SUB-APPENDIX G-3

DELFT3D MODELING REPORT

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SOUTHERN PALM BEACH ISLAND COMPREHENSIVE SHORELINE STABILIZATION PROJECT DELFT3D MODELING REPORT

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1.0 INTRODUCTION

Under direction of the U.S. Army Corps of Engineers (USACE), CB&I Coastal Planning & Engineering, Inc. (CB&I) assisted in the development of the Southern Palm Beach Island Comprehensive Shoreline Stabilization Project Environmental Impact Statement (EIS). The initial tasks associated with the effort included public scoping and agency coordination to determine what data was necessary to develop the EIS. After review of the data and previous work, the USACE has determined that numerical modeling of sediment transport was required to obtain necessary data that is not currently available.

The Project Area for the Southern Palm Beach Island Comprehensive Shoreline Stabilization Project (the Project) comprises approximately 2.07 miles of shoreline and nearshore environment. The north and south limits are Florida Department of Environmental Protection (FDEP) range monuments (R-monuments) R-129-210 (south end of Lake Worth Municipal Beach) and R-138+551 (south of the Eau Palm Beach Resort and Spa in Manalapan), respectively (Figure 1-1). The Project Area's beaches provide storm protection to residential and public infrastructure and serve as nesting areas for marine turtles.

A numerical modeling study was conducted to assess the potential impacts to hardbottom as a result of the proposed alternatives. Morphology and sediment transport analysis of proposed alternatives for the EIS Project Area was conducted using the Delft3D model. The simulation of nearshore hardbottom is included in the model.

As part of a previous study conducted for Palm Beach County, a Delft3D numerical model (CPE, 2013) was developed, calibrated and applied to evaluate Project alternatives along the shoreline of South Palm Beach, Lantana, and Manalapan. The setup, initially focused on the South Palm Beach project area, was expanded for this study to include the Town of Palm Beach in evaluating the combined project area.

The study presented herein builds upon the following series of earlier reports:

- Coastal Planning & Engineering, Inc., 2007a. Town of South Palm Beach/Town of Lantana Erosion Control Study, Coastal Planning & Engineering, Inc., Boca Raton, FL.

- Coastal Planning & Engineering, Inc., 2010. Central Palm Beach County Comprehensive Erosion Control Project, Numerical Calibration of Wave Propagation and Morphology Changes, Coastal Planning & Engineering, Inc., Boca Raton, FL.

- Coastal Planning & Engineering, Inc., 2011. Central Palm Beach County Comprehensive Erosion Control Project Numerical Modeling of Shore Protection Alternatives, Coastal Planning & Engineering, Inc., Boca Raton, FL.

- Coastal Planning & Engineering, Inc., 2013. Central Palm Beach County Comprehensive Erosion Control Project Reformulated Shore Protection Alternatives, Coastal Planning & Engineering, Inc., Boca Raton, FL.

- The Coalition to Save Our Shoreline, Inc. (SOS). Beach Nourishment Plan and Design for Reach 8 - Design Basis, Town of Palm Beach, FL. Prepared by Erickson Consulting Engineers (ECE).

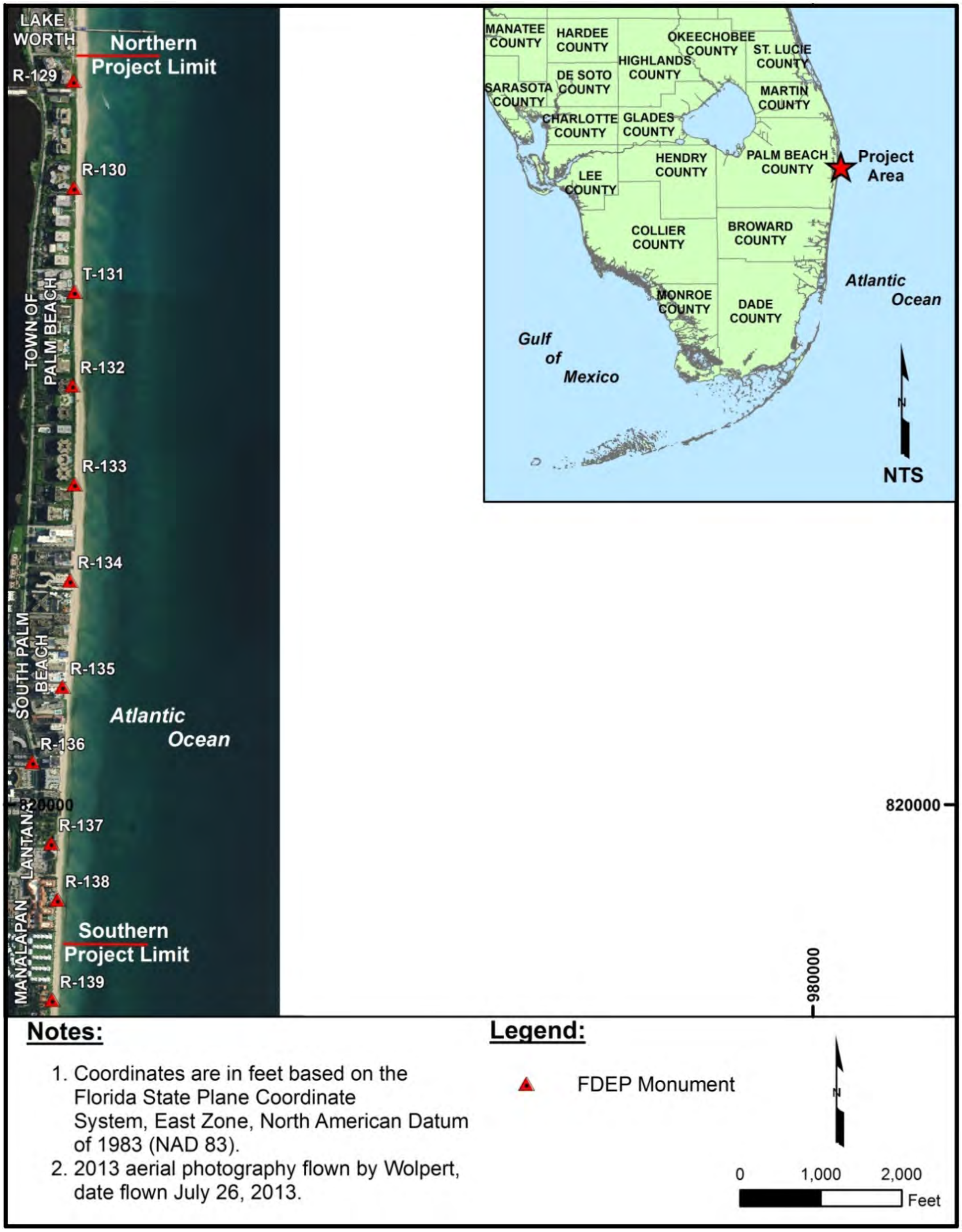

Figure 1-1. Southern Palm Beach Island Comprehensive Shoreline Stabilization Project Location.

The alternatives that were considered in the analysis included:

- Alternative 1 – No Action Alternative (Status Quo) and referenced herein as the existing conditions.
- Alternative 2 – The Applicants' Preferred Project (Proposed Action): Beach and Dune Fill with Shoreline Protection Structures
- Alternative 3 – The Applicants' Preferred Project without Shoreline Protection Structures
- Alternative 4 – The Town of Palm Beach Preferred Project and County Increased Sand Volume without Shoreline Protection Structures
- Alternative 5 – The Town of Palm Beach Increased Sand Volume and County Preferred Project Alternative 6 – The Town of Palm Beach Increased Sand Volume Project and County Increased Sand Volume without Shoreline Protection Structures Project
- Alternative 6 – The Town of Palm Beach Increased Sand Volume Project and County Increased Sand Volume Project without Shoreline Protection Structures
- Alternative 7a – The Coalition to Save Our Shoreline, Inc. (SOS) option with increased sand volume and the County Preferred Project. The fill template consists of beach fill and dune restoration between R-129-210 and R-134+135 with shoreline protection structures. The sand fill volumes required this plan are greater than the volumes for Alternative 6 over the same shoreline extents. For the purpose of modeling, Alternative 7a was defined as the increased sand volume SOS option north of R-134+135 and Alternative 2 to the south.
- Alternative 7b – The Town of Palm Beach increased sand volume with two shoreline protection structures (The Coalition to Save Our Shoreline, Inc. (SOS) Alternative) and the County Preferred Project. The fill template consisted of beach

fill and dune restoration between R-129-210 and R-134+135 with shoreline protection structures. The sand fill volumes required for the SOS preferred option are smaller than the volumes for Alternative 7a over the same shoreline extents. For the purpose of modeling, Alternative 7b was defined as the SOS option north of R-134+135 and Alternative 2 to the south.

In addition, the alternatives were separated into the Town of Palm Beach and the County projects and modeled individually to evaluate the effects/impacts attributable to the individual projects.

2.0 METHODOLOGY

The primary modeling tool used in this study was the Delft3D morphological modeling package (Deltares, 2011). This package consists of two models, which are coupled together to determine changes in a topographic and bathymetric surface based on the effects of waves, water levels, winds, and currents. Wave propagation from the offshore to the nearshore area is estimated using the Simulating Waves Nearshore Model (SWAN 40.72ABCDE, Delft University of Technology, 2008). Delft3D-FLOW utilizes the output waves from SWAN, along with the varying water levels offshore and the bathymetry, to determine the resulting currents, water levels, sediment transport, erosion, and deposition. Based on the estimated erosion and deposition at each time step, the Delft3D-FLOW model calculates the subsequent elevations of the topographic and bathymetric surface and sends the updated bathymetry back to the SWAN model. Typical time steps in Delft3D-FLOW range from 1 second to 60 seconds, while wave propagation estimates in the SWAN model are performed every 1 to 3 hours. Given the interaction between the currents, hardbottoms, and waves, Delft3D is an effective means of evaluating the performance and impact of structures, and beach fill alternatives within the Study Area.

3.0 MODEL SETUP

3.1. Grids

To perform morphological calibration and productions runs, four numerical grids were used (Figure 3-1). The following is a brief description of each grid:

1. A regional wave grid was designed to examine wave transformation processes. The regional wave grid extends from near Highland Beach to 2 miles north of Palm Beach Inlet reaching depths up to 700 feet, NAVD (Figure 3-1).

2. An intermediate wave grid was designed to examine wave propagation from deep to shallow water, transferring waves from regional to local grid (Figure 3-1). The intermediate grid was nested in regional grid.

3. A local wave grid was designed to examine detailed, shallow water wave processes along the Study Area. Near the shoreline and in the nearby area of proposed alternatives, grid resolution was increased to simulate refraction, diffraction, and breaking processes (Figure 3-2). The local wave grid was nested in intermediate wave grid.

4. A flow grid was designed to examine circulation patterns and morphological changes along the Study Area. The perimeter cells of the grid were trimmed to ensure stable coupling between the SWAN model and the Delft3D-Flow model (Figure 3-3).

All grids were constructed in Cartesian coordinates based on the Florida State Plane Coordinate System, East Zone, North American Datum of 1983 (FLE-NAD83). Grid characteristics are summarized in Table 3-1.

The model's developers (Deltares) have established guidelines for grid cell smoothing and orthogonality that were used. Smoothing represents the change in cell size between two rows of grid cells. A smoothing value of 1.1 indicates that the cell size between two rows of grid cells increases by 10%. The maximum smoothing value recommended by model developers is 1.2. Orthogonality is equivalent to the angle between the longshore and cross-shore grid lines. The angles between the longshore and cross-shore grid lines should be at least 87.7 degrees within the area of interest. All four grids follow the Deltares guidelines for smoothing and orthogonality (see Table 3-1).

Figure 3-1. Computational grids used in Delft3D-WAVE and Delft3D-FLOW calibration and production runs.

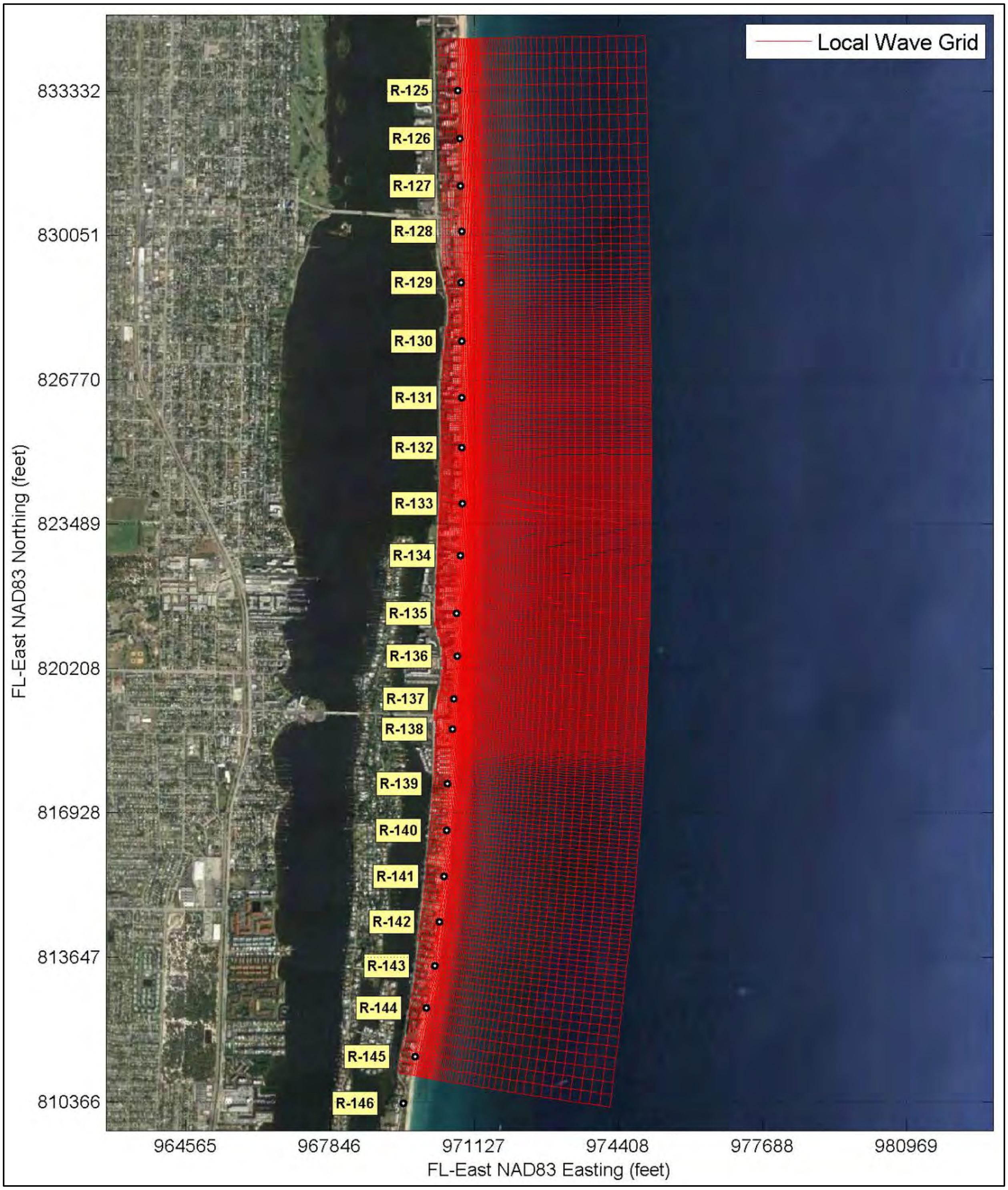

Figure 3-2. Local wave grid used in calibration and production runs.

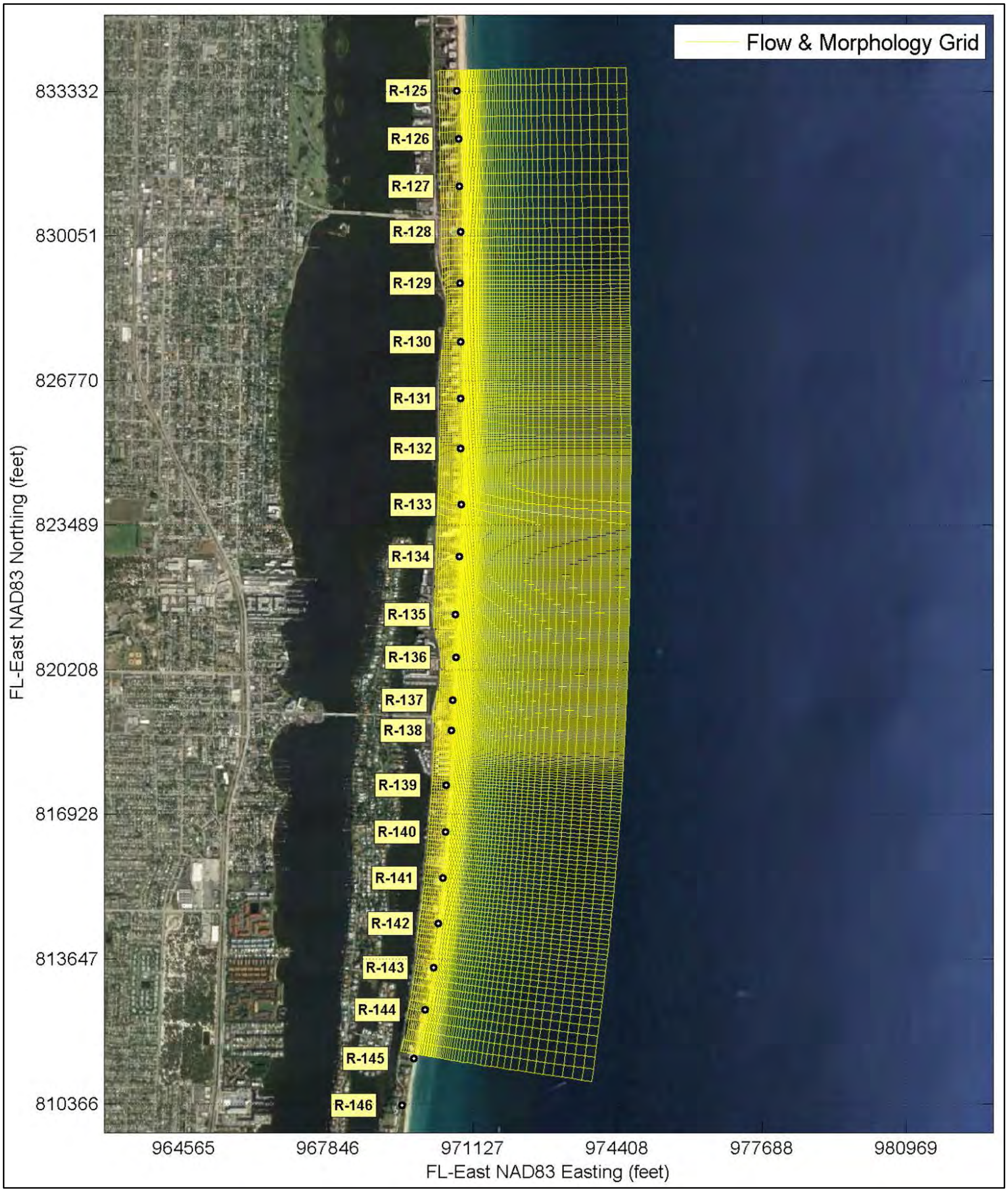

Figure 3-3. Flow and morphology grid used in calibration and production runs.

Table 3-1. South Palm Beach – Calibration Grids.

	Regional Wave Grid	Intermediate Wave Grid	Local Wave Grid	Flow Grid
# of Longshore Cells	36	49	405	401
# of Cross-Shore Cells	124	109	67	65
Longshore Spacing (feet) - Min.	1,148.00	312.00	30.00	44.69
Longshore Spacing (feet) - Max.	1,312.00	344.00	354.00	171.33
Cross-shore Spacing (feet) - Min.	623.00	164.00	20.00	50.92
Cross-shore Spacing (feet) - Max.	1227.00	328.00	233.00	211.88
Longshore Smoothness - Min.	1.00	1.00	1.00	1.00
Longshore Smoothness - Max.	1.00	1.00	1.10	1.10
Cross-shore Smoothness - Min.	1.00	1.00	1.00	1.00
Cross-shore Smoothness - Max.	1.11	1.11	1.13	1.13
Orthogonality (deg.) - Min.	90.00	90.00	89.90	89.90
Orthogonality (deg.) - Max.	90.00	90.00	90.00	90.00

3.2. Initial Bathymetry

The primary sources of topographic and bathymetric data for this model study are listed in Table 3-2. Conversions between MSL and NAVD88 assumed MSL = -0.92 feet NAVD88. All the models were run in MSL.

Table 3-2. Bathymetric and Topographic Data Sources.

Survey Date	Type	Area	Source	Vertical Accuracy (feet)
January 2012	Beach Profiles	R-135 to R-164	FDEP (2012)	0.1 to 0.5
September-November 2011	Beach Profiles	R-73 to R-135	ATM (2012)	0.1 to 0.5
December 2008	High-Density Beach Profiles	R-132 to R-143	Sea-Diversified (2008)	0.1 to 0.5
October-December 2008	Beach Profiles	R-77 to R-135	CPE (2009)	0.1 to 0.5
January-February 2006	LIDAR	Palm Beach County	USACE (2006)	0.5
1963-1964	Hydrographic	Palm Beach County	NOAA (2006)	1.4

Bathymetry for the morphologic calibration period was based on the following data sources (see also Table 3-2):

1. December 2008 high-density beach profiles (i.e., spaced at 500 feet alongshore) (Sea-Diversified, 2008)
2. October-December 2008 beach profiles (CPE, 2009)
3. 2006 Lidar (USACE, 2006)
4. 1963-1964 hydrographic survey (NOAA, 2006)

For morphology calibration, the primary data set was the December 2008 high-density beach profiles, followed by October-December 2008 beach profiles. The 2006 Lidar data was used to represent topography beyond the beach profiles, while the hydrographic survey from 1963-1964 were used to represent the bathymetry at deeper water depths for the intermediate and regional wave grids. The resulting bathymetries for the local wave grid and the flow and morphology grid appear in Figure 3-4 and Figure 3-5. The bathymetries for the regional and intermediate grids are shown in Figure 3-6 and Figure 3-7.

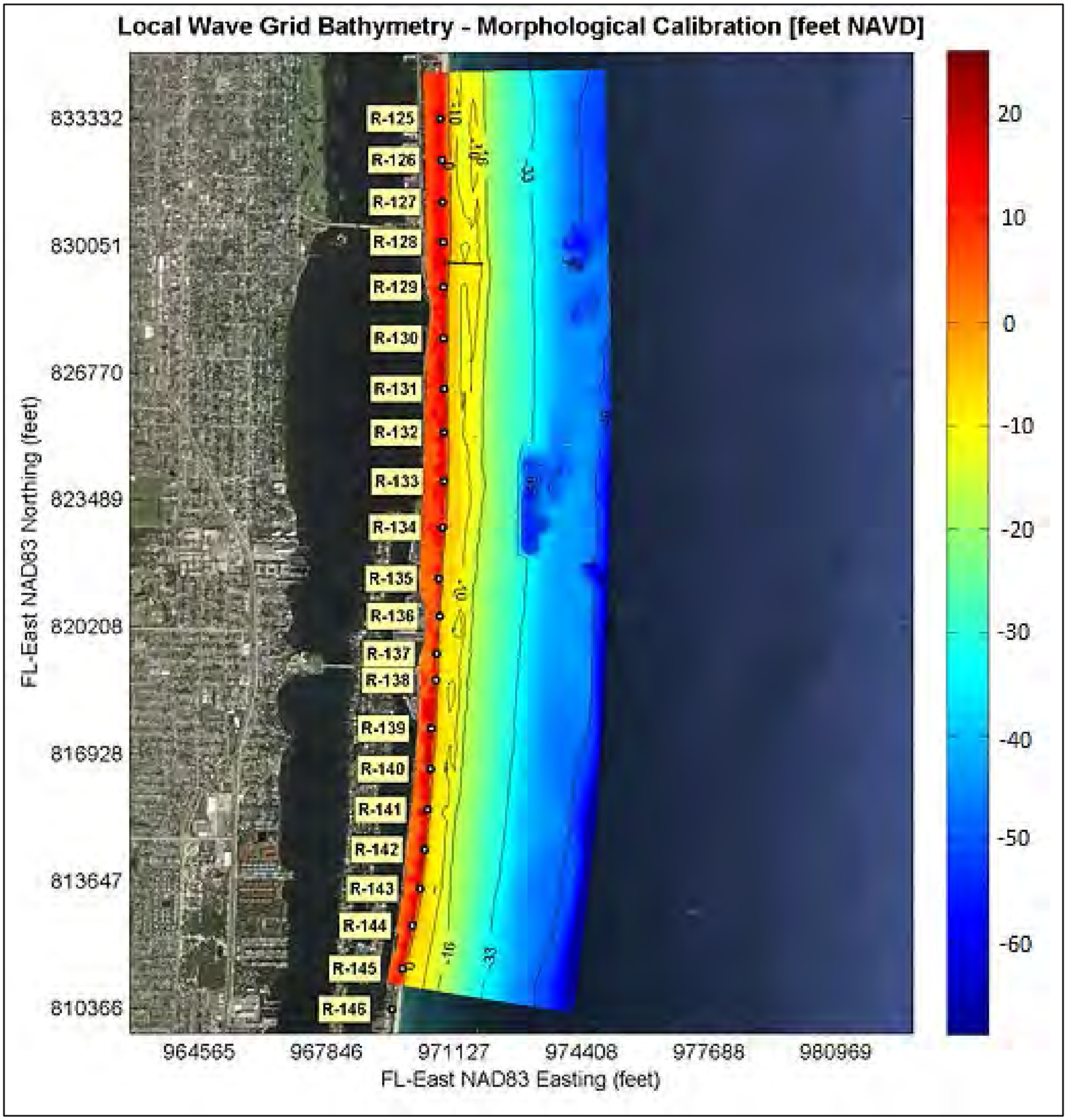

Figure 3-4. Local wave grid bathymetry (feet NAVD88) used in morphological calibration run.

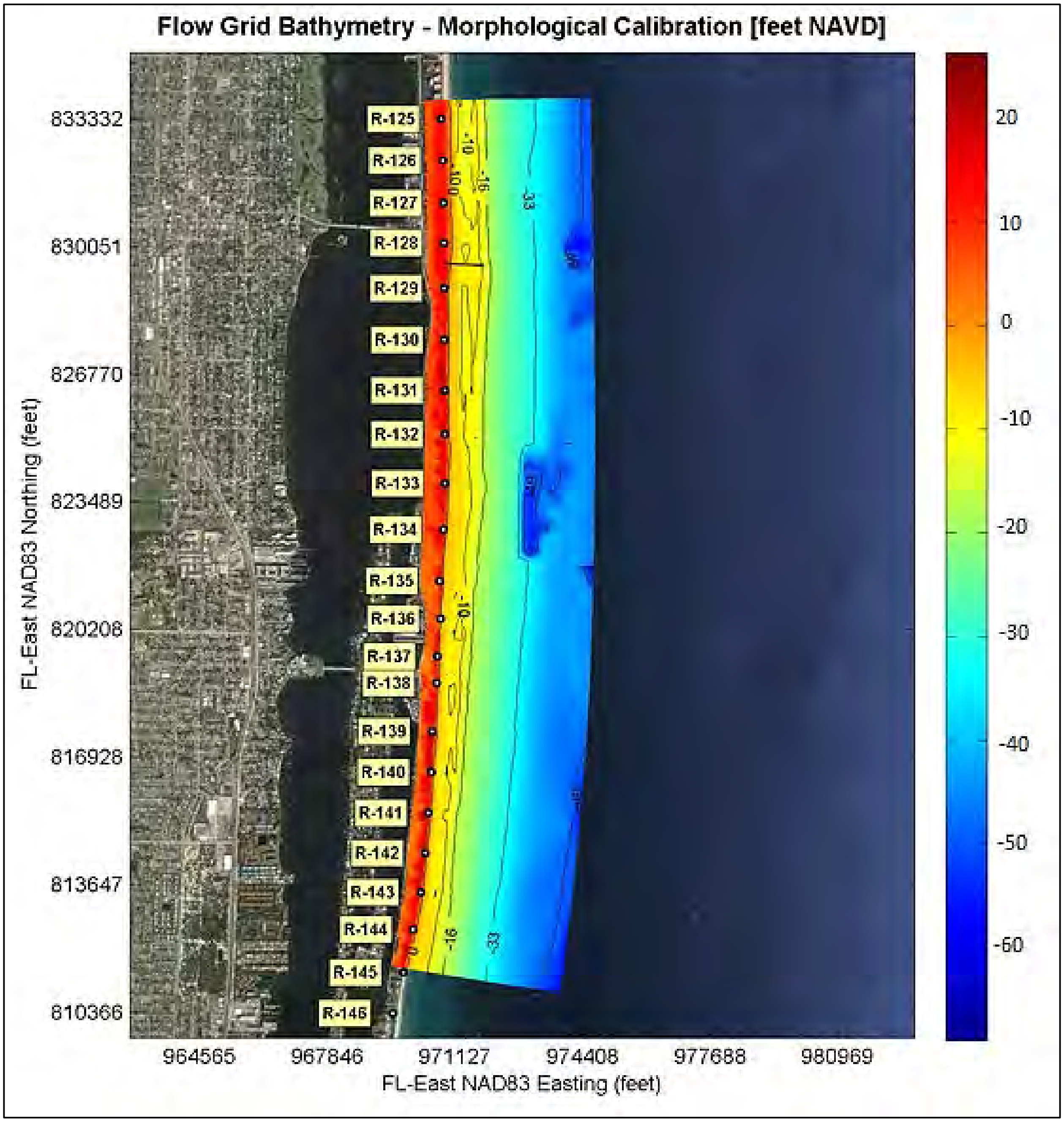

Figure 3-5. Flow and morphology grid bathymetry (feet NAVD88) used in morphological calibration run.

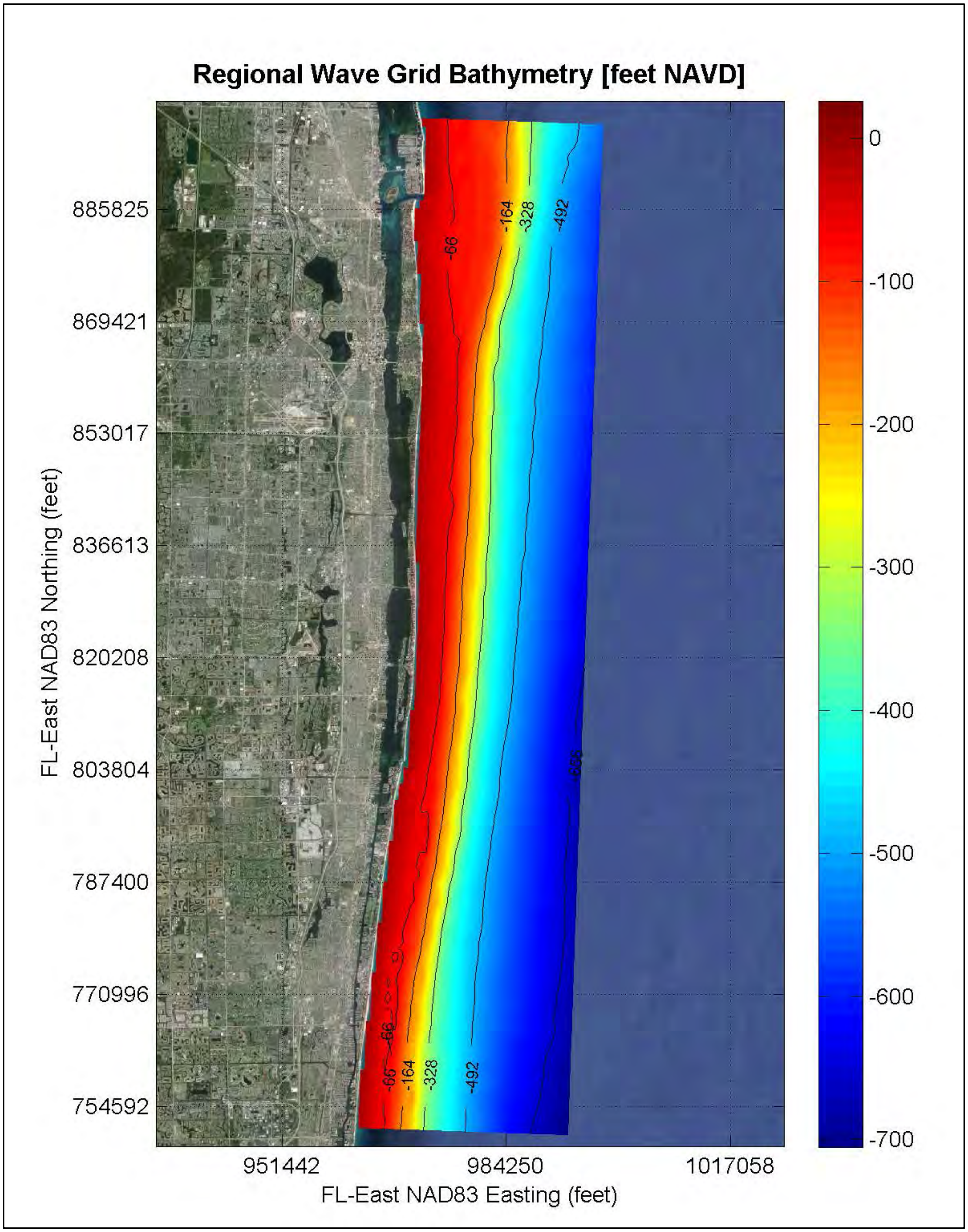

Figure 3-6. Regional wave grid bathymetry (feet NAVD88) used in morphological calibration run.

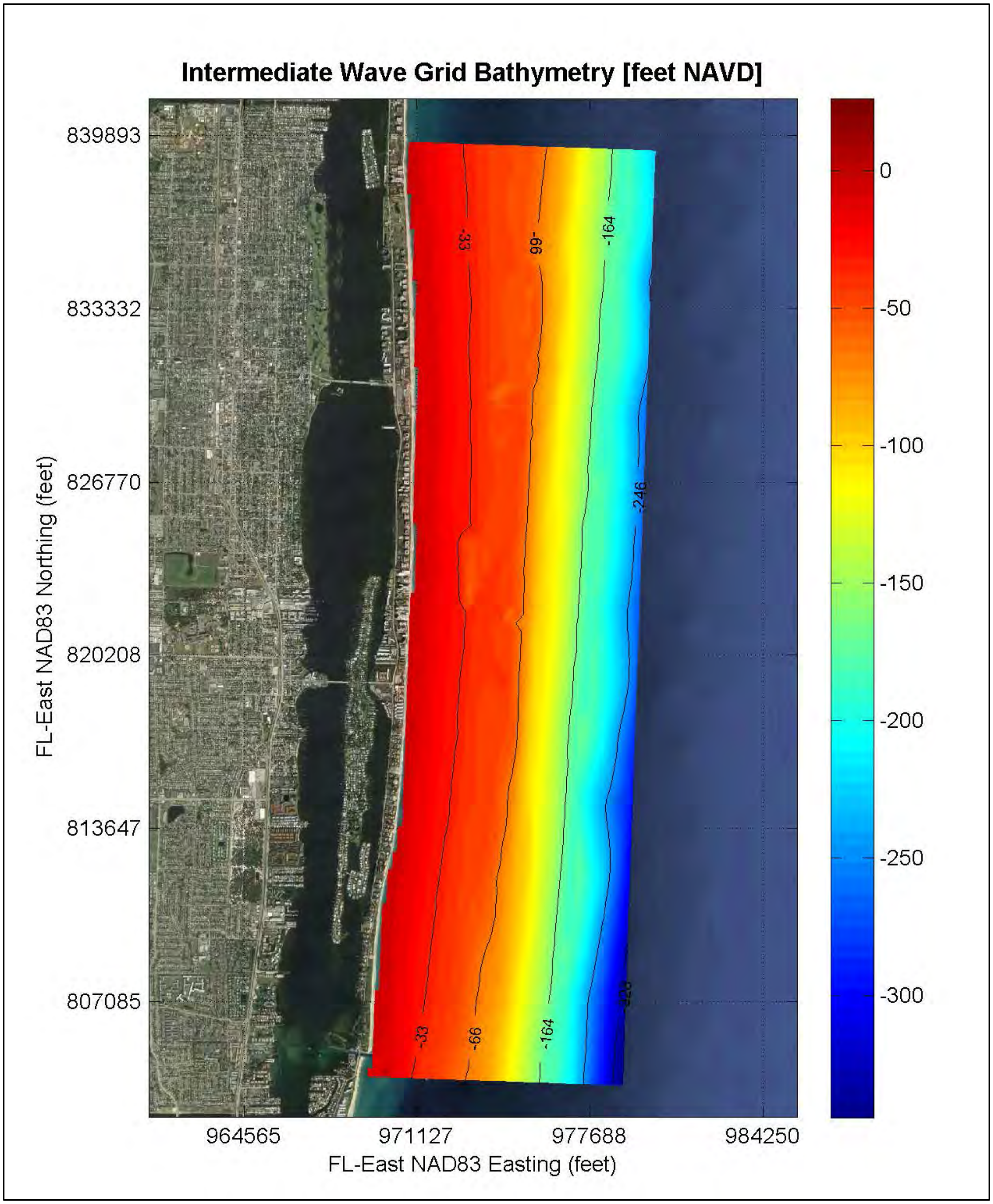

Figure 3-7. Intermediate wave grid bathymetry (feet NAVD88) used in calibration runs.

3.3. Water Levels

Tides at the Project Area were based at tidal datums along Lake Worth Pier Station located at 26° 36.7' N, 80° 2.0' W (NOAA, 2011) which are presented in Table 3-3. The observed water levels from March 2014 are shown in Figure 3-8. Tides at the Project Area are semidiurnal with amplitudes averaging 2.74 feet based on the vertical difference between MHW and MLW. Tides were represented as morphological tide, described in Section 4.2.4 below.

Table 3-3: Tidal Datums, Lake Worth Pier, FL, NOAA Station 8722670 (NOAA, 2011).

Datum	Abbrev.	(feet MLLW)	(feet NAVD88)
Mean Higher High Water	MHHW	3.01	0.58
Mean High Water	MHW	2.87	0.44
North American Vertical Datum of 1988	NAVD88	2.42	0.00
Mean Sea Level	MSL	1.51	-0.92
Mean Tide Level	MTL	1.50	-0.92
Mean Low Water	MLW	0.13	-2.29
Mean Lower Low Water	MLLW	0.00	-2.42

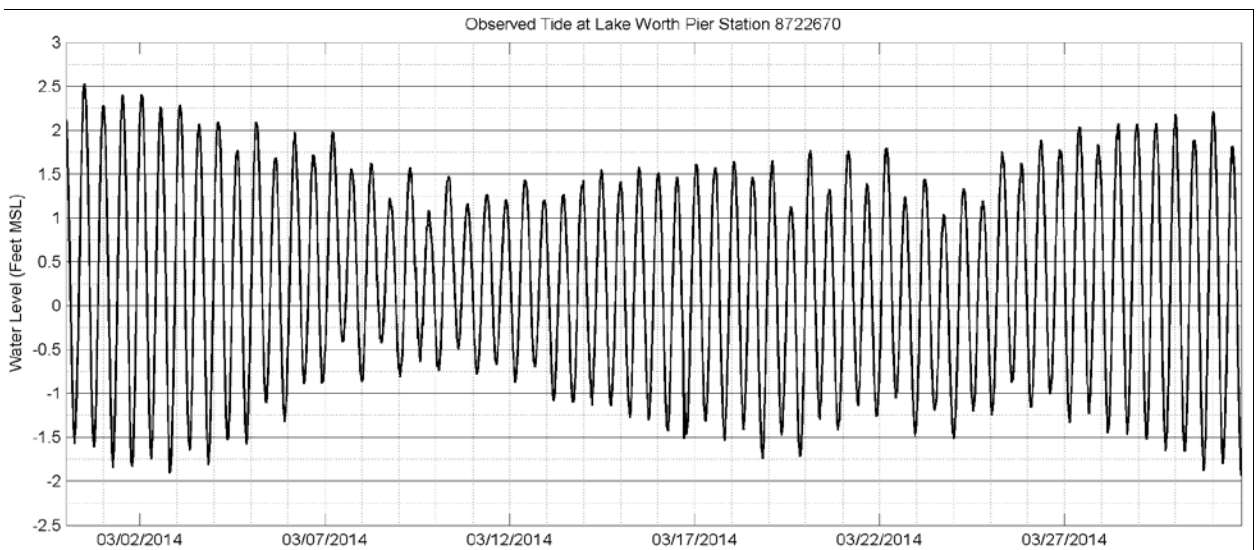

Figure 3-8. Observed water levels at Lake Worth Pier Station.

3.4. Offshore Wind and Wave Data

The wind and wave data used in this modeling study were obtained from WIS (Wave Information System) hindcast data (v02) at Station 63461 over the time period between 1980 and 2012. The data source was located approximately 12 miles offshore of the Study Area (Figure 3-9) at 26.58° N, 79.83° W. All wave and wind data was provided in SI units, with times referenced to Greenwich Mean Time (GMT). WIS Station data was given every 3 hours.

WIS Hindcast Data is generated from numerical models (WISWAVE, WAM) driven by climatological wind fields overlaid on grids containing estimated bathymetries. The WIS numerical hindcasts supply long-term wave climate information at nearshore locations (stations) of U.S. coastal waters.

Time series of significant wave height (Hs), peak period (Tp) and wave peak direction (Dirp) from WIS Station ST 63461 appear in Figure 3-10. Time series of wind velocity and wind direction from WIS Station ST 63461 appear in Figure 3-10. Directional wind and wave statistics are presented in Figure 3-12 and Figure 3-13, respectively. In general, winds come from all directions, but there are a large percentage of winds that come from E to S quadrants. The prevailing directions of waves are from NE to ESE.

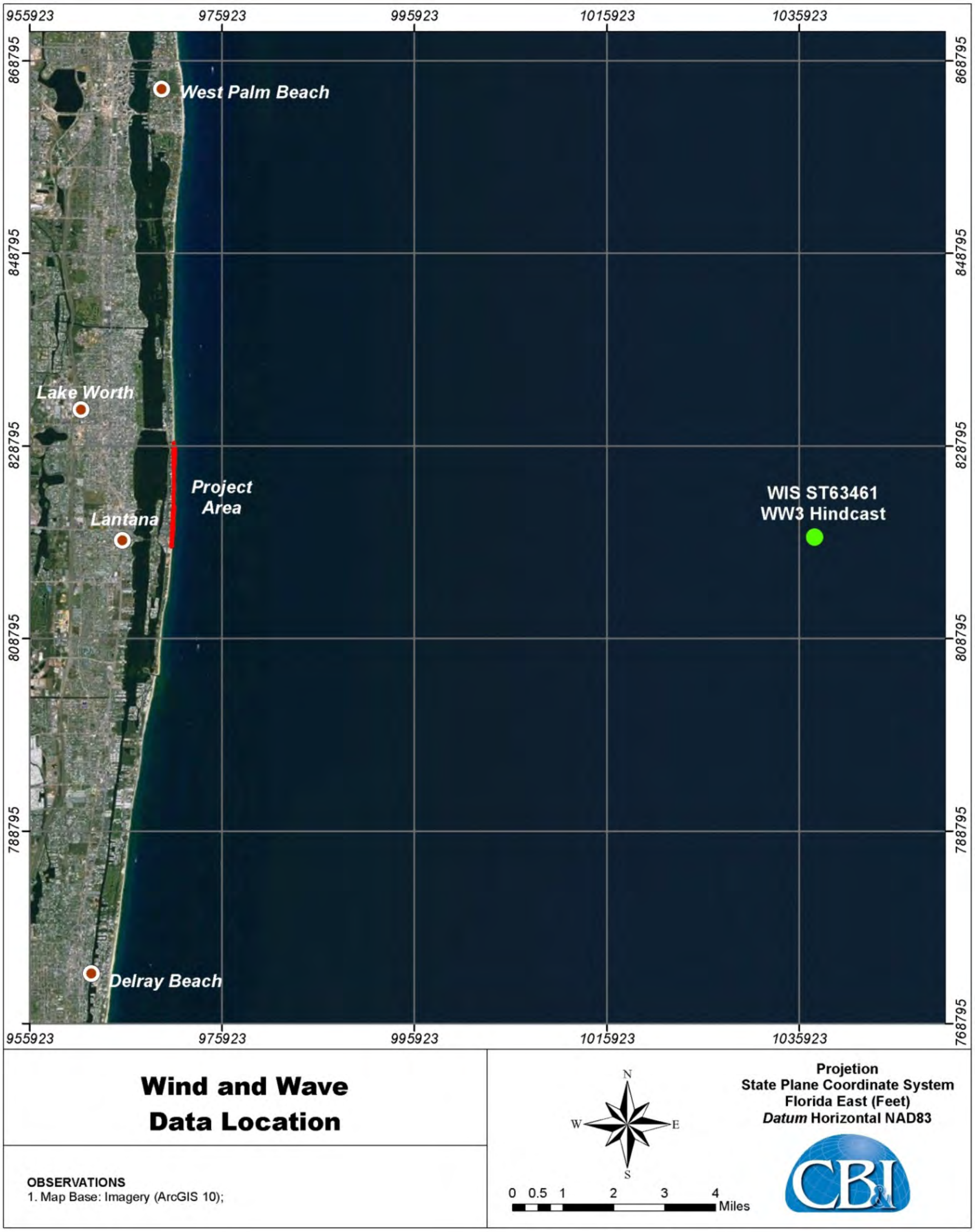

Figure 3-9. Location of the wind and wave data sources.

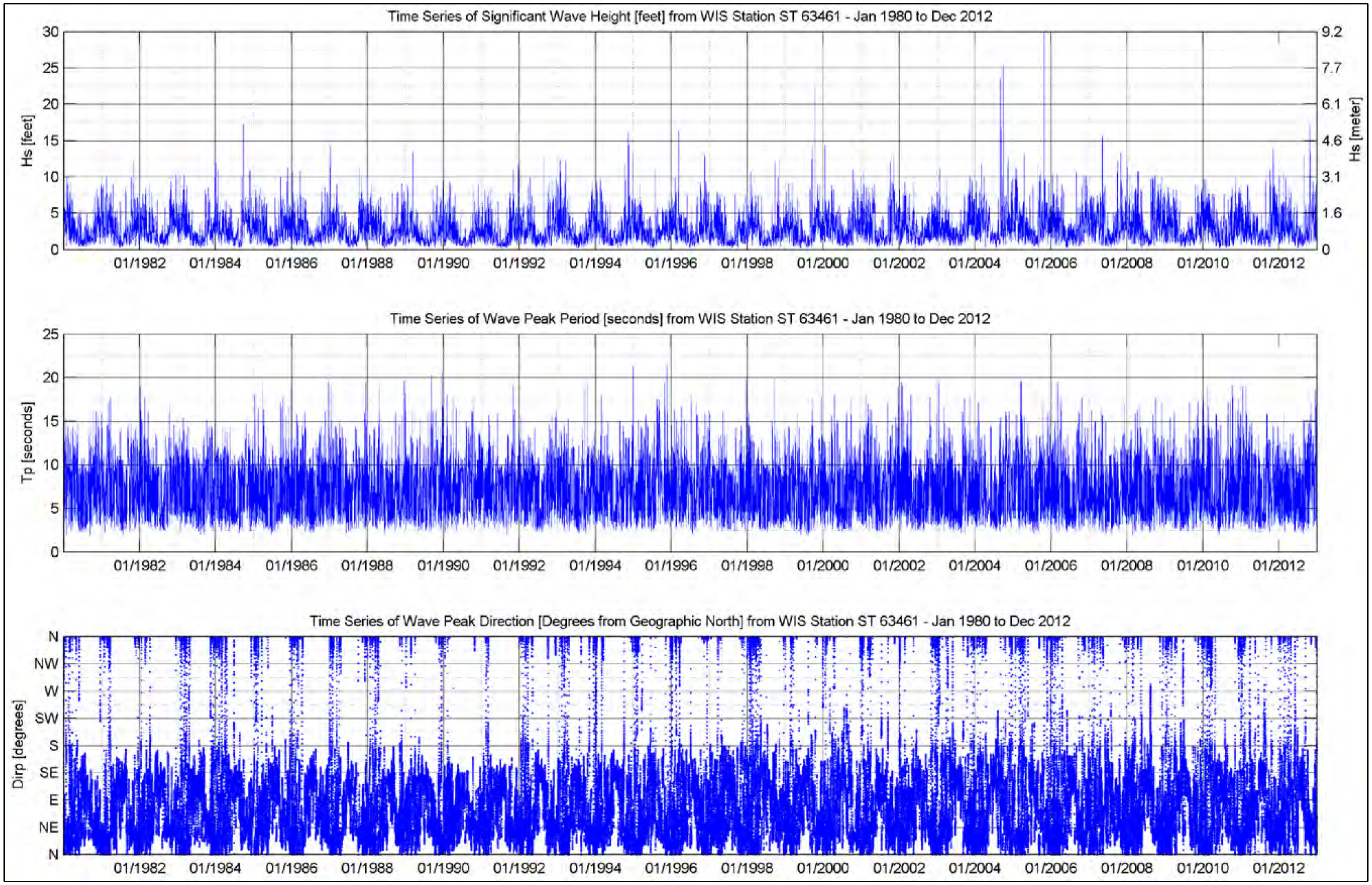

Figure 3-10. Hindcast wave height (Hs), peak period (Tp) and wave peak direction at WIS Station ST 63461.

