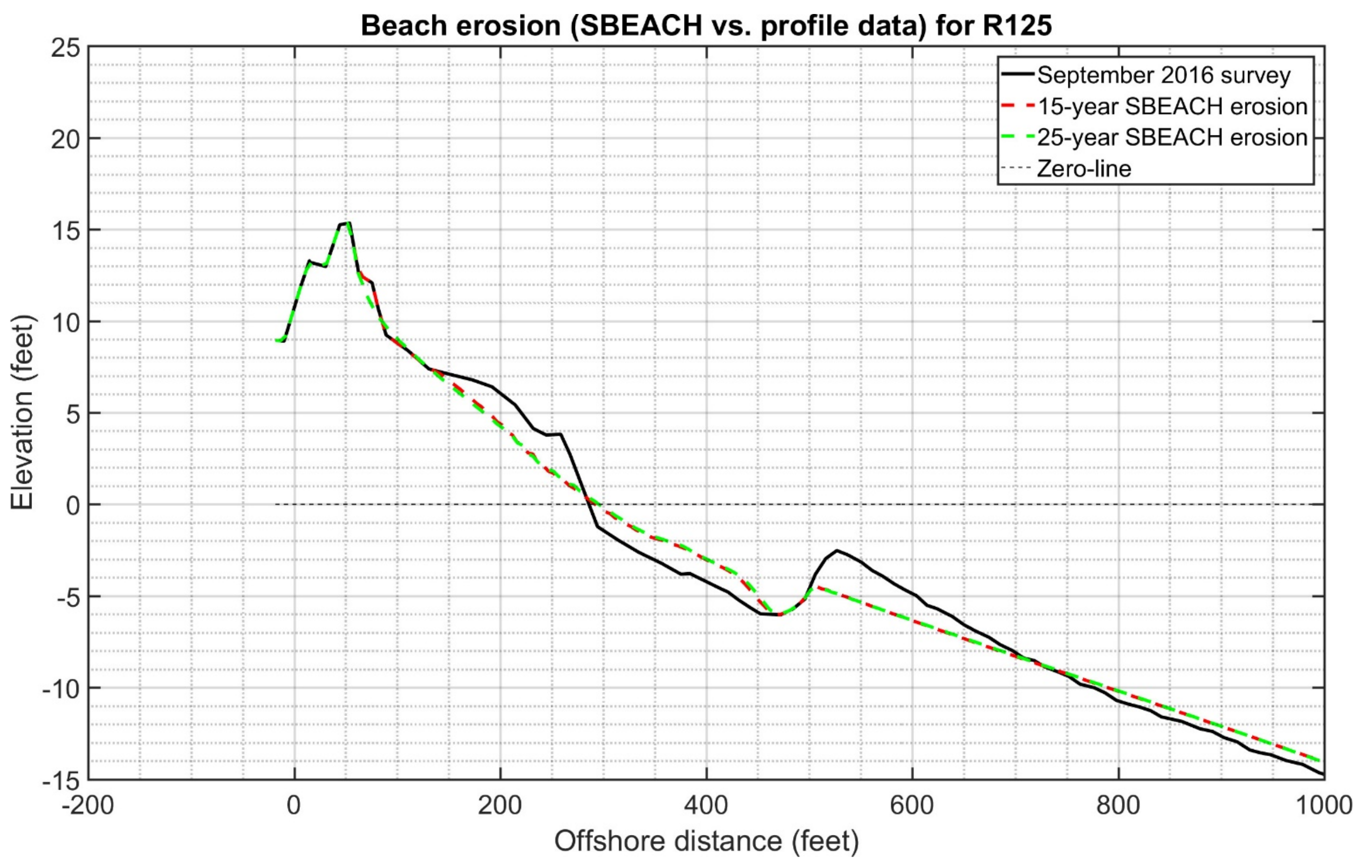
Beach erosion (SBEACH vs. profile data) for R125
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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5
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-5
-10
-15
-200
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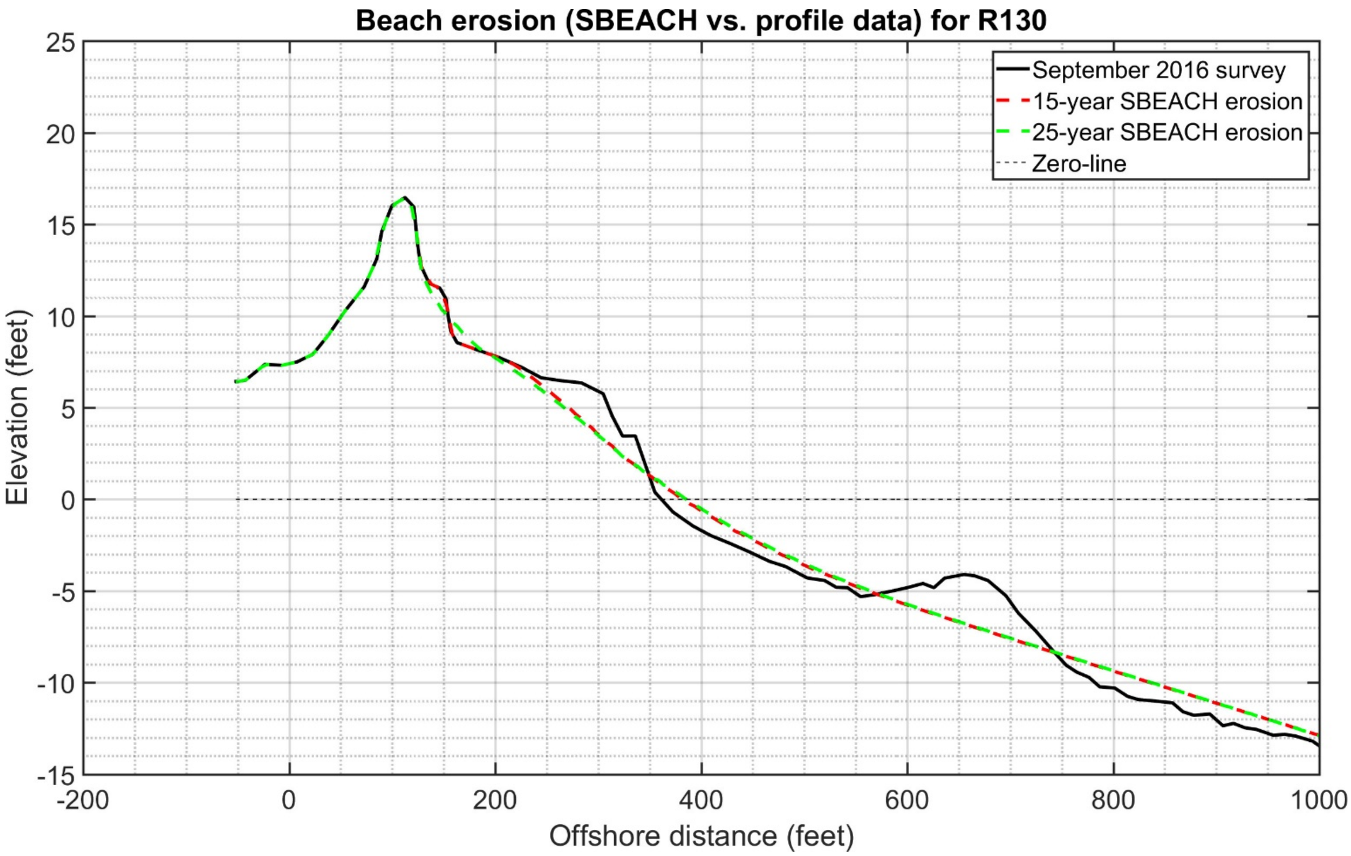
Beach erosion (SBEACH vs. profile data) for R130
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
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-15
-200
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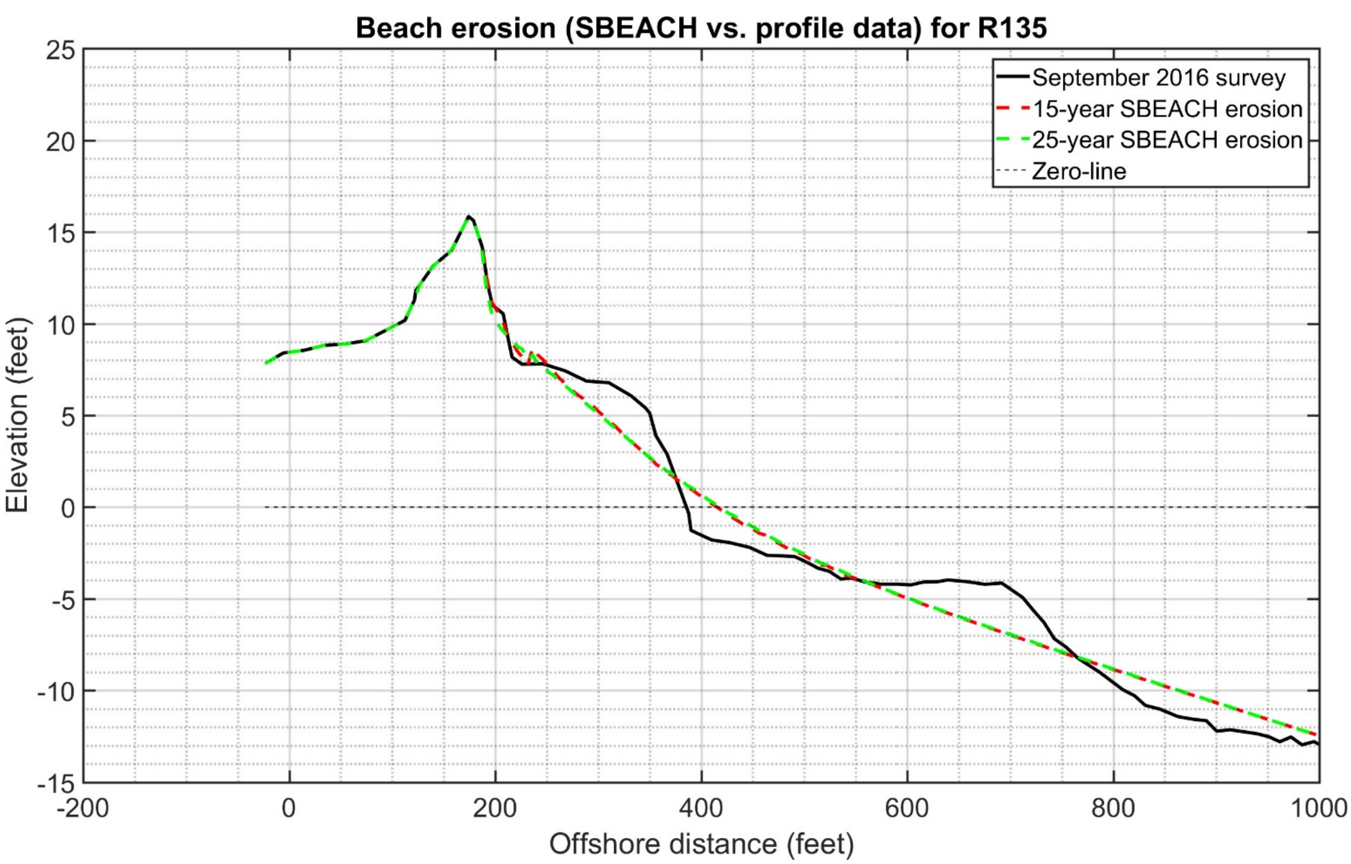
Beach erosion (SBEACH vs. profile data) for R135
