STATE OF SEBASTIAN THE INLET REPORT: 2016

An Assessment of Inlet Morphologic Processes, Shoreline Changes, Local Sediment Budget and Beach Fill

By

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Executive Summary

The annual update of the State of Sebastian Inlet includes five major areas of work; 1) an update of the analysis of volume contained in the inlet sand reservoirs, 2) analysis of morphologic changes within the inlet system, 3) analysis of the sand budget based on the results of the sand volume analysis, 4) an update of the shoreline change analysis, and 5) numerical modeling analysis of littoral transport around Sebastian Inlet. The sand volumetric analysis includes the major sand reservoirs within the immediate inlet system and sand volumes within the extended sand budget cells to the north and south of Sebastian Inlet. The volume analysis for each inlet sand reservoir extends from 2005 to 2015. Similar to the volumetric analysis described in previous state of the inlet reports, most inlet sand reservoirs are in a long-term dynamic equilibrium characterized by occasional large seasonal changes in volume superimposed on longer term trends of a lower order of magnitude. An example of this is the volume history of the Sebastian Inlet flood shoal, which has undergone little net volume change between 2005 and 2015, but can experience seasonal variations that exceed 100,000 cubic yards.

The most noticeable shift in the flood shoal volume is a decrease of about 220,000 cubic yards between 2011 and 2015. This change is considered to be temporary and due to excavation and expansion of the sand trap in winter-spring of 2012 and 2014, which effectively limits the sediment supply to the flood shoal. Likewise, the Sebastian Inlet ebb shoal has experienced gradual net gain in volume since 2005 along with larger seasonal variations in volume that include occasional sand volume gains and losses in a range of 50,000 to 100,000 cubic yards. In the period of 2012 to 2015, the ebb shoal has increased in volume by about 35,000 cubic yards, whereas the lower ebb shoal has increased in volume by about 50,000 cubic yards. By the summer survey of 2015 the flood shoal had completely recovered sand volume declines related to excavation of the Sebastian inlet sand trap.

The dynamic equilibrium of sand reservoirs associated with Sebastian Inlet is also reflected in sediment budget calculations. Whereas net changes in sediment budget cells, including the cell that contains Sebastian Inlet sand reservoirs, are relatively small over a 10-year period, seasonal changes in any of the cells can occasional exceed 100,000 cubic yards. In this report the sand budget for the Sebastian Inlet region is reported at several different time scales, including longer time scales of 5 to 10 years and a shorter time scale of 3 years. Over the time period of 2005-2015 the sand budget cell that includes all sand reservoirs associated with the inlet have retained very little sand. When comparing winter to winter sand budgets in the 2005 to 2015 period the inlet area has retained an annual average of about 17,400 cubic yards of sand. The summer to summer sand budget calculations over the 2005 to 2015 period indicate that on an annual basis the inlet released about 12,000 cubic yards of sand.

Similar to the sand volume analysis, the results of shoreline mapping from survey data and aerial imagery vary considerably by time scale. Over the 10-year time scale from 2005 to 2015, shoreline changes south of the inlet reflected the position of beach fill placement in 2007, 2011, 2012 and 2014. These projects provided sections of advancing or stable shoreline. Areas of shoreline recession over this time period between FDEP R-markers of about R8 and R17 can be interpreted as lateral dispersion of beach fill material in this area. The influence of sand placement from the sand trap excavation during the spring of 2014 can be seen in the survey based shoreline plots between summer 2014 and summer 2015. Sand placed in the winter to spring period in the R3 to R7 of the beach to the south of Sebastian Inlet can be seen shifting to the south into the R15 to R20 segment of the beach.

The shoreline position measured in the aerial image survey areas north of Sebastian Inlet was stable during the summer 2004 to summer 2015 period. Over the 2005 to 2015 period, the sand budget analysis indicates loss of sand volume in this area, but at a relatively small magnitude on an annual average basis. When viewed in the summer 2010 to summer 2015 time frame, the shoreline north of Sebastian Inlet was recessional. Sand volume losses during the period were also relatively large, especially in the 2012 to 2015 period. This time period corresponded to greater shoreline stability and episodic sand volume gains in sand budget cells south of Sebastian Inlet. Thus, the combination of shoreline changes and sand volume changes track the episodic bypassing of sand from north to south across the inlet. Part of this signal is due to excavation and bypassing of sediment from the Sebastian Inlet sand trap in t 2012 and 214.

The Sebastian Inlet Coastal Processes Model was used to investigate the sediment backpassing processes. Changes were made to the existing model to increasing high resolution computational cells alongshore and update input files such as waves, winds and bottom topography. Longshore sediment transport rates were computed within the model and compared well with field data. Model results indicate that backpassing or reversals of sediment transport episodically occur. Sand backpassing occurs primarily during energetic periods and is most likely driven by a complex wave current interaction. Local, temporary reversals can occur anywhere in the model domain. This analysis will be continued for future model runs to monitor changes in longshore sediment transport rate.

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1.0 Introduction and Previous Work

This report extends the analysis of the State of Sebastian Inlet from the publication of the 2014 report through the summer months of 2015. In the original 2007 report, sand volume changes, sand budget, and morphological changes between 1989 and 2007 were examined (Zarillo et al. 2007). In addition, shoreline changes were documented between 1958 and 2007 using aerial images and between 1990 and 2007 using field survey data. In the 2013 report, much of the long-term analysis presented in the 2007 report was summarized in the main body of the text and re-stated in a series of appendices. This effort was to present a long term analysis of inlet evolution and associates management strategies that have been applied over the years.

In the present report, the morphological analysis, sand budget analysis and the shoreline analysis are updated to 2015. In addition, a model based analysis of the littoral sand transport across Sebastian Inlet is presented as part of an ongoing analysis of the regional sand budget based on both topographic surveys and model analysis. Recommendations are made for applying the results of State of the Inlet Analysis to the ongoing Sebastian Inlet Management Plan.

2.0 Sand Volume Analysis and Sediment Budget

This section of the report provides an update of the sand budget around the inlet based on semiannual surveys of topography and changes in the sand volume contained in the various shoals associated with Sebastian Inlet. Much of the information in this report can be found in a series of annual issued annual "State of the Inlet" reports issued since 2007. The body and appendices of these reports provides detailed analyses of morphological and physical processes that control the dynamic equilibrium of the Sebastian Inlet system. In this section of the 2016 Inlet report details of sand volume and sediment budget exchanges around the inlet are provided to verify and update of the Sebastian Inlet Sand Budget

The sandy shoals and veneers of sand within the Sebastian Inlet system are considered sand volume reservoirs that can gain, retain, and export sand throughout the system. A conceptual model of inlet sand reservoirs is given in a paper by Kraus and Zarillo, (2003). The concepts presented in this paper are the conceptual basis of littoral sand budgets in the vicinity of tidal inlets. Figure 1 shows the concepts of exchanges among tidal inlet sand reservoirs, including bypassing of sand across the inlet entrance to nourish adjoining shoreface and beaches. This visual concepts included in Figure 1 are the basis of terms used in sediment budget calculations (Rosati et al 1999)

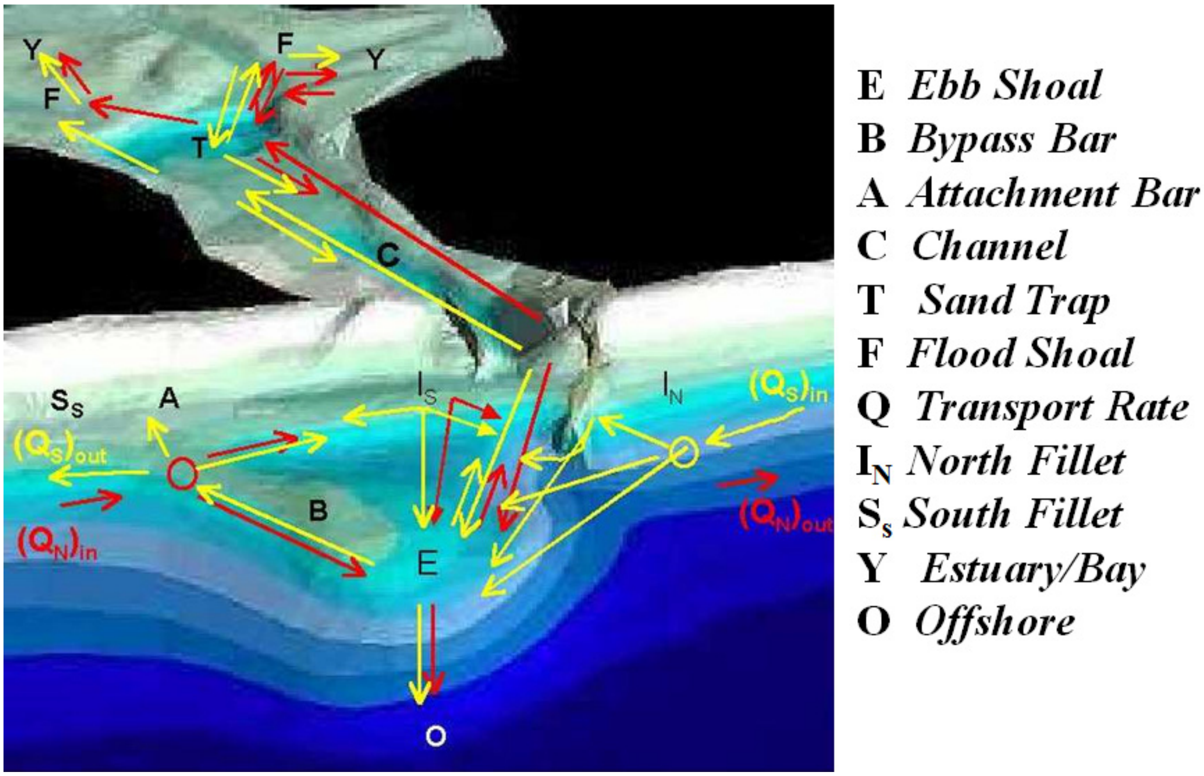

Figure 1. Schematic vector diagram of sediment transport pathways among sand reservoirs at Sebastian Inlet (From Kraus and Zarillo, 2003).

After a review of intermediate to short-term sand volume changes within Sebastian Inlet shoals and sand budget cells, the annualized sand budget in the inlet region is quantified. Sand budgets are presented as annualized terms, but calculated over intermediate to longer term time periods. It will be noted in the summary and conclusions that the magnitude of the budget terms, including sand volume retained or exported by the inlet can change according to time scale (Zarillo, 2010). Time scales of 5 years and longer, provide less variable terms and more consistency for management.

2.1 Sand Volume Analysis Methods

Certified hydrographic surveys of the inlet system and the surrounding shoreface and beaches have been conducted for the by Sebastian Inlet Tax District (SITD) since the summer of 1989. Table 1 lists the surveys completed in the past decade. Starting in winter 1991, surveys have been performed on a semiannual basis. Offshore elevation data are gathered by conventional boat/fathometer surveying methods from -4 ft. to -40 ft. in accordance with the Engineering Manual for Hydrographic Surveys (USACE, 1994). Figure 2 shows the survey area including the entire inlet system (ebb shoal, throat, sand trap and flood shoal, etc.), and the adjacent barrier island system as well. The survey area extends approximately 30,000 ft. north (Brevard County) and 30,000 ft. south (Indian River County) of the inlet. Beach profiles taken about every 500 ft. Since 2011 survey methods have included multi-beam swath methods on the south side of the inlet entrance. The multibeam data provides high spatial resolution in areas where reef rock outcrops occur

This comprehensive dataset provides excellent support for volumetric calculations of inlet shoal and morphologic features, as well as for the analysis of changes in shoreline position through a “zero contour” extraction technique. Datasets used for this report are complete though the winter of 2015.

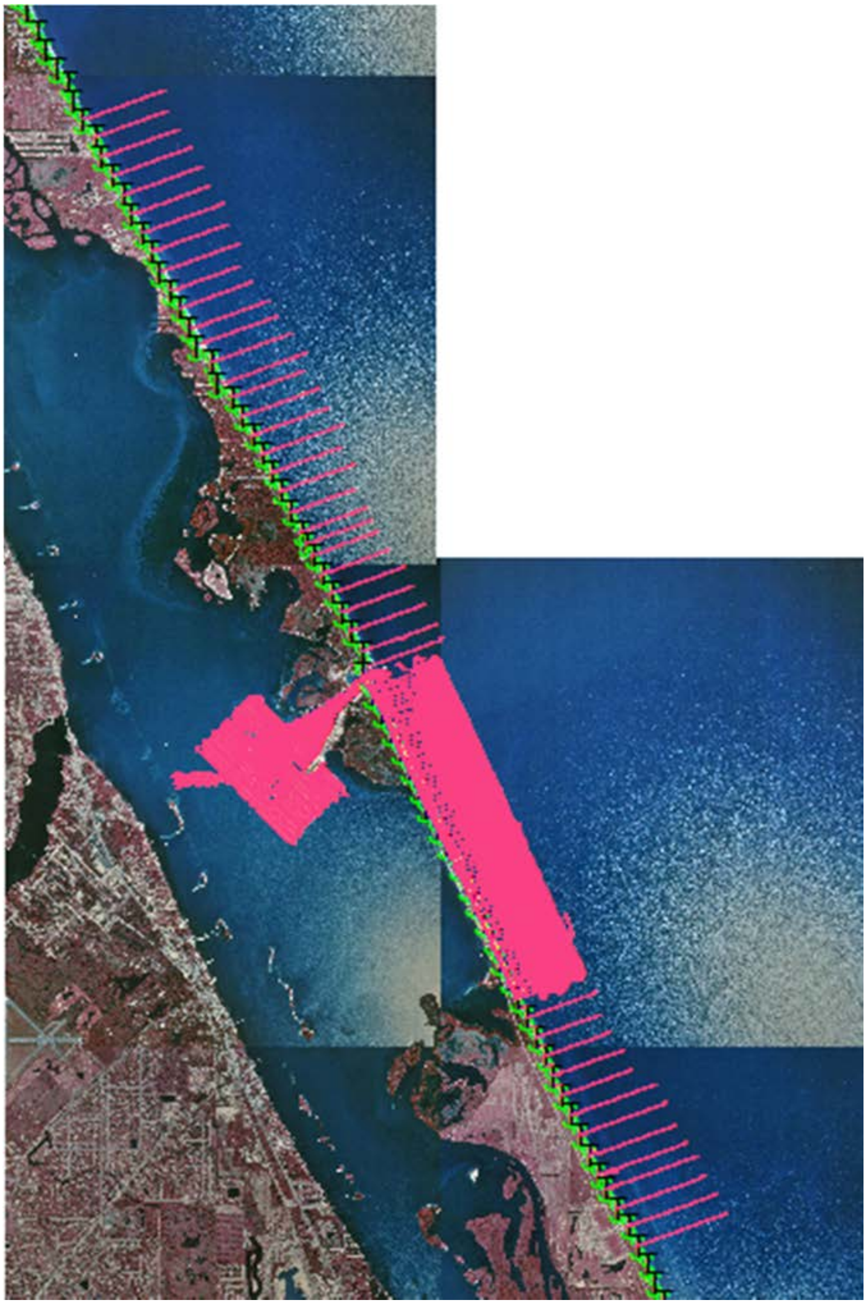

Figure 2. Extent of hydrographic survey (2015 summer).

Table 1. Summary of Hydrographic Surveys (Source: Sebastian Inlet Tax District).

Survey Date	Ebb shoal	Channel	Sand trap	Flood shoal	North beach (ft)	South beach (ft)
Jan-05	x	x	x		30,000	30,000
Jul-05	x	x	x		30,000	30,000
Jan-06	x	x	x	x	30,000	30,000
Jul-06	x	x	x	x	30,000	30,000
Jan-07	x	x	x	x	30,000	30,000
Jul-07	x	x	x	x	30,000	30,000
Jan-08	x	x	x	x	30,000	30,000
Jul-08	x	x	x	x	30,000	30,000
Jan-09	x	x	x	x	30,000	30,000
Jul-09 *	x	x	x	x	30,000	30,000
Jan-10 *	x	x	x	x	30,000	30,000
Jul-10 *	x	x	x	x	30,000	30,000
Jan-11 *	x	x	x	x	30,000	30,000
Jul-11 *	x	x	x	x	30,000	30,000
Jan-12 *	x	x	x	x	30,000	30,000
Jul-12 *	x	x	x	x	30,000	30,000
Jan-13 *	x	x	x	x	30,000	30,000
Jul-13 *	x	x	x	x	30,000	30,000
Jan-14 *	x	x	x	x	30,000	30,000
Jul-14 *	x	x	x	x	30,000	30,000
Jan-15 *	x	x	x	x	30,000	30,000
Jul-15*	x	x	x	x	30,000	30,000

* Multibeam data

Once each hydrographic survey is complete, volumetric data are added to the series and volume changes from one survey to another are calculated. For consistent comparison from survey to survey, the Sebastian Inlet region is divided into subsections representing either a sand budget cell or sand reservoir. Figure 3 shows the sand budget cells used to calculate the changes in sediment volume associated with littoral transport rates over time. The N2 and N1 cells are north of the inlet entrance. N2 is bounded by FDEP R-Markers

R189 and R203 in south Brevard County whereas the N1 sand budget cell is bounded between R203 and R215. The inlet cell includes all of the sand reservoirs (Figure 4) and in bounded on the north by R215 and on the south in Indian River County by R4. On the south side of Sebastian Inlet sand budget cells are designated as S1 an S2. S1 extends from R4 in Indian River County to R16, whereas the S2 cell extends from R16 to R30. All of the cells extend seaward to a depth of -40 feet, NAVD88, which is considered beyond the depth of closure for changes in topography.

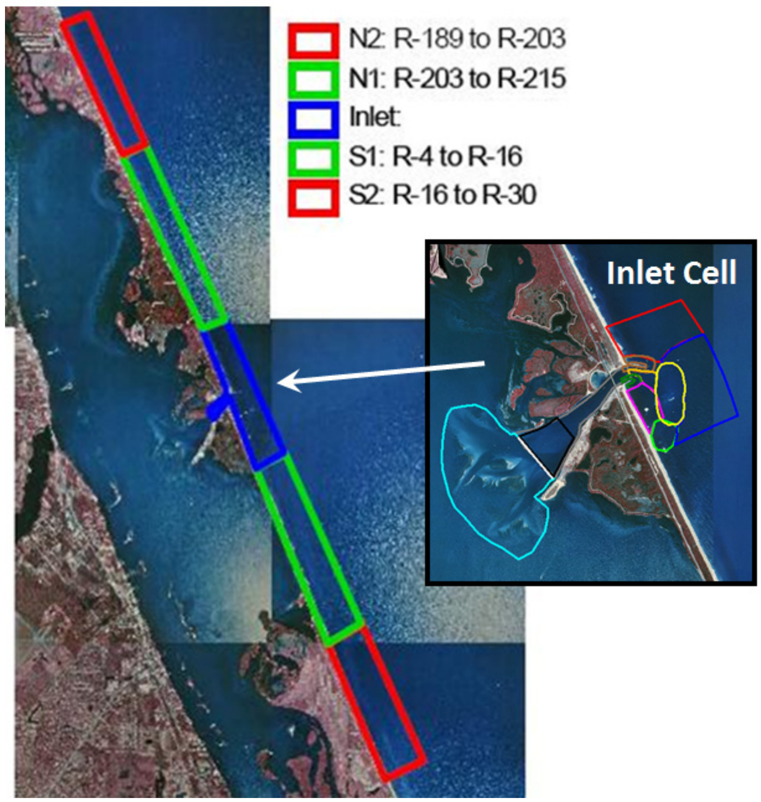

Figure 3. Sand budget cells.

Within the Inlet sand budget cell (Figure 3) further subdivision are made to characterize sand reservoirs that exchange sand under the influence of strong tidal currents and waves. These subdivisions are shown and identified in Figure 4. Sand reservoirs are volumetrically large and control the magnitude of the topographic changes and sand bypassing within the Sebastian Inlet. The major reservoirs include the ebb shoal, flood shoal, and the sand trap. The ebb shoal is further subdivided into the upper ebb shoal, also terms the sand bypass bar, and the lower ebb shoal, which extends to the -40 ft. The sand trap, first excavated in 1972 and expanded in 2014 also influences the volume of the sand budget when it is periodically dredged.   Other sand reservoirs contain lower sand volume restive to the ebb and flood shoal by my exert influence over sand transfer as exchange locations as shown in Figure 4. The attachment bar on the south side of the inlet serves this role.

The raw survey data in Easting, Northing, and elevation is imported into the ArcGIS software platform. Using 3D analysis and spatial analysis capabilities of GIS, the total volume of sediment in each cell or reservoir is calculated relative to a base elevation. These volumes are then compared between survey dates.