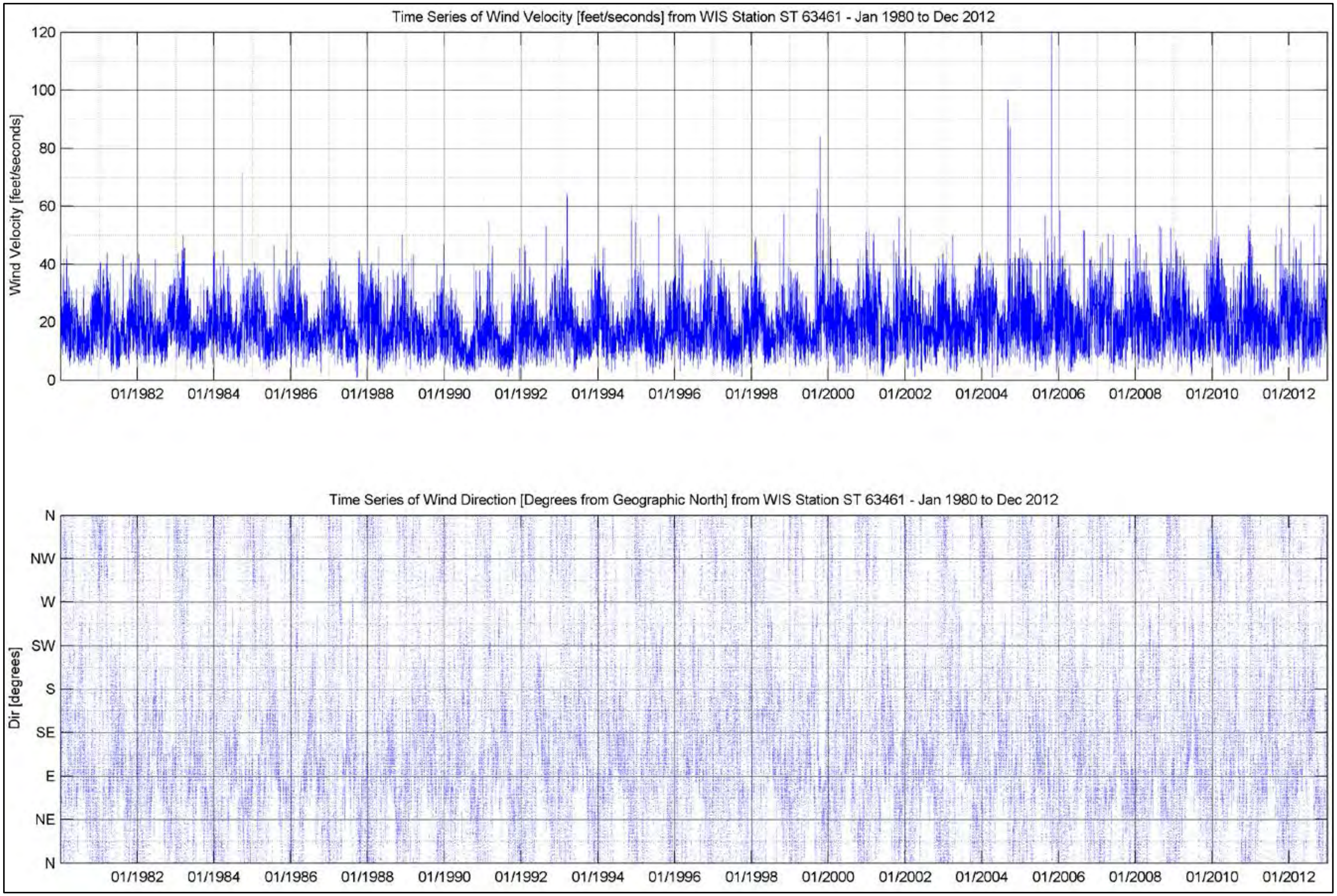

Figure 3-11. Hindcast wind velocity [feet/seconds] and wind direction [degrees] at WIS Station ST 63461.

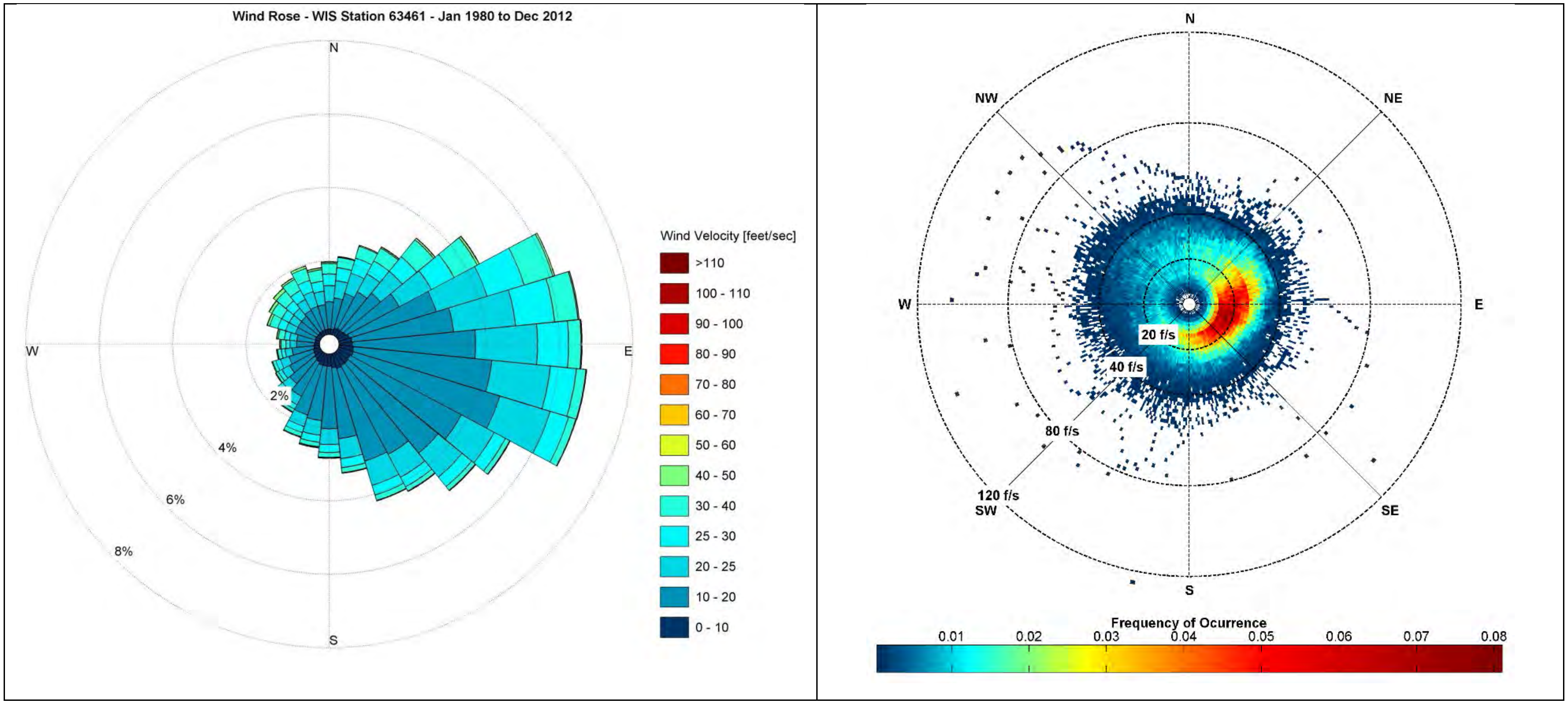

Figure 3-12. Directional wind statistics for WIS Station ST 63461 from January 1980 to December 2012.

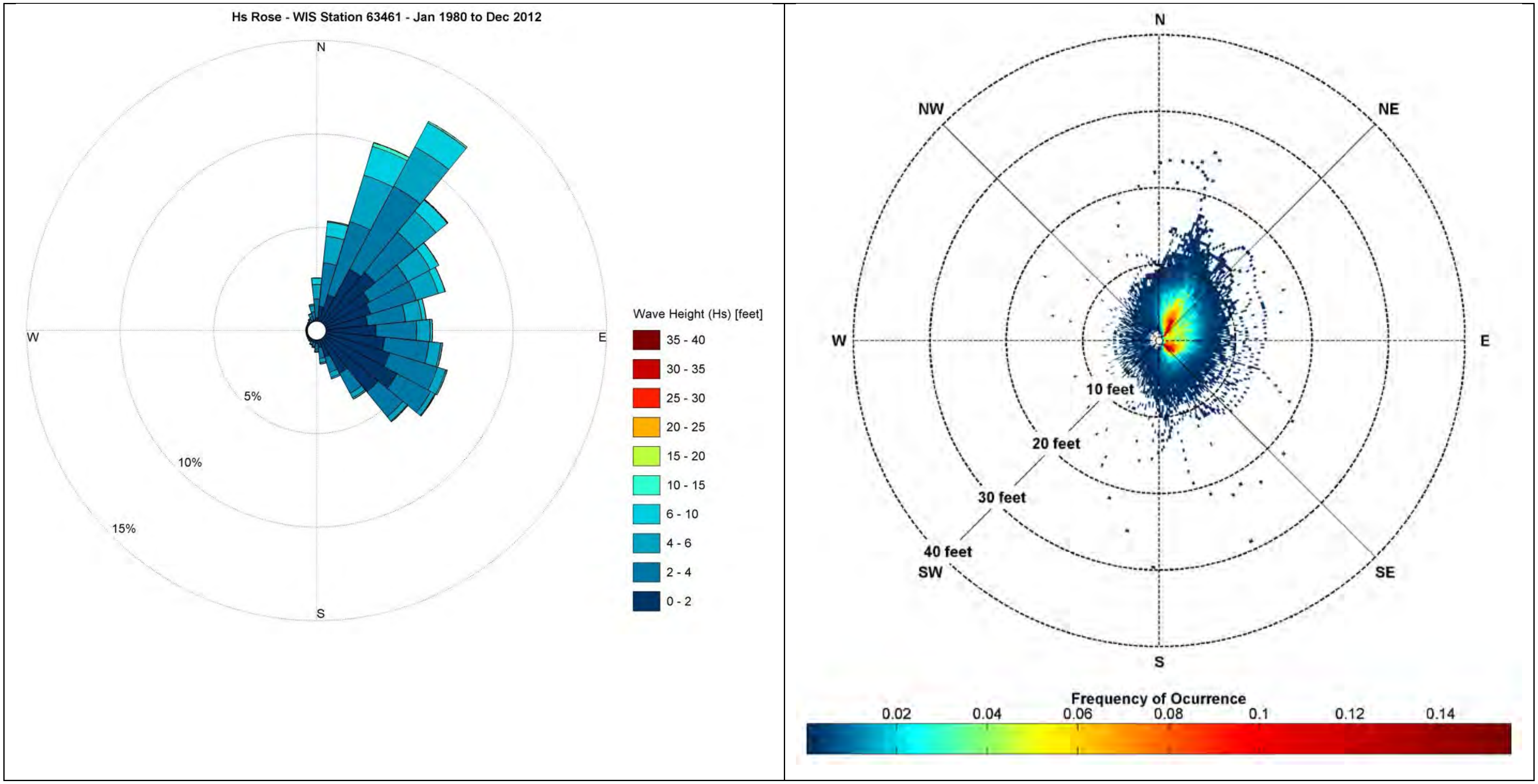

Figure 3-13. Directional wave statistics for WIS Station ST 63461 hindcast from January 1980 to December 2012.

3.5. Sediments

Sediments within the Project Area are a mixture of quartz and carbonate sands. The most recent sand samples over the entire Project Area were taken by Palm Beach County (1993). While several dune restoration projects have been constructed since that effort (see Table 3-4), no major beach nourishment projects have been constructed within the Project Area. Thus, the Palm Beach County (1993) samples were assumed to provide a reasonable characterization of the native sediments across the beach profiles (dry beach, surf zone, and submerged profile) as a whole. Based on the composite for profile lines R-124 to R-139 (Palm Beach County, 1993, p. 32), the mean grain size is approximately 0.36 mm (1.49ϕ), with a sorting value of 0.78ϕ, a silt content of 0.02%, and a carbonate content of 42%. However, it is noted that wave action has likely sorted out the finer sediments from the beach resulting in coarser sediment characteristics.

Table 3-4. Recent dune and beach nourishment projects.

Date	Volume (cy)	Extents	Sand Source
2003	1,000	R-135+460 to R-137+410	Upland
2005	3,132	R-135+460 to R-137+410	Upland
2005	5,814	R-135+460 to R-137+410	Upland
2006	141,458	R-116.5 to R-119-300; R-126 to R-127+100; R-129+200 to R-133+500	Offshore Borrow Area
2006	1,100,000	R-118+700 to R-126	Offshore Borrow Area
2007	6,750	R-135+460 to R-137+410	Upland
2008	11,000	R-135+460 to R-137+410	Upland
2009	10,000	R-135+460 to R-137+410	Upland
2011	56,000	Dune R-129 to R-133	Upland

3.6. Hardbottom

Hardbottom was incorporated into the Delft3D model by spatially varying the erodible sediment depth and sediment thickness based on physical measurements, survey data and aerial delineations. Erodible sediment depth is defined by an elevation fixed in time demarking the surface of the hardbottom such that erosion of sand cannot occur below this depth in the model. Sediment thickness varies with time based on the sand layer on top of the hardbottom resulting from model simulations. To develop the erodible sediment depth, the following steps were taken:

1. The hardbottom database was acquired from the Palm Beach County's Department of Environmental Resources Management. This database was distributed in the form of a Shape File outlining hardbottom areas appearing in the 1993, 2000, 2001, 2003, 2004, 2005, 2006, 2007, 2008, and 2009 aerials. Blue Kenue 3.3.4 was used to convert the hardbottom information into a plain-text file listing the years and coordinates of each outcropping. The database has been used by the County to assess natural habitats and permit coastal projects. In addition, the 2000-2009 mappings have been incorporated into the Beach Management Agreement dataset administered by the FDEP.

2. To supplement the information above:

    - Post-Hurricane Jeanne hardbottom areas were digitized from aerial photographs taken in January 2005 and March 2005.

    - Nearshore hardbottom areas were digitized from December 2002 aerials provided by the U.S. Geological Survey (USGS) Earth Explorer. These hardbottom areas were combined with 2002 offshore hardbottom mapping provided by the Florida Fish and Wildlife Conservation Commission (FFWCC, http://ocean.floridamarine.org/mrgis/Description_Layers_Marine.htm).

    - The 1993 hardbottom mapping from FFWCC was combined with the 1993 hardbottom mapping from the Palm Beach County database.

    - Vertical relief measurements of hardbottom habitat in the Project Area from R-130 to R-143 were collected in January 2009, April 2009 and April 2010 by Coastal Planning & Engineering, Inc. and CZR, Inc. (CPE, 2010a). Measurements were obtained along the nearshore and offshore edges of the hardbottom formation. These measurements along the edges were not be the highest relief areas within the formation, but provided “ground truth” data at the locations sampled. Measurements from the sand bottom to the top of hardbottom edges ranged from 1 cm to 65 cm (0 to 2 feet).

- The March 2012 hardbottom mapping was digitized from March 2012 aerial photographs flown by Aerial Cartographics of America on behalf of the Town of Palm Beach and FDEP. The quality of the photographs and the water clarity during the flight date was sufficient for this purpose.

- The July 2013 hardbottom delineation was digitized from July 25-26, 2013 aerial photographs flown by Woolpert, Inc. on behalf of Palm Beach County. The clear and shallow waters of the Study Area allowed the hardbottom resources to be delineated (CB&I, 2014).

- The Delft3D model sediment thickness layer and calibration was completed prior to the 2014 data becoming available. The 2014 data was reviewed and found to be within the extents of exposed hardbottom delineated by historical aerial interpretations. The sediment thickness layer and calibration was not altered during the additional modeling of the various grain sizes to maintain consistency with the initial modeling.

3. Bathymetries for the Flow & Morphology Grids from 1993 to 2009 were developed from the topographic and bathymetric surveys listed in Table 3-5. For each year’s hardbottom delineation, grid points within the respective hardbottom areas were identified. The elevations of the exposed hardbottom areas at those grid points were then estimated based on the concurrent survey. For example, the elevations of the exposed hardbottom in 2002 were based on the bathymetric grid surface drawn from the November 2002 LIDAR survey.

4. To further extend the hardbottom surfaces developed above, two additional data sources were used:

- The first reflector (seismic) mapping developed for the 2007 Town of Palm Beach borrow area investigation (Finkl, et al., 2008) was used. The seismic reflector is an indication of the first occurrence of bedrock beneath the sand. This remote sensing investigation provided data to fill the gaps between other data sets and expand the subsurface bedrock map.

- The minimum beach profile elevations of the beach profile envelope on FDEP profiles R-124 to R-137. The beach profile envelope consists of the area bounded by the maximum and minimum elevations found at distances along a profile throughout time. This was used to estimate erodible depth elevations where neither hardbottom information nor seismic data were available. The minimum beach profile elevation was developed using physical beach surveys and the Average Profile tool in Beach Morphology Analysis Package 2.0.

Using the methods and data sources listed above, several iterations of the erodible sediment depth and sediment thickness were developed as part of the morphology model calibration process, similar to CPE (2010a).

Table 3-5. Surveys Used to Estimate Hardbottom Outcropping Elevations in Feet NAVD88.

Hardbottom Mapping	Closest Survey Date(s)	Survey Data Sources*
1993	July-October 1990	FDEP - PB9008_CCC_1.PRF
2000	Fall-Winter 2000-2001	FDEP - PB0102_MAE_1.PRF
2001	August 2001	FDEP - PB0109_MAE_1.PRF
2002	Nov 2002 LIDAR	Tenix (2003)
2004	June 2004 LIDAR	USACE (2004)
Jan.-March 2005 (Post-Jeanne)	Nov 2004 LIDAR	USACE (2004)
2005	May-Aug. 2005	CPE (2005) FDEP - PB0507_MAE_1.PRF
2006	May 2006: Project Area April 2006: Nearshore R-124 to R-134 Jan-Feb 2006: Remaining Areas	Sea Diversified (2006) Bean-Stuyvesant (2006) USACE (2006)
2007	May-Sept 2007	CPE (2007d) FDEP - PB0709_MAE_1.PRF
2008	Sept-Dec 2008	Sea Diversified (2008) CPE (2009) FDEP - PB0809_BLI_1.PRF
2009	October 2009	FDEP - PB0909_BLI_1.PRF
2012	Jan 2012 and Sept-Nov 2011	FDEP - PB1109_SDI_1.PRF ATM (2012)
2013	July 2013	ATM (2013)

*NOTE: The FDEP surveys are taken from the FDEP Historic Shoreline Data / Profile Data database, ftp://ftp.dep.state.fl.us/pub/water/beaches/HSSD/ProfileData/prof839088/ PALPZ.ZIP.

3.7. Existing Structures and Features

Seawalls – The locations and elevations of the existing seawalls were verified based on the March 2012 aerial photograph, the Town of Lantana Seawall drawings by Taylor Engineering (2009), and the beach profile surveys listed in Table 3-2.

In the SWAN model, the seawalls were treated as vertical walls with finite heights (“dams”) ranging from +12.4 to +18.7 feet NAVD88. The overtopping coefficients α = 1.8 and β = 0.1 were equal to the recommended values for vertical walls (Deltares, 2011b). Reflection coefficients were assumed to be equal to 20%, similar to CPE (2010, 2011). In the Delft3D-FLOW model, the seawalls were treated as “thin-dams” that prevented flow from occurring through or over the structures regardless of water level.

Lake Worth Pier – As shown in Figure 3-14, the Lake Worth Pier has a localized influence on the shoreline shape. Accordingly, several representations of the Lake Worth Pier in the model were examined.

Figure 3-14. January 24, 2009 Aerial Photograph of the Lake Worth Pier.

The final calibration run identified the Lake Worth Pier as a structure with a permeability of 85% for modeling purposes. In the SWAN model, the pier was treated as a "sheet" of infinite height with transmission coefficients of 0.85. In the Delft3D-FLOW model, the pier was treated as a "porous plate", or a partially transparent structure that extends into the flow along one of the grid directions, with a thickness that is smaller than the grid size in the direction normal to the porous plate. Unlike other types of structures in the Delft3D-FLOW model, mass and momentum can be exchanged through the porous plate.

Phipps Ocean Park South Borrow Area – The borrow area located south of Lake Worth Pier is represented in the model. The borrow area is located approximately 2,000 to 3,200 feet offshore at R-133 as shown in Figure 3-15. According to spatial resolution of the grid domain in this area, the edges of borrow were slightly smoothed, but in general was well represented in the numerical domain. Figure 3-16 illustrates the borrow area representation in plan view.

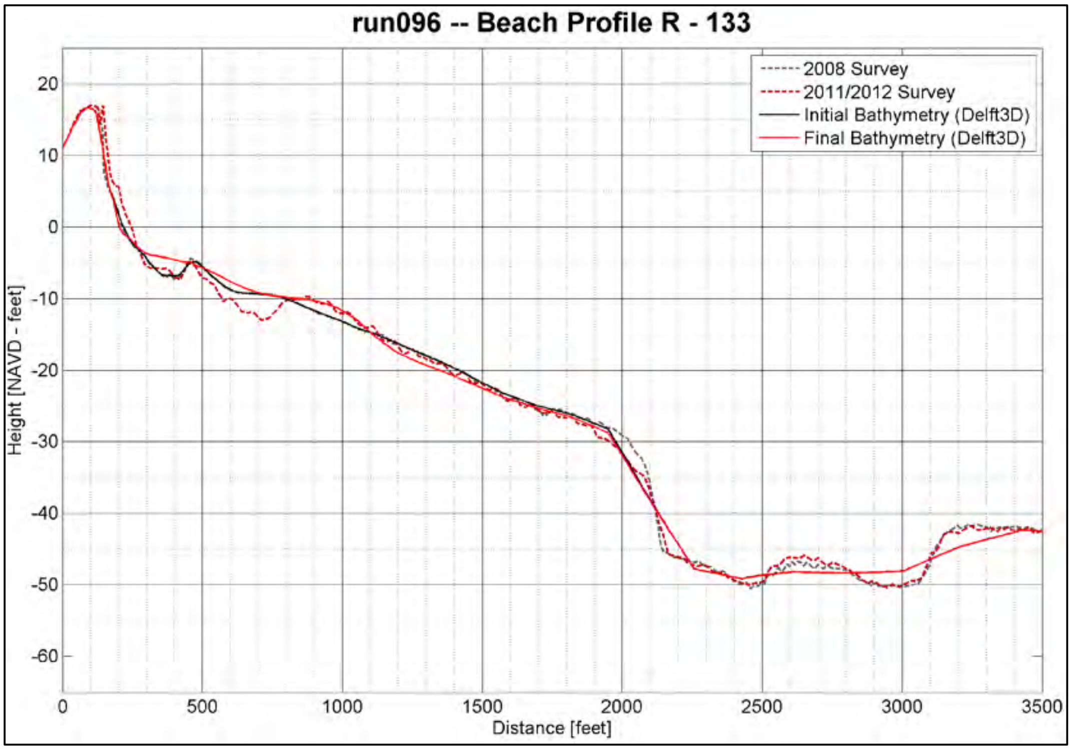

Figure 3-15. Representation of Phipps Ocean Park borrow area in numerical domain, profile from monument R-133.

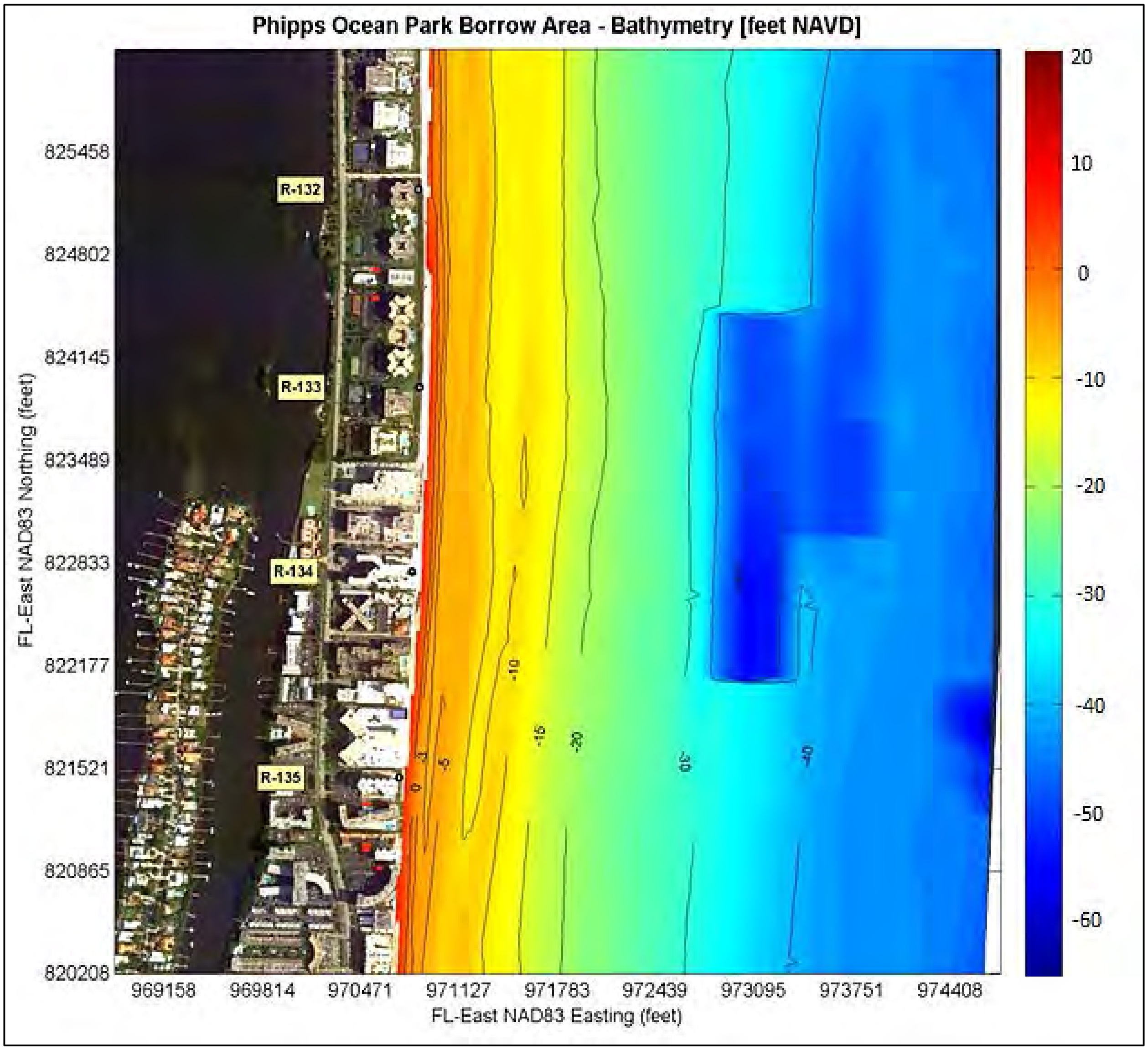

Figure 3-16. Plan view representation of Phipps Ocean Park borrow area bathymetry.

4.0 MODEL CALIBRATION

Calibration of the Delft3D model was completed in two main parts: first, through comparison and calculated hydrodynamics and secondly through comparison of morphologic changes. After the model calibration was performed, it was expected for the model to produce a close representation of the measured sediment transport and the measured morphologic changes.

4.1. Updated SWAN and Delft3D-FLOW Model Calibration

Calibration of the SWAN model was performed using wave measurements collected near the Project Area in 2008 (CPE, 2010b). SWAN model was calibrated primarily in terms of the JONSWAP bottom friction value (C_{jon}). Four values of C_{jon} were examined – the default value (0.067), a lower value (0.05), and two higher values (0.1 and 0.2). Setting the friction value to 0.2 led to the best fit between the observed wave heights and the simulated wave heights at the Offshore ADCP (Figure 4-1). The simulated waves also compared favorably with the observed waves at the Nearshore ADCP given C_{jon} = 0.2 (Figure 4-2).

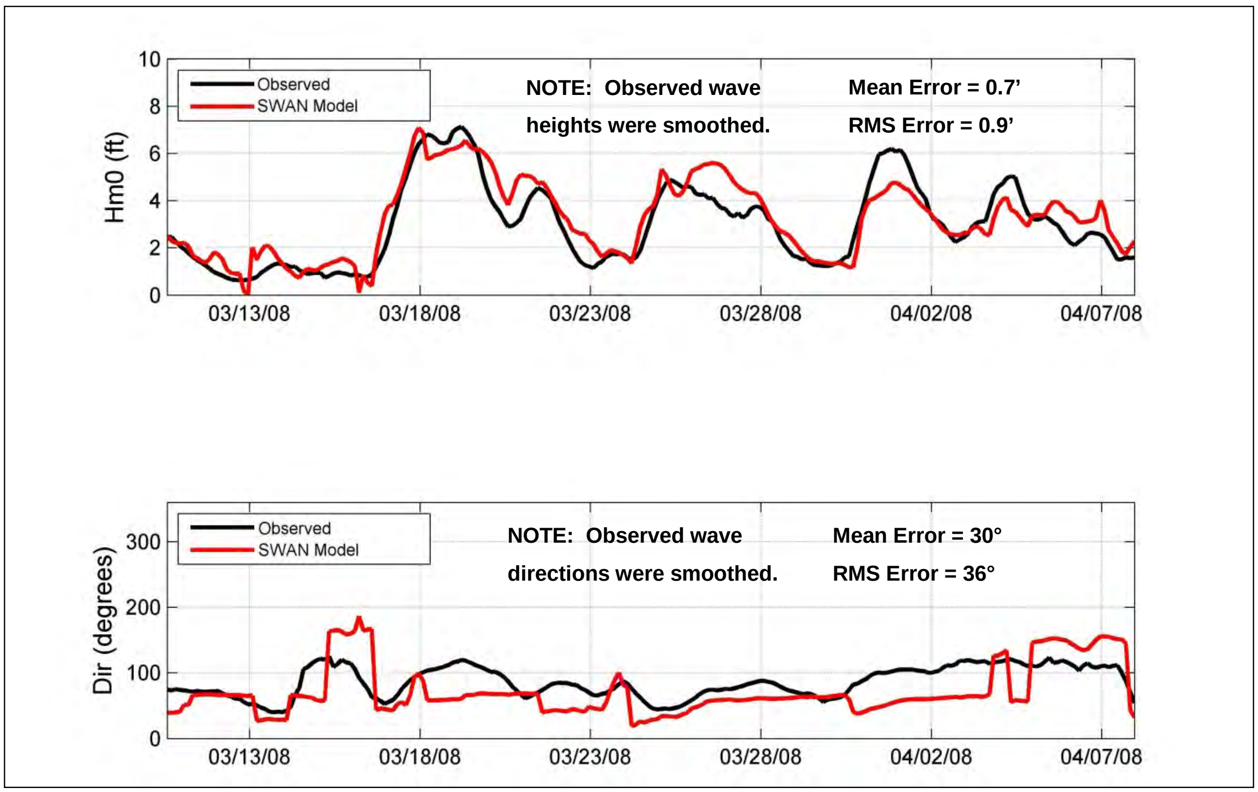

Figure 4-1. Simulated and Observed Waves at the Offshore ADCP given C_{jon} = 0.2 (CPE, 2010b).

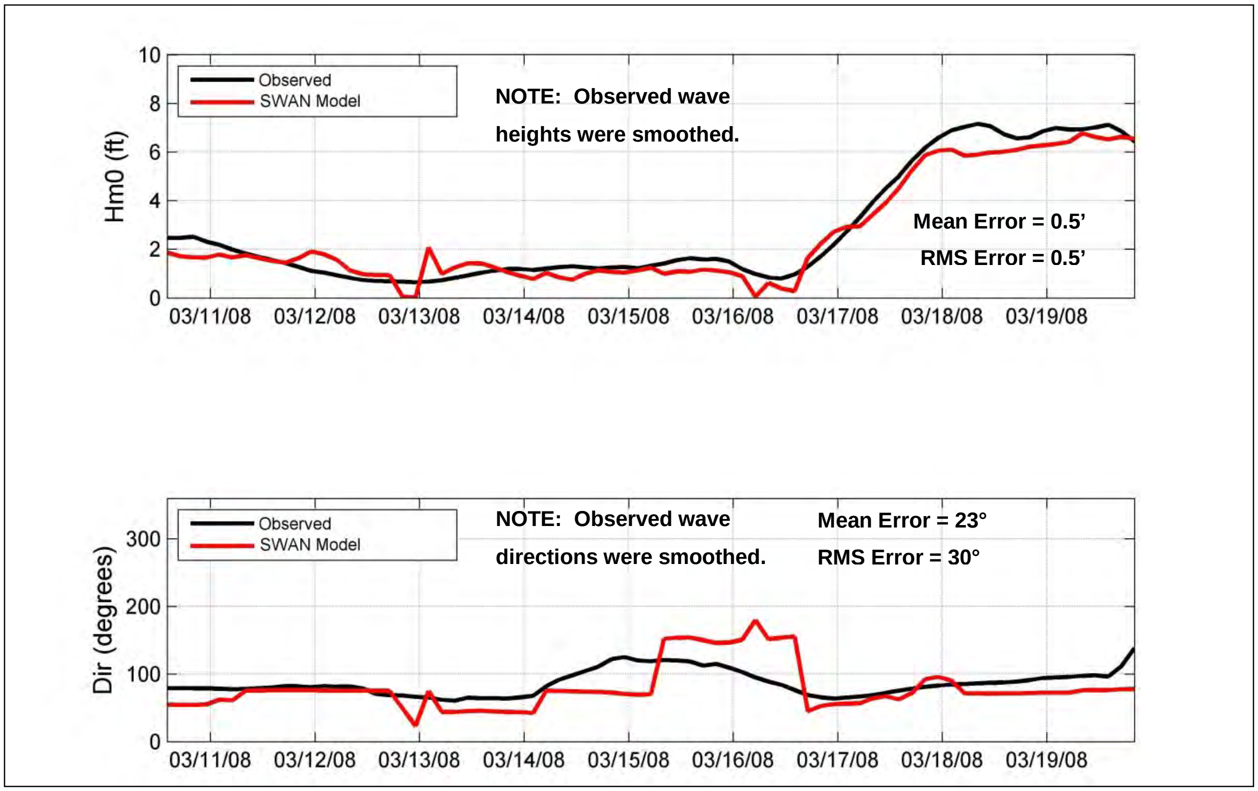

Figure 4-2. Simulated and Observed Waves at the Nearshore ADCP given Cjon = 0.2 (CPE, 2010b).

Following the calibration of SWAN model, 47 simulations were conducted in previous studies (CPE, 2010a) to calibrate the patterns within Delft3D-FLOW. The flow parameters used in the Delft3D-FLOW model were set to the values recommended by Deltares (2011) as detailed in Appendix 2 of CPE (2010b). As part of the model calibration process, longshore current velocities were reviewed to ensure that the currents were reasonable under the wave cases being utilized in the SWAN and Delft3D-FLOW models. Additional details regarding the SWAN model calibration appear in CPE (2010b).

4.2. Morphology Calibration

4.2.1. Hypercube Method for Estimating Nearshore Waves

The WIS hindcast Station (Station 63461) data was used for morphology calibration. The dataset includes both wind and wave data. A concurrent wave record in nearshore regime was developed using Delft3D and Hypercube Method. This nearshore record was called the Hypercube Output Location and located in a water depth of approximately 57 feet as shown in Figure 4-3. The Hypercube Method is briefly described below.

Due to the long time period (32 years) of wave data, modeling the wave record at a 3-hour time step using SWAN is computationally time intensive. As an alternative, the Hypercube technique developed by the Environmental Hydraulic Institute of the University of Cantabria, Spain (Instituto de Hidraulica Ambiental de la Universidad de Cantabria - IH Cantabria) was used. This Hypercube method suggests simulating a large number of deep water wave cases in SWAN using different combinations of wave height, period, and direction that cover the entire ranges of these parameters. The nearshore wave field for all the offshore wave data record can be constructed using three-dimensional ("cube"), linear interpolation based on the SWAN results for each wave case (see Figure 4-4). This procedure is similar to the lookup method used to couple GENESIS to an external wave transformation model (Hanson & Kraus, 1989, p. 74). However, the number of wave cases in this study is much larger – the total number of wave cases summarized in Table 4-1 is 1,111 (Figure 4-5).

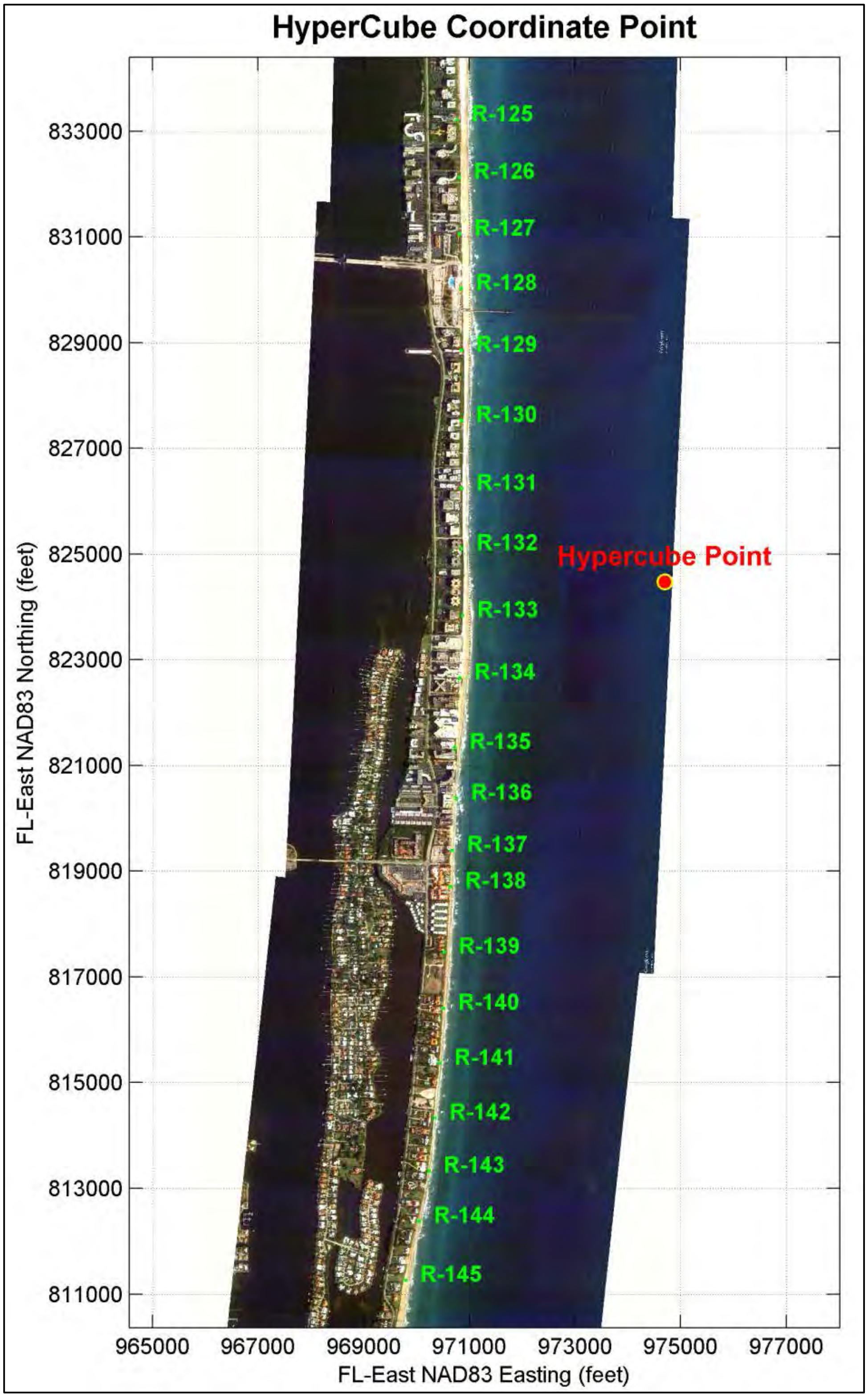

Figure 4-3. Location of Hypercube Output.

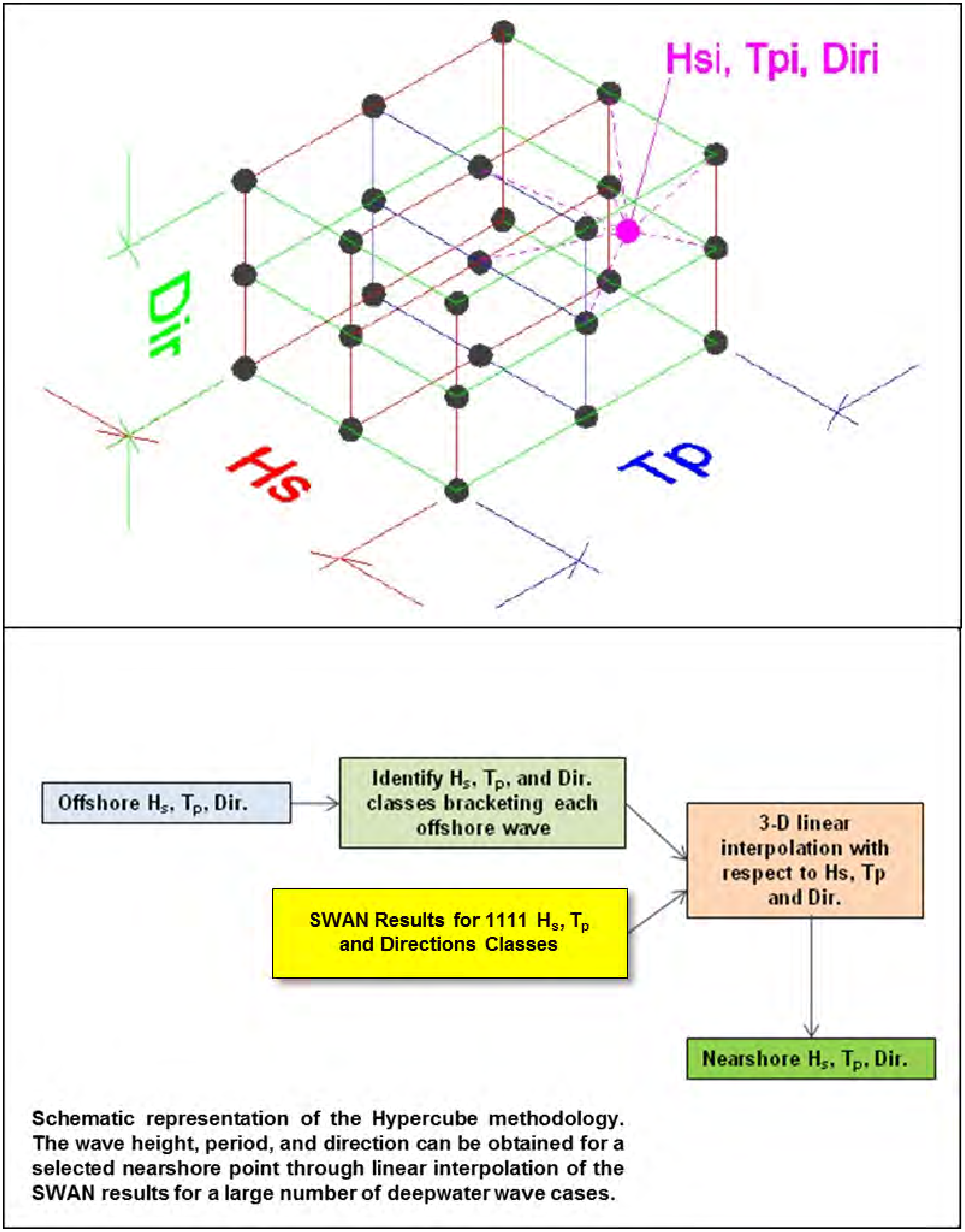

Figure 4-4. Schematic representation of the Hypercube methodology.

Table 4-1. Summary of Hypercube Wave Cases at WIS Station ST 63461.

Sign. Wave Height		Peak Wave Period	Wave Direction
(m)	(feet)	(sec.)	(deg.)
0.5	1.6	2	0.0
1.0	3.3	3	22.5
1.5	4.9	4	45.0
2.0	6.6	5	67.5
2.5	8.2	6	90.0
3.0	9.8	7	112.5
3.5	11.5	8	135.0
4.0	13.1	9	157.5
4.5	14.8	10	180.0
5.0	16.4	11	202.5
5.5	18.0	12	225.0
6.0	19.7	13	247.5
6.5	21.3	14	270.0
7.0	23.0	15	292.5
7.5	24.6	16	315.0
8.0	26.2	17	337.5
8.5	27.9	18	360.0
9.0	29.5	19	
10.0	32.8	20	
10.5	33.4		

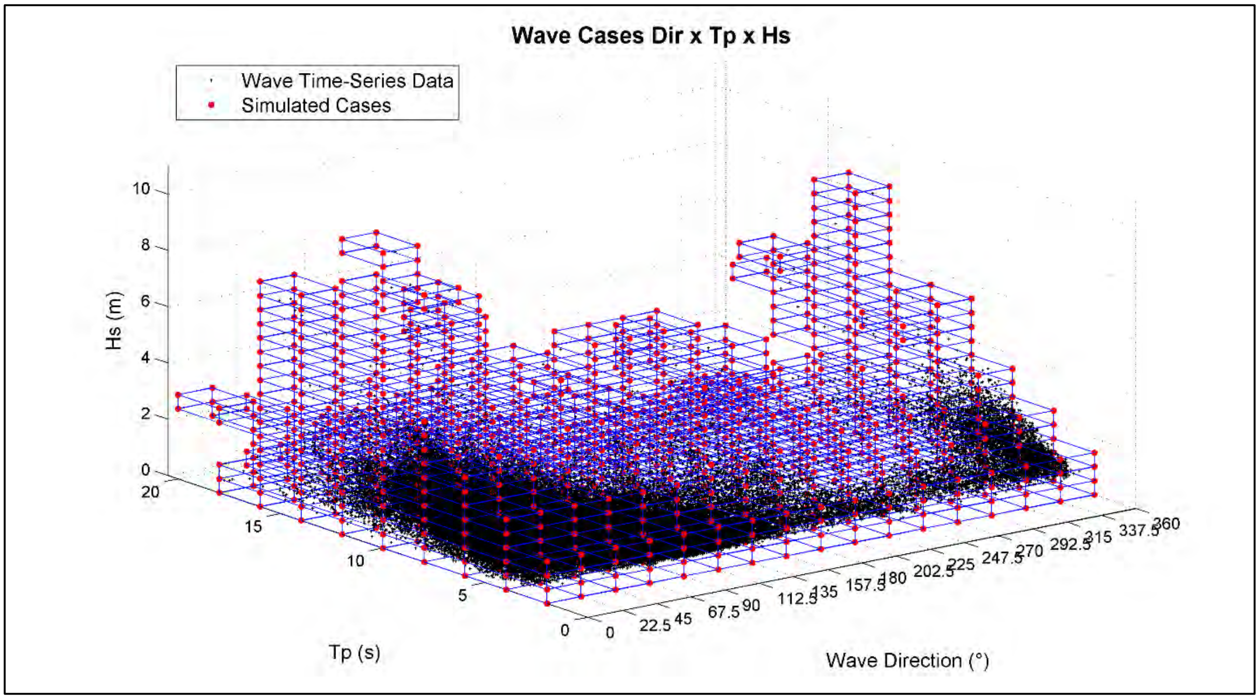

Figure 4-5. 3D plot of waves cases selected of WIS Station ST 63461.

Each of the 1,111 wave cases was then run through the SWAN model to determine the corresponding wave height, period and direction at the Hypercube Output Location. The SWAN model was run in stationary mode, which assumed that changes to the waves with respect to time were slow in comparison to the time required for a wave to travel the lengths of each grid. The multi-year wave record of WIS Station 63461 and the SWAN model results were then fed into the lookup and interpolation algorithm in Figure 4-4 to estimate the concurrent wave heights, periods and directions at the nearshore Hypercube Output Location.

Figure 4-6 presents the directional diagram frequency for the reconstructed data of wave height and wave period at the Hypercube Output Location. The reconstructed data resulted in high frequency waves at a height of 2 feet coming from northeast to southeast, while waves up to 4 feet in height dominated the northeast quadrant. The largest wave height recorded at the Hypercube Output Location had height of 16 feet from quadrant ESE. The northeast quadrant was characterized with wave periods ranging from 4.5 to 13 seconds. Waves from east and southeast had two dominant bands of wave periods ranging between 4-5 seconds and between 9-10 seconds.