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
-10
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-200
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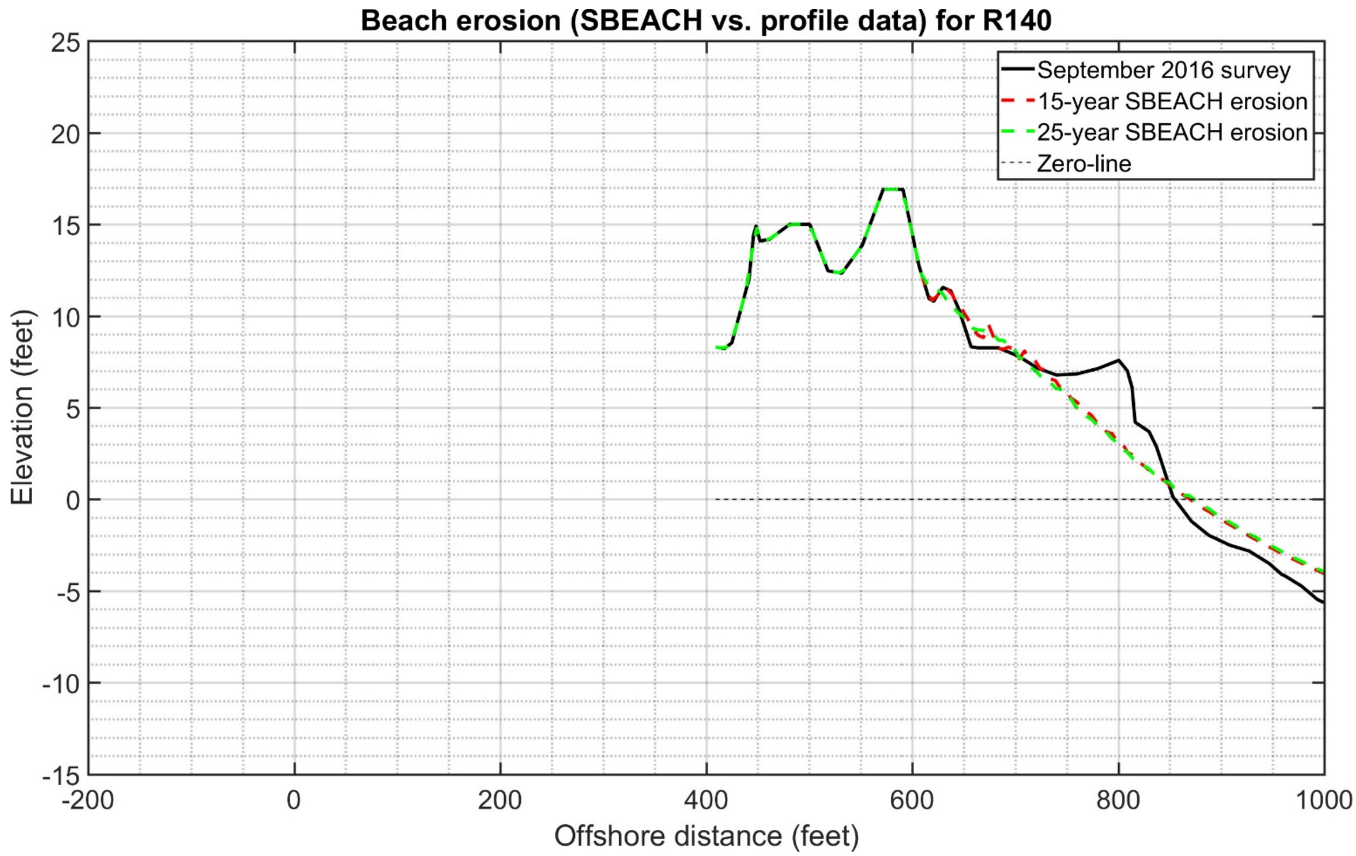
Beach erosion (SBEACH vs. profile data) for R140
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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20
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-5
-10
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-200
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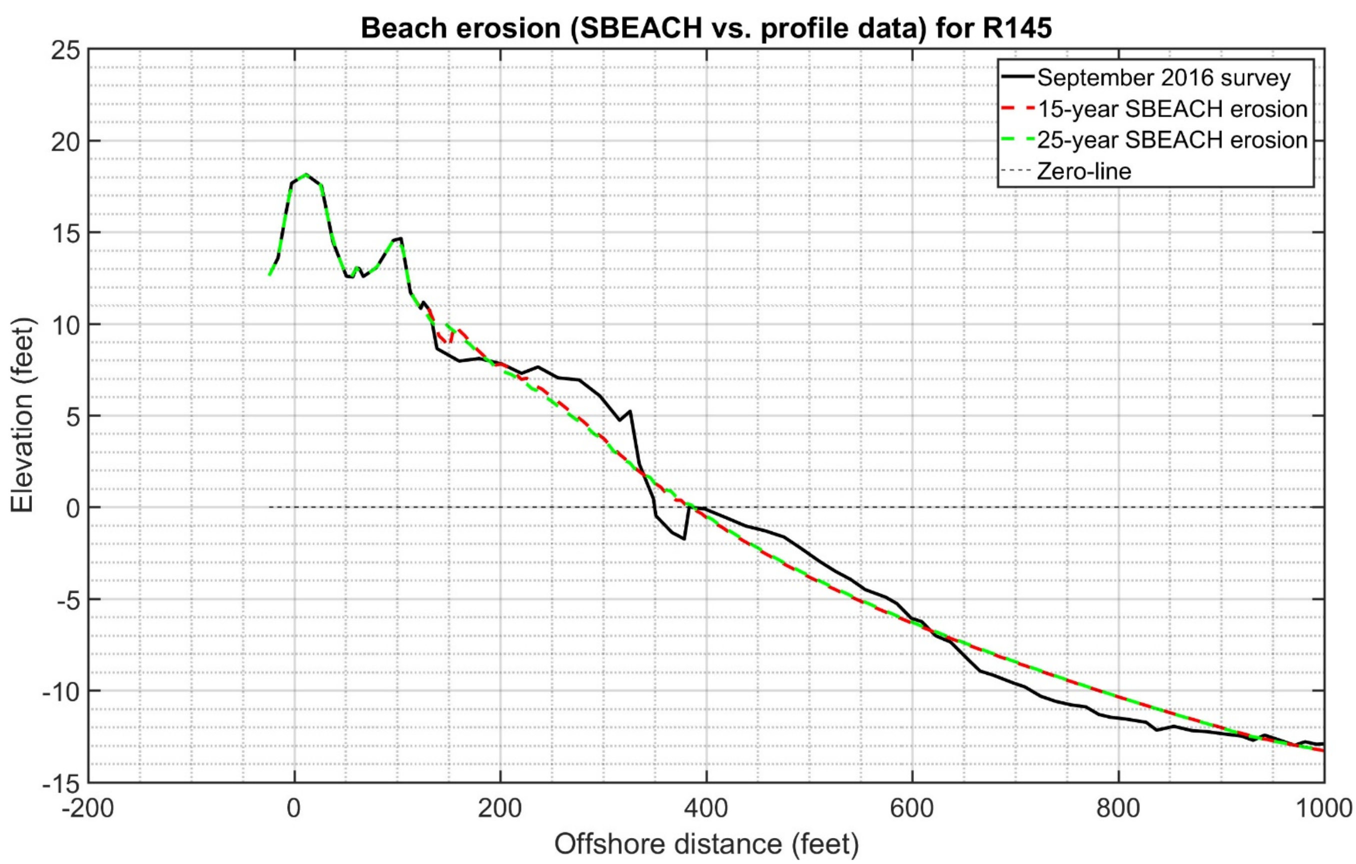
Beach erosion (SBEACH vs. profile data) for R145
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-200