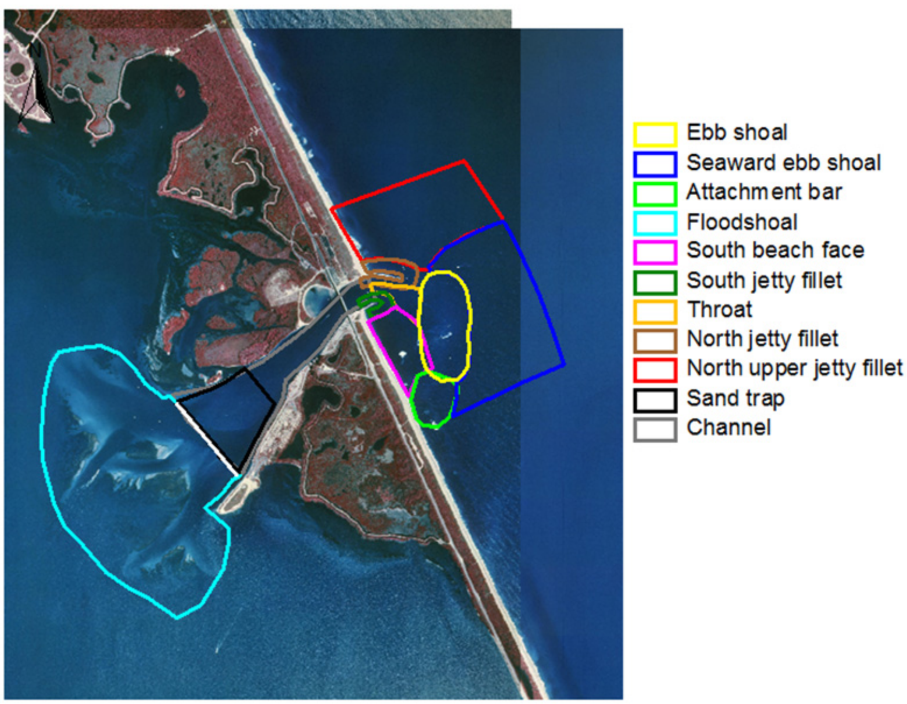

Figure 4. Morphologic features forming the inlet system reservoir.

3.0 Sand Reservoir Volume Analysis

The sand reservoirs are contained within the inlet sand budget cell (Figures 3 and 4). In order to fully understand the sand budget process it is important to examine volume adjustments of each sand reservoir over time and in terms of variability and volume magnitude. Along with the sand reservoirs within the inlet, it is also useful to examine sand volume changes in sand budget cells contained within the barrier island system to the north and south of Sebastian Inlet. By considering the volume and variability of budget terms over shorter and longer time periods, the sand budget analysis can be more effectively applied to managing the regional sand resources. Thus, before presenting the sand budget for the Sebastian Inlet region, the volume evolution is reviewed for the major inlet sand reservoirs and for the cells within the sand budget calculation

Results presented in the volumetric analysis are divided into two subsections. Section 3.1 presents the volumetric evolution of the largest sand reservoirs within the inlet sand budget (Figure 4) with plots of net seasonal and cumulative volume change over time. Section 3.2 presents the volumetric evolution of the inlet littoral cells used for the sand budget computation (**Error! Reference source not found.**). The calculated net seasonal volume changes (ΔV) serve as inputs to the sand fluxes (ΔQ) for the budget calculations discussed in Section 4 When reviewing the time series plots of volume changes in sand reservoirs and sand budget cells, the range of the vertical scale should be noted for each. Smaller, sand bodies having less total volume have a much smaller range in volumetric changes competed to large sand bodies such as the flood shoal.

3.1 Individual Inlet Sand Reservoirs

The volumetric evolution of the ebb shoal (bypass bar) illustrated in Figure 5, shows cumulative volume gains of approximately +65,000 cubic yards since 2004. Volume gains and losses that integrate over time to provide net volume change occur on short time scales that are usually on the order of 6 to 12 months. Volume gains or losses are most often followed by counter balancing volume losses or gains. For instance, 12-months of sand volume gains on the ebb shoal from July 2013 to July 2014 were followed by about a 25,000 cubic yard sand volume loss from July 2014 to January 2015. This gain was followed by a 25,000 cubic yard lost on the ebb shoal from winter to summer of 2015 (Figure 5). Although seasonal and annual changes on the ebb shoal can exceed 30,000 cubic yards. The net sand volume change over the past 5 years is less than 10,000 cubic yards. (Figure 5, 2010 – 2015).

The volumetric evolution of the larger lower ebb shoal (Figure 5) also experienced a similar pattern volume fluctuation between July 2013 and the summer survey of 2015. A year of sand volume gains reaching a volume of sand about 100,000 cubic yards from July 2013 to July 2014, was follows by a 72,000 cubic yard loss from July 2014 to January 2015. Between the winter and summer surveys of 2015 the lower ebb shoal area has gained about 25,000 cubic yards of sand. The changes on volume occur in a series of short term adjustments rather than longer term trends. However, that average annual change in volume of the lower ebb shoal since 2004 is about +25,000 cubic yards. In the 5-year period since summer 2010 that annual net volume is about +20,000 cubic yards.

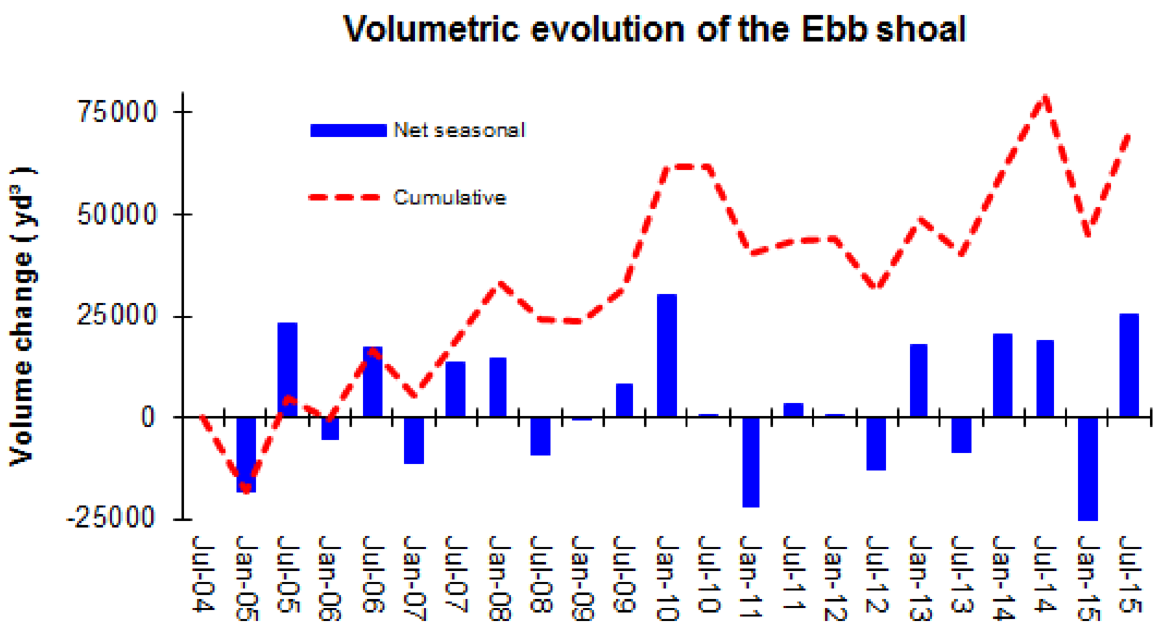

Figure 5. Volumetric evolution of the ebb shoal from summer 2004 to summer 2015

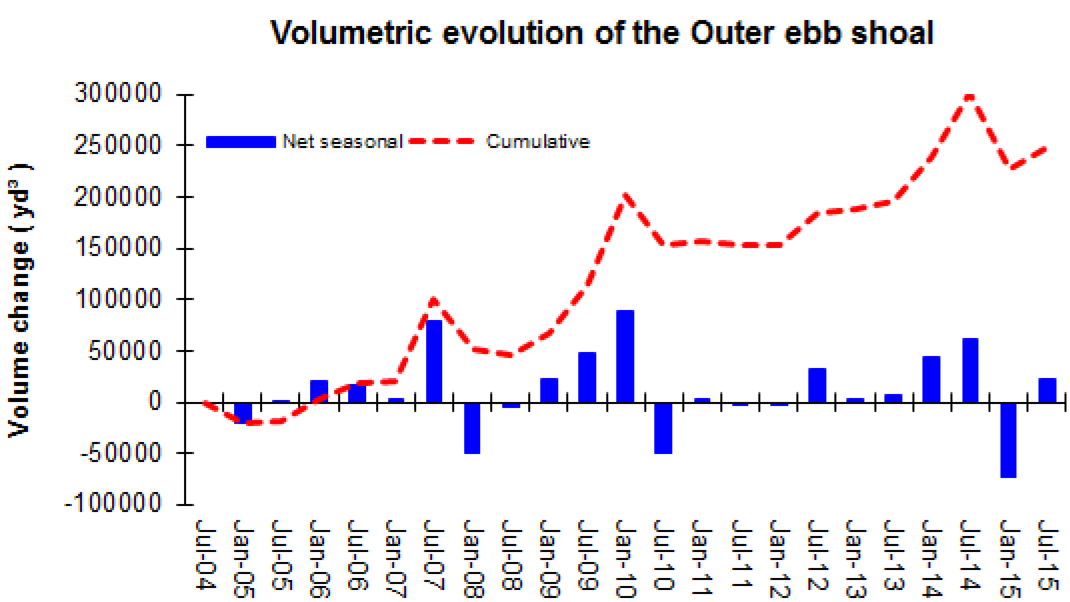

Figure 6. Volumetric evolution of the lower ebb shoal from summer 2004 to summer 2015.

The volumetric evolution of the attachment bar is small due to its role as a sediment redistribution zone (rather than an accumulation or storage zone (Zarillo et al., 1997).

Recent spikes in volume (Figure 7) are most likely related to handling of beach fill material placed from the 2012 and 2014 sand trap projects. A similar spike in volume occurred in 2007 when the sand trap was dredged and fill placed on the beach near the attachment bar. Beach fill related gains recorded in the summer 2014 and winter 2015 surveys have been almost complexly balanced by sand volume loss recorded in the summer 2015 survey data. Net sand volume change in the attachment bar over the past 10 years is near zero.

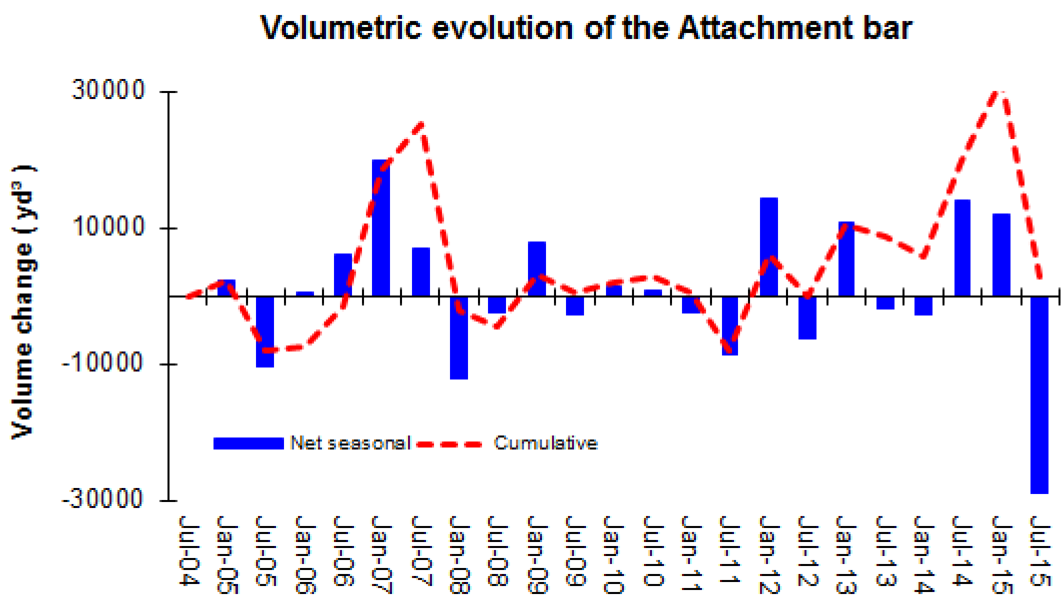

Figure 7. Volumetric evolution of the attachment bar from summer 2004 to winter 2015.

The volumetric evolution of the sand trap is presented in Figure 8. Post dredge annual sand volume gains are on the order of 30,000 to 40,000 cubic yards averaging 15,000 to 20,000 cubic yards every 6 months. The record from January, 2012 to July, 2014 clearly marks the recent dredging projects to bypass material and expand the sand trap in 2014. The figure illustrates the mechanical bypassing of spring 2012 with the removal of approximately 85,000 cubic yards of sand from the sand trap. In the winter to spring of 2014, approximately 160,000 cubic yards of material were removed as the trap was expanded. About 120,000 cubic yards of this material was placed to the south of Sebastian Inlet between R4 and R10. Since the 2014 sand trap expansion sand volume gains have totaled about 38,000 cubic yards. The gains were unevenly split in the two 6-month periods between July 2014 and July 2015. Most of the gains were realized in the first 6-months after the expansion was completed.

Volumetric changes for the flood shoal (Figure 9) showed losses from summer 2011 to summer 2015. Temporary loss of sand volume from the flood shoal is associated with sand trap dredging, which temporarily limits the supply of sand reaching the shoal. The pattern of recovery can be seen after the sand trap excavation in 2007 when the flood shoal recovered its volume by summer of 2008. After a period of continuing relatively large sand volume loss beginning in January 2012, the flood shoal entered a recovery period, which is now complete as seen in Figure 9. Net volume change over the flood shoal in the 10-year period since 2004 is near zero although inter-annual sand volume fluctuations of more than 200,000 cubic yards can occur.

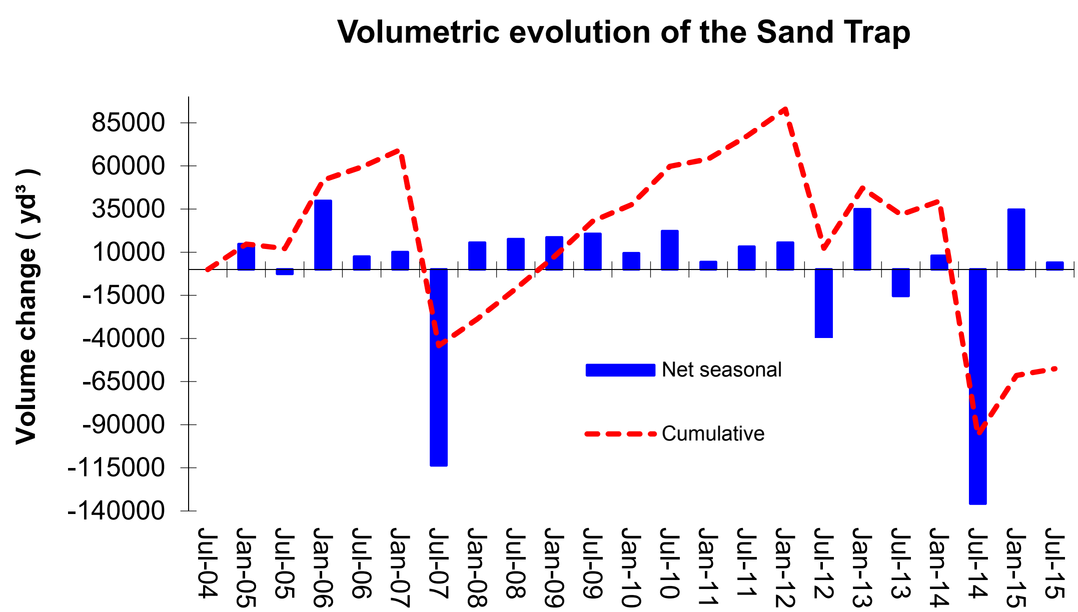

Figure 8. Volumetric evolution of the sand trap from summer 2004 to summer 2015.

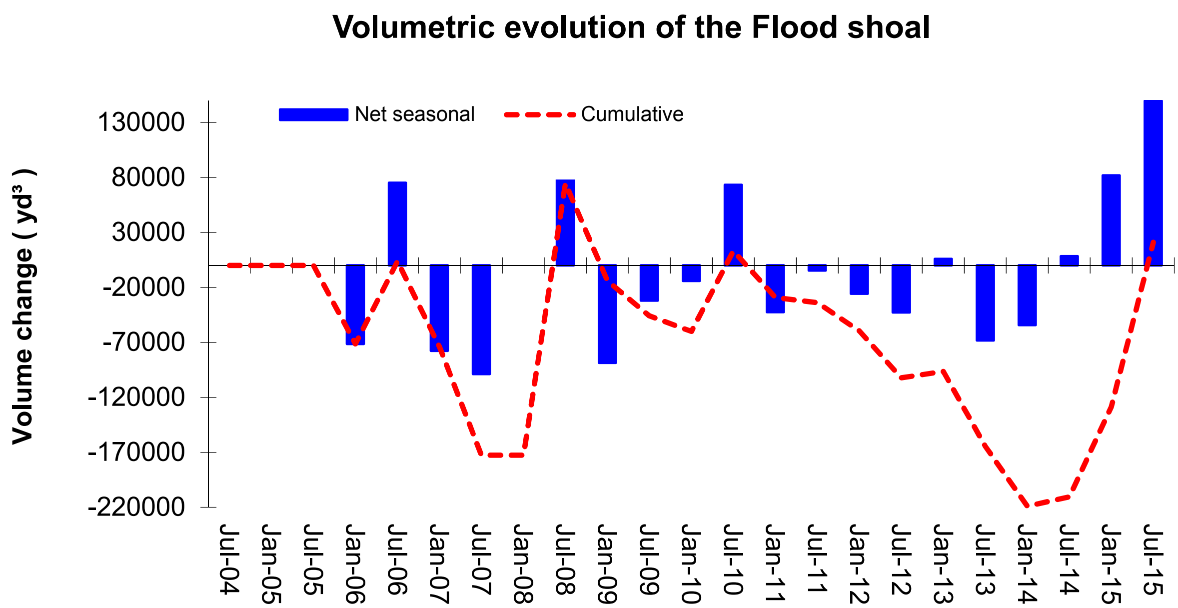

Figure 9. Volumetric evolution of the flood shoal from summer 2004 to summer 2015.

3.2 Sand Budget Cells

The sediment budget calculations discussed in the report depend on the analysis of individual sand budget cells. The sand budget computational cells are shown in Figure 3 (Zarillo et. al. 2007, 2013, and 2014). The inlet sand budget cell encompassing the nearshore zone from R215 in Brevard County to R4 in Indian River County, includes the ebb shoal, attachment bar and all other reservoirs shown in Figure 4. Annualized volume changes (ΔV) for each cell, calculated over different time periods, were added to the sand budget equation to calculate the annual net littoral sand transport in and out of each cell. Annualized placement and removal volume data were also included to account for dredging/mechanical bypassing and beach fill activities in the cells concerned. Time series of volumetric change for the five littoral cells since 2004 are presented in Figure 10 through Figure 14, ranging from the northernmost to the southernmost distal cells.

Volume changes for the N2 cell, the section between R189 and R203, are presented in Figure 10. Results indicate small net change in volume from 2004 to 2014. However, a large fluctuation in sand volume occurred in 2007 to 2008. In 2009, the sand volume of the

N2 cell returned to equilibrium punctuated by seasonal shift in volume that consisted of sand volume gains in the winter followed by losses or smaller gains in the summer.

Recent activity consist of a volume loss of about 500,000 cubic yards from July 2014 to July, 2015. As indicated by the dotted line in Figure 10, cumulative change for the N2 cell approximated -400,000 cubic yards since 2004. Most of this loss occurred within the latest event of 2014 -2015.

Volume changes for the N1 cell, (R203 and R215), are presented in Figure 11. Similar to the N2 cell, volume changes in N2 are usually seasonal; characterized by gains in the winter months and volume losses in the summer months. This cycle is related to the stronger south directed littoral drift under winter conditions sending more sand into the N2 and N1 cells from the beach and shoreface to the north in Brevard County.

Net sand volume change in the N1 cell since 2004 is driven by a series of events rather than a trend. After the large sand volume fluctuation of 2007-2008 the most recent sand volume changes are related to a large sand volume loss from July 2014 to July 2015 volume The sand volume loss since July 2014 is 500,000 cubic yards (Figure 11).

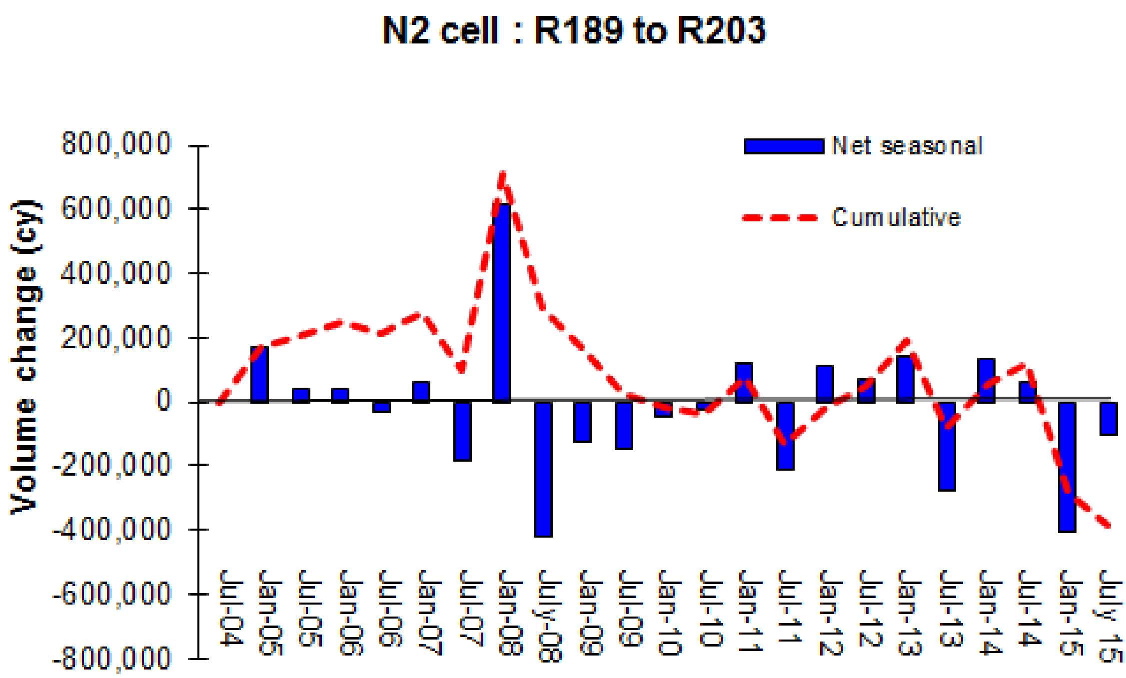

Figure 10. Recent volumetric evolution of the N2 sand budget cell.