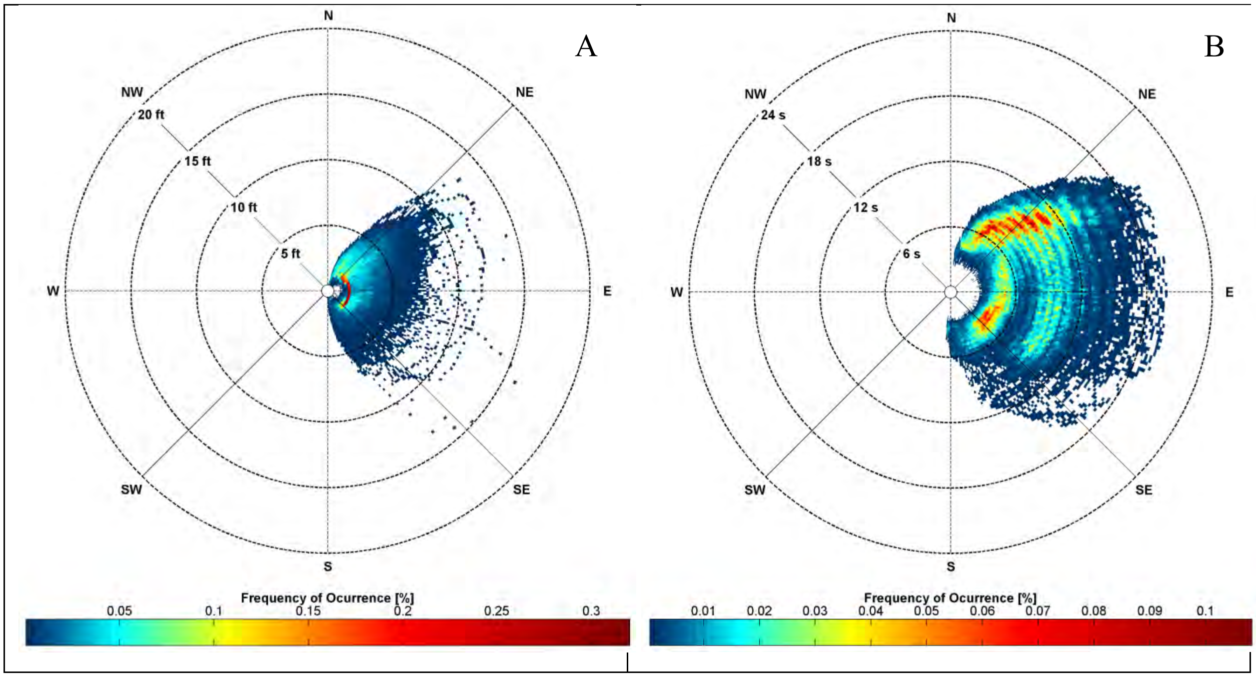

Figure 4-6. Directional diagram frequency to wave height [feet] (A) and wave period [s] (B) on Hypercube Output Location for 32 year time series.

4.2.2. Wave and Wind Cases

For morphological calibration and production runs, wave cases nearshore obtained with Hypercube were selected based on the wave energy flux:

$$E_p \approx 1.56\, T_p \rho g H_s^2 / 16$$

where

E_p = energy flux

T_p = peak wave period (seconds)

ρ = sea water density (1,025 kg/m^3)

g = gravitational acceleration (9.81 m/s^2)

H_s = significant wave height (m)

Based on the estimates above, the offshore direction bands generating 95% of the nearshore wave energy were identified, as shown in Figure 4-7. Waves originating from the north (5°) to the east-southeast (155°) of combined WIS Station ST 63461 accounted for approximately 95% of the wave energy reaching the nearshore Hypercube Output Location.

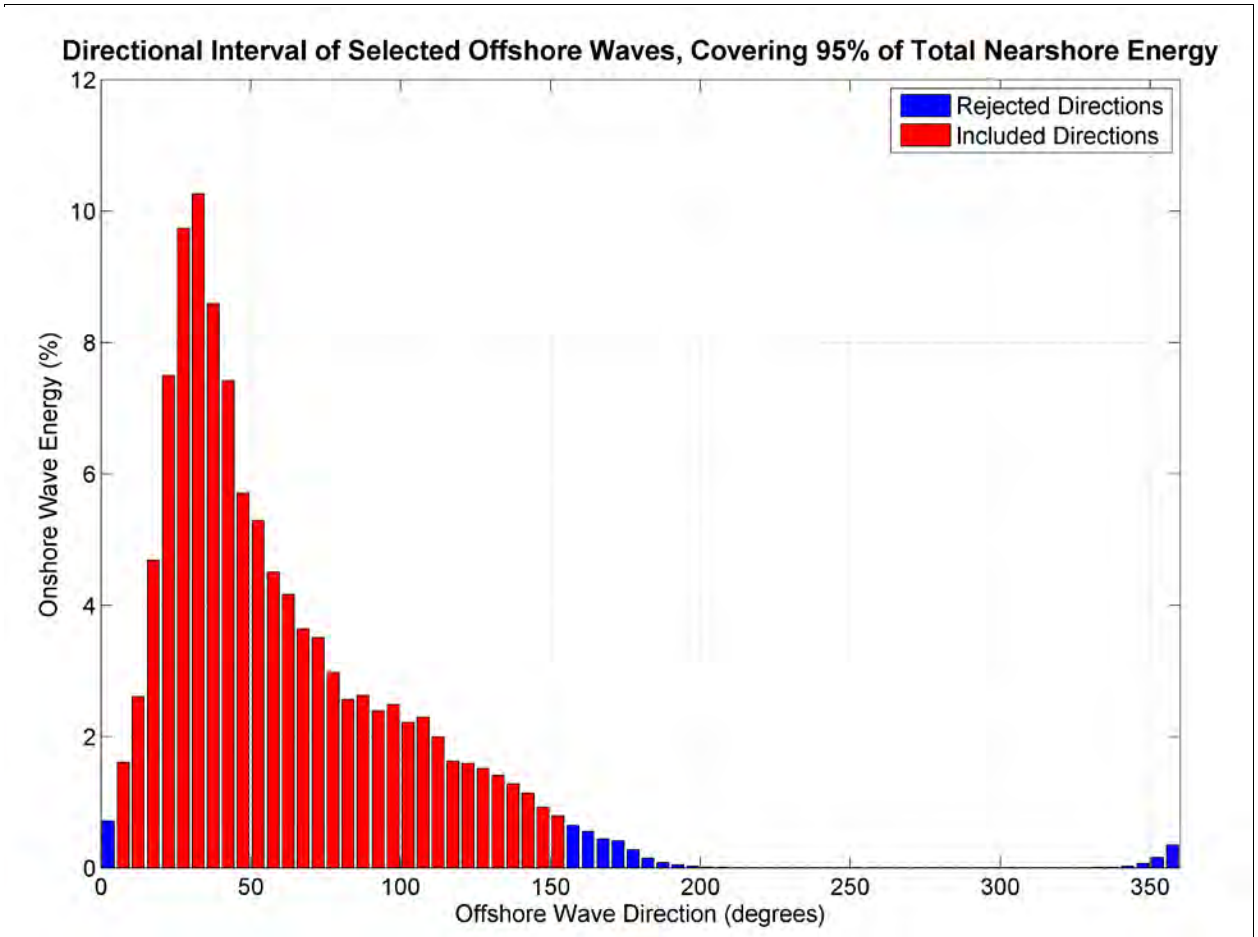

Figure 4-7. Wave record of combined WIS Station ST 63461 generating 95% of the wave energy at the nearshore Hypercube Output Location.

After selecting offshore wave cases that covers 95% of total nearshore energy, 6 directional bins were delineated. Each directional bin offshore represented a nearly equal amount of wave energy in shallow water; the 6 bins combined represented 95% of the shallow water wave energy in KW-h/m. Each of the 6 directional bins were further divided into 3 height classes, with each height class representing nearly equal amounts of wave energy in shallow water. This procedure resulted in 18 wave cases, which are presented in Figure 4-8 and Figure 4-9 and listed in Table 4-2. An additional wave case was developed representing calm conditions and times during which the predominant wave directions were towards offshore (from land to sea). Wind velocities during each wave case were averaged from the concurrent winds during each wave case at offshore location, and were assumed to be uniform over the model grids. The wave cases were organized by directional class (left to right) and increasing significant wave height within each class as shown in Figure 4-8. To avoid situations where one wave case is simulated following another wave case from the same direction, the 18 wave cases were rearranged and modeled in the order shown in Table 4-2. Alternating the wave cases allows the beach to reestablish equilibrium before subsequent wave cases from a given directional class. Repeated wave cases from the same direction without calm periods may result in morphological changes that become irreversible within the model.

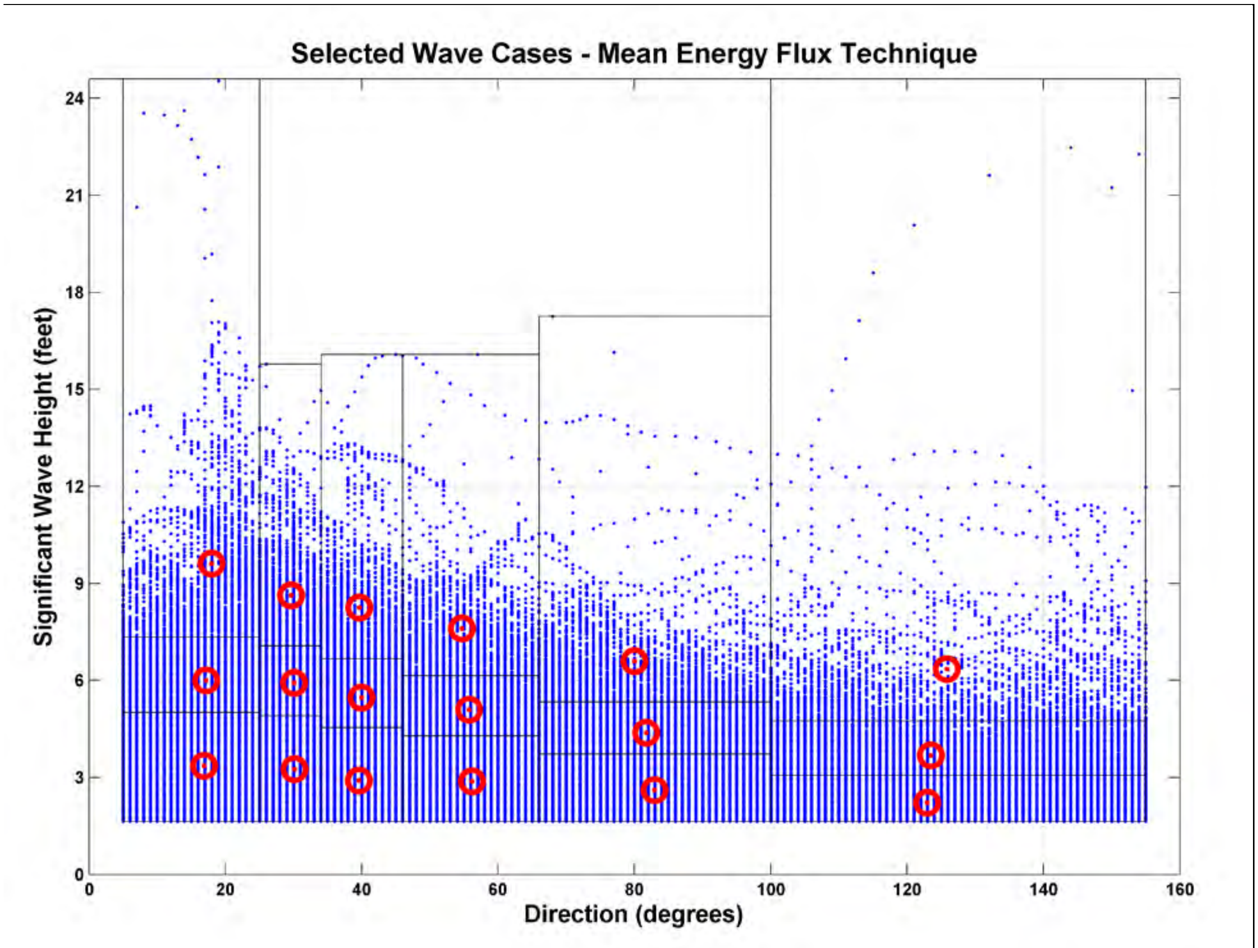

Figure 4-8. Selected wave cases using the mean energy flux technique.

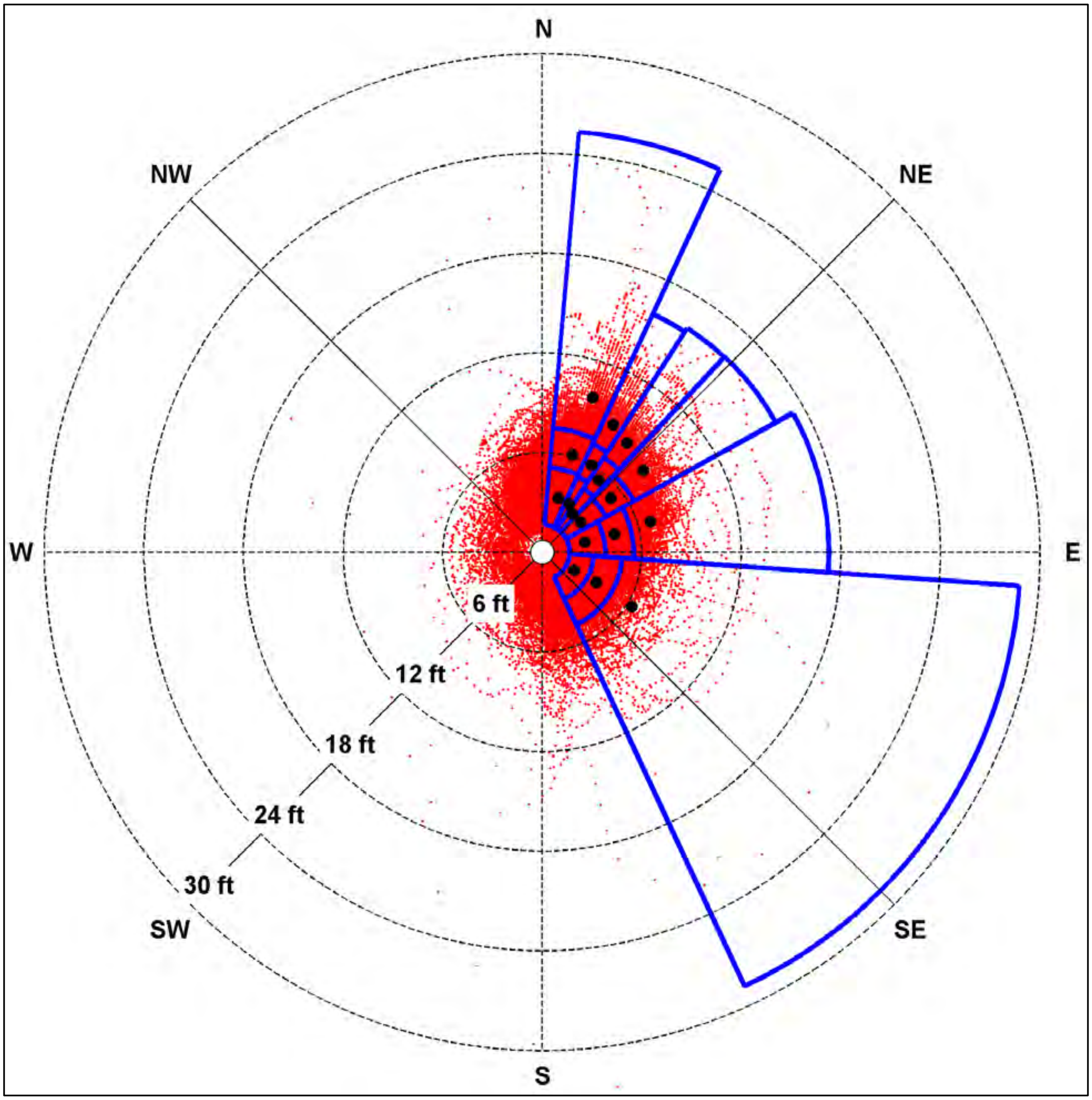

Figure 4-9. Selected wave cases using the mean energy flux technique.

Table 4-2. Wave cases selection for morphological calibration of South Palm Beach, FL.

Wave Case	Hs (feet)	Tp (sec.)	Wave Dir. (°)	Dir. Spread-ing (°)	Wind Speed (feet/s)	Wind Dir. (°)	Percent Occur. In One Year	Days in Model in One Year	Morfac (Calibration)
#1	2.92	9.35	37.93	25.00	8.11	5.12	5.52%	20.15	38.95
#2	3.72	5.64	119.07	4.00	20.98	2.14	4.11%	15.02	29.03
#3	9.78	10.09	18.06	25.00	30.40	359.45	0.93%	3.39	6.55
#4	6.03	10.10	29.55	25.00	18.60	49.36	1.53%	5.58	10.78
#5	6.77	6.98	74.42	15.00	30.54	45.22	1.11%	4.04	7.8
#6	5.23	7.80	51.83	15.00	24.29	43.27	1.84%	6.71	12.97
#7	3.40	7.60	16.90	15.00	13.28	78.74	8.26%	30.16	58.29
#8	8.34	9.87	37.90	25.00	30.69	67.54	0.67%	2.45	4.74
#9	2.23	5.30	119.89	4.00	15.10	61.35	11.75%	42.88	82.89
#10	6.11	8.72	17.13	25.00	22.68	87.42	2.44%	8.91	17.23
#11	6.30	6.51	121.16	15.00	28.66	78.31	1.17%	4.27	8.25
#12	2.65	7.01	77.08	15.00	15.82	75.02	7.45%	27.18	52.53
#13	8.77	10.84	29.20	25.00	27.66	99.22	0.70%	2.56	4.94
#14	5.52	9.58	38.03	25.00	20.76	95.84	1.57%	5.73	11.08
#15	3.32	8.78	29.61	25.00	7.86	95.78	5.31%	19.39	37.48
#16	7.81	8.56	51.10	25.00	32.37	132.86	0.75%	2.73	5.29
#17	4.49	6.51	76.13	15.00	23.65	138.21	2.91%	10.64	20.56
#18	2.91	8.36	52.20	25.00	12.98	136.62	5.43%	19.81	38.29
#CALM	0.98	6.00	20.00	15.00	6.56	20.00	36.55%	133.40	257.85

4.2.3. Morphological Acceleration Factors

To decrease the time needed for the morphological computation, morphological acceleration factors were used, as described in Lesser et al (2004) and Benedet and List (2008). The preliminary morphological acceleration factor M (Table 4-2, last column) was estimated according to the following:

$M = T_{study\ period} / T_{model\ period}$

where

$T_{study\ period}$ = (length of the study period) x (percent occurrence for each wave case)

$T_{model\ period}$ = duration of the wave case in the model simulation

For example, a wave case that occurs 14 days a year can be simulated over 24 hours with an M value of 14. It is common practice between Delft3D users to use lower M values for high wave cases, when the most significant morphological changes occur, and higher M values for smaller wave cases, where little change takes place.

4.2.4. Morphological Tides

Besides schematized wave cases, the tides must also be schematized to run the morphological model. The main purpose of reducing tidal data is to replace the complex pattern of the real tide in the Study Area by a simplified tide, also called morphological tide. The morphological tide produces the same residual sediment transport and morphological pattern of changes that the actual tide produces (LESSER, 2009).

Tidal data reduction to a sinusoidal tide with constant periodicity allows each wave case to be propagated by at least one full tidal cycle. Thus, all wave cases are influenced by the same tidal amplitude and phase.

The methodology of reduction used in this study considers a tidal wave with semi-diurnal cycle, equivalent to the lunar main component M2 (12.42107 hours or 745 minutes) and amplitude varying between MLW and MHW, oscillating around MSL.

4.3. Results of Morphological Calibration

Calibration of sediment transport, erosion and deposition within Delft3D-FLOW model was performed in terms of the volume, profile changes, and morphologic changes during the 3.3 year period between the September/October 2008 and January 2012 beach surveys. The sediment transport was also evaluated. A total of 98 test simulations and calibration runs were conducted to identify the parameters best suited to simulating the general erosion pattern along the Study Area. To improve the fit between the model results and the observed changes, the model was run with 5 vertical layers and the parameters listed below were examined. The selected values for the parameters are presented in Table 4-3.

- Vertical Eddy Viscosity and Eddy Diffusivity: The Delft3D-FLOW model has four types of turbulence formulations used to determine the vertical turbulent eddy viscosity and the vertical turbulent eddy diffusivity. The types of formulations are: Constant, Algebraic, K-L, and K-epsilon. If the constant turbulence model is selected, the background values are applied throughout the model domain. In all the other cases, the uniform values are used as the minimum value for the turbulent contribution (Deltares, 2011). This model was run using the K-epsilon formulation in which the coefficients are determined by the transport equations for both the turbulent kinetic energy and the turbulent kinetic energy dissipation. Therefore the input values for eddy viscosity and diffusivity were set to the minimum value (vertical eddy viscosity = 0; vertical eddy diffusivity = 0).

- Horizontal Eddy Viscosity and Eddy Diffusivity: These two values govern the horizontal, diffusive spreading of momentum and materials, respectively. Higher values of either parameter increase the degree of diffusive spreading. In the case of eddy diffusivity, increased spreading of material results in smoother bathymetric contours. Also, eddy diffusivity parameter is used to control the formation / destruction of bars in zone surf area.

- Sediment layer thickness at bed: In Delft3D it is possible to define space varying erodible areas, and this feature is very useful in areas with hardbottom (that are not erodible) and in areas with different thickness of sediment available to be eroded. When the sediment thickness is set equal to zero in hardbottom areas, it means the model won't erode but will be able to deposit above hardbottom. Final sediment layer thickness chosen for morphological calibration is presented in Figure 4-10.

- Bottom roughness: In order to better represent current patterns generated by hardbottom friction, different Chézy values were tested. A lower Chézy value was used in the areas mapped as hardbottom in order to increase bottom friction represented by the model.

- BED & SUS: These two values govern sediment transport due to currents, including wave-driven currents. Of the various constants in the Delft3D-FLOW model, these values have the largest influence on the sediment transport, erosion, and accretion rates. The values typically range from 0.5 to 2.0.

- BEDW & SUSW: These two values govern the sediment transport associated with the orbital motions that waves generate over the water depth at a given location. Higher values of BEDW and SUSW tend to increase onshore-directed sand transport and nearshore bar formation. Typical value of BEDW & SUSW range from 0 to 0.3.

The primary objective of the Morphology Calibration is to replicate the general trends (qualitative) and overall magnitude (quantitative) of sediment transport within the project area. Considering that the results of this analysis will be used for evaluation of potential impacts to hardbottom, the overall patterns of sediment migration were evaluated in addition to volumetric changes.

In general, the following are the calibration objectives:

- Calibration of modeled volume changes by profile line compared to measured changes within a reasonable range associated with survey error and model resolution.
- Validation of sediment transport trends through comparison of volume change magnitudes updrift, downdrift and within the project area.
- Comparison of observed and simulated beach profiles to assess general cross-shore processes and morphologic features such as and bars and troughs.
- Comparison of observed and simulated morphologic changes over time to assess the model's skill at replicating general sedimentation and erosion patterns.

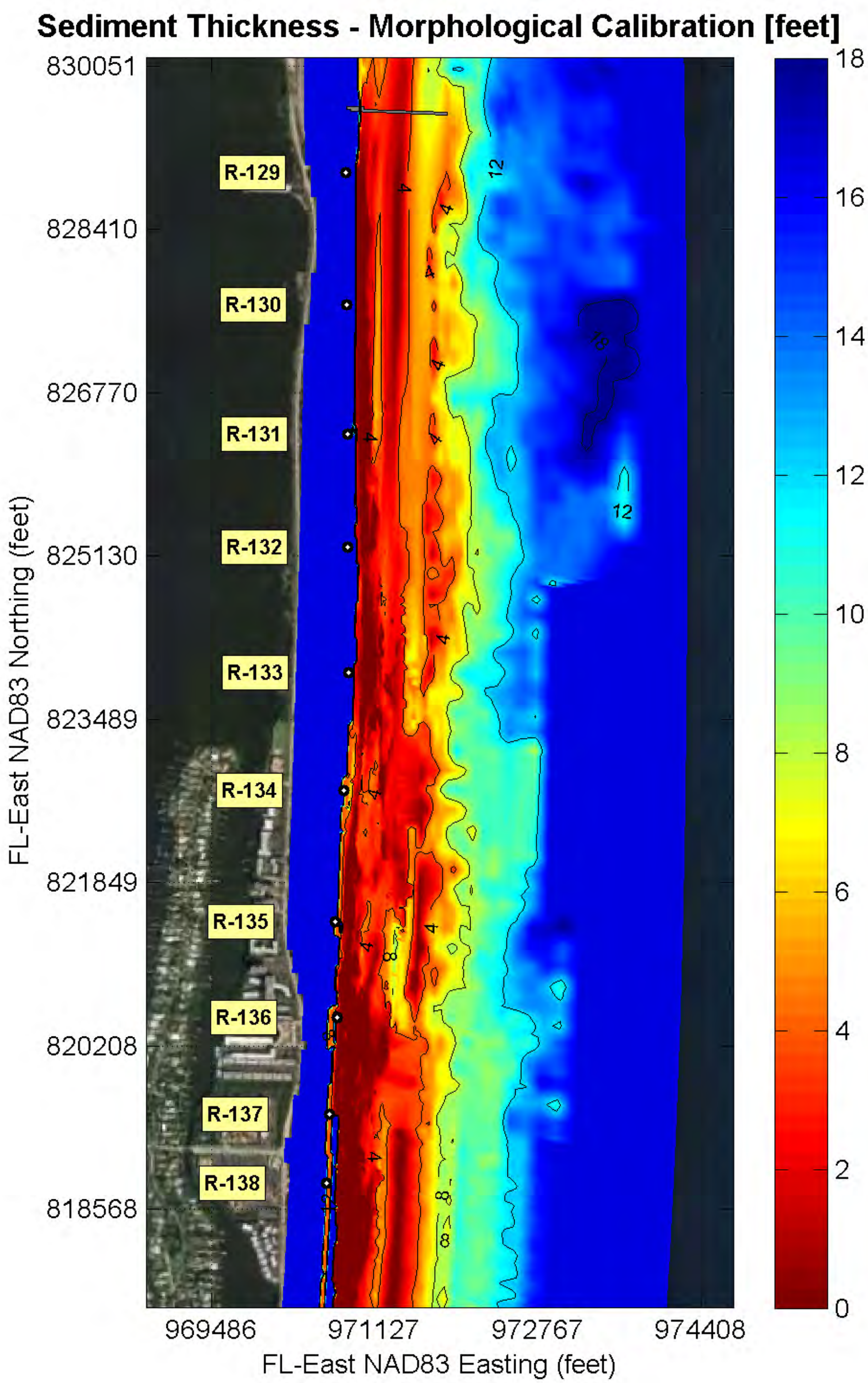

Figure 4-10. Sediment layer thickness used in morphological calibration.

Table 4-3. Summary of final calibration parameters used in morphology model.

	Min.	Default	Max.	Selected Value
SWAN Wave Transformation Model Parameters:				
Breaking Parameter γ (Hb/db)	0.55	0.73	1.20	0.73
Breaking Parameter α	0.1	1.0	10.0	1.0
Bottom Friction Coef. for Waves (Optional):				
JONSWAP Friction Value (m^2/s^3)	0.000	0.067	None	0.2
Collins Friction Value	0.000	0.015	None	Not used
Madsen Roughness Scale (m)	0.0000	0.0500	None	Not used
Triads - Energy Transfer from low to high frequencies in shallow water	-N/A-	Off	-N/A-	Off
Diffraction	-N/A-	Off	-N/A-	On
Wind Growth	-N/A-	On	-N/A-	On
JONSWAP Peak Enhancement Factor (for input waves specified in terms of height, period, and direction)	-N/A-	3.3	-N/A-	1.08
Delft3D-FLOW Model, Flow Parameters:				
Bottom Friction Coef. for Flow:				
Chezy's Friction Coef. C	0	65	1000	65
Manning's n	0.000	None	0.040	Not Used
Horiz. Eddy Viscosity (m^2/s)	0	10	100	10
Vertical Eddy Viscosity:				
Constant (m^2/s)	0	1×10^{-6}	100	Not used
Algebraic	-N/A-	-N/A-	-N/A-	Not used
K-L	-N/A-	-N/A-	-N/A-	Not used
K-Epsilon	-N/A-	-N/A-	-N/A-	Used

Table 4-3. (Cont.) Summary of final calibration parameters used in morphology model.

	Min.	Default	Max.	Selected Value
Delft3D-FLOW Model, Sediment Transport Parameters:				
Spin-up Interval - # of hours between the start of the simulation and the initiation of erosion & deposition estimates	0	6	None	12 hr
Density of sediment grains (kg/m^3)	100	2650	4000	2650
Dry bed density (kg/m^3)	Sand 500	Sand 1600	3000	1600
Median Grain Size (mm)	0.064	0.200	2.000	0.36
Horiz. Eddy Diffusivity (m^2/s)	0	10	1000	1.5
Vertical Eddy Diffusivity (m^2/s)				
Constant (m^2/s)	0	1×10^{-6}	100	Not used
Algebraic	-N/A-	-N/A-	-N/A-	Not used
K-L	-N/A-	-N/A-	-N/A-	Not used

K-Epsilon	-N/A-	-N/A-	-N/A-	Used
Dry Cell Erosion Factor	0	0	1	0.5
BED - Current-Related Bedload Transport Factor (including wave-driven currents)	0	1	100	0.5
SUS - Current-Related Suspended Load Transport Factor (including wave-driven currents)	0	1	100	0.5
BEDW - Wave-Related Bedload Transport Factor	0	1	100	0.02
SUSW - Wave-Related Suspended Load Transport Factor	0	1	100	0.02

Final calibration run results for volume changes (Run 96) are presented in Figure 4-11. Overall, the calibrated Delft3D-FLOW model is best suited to estimating general trends, patterns and overall sediment transport magnitudes.

The volume curves show good agreement over the Study Area. Volume changes are within the margin of error, which were based on the uncertainty associated with hydrographic surveying. The modeled curve deviates less than 10 cy/foot/year from the measured values at monuments R-128 and R-130. During the calibration period, the section that showed greater erosive tendency on the order of 10 cy/foot/year between monuments R-134 and R-138 was captured by the model. In other sections, the magnitude of the modeled volumetric changes was consistent with observed changes during the calibration period.

Based on the volumetric changes from the morphological model calibration, a sediment budget was developed to validate the longshore movement of sand within the Study Area. The Study Area was divided into three sectors (boxes) as shown in Figure 4-12.

- Updrift – north of the Project Area defined between R-127 and R-129-210
- Project Area – defined between R-129-210 and R-138+551
- Downdrift – south of the Project Area defined between R-138+551 and R-141+586

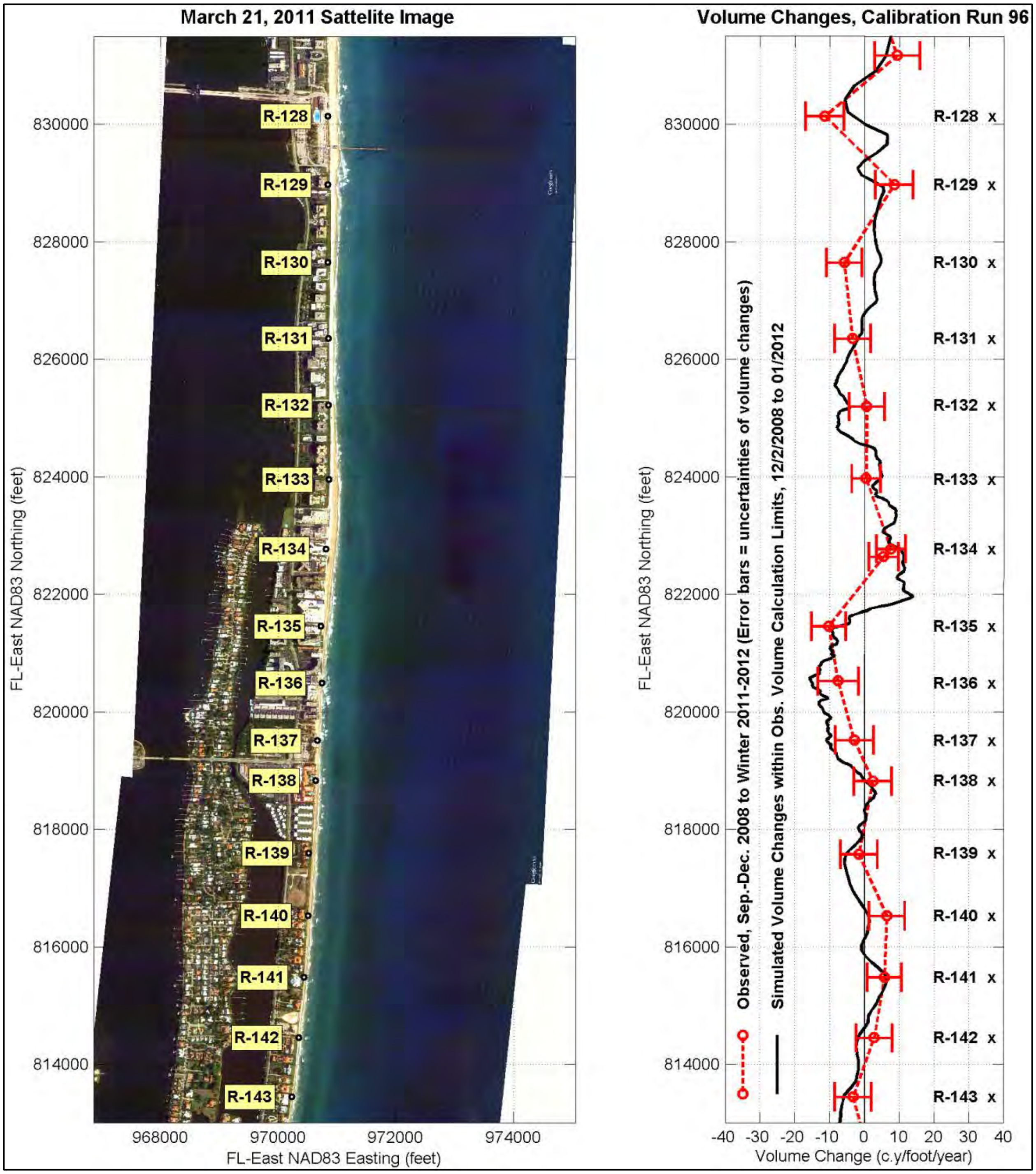

Figure 4-11. Simulated and observed volume changes between October 2008 and January 2012 given selected calibration run (Run 96).

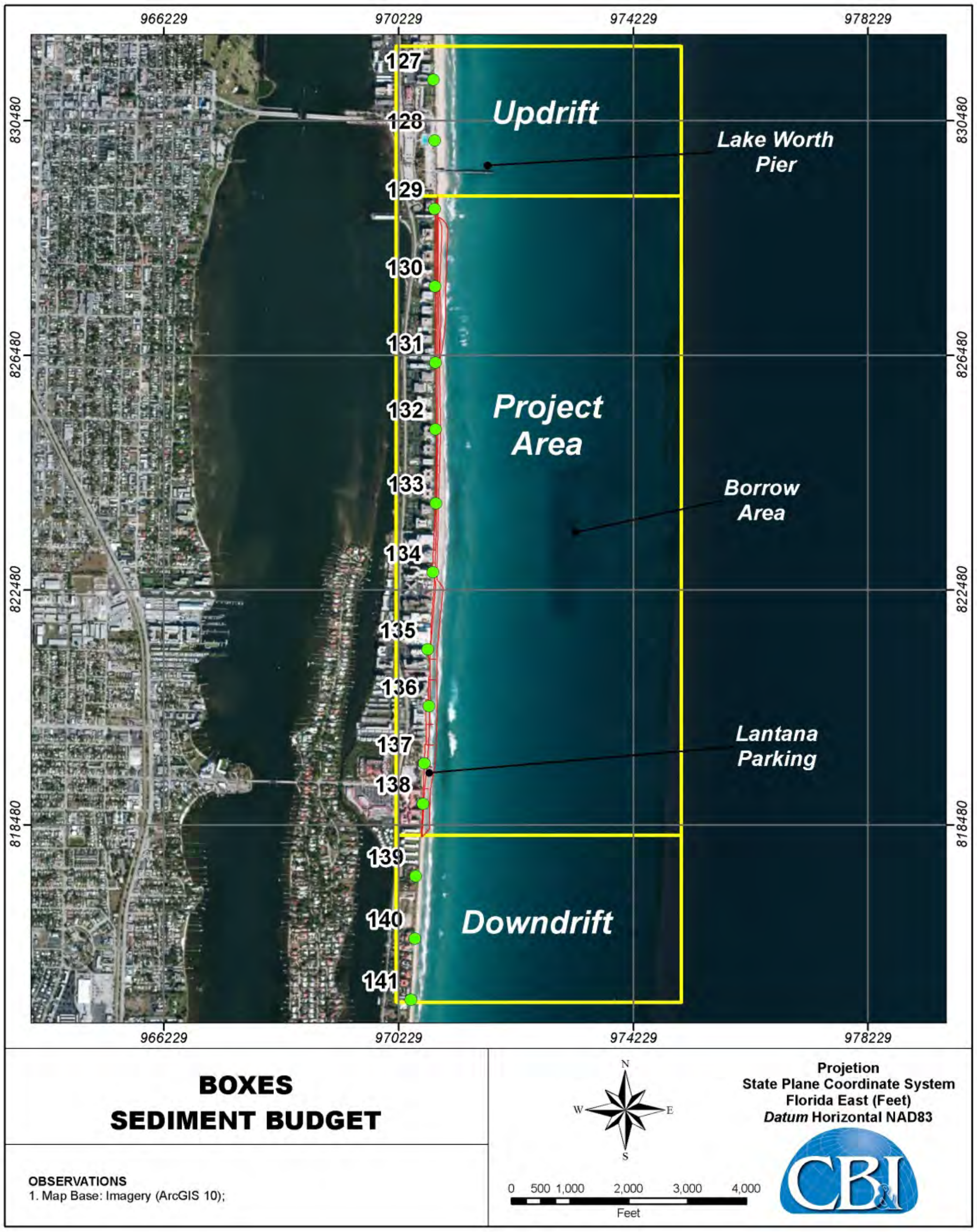

Figure 4-12. Boxes location used for sediment budget validation.

As validation that the model represents actual conditions, Figure 4-13 shows that the modeled (simulated) sediment budget analysis and the rate of transport (cy/year) agreed well with the observed values. Red arrows represent net transport. The values (bold) in boxes represent the sediment budget within each sector. Initial net sediment transport updrift (57,000 cy/yr) was obtained from the sediment transport results of the calibrated model. The simulated and observed data confirmed the erosional trend within the Project Area with a difference in magnitude of 800 cy/yr (5%). Over the length of the Project Area, this equates to a difference of approximately 0.1 cy/yr/ft of shoreline, which is trival in terms of coastal processes.

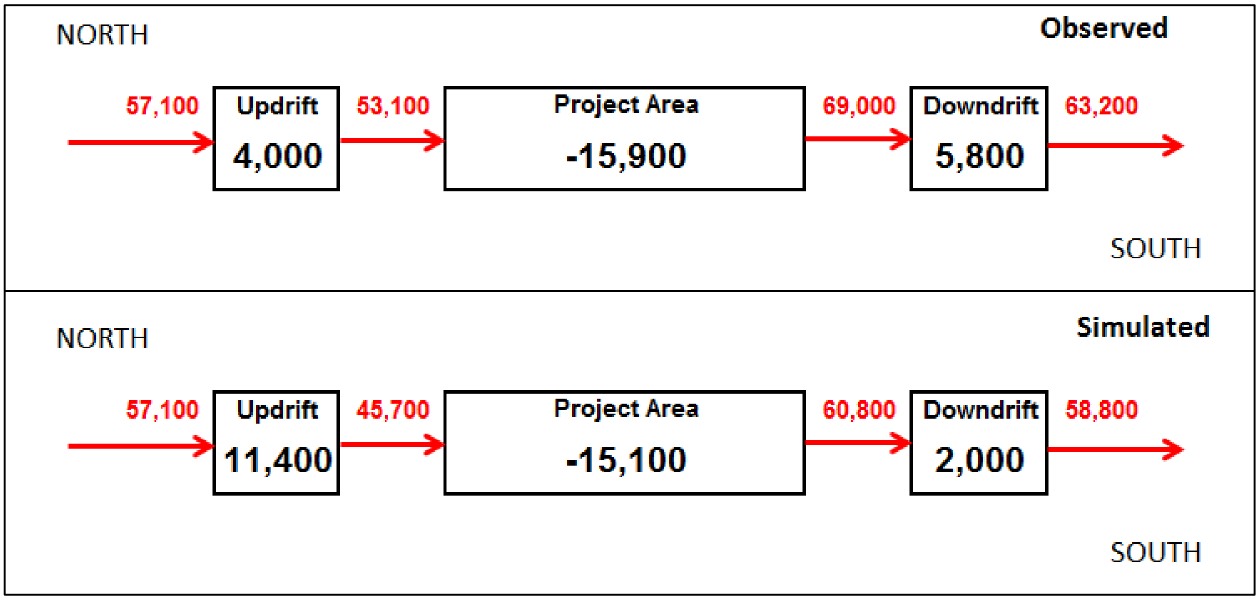

Figure 4-13. Simulated and observed sediment budget (cy/yr) between October 2008 and January 2012 given selected calibration run (Run 96). Red arrows indicate net sediment transport (cy/yr).

Comparisons between observed and modeled beach profiles are presented in Figure 4-14 through Figure 4-17 provides further validation of cross-shore processes and morphologic features. The profiles illustrate that the modeled morphology represents the observed changes between the 2008 and 2011/2012 surveys. In particular the model was able to reproduce the evolution of the offshore bar formations between -5 and -15 feet, NAVD88 within the surf zone.

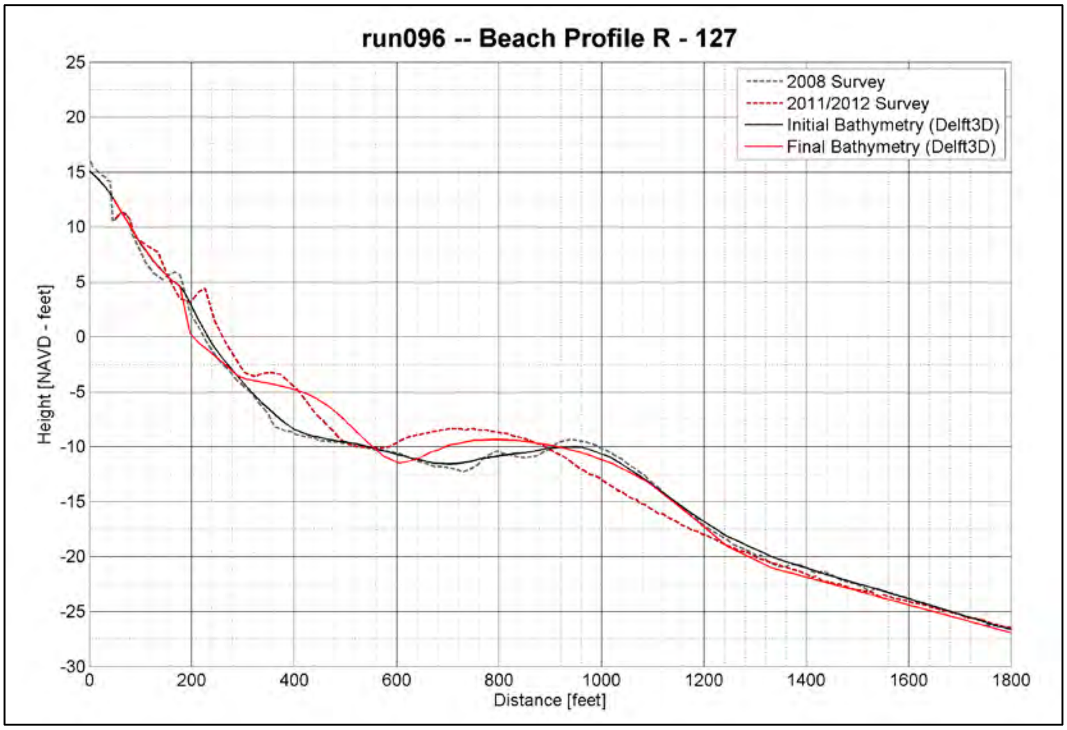

Figure 4-14. Comparison of observed and modeled beach profile R-127 for the initial and final bathymetry considered in the calibration period.

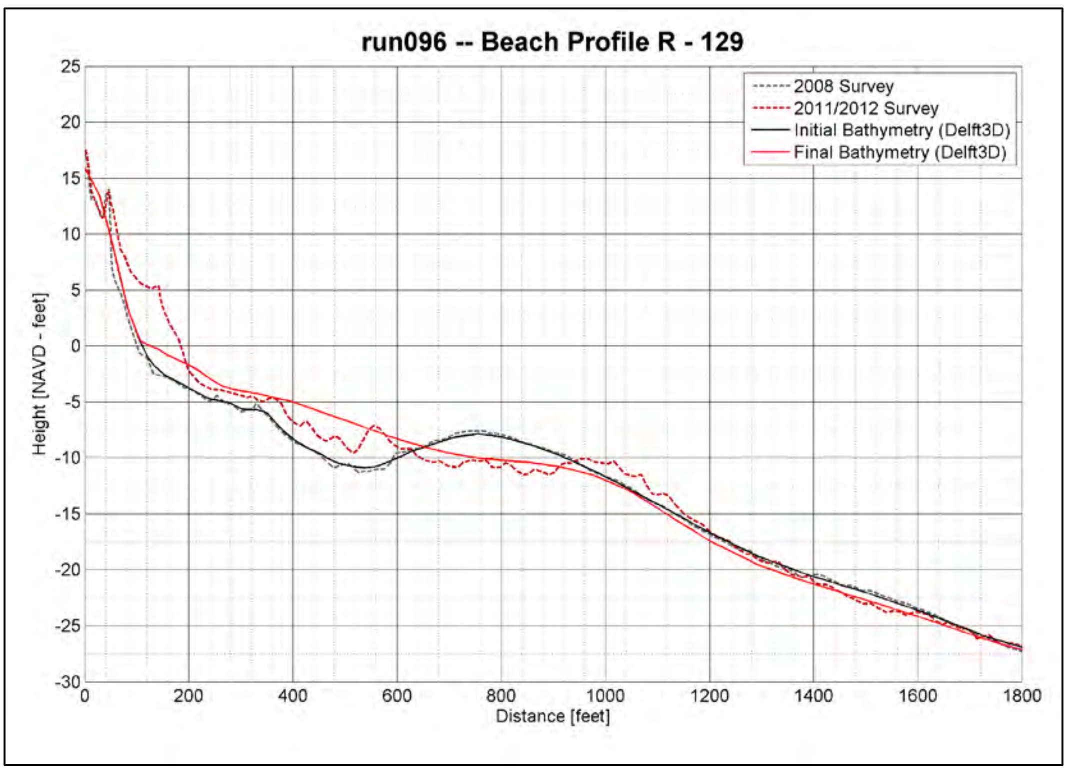

Figure 4-15. Comparison of observed and modeled beach profile R-129 for the initial and final bathymetry considered in the calibration period.

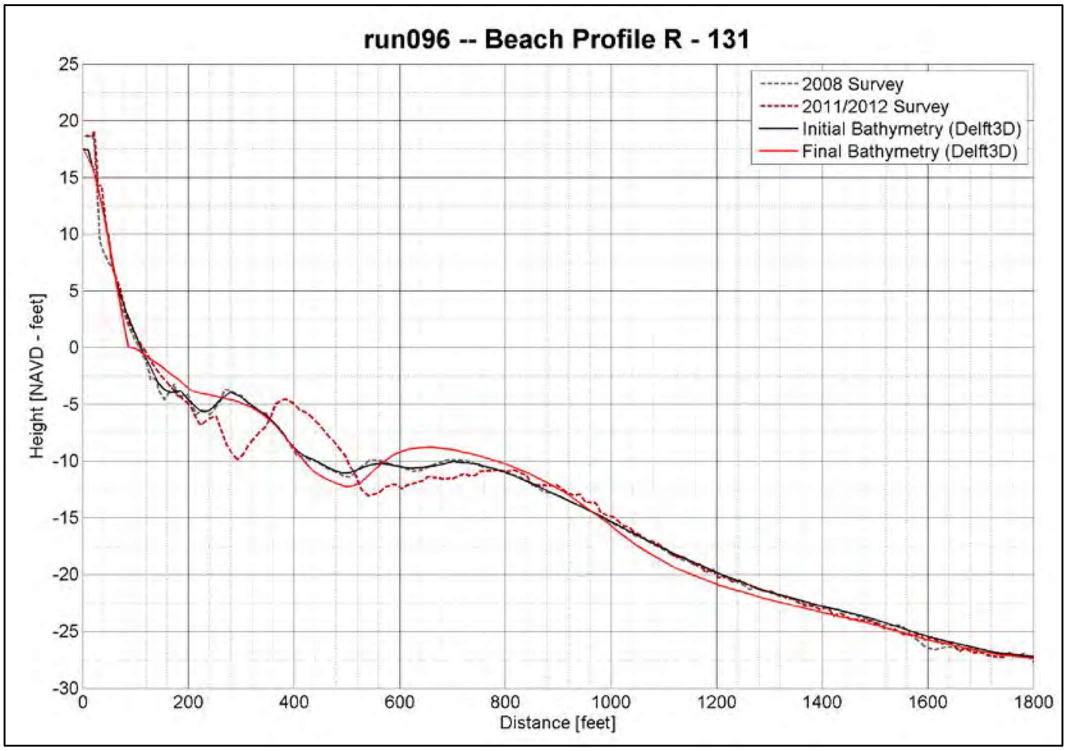

Figure 4-16. Comparison of observed and modeled beach profile R-131 for the initial and final bathymetry considered in the calibration period.