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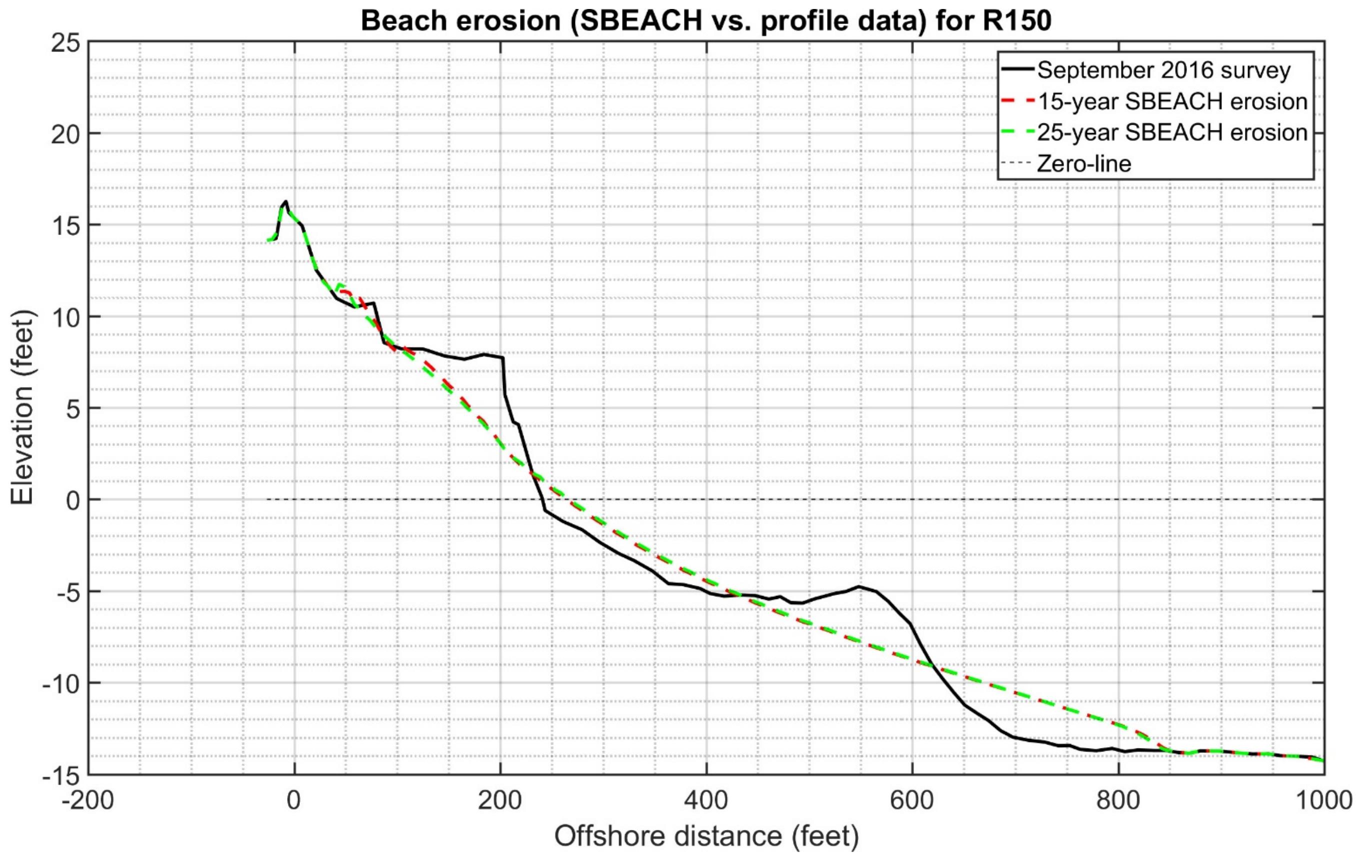
Beach erosion (SBEACH vs. profile data) for R150
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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15
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5
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-5
-10
-15
-200
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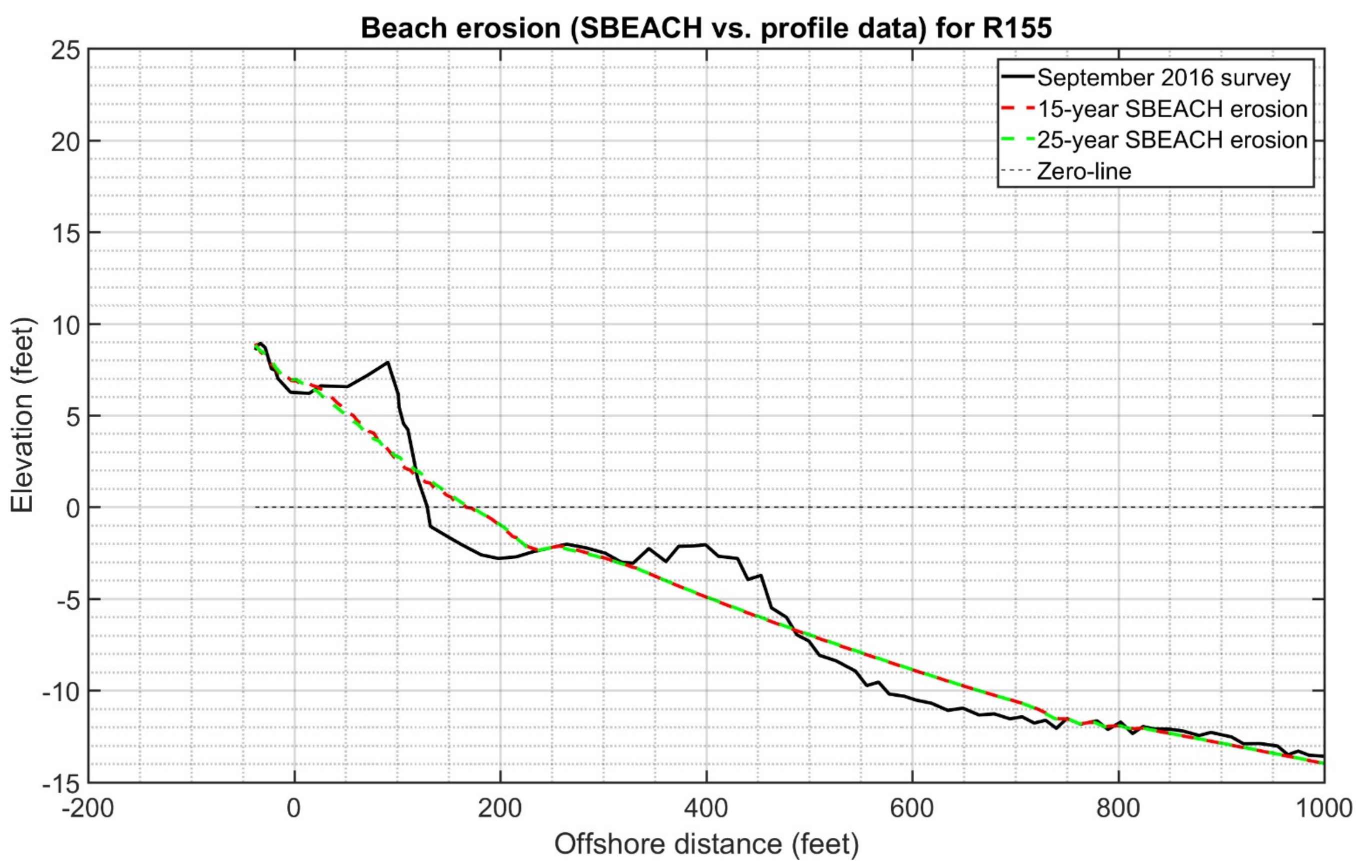
Beach erosion (SBEACH vs. profile data) for R155
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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-5
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-200