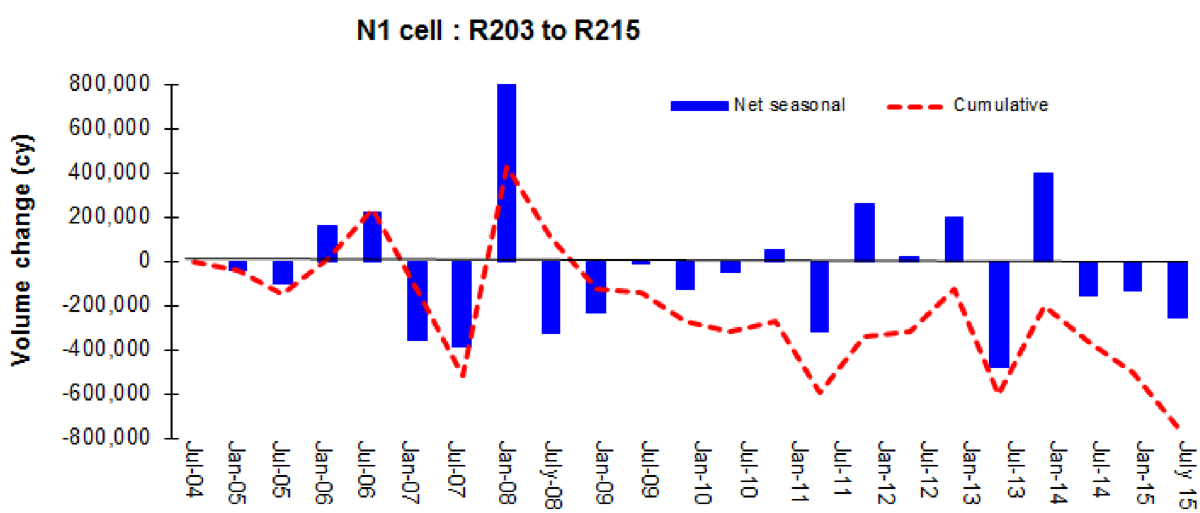

Figure 11. Recent volumetric evolution of the N1 sand budget cell.

Volume changes for the inlet sand budget cell are shown in **Error! Reference source not found.**. Sand volume in this budget cell is the sand trap and sand stored in the channel and the fillet areas within about 4,000 feet of beach and shoreface to the north and south of the inlet entrance (Figure 4). Sand volume seasonally fluctuates showing moderate gains in the higher energy winter months and moderate losses in the lower energy summer months. Divergence from this pattern occurs in association with major storms or in response to bypassing from the sand trap. Over the last decade, net change in sand volume in this cell is near zero, but seasonal to annual volume fluctuations can be on the order of 50,000 to 1000 cubic yards Since January of 2004 the inlet cell has maintained an equilibrium volume that includes small seasonal variation and larger abrupt volume changes linked to dredging of the sand trap in 2007, 2012, and 2014.

When considering an inlet sand budget cell that includes the flood shoal (**Error! Reference source not found.**Again, short term large fluctuations are linked to dredging of the sand trap occur. Abrupt sand volume loss is followed by abrupt gains as the inlet returns to a normal equilibrium.

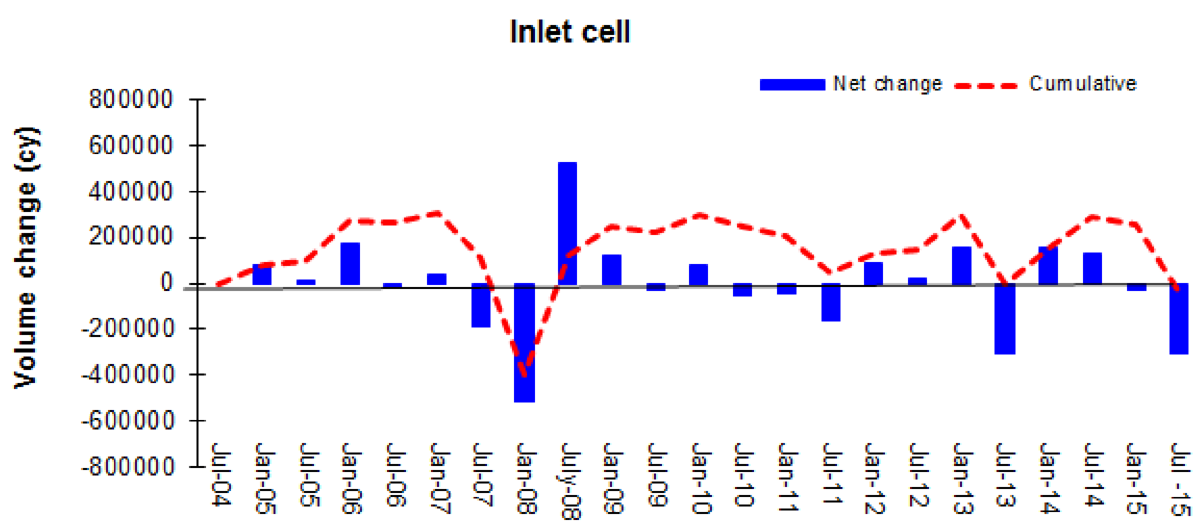

Figure 12. Recent volumetric evolution of the Inlet sand budget cell

The volumetric evolution of the S1 cell, situated directly south of the inlet cell between R4 and R16, is presented in Figure 13. The normal volume change pattern in this cell is a seasonal variation marked by volume gain in the winter and volume loss in the summer as seen between July, 2007 and July, 2010. The signature of the late 2007 and early 2008 placement of more than 200,000 cubic yards of sand in this cell is seen in Figure 13. More recently, the signature of the 2013 and 2014 fill projects from the Sebastian inlet sand trap is apparent. After the 2007 fill project constructed by Indian River County, the seasonal variations in sand volume were amplified and followed by slightly declining volumes until 2010. Since 2010, the pattern has been a decline in sand volume punctuated by volume gains related to sand trap bypass project. In the period from July 2014 to July 2015 a large volume fluctuation occurred consisting of about a 300,000 cubic yard gain of sand followed by a nearly equal loss of sand volume. This overall pattern of gain followed by loss was matched in all of the sand budget cells except the S2 cell to the south located between R16 and R30 (Figure 15). I n this cell the pattern was reversed and included a July 2014 to January 2014 sand loss of about 700,000 cubic yards of sand followed by a gain of approximately 450,000 cubic yards. This is interpreted as a sand being temporarily impounded in sand budget cells to the north shifting and bypassing to the south into the S2 cell.

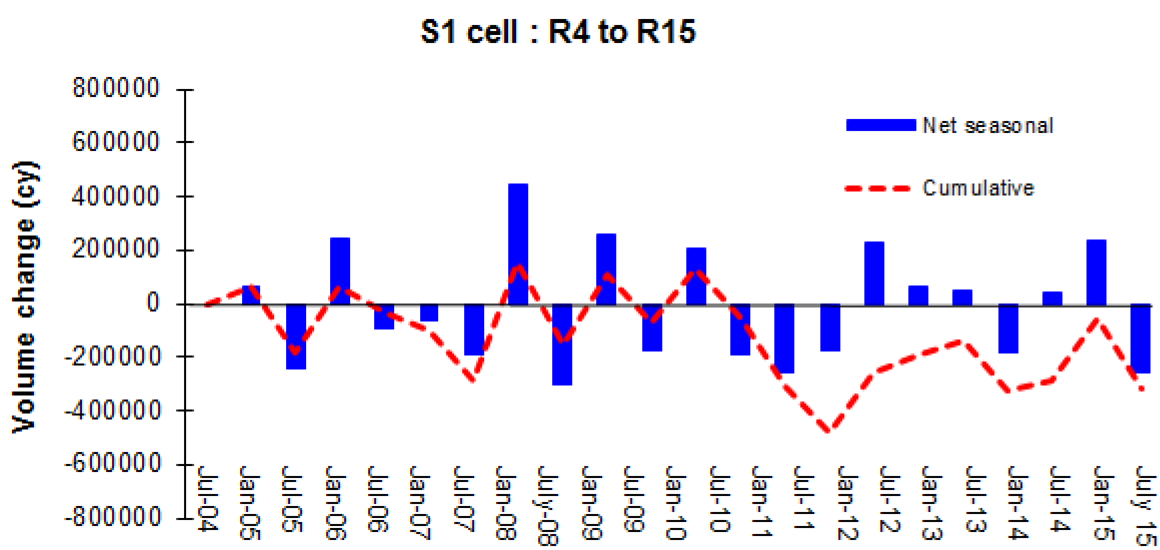

Figure 13. Recent volumetric evolution of the S1 sand budget cell.

The record of sand volume changes in the S2 cell is one of abrupt gains followed by a trend of declining sand volume that can extend over several years. The sand budget in the S2 cell is influenced by both the seasonal wave climate, and natural and mechanical bypassing of sand around Sebastian Inlet. The episodes of strong seasonal gains of sand volume in S2 (Figure 14) are most likely to be due to sand bypassing around the inlet and sand placement updrift of S2 in the S1 cell. A lag time of sand volume increase is required for the sand to reach S2. Depending on variations in wave climate and storm activity it may take up to a year for sand to reach this zone from sand bypassing and updrift placement. A Net sand volume gain in S2 from 2004 to 2014 is about 75,000 cubic yards.

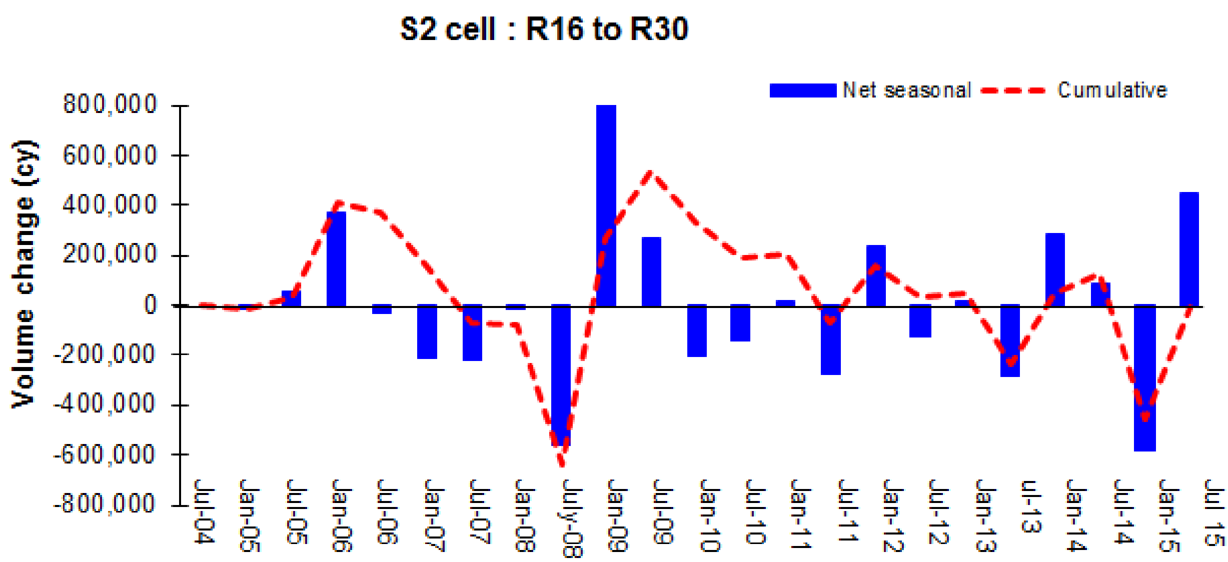

Figure 14. Recent volumetric evolution of the S2 sand budget cell.

3.3 Analysis of Sand Volume Changes, 2004 – 2015

Individual sand reservoirs and sand budget cells show short term changes when integrated over time yield a net sediment budget when place in an annualized format. Further, short term changes can be spatially tracked though the barrier island-inlet system to observe how sand is moved from one compartment to another. Thus, in order formulate a regional sand budget based on these data it is important to consider temporal interrelation among the sand volume components of the Sebastian Inlet system. The time scale of a sediment budget should consider the dynamics of sand volume adjustments. Establishing a sediment budget on a very short time scale could reflect only abrupt changes from seasonal storms and not account for ongoing trends. To view the interrelation and exchanges among of the sediment budget cells (Figure 3), Figure 15 compares sand volume changes all five of the sediment budget cells (N1, N2, Inlet, S1, S2) between summer 2004 and summer 2015. The figure shows the seasonal volume changes along with the cumulative volume change over this time period. Events of larger sand volume changes that correlation among the cells are shown and grouped on the plot. The S1 cell showed no net sand volume change between 2007 and 2010, but displayed repeated seasonal changes of sand volume gain in the winter and volume loss in the summer.

Sand volume change in the S2 cell (R16-R30) is marked by seasonal variations and little net change between 2004 and 2015. The S2 cell includes a large fluctuation in sand volume between July 2008 and January 2009. The same event, volume loss and rebound is seen in the S1 cell but to a lesser magnitude. Sand volume losses were also recorded in the N1 and N2 cells, but with no corresponding rebound. The 800,000 cubic yard rebound in sand volume in the S2 cell and the 200,000 cubic yard rebound in S1 recorded in the July 2009 survey is likely due to renewed sand bypass across Sebastian Inlet as the flood shoal, sand trap, and Inlet cell returned to an equilibrium volume

Changes in the S2 cell over the past 2 years reflect continued exchanges of sand volume from budget cells to the north. The S2 cell completed a large fluctuation marked by a 700,000 cubic yard loss of sand volume between summer of 2014 and winter of 2015 followed by a 400,000 cubic yard gain by the summer of 2015. The fluctuation can be accounted for by temporary sand volume storage in the Inlet Cell and S1 cell to the north followed by release of the stored sand southward to the S2 cell by the summer 2015 survey.

Within the Inlet Cell (components shown in Figure 4) a sand volume gains in 2014 were released to the south by the time of the summer 2015 topographic survey. Excluding the flood shoal, the overall inlet cell gain is near an annual average of zero since 2004

From 2004 to 2015, the total net loss in sediment volume over cell N1, N2, S1, and S2 cells was about 1.5 million cubic yards, whereas the net sediment gain within the inlet cell was near zero. If flood shoal sand volume gains are included the net gains of sand volume within the inlet system is about 21,000 cubic yards or about 1.4 % of total losses on the beach and shoreface segments to the north and south of the inlet system.

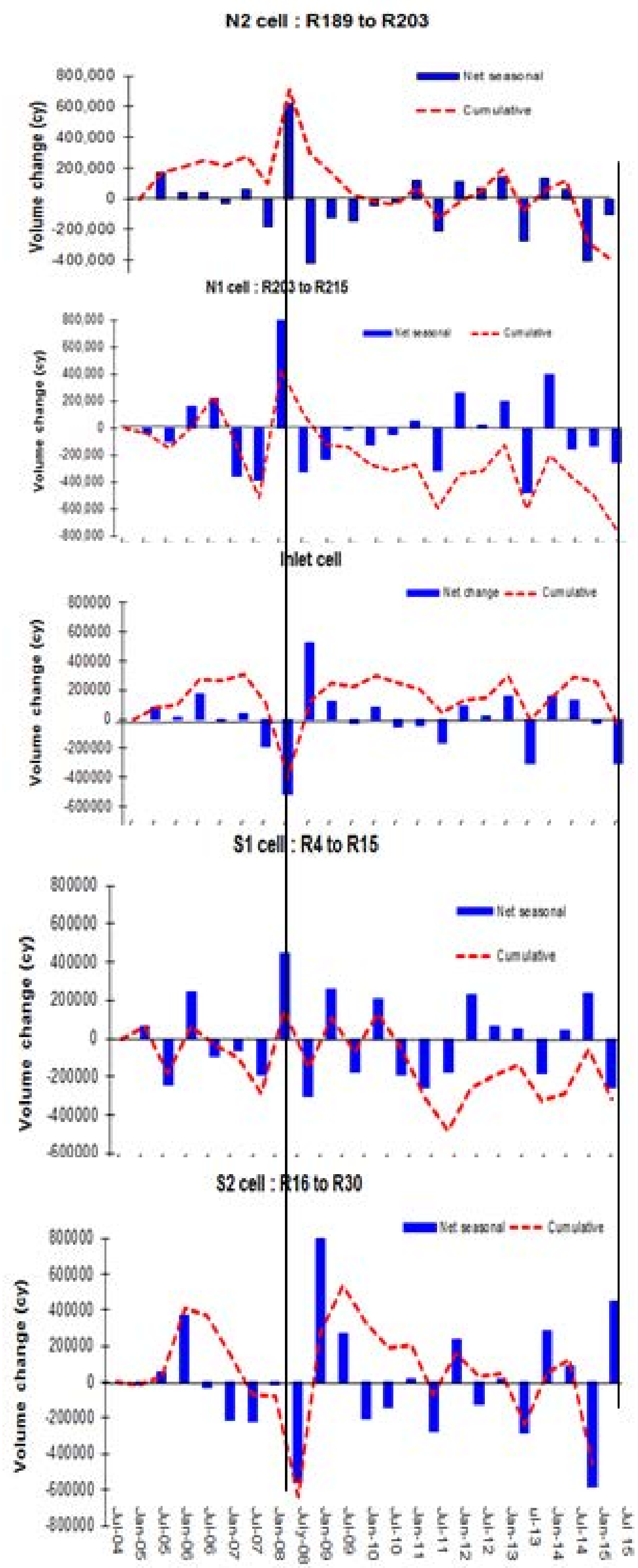

Figure 15. Comparison of sand volume chnages within the Sebastian Inlet seidment budget cells from summer 2004 to summer 2015.

Other smaller fluctuation is sand volume that correlate among the cells are also seen in Figure 15. Since most of these fluctuations are paired volume losses and gains, they are driven by seasonal variations in wave climate and littoral transport along with along with occasional larger events initiated by storms or dredging of the sand trap. Therefore the and budget calculations discussed in the following section (Section 4) are presented at time scales of 3 to 10 years based on the data reviewed in this section. Data presented in this report and in all of the Sebastian Inlet "State of the Inlet" reports show that the Inlet cell and many of its component shoals have equilibrium volumes. These are considered in sand budgets along with the seasonal signal in the other budget cells, by calculating over periods of 5 years or longer and by presenting budgets bounded by winter and summer data sets.

4.0 Sand Budget: Sebastian Inlet and Surrounding Barrier Segments

4.1 Methods

A sediment budget uses the conservation of mass to quantify sediment sources, sinks, and pathways in a littoral cell environment. It is used to quantify the effects of a changing sediment supply on the coastal system and to understand the large-scale morphological responses of the coastal system. The sediment budget equation is expressed as:

$$\sum Q_{source} - \sum Q_{\sin k} - \Delta V + P - R = residual \qquad \text{Equation 1}$$

The sources (Q_{source}) and sinks (Q_{sink}) in the sediment budget together with net volume change within the cell (ΔV) and the amounts of material placed in (P) and removed from (R) the cell are calculated to determine the residual volume. For a completely balanced cell the residual would equal zero (Rosati and Kraus, 1999). **Error! Reference source not found.** schematically shows how calculations are made within each cell of the sediment budget model.

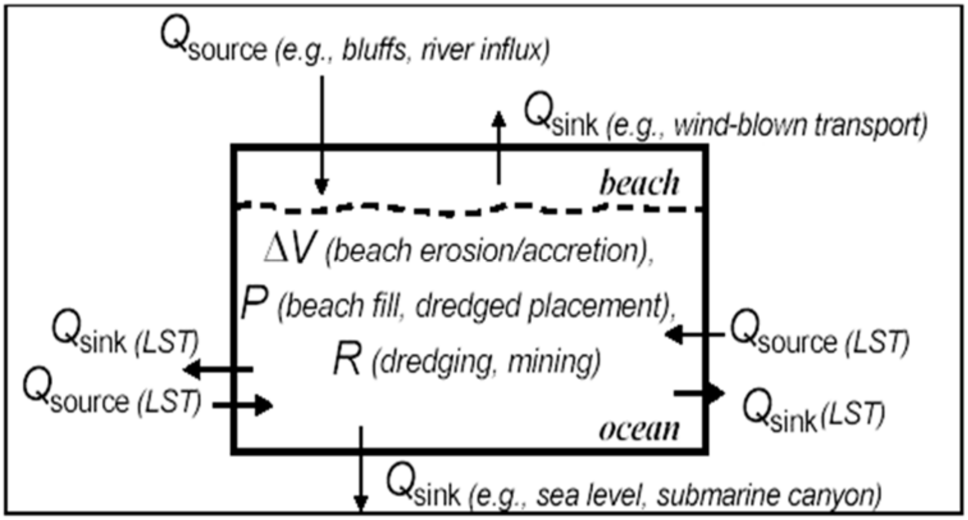

Figure 16. Schematics of a littoral sediment budget analysis (from Rosati and Kraus, 1999).