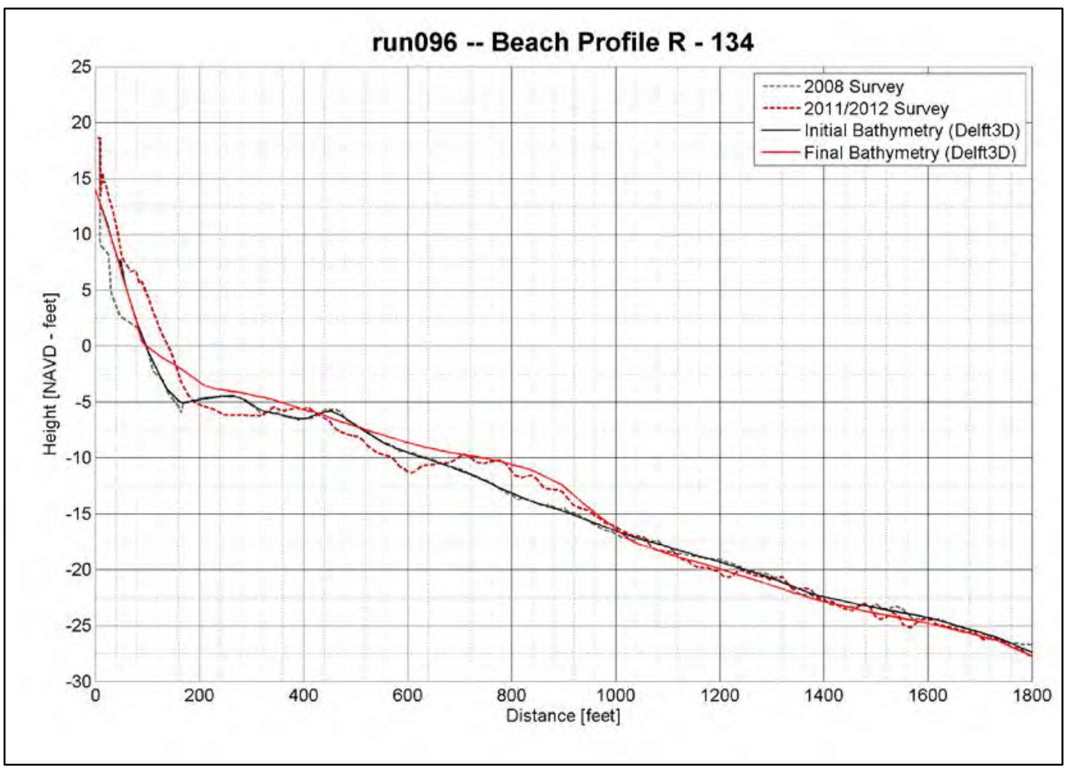

Figure 4-17. Comparison of observed and modeled beach profile R-134 for the initial and final bathymetry considered in the calibration period.

Model performance was also verified by comparing the simulated morphology changes and measured morphology changes over the 3.3 year period between the September/October 2008 and January 2012. The comparison is shown in Figure 4-18 with red shaded areas representing erosion and green shaded areas representing sedimentation. The model captures the overall morphologic changes that were measured during the calibration period. Specifically, the model was able to replicate the general locations and patterns of shifts and reversals between nearshore and offshore sedimentation/erosion patterns within the project. Qualitative comparisons are provided below:

- General onshore migration of sand into nearshore bar formations throughout study area.
- Sedimentation and erosion along bars and troughs throughout study area.
- Nearshore sedimentation occurred between R-129 and R-131.
- Sedimentation shifted offshore between R-131 to R-R-135.
- Sedimentation reversed shifting onshore between R-135 and R-137.
- Sedimentation shifted offshore between R-137 and R-144.

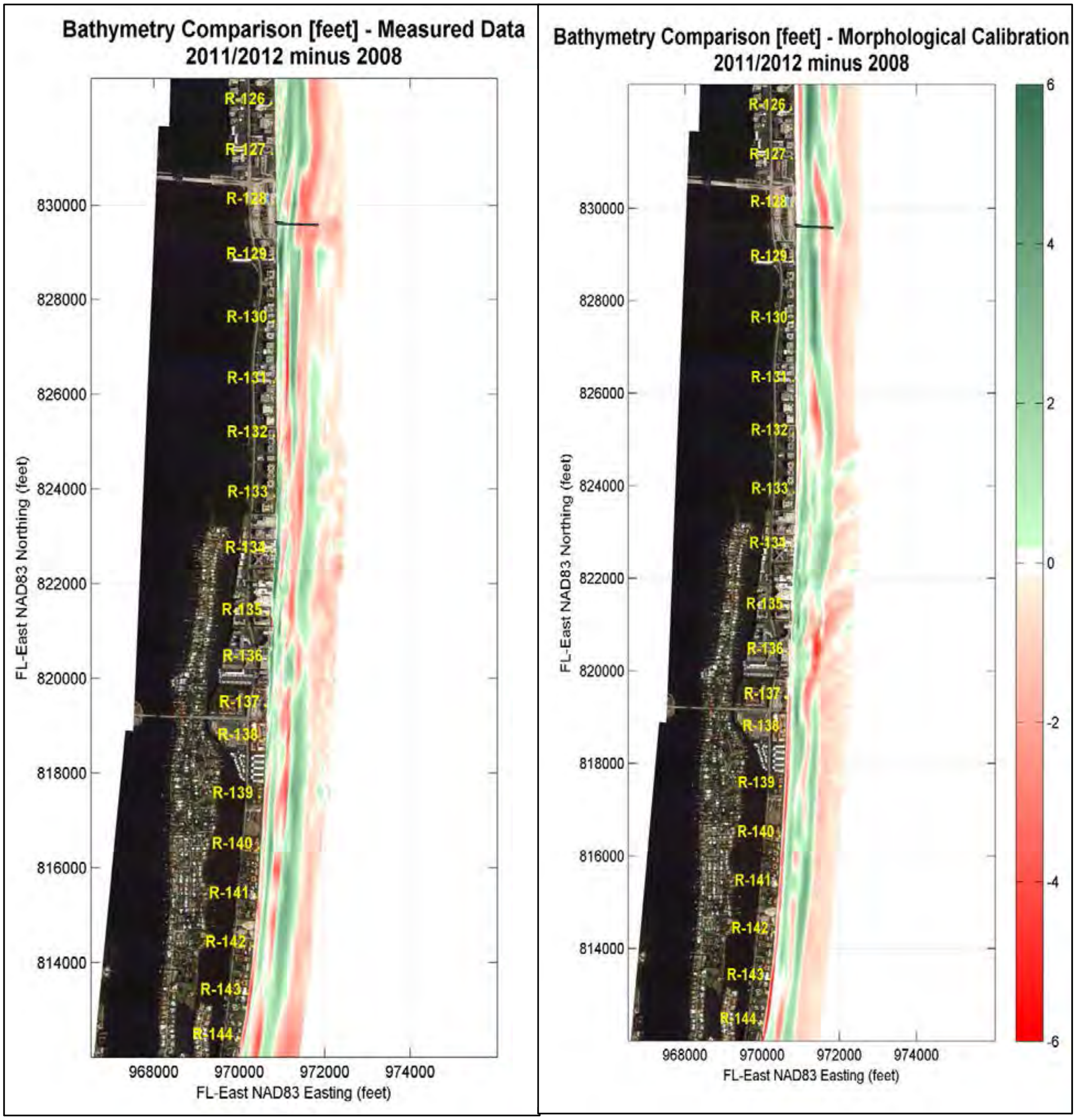

Figure 4-18. Bathymetry Comparison of Measured and Modeled Morphological Changes.

4.4. Model Calibration Summary

Calibration of the model resulted in reasonable agreement between the simulated and measured morphological changes for the expectations and intended use of the model results. Agreement was demonstrated during the calibration period based on the following:

- Volume changes showed that the magnitude of the modeled volumetric changes was consistent with the measured changes.
- Sediment budget analysis demonstrated that the modeled and measured changes have similar erosional trends within the Project Area. In addition it showed that the modeled transport rate was in agreement with the measured rates.
- Measured and modeled beach profiles illustrate that the modeled morphology represents cross-shore features such as the evolution of the offshore bar formations within the surf zone.
- The modeled morphologic changes captured the overall measured erosion and sedimentation demonstrating the model's skill in simulating the general patterns occurring within the project area.

5.0 ALTERNATIVES ANALYSIS

The calibrated model was used to assess the performance of several alternatives and track the movement of sand within the littoral system over a three year simulation period. A total of eight alternatives were considered. An additional seven "separated" alternatives (i.e. Alternative 2T and Alternative 2C) were modeled in order to identify the individual project related effects/impacts associated with the Town of Palm Beach (T) and the County (C) fill templates as "stand-alone" projects. It should be noted that "separated" alternatives were not modeled for every combined alternative as the separated fill templates were captured within other model runs. Plan views and cross-section plots of each alternative listed below are presented in Chapter 2 and Sub-Appendix G-5.

- <u>Alternative 1</u> – No Action Alternative (Status Quo) and referenced herein as the existing conditions.

- <u>Alternative 2</u> – The Applicants' Preferred Project (Proposed Action) with Beach and Dune Fill with Shoreline Protection Structures. From north to south, the project would include placing sand to enhance the dune from R-129-210 to R-129+150, dune and beach berm from R-129+150 to R-131, dune from R-131 to R-134+135 (Town of Palm Beach southern limit), and beach berm from R-134+135 to R-138+551. South of the Town of Palm Beach seven (7) low-profile groins were included from R-134+135 to R-138+551.

- Alternative 2T – The portion of Alternative 2 between R-129-210 and R-134+135 within the Town of Palm Beach.
- Alternative 2C – The portion of Alternative 2 between R-134+135 and R-138+551 within the County project area.

- Alternative 3 – The Applicants' Preferred Project (Proposed Action) without Shoreline Protection Structures.
    - Alternative 3C – The portion of Alternative 3 between R-134+135 and R-138+551 within the County project area.
- Alternative 4 – The Town of Palm Beach Preferred Project and County Increased Sand Volume without Shoreline Protection Structures. The sand volume within the County was increased by advancing the beach berm on average 50 feet seaward as compared to Alternative 2.
- Alternative 5 – The Town of Palm Beach Increased Sand Volume and County Preferred Project. The sand volume within the Town of Palm Beach was increased by advancing the dune and beach berm on average 10 feet seaward from R-129-210 to R-131 and the dune on average 50 feet seaward from R-132 to R-134+135 (Town of Palm Beach southern limit) as compared to Alternative 2.
- Alternative 6 – The Town of Palm Beach Increased Sand Volume Project and County Increased Sand Volume without Shoreline Protection Structures. The volume was increased by advancing the dune and beach berm on average 10 feet seaward from R-129-210 to R-131, the dune on average 50 feet seaward from R-132 to R-134+135 (Town of Palm Beach southern limit), and the beach berm on

average 50 feet seaward from R-134+135 to R-138+551 as compared to Alternative 2.

- Alternative 6T – The portion of Alternative 6 between R-129-210 and R-134+135 within the Town of Palm Beach.
- Alternative 6C – The portion of Alternative 6 between R-134+135 and R-138+551 within the County project area.

- Alternative 7a – The Coalition to Save Our Shoreline, Inc.'s (SOS) option with increased sand volume and the County Preferred Project. The fill template consists of beach fill and dune restoration between R-129-210 and R-134+135 with shoreline protection structures. The shoreline protection structures included two (2) T-head groins positioned in the southern portion of the Town of Palm Beach's project area between R-132+550 and R-132+270. The sand fill volumes required this alternative are greater than the volumes for Alternative 6 over the same shoreline extents. For the purpose of modeling, Alternative 7a was defined as the increased sand volume SOS option north of R-134+135 and Alternative 2 to the south.

    - Alternative 7aT – The portion of Alternative 7a between R-129-210 and R-134+135 within the Town of Palm Beach.

- Alternative 7b – The Town of Palm Beach increased sand volume with two shoreline protection structures (The Coalition to Save Our Shoreline, Inc. (SOS) Alternative) and the County Preferred Project. The fill template consisted of beach fill and dune restoration between R-129-210 and R-134+135 with shoreline protection structures. The shoreline protection structures included two (2) T-head groins positioned in the southern portion of the Town of Palm Beach's project area between R-132+550 and R-132+270. The sand fill volumes required for the SOS preferred option are smaller than the volumes for Alternative 7a over the same shoreline extents. For the purpose of modeling, Alternative 7b was defined as the SOS preferred option north of R-134+135 and Alternative 2 to the south.

- Alternative 7bT – The portion of Alternative 7bT between R-129-210 and R-134+135 within the Town of Palm Beach.

The fill volumes required to construct the templates for each of the alternatives were estimated based on the 2011-2012 beach profile surveys. Table 5-1 and Table 5-2 summarizes the alternatives and the design fill volumes. Table 5-3 summarizes the volumetric fill densities (cy/ft) by alternative. The volumes and dimensions present in Table 5-1 through Table 5-3 were estimated based beach profiles surveys at the FDEP R-monuments. The location and elevation of the fill templates were maintained within the model, but due to linear interpolation of the bathymetry between R-monuments and the size of the numerical grid, the volume of fill included in the model may differ.

Table 5-1. Summary of Alternatives.

	Design Fill Volumes (based on winter 2011/2012 profiles)	Shoreline Protection Structures
Alternative 1	No Action Scenario	
Alternative 2	Total volume of 117,300 cy	7 groins between R-135+160 and R-137+422
Alternative 2T	Total volume of 53,800 cy	Alternative 2 Town of Palm Beach only (no groins)
Alternative 2C	Total volume of 63,500 cy	Alternative 2 County only (with 7 groins)
Alternative 3	Total volume of 117,300 cy	no structures
Alternative 3C	Total volume of 63,500 cy	Alternative 2 County only (no structures)
Alternative 4	Total volume of 225,900 cy	no structures
Alternative 5	Total volume of 164,400 cy	7 groins between R-135+160 and R-137+422
Alternative 6	Total volume of 273,000 cy	no structures
Alternative 6T	Total volume of 100,900 cy	Alternative 6 Town of Palm Beach only (no structures)
Alternative 6C	Total volume of 172,100 cy	Alternative 6 County only (no structures)
Alternative 7a	Total volume of 401,600 cy	7 groins between R-135+160 and R-137+422; 2 T-head between R-132+550 and R-133+270
Alternative 7aT	Total volume of 338,100 cy	Alternative 7a Town of Palm Beach only (2 T-head between R-132+550 and R-133+270)
Alternative 7b	Total volume of 230,000	7 groins between R-135+160 and R-137+422; 2 T-head between R-132+550 and R-133+270
Alternative 7bT	Total volume of 166,500	Alternative 7b Town of Palm Beach only (2 T-head between R-132+550 and R-133+270)

Table 5-2. Summary of Alternatives. Volume expressed in cubic yards based on winter 2011/2012 beach profiles.

Alternative	Total CY	Above HTL CY	Between MHW and HTL CY	Below MHW CY
Alt 2	117,300	67,700	20,100	29,500
Alt 2T	53,800	34,500	9,300	10,000
Alt 2C	63,500	33,200	10,800	19,500
Alt 3	117,300	67,700	20,100	29,500
Alt 3C	63,500	33,200	10,800	19,500
Alt 4	225,900	113,200	37,000	75,700
Alt 5	164,400	108,300	22,500	33,600
Alt 6	273,000	153,800	39,300	79,900
Alt 6T	100,900	75,100	11,700	14,100
Alt 6C	172,100	78,700	27,600	65,800
Alt 7a	401,600	187,100	60,300	154,200
Alt 7aT	338,100	153,900	49,500	134,700
Alt 7b	230,000	102,800	39,900	87,300
Alt 7bT	166,500	69,600	29,100	67,800

Table 5-3. Summary of volumetric fill densities by monuments and alternatives based on winter 2011/2012 beach profiles.

	Volumetric Fill Density (cy/ft)						
Monuments	**Alt 2**	**Alt 3**	**Alt 4**	**Alt 5**	**Alt 6**	**Alt 7a**	**Alt 7b**
R-129	0.0	0.0	0.0	12.6	12.6	25.5	1.9
R-130	16.3	16.3	16.3	22.5	22.5	65.8	32.5
R-131	9.2	9.2	9.2	9.1	9.1	68.2	47.9
R-132	8.5	8.5	8.5	8.5	8.5	61.4	27.0
R-133	0.0	0.0	0.0	19.1	19.1	53.4	27.5
R-134	7.6	7.6	7.6	22.8	22.8	7.6	7.6
R-135	10.7	10.7	31.9	10.7	31.8	10.7	10.7
R-136	27.9	27.9	53.8	27.9	53.8	27.9	27.9
R-137	13.1	13.1	54.0	13.1	54.0	13.1	13.1
R-138	10.4	10.4	28.2	10.4	28.2	10.4	10.4

5.1. Setup

Model calibration was based on the initial 2008 conditions and replicating the observed 2011-2012 conditions after the 3.3 year simulation period. For the alternatives analysis, the 2011-2012 conditions were used as the initial input into the model. While the parameters (Table 4-3) established during calibration of the model were used, three inputs were updated for the analysis.

- Bathymetry
- Hardbottom and Sediment Layer Thickness
- Shoreline Protection Structures

5.1.1. Bathymetry

Bathymetries for the local wave grid and the flow and morphology grid were updated based on the following data sources (see also Table 3-2):

1. January 2012 beach profiles (FDEP, 2012).
2. September-November 2011 beach profiles (ATM, 2012).
3. 2006 Lidar (USACE, 2006).
4. 1963-1964 hydrographic survey (NOAA, 2006).

The primary data set was January 2012 beach profiles, followed by the September-November 2011 beach profiles. Lidar data from 2006 was used to represent topography of inland area beyond the beach profiles, while the hydrographic survey from 1963-1964 was used to represent the deeper water depths extending to the intermediate and regional wave grids. The resulting bathymetry of the flow and morphology grid appears in Figure 5-1. This bathymetry represents the existing conditions for comparison with the alternatives.

The fill proposed for each of the alternatives was added to the existing conditions to create the initial input bathymetries for the alternatives.

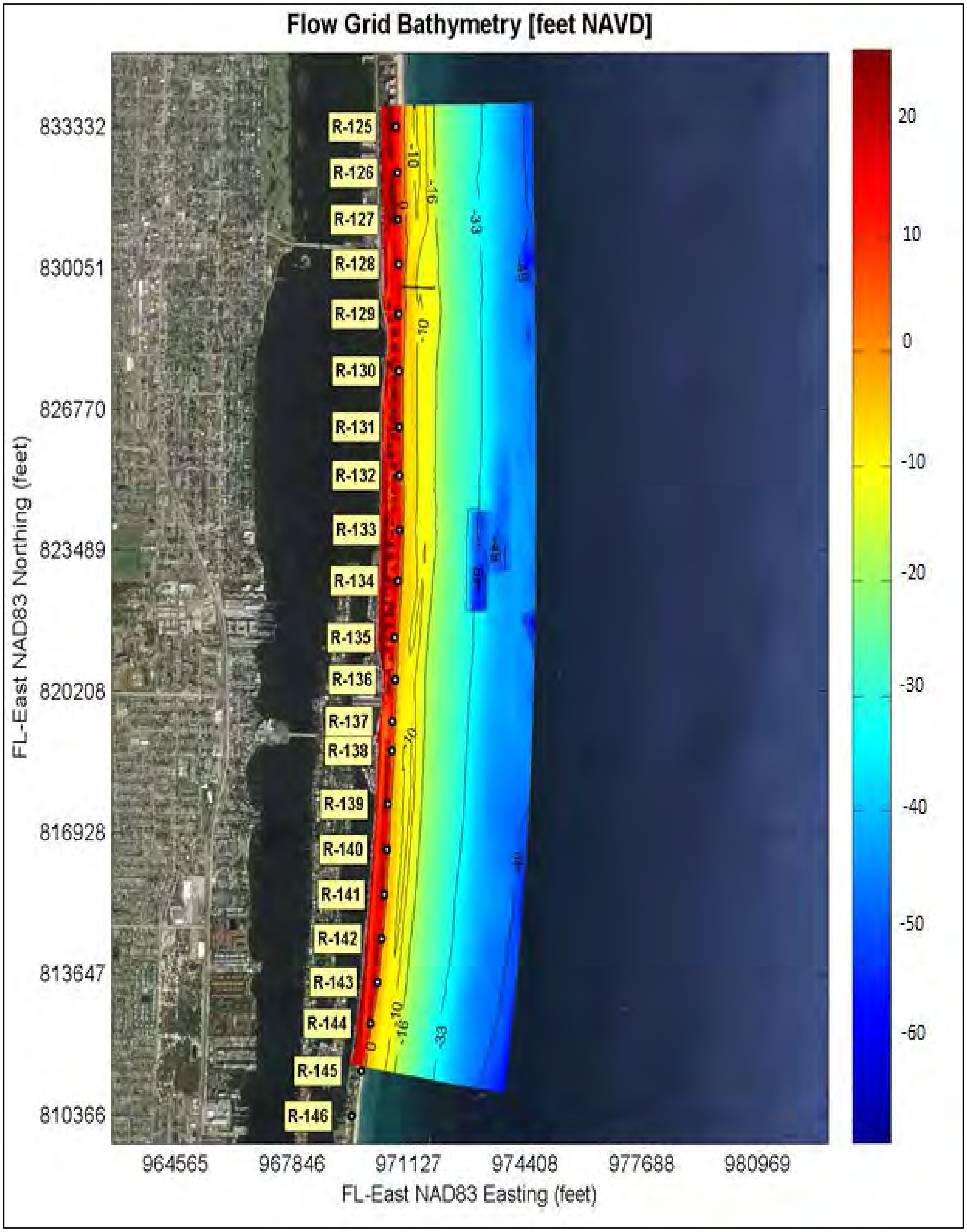

Figure 5-1. Flow and morphology grid bathymetry (feet NAVD88) used in production runs.

5.1.2. Hardbottom and Sediment Thickness

The thickness of sediment used in alternatives runs was updated from the morphological calibration using the 2011-2012 surveys and 2012 hardbottom mapping. Areas where the 2012 survey was shallower than the hardbottom depth established during calibration were verified throughout the numeric domain. In these regions, the difference between the 2011-2012 survey and calibrated hardbottom elevation was added to the sediment thickness, thus setting an initial thickness for the alternatives analysis that corresponded to the 2011-2012 bathymetry. These sediment thicknesses represent the existing conditions (Figure 5-2).

Similarly, the thicknesses were updated to account for the proposed fill for each of the alternatives. The thickness of the fill was determined by subtracting 2011-2012 bathymetry from the fill bathymetry. The differences were added to the sediment thicknesses to create the initial input for the alternatives.

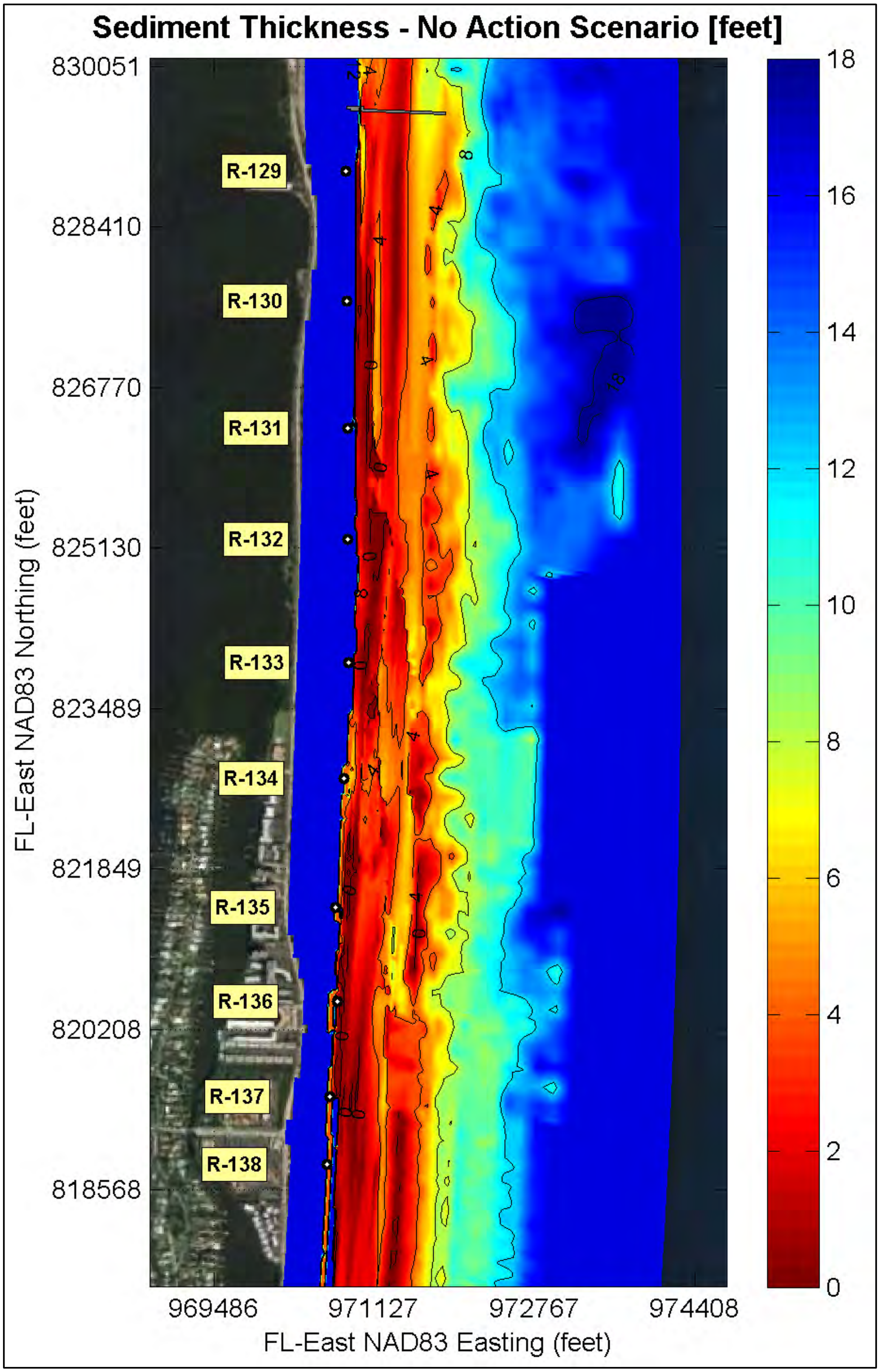

Figure 5-2. Initial sediment thickness of No Action scenario.

5.1.3. Shoreline protection structures

Alternatives 2, 5, and 7 proposed shoreline protection structures as outlined in Table 5-1. As discussed above in Section 3.7 for the Lake Worth Pier, a coefficient was required to account for the porosity of the structures. In the Delft3D-Flow model, these structures were represented as porous plates with a value of 1.0 (permeable).

5.2. Alternative 1 – No Action Alternative (Status Quo)

Alternative 1 is the No Action Alternative. The bathymetry for this alternative is based on the existing conditions as discussed above. The evolution of the existing conditions after the 3 year simulation period is shown Figure 5-3. Included in the figure, the graphic on the right shows the erosional areas (red areas) and sedimentation areas (green areas) during this period. The graphic depicts the dynamic nature of the Project Area with sand generally accumulating within the offshore bar and trough features, which parallel the shoreline. Sand eroded from the dry beach is transported alongshore and seaward, while sand offshore of the bar is transported alongshore and landward. The hardbottom delineated represents exposed hardbottom digitized from aerial photography collected March 30, 2012.

Figure 5-4 shows the annual rate of sediment transport for each alternatives and No Action scenario. Positive values denote north to south transport. This analysis highlights the change in the sediment transport rate at R-135 where there is an approximate 5° change in coastline orientation (89° to the north and 94° to the south relative to Geographical north). The details of the model runs for each alternative are described in the following sections.

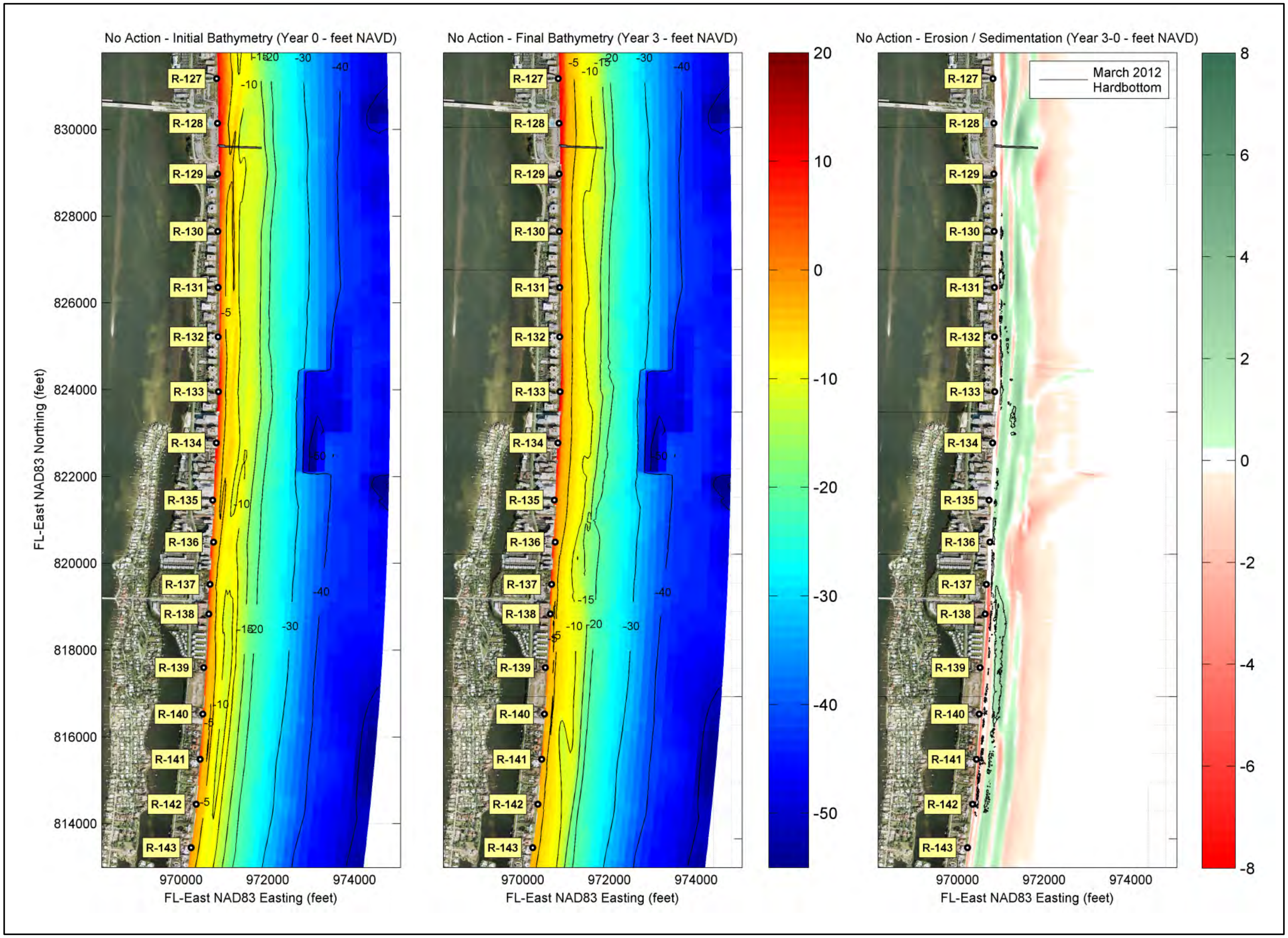

Figure 5-3. Initial bathymetry, final bathymetry and erosion sedimentation after 3 years of simulation, No Action scenario.

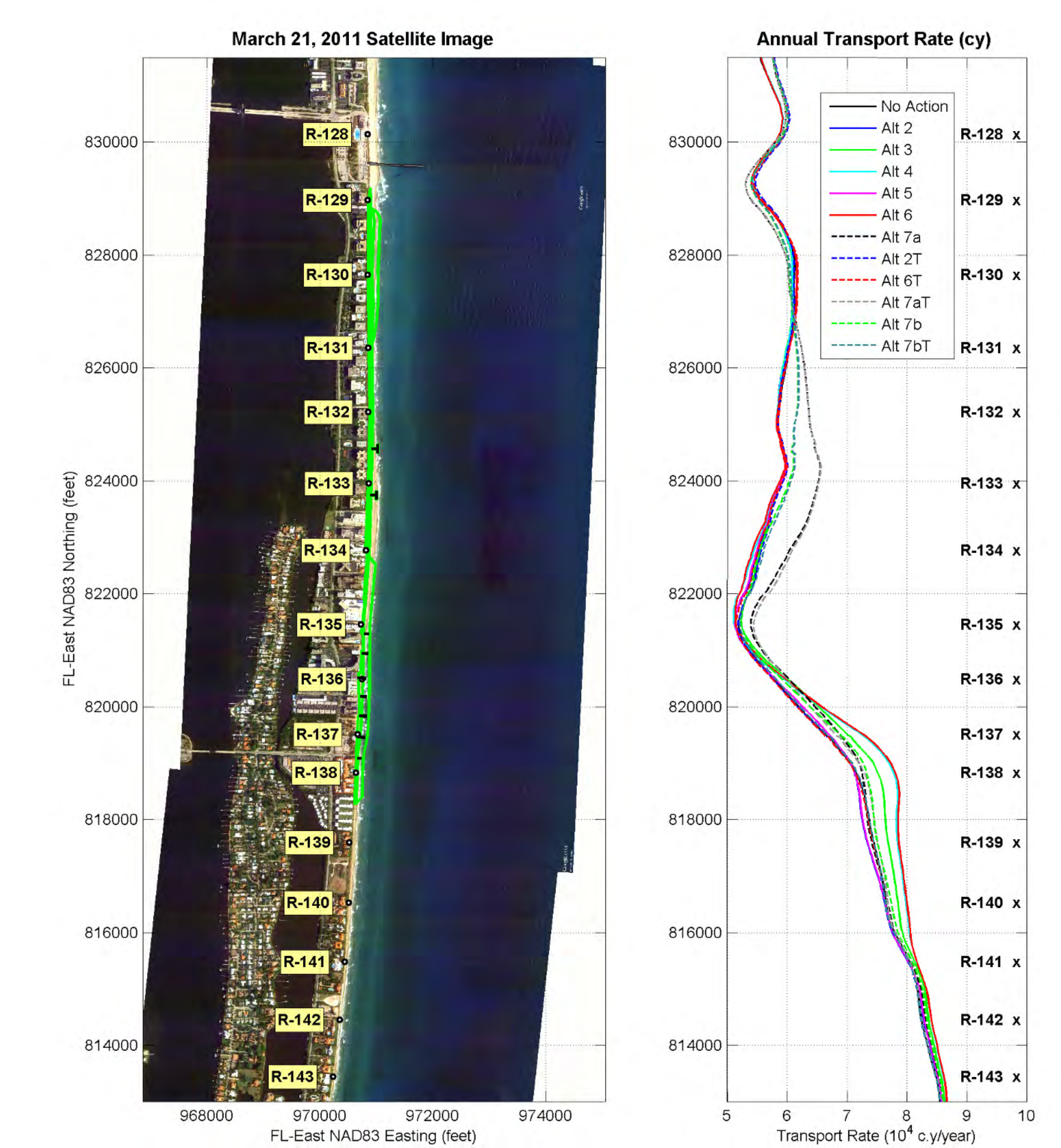

Figure 5-4. Annual transport rate (cy) for Alternatives and No Action Alternative.

5.3. Alternative 2 - The Applicants' Preferred Alternative (Proposed Action): Beach and Dune Fill with Shoreline Protection Structures Project

5.3.1. Combined Action

Alternative 2 includes seven groins south of R-135 and the placement of approximately 117,300 cubic yards of fill material between R-129-210 and R-138+551.

The volumetric changes for the alternative after 3 years compared to the No Action scenario are shown in Figure 5-5. The yellow line shows the volume change for the No Action scenario (initial existing bathymetry subtracted from the final No Action bathymetry). The blue line shows the volume change for the alternative (initial existing bathymetry subtracted from the final alternative bathymetry). The black line shows the initial fill volume placed for the alternative. The volumetric impacts/benefits associated with the alternative are denoted by the red line, which is the difference between the yellow and blue lines. Locations where the red line is positive denote benefits provided by the alternative in that there is more volume at a particular location as compared to the No Action scenario after the 3 year simulation period. Likewise, locations where the red line is negative denote impacts associated with the alternative in that there is less volume at a particular location as compared to the No Action. North of R-139 the alternative shows benefits, while to the south there are impacts extending to approximately R-142. This impact may be attributed to the retention of sand within the groin field between R-135 and R-138.

The initial bathymetry for the alternative compared to the final bathymetry for the alternative after the 3 year simulation period is shown in Figure 5-6. Similar to the No Action Alternative, the fill from the upper portion of the profile is eroded and deposited within the offshore bar and trough. Sand landward of the bar is transported landward.

The temporal evolution of the fill at one year time steps is tracked in Figure 5-7. The erosion and sedimentation represents the change between the alternative bathymetry as compared to the No Action bathymetry at a given time step. The movement of sand within the Study Area is depicted by the areas of sedimentation (green shaded areas) and areas of scour (red shaded areas). Hardbottom exposure and subsequent burial occurs naturally within the study area. The model suggests that areas of exposed hardbottom may be covered as a result of the alternative, while other areas may scour increasing hardbottom exposure.

Within the areas of sand movement, hardbottom coverage is delineated by the green outlines, while hardbottom exposure is delineated by the red outlines. The areas of sedimentation/scour and areas of coverage/exposure migrate over time as sand is redistributed during the 3 year simulation period. At the end of the 3 years, there was an estimated coverage of 8.62 acres of hardbottom and an exposure of 3.84 acres attributed to the alternative. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -4.78 acres.

To assess time-dependent changes, areas of sedimentation greater than 0.2 feet for years 0, 1, 2 and 3 are highlighted in Figure 5-8. Changes less than 0.2 feet were not considered, to account for potential survey error and limits of model precision. The model suggested that the fill is transported to the south as it is redistributed offshore.

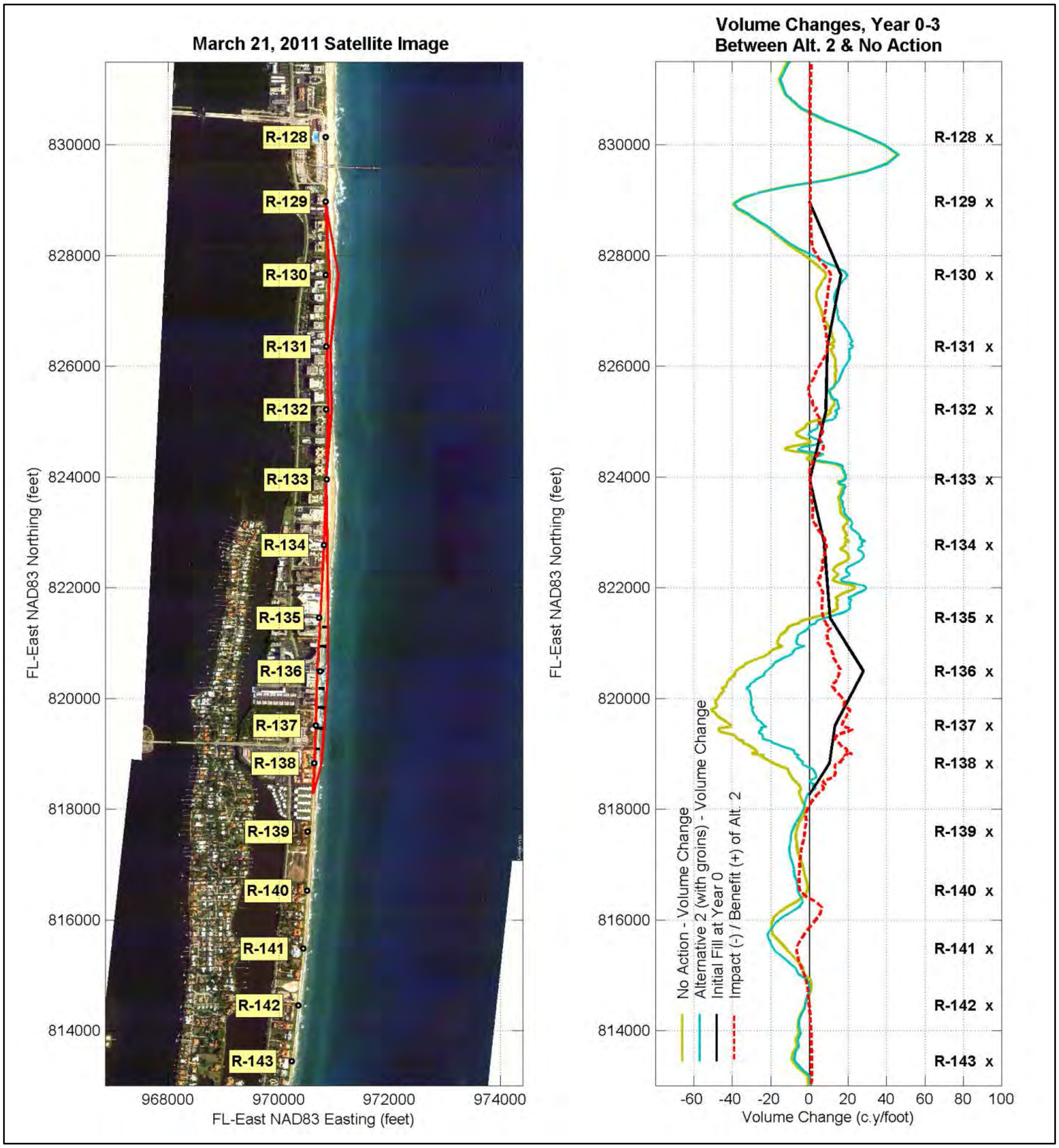

Figure 5-5. Volume changes for Alternative 2.

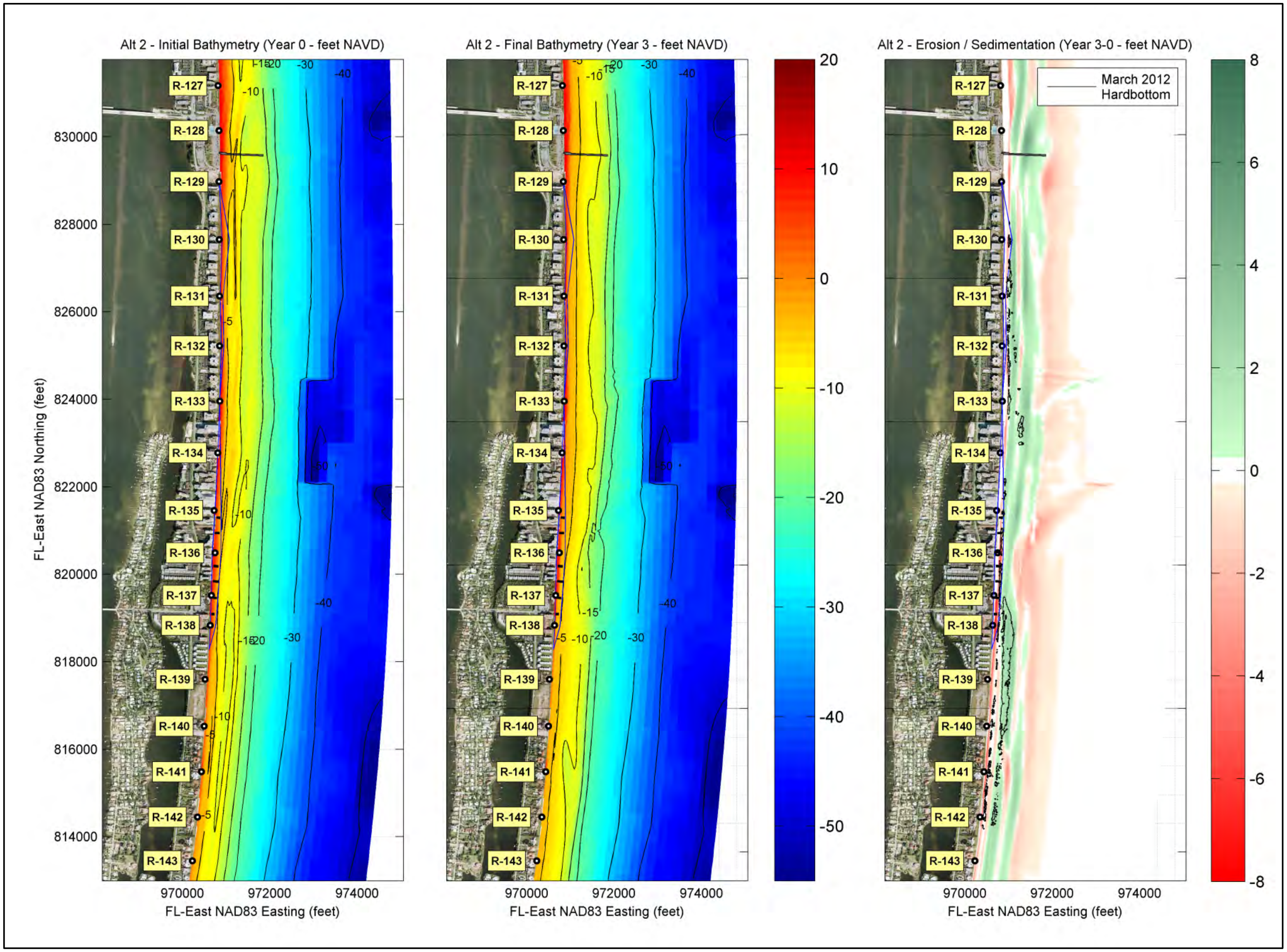

Figure 5-6. Erosion/Sedimentation after 3 years of simulation, Alternative 2.

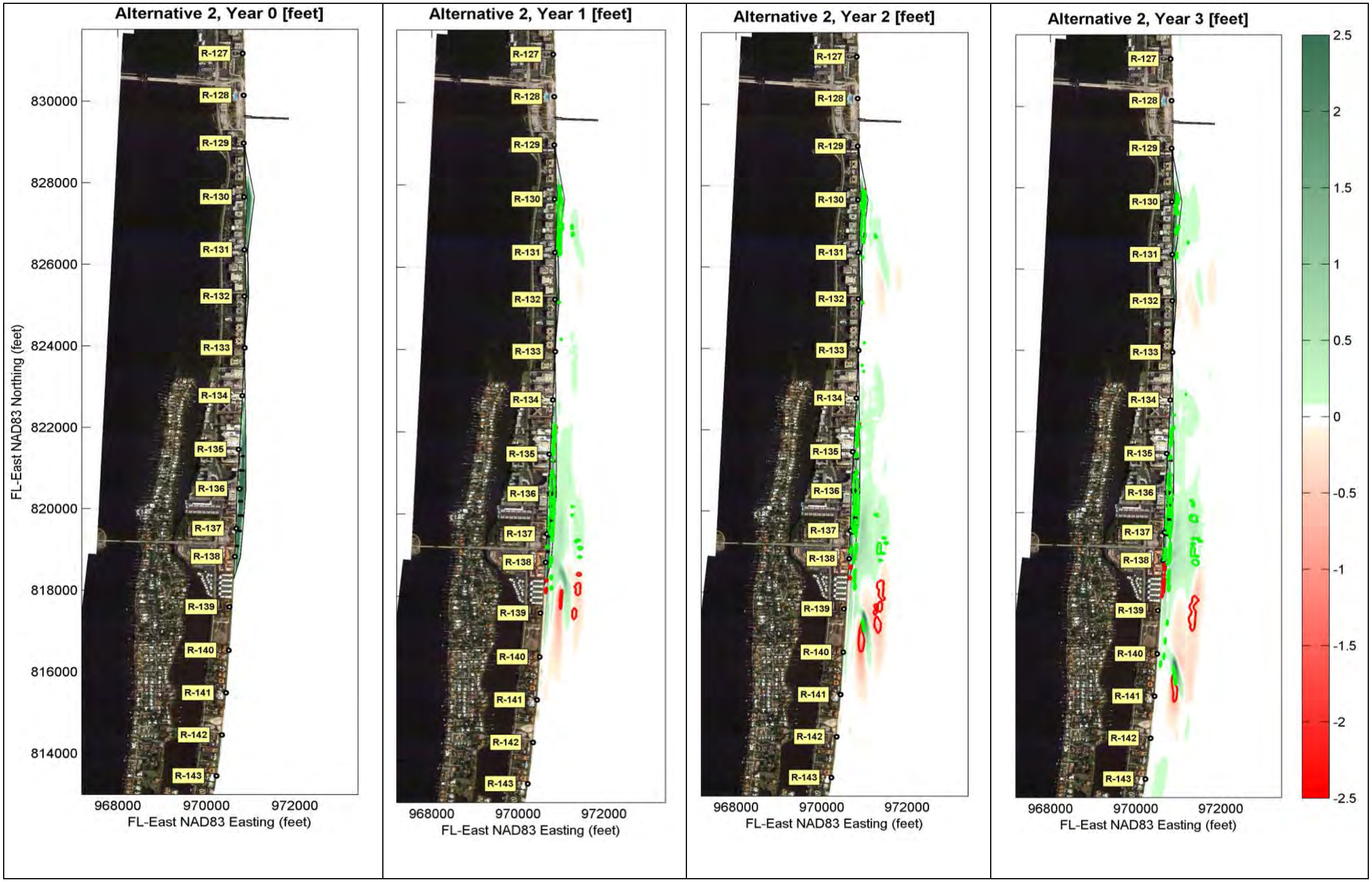

Figure 5-7. Temporal evolution of beach nourishment for Alternative 2, compared to No Action scenario.