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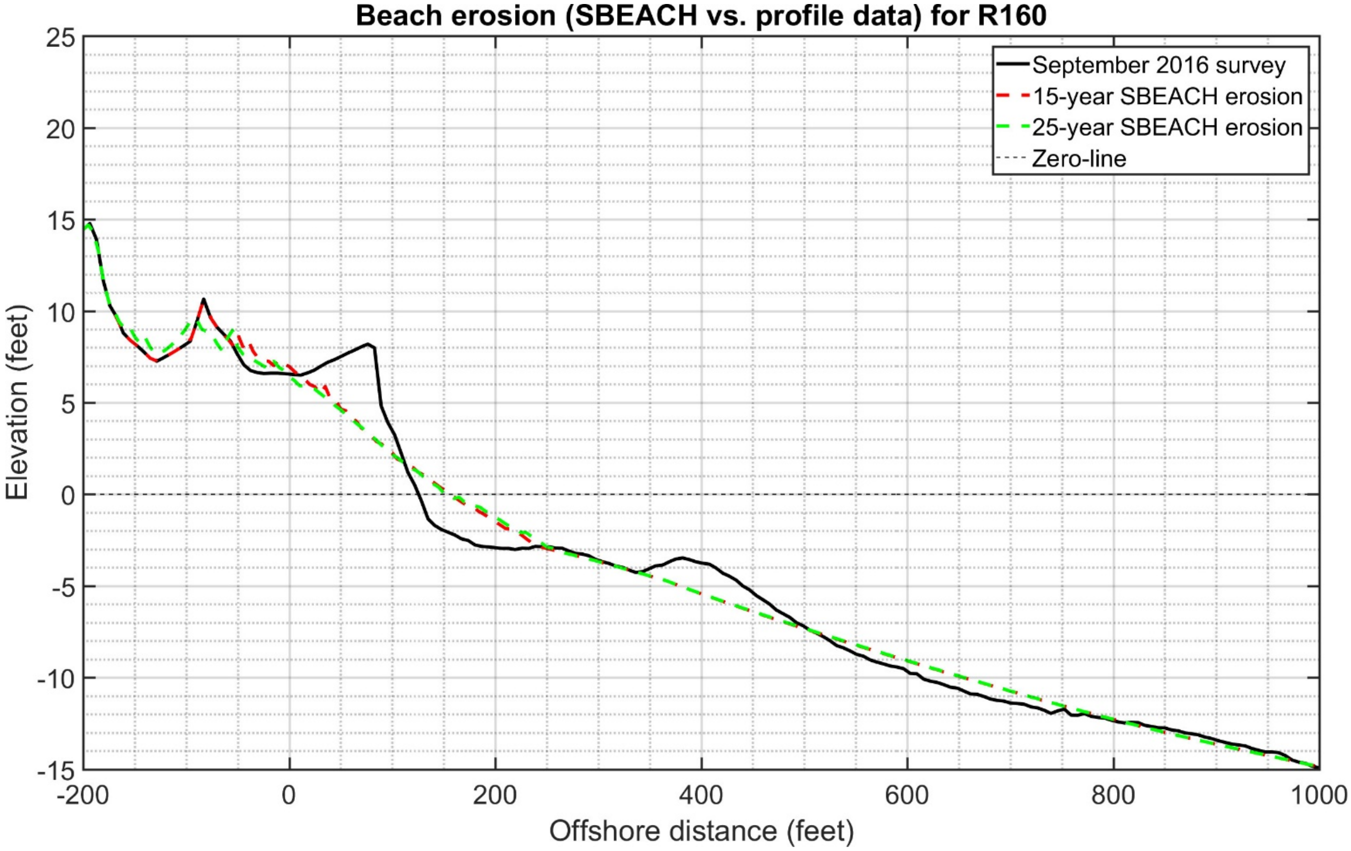
Beach erosion (SBEACH vs. profile data) for R160
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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5
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-5
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-200
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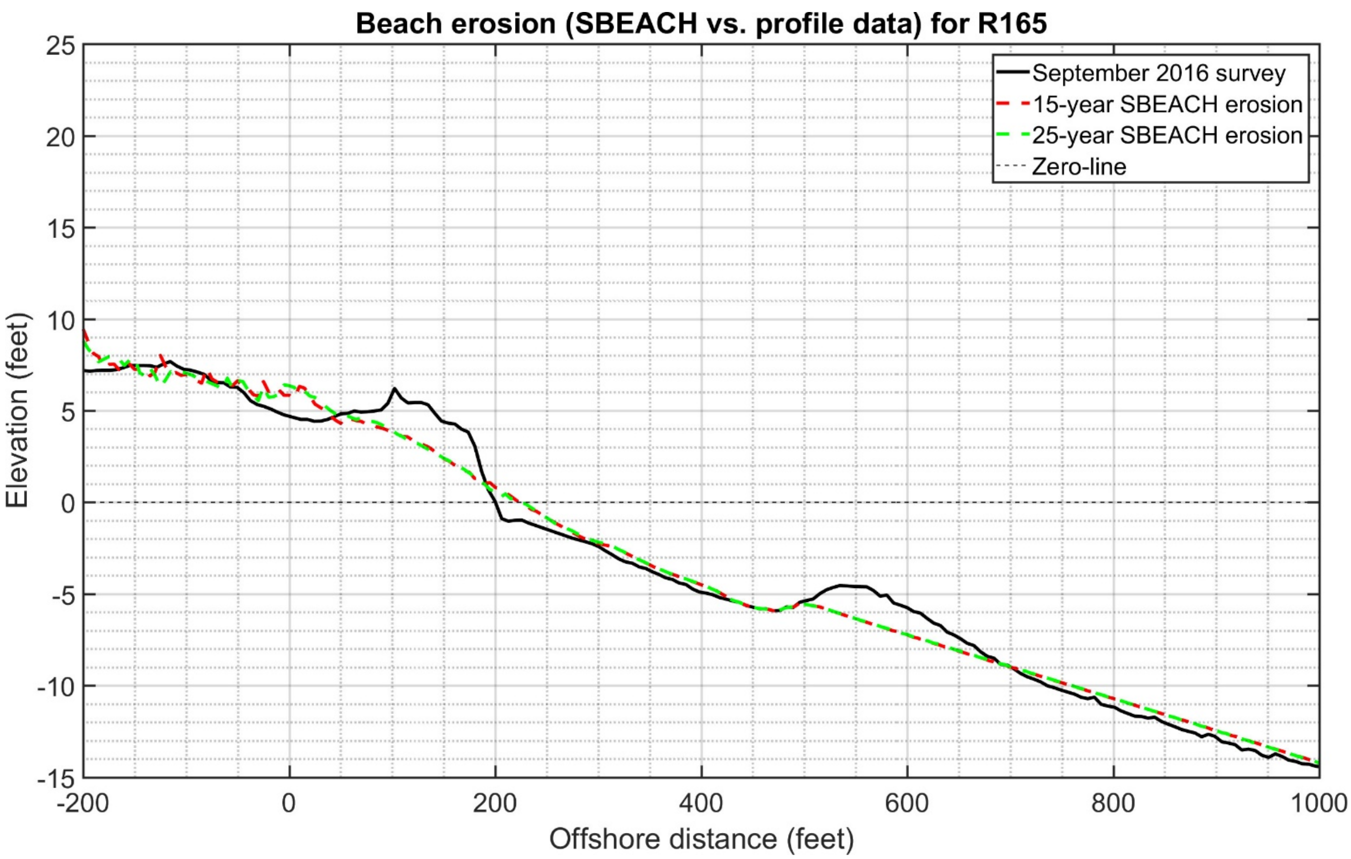
Beach erosion (SBEACH vs. profile data) for R165
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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-5
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-200