Determination of net volume change for the local sediment budgets for Sebastian Inlet was based on volumetric analysis masks presented in section 3.0. The sediment budget encompasses the area between monuments R189 in Brevard County to monument R30 in Indian River County. Since variability of the seasonal signal overshoots the average range of values in the sediment budget, the temporal scale of the calculations is based on several time periods ranging from two to ten years from summer 2004 to summer 2014. The computation cells (masks) that were used to establish the local sediment budget are schematically shown in the volumetric section (see Figure 3). Volume changes for each mask were determined according to the methods described above in the net topographic changes section and input into the Sediment Budget Analysis System (S.B.A.S) program, provided by the Coastal Inlet Research Program. Details of these procedures can be found in the technical report by Rosati et al. 2001. Based on super regional sediment budget calculations described in Zarillo et al, 2007 t an input value (Q_{source}) of 160,000 yd^3/yr. was chosen. The placement values (*P*) into the S1 (R4 to R16) and S2 cells (R16 to R30) correspond to the beach fill projects and were included in the calculations. Removal of sand (R) through mechanical bypassing was included (*R*) to account for the spring 2007, 2012, and the 2014 dredging projects within the sand trap. However, removal of sand (R) through offshore losses was assumed to be zero for all cells, as the boundaries of the masks extend beyond the depth of closure. Placement and removal values are annualized and presented in Table 2.

Table 2. Annualized placement and removal volumes for sand budget calculations.

Time Period	Season	Placement S1 (cy/yr.)	Placement S2 (cy/yr.)	Removal Inlet (cy/yr.)
2005 – 2015	Winter	35355	17,361	36754
2005 – 2015	Summer	35,356	17,361	36,754
2010 – 2015	Winter	53,571	34721	56508
2010 – 2015	Summer	53,571	34721	56508
2012-2015	Winter	89,285	28,640	94,180
2012-2015	Summer	72,928	0	53,513

4.1 Sand Budget Results

The sand budget is presented on three distinct time scales ranging from a longer term budget for the past 10-years to a short term budgets that examines volume changes and sand flux over 5 and 3-year year periods. The budget uses calculated annualized volume change per cell as inputs. Annualized beach fill material is accounted for in the S1 and S2 cells (R4-R16 and R16-R30, respectively), along with dredging of the sand trap in 2007, 2012, and 2014.

Interpretation of the fluxes, especially those leaving the southernmost cell (S2, R16-R30) must consider that the sand budget assumes a fixed input of +100,000 cy/yd. entering the first north cell (N2). Sand transport was assumed to flow north to south. Positive numbers indicate an increased flux toward the south, which was likely representative of the Sebastian Inlet area on a larger scale, whereas negative results indicate a reversal of sediment transport to the next cell north. Thus a negative volume change for a cell meant that volume was gained in a south cell or was available for that cell.

A long-term sand budget is listed in **Error! Reference source not found.** and covers the period from 2005 through 2015. A comparison is made between winter and summer-based budgets. The annualized sand budget shown in Table 3 includes annualized sand volume losses in the N2 and N1 budget cells for this time period (see Figure 10, Figure 11). This resulted in large values for Q (littoral transport) past these cells for both the winter and summer sand budgets. In the winter, sand budget the inlet cell (see Figure 3) retained annual average of about 21,000 cu. yd. of sand, whereas in the summer sand budget retained an annual average of about 24,000 cu. yd. of sand was retained. The 2000 to 2015 analysis accounts for dredging of the sand trap and fill placement in this period. The annualized values of fill (placement) and dredging (removal) are listed in Table 2. Thus, in both the winter and summer sand budgets Sebastian Inlet retains a relatively small amount of sand on an annual basis and naturally bypasses an annual average of more than 120,000 cu. yd.

Table 3. Annualized volume changes per cell and flux (2005 – 2015).

Time Period	**Winter 2005 - Winter 2015**		**Summer 2005 - Summer 2015**	
Sediment Budget Cell	**ΔV (cy/yr.)**	**Q (cy/yr.)**	**ΔV (cy/yr.)**	**Q (cy/yr.)**
North 2	-51,943	151,943	-59,379	159,379
North 1	-49,677	201,620	-60,871	220,251
Inlet	**17,458**	**147,408**	**-12,049**	**195,546**
South 1	-9,060	191,824	-14,237	245,139
South 2	-64,725	273,911	-3,904	266,404

Table 4. Annualized volume changes per cell and flux (2010 – 2015).

Time Period	Winter 2010 - Winter 2015		Summer 2010 - Summer 2015	
Sediment Budget Cell	ΔV (cy/yr.)	Q (cy/yr.)	ΔV (cy/yr.)	Q (cy/yr.)
North 2	-55,834	155,834	-66,440	166,440
North 1	-65,189	221,023	-88,034	254,474
Inlet	6,867	157,647	-62,286	260,251
South 1	-44,241	255,460	-89,699.73	296,380
South 2	-179,818	488,850	-60,703.9	322,363

Short-term Sand Budget

The annualized changes and associated fluxes for 2012 to 2015 short-term periods are presented in **Error! Reference source not found.**. In the winter 2012 to winter 2015 sand budget, the removal of material from the sand trap in early 2012 and again in winter 2014 is included in the calculation. Likewise, annualized placement of fill in the S1 and S2 cells is considered for this period. The summer 2012 to summer 2014 sand budget considers dredging of the sand trap during the winter of 2014 and the annualized placement of sand in the S1 budget cell (see Table 1).

In the winter to winter sand budget, deposition in the N2 and N1 cells reduced the initial flux of sand into N2 the (150,000 cu. yd.) to about 46,000 cubic yard passing though the N2 cell. Within the inlet cell, the ΔV and Q terms reflect removal of sand from the sand trap and distorts the sand bypass value to appear as if the inlet is moving sand to the north. However, given the annualized accumulation of sand in the N1 and N2 cells for this period, it is possible that some of the fill from the sand trap that was placed on the south beach was back passed to the inlet and moved to the north. Sand volume losses in the S1 and S2 cells may have been reduced by sand placement and contributed to the net southward flow of littoral drift through these cells.

The summer 2012 to summer 2014 sand budget calculation was substantially different from the winter to winter budget. This summer sand budget has less material dredged and placed and more sand volume added to S1 and S2 cells. The N2 cell retained a similar annualized sand volume amount compared to the winter budget, whereas the N1 cell lost about 22,000 cubic yards of sand, which was added to the Q value of transport passing through this cell. The inlet cell as a whole retained about 61,000 cubic yards on an annualized basis during this period. The Q littoral transport values are negative from the inlet cell and to the south indicating net transport from south to north over the 2-year summer to summer time period in a reversal zone to the south of the inlet. On the other hand the Q littoral transport values north of Sebastian Inlet are strongly positive driven by the initial input values of 150,000 cubic yards into N1 and erosion in the N1 cell. The overall summer to summer budget indicated possible convergence of sand from the littoral system, thus explaining in part retention of sand within the inlet budget cell. Since previous work indicated that there is strong seasonal variability in the local sand budget and some variability year to year, caution should be taken when applying short term sand budgets for longer term management of sand resource. Longer term sediment budgets on a time scale of 5 years and longer have proven to be more stable and more useful for long term planning.

Table 5. Annualized volume changes per cell and flux 2012 – 2015.

Time period	**Winter 2012 - Winter 2015**		**Summer 2012 - Summer 2015**	
Sediment Budget Cell	**ΔV (cy/yr.)**	**Q (cy/yr.)**	**ΔV (cy/yr.)**	**Q (cy/yr.)**
North 2	-43,700	143,700	-105,532	205,532
North 1	27,487	116,212	-119,268	324,800
Inlet	61,565	-39,533	-48,795	320,082
South 1	48,403	1,359	79,475	313,535
South 2	-108,801	138,799	-47,241.2	389,416

When considering the time scale of the sand budget calculations it is obvious that a sand budget based on a shorter time period as shown in Table 5 is of limited use for long term planning. Seasonal effected have strong influence in the shorter term budget calculation as illustrated in Table 3 where littoral drift convergence may temporarily backpass sediment from Indian River County to the inlet sand reservoirs. Over the longer term such effect are average to an equilibrium and net littoral drift is from north to south in the vicinity of the inlet (Tables 3, 4 and 5).

5.0 Morphologic Changes

5.1 Methods

The analysis uses the same dataset and overall methodology as the sand volume analysis described in the section above. The bathymetric changes section is subdivided according to the time period of analysis. The time covered in this report is from winter 2013 through summer 2014, a period of about 18 months. The net bathymetric changes over a 15-year and 20-year periods are presented in the series of earlier report (Zarillo et al, 2007, 2012, 2013). In the color code for figures depicting topographic change, blue represents erosion, whereas red indicates deposition. Topographic changes were combined with results from shoreline changes and sand budget calculations for a better understanding of the sedimentation processes.

5.2 Topographic Changes 2012 to 2015

Figures 17 and 18 cam be compared with the winter to winter and summer to summer sediment budgets presented in

Table 5. The winter 2012 to winter 2015 topographic changes shown in Figure 17 Shore the sand accumulations in the N2 and S1 budget cells. Sand volume accretions of about 61,000 cubic yards in the inlet sand budget cell is largely due to accumulations on the ebb shoal as seen in Figure 17 and in Figure 5. The topographic results of dredging in the sand trap are also apparent.

When comparing the summer to summer topographic changes between 2012 and 2015 (Figure 18) they reflect sand volume losses within the inlet sediment budget cell and in the N1 sand budget cell that are listed in

Table 5. A small gain the in S1 sand budget cell occurred between R4 and R15. Sand volume loss within the inlet budget cell (

Table 5) in this time period are due to volume loss on the beach and shoreface between the Inlet and R4 and also due to excavation of the sand trap. A sand volume gain on the ebb shoal of approximately 39,000 cubic yards (Figure 6) is clearly shown in Figure 18.

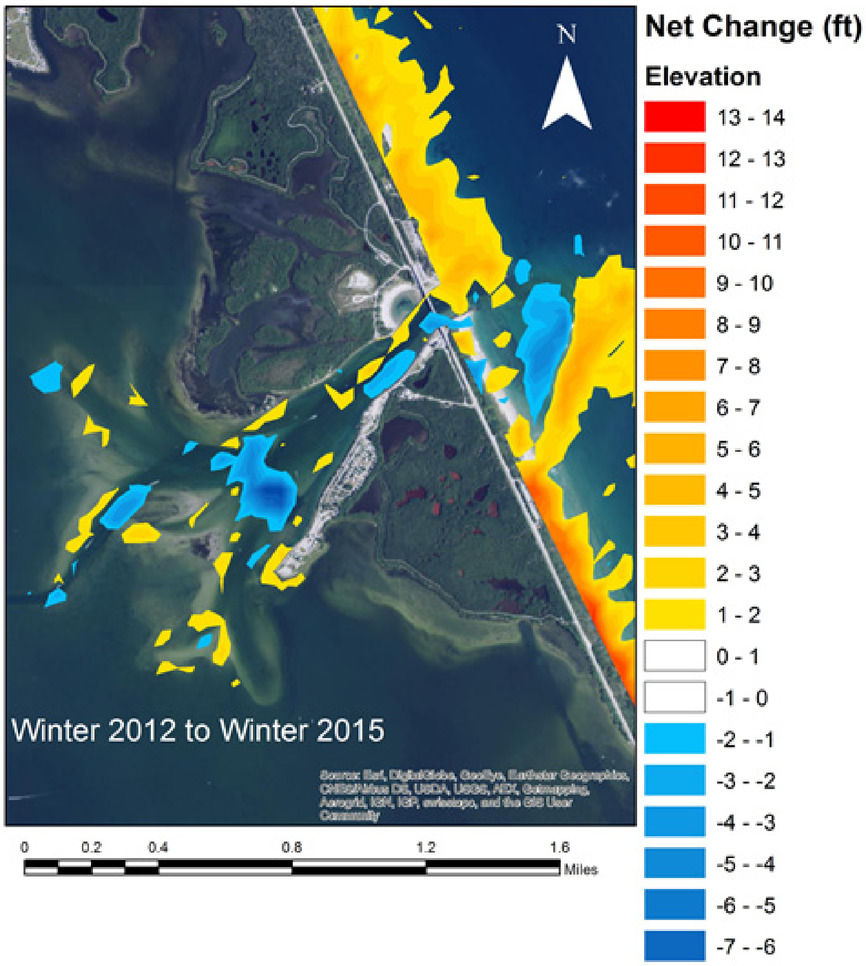

Figure 17. Topographic changes between winter 2012 and winter 2015 determined from survey data.

5.3 Topographic Changes 2014 to 2015

Recent topographic changes o in the vicinity of Sebastian Inlet are available from analysis of three survey data sets available between summer 2014 and the latest data set completed in the summer of 2015. Figure 19 shows topographic changes around the inlet that were calculated from the differences between the summer 2014 and winter 2015 survey data. Figure 20 shows the calculated topographic changes between the winter 2015 and summer 2015 survey data. The changes shown in these figures can be compared with sand volume change data shown series of figures of sand reservoirs and sand budget cells shown in Section 3.1 and 3. 2 of this report. For instance sand volume losses between summer 2015 and winter 2015 shown in Figure 19 are also reflected in Figure 11and Figure 12, which show sand volume losses within the inlet sand budget cell and the N1 cell just to the north. Likewise a gain in volume within the sand trap are shown in Figure 19 is also reflected in sand volume changes shown in Figure 8 for this time period. Sand volume losses in the attachment bar (Figure 7) and in the ebb shoal (Figure 6) from summer 2014 to winter 2015 are seen in Figure 19.

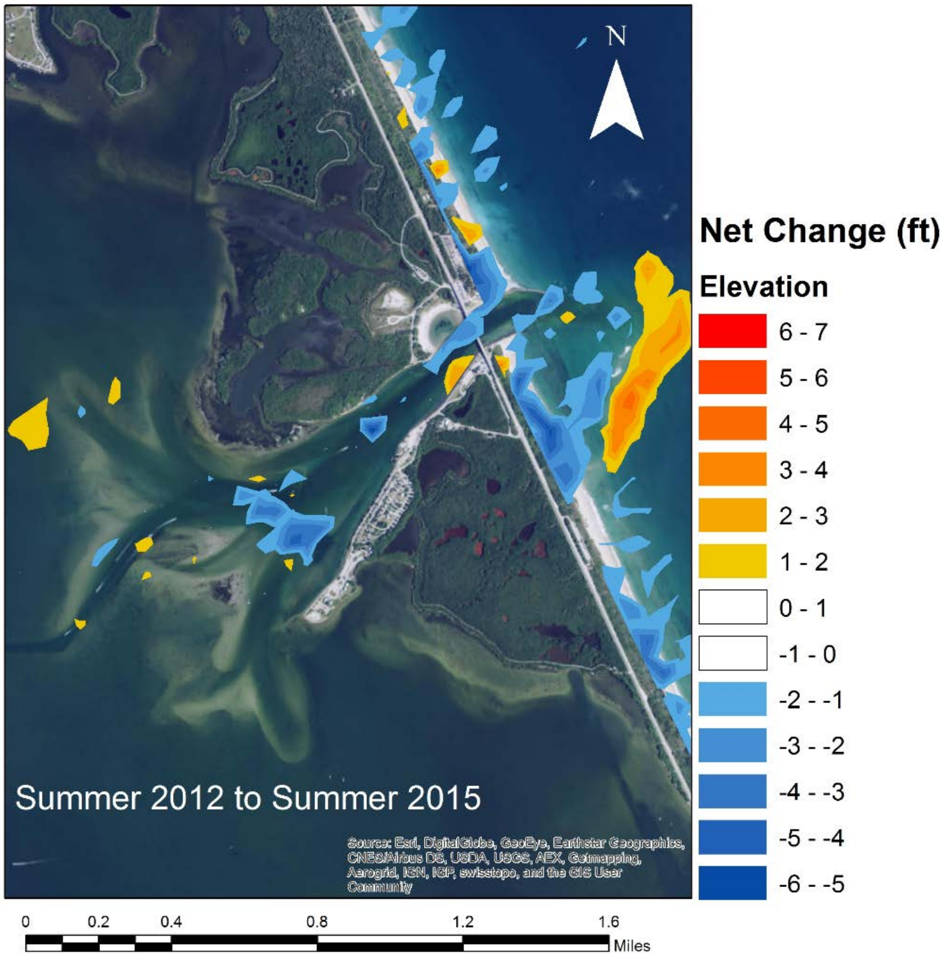

Figure 18. Topographic changes between summer 2012 and summer 2015 determined from survey data.

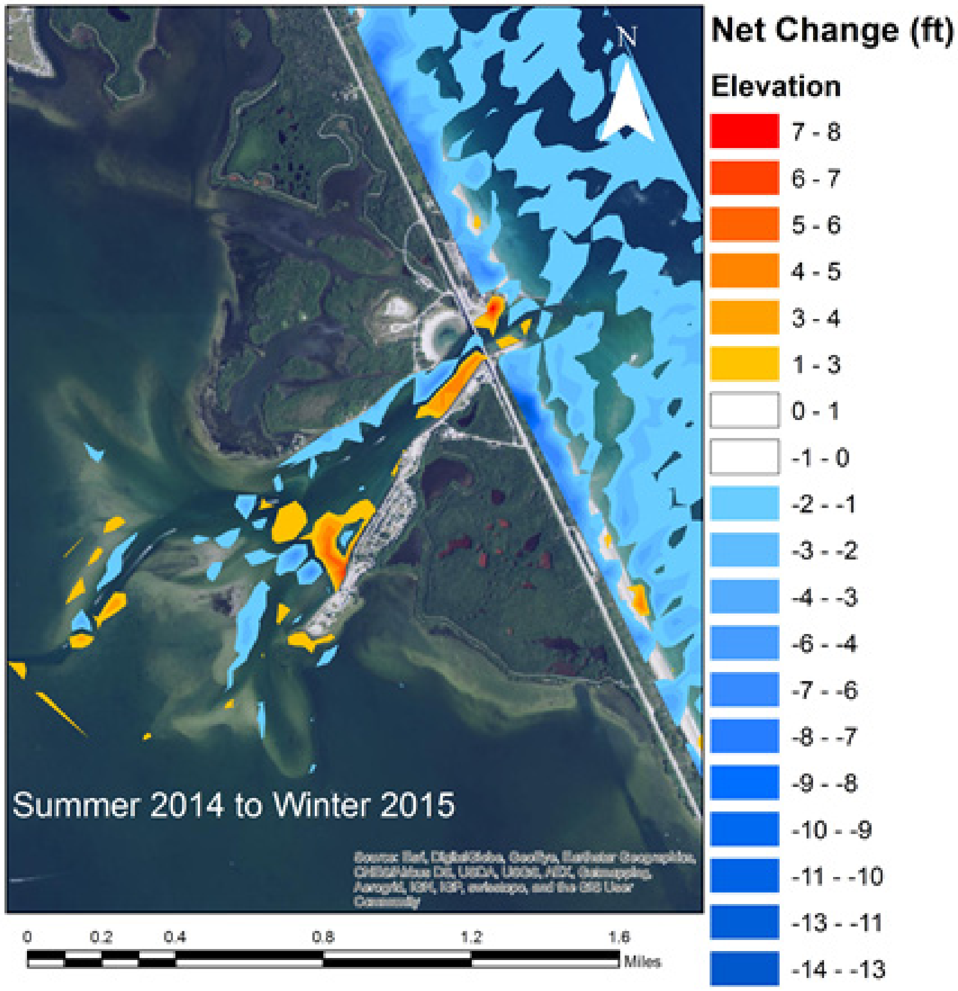

Figure 19. Topographic changes between summer 2014 and winter 2015 determined from survey data.

Topographic change patterns for the latest available survey data set are shown in Figure 20. Sand volume losses within the inlet budget cell (Figure 12) are the result of volume loss over the north fillet area, the south beach and shoreface down to about R4, and sand bypassing from the attachment bar area (Figure 7). Sand volume gains over the ebb shoal shown in Figure 20 are consistent with ebb shoal data in Figure 5. Likewise sand volume gains over the flood shoal are seen to occur mostly in the channel areas.