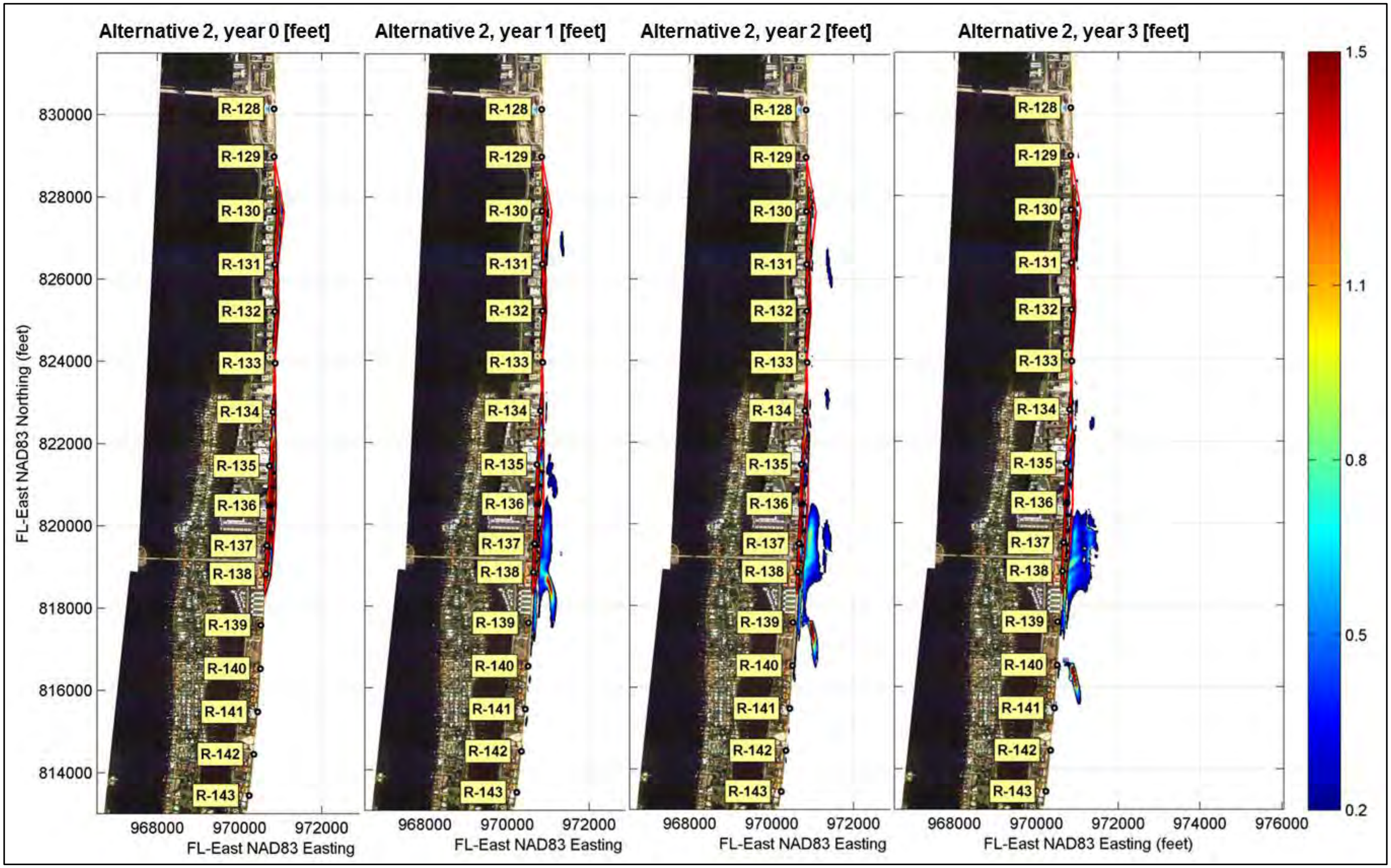

Figure 5-8. Sediment Accumulation greater than 0.2 ft for Alternative 2.

5.3.2. Separated Actions

Alternative 2T (Town of Palm Beach portion of alternative)

Alternative 2T represents the same conditions as Alternative 2 but for the Town of Palm Beach portion only. Alternative 2T consisted of the placement of 53,800 cubic yards of sand between R-129-210 to R-134+135. Model results for Alternative 2T are shown in Figure 5-9 through Figure 5-12.

At the end of the 3 year simulation period, there was an estimated coverage of 1.24 acres of hardbottom and an exposure of 0.20 acres attributed to the alternative as depicted in Figure 5-11. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -1.04 acres.

Areas of sedimentation with thicknesses greater than 0.2 feet (Figure 5-12) are shown at approximately R-131 during Year 1 and Year 2, while the areas have diffused by Year 3. The areas of sedimentation coincide with the highest fill density for the alternative at R-131. Sedimentation is not apparent outside the alongshore extents of the Project Area for Alternative 2T.

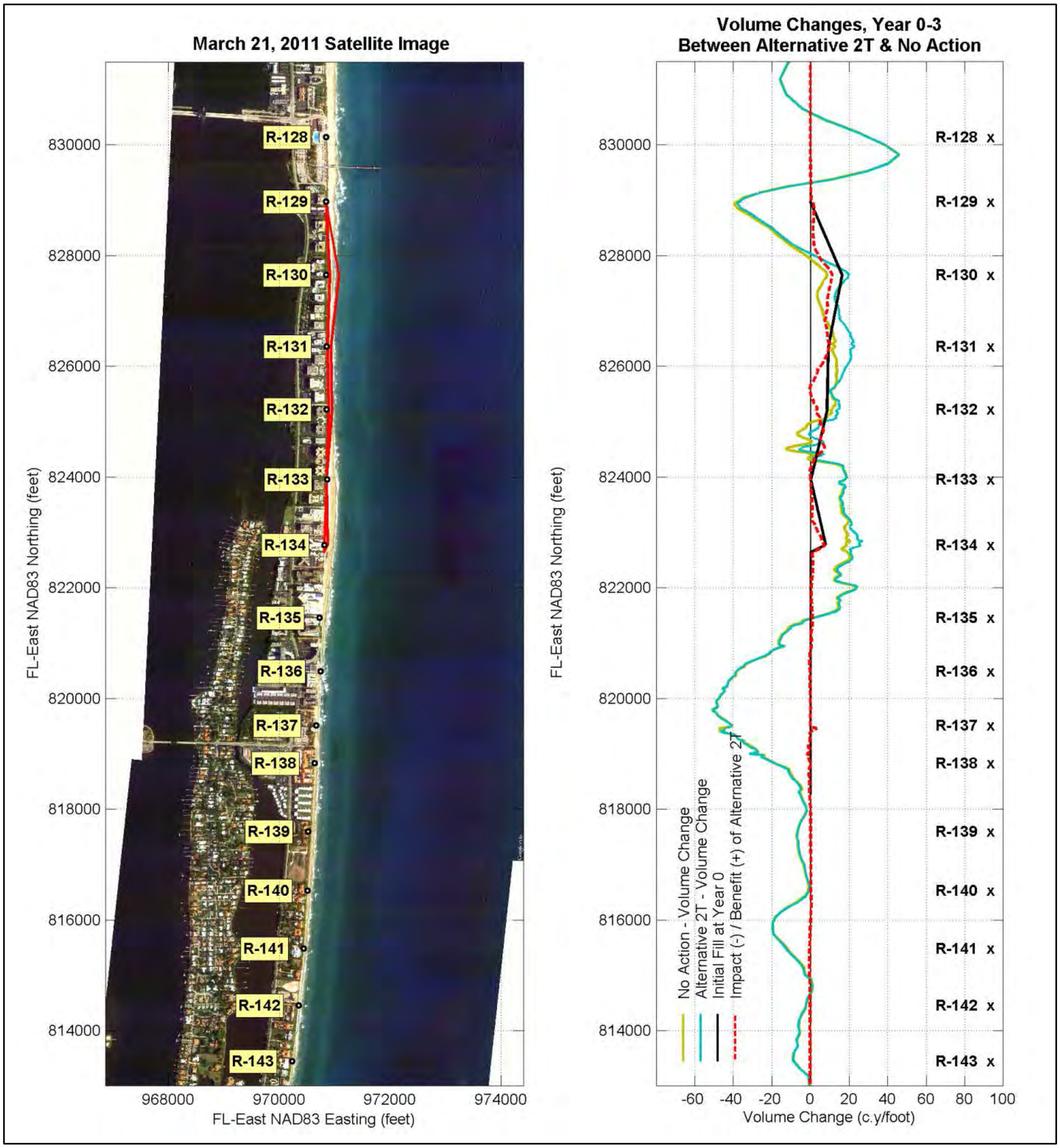

Figure 5-9. Volume Changes to Alternative 2T.

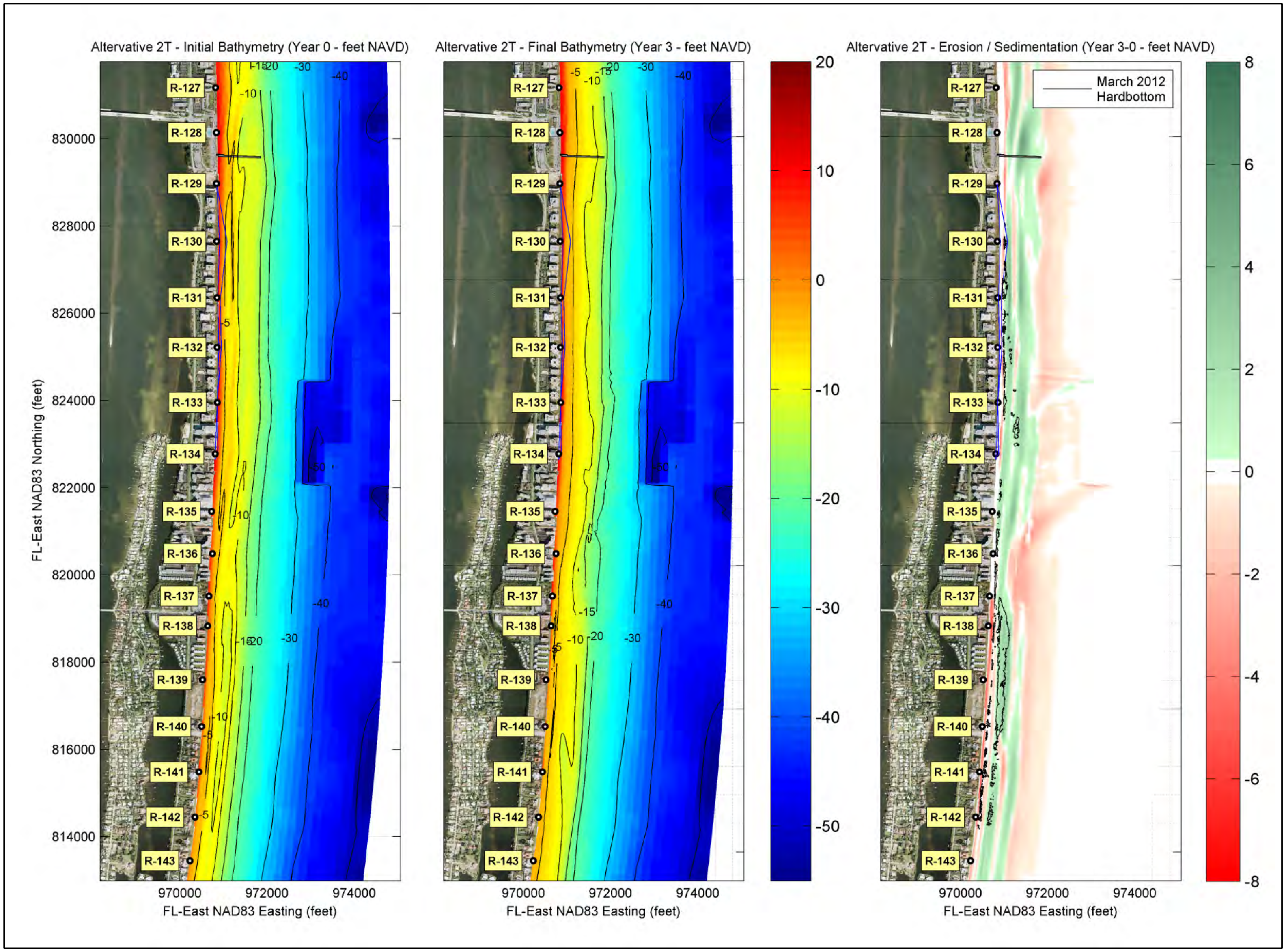

Figure 5-10. Erosion/Sedimentation after 3 years of simulation, Alternative 2T.

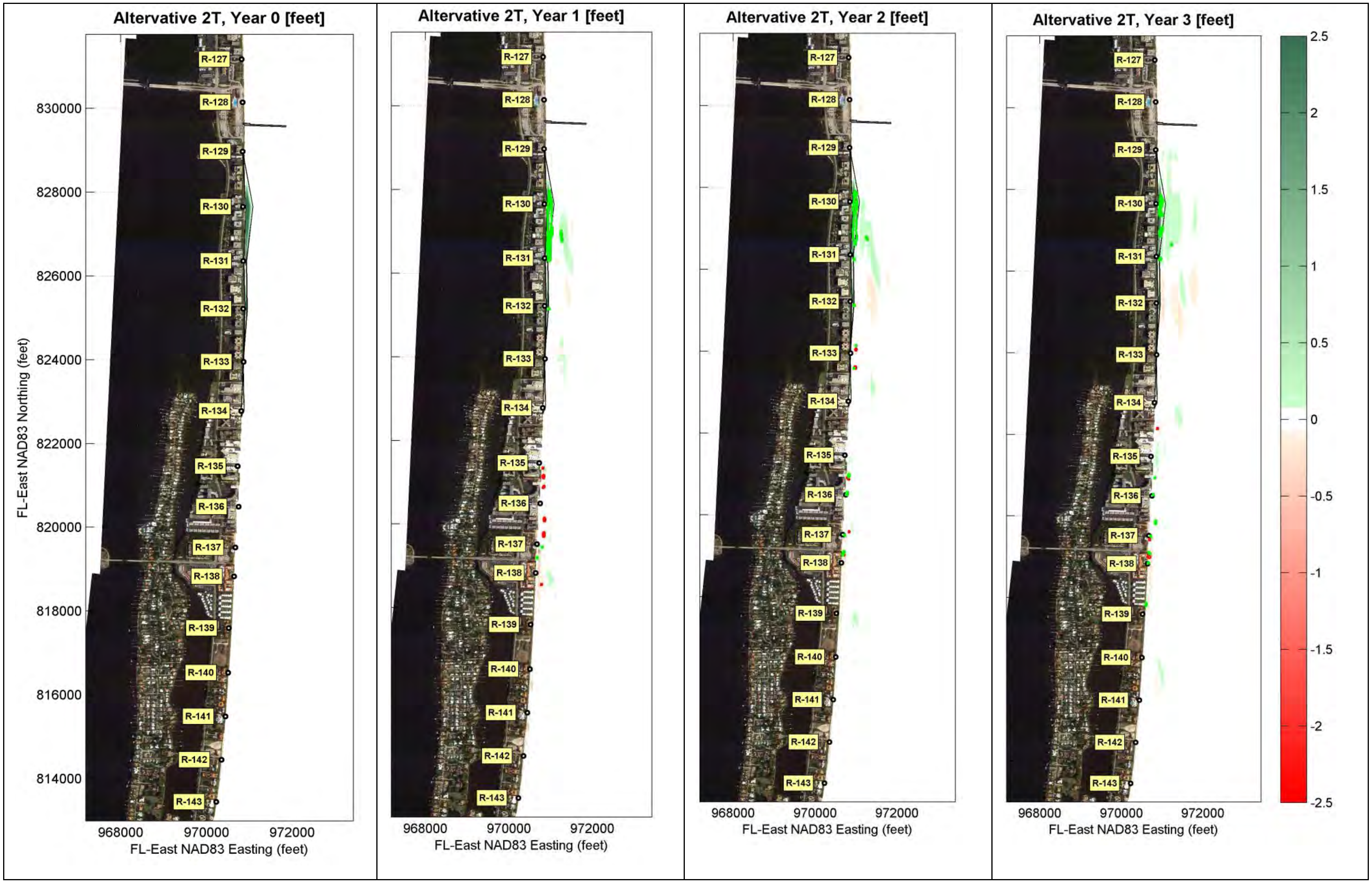

Figure 5-11. Temporal evolution of beach nourishment for Alternative 2T, compared to No Action scenario.

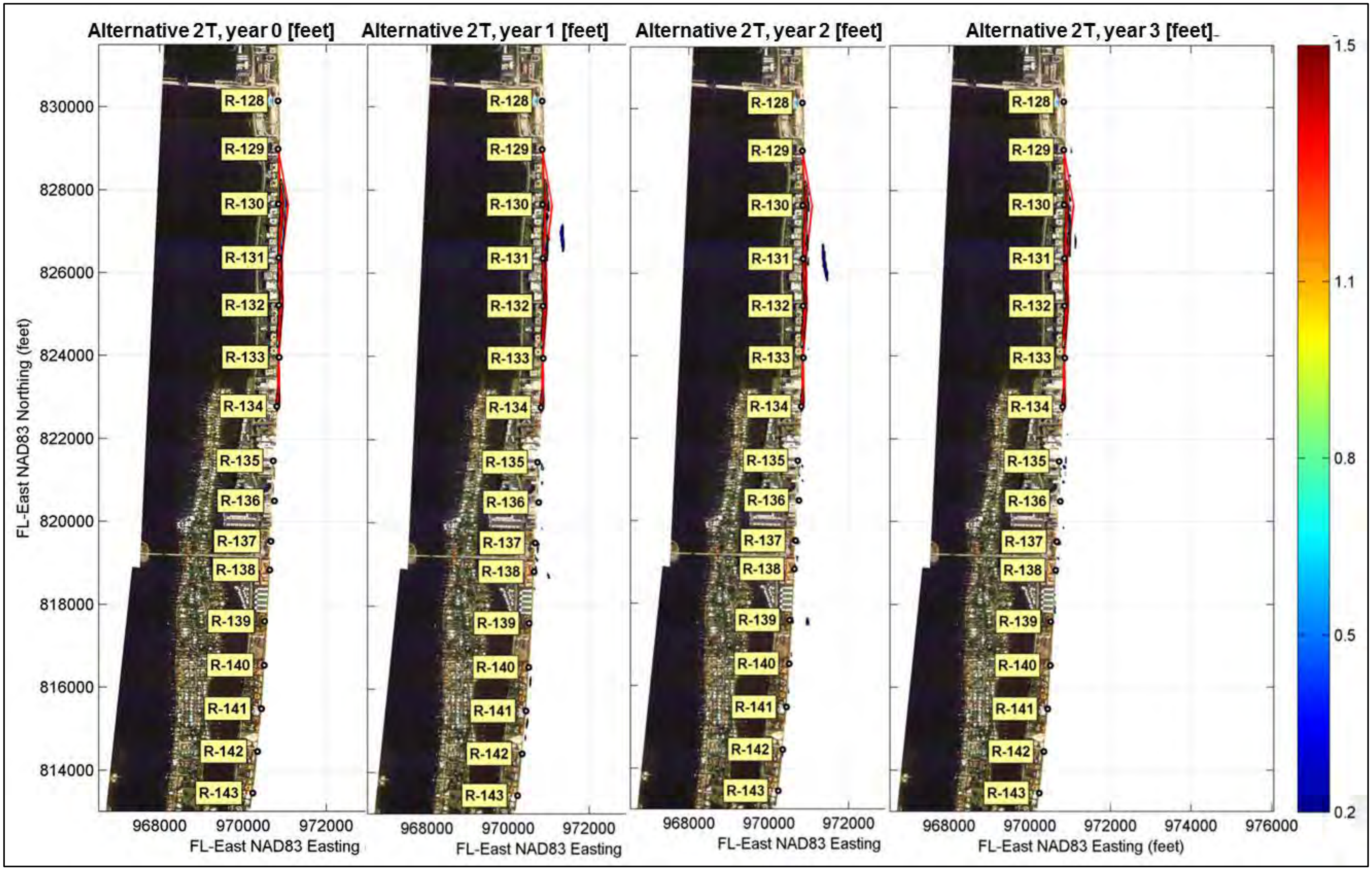

Figure 5-12. Sediment Accumulation greater than 0.2 ft for Alternative 2T.

Alternative 2C (County portion of alternative)

Alternative 2C presents a sand placement of 63,500 cubic yards between R-134+135 and R-138+551 in combination with seven groins between R-135+160 and R-137+422. Model results for Alternative 2C are shown in Figure 5-13 through Figure 5-16.

At the end of the 3 year simulation period, there was an estimated coverage of 7.76 acres of hardbottom and an exposure of 3.55 acres attributed to the alternative as depicted in Figure 5-15. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -4.21 acres.

Model results suggest that the behavior of Alternative 2C is similar to Alternative 2, within County's project area. Areas of sedimentation greater than 0.2 (Figure 5-16) are located at the southern half of the project area for Alternative 2C and by Year 3 extend downdrift to approximately R-141.

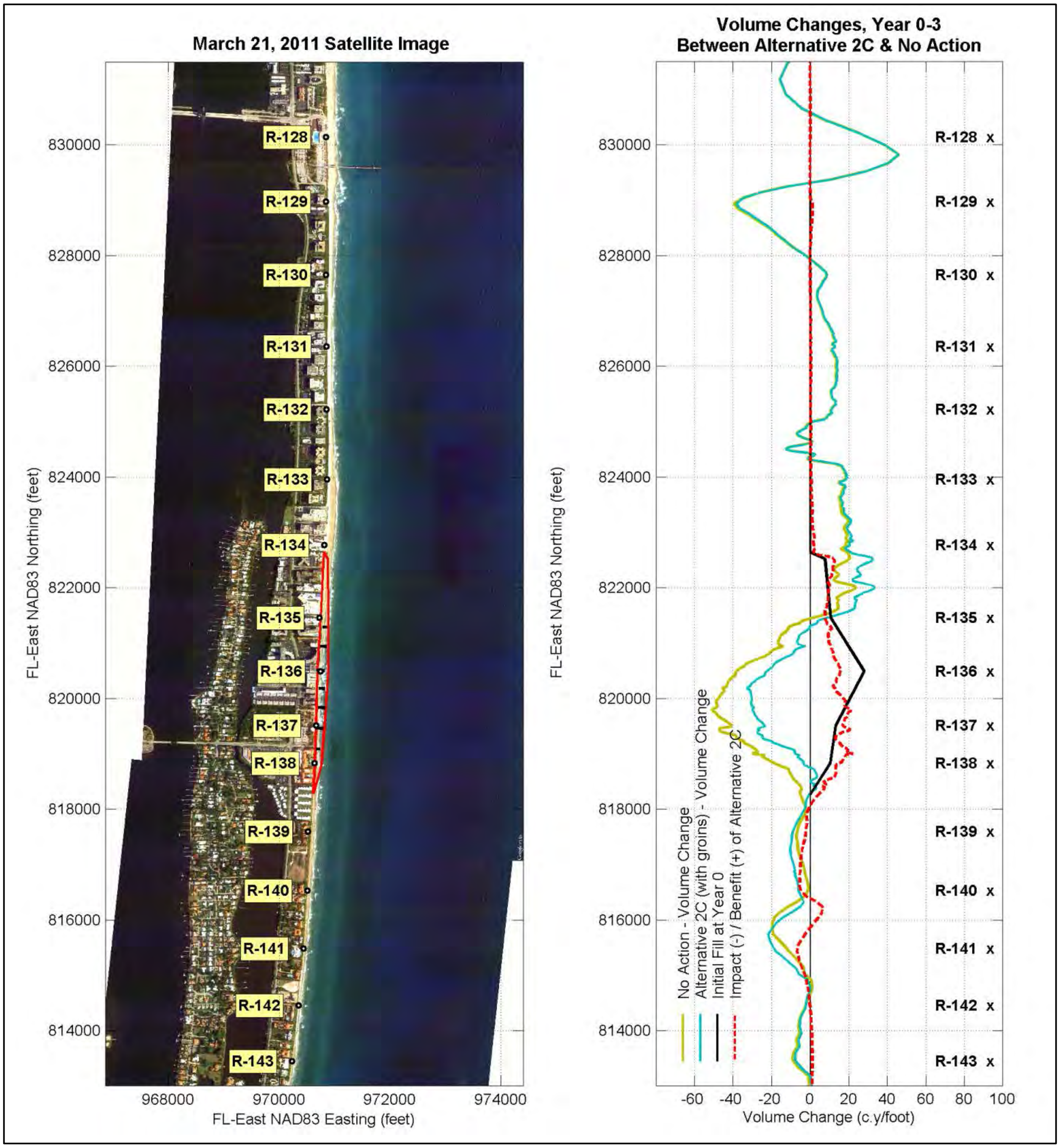

Figure 5-13. Volume changes to Alternative 2C.

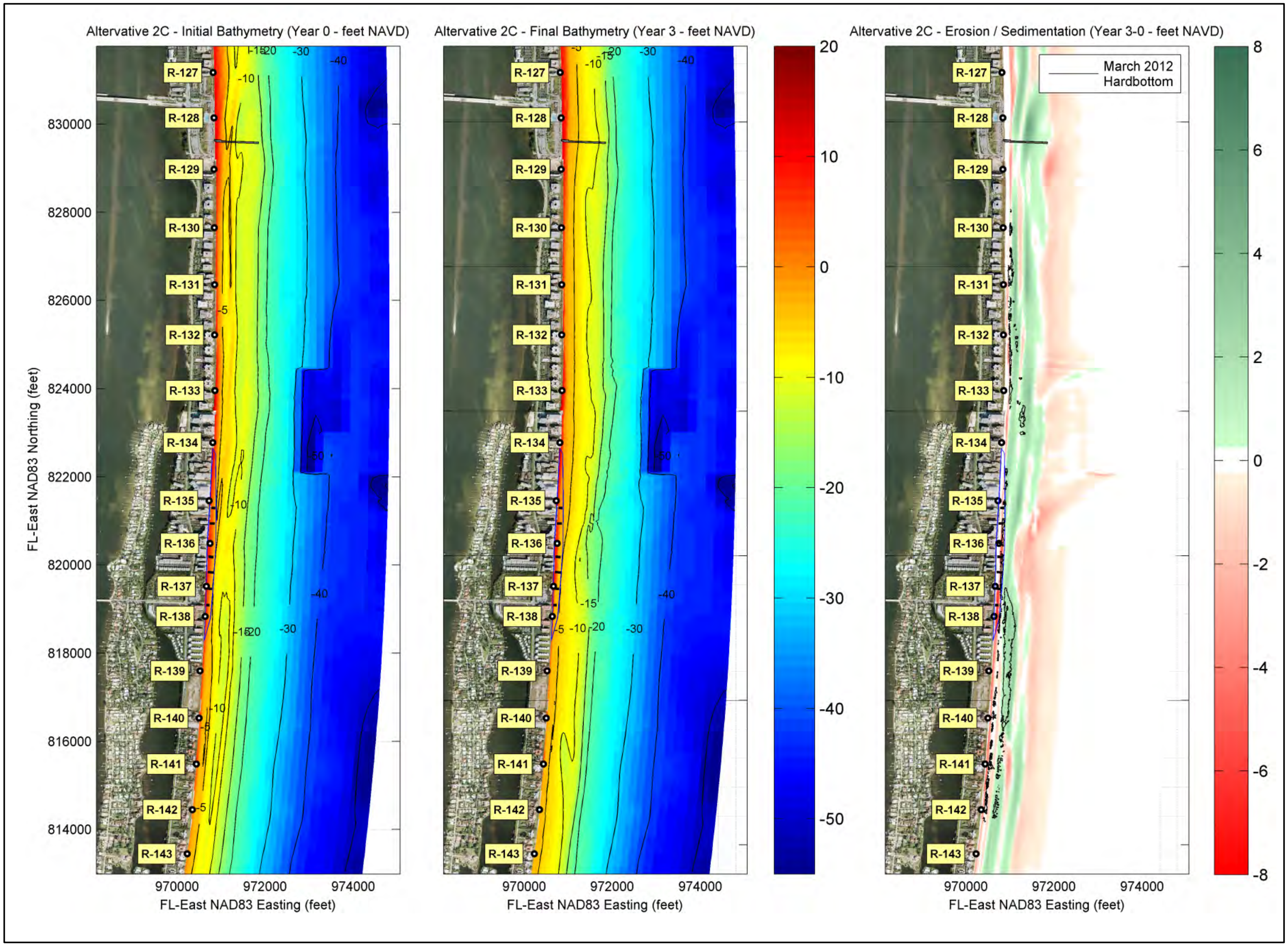

Figure 5-14. Erosion/sedimentation after 3 years of simulation, Alternative 2C.

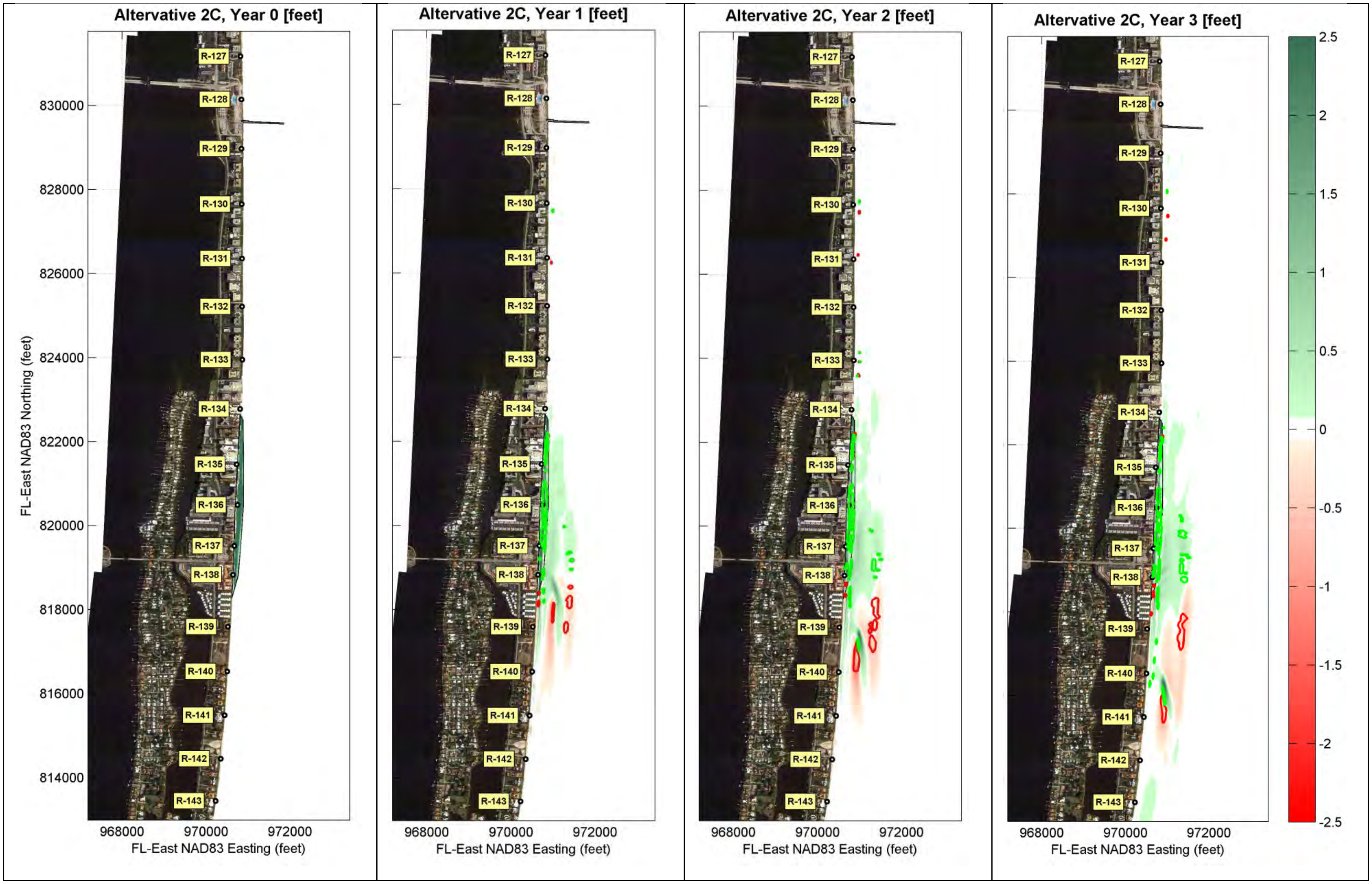

Figure 5-15. Temporal evolution of beach nourishment for Alternative 2C, compared to No Action scenario.

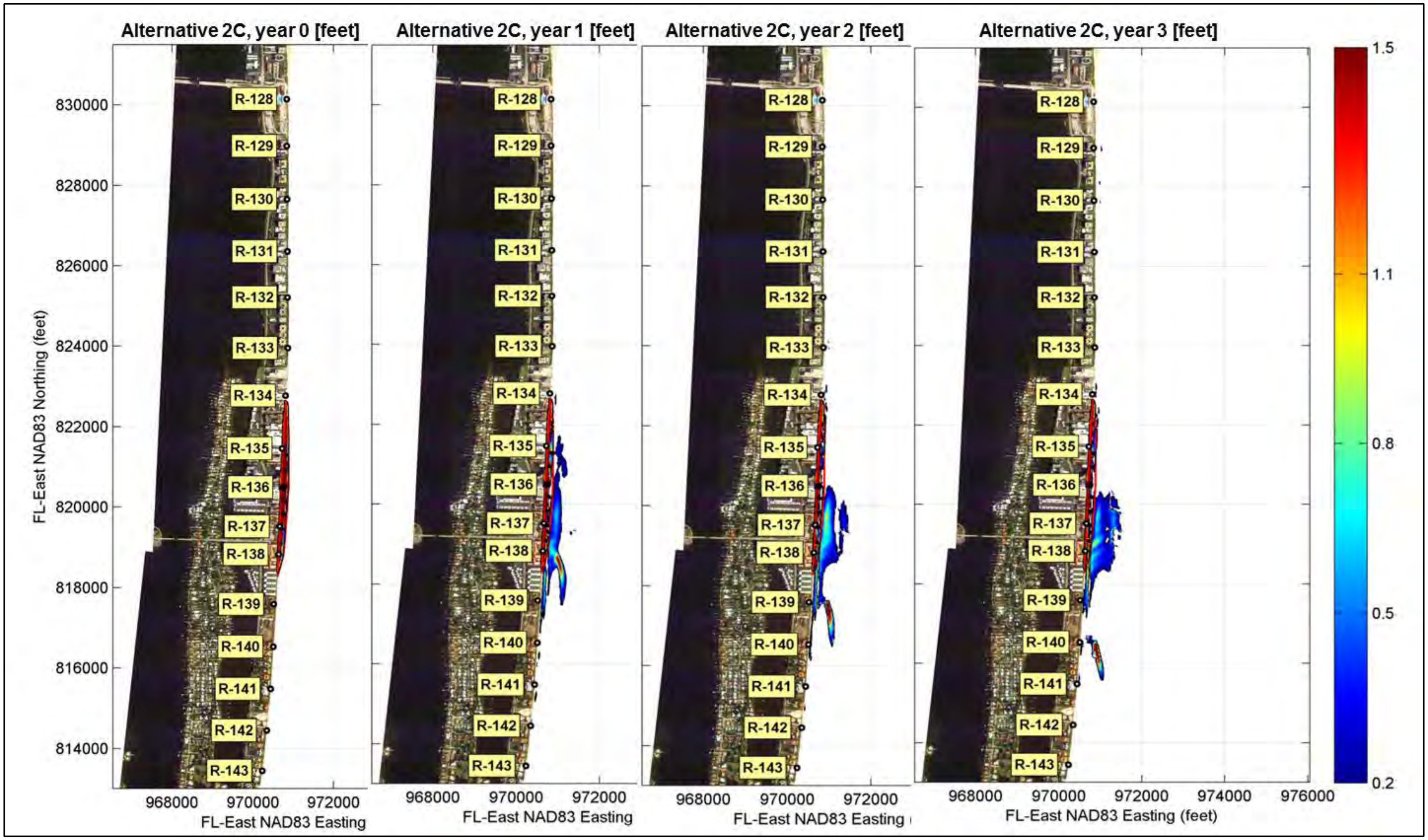

Figure 5-16. Sediment accumulation greater than 0.2 ft for Alternative 2C.

5.4. Alternative 3 - The Applicants' Preferred Project without Shoreline Protection Structures

5.4.1. Combined Action

Alternative 3 features the same fill layout as Alternative 2, however groins were not included. Model results given in Alternative 3 appear in Figure 5-17 through Figure 5-20.

The model results show behaviors similar to Alternative 2, but Alternative 3 results in greater erosion of fill volume in between R-134 and R-138 monuments and accretion downdrift as shown in Figure 5-18. This indicates that in the absence of the groins, greater spreading in the longshore direction could be anticipated for Alternative 3 as compared to Alternative 2. Figure 5-19 and Figure 5-20 show the temporal evolution of the fill from year 0 to year 3. Compared to Alternative 2, Alternative 3 shows less cross shore spreading of the fill. This is attributed to the fill being transported downdrift in the absence of the groins.

The main difference compared to Alternative 2 was the movement of fill between monuments R-135 and R-140. Alternative 3 showed greater alongshore spreading extending downdrift R-141.

At the end of the 3 year simulation period, there was an estimated coverage of 8.09 acres of hardbottom and an exposure of 0.80 acres attributed to the alternative as depicted in Figure 5-19. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -7.29 acres.

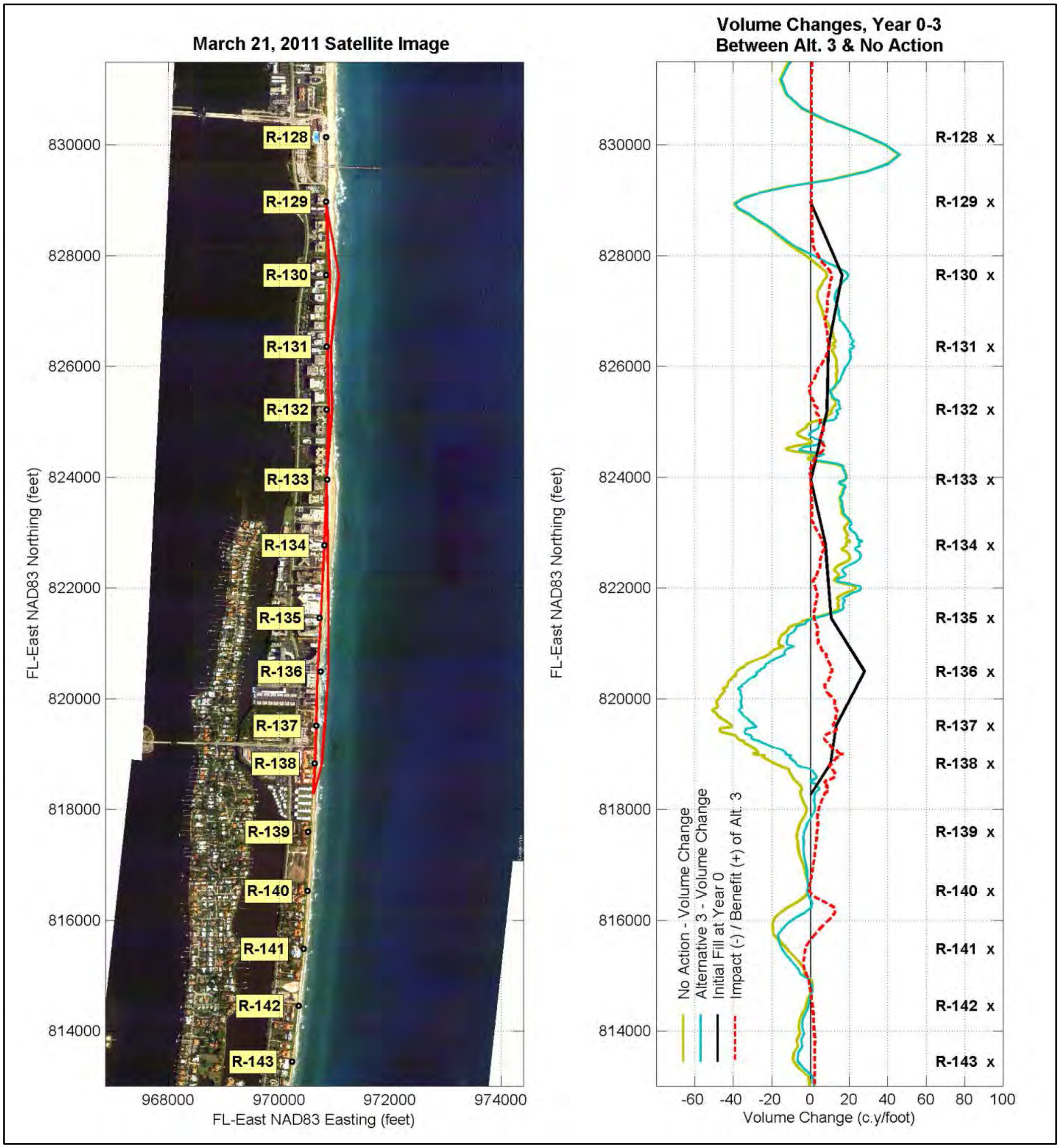

Figure 5-17. Volume changes to Alternative 3.

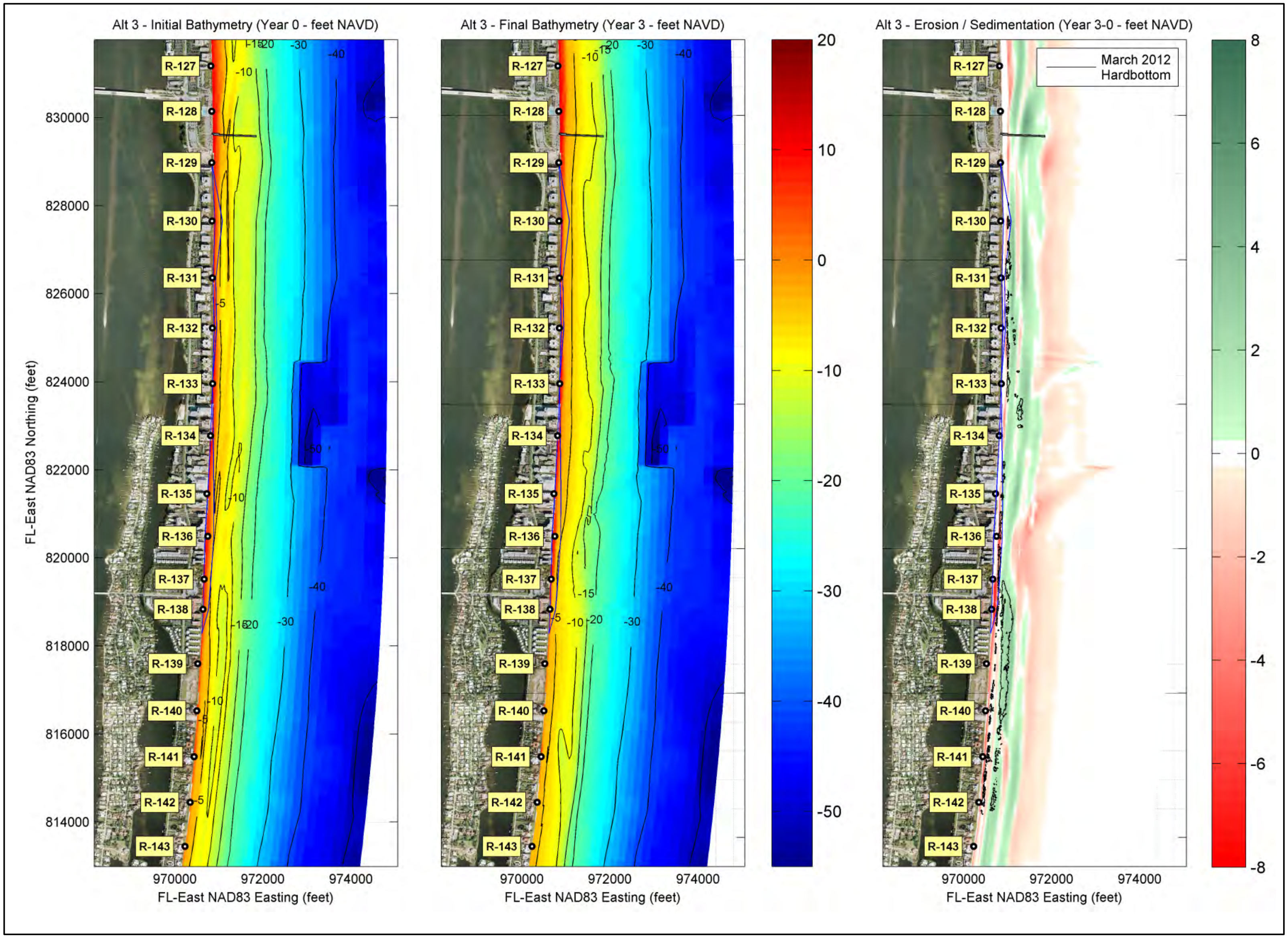

Figure 5-18. Erosion/sedimentation after 3 years of simulation, Alternative 3.

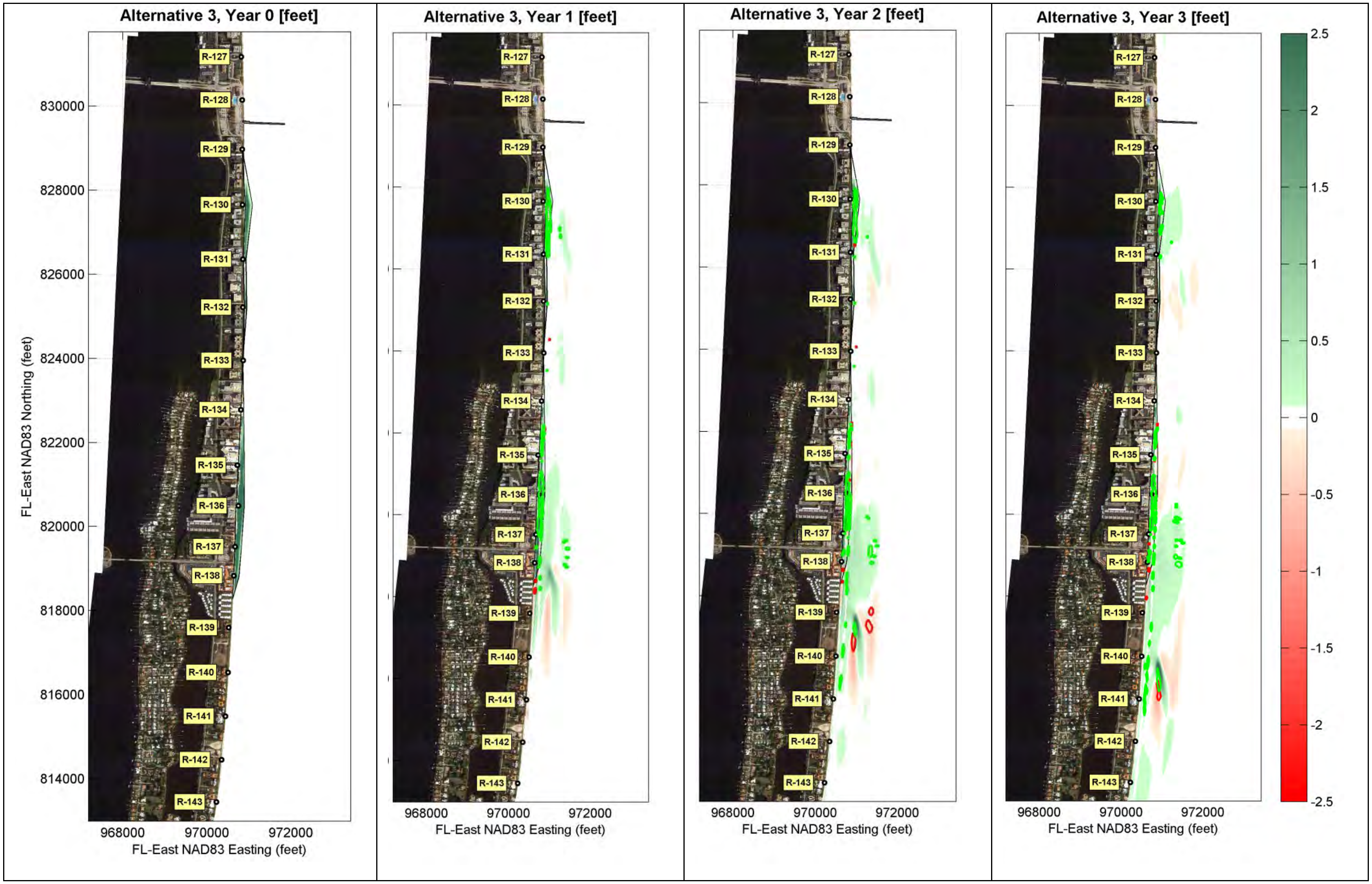

Figure 5-19. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 3, compared to No Action scenario.