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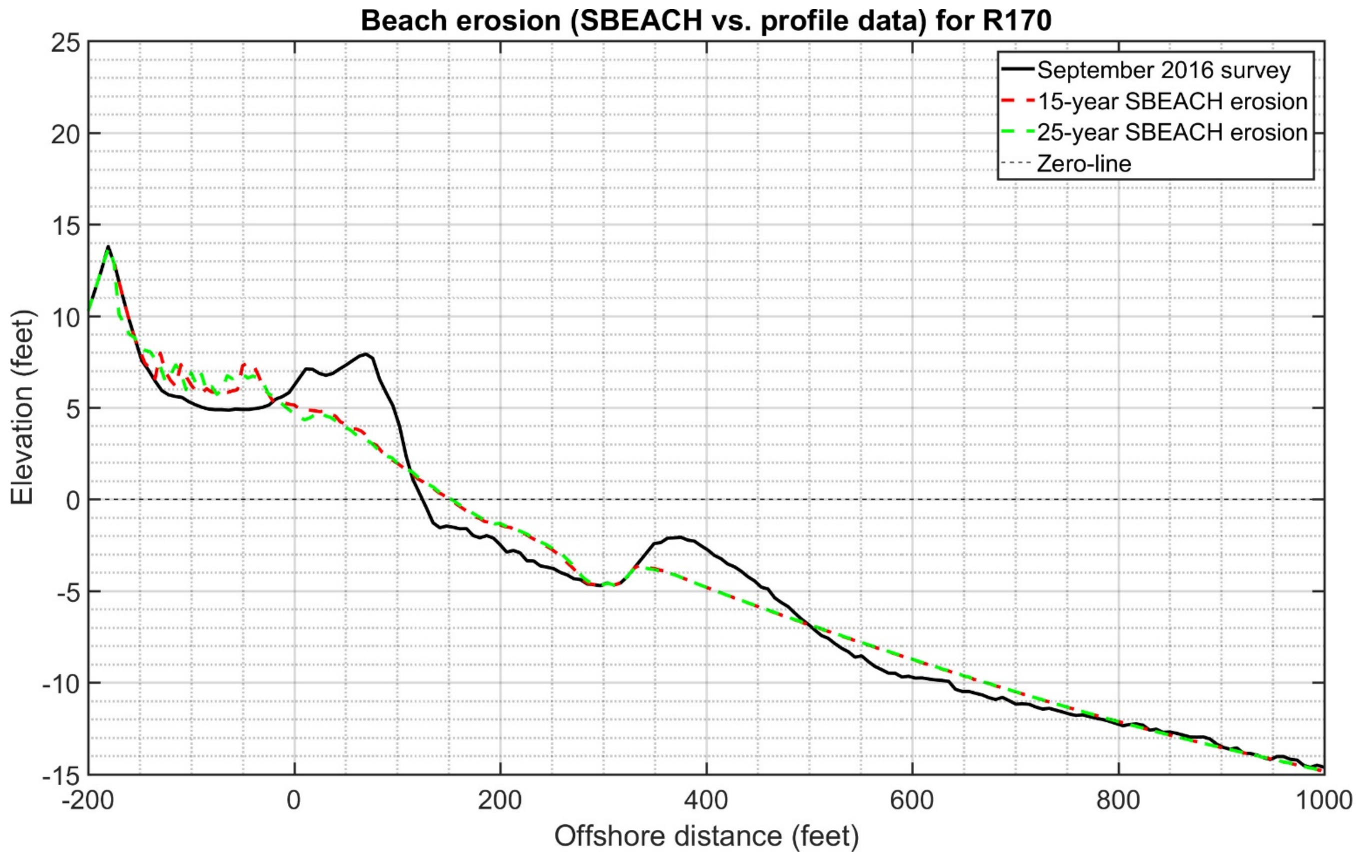
Beach erosion (SBEACH vs. profile data) for R170
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
-10
-15
-200
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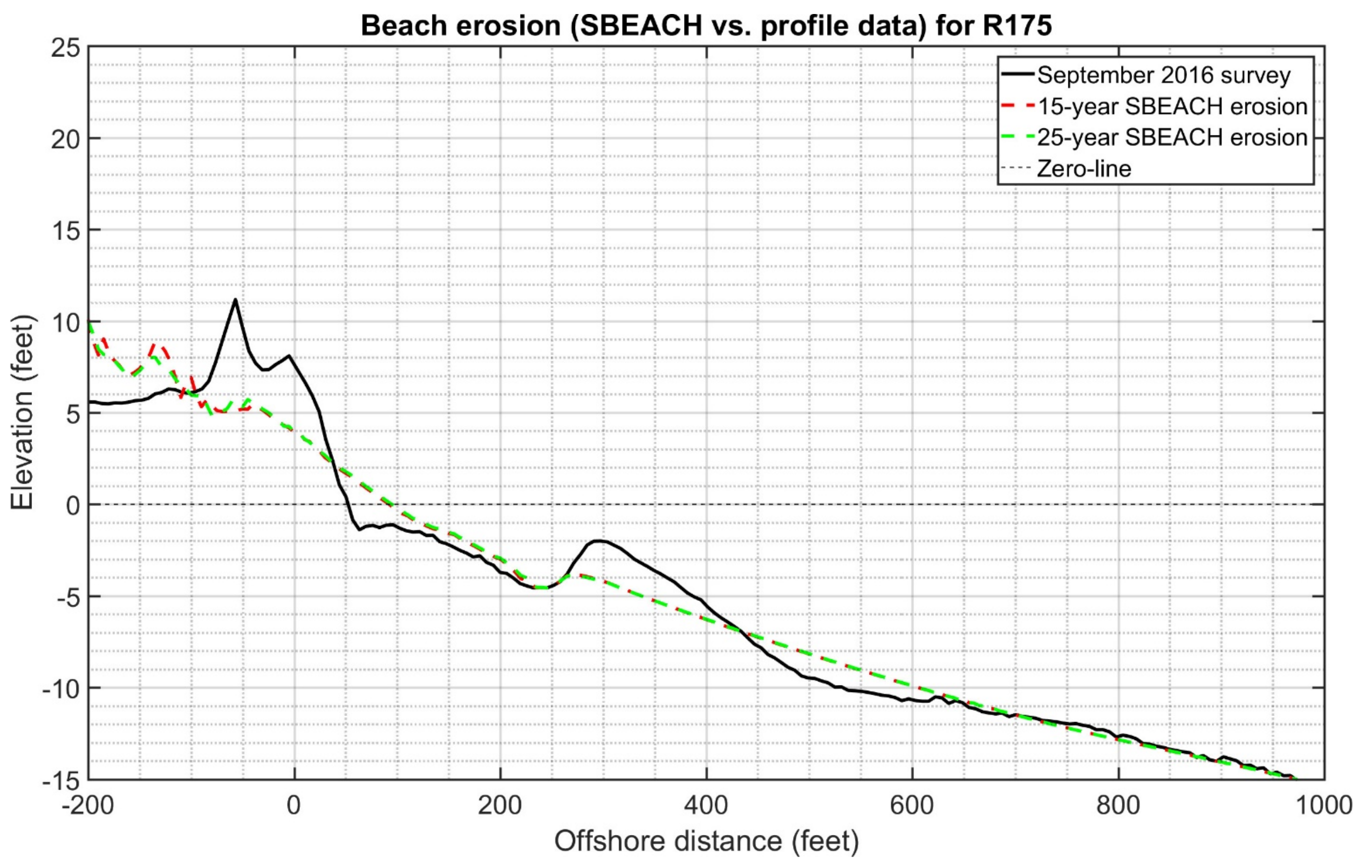
Beach erosion (SBEACH vs. profile data) for R175
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
-10
-15
-200
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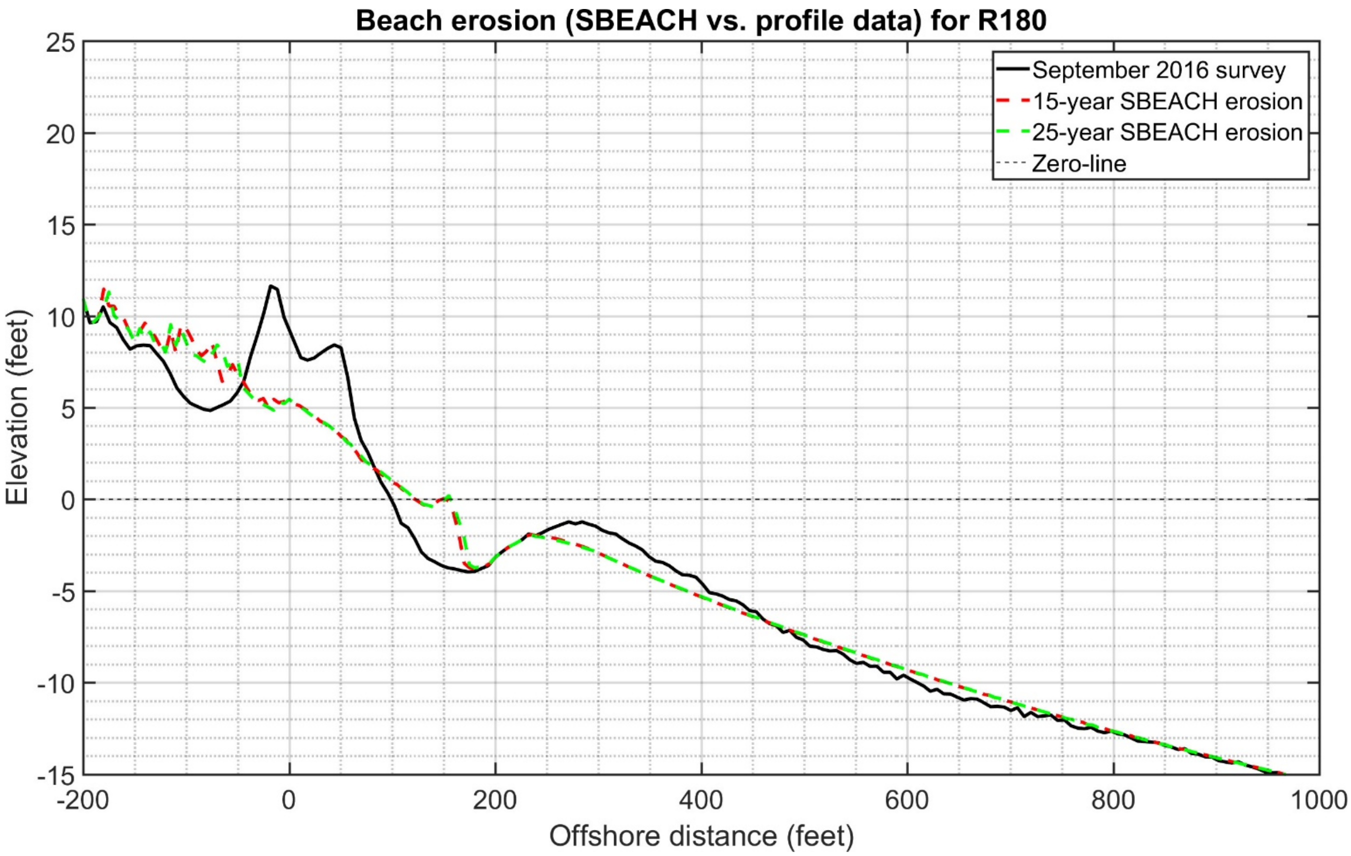
Beach erosion (SBEACH vs. profile data) for R180
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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5