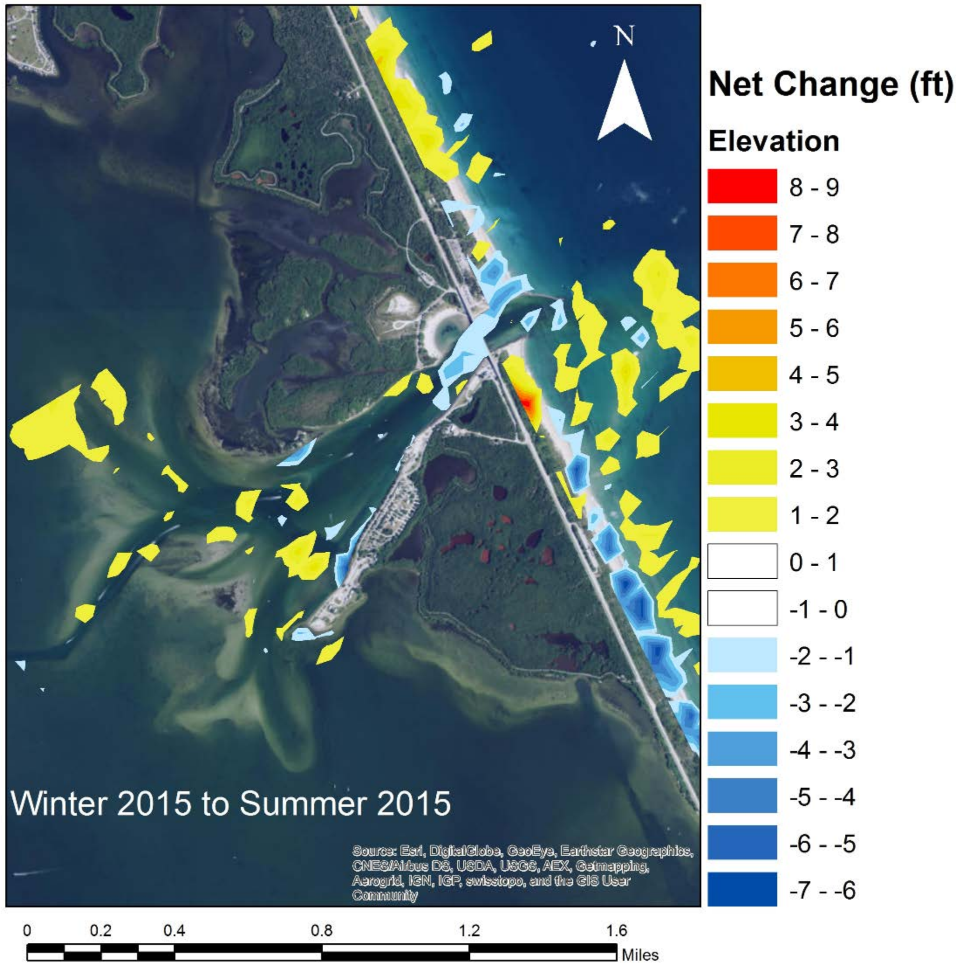

Figure 20. Topographic changes between winter 2015 and summer 2015 determined from survey data.

6.0 Image-Based Shoreline Changes

Shoreline positions were digitized from the geo-referenced aerial imagery for a domain covering approximately 7 miles north to 7 miles south of Sebastian Inlet, FL (~75,000 ft, Table 6). Changes to the shoreline position were determined by comparing 30 time series of transects generated every 25 ft. along the coast. Table 7 indicates the extent of coverage for each of the time series used in the analysis according to the total number of transects and the alongshore distances. Transects were generated using the BeachTools© extension for ArcView3.2© from a standardized baseline (~SR A1A) to the wet/dry line (low-tide terrace). The change in shoreline position was determined by subtracting the distances along each transect between time-series of interest. Shoreline change rates were calculated using both the End Point Rate (EPR) and Linear Regression (LR) methods (Crowell et al., 1993; Morton et al., 2002). For details on the methodology the reader is referred to the previous report. In this version of the report, long-term changes and rates of change have been updated for the time spans of 1958-2015 (historical) and the short-term analysis covered the years 2004-2015 (recent). An additional short-term analysis section has been included to account for the changes occurring since the previous report, spanning from 2010-2015 (recent), as well as those changes occurring during the 2014-2015 (yearly) time span.

Table 6. Summary of aerial imagery since 2005 coverage.

Fly Dates	Scale	Quality	Coverage (mi.)	Source
June, 2015	1:2400	Excellent	7 to 7	SITD
June, 2014	1:2400	Excellent	7 to 7	SITD
July, 2013	1:2400	Excellent	7 to -7	SITD
July, 2012	1:2400	Excellent	7 to -7	SITD
July, 2011	1:2400	Excellent	7 to -7	SITD
July, 2010	1:2400	Excellent	7 to -7	SITD
July, 2009	1:2400	Excellent	7 to -7	SITD
July, 2008	1:2400	Excellent	7 to -7	SITD
14-Feb-07	—	Excellent	6.2 to -6.4	SITD
Dec, 2005	1:2400	Excellent	7 to -7	BCPA/IRCPA

Table 7. Summary of shoreline transect coverage.

Domains	Transect ID	R Marker	Miles
North	0-1480	180.5-219	7.0
South	1508-2974	0-37.5	6.9
N3	0-880	160.5-203	4.2
N2	880-1364	203-216	2.3
N1	1364-1480	216-219	0.6
Inlet	1365-1645	BC216-IRC4	1.3
S1	1508-1627	0-3.5	0.6
S2	1627-212-	3.5-16	2.3
S3	2120-2974	16-37.5	4.0

6.1 Results

The results presented and discussed in this section on image-based shoreline change will focus on the linear regression method (LR). However results obtained through the use of the end-point-rate (EPR) method are also included despite its use being subject to several disadvantages. For example, if either shoreline is uncharacteristic, the resulting rate of change will be misleading; also data between the endpoints that is ignored may produce rates that do not capture important trends or changes in trends, especially as temporal variation increases (Dolan et al. 1991). The reader is referred to the earlier version of the report for more information on both (the linear regression and end-point-rate) of method used. Average rates of shoreline change are listed in Table 8 according to shoreline segments described in

Table 7.

Table 8. Average rate of change for EPR and LR methods (ft./yr.).

Extent		Method	('58-'15)	('04-'15)	('10-'15)	('14-'15)
N-S		EPR	-0.2668	-0.7732	1.9663	-8.9012
		LR	0.3094	-0.6872	-1.0294	-8.0558
Brevard Co.	N	EPR	0.2829	-1.2678	2.0211	-6.6738
		LR	0.5804	-0.9879	-1.2422	-6.0024
Indian River Co.	S	EPR	-1.1928	-0.2778	1.9131	-11.1494
		LR	0.0352	-0.3800	-0.8146	-10.1462
Brevard Co.	R180.5 – 203 (N3)	EPR	-0.2910	-0.8827	2.5359	-8.6982
		LR	0.4268	-0.1133	-0.9953	-7.2271
	R203 – 216 (N2)	EPR	0.8806	-1.8109	1.3337	-7.2891
		LR	0.7473	-2.0454	-1.8922	-7.2891
	R216 – 219 (N1)	EPR	1.3959	-1.4220	1.6580	8.6128
		LR	1.0420	-3.2062	-0.4212	8.6128
Indian River Co.	R1 – 3.5 (S1)	EPR	0.6822	0.3167	-2.6684	-38.1231
		LR	2.6397	-0.5920	-5.4228	-37.8054
	R3.5 – R16 (S2)	EPR	-1.4227	-1.6316	1.5259	-5.8184
		LR	0.7605	-2.8211	-0.7195	-5.8184
	R16 – 37.5 (S3)	EPR	-1.7921	0.5484	2.9221	-10.3932
		LR	-0.7458	1.0553	-0.2280	-8.8008
Inlet		EPR	0.9668	-0.3777	-0.3969	-16.4356
		LR	1.8907	-1.7279	-2.7567	-16.4356

In general, both methods yielded similar results with most of the values in the same order of magnitude and with either a positive or negative trend in concordance with each other. Some instances where opposing trends are encountered are for the period of 1958-2015 for the N-S, S, S2 domains, in the 2004-2015 period for the S1 domain, in the 2010-2015 period for the N-S, N, S, N1, N2, N3, S2, S3 domains where the EPR and the LR methods have opposite signs. The rest of this section will provide more details on the results obtained for each of the periods updated.

Historical Period (1958-2015)

As compared to 1958, the distance from the baseline to the wet/dry line has retreated by more than 60 ft. along transects immediately north of the inlet and accreted close to +50 ft. just south of the south jetty (Figure 21) according to the results obtained with the EPR method. This method also indicates that the average change in shoreline position from 1958 to 2015 is -15.21 ft. of retreat at an average rate of -0.27 ft./yr. (Table 8). Despite the indication by the end-point-rate (EPR) method of shoreline retreat along most of the study extent from 1958 to 2015, the linear regression (LR) method indicates that the long-term trend is toward accretion (Figure 22). Close to seventy percent of the 14 miles of the study area is accreting at an average rate of +0.31 ft./yr., while only thirty percent (30%) of the region shows erosional patterns (Figure 22, Table 9).

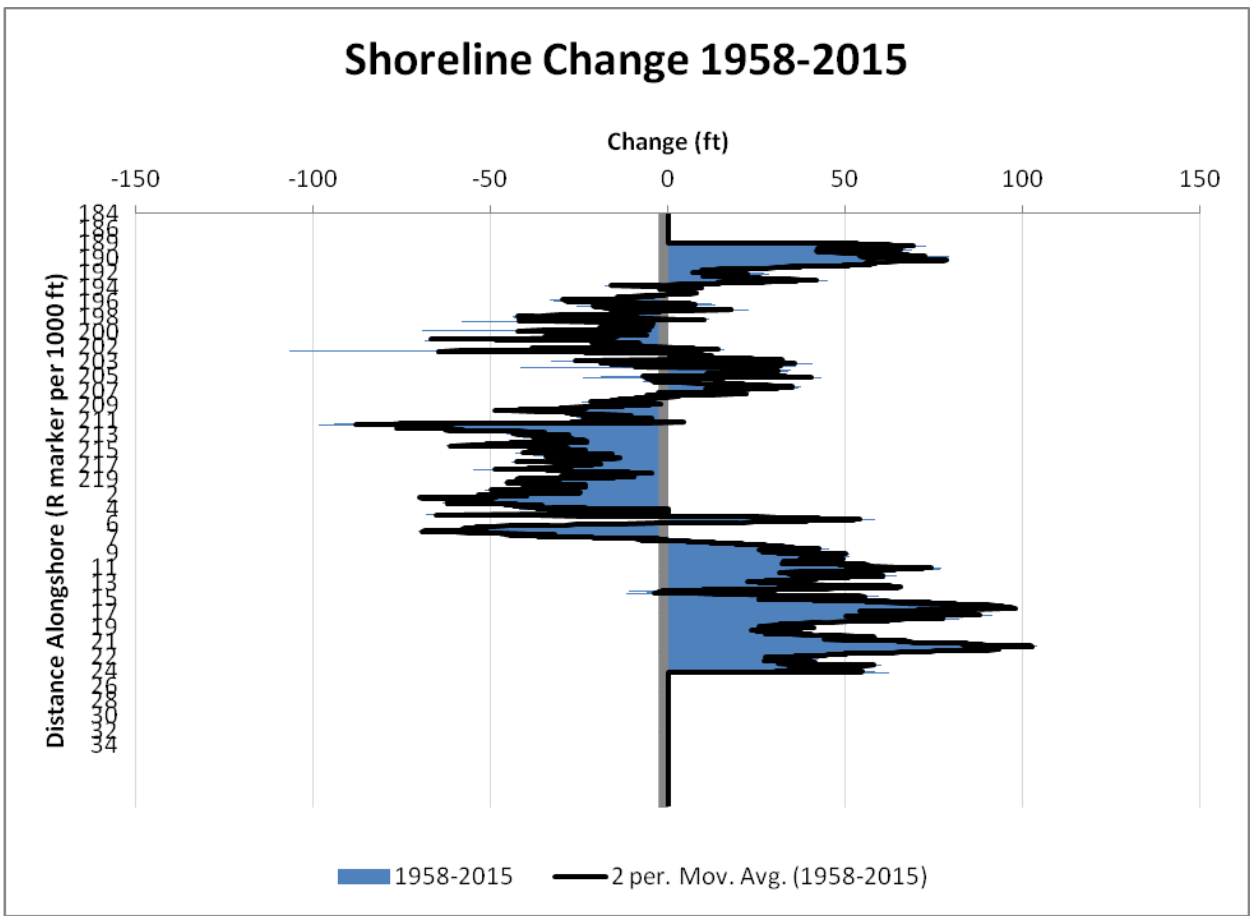

Figure 21. Change (ft.) in shoreline position from 1958-2015.

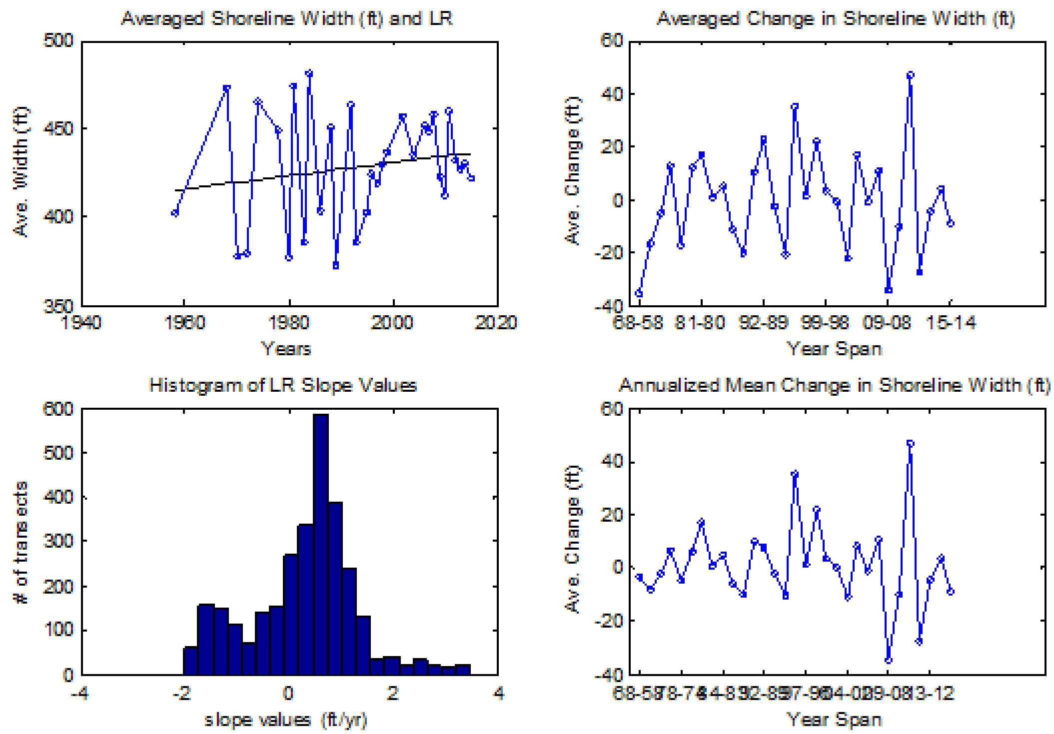

Figure 22. Average shoreline position with LR trend (top) and histogram indicating number of transects and slope value (bottom) for the entire domain (left) and for the inlet domain (right) 1958-2012.

The greatest area of accretion occurs just south of the inlet between the jetty and the attachment bar (S1) from R2 to R4 with a maximum of +3.48 ft. /yr. at an average of +2.64 ft. /yr. In contrast, the region from R16 to R 37 (S3) is predominantly erosional with an average rate of change of -0.75 ft. /yr. including the maximum erosion rate of -2.00 ft. /yr. for the entire domain of the study area (near R-26). The northern sub-domain is also predominantly accreting with only smaller regions showing erosional trends. The left side of Figure 23 highlights the percentage of erosion vs. accretion for the entire domain during this fifty-seven year period, whereas the right side of Figure 23 is a plot of all the shoreline positions used in the study.

Table 9. Summary of changes for the historical period (1958-2015).

Extent	Range (ft. /yr.)	Average LR (ft. /yr.)	Erosion %	Accretion %
North to South	-2.00 to +3.4843	+0.3094	30.08	69.01
North	-0.86 to 1.9316	+0.5804	19.65	80.32
South	-2.00 to 3.4843	+0.0352	41.17	58.76
N3	-0.86 to1.9316	+0.4268	32.58	67.42
N2	-0.05 to1.5883	+0.7473	0.82	99.18
N1	0.69 to 1.3896	+1.0420	0	100
Inlet	0.00 to +3.4843	+1.8907	0	90.39
S1	0.00 to +3.4843	+2.6397	0	99.17
S2	-0.09 to 2.4972	+0.7605	1.01	98.99
S3	-2.00 to 0.7576	-0.7458	70.06	29.94

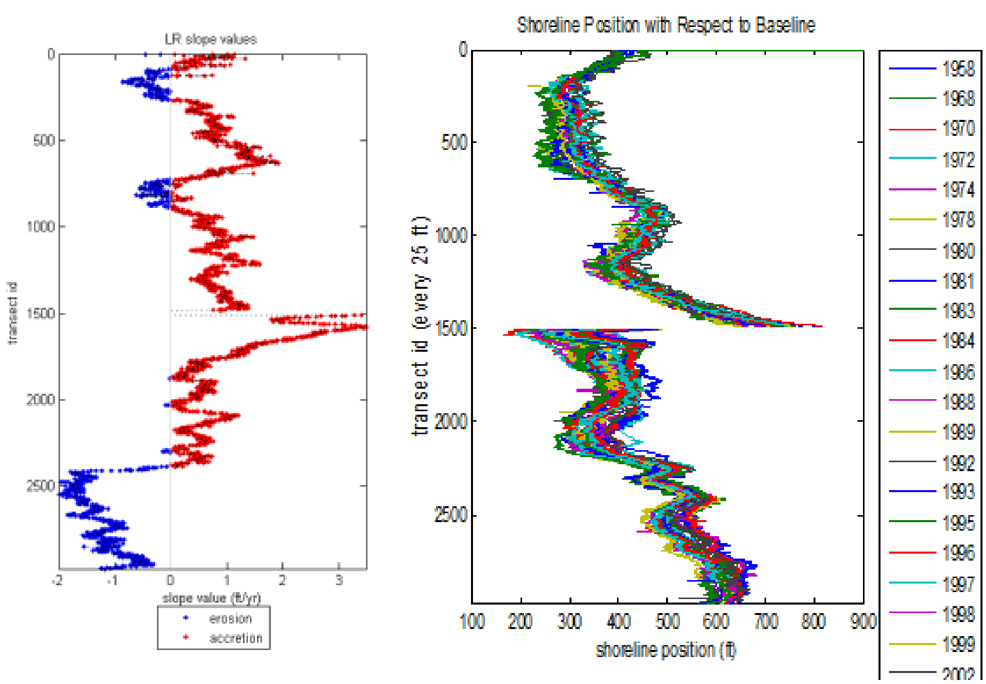

Figure 23. Percent erosion and accretion (left) and shoreline position (right) for 1958-2015.

Recent Period (2004-2015)

The trend obtained by analyzing ten time series of data representing the last eleven years of shoreline change indicates the beaches along the 14 mile domain are predominantly eroding. In this case both methods (EPR and LR) are in agreement that the majority of the study area is experiencing erosion. Almost seventy percent of the entire area from north to south is erosional with an average rate of change of -0.69 ft. /yr.

The area immediate to the south of the jetty down to R-4 seem to have advanced the shoreline position to about +30 ft., while the entire north extent has receded to an average of -10.89 ft. at -0.99 ft/yr. (Figure 24). A closer inspection to each sub-domains indicate almost all sub-cells are erosional but one (S3). The southernmost region from R16-R37.5 (sub-cell S3) is the only area in which accretion is occurring at 62.8% with a rate of change of +1.06 ft/yr.

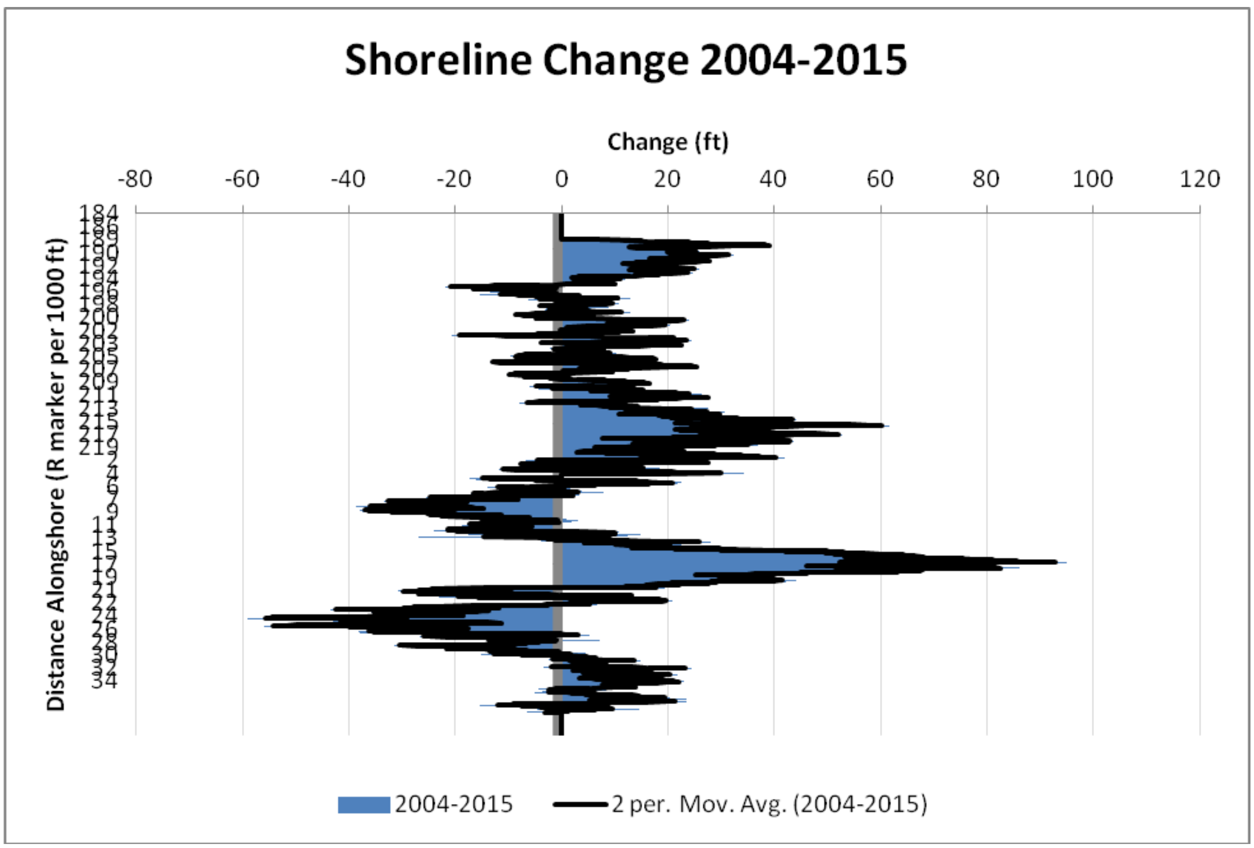

Figure 24. Change (ft.) in shoreline position from 2004-2015.