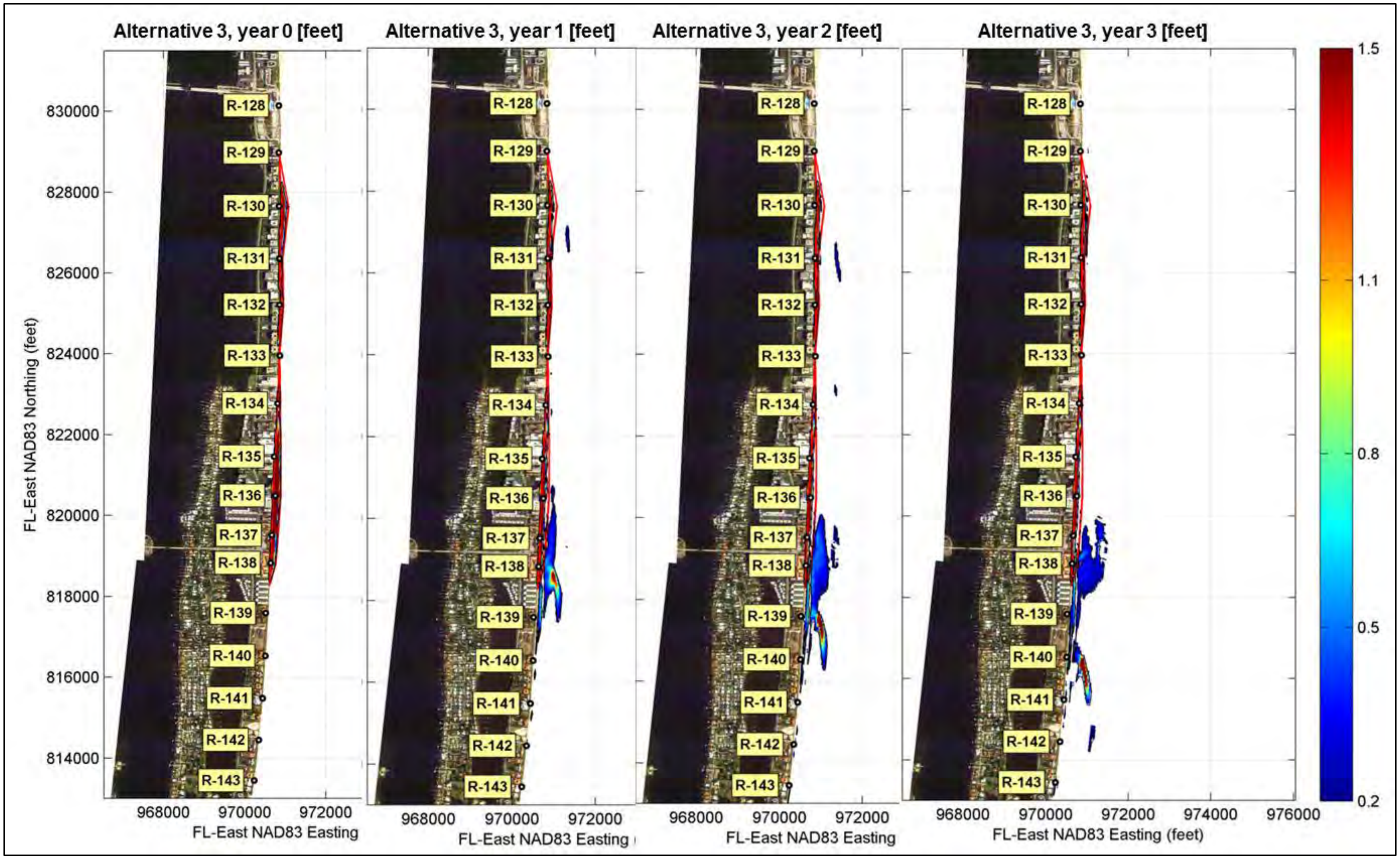

Figure 5-20. Sediment Accumulation greater than 0.2 ft for Alternative 3.

5.4.2. Separated Actions

Alternative 3C (County portion of alternative)

Alternative 3C presents the same fill configuration as Alternative 2C, but without structures. Model results given Alternative 3C are shown in Figure 5-21 through Figure 5-24. The model shows similar patterns of sedimentation as Alternative 3, which included the Town of Palm Beach's portion of the project.

At the end of the 3 year simulation period, there was an estimated coverage of 7.15 acres of hardbottom and an exposure of 0.90 acres attributed to the alternative as depicted in Figure 5-23. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -6.25 acres.

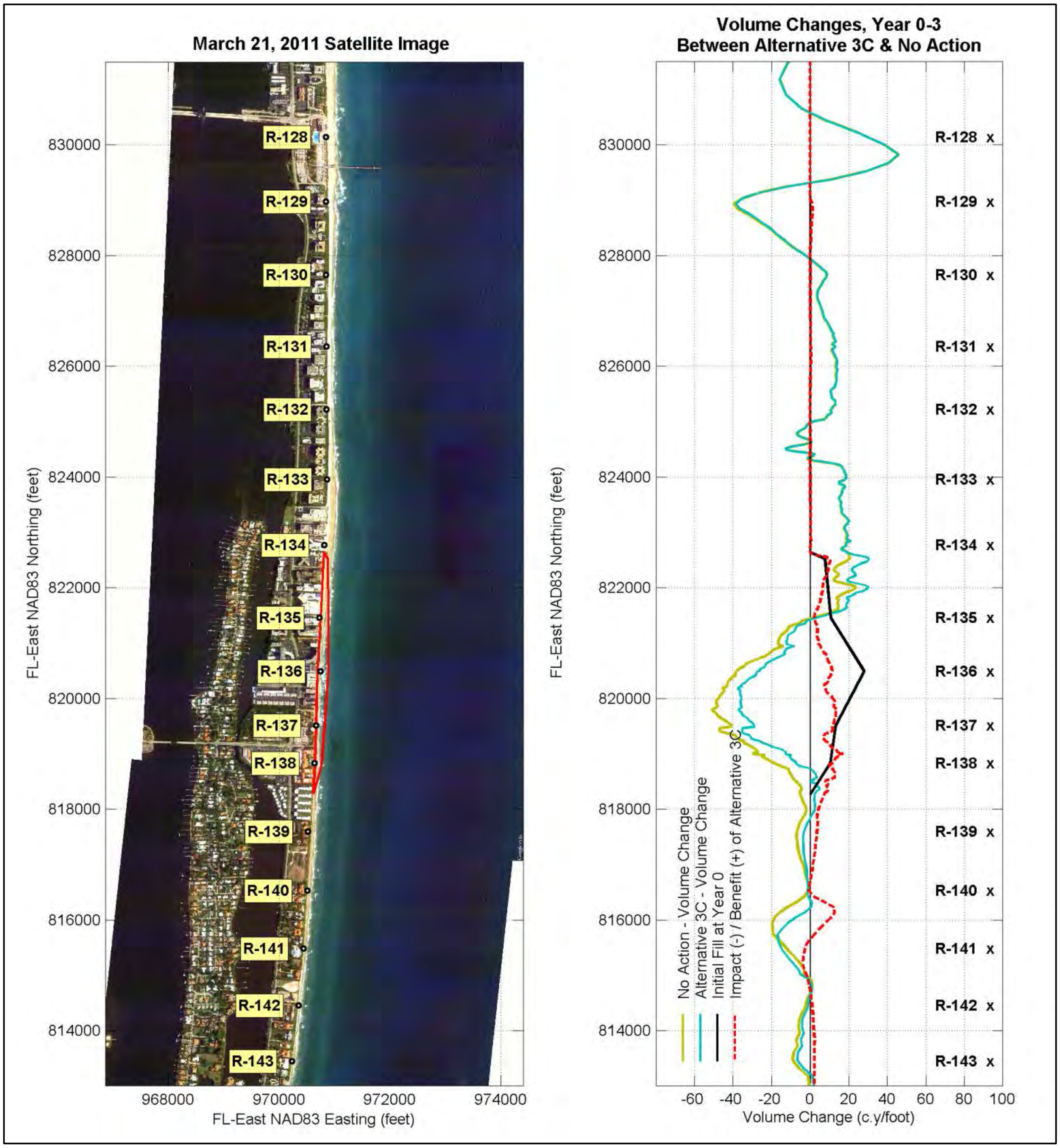

Figure 5-21. Volume Changes to Alternative 3C.

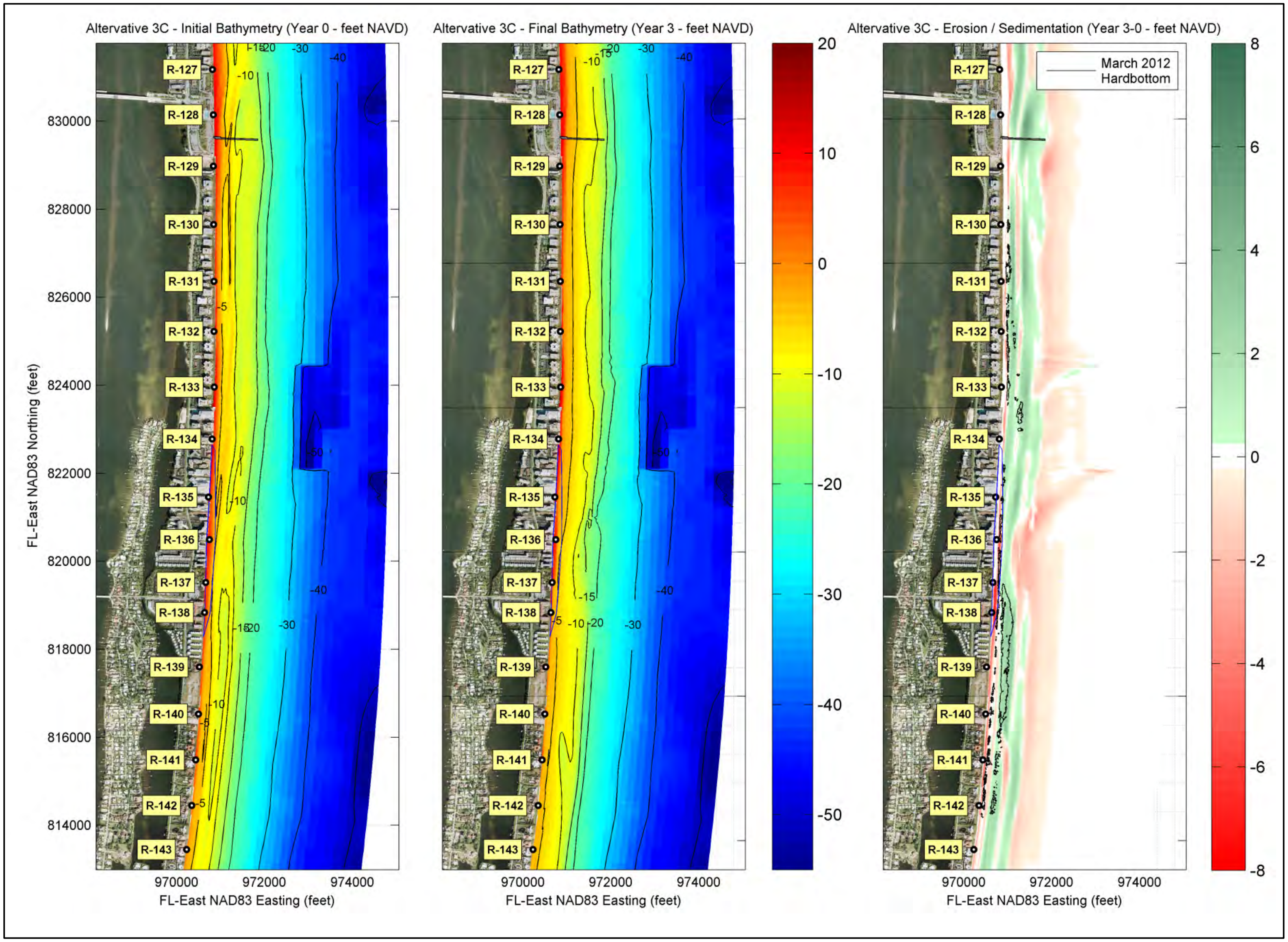

Figure 5-22. Erosion/Sedimentation after 3 years of simulation, Alternative 3C.

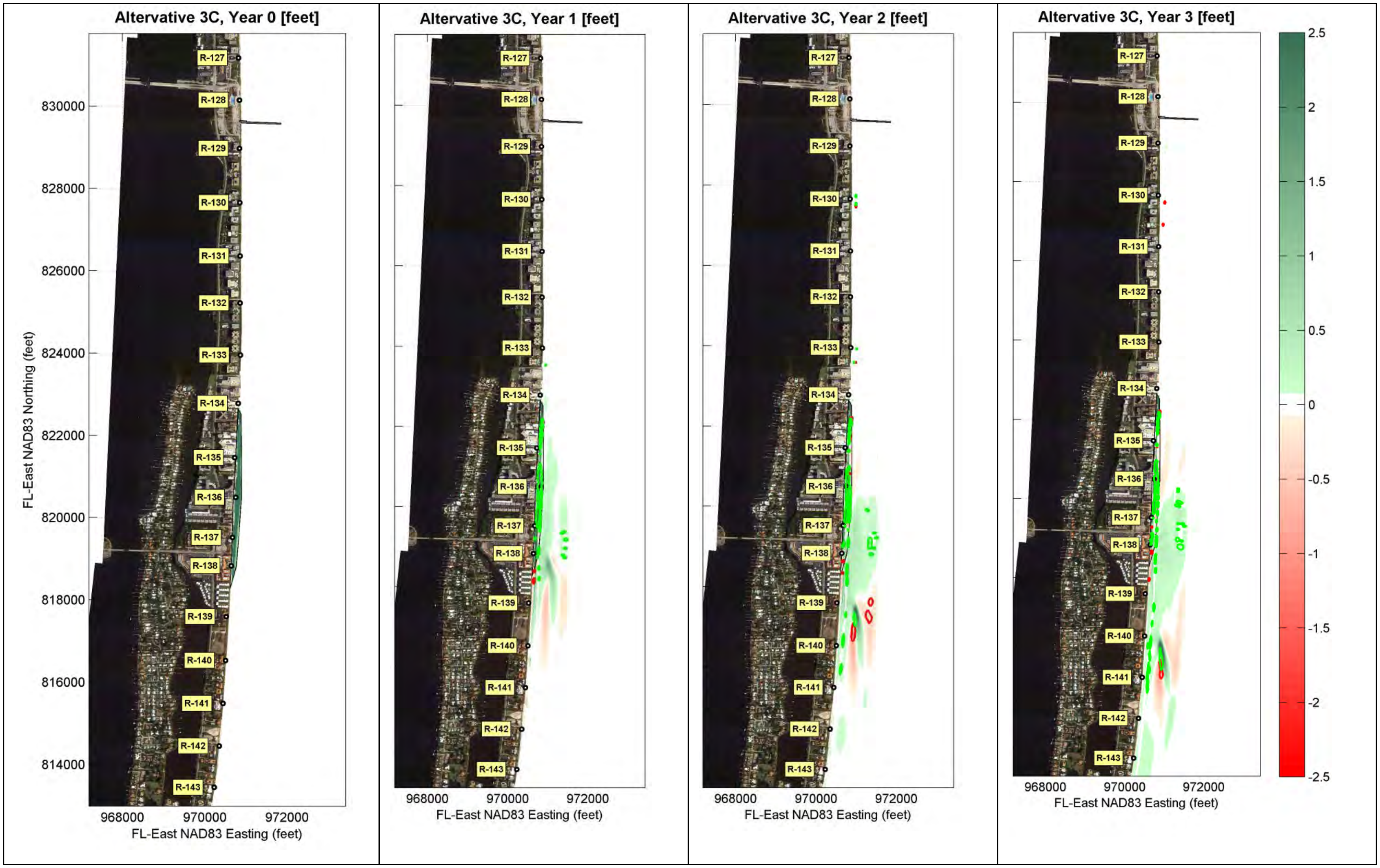

Figure 5-23. Temporal evolution of beach nourishment for Alternative 3C, compared to No Action scenario.

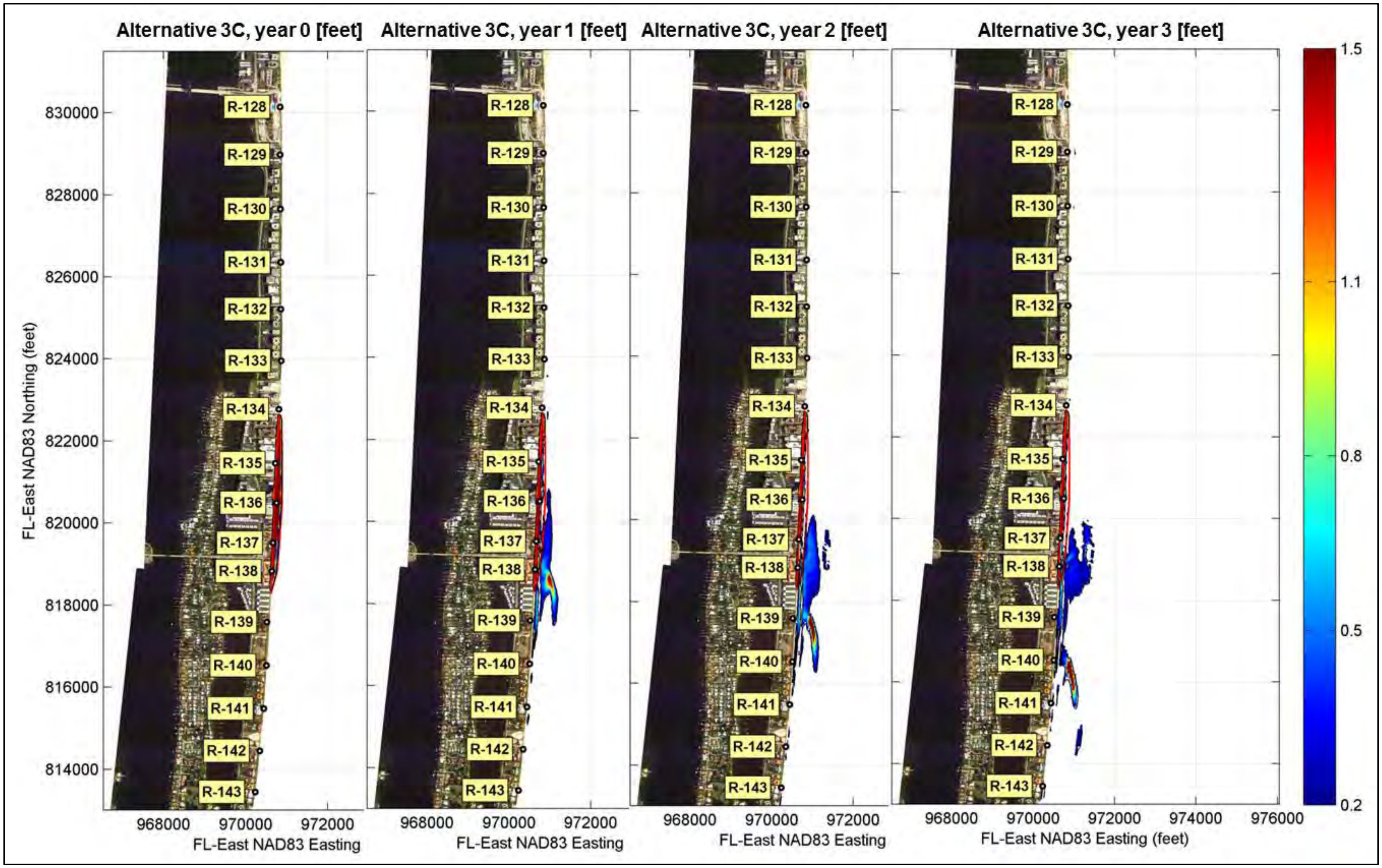

Figure 5-24. Sediment Accumulation greater than 0.2 ft for Alternative 3C.

5.5. Alternative 4 - The Town of Palm Beach Preferred Project and County Increased Sand Volume Project without Shoreline Protection Structures

Alternative 4 includes the placement of 225,900 cubic yards of sand between R-129-210 and R-138+551. Model results for Alternative 4 are shown in Figure 5-26 through Figure 5-28. The sedimentation patterns north of R-134 are similar to Alternative 3, which is expected given that the fill volumes north of R-134 were maintained for Alternative 4. South of R-134 larger fill volumes were included as compared to Alternative 3. The larger fill volumes resulted in increased coverage of sedimentation areas within the County's project area as compared to Alternative 3.

At the end of the 3 year simulation period, there was an estimated coverage of 12.15 acres of hardbottom and an exposure of 0.67 acres attributed to the alternative as depicted in Figure 5-27. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -11.48 acres.

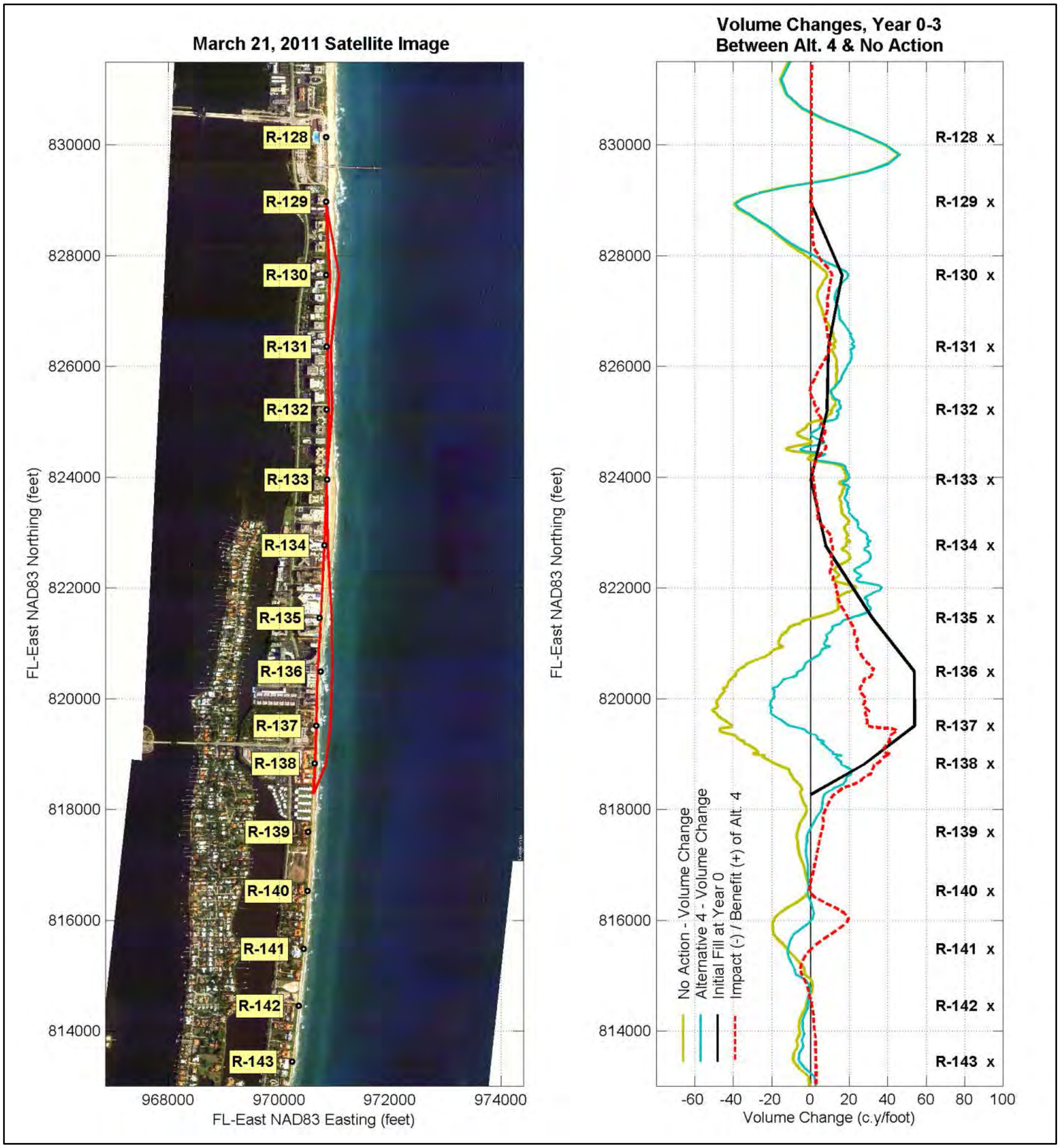

Figure 5-25. Volume changes to Alternative 4.

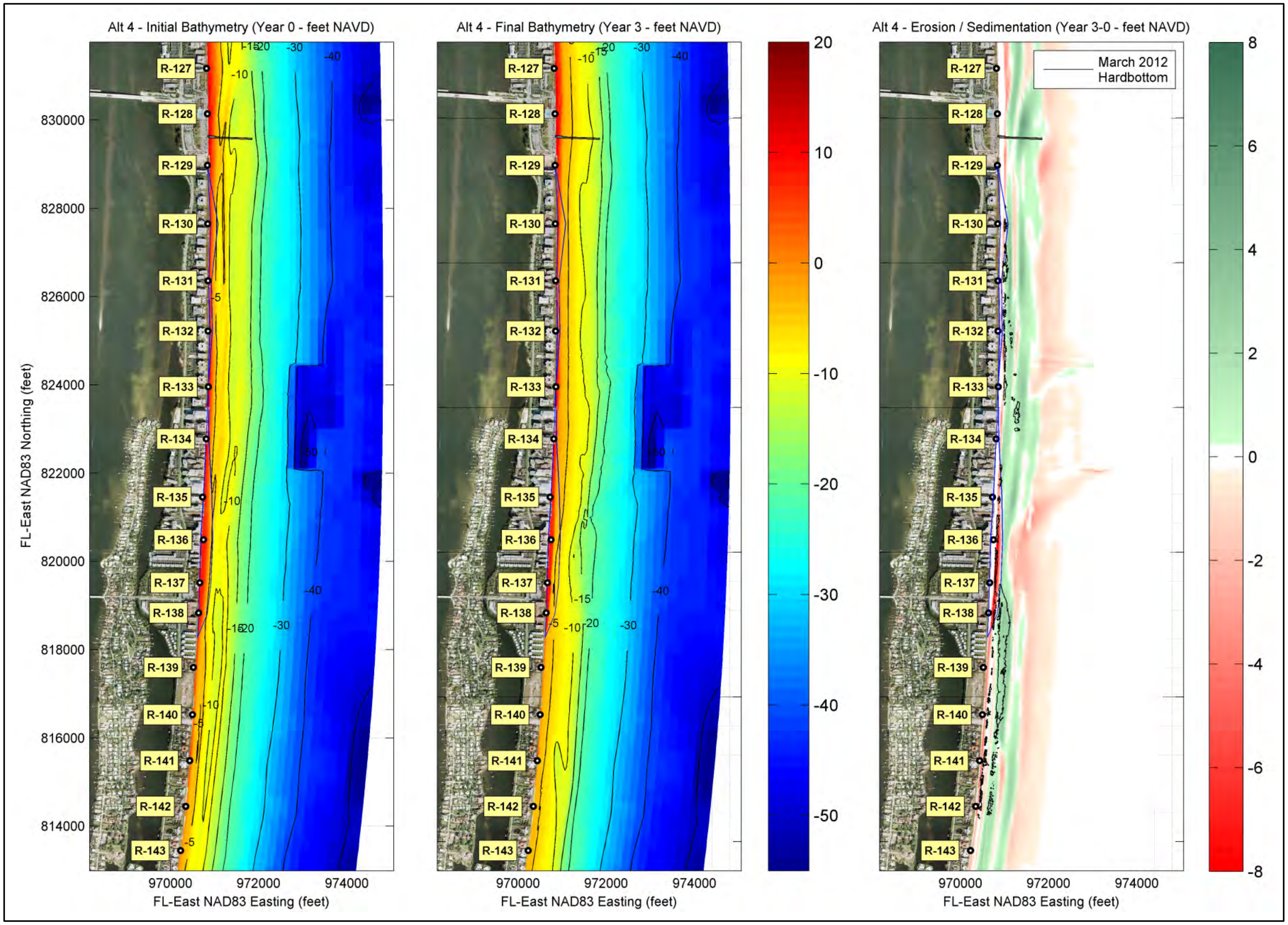

Figure 5-26. Erosion/Sedimentation after 3 years of simulation, Alternative 4.

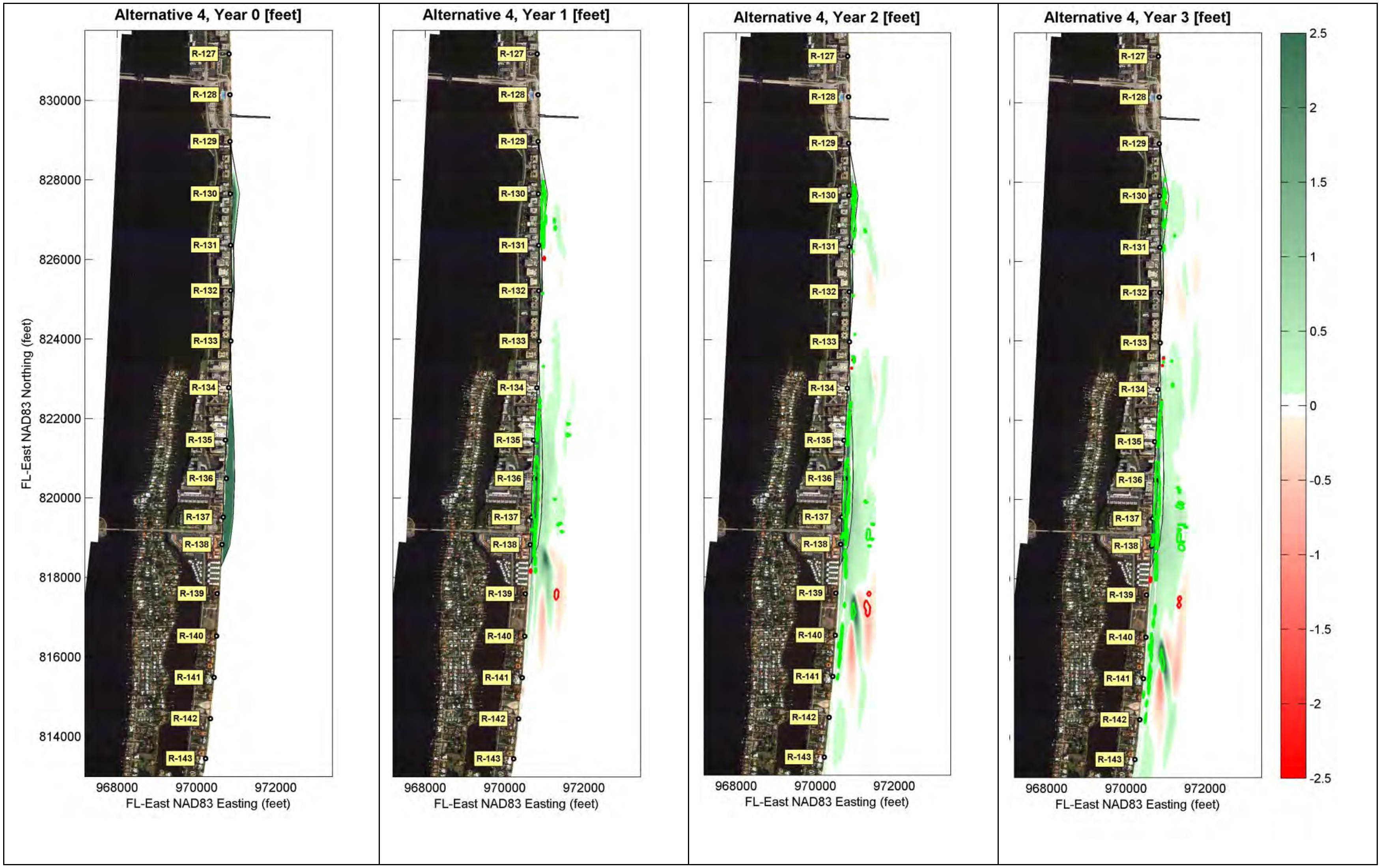

Figure 5-27. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 4.

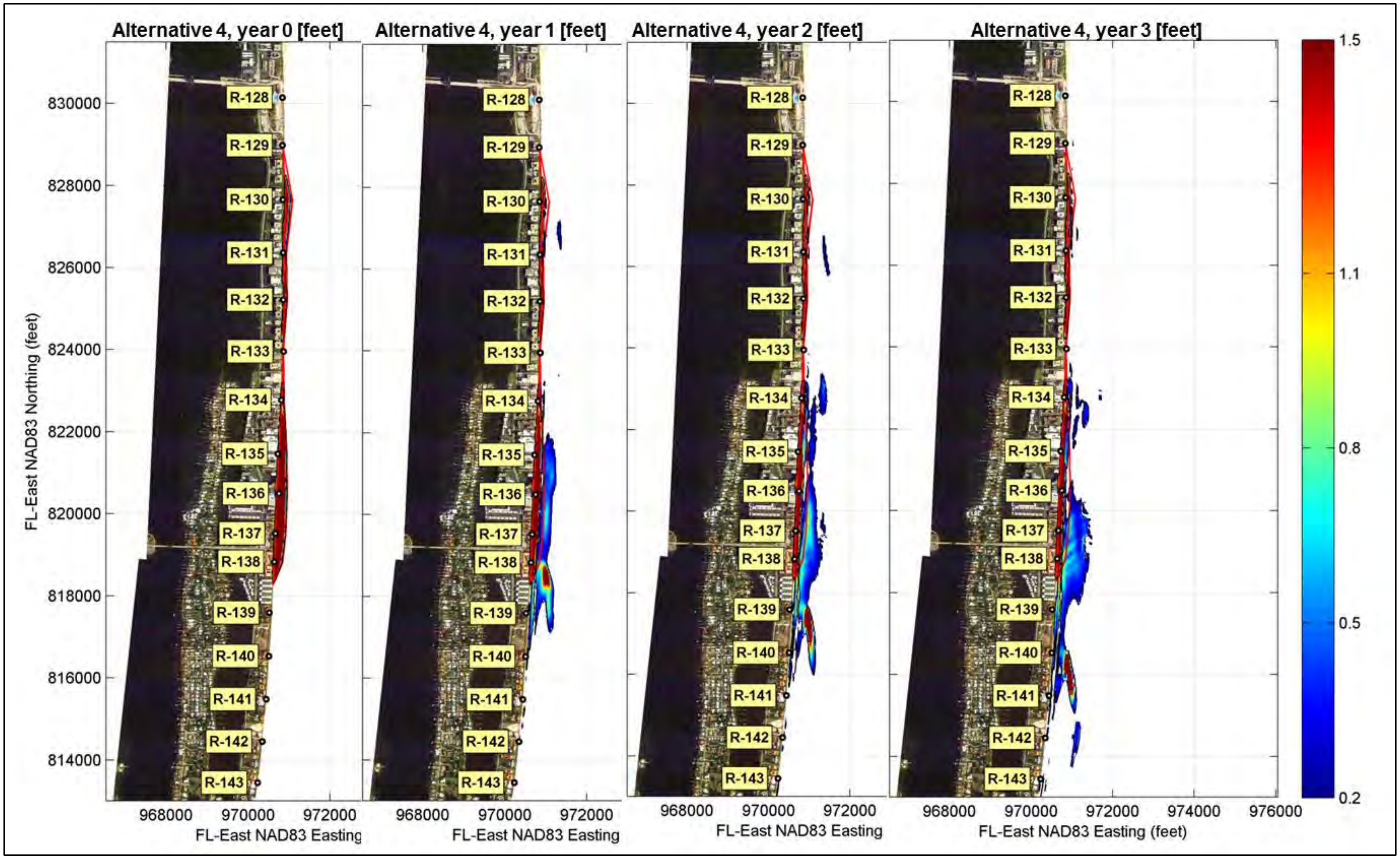

Figure 5-28. Sediment accumulation greater than 0.2 ft for Alternative 4.

5.6. Alternative 5 - The Town of Palm Beach Increased Sand Volume Project and County Preferred Project

Alternative 5 places seven groins between R-135+160 and R-137+422 and 164,500 cubic yards of fill material between R-129-210 and R-138+551. Model results given in Alternative 5 appear in Figure 5-29 through Figure 5-32. The fill volume north of R-134+135 is increased as compared to Alternative 3, while the fill volume to the south is the same as Alternative 2. The sedimentation areas in the Town of Palm Beach's portion of the project increased as compared to Alternative 3.

At the end of the 3 year simulation period, there was an estimated coverage of 10.09 acres of hardbottom and an exposure of 3.44 acres attributed to the alternative as depicted in Figure 5-31. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -6.64 acres.

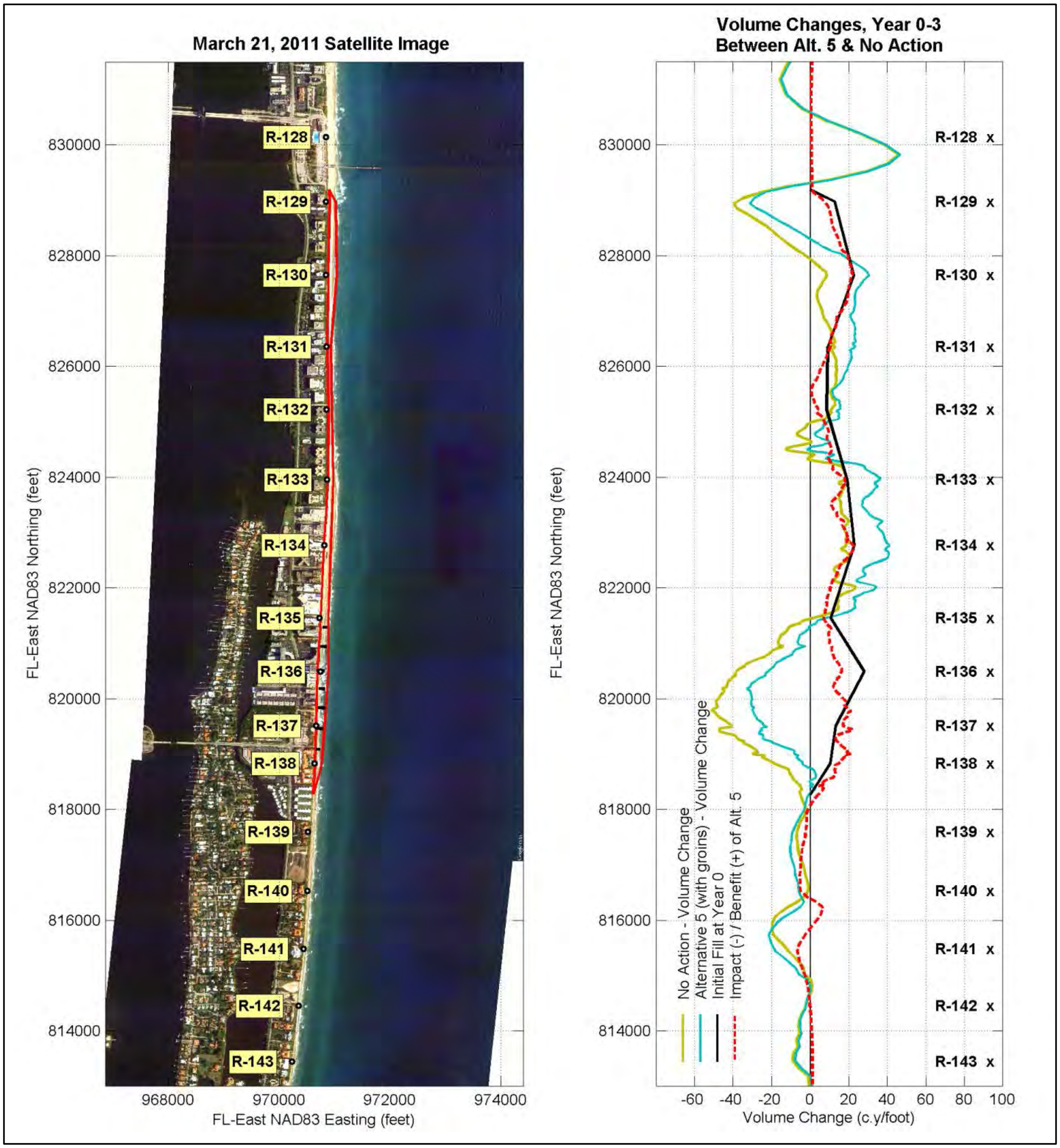

Figure 5-29. Volume changes, Alternative 5.

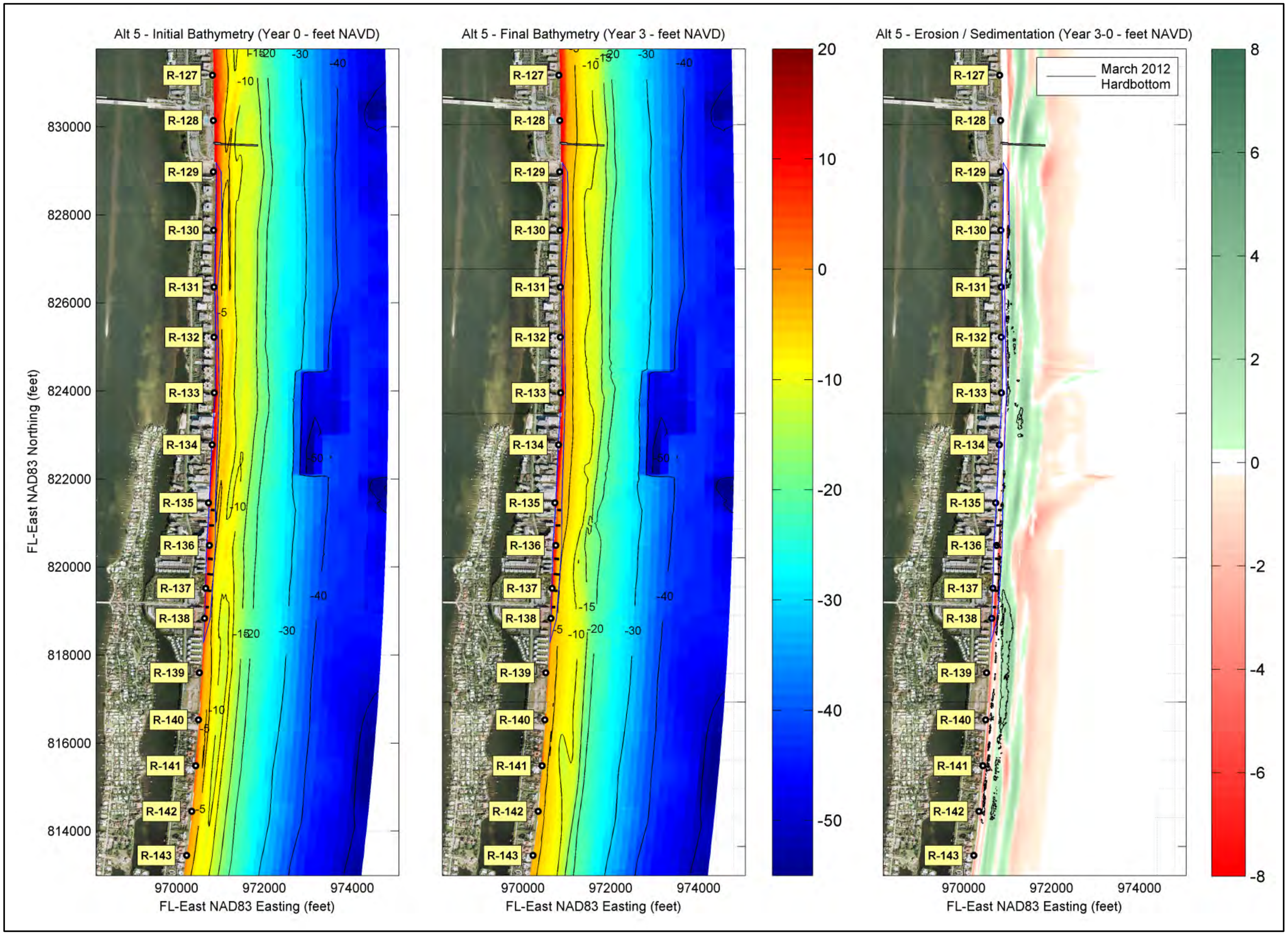

Figure 5-30. Erosion/Sedimentation after 3 years of simulation, Alternative 5.

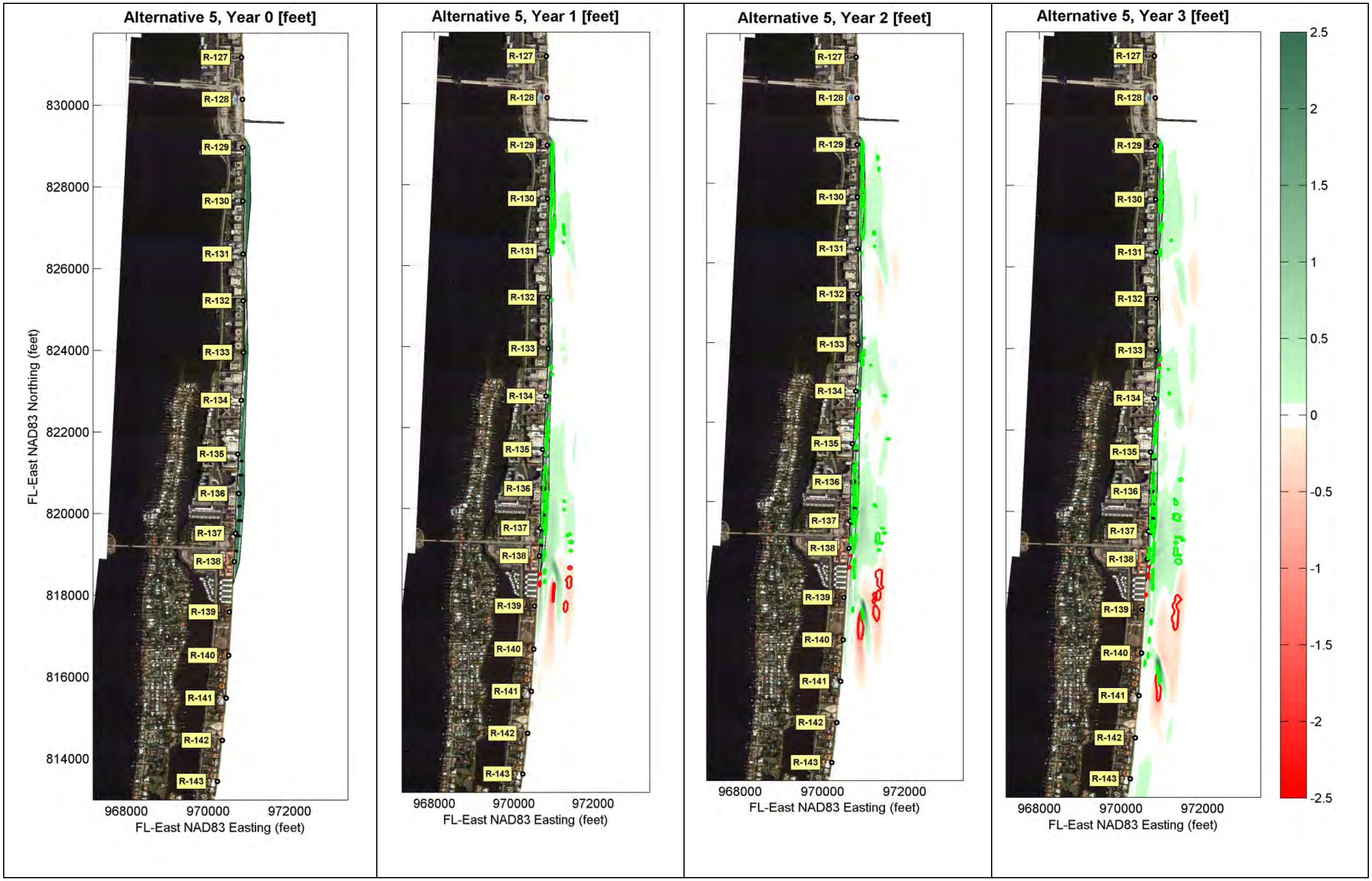

Figure 5-31. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 5.

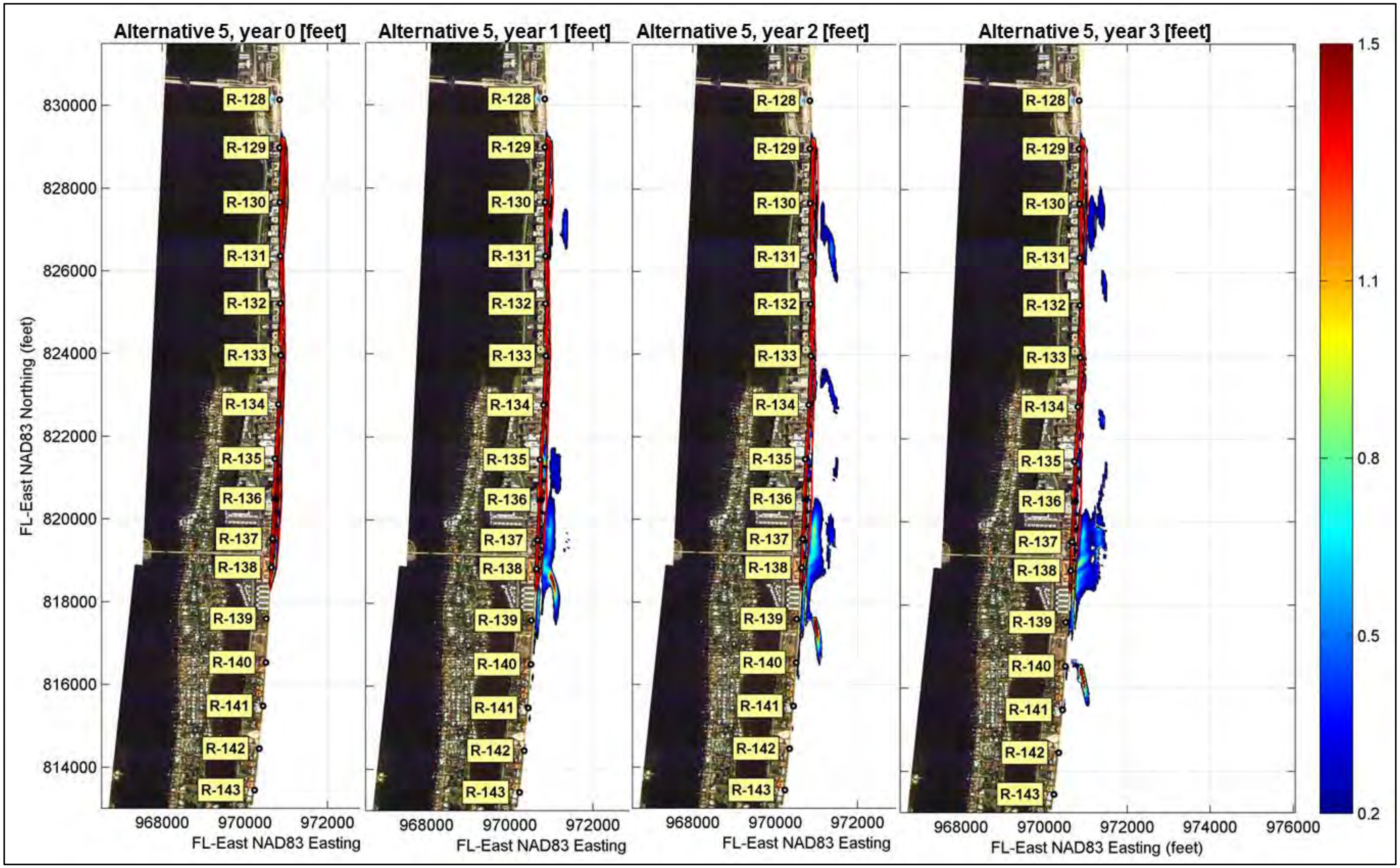

Figure 5-32. Sediment Accumulation greater than 0.2 ft for Alternative 5.