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-5
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-15
-200
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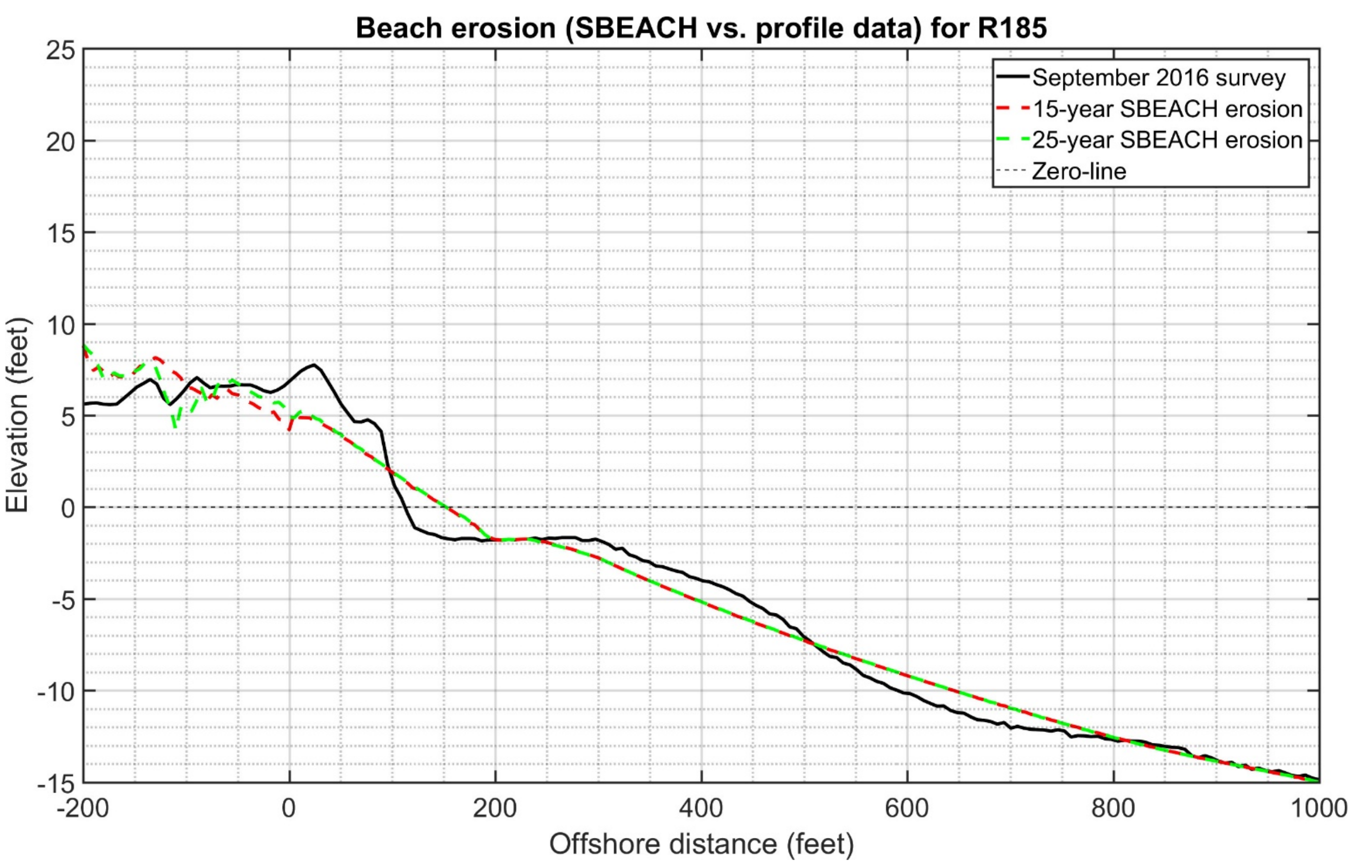
Beach erosion (SBEACH vs. profile data) for R185
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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-5
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-200
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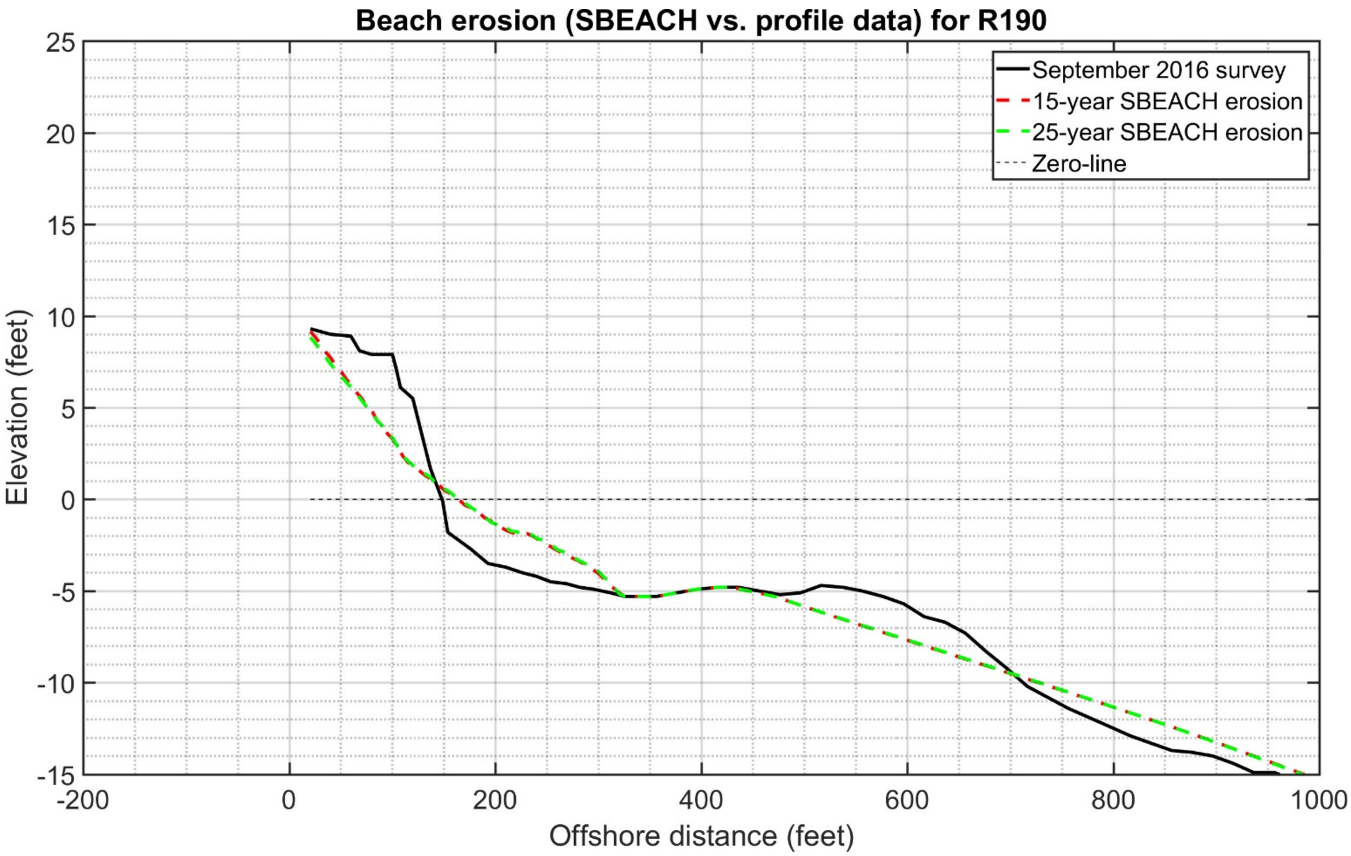
Beach erosion (SBEACH vs. profile data) for R190
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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-200