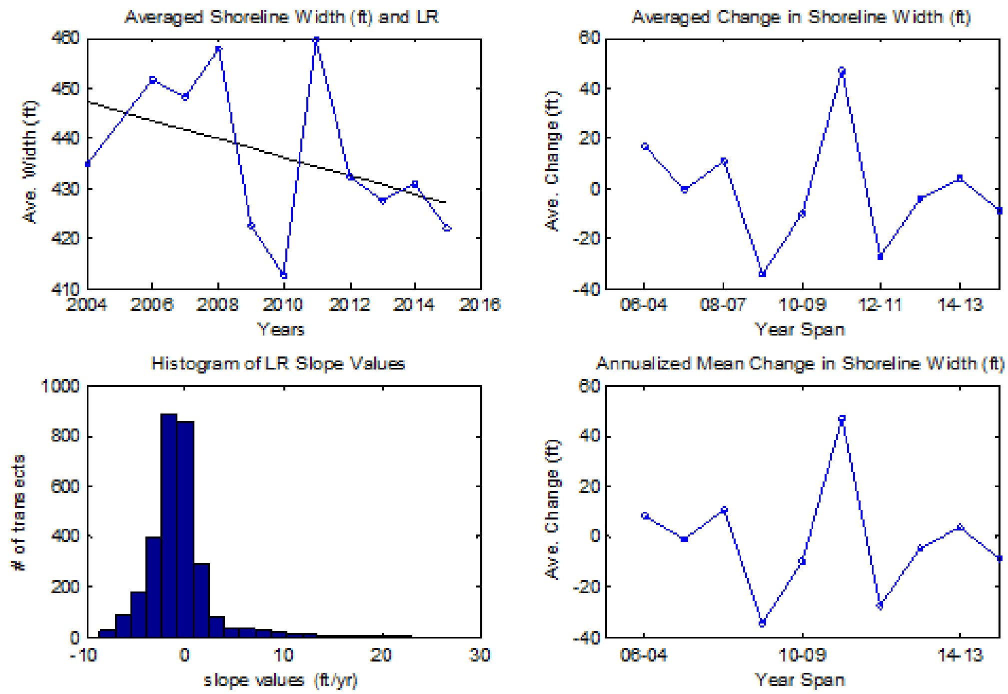

Figure 25. Average shoreline position with LR trend (top) and histogram indicating number of transects and slope value (bottom) for the entire domain (left) and for the inlet domain (right) 2004-2015.

Table 10. Summary of short-term changes for the recent period (2004-2015**)**

Extent	Range (ft/yr.)	Average LR (ft/yr)	Erosion %	Accretion %
North to South	-8.73 to 23.0400	-0.6872	69.21	29.78
North	-5.21 to 23.0400	-0.9879	86.56	13.23
South	-8.73 to 14.3750	-0.3800	52.90	47.03
N3	-4.75 to 23.0400	-0.1133	79.68	19.98
N2	-5.21 to 1.1859	-2.0454	95.88	4.12
N1	-5.10 to -1.6399	-3.2062	100	0
Inlet	-5.49 to 1.2513	-1.7279	71.89	18.51
S1	-2.88 to 1.2201	-0.5920	69.17	30.00
S2	-8.73 to 2.6395	-2.8211	76.11	23.89
S3	-5.41 to 14.3750	1.0553	37.19	62.81

The left side of Figure 26 highlights the percentage of erosion vs. accretion for the entire domain during this 11 year period, whereas the right side of Figure 26 is a plot of all the shoreline positions used in the study.

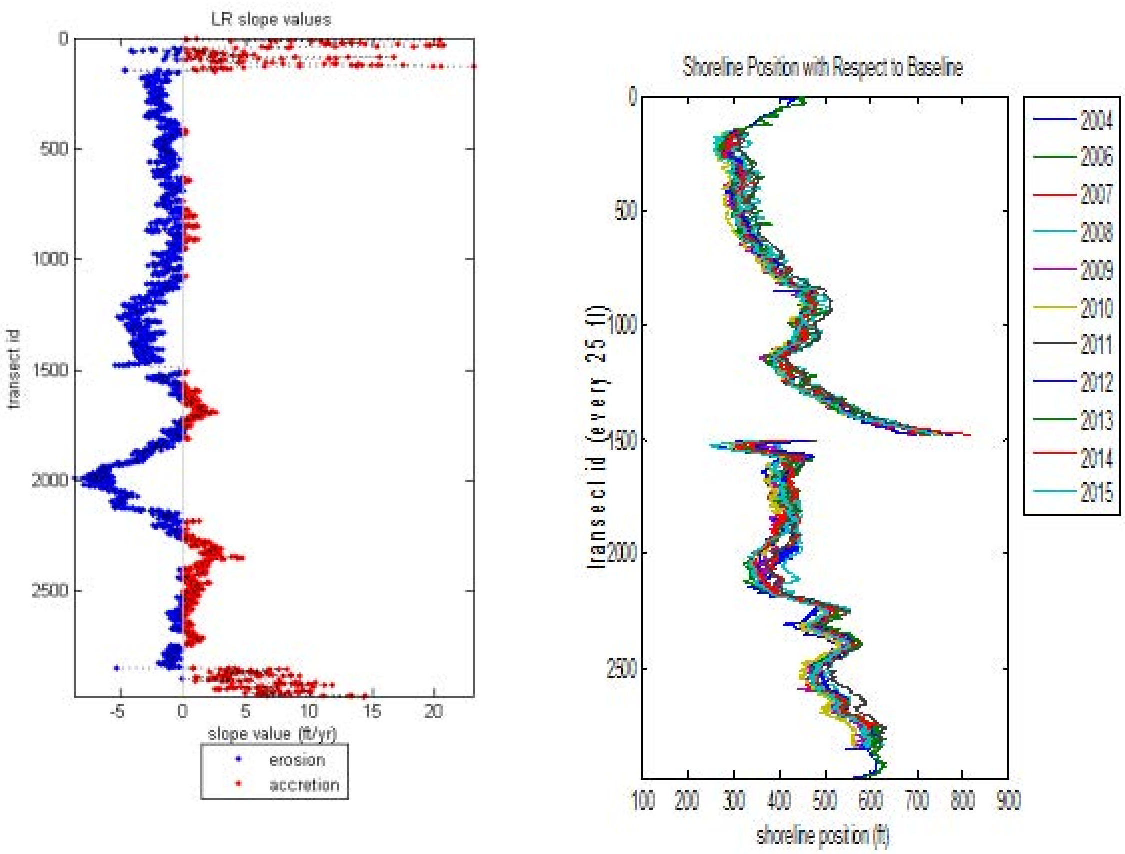

Figure 26. Percent erosion and accretion (left) and shoreline position (right) for 2004-2015

Latest Update (2010-2015)

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Despite the indication by the linear regression (LR) method of shoreline retreat along most of the study extent from 2010 to 2015, the end-point-rate (EPR) method indicates that the trend is toward accretion (Figure 28) Analysis of the latest update shoreline changes from 2010 to 2015 indicates the overall region under study has a mix of accretion and erosion, 9.83 ft of accretion (Table 11, Figure 29) at a rate of 1.97 ft/yr. occurred according to the EPR method (Table 8,last tabs LR/EPR) and erosion at a rate of -1.03 ft/yr. with the LR method. The erosional trend is encountered throughout the entire 14 mile extent and also noted in the more detailed analysis for each sub-cell domain (Table 11). The percentages of the areas showing erosional trend range from 84.8% at S3 up to 100% erosion in sub-cells N1, S1 and S2 (Figure 29)

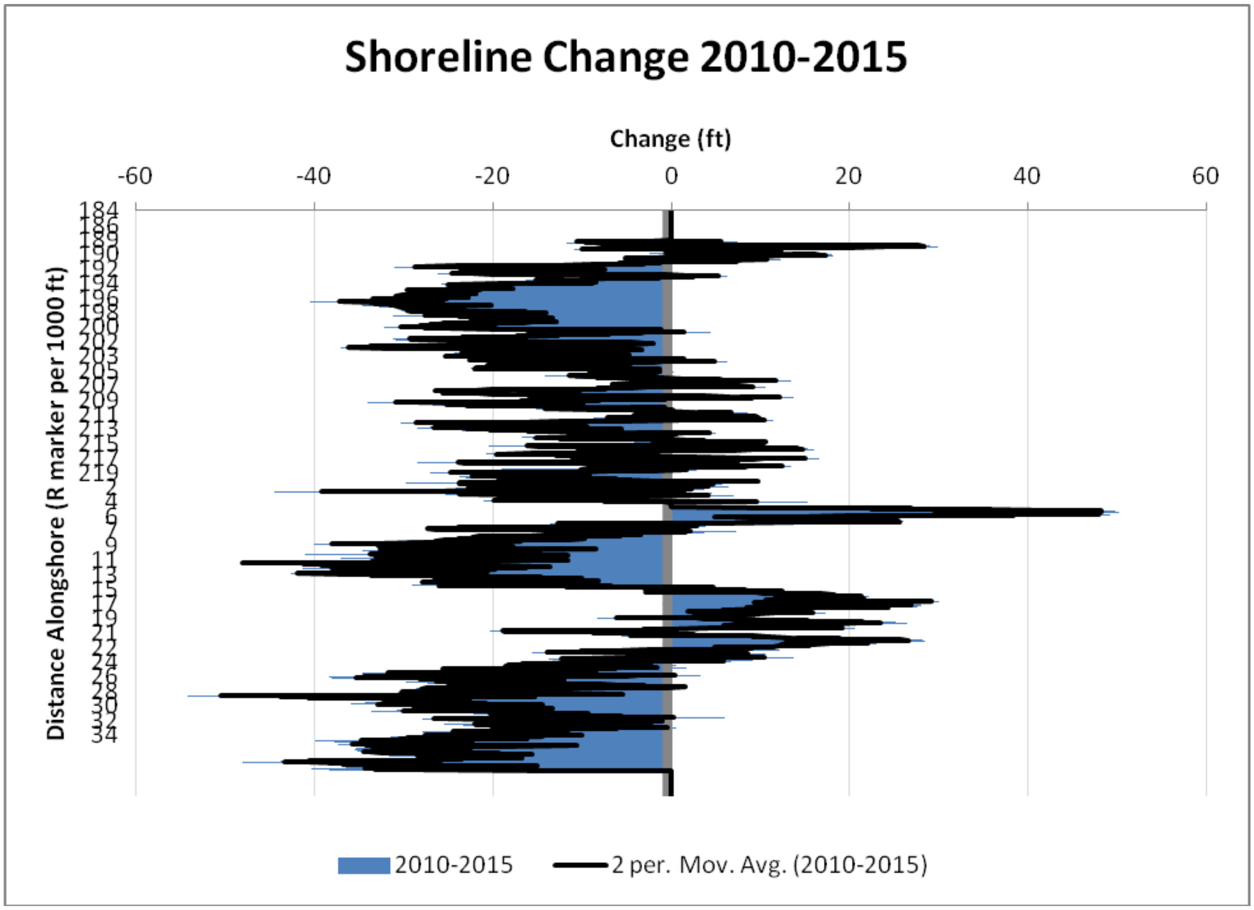


Figure 27. Change (ft) in shoreline position from 2010-2015.

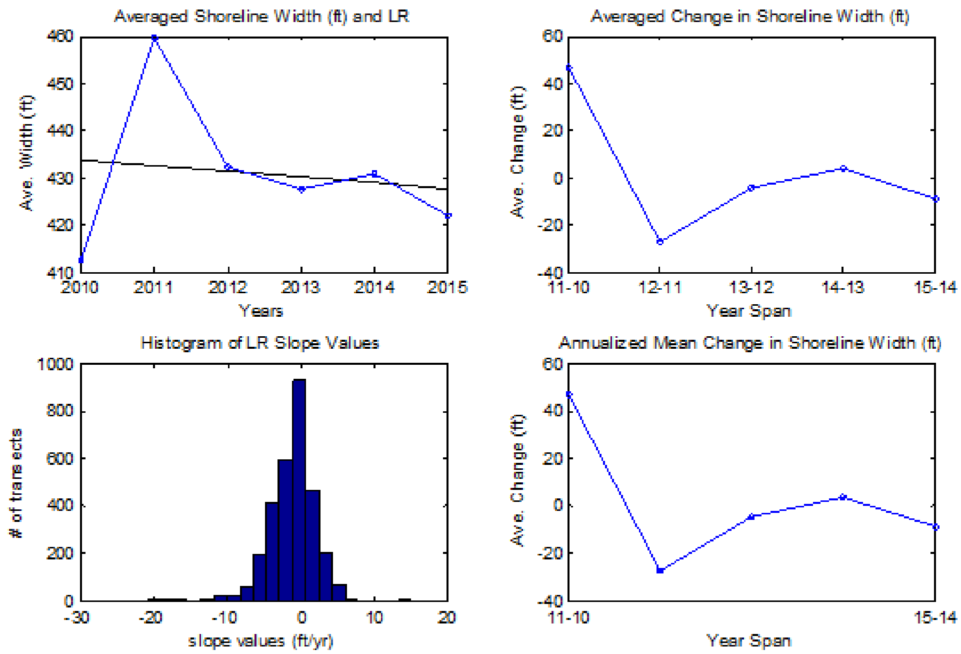


Figure 28. Summary of short-term changes for the latest update (2010-2015).

Table 11. Summary of changes for the recent period (2010-2015).

Extent	Range (ft/yr.)	Average LR (ft/yr.)	Erosion %	Accretion %
North to South	-20.77 to 15.0430	-1.0294	57.61	32.20
North	-20.77 to 4.0389	-1.2422	65.97	23.97
South	-12.89 to 15.0430	-0.8146	50.24	41.04
N3	-20.77 to 3.5921	-0.9953	56.19	26.90
N2	-6.49 to 2.4246	-1.8922	85.77	14.23
N1	-4.02 to 4.0389	-0.4212	58.12	41.88
Inlet	-12.89 to 4.0389	-2.7567	62.63	27.76
S1	-12.89 to 3.3303	-5.4228	85.00	14.17
S2	-8.43 to 7.0917	-0.7195	50.81	49.19
S3	-6.53 to 15.0430	-0.2280	45.15	40.00

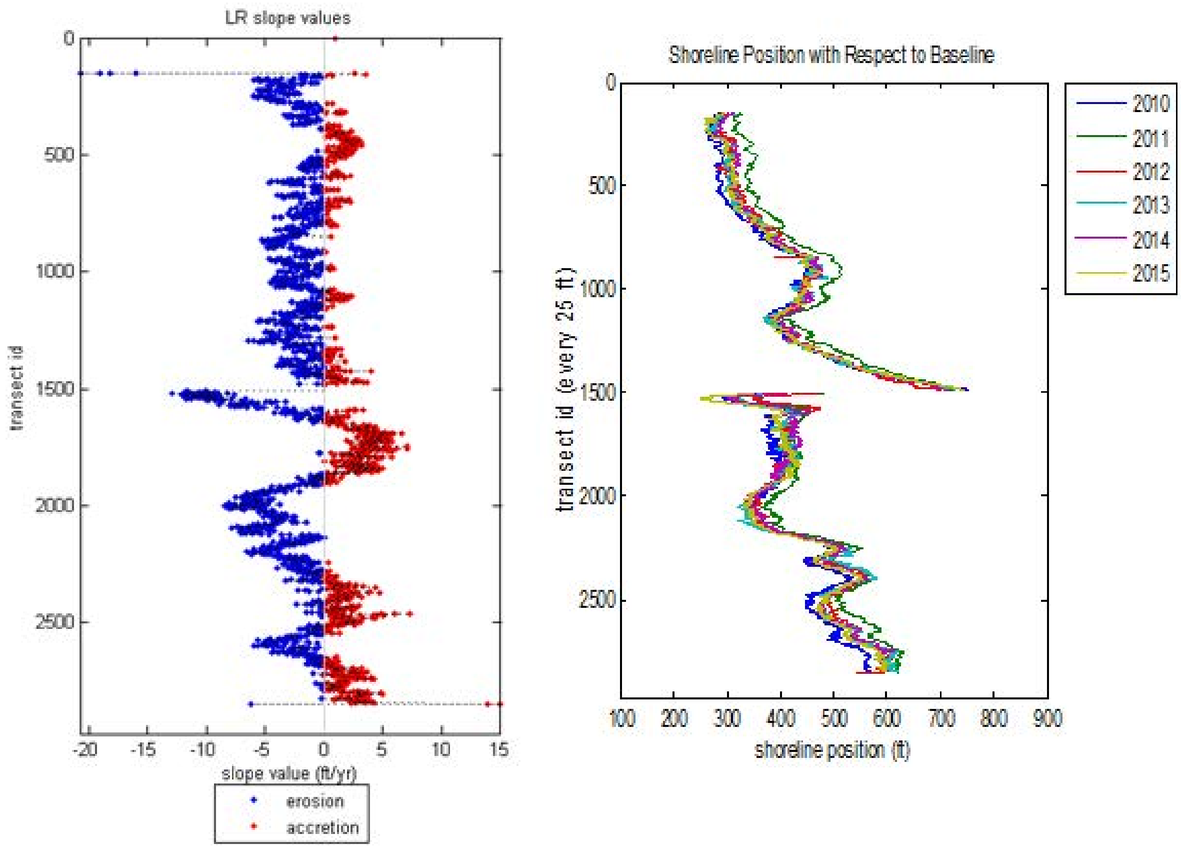


Figure 29 Percent erosion and accretion (left) and shoreline position (right) for 2007-2012.

Yearly Update (2014-2015)

Analysis of the most recent shoreline changes from 2014 to 2015 (Figure 30 and Figure 31) indicate the overall region under study has an average shoreline retreat at a rate of -8.90 ft over the previous year according to the EPR method (Table 8 last tabs LR/EPR and Figure 32), and -8.06 ft with the LR method. The erosional trend is encountered throughout almost all the entire 14 mile extent, with the exception of N1 subdomain, and noted in the more detailed analysis for each sub-cell domain (Table 12). The percentages of the areas showing erosional trend range from 60.9% at the inlet subdomain, up to 99.2% erosion in S1 (Table 12 and **Figure 32**).

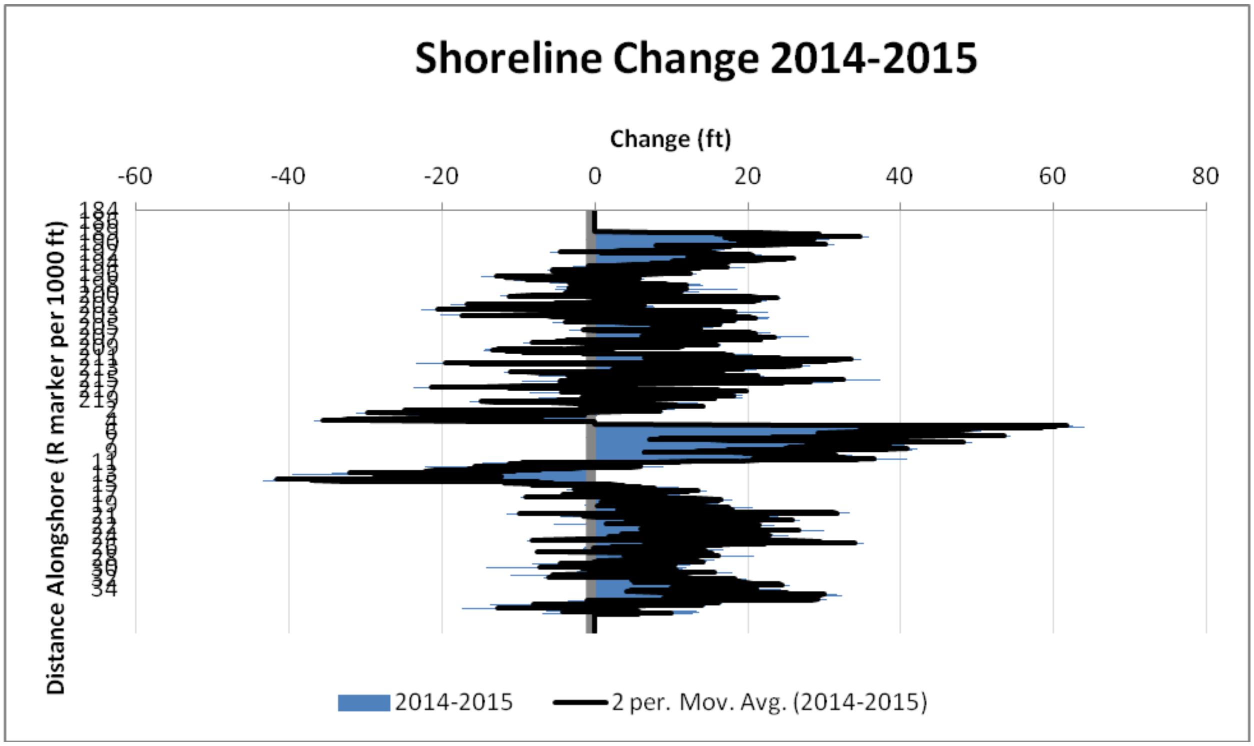


Figure 30. Change (ft) in shoreline position from 2014-2015.