5.7. Alternative 6 - The Town of Palm Beach Increased Sand Volume Project and County Increased Sand Volume without Shoreline Protection Structures Project

5.7.1. Combined Action

Alternative 6 includes the increased sand volume north of R-134+135 modeled for Alternative 5 and the increased volume south of R-134+135 modeled for Alternative 4. Model results given in Alternative 6 appear in Figure 5-33 through Figure 5-36. Alternative 6 shows the greatest coverage of sedimentation areas greater than 0.2 feet as compared to Alternatives 2 through 5.

At the end of the 3 year simulation period, there was an estimated coverage of 13.43 acres of hardbottom and an exposure of 0.44 acres attributed to the alternative as depicted in Figure 5-35. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -12.99 acres.

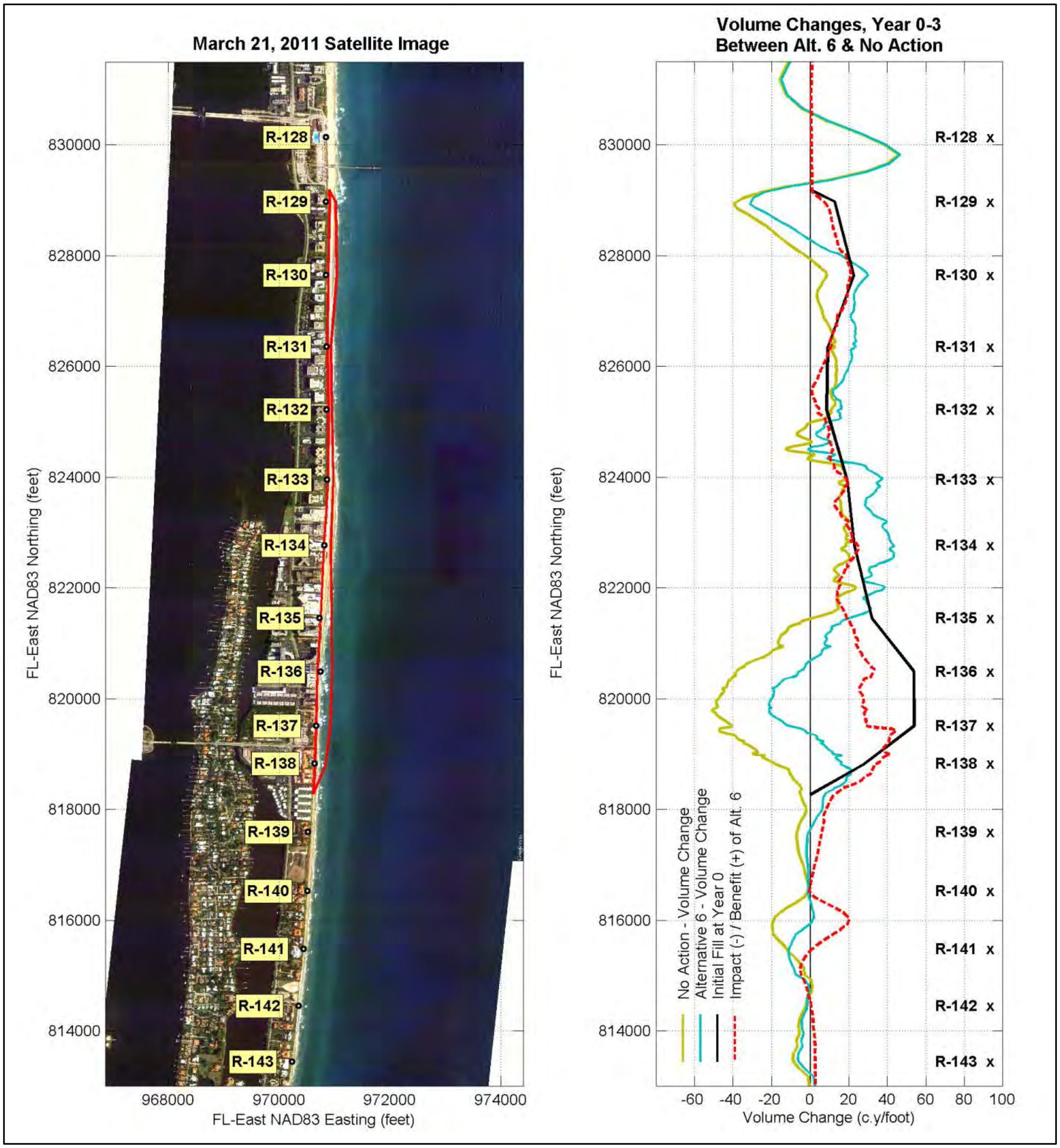

Figure 5-33. Volume changes, Alternative 6.

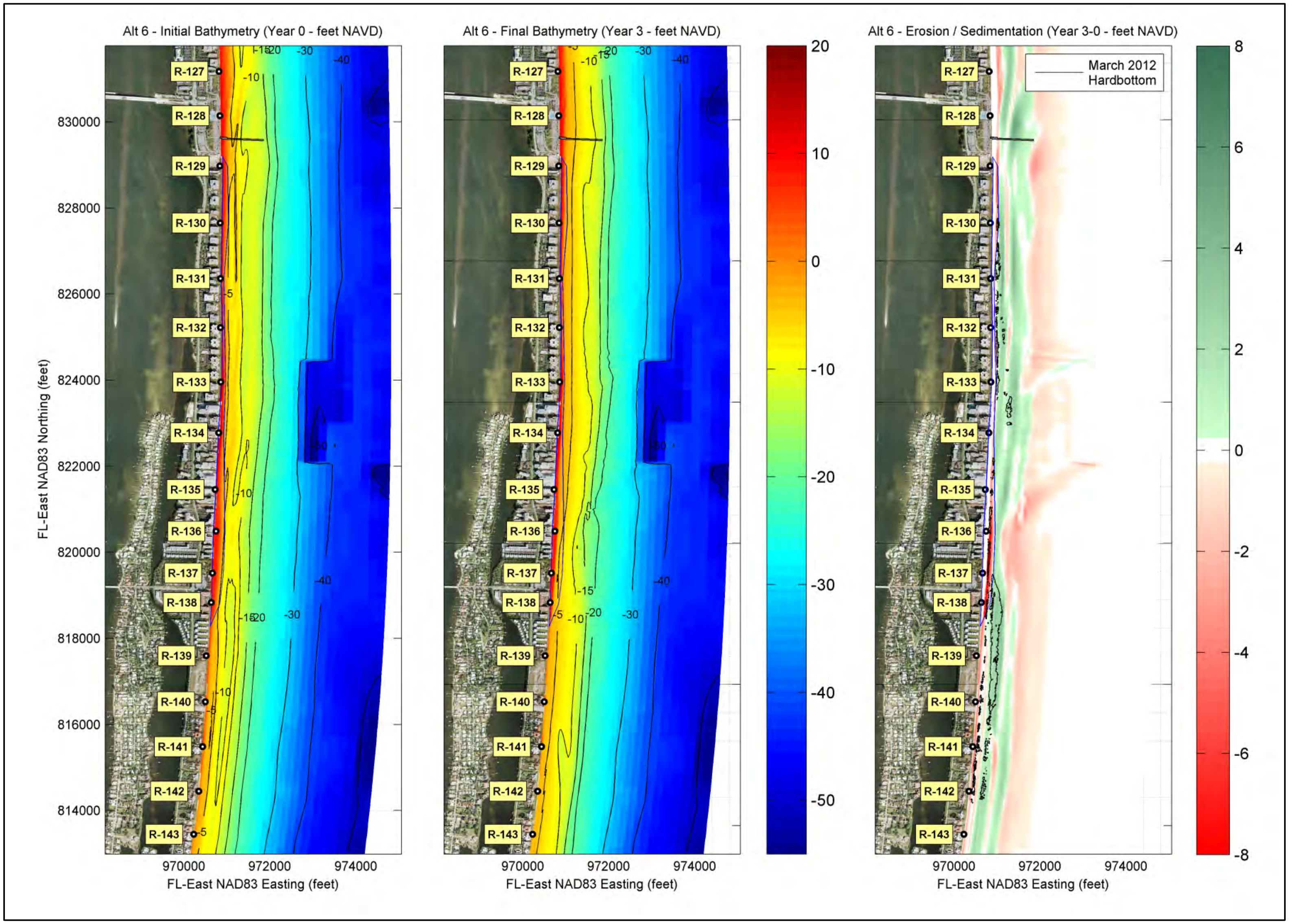

Figure 5-34. Erosion/Sedimentation after 3 years of simulation, Alternative 6.

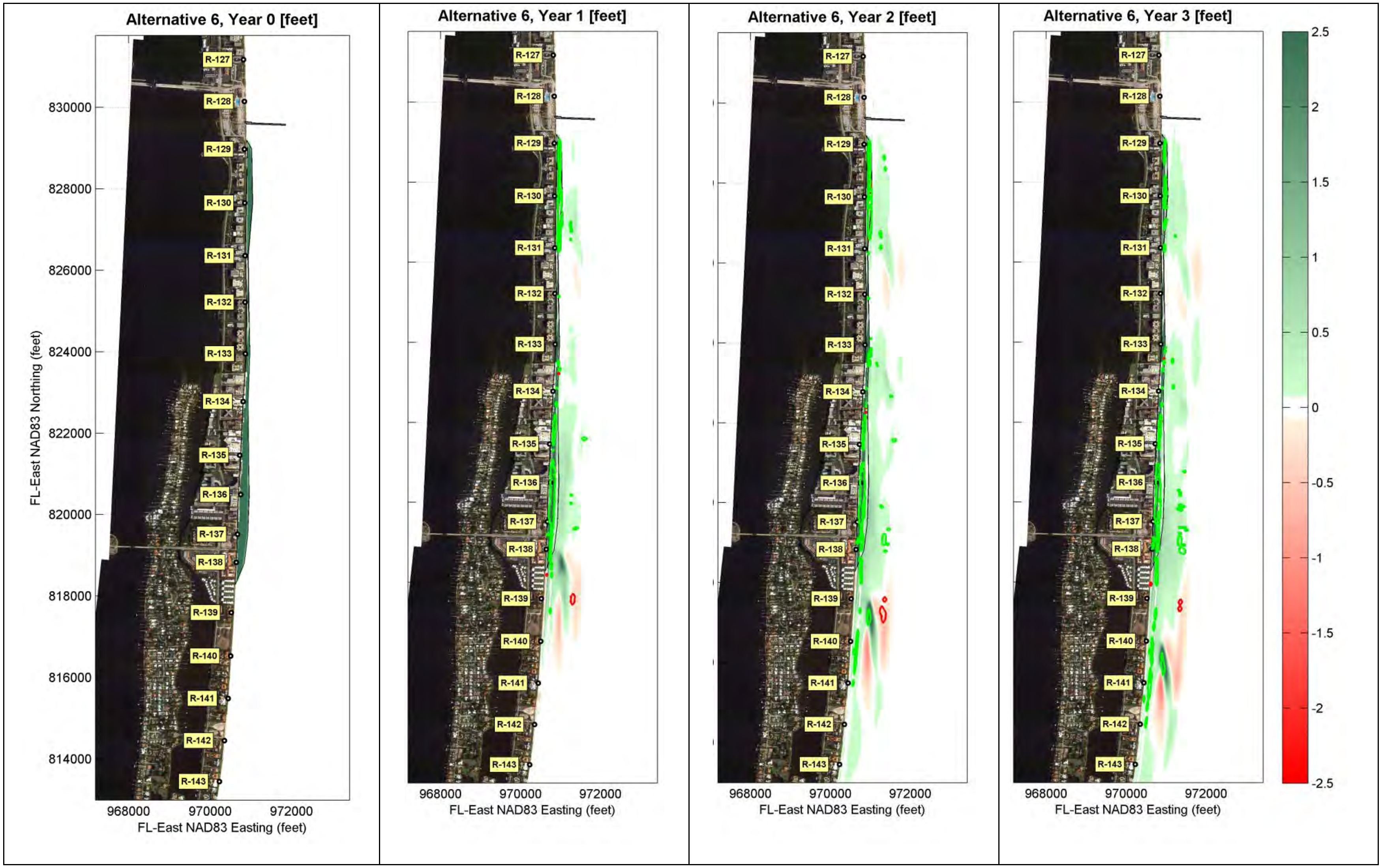

Figure 5-35. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 6, compared to No Action scenario.

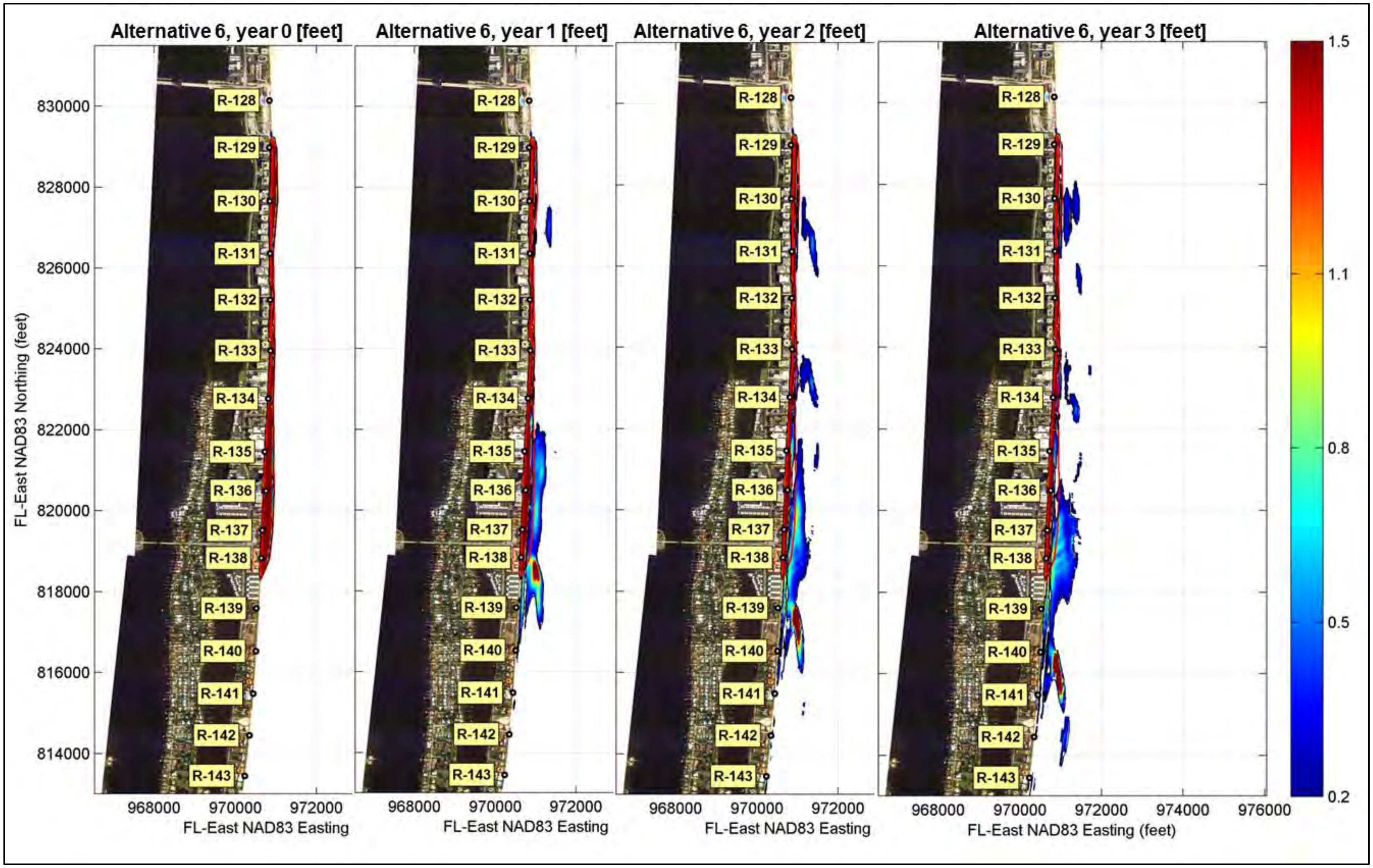

Figure 5-36. Sediment Accumulation greater than 0.2 ft for Alternative 6.

5.7.2. Separated Actions

Alternative 6T (Town of Palm Beach portion of alternative)

Alternative 6T presents a sand placement of 101,000 cubic yards along R-129-210 and R-134+135. Model results for Alternative 6T are shown in Figure 5-37 through Figure 5-40. The results show that the sedimentation areas greater than 0.2 feet within the Town of Palm Beach are less as compared to Alternative 6. This suggests that the fill placed to the south within the County for Alternative 6 may spread into the Town of Palm Beach limits.

At the end of the 3 year simulation period, there was an estimated coverage of 2.29 acres of hardbottom and an exposure of 0.08 acres attributed to the alternative as depicted in Figure 5-39. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -2.21 acres.

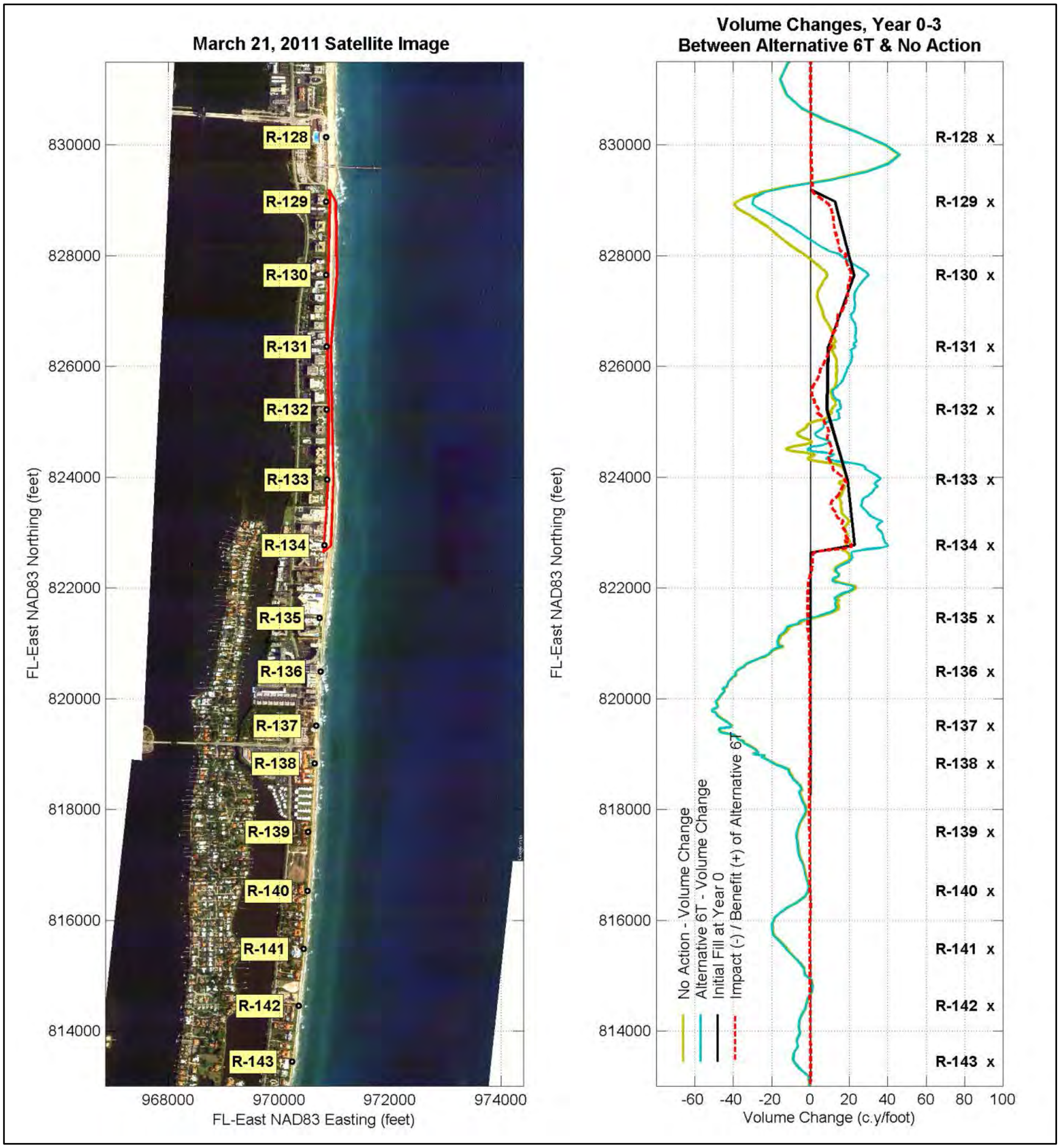

Figure 5-37. Volume changes, Alternative 6T.

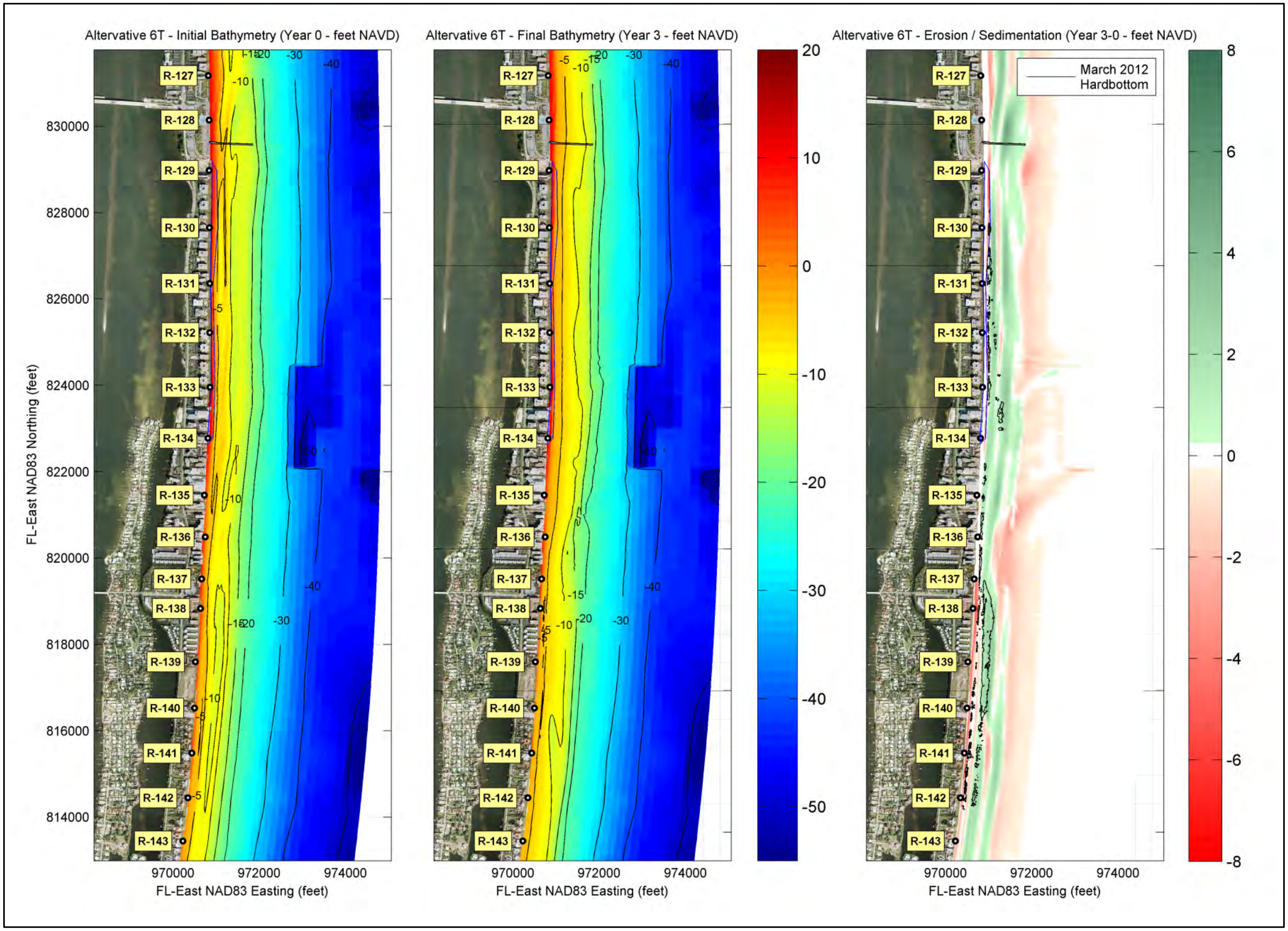

Figure 5-38. Erosion/sedimentation after 3 years of simulation, Alternative 6T.

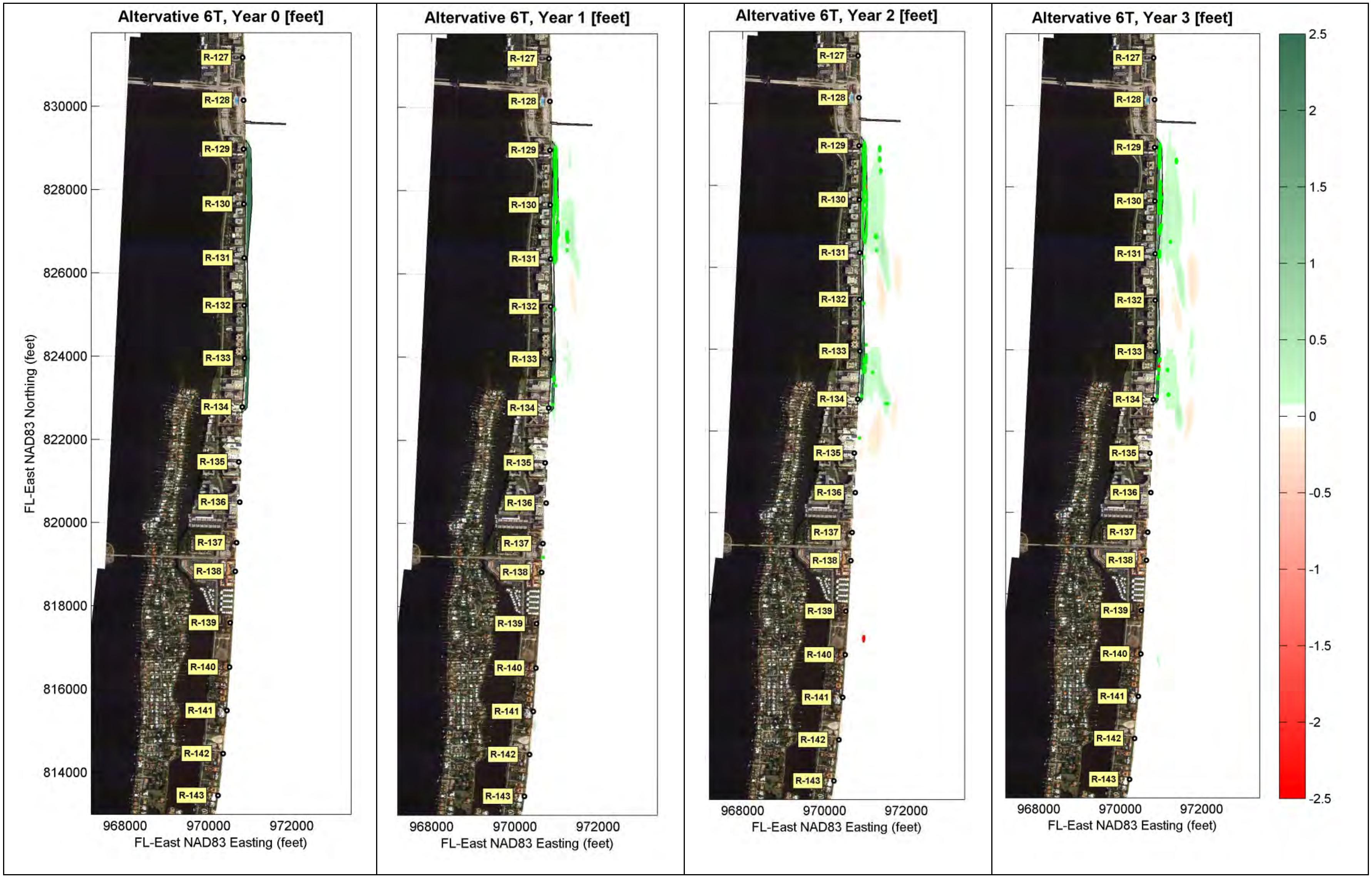

Figure 5-39. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 6T, compared to No Action scenario.

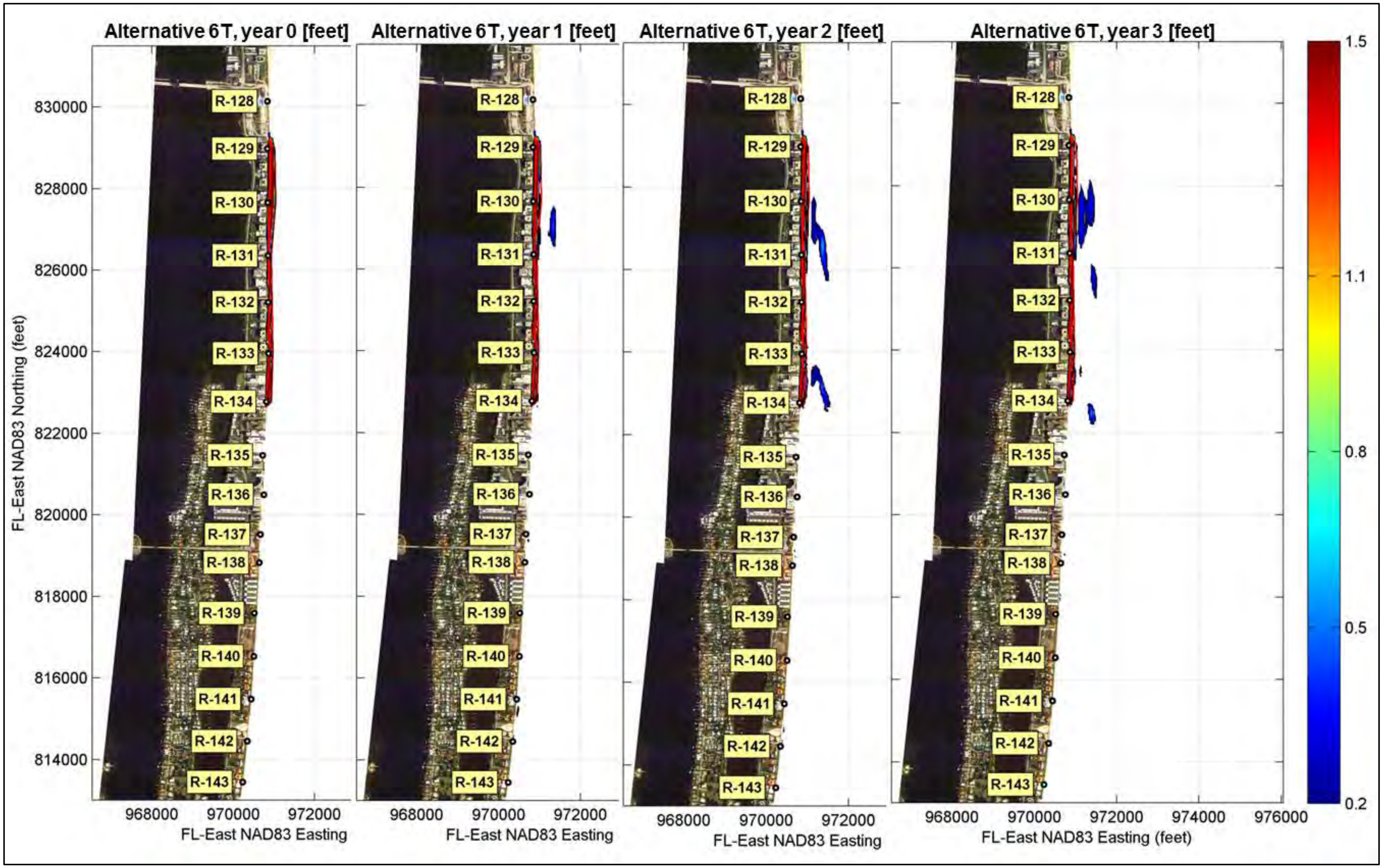

Figure 5-40. Sediment accumulation greater than 0.2 ft for Alternative 6T.

Alternative 6C (County portion of alternative)

Alternative 6C presents a sand placement of 172,000 cubic yards along R-134+135 and R-138+551. Model results for Alternative 6C are shown in Figure 5-41 through Figure 5-44. The sedimentation areas greater than 0.2 feet indicate that a majority of the areas are located offshore and downdrift of the County's project area, but some spreading to the north into the Town of Palm Beach is shown.

At the end of the 3 year simulation period, there was an estimated coverage of 11.26 acres of hardbottom and an exposure of 0.48 acres attributed to the alternative as depicted in Figure 5-43. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -10.77 acres.

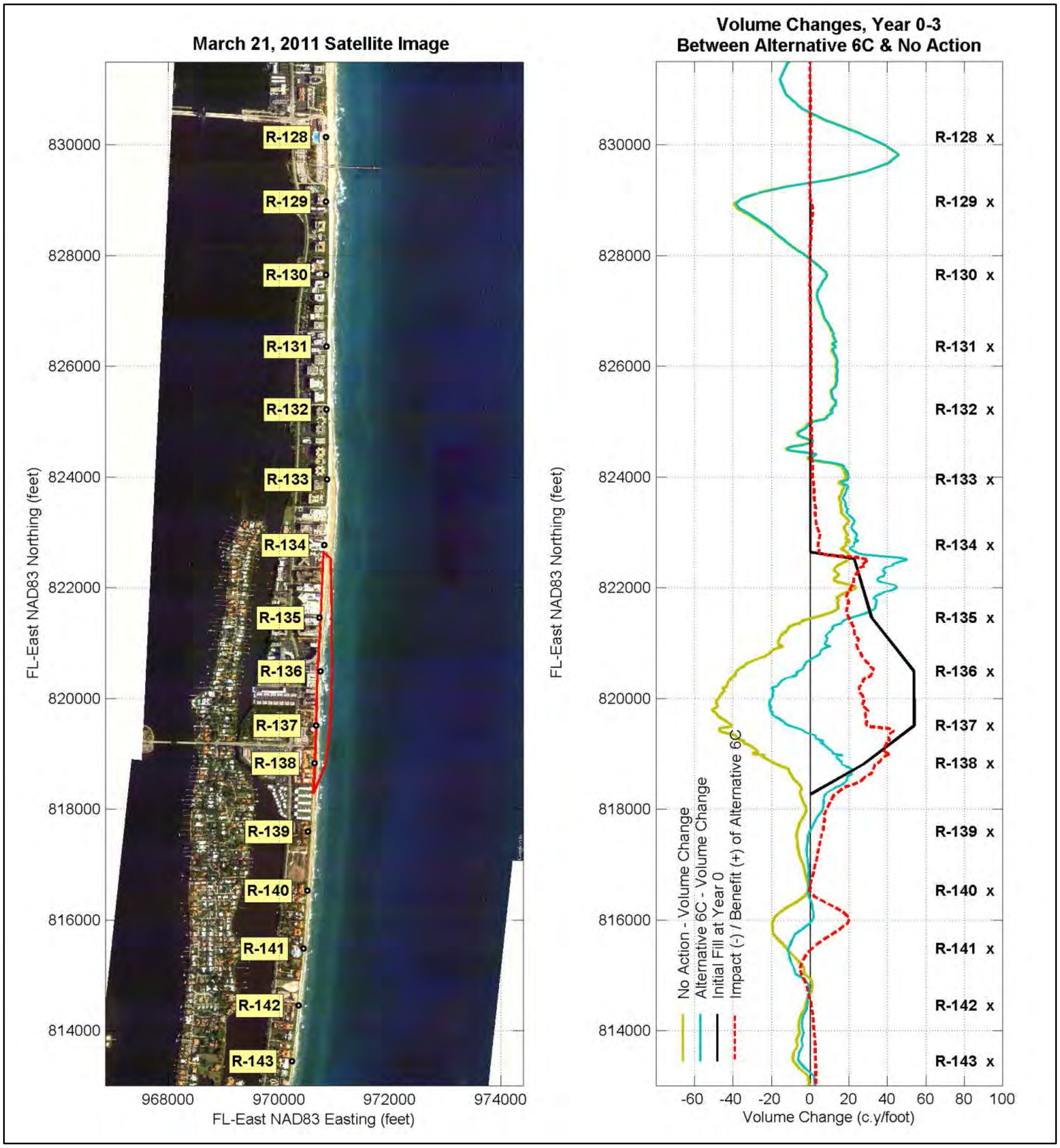

Figure 5-41. Volume changes, Alternative 6C.

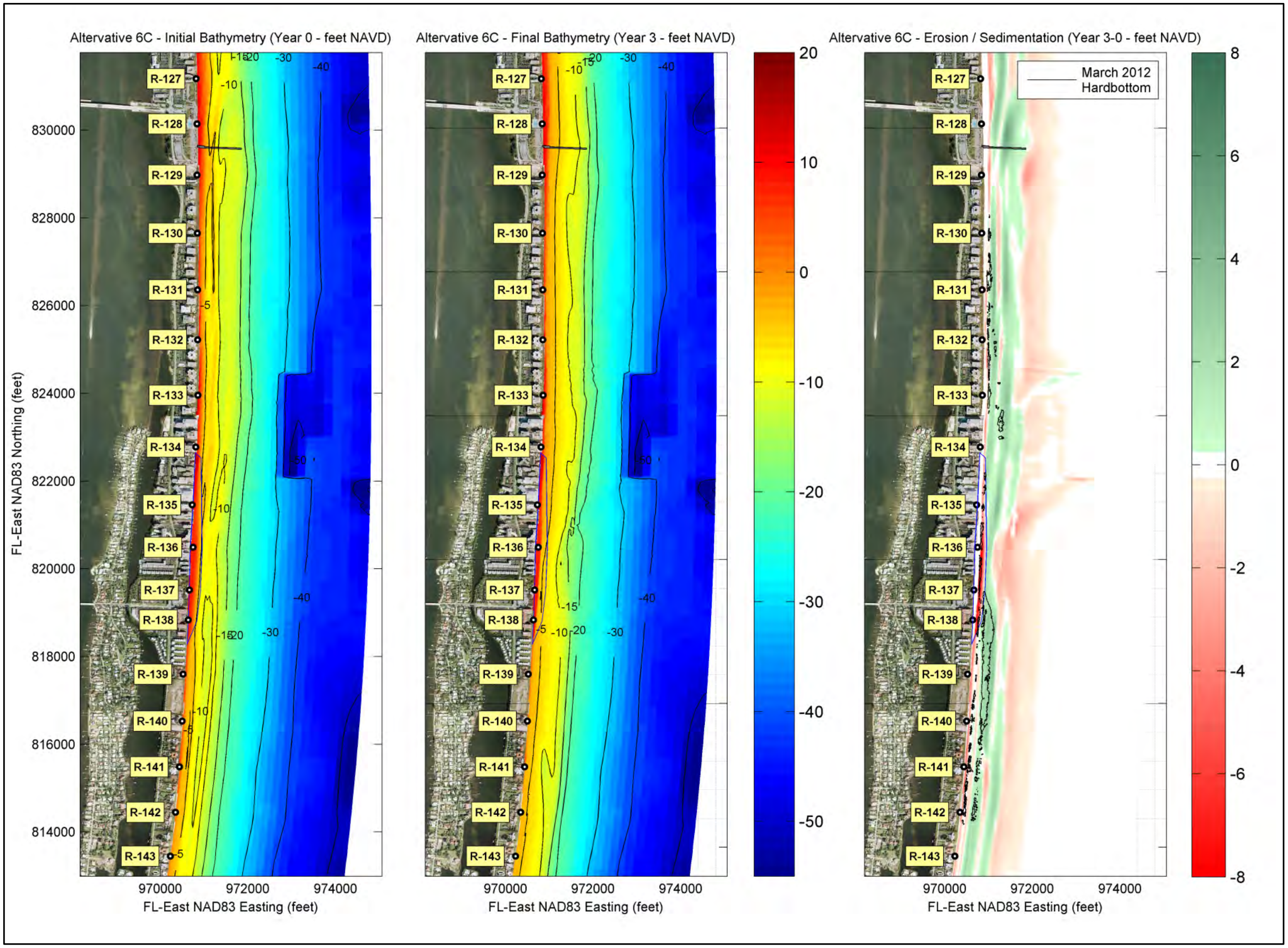

Figure 5-42. Erosion/sedimentation after 3 years of simulation, Alternative 6C.

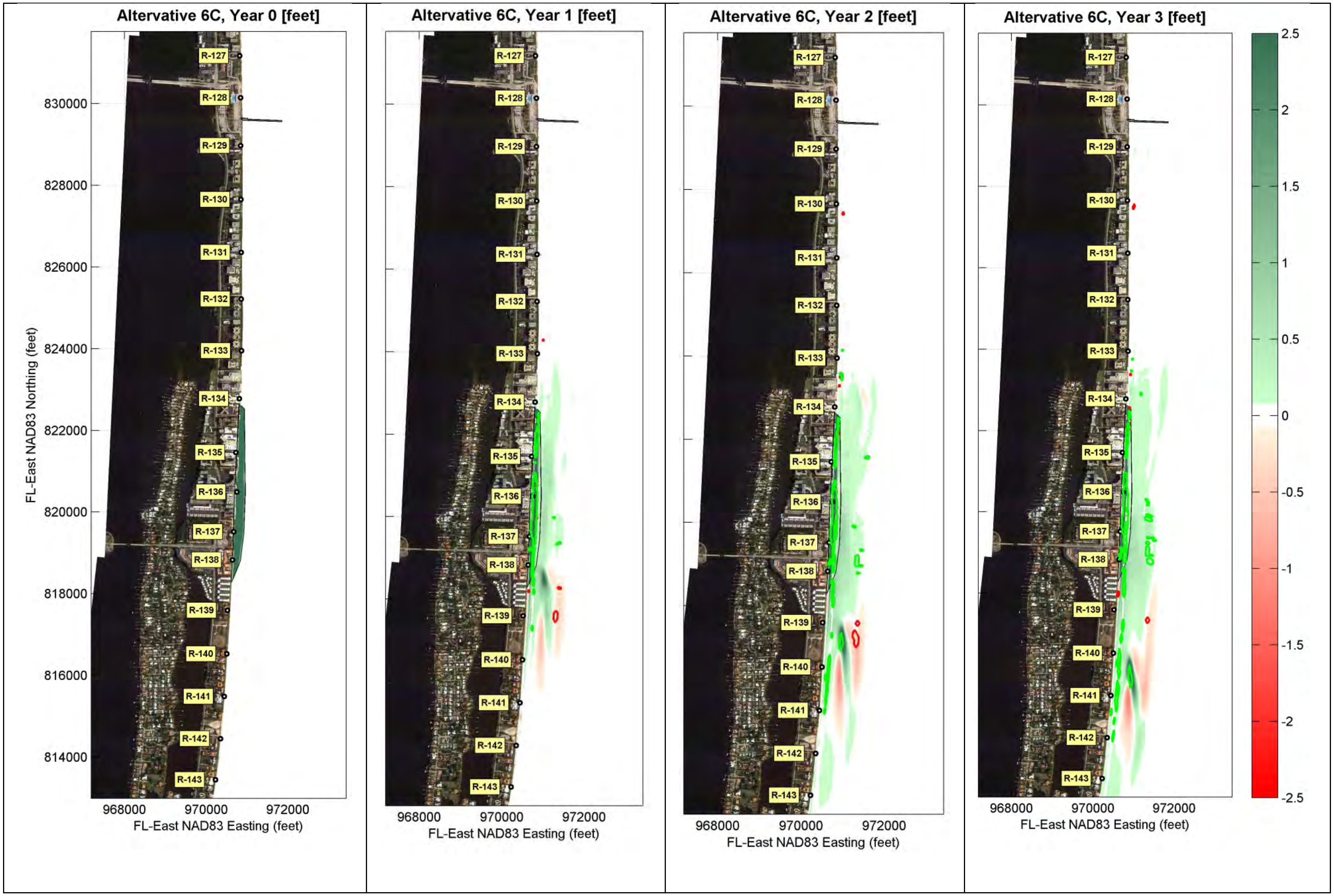

Figure 5-43. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 6C, compared to No Action scenario.

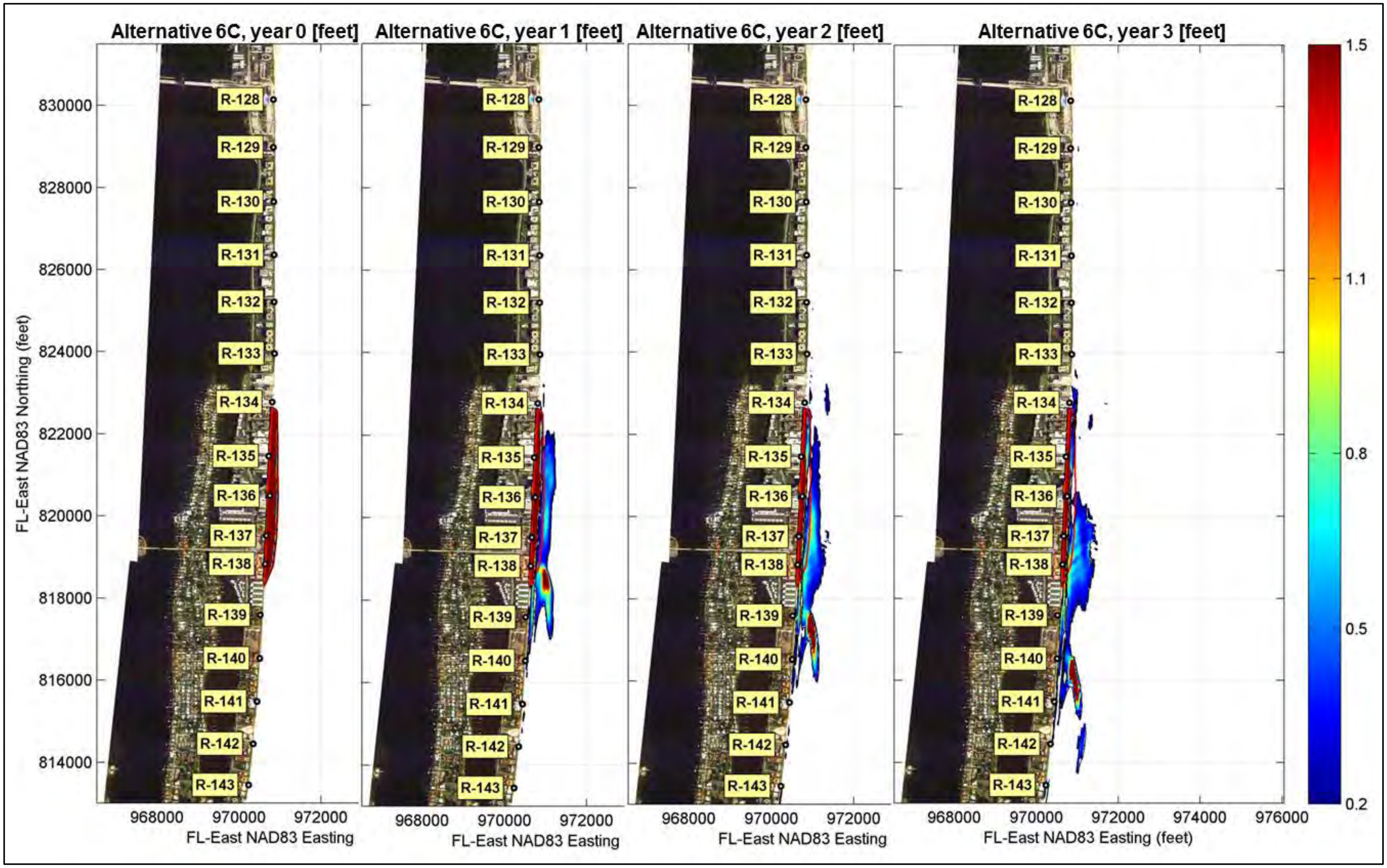

Figure 5-44. Sediment accumulation greater than 0.2 ft for Alternative 6C.