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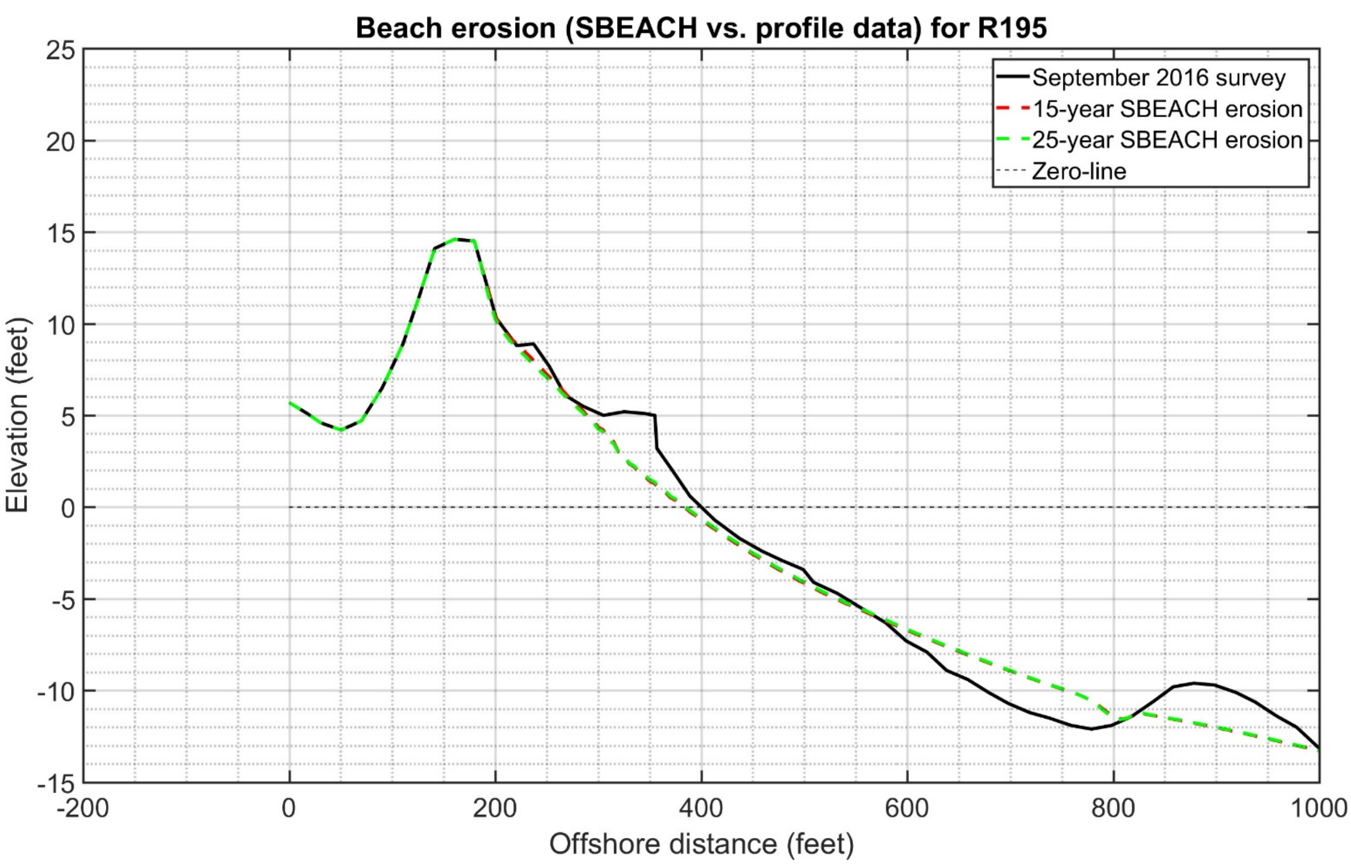
Beach erosion (SBEACH vs. profile data) for R195
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
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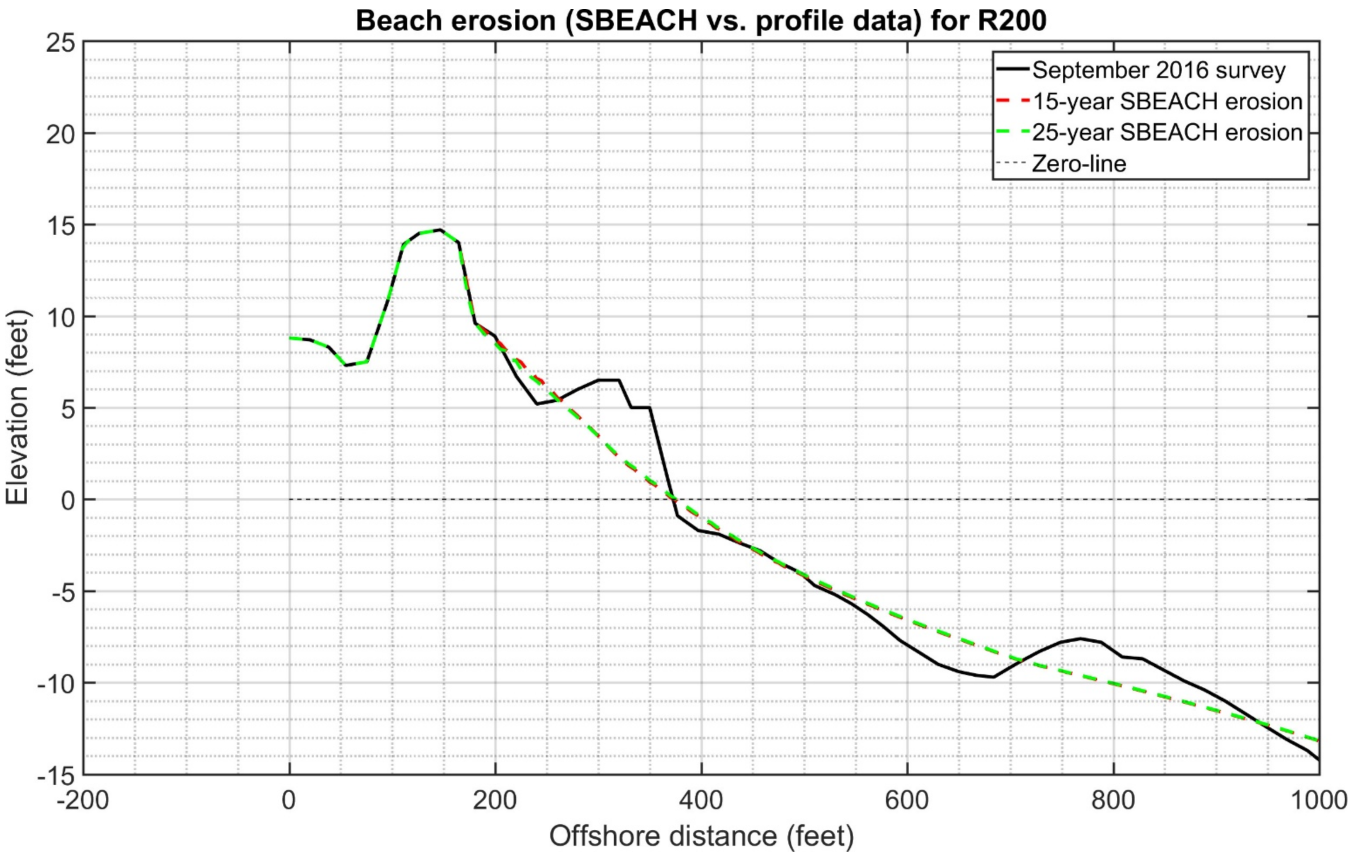
Beach erosion (SBEACH vs. profile data) for R200
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
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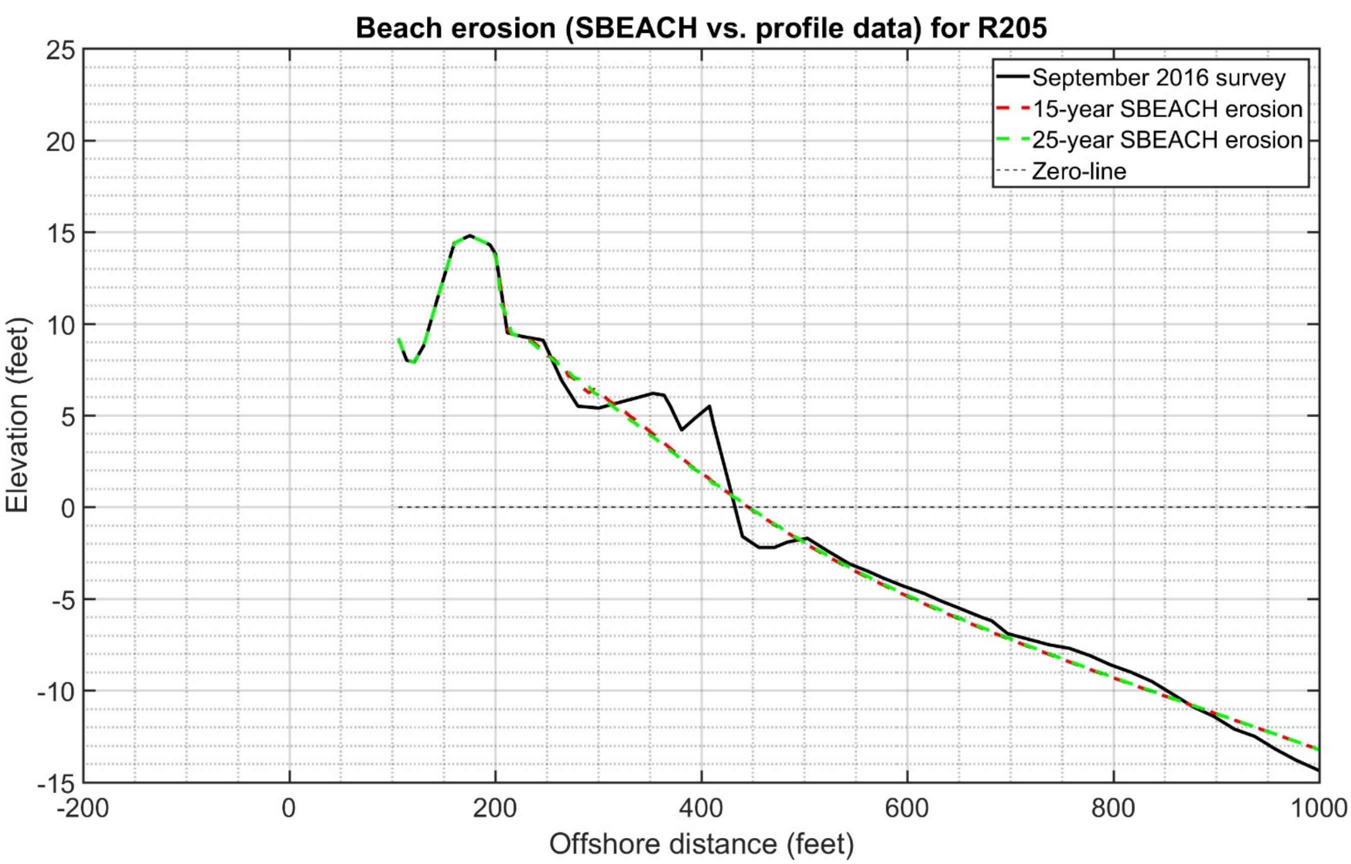
Beach erosion (SBEACH vs. profile data) for R205
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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-200