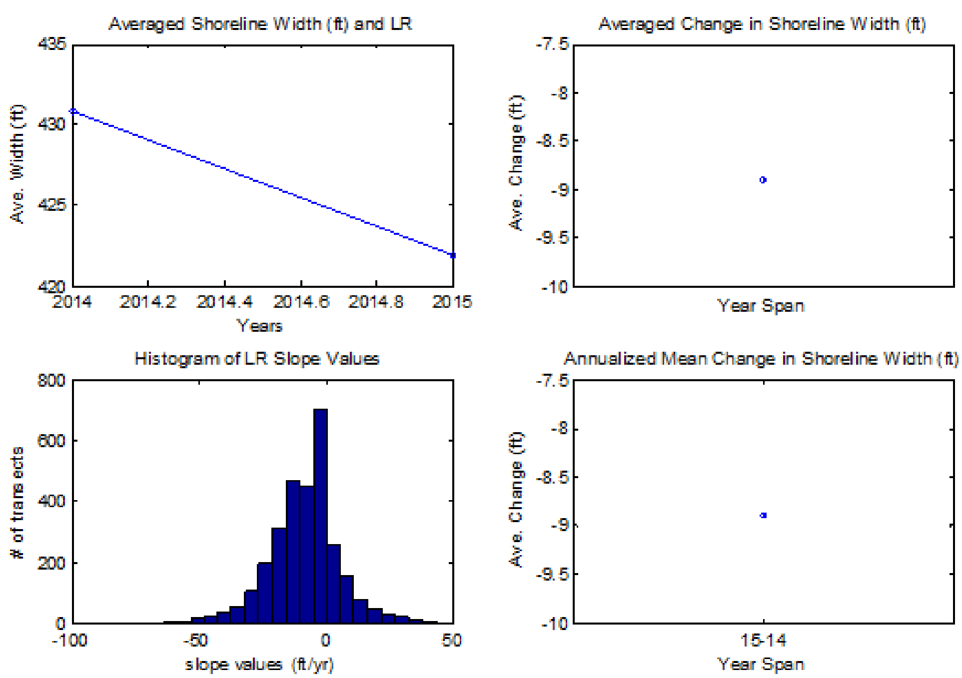
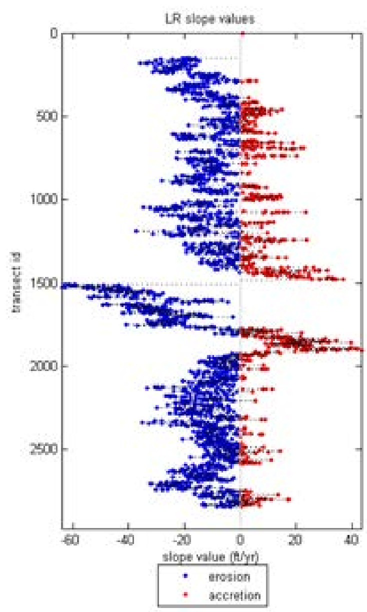


Figure 31. Average shoreline position with LR trend (top) and histogram indicating number of transects and slope value (bottom) for the entire domain (left) and for the inlet domain (right) 2014-2015.

Table 12. Summary of short-term changes for the recent period (2014-2015).

Extent*	Range (ft/yr.)	Average LR (ft/yr.)	Erosion %	Accretion %
North to South	-64.02 to 43.4100	-8.0558	68.27	21.41
North	-37.30 to 36.7800	-6.0024	64.28	25.66
South	-64.02 to 43.4100	-10.1462	73.55	17.45
N3	-35.76 to 22.6800	-7.2271	64.36	18.72
N2	-37.30 to 23.8300	-7.2891	72.58	27.42
N1	-14.41 to 36.7800	8.6128	29.06	70.94
Inlet	-64.02 to 36.7800	-16.4356	60.85	29.54
S1	-64.02 to 0.0000	-37.8054	99.17	0.00
S2	-49.28 to 43.4100	-5.8184	66.40	33.60
S3	-35.10 to 17.3600	-8.8008	74.15	10.53



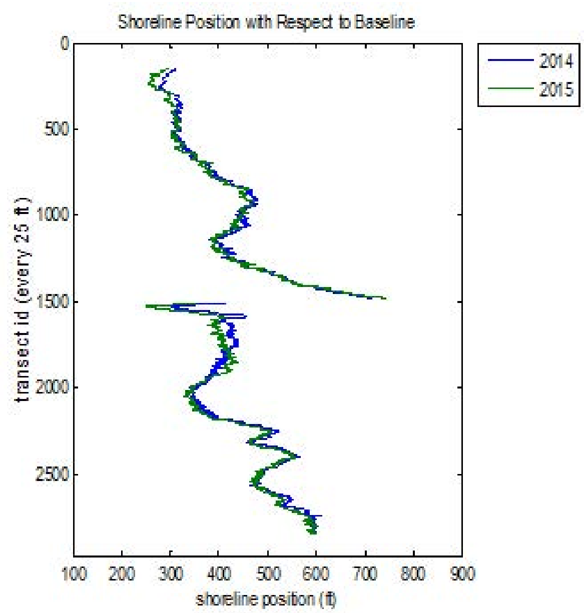


Figure 32. Percent erosion and accretion (left) and shoreline position (right) for 2014-2015.

The summary analysis is according the shoreline segments outlined in **Table 7** and repeated in Table 13 below. Table 14, Table 15, and Table 16 summarize the analysis of shoreline changes around Sebastian inlet for selected time periods between 1958 and 2015. The rates of change and the average change are summarized for each of the regional segments listed in Table 13. The north and south segments present the analysis for the beaches over a distance 7 miles to the north and to south the inlet entrance. The N3, N2m and N2 Segments are subsets of the beaches north of the inlet. The S1, S2 and S3 segments are subsets of the 7-mile beach of beach to the south of the inlet. The analysis is presented according to bot the linear regression method (LR) and the end point method (EPR).

Table 13. Summary of shoreline segments for shoreline change analysis. (Also listed in Table 3)

Domains	Transect ID	R Marker	Miles
North	0-1480	180.5-219	7.0
South	1508-2974	0-37.5	6.9
N3	0-880	160.5-203	4.2
N2	880-1364	203-216	2.3
N1	1364-1480	216-219	0.6
Inlet	1365-1645	BC216-IRC4	1.3
S1	1508-1627	0-3.5	0.6
S2	1627-212-	3.5-16	2.3
S3	2120-2974	16-37.5	4.0

Table 14. Summary of results (including mean shoreline position) from the EPR and LR methods for aerial data sources. North to South, North and South only extents

			LR		EPR			
Spatial Extent	**Temporal Range**	**Mean Shoreline (ft)**	**Change Rate of Mean Shoreline (ft/yr.)**	**Change Rate (ft/yr.)**	**Mean Change (ft)**	**Mean Annualized Change (ft/yr.)**	**Mean Overall Change (ft)**	**Mean Overall Change Rate (ft/yr.)**
North to South	1958 to 2015	428.4520	0.3094	0.3096	-0.5900	1.2567	-8.2706	-0.2668
	2004 to 2015	436.2877	-0.6872	-1.3714	-0.8060	-1.6504	-7.7320	-0.7732
	2010 to 2015	430.7232	-1.0294	-1.1097	1.9669	1.9669	9.8317	1.9663
	2014 to 2015	426.3770	-8.0558	NaN	-8.9012	-8.9012	-8.9012	-8.9012
North	1958 to 2015	457.0476	0.5804	0.5811	1.0677	0.8664	8.7686	0.2829
	2004 to 2015	408.1879	-0.9879	-1.7735	-1.2449	-1.8403	-12.6776	-1.2678
	2010 to 2015	403.5756	-1.2422	-1.3296	2.0109	2.0109	10.1054	2.0211
	2014 to 2015	399.9855	-6.0024	NaN	-6.6738	-6.6738	-6.6738	-6.6738
INLET	1958 to 2015	469.9303	1.8907	1.8907	1.0857	2.0262	29.9708	0.9668
	2004 to 2015	499.3963	-1.7279	-1.7279	-0.3777	-2.1231	-3.7768	-0.3777
	2010 to 2015	492.4359	-2.7567	-2.7567	-0.3969	-0.3969	-1.9847	-0.3969
	2014 to 2015	484.5253	-16.4356	NaN	-16.4356	-16.4356	-16.4356	-16.4356
South	1958 to 2015	423.0191	0.0352	-0.1175	-1.1389	0.8874	-36.9781	-1.1928
	2004 to 2015	463.9611	-0.3800	-0.9703	-0.3716	-1.4669	-2.7776	-0.2778
	2010 to 2015	457.4650	-0.8146	-0.8925	1.9197	1.9197	9.5656	1.9131
	2014 to 2015	452.4815	-10.1462	NaN	-11.1494	-11.1494	-11.1494	-11.1494

Table 15. Summary of results (including mean shoreline position) from the EPR and LR methods for aerial data sources. Sub-cells north extents.

			LR		EPR			
Spatial Extent	**Temporal Range**	**Mean Shoreline (ft)**	**Change Rate of Mean Shoreline (ft/yr)**	**Change Rate (ft/yr)**	**Mean Change (ft)**	**Mean Annualized Change (ft/yr)**	**Mean Overall Change (ft)**	**Mean Overall Change Rate (ft/yr)**
N3	1958 to 2015	351.3874	0.4268	0.4278	-2.0589	-1.5239	-9.0196	-0.2910
	2004 to 2015	346.3003	-0.1133	-1.3650	-0.9469	-1.8063	-8.8268	-0.8827
	2010 to 2015	341.1419	-0.9953	-1.1028	2.5221	2.5221	12.6794	2.5359
	2014 to 2015	337.3350	-7.2271	NaN	-8.6982	-8.6982	-8.6982	-8.6982
N2	1958 to 2015	448.6452	0.7473	0.7473	0.3748	0.6036	27.2980	0.8806
	2004 to 2015	452.3978	-2.0454	-2.0454	-1.8109	-1.9974	-18.1086	-1.8109
	2010 to 2015	447.0535	-1.8922	-1.8922	1.3337	1.3337	6.6687	1.3337
	2014 to 2015	443.1833	-7.2891	NaN	-7.2891	-7.2891	-7.2891	-7.2891
N1	1958 to 2015	617.4661	1.0420	1.0420	1.5150	1.5829	43.2738	1.3959
	2004 to 2015	622.9944	-3.2062	-3.2062	-1.4220	-1.7452	-14.2201	-1.4220
	2010 to 2015	613.6783	-0.4212	-0.4212	1.6580	1.6580	8.2901	1.6580
	2014 to 2015	614.5338	8.6128	NaN	8.6128	8.6128	8.6128	8.6128

Table 16. Summary of results (including mean shoreline position) from the EPR and LR methods for aerial data sources. Sub-cells south extents.

			LR		EPR			
Spatial Extent	**Temporal Range**	**Mean Shoreline (ft)**	**Change Rate of Mean Shoreline (ft/yr)**	**Change Rate (ft/yr)**	**Mean Change (ft)**	**Mean Annualized Change (ft/yr)**	**Mean Overall Change (ft)**	**Mean Overall Change Rate (ft/yr)**
S1	1958 to 2015	342.5017	2.6397	2.6619	0.6822	2.1723	21.1493	0.6822
	2004 to 2015	389.4814	-0.5920	-0.5969	0.3167	-2.5749	3.1675	0.3167
	2010 to 2015	383.9426	-5.4228	-5.4684	-2.6684	-2.6684	-13.3420	-2.6684
	2014 to 2015	366.6508	-37.8054	NaN	-38.1231	-38.1231	-38.1231	-38.1231
S2	1958 to 2015	374.5251	0.7605	0.7605	-1.8081	-0.0313	-44.1026	-1.4227
	2004 to 2015	401.3569	-2.8211	-2.8211	-1.6316	-2.4551	-16.3165	-1.6316
	2010 to 2015	392.2176	-0.7195	-0.7195	1.5259	1.5259	7.6293	1.5259
	2014 to 2015	390.9824	-5.8184	NaN	-5.8184	-5.8184	-5.8184	-5.8184
S3	1958 to 2015	511.1083	-0.7458	-0.7458	-2.6749	1.4964	-55.5562	-1.7921
	2004 to 2015	516.8624	1.0553	0.2092	0.4006	-0.6055	5.4839	0.5484
	2010 to 2015	513.6926	-0.2280	-0.2678	2.9269	2.9269	14.6107	2.9221
	2014 to 2015	508.3572	-8.8008	NaN	-10.3932	-10.3932	-10.3932	-10.3932

7.0 Survey Based Shoreline Changes

7.1 Methods

Analysis of the shoreline position derived from hydrographic surveys was based on digitizing the zero-contour to represent the shoreline. The zero-contour is based on the NAVD88 vertical datum used during the ground surveys. The advantage for using surveys to determine the shoreline position was the improved temporal resolution since hydrographic surveys are typically performed on a seasonal basis at Sebastian Inlet. However, there is a trade-off for spatial resolution because transects were typically spaced 500 ft to 1,000 ft apart. As described in the methods section on analyzing the evolution of inlet reservoirs, generating a survey-based shoreline began with generating contour plots using the ImageAnalyst© extension in Arcview3.2©. Once the XYZ data files from hydrographic surveys were contoured, the extension was also used to highlight the zero-contour so that this one interval could be digitized to represent the position of the shoreline. Once highlighted, the zero-contour was extracted by hand-tracing the contour using shoreline-generating tool in BeachTools© (Hoeke et al. 2001). To determine the change in shoreline position, a common baseline with a NAD27 projection running along the SRA1A was created manually using BeachTools©. This extension was also used to generate perpendicular transects from this baseline to the digitized shoreline every 100 ft, which roughly corresponded to the interval used in the ground surveys. A total of about 600 transects were generated including 300 transects north and 300 transects south of the inlet. For detailed methodology on the shoreline change calculations, the reader is referred to previous reports (Zarillo et al., 2007, 2009, 2010).

7.2 Shoreline changes 2014 to 2015.

The survey bases shoreline changes shown in Figure 33 show shoreline accretion south of Sebastian inlet within the sand budget cell S1. This is constant with sand volume changes shown in Figure 13 for the S1 cell. Further, inspection of sand volume changes across the N1, N2, and Inlet sand budget cells shown in Figure 10, Figure 11, and Figure 12 respectively shows that sand has moved in a net southward direction to nourish the S1 cell over this time period. The S1 sand budget cell, which extends from R-Marker 4 to R-Marker 15 also benefited from approximately 111,000 cubic yards of from the sand trap, which was placed on the beach between R-3 to R7 in the winter of 2014.

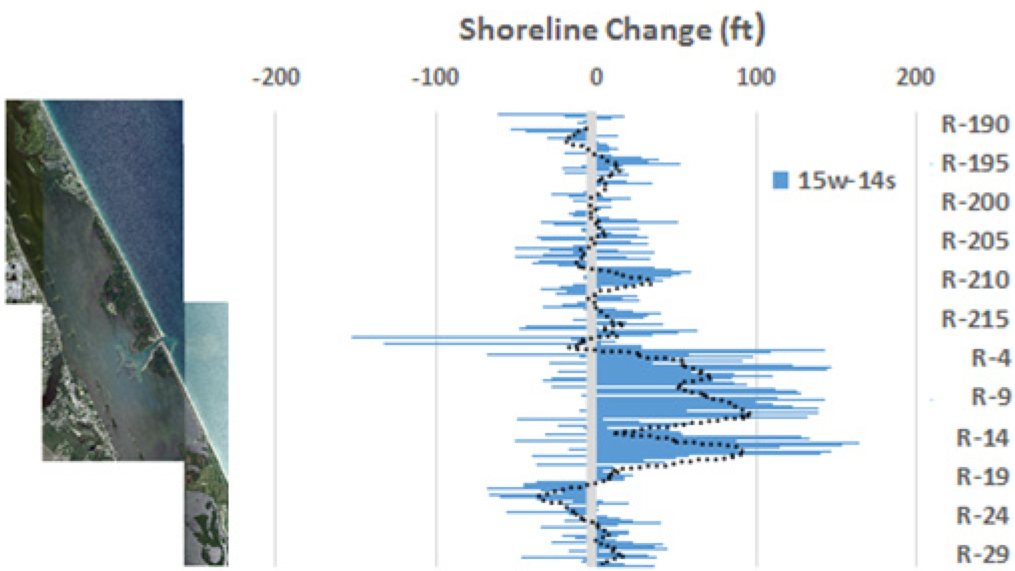


Figure 33. Survey-based Shoreline changes from summer 2014 to winter 2015.

Shoreline changes between the winter and summer surveys of 2015 shown in Figure 34 reflect net transport of sand though the S1 cell into the S2 cell (R15-R30) where the shoreline position was stable or showed moderate accretion. This is consistent with sand volume gains in the S2 cell shown in Figure 14 and sand volume decreases the S1 cell shown in Figure 13 in the 2015 winter to summer period.

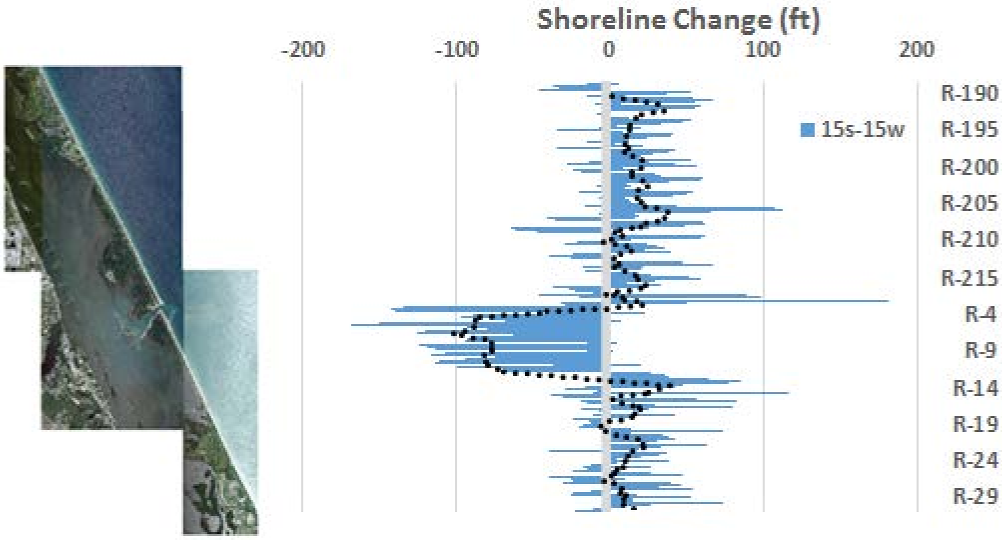


Figure 34. Survey-based Shoreline changes from winter 2015 to summer 2015.

Figure 35 and Figure 36 show measured shoreline changes over the most recent winter to winter and summer to summer 12-month periods. The winter winter2014 to winter 23015 shoreline changes are similar in pattern and magnitude to the summer 2014 to winter 2015 changes shown in Figure 33. The benefits of sand by passing from the Sebastian Inlet sand trap are apparent in this time period. The 6 month period following as shown in Figure 35 shows that this fill of 110,000 yards of sand original placed in the R3 to R7 area is moving to the south into sand budget cell S2. This cell to cell movement is also apparent in Figure 35, which shows shoreline changes over the 12-month period from summer 2014 to summer 2015. The fill placement form the san d trap is in the process is moving to the south into sand budget cell S2 where it increased the width of the beach.

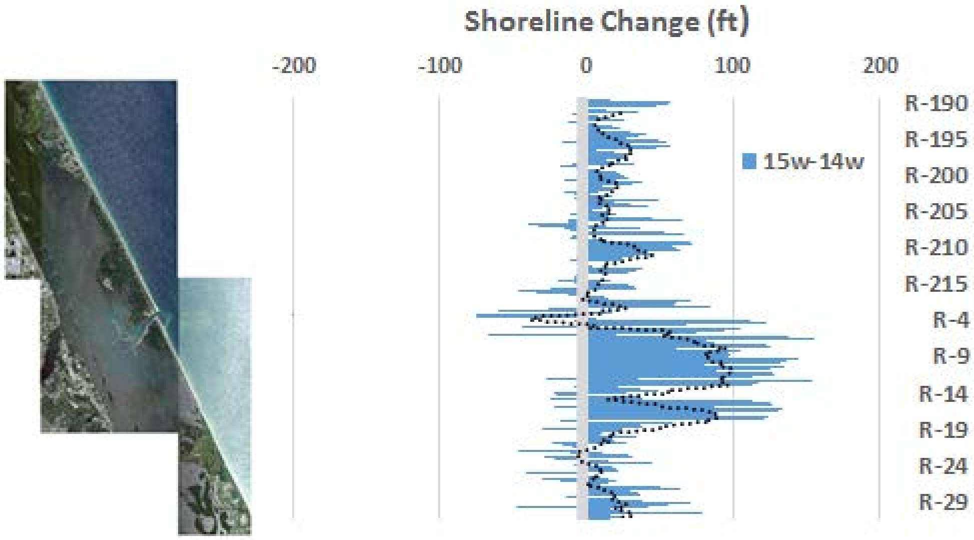


Figure 35. Survey-based Shoreline changes from winter 2014 to winter 2015.