5.8. Alternative 7a - The Coalition to Save Our Shoreline, Inc. (SOS) Option with Increased Sand Volume and the County Preferred Project

Alternative 7a consists of placement of sand within the Town of Palm Beach and shoreline protection structures (T-head groins). Two T-head groins were included between R-132 and R-134. The sand fill volumes required for the SOS plan are greater than the volumes for Alternative 6 within the Town of Palm Beach. The sand volume within the Town of Palm Beach was increased by advancing the dune on average 30 feet from R-129-210 to R-131, advancing the beach berm on average 70 feet seaward from R-129-210 to R-131, and including a beach berm with an average width of 135 feet from R-130 to R-134 as compared to Alternative 2. Within the County the sand fill volumes and shoreline protection structures for Alternative 7a were the same as that for Alternative 2.

5.8.1. Combined Action

Alternative 7a places seven groins between monuments R-135+160 and R-137+422, and two T-heads located between R-132+556 and R-133+269. In addition, the alternative includes the placement of approximately 401,600 cubic yards of sand between R-129-210 and R-138+551 monuments. Model results given in Alternative 7a appear in Figure 5-45 through Figure 5-48.

North of R-134+135, Alternative 7a contains the largest fill volume as compared to Alternatives 2 through 6. South of R-134+135, the fill volume is the same as Alternative 2. The increased fill volume results in sedimentation greater than 0.2 feet throughout the Town of Palm Beach and County. The sedimentation areas extend the furthest north as compared to the other alternatives.

At the end of the 3 year simulation period, there was an estimated coverage of 13.91 acres of hardbottom and an exposure of 3.28 acres attributed to the alternative as depicted in Figure 5-47. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -10.64 acres.

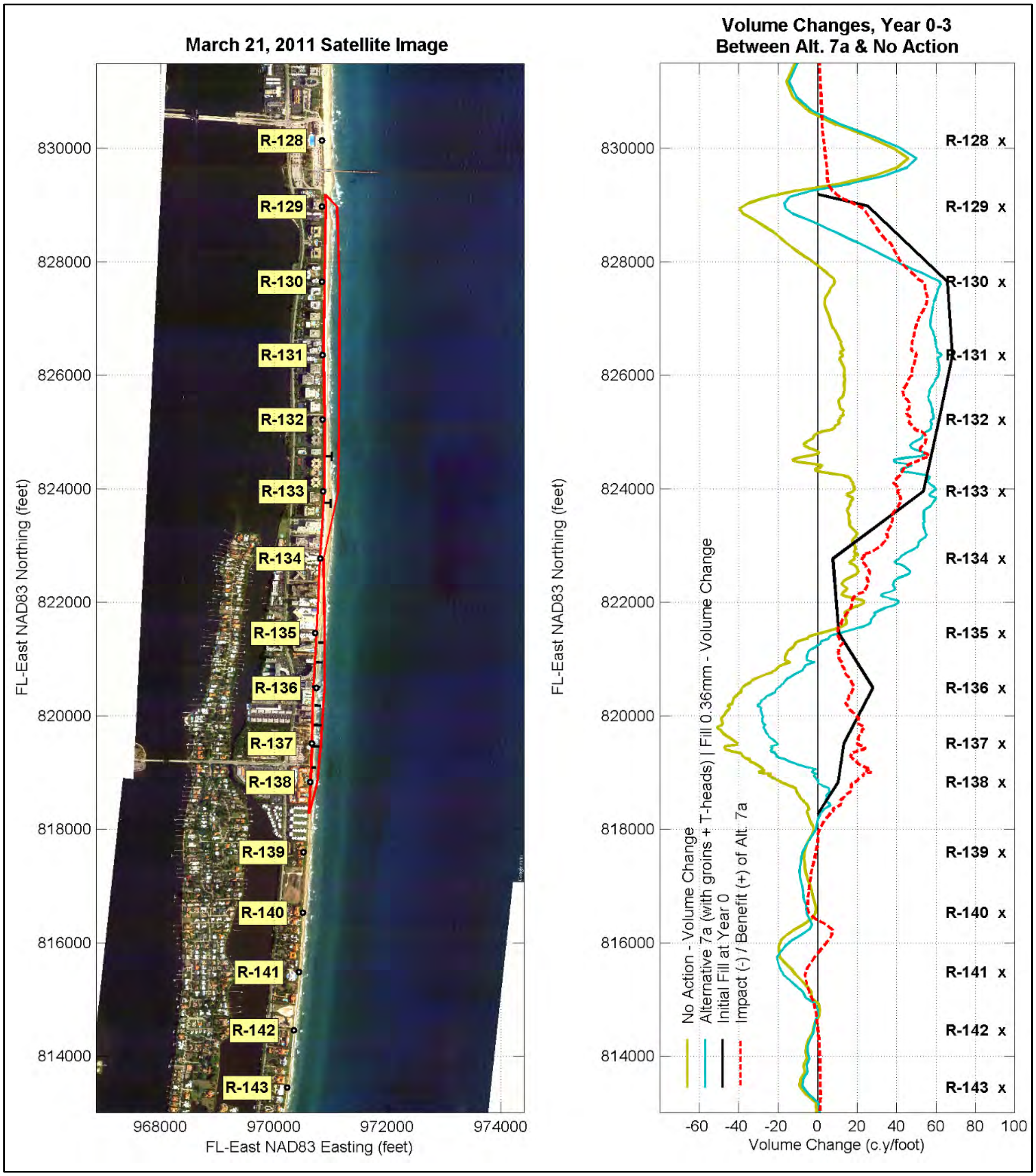

Figure 5-45. Volume changes, Alternative 7a.

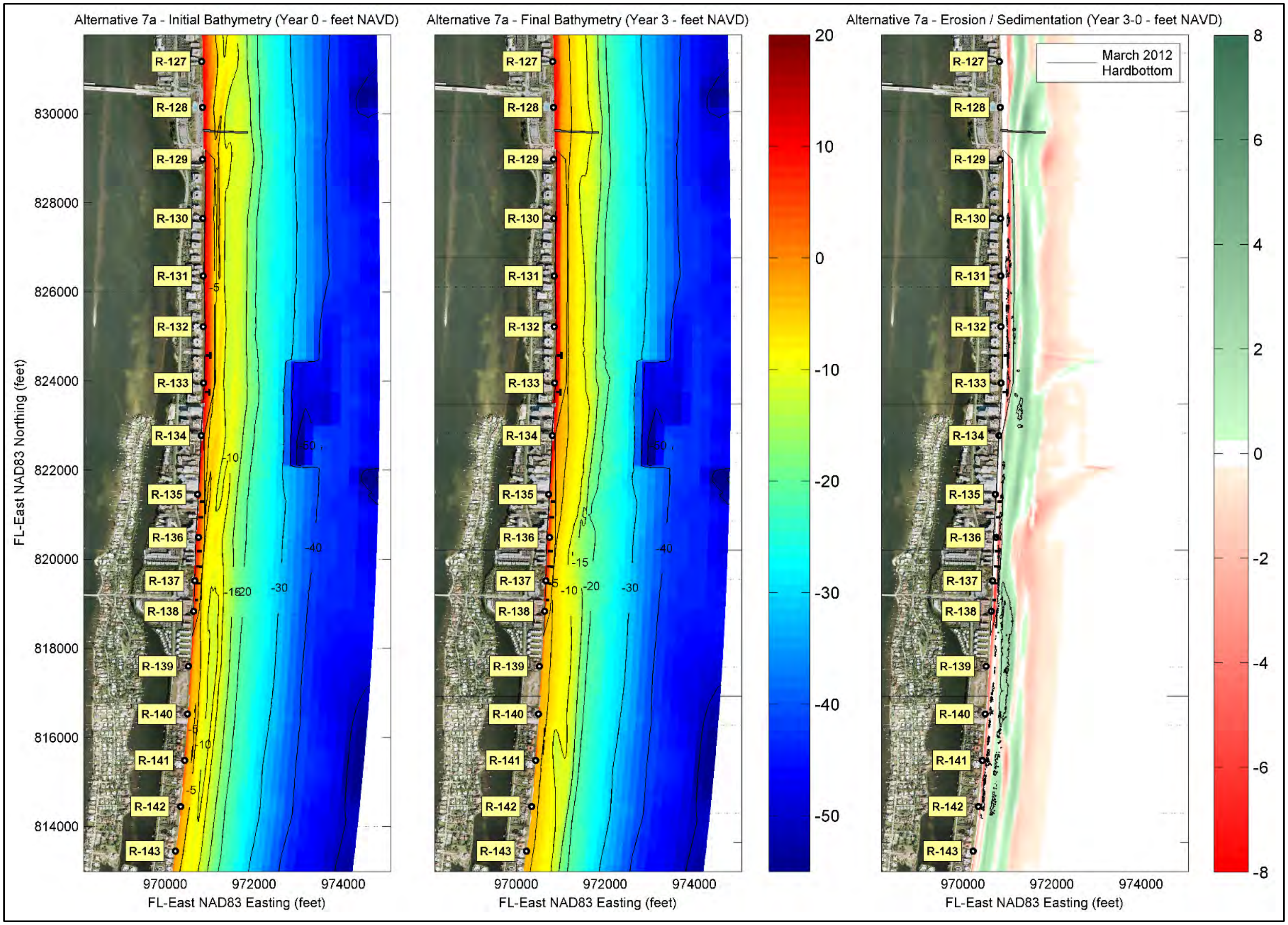

Figure 5-46. Erosion/sedimentation after 3 years of simulation, Alternative 7a.

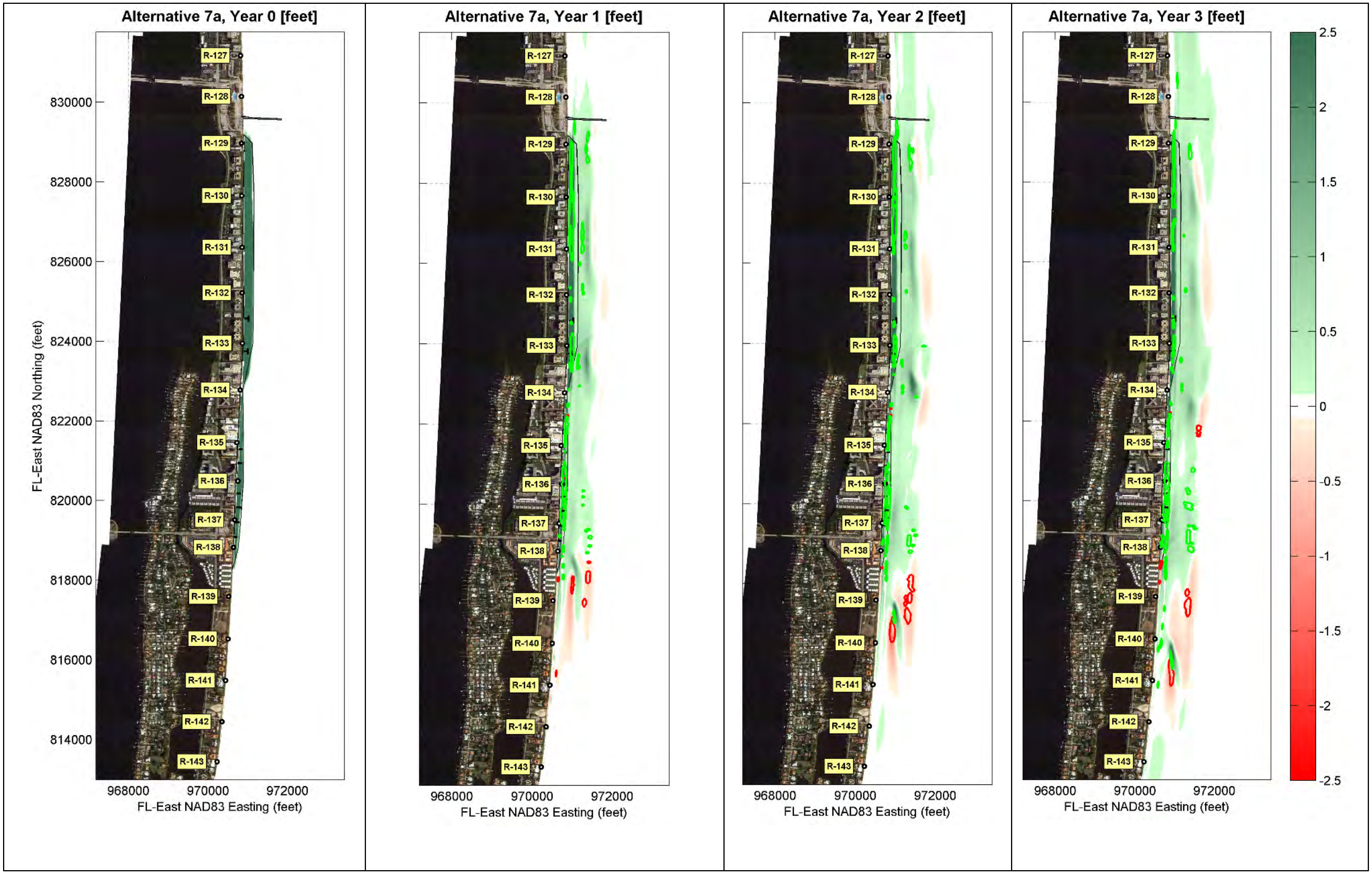

Figure 5-47. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 7a, compared to No Action scenario.

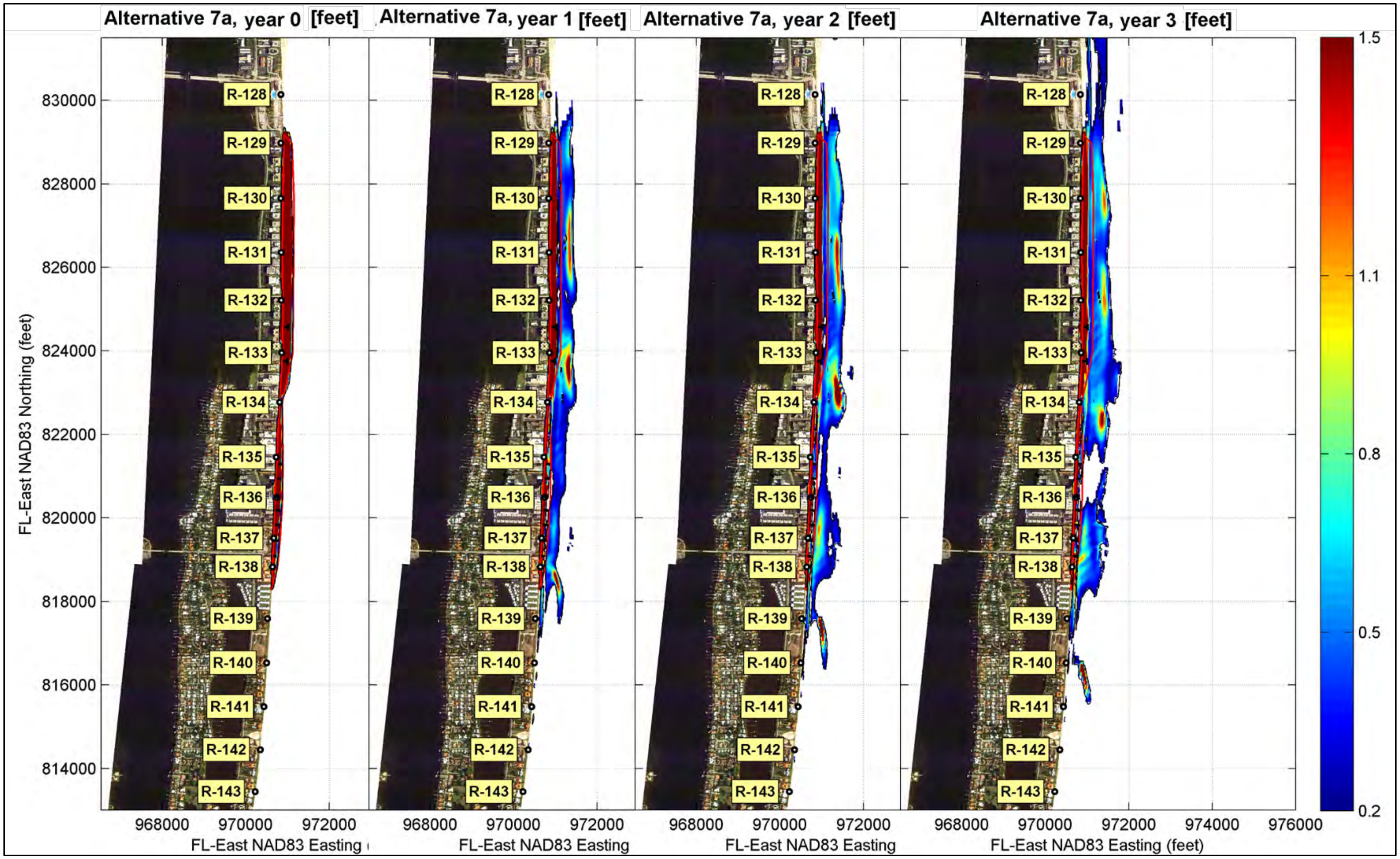

Figure 5-48. Sediment accumulation greater than 0.2 ft for Alternative 7a.

5.8.2. Separated Actions

Alternative 7aT (Town of Palm Beach portion of alternative)

Alternative 7aT presents a sand placement of 338,072 cubic yards along R-129-210 and R-134+135 and two T-heads located between R-132+556 and R-133+269. Model results for Alternative 7aT are shown in Figure 5-49 through Figure 5-52. The sedimentation areas greater than 0.2 feet extend throughout the Town of Palm Beach's project area and into the County. This indicates that some of the sedimentation areas within the County shown in Alternative 7a could be attributed to the fill placed to the north within the Town of Palm Beach.

At the end of the 3 year simulation period, there was an estimated coverage of 6.34 acres of hardbottom and an exposure of 0.80 acres attributed to the alternative as depicted in Figure 5-51. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -5.54 acres.

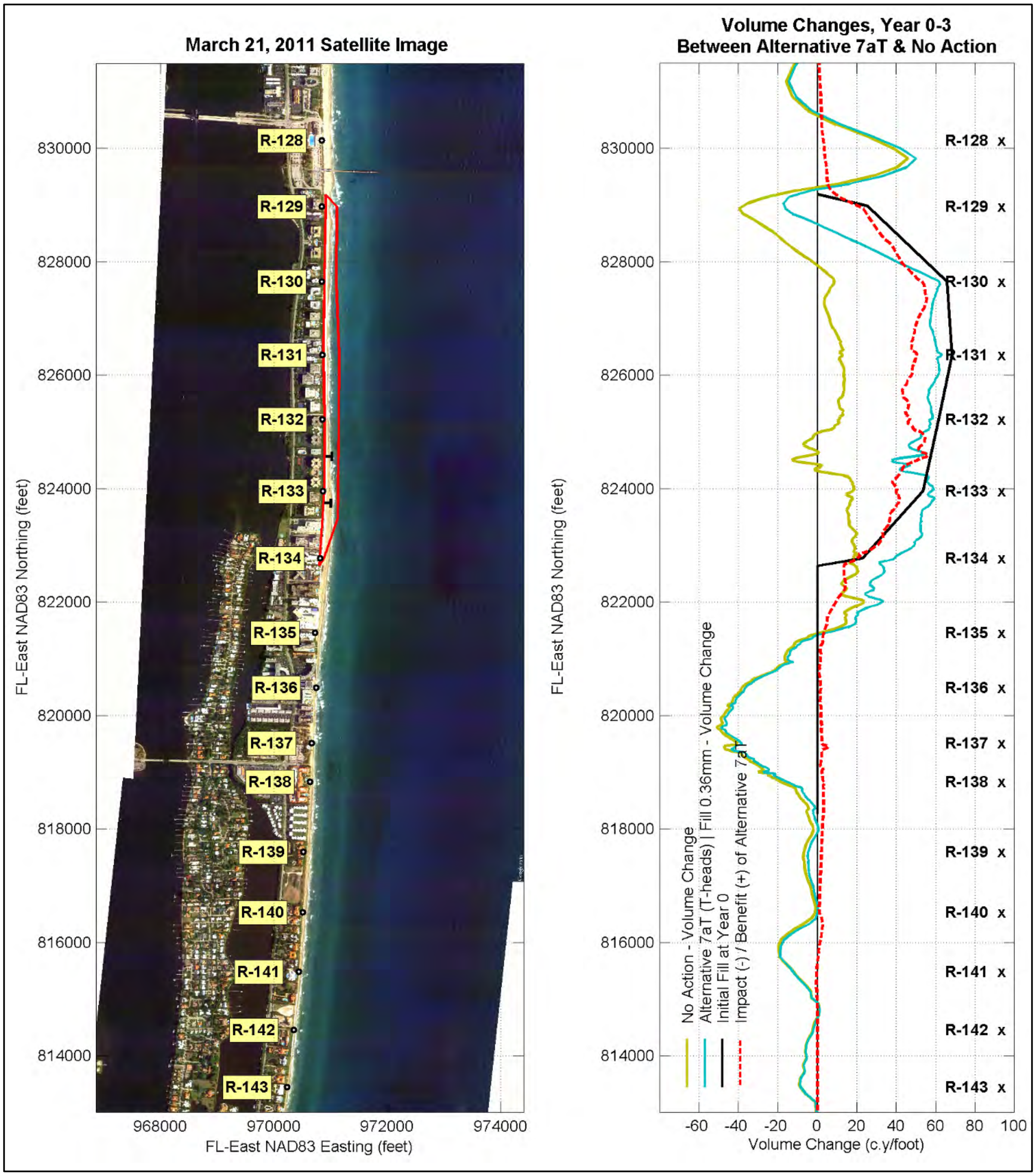

Figure 5-49. Volume changes, Alternative 7aT.

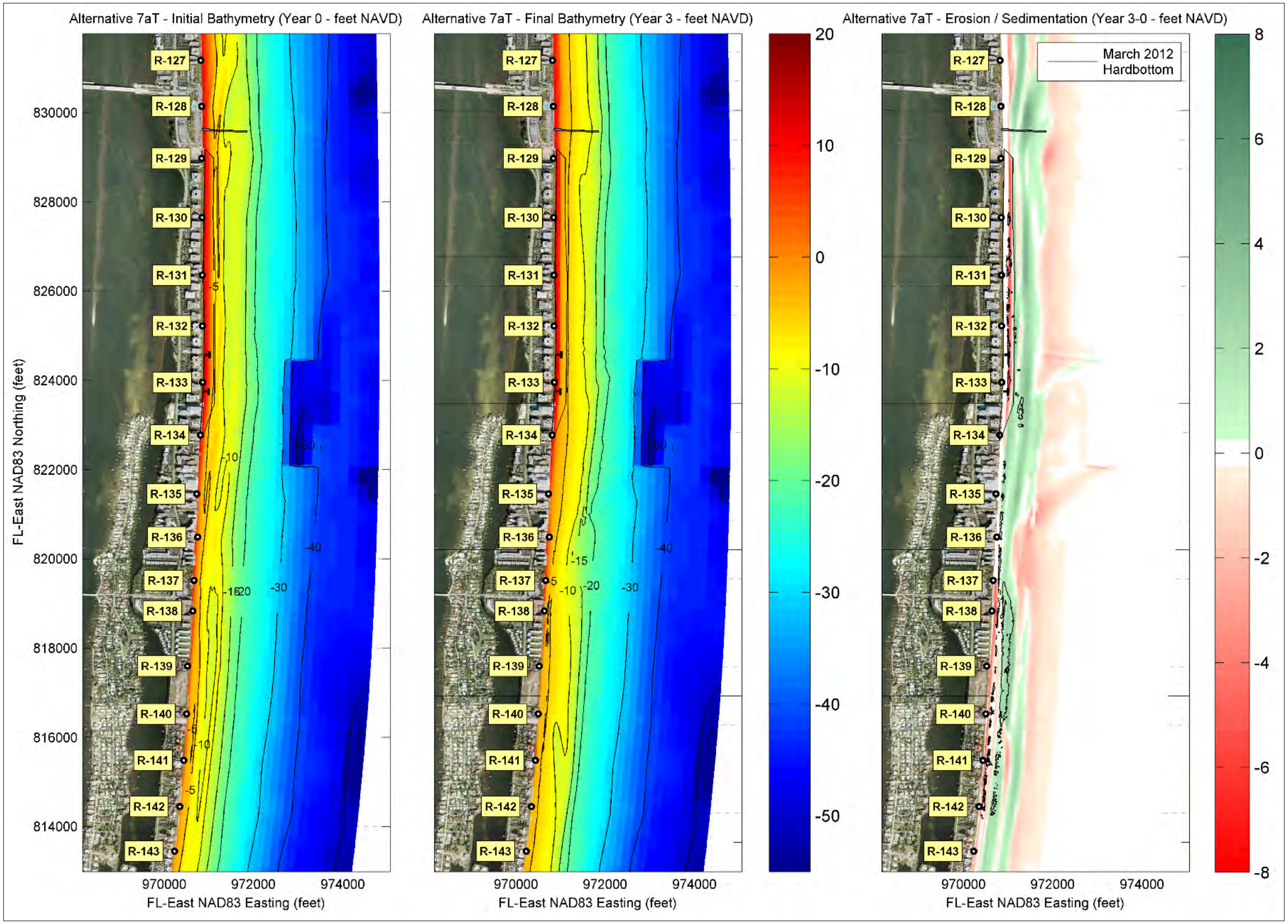

Figure 5-50. Erosion/sedimentation after 3 years of simulation, Alternative 7aT.

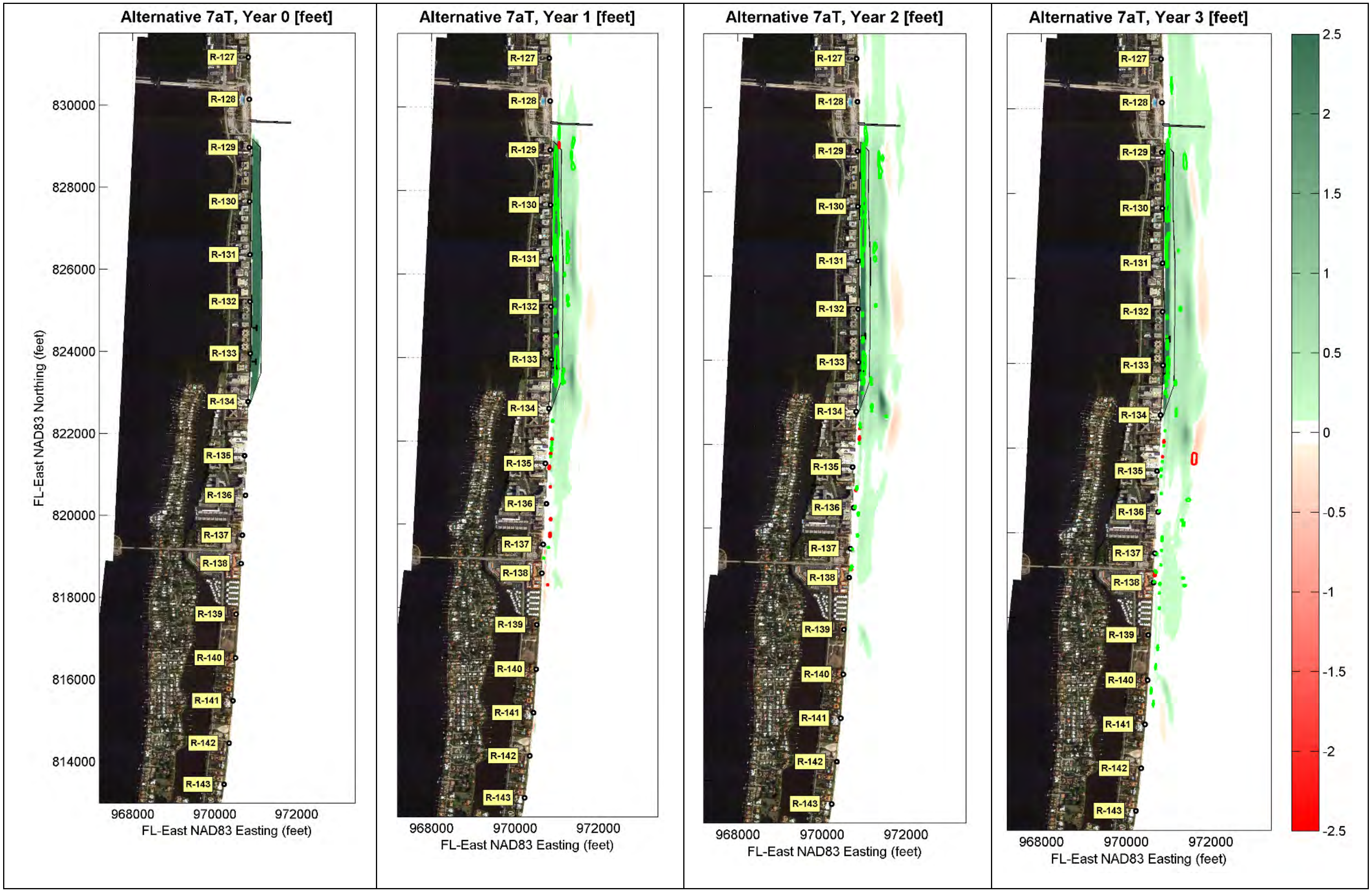

Figure 5-51. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 7aT, compared to No Action scenario.

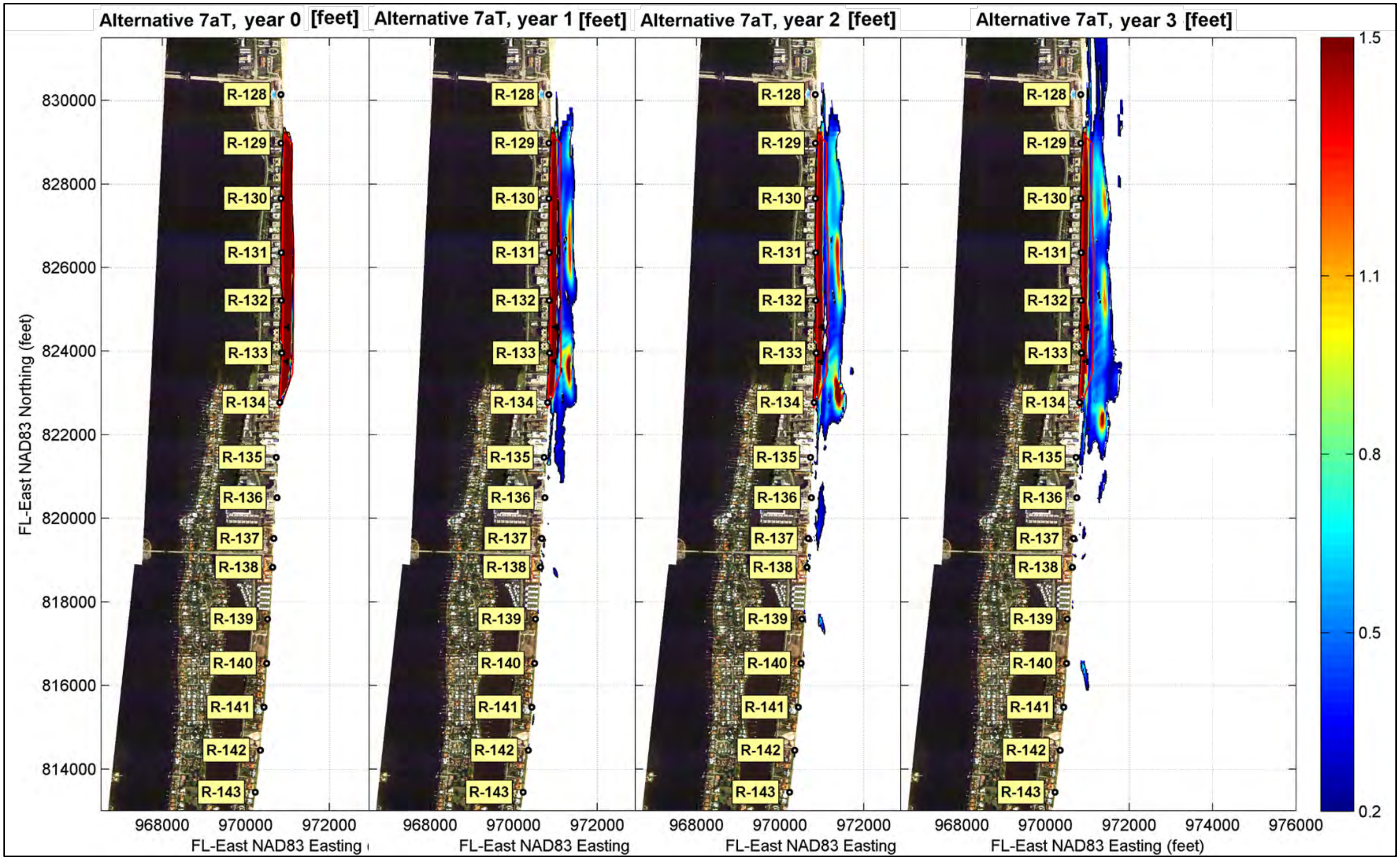

Figure 5-52. Sediment accumulation greater than 0.2 ft for Alternative 7aT.

5.9. Alternative 7b - The Town of Palm Beach Increased Sand Volume with Two Shoreline Protection Structures (The Coalition to Save Our Shoreline, Inc. (SOS) Alternative) and the County Preferred Project

Alternative 7b is the preferred project plan provided by the Coalition to Save Our Shoreline, Inc for the Town of Palm Beach. The preferred plan places approximately 166,500 CY of high quality beach compatible sand. The preferred project plan has two structures (groins or T-head groins constructed of sheet pile) at the southern end to reduce sand losses from the south end.

5.9.1. Combined Action

Alternative 7b places seven groins between monuments R-135+160 and R-137+422, and two T-heads located between R-132+556 and R-133+269. In addition, the alternative includes the placement of approximately 231,000 cubic yards of sand between R-129-210 and R-138+551 monuments. Model results given in Alternative 7b appear in Figure 5-53 through Figure 5-56.

The fill volume north of R-134+135 is increased as compared to Alternative 6 and decreased as compared to Alternative 7a. South of R-134+135, the fill volume is the same as Alternative 2. The results are similar to the results for Alternative 7a, but generally with lower impact since the fill volume was lower. The increased fill volume results in sedimentation greater than 0.2 feet throughout the Town of Palm Beach and County.

At the end of the 3 year simulation period, there was an estimated coverage of 13.29 acres of hardbottom and an exposure of 2.08 acres attributed to the alternative as depicted in Figure 5-55. The net change in hardbottom at the end of the simulation period (exposure minus coverage) as a result of the project is estimated to be -11.12 acres.

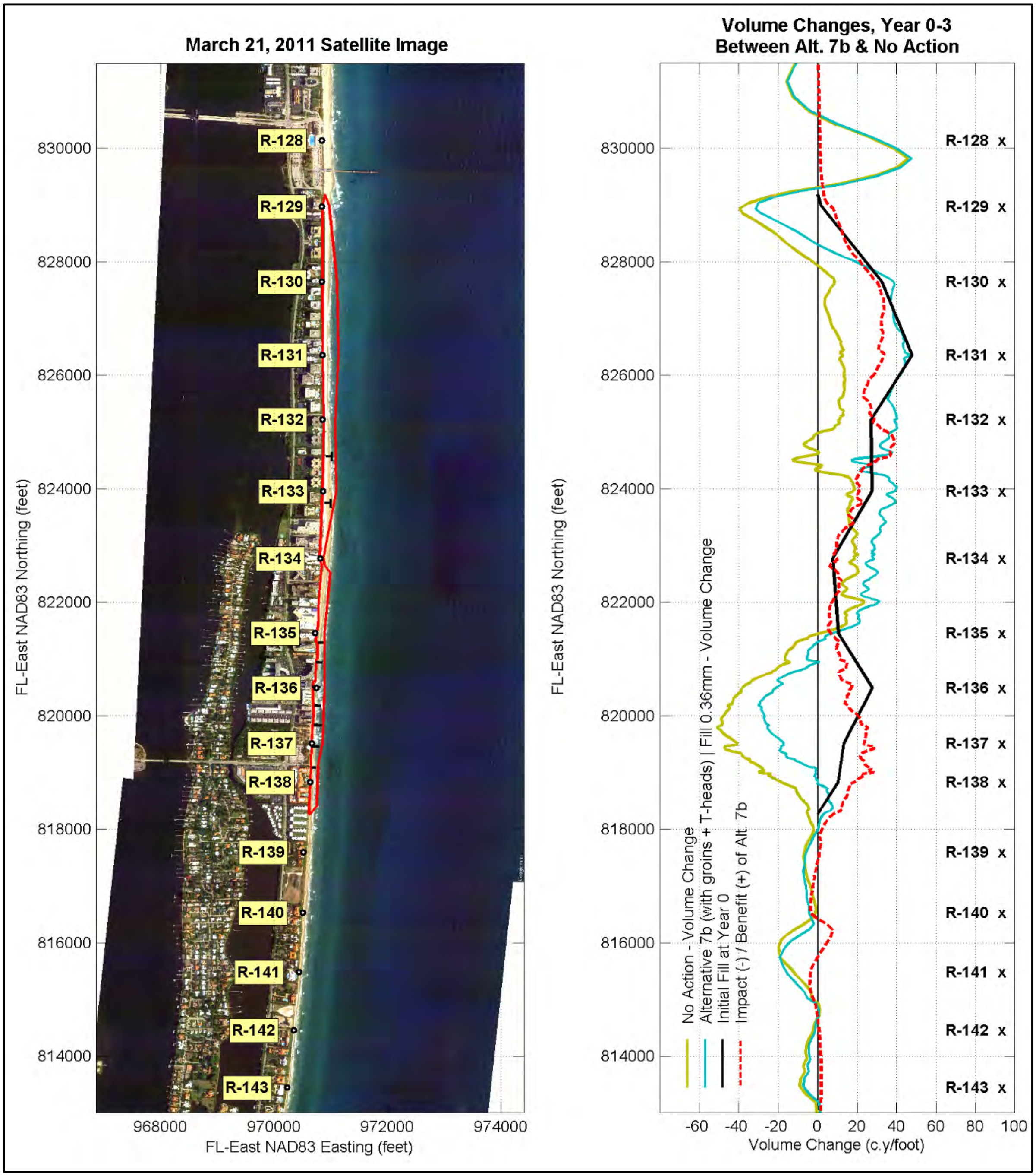

Figure 5-53. Volume changes, Alternative 7b.

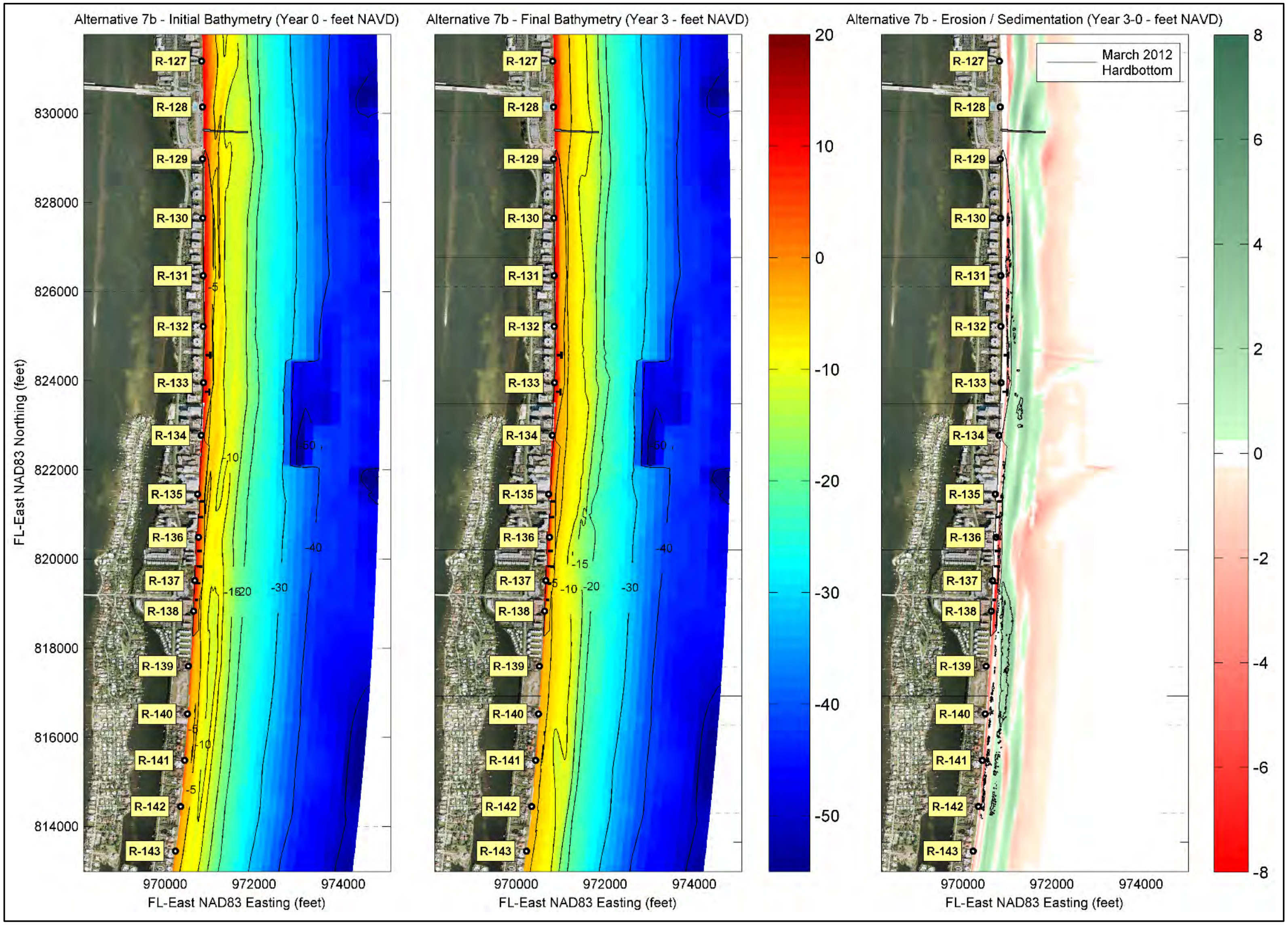

Figure 5-54. Erosion/sedimentation after 3 years of simulation, Alternative 7b.

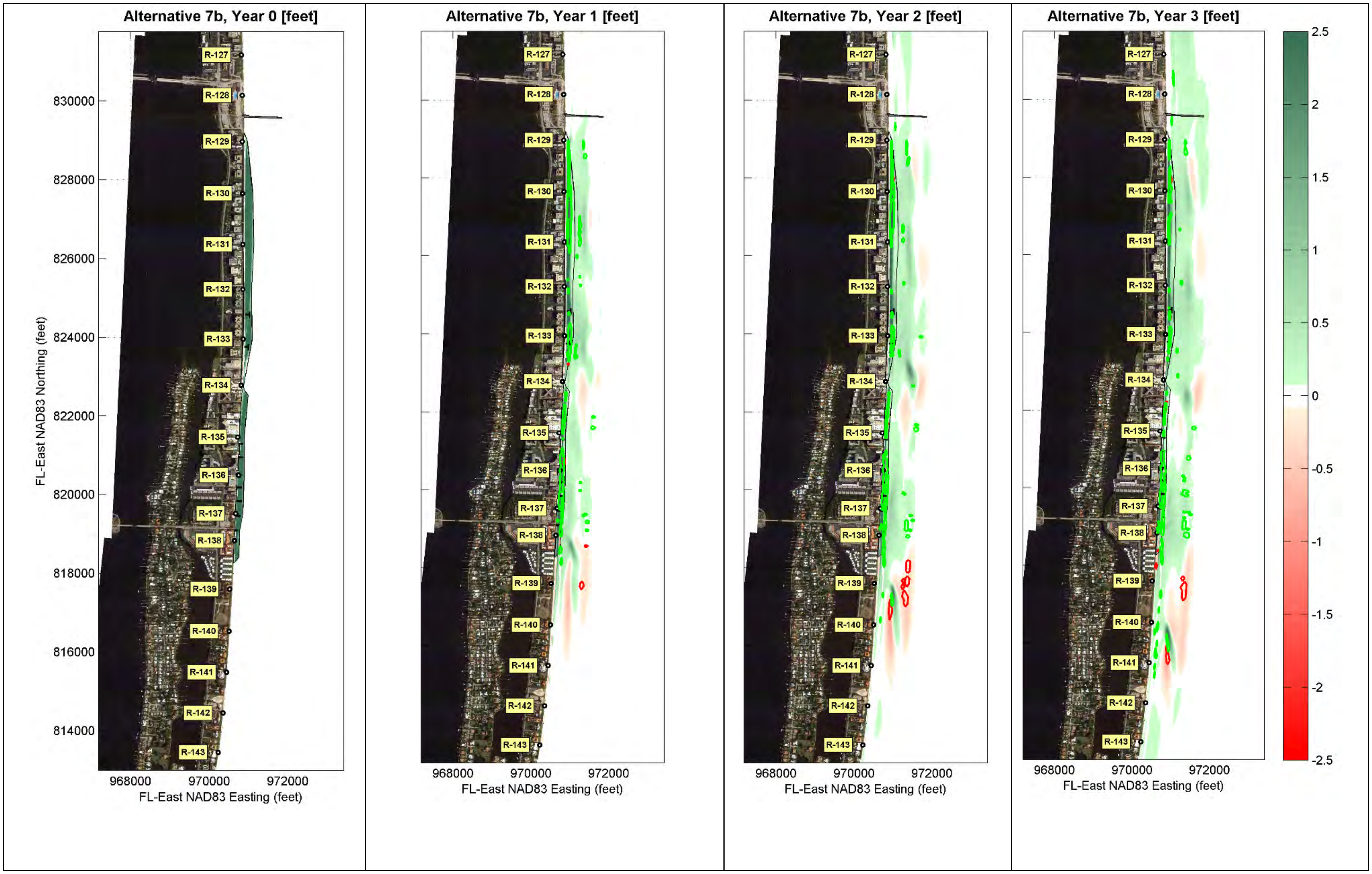

Figure 5-55. Temporal evolution of erosion (red) / sedimentation (green) for Alternative 7b, compared to No Action scenario.

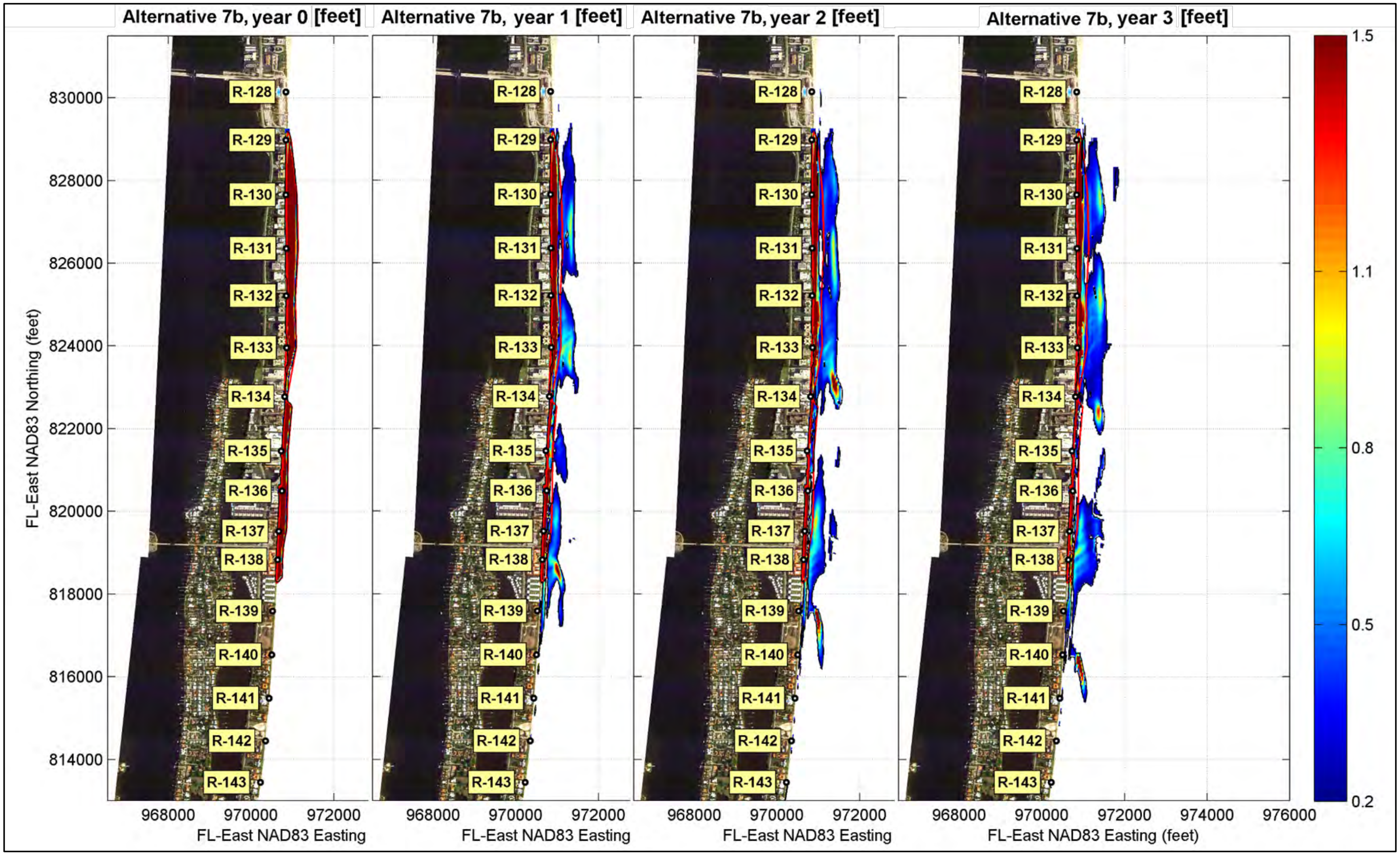

Figure 5-56. Sediment accumulation greater than 0.2 ft for Alternative 7b.