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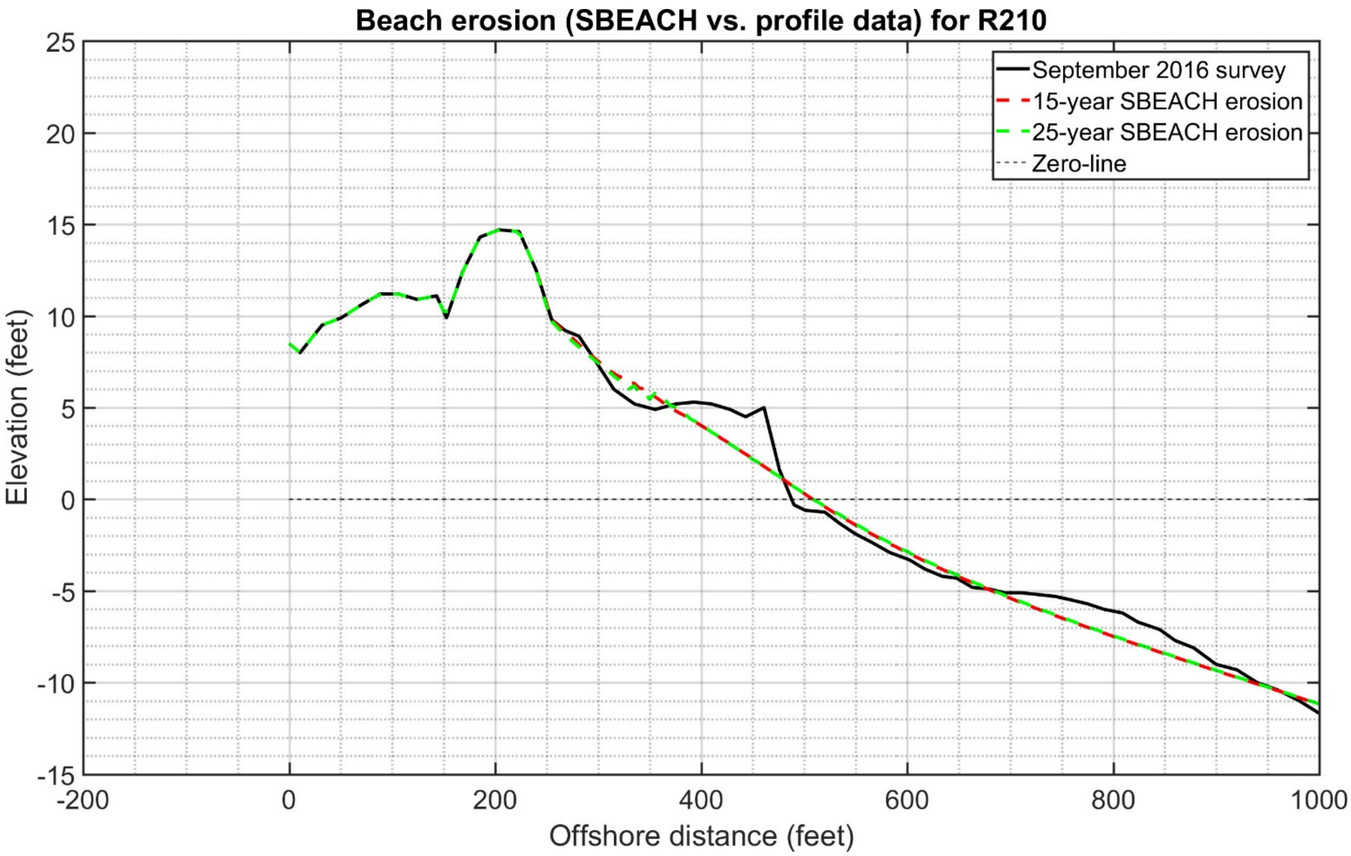
Beach erosion (SBEACH vs. profile data) for R210
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
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-200
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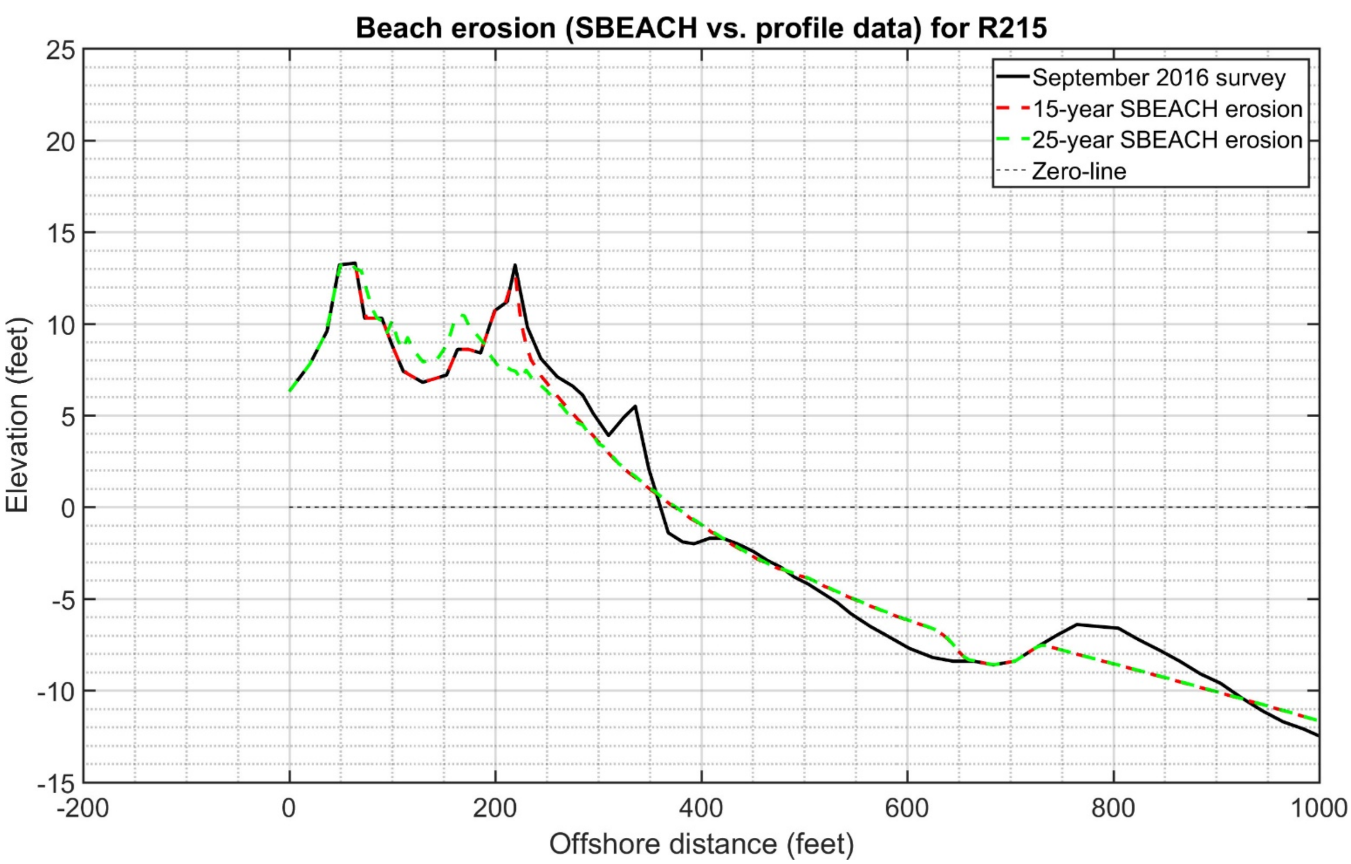
Beach erosion (SBEACH vs. profile data) for R215
September 2016 survey
15-year SBEACH erosion
25-year SBEACH erosion
Zero-line
Elevation (feet)
Offshore distance (feet)
25
20
15
10
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-5
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-15
-200
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