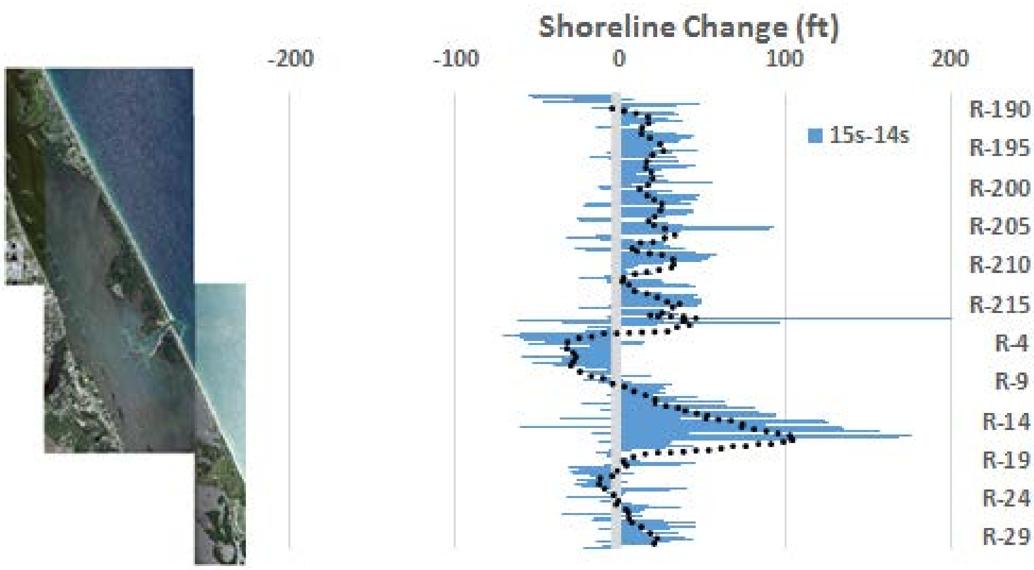


Figure 36. Survey-based Shoreline changes from summer 2014 to summer 2015.

8.0 Hydrodynamic and Morphodynamic Numerical Modeling

8.1 Model Set Up

The model set up consists of three distinct components; a regional wave grid, a local wave grid and a local flow grid. The regional wave grid is used to bring waves in from offshore using data from NOAA's Wave Watch III as a model input. Modeled wave data is then extracted from the regional grid and used as a model input for the local wave grid. Water level data is developed to include the seasonal high and low stand of sea level which fluctuates by approximately a meter several times a year.

The regional wave model grid uses a traditional Cartesian grid configuration with uniform refinement throughout the grid. The grid consists of 71,640 computational cells with an alongshore distance of 18 km with a cross shore span of 40 km extending to water depths of 40 meters. This distance corresponds with the Wave Watch 3 node.

Previous work (Zarillo, et al, 2015; 2014) has shown that a constant nearshore refinement is most effective for simulating cross shore and alongshore processes. Two flow model grids were developing using a telescoping quadtree approach for the winter and spring runs. The most recent available bottom topography was used to develop the final merged bathymetry dataset. Additional bottom topography refinement was added around Coconut Point with the additional beach profiles that were performed during the prior year survey efforts. Figure 37 shows the flow grid configuration with constant alongshore refinement. The grid spans approximately 17.8 km alongshore spanning from R-189 in Brevard County to R-30 in Indian River County. The grid encompasses the Indian River Lagoon, the Sebastian Inlet and extends offshore to a water depth of 17 m which is approximately 6 km offshore. The domain cross shore dimension is approximately 10.5 km. The flow grid contains 289,512 computational cells ranging from 5 m by 5 m closest to the inlet to a maximum of 160 m by 160 m in the offshore areas. This telescoping quadtree approach optimizes computational time while increasing the ability for high levels of resolution in the nearshore and inlet areas. Additional refinement was added to the nearshore areas to increase computational capabilities for longshore sediment transport computations that are the primary focus of this work.

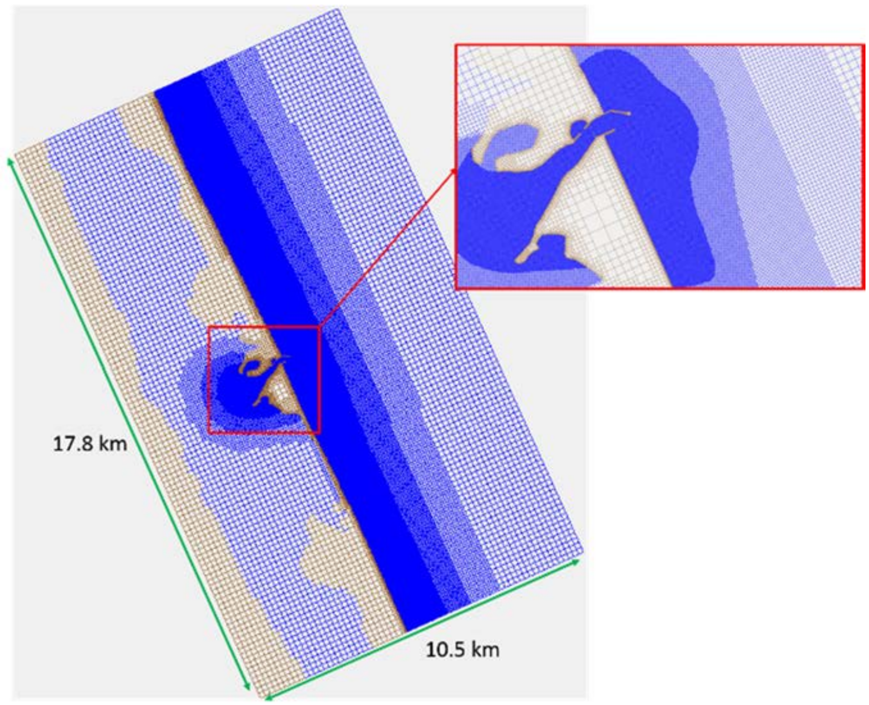


Figure 37. Flow Grid Domain and Refinement

Model temporal set up was determined by the bottom topography survey dates and the desired seasons. The model run times are summarized in the following table.

Table 17. Model Temporal Set Up

Model	Start	End	Months
Winter 2014 – 2015	6/1/2014	1/31/2015	8
Spring 2015	1/1/2015	7/31/2015	7

Longshore Sediment Transport Rate Methodology

Sediment transport is a function of a variety of coastal processes including waves, currents and water elevation. This section will examine each of these processes and their impact on sediment transport at Sebastian Inlet. Longshore sediment transport can be described as the sediment that "…moves along a coastline under the action of waves and the longshore currents" (Dean, 2002). Sediment moves in a variety of mechanisms including bed load, suspended load and swash load. Bed load is the sediment that moves along the bottom either in sheet flow or rolling along the bottom. Suspended load is sediment that is moving within the water column and moved by currents. Swash load refers to the material moved onto the beach face in the swash zone (Dean, 2002).

Presently, there is no gauge or sensor that directly measure longshore sediment transport. Traditionally, indirect measurements techniques such as impoundment of sand at a jetty or dredging records are used to estimate longshore sediment transport but can be problematic and not resolve seasonal or annual variability which can cause errors in estimation. More direct field measurements such as streamer traps are labor intensive and used for relatively short deployments. Optical Backscatter Sensors or other acoustic based instruments "…are capable of providing measurements with high spatial and temporal resolution, they have not been broadly used for many reasons; among them, high cost, lack of reliable field calibration, and omission of the bedload remain the major obstacle" (Wang, 1998).

The Coastal Modeling System includes a combined bed load and suspended approach to predict sediment transport referred to as the non-equilibrium total load (NET). The NET model for sediment transport uses a non-equilibrium approach to the suspended load and assumes a local equilibrium for the bed load. Figure 38 conceptually depicts the sediment and current vertical profiles represented in the CMS model.

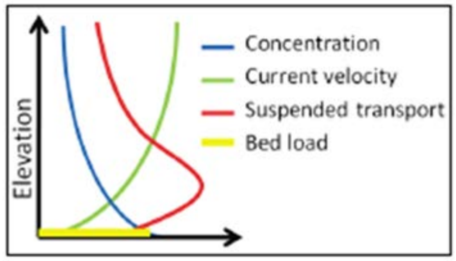


Figure 38. Schematic of sediment and current vertical profiles (Sanchez, 2014).

In order to understand the backpassing and bypassing processes that occur at Sebastian Inlet, the longshore sediment transport rate was computed using a procedure outlined in (Sanchez, 2012) and a brief description of the theory is included in following sections. A series of arcs were constructed within an observation coverage within SMS oriented perpendicular to the shoreline and extending past the breaker line of approximately 12 meters. Observation coverages are used to extract computed data from the model solution files. These cross shore arcs were established using the existing field beach profiles that are collected from the field annually as a guide. A total of 60 arcs were constructed to calculate longshore sediment transport rates and are shown in Figure 39 displayed with the bottom topography contours.

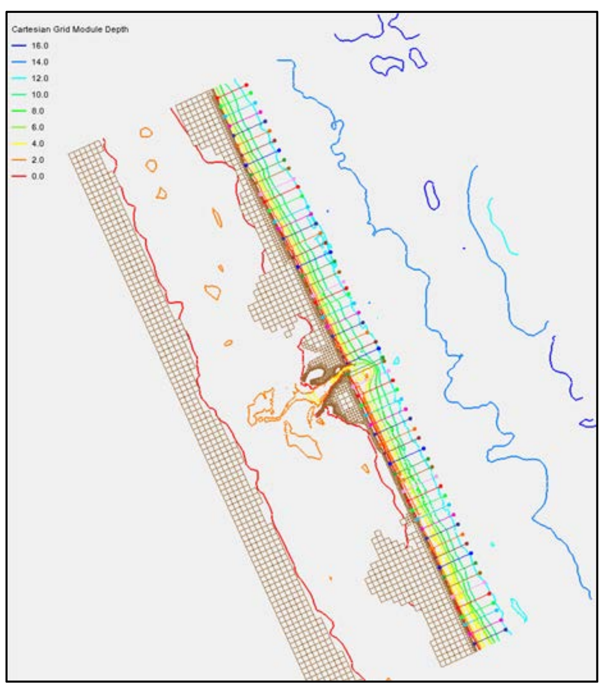


Figure 39. Longshore Sediment Transport Arcs

The sediment flux is computed across these observational arcs using the model output for net total load sediment transport. Each arc directional convention is towards the south for positive sediment transport and negative to the north.

8.2 Model Results

The model results are focused on the longshore sediment transport rate calculations and morphology change predictions. The results will be presented first looking at spatial variability followed by temporal variability. This approach is to reflect the dependence of sediment transport on coastal processes that change both spatially and temporally.

Longshore Sediment Transport Rate Calculations

Net longshore sediment transport rates were computed over both seasonal runs and on a monthly basis to examine the relationship between the alongshore sediment transport rates and hydrodynamic processes. Longshore sediment transport rates were calculated using the procedure outlined in Sanchez, 2012. The model domain was separated into three sections; North Extent, Inlet Extent and South Extent. The regions are depicted in Figure 40.

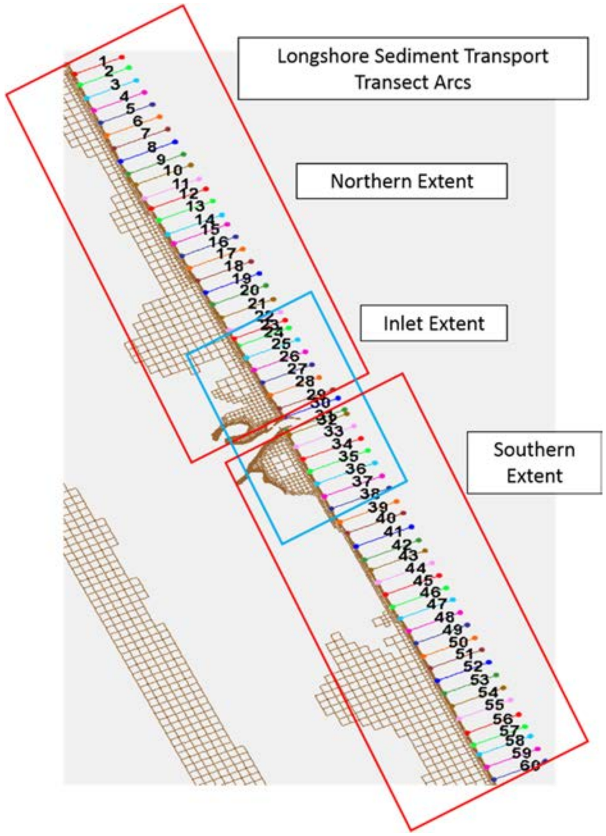


Figure 40. Longshore Sediment Transport Extents

Wave height and direction were extracted from the model solution in each of the extents to examine the relationship between sediment transport and wave magnitude and direction. For clarity, the Winter Run longshore sediment transport rates will be presented first over the entire run to establish general trends and then followed by selected monthly analysis. The Spring Run will follow in the same format.

Winter 2014 Model Run: June 2014 – January 2015

Figure 41 shows the net longshore sediment transport volume calculated over the winter 2014 run for the northern extent of the model domain. These numbers are total volumes computed over the entire 8 month run and are shown in cubic meters. The red arrow southward denotes the convention for positive net sediment transport. The wave rose indicates the waves approach the shoreline roughly shore normal but a certain amount of energy is directed southward. Arc 21 indicates a net transport rate northwards while the remaining arcs indicate sediment transport towards the south. This may indicate a nodal point in the shoreline and is also supported by a lower volume immediately southward. A northward movement of sand at this location is also reflected throughout the individual months consistently. Volumes range from 7,500 cubic meters at Arc 23 and a maximum of 19,000 cubic meters at Arc 7 which is located in the northern most portion of the domain.

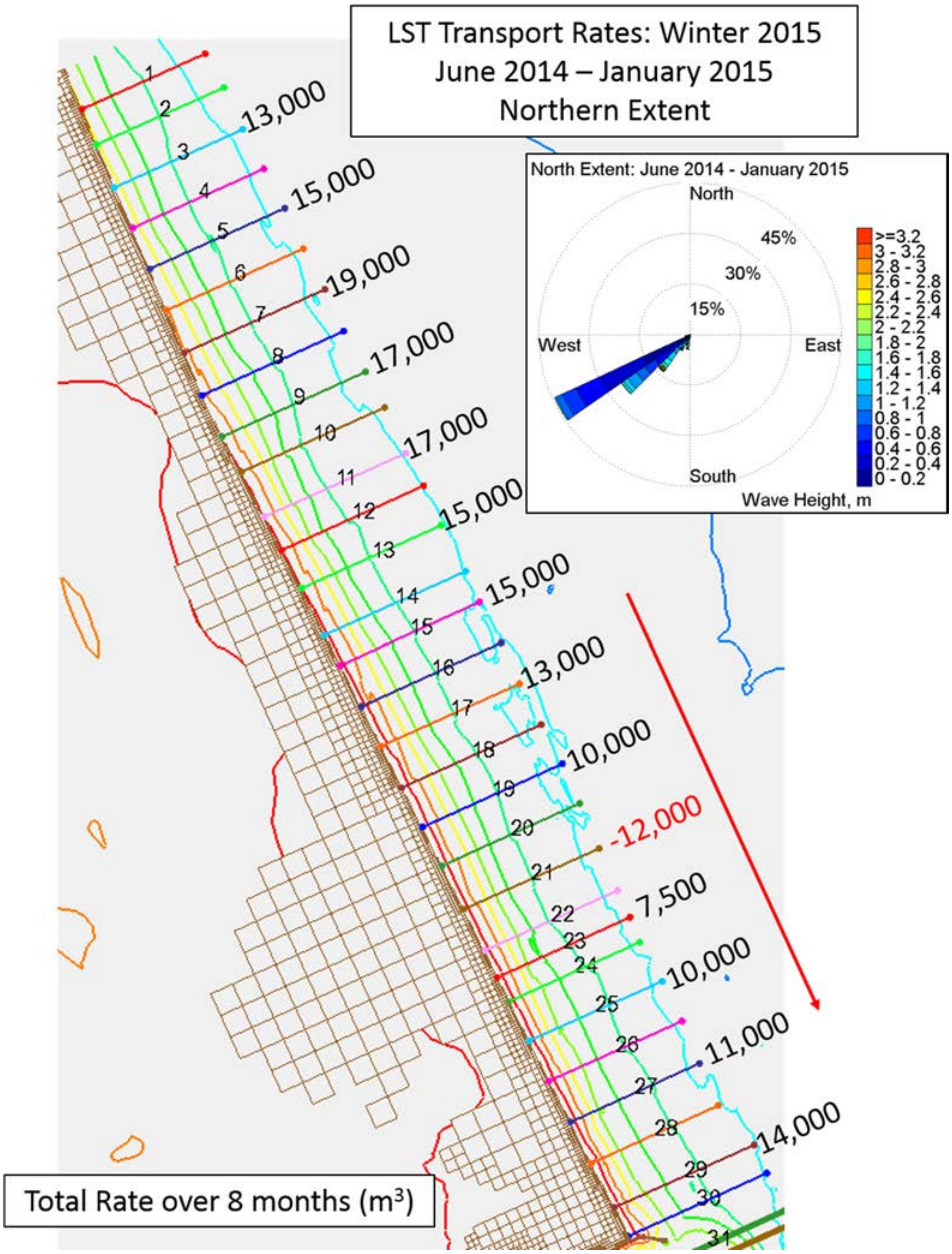


Figure 41. Calculated Longshore Sediment Transport Rates: Winter 2014 Model Run North Extent.

Figure 42 depicts the net longshore sediment transport volumes calculated during the winter 2014 model run for the inlet extent only. The wave rose is similar to the wave rose in the Northern Extent (Figure 41) but more energy is directed more southward. The rates range from 5,000 cubic meters immediately south of the south jetty to 37,500 cubic meters over the downdrift attachment areas and ebb shield. The low volume directly south of the south jetty is in line with the recirculatory gyre which is observed in the current plots and animations. This down drift erosional behavior is common to inlets. Larger volumes immediately south of the inlet at arcs 32 through 34 indicate material accreting on the ebb shield and downdrift attachment bar. Volumes return to more averages values observed in the northern extent (Figure 41).

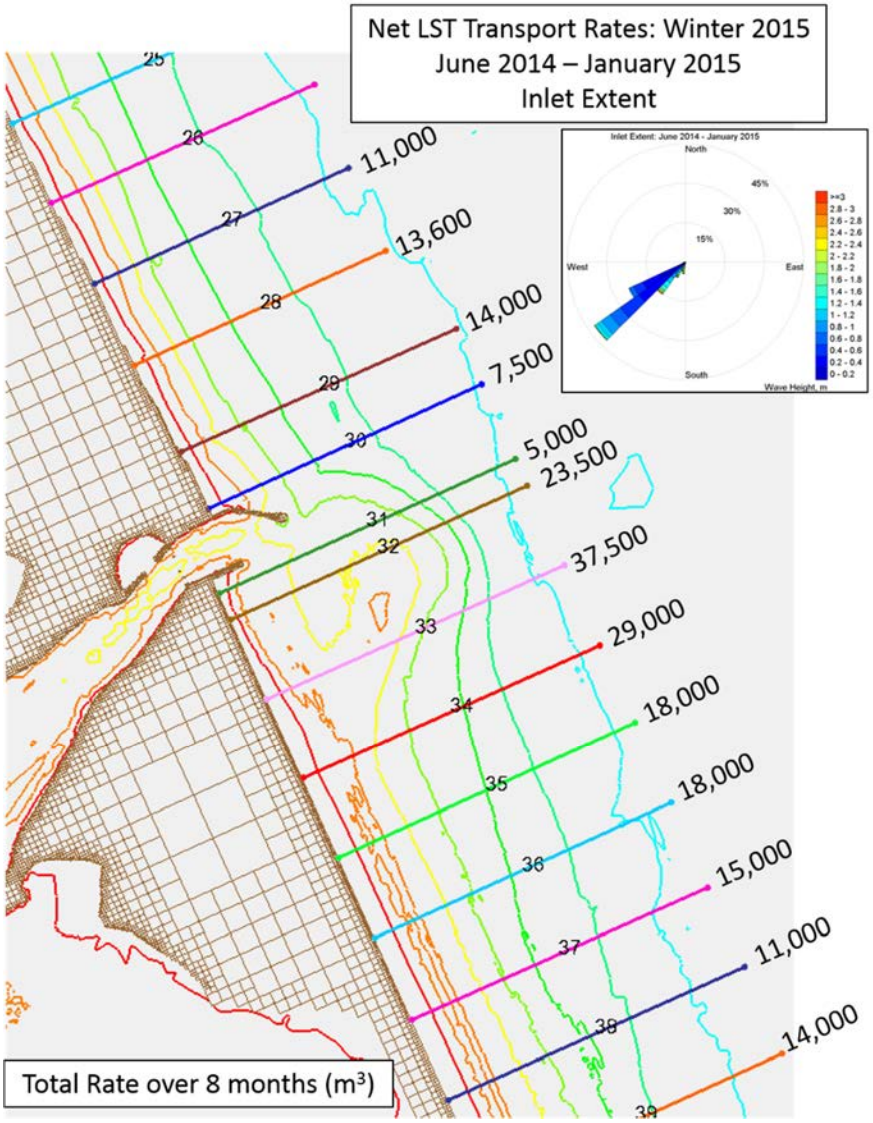


Figure 42. Calculated Longshore Sediment Transport Rates: Winter 2015 Model Run Inlet Extent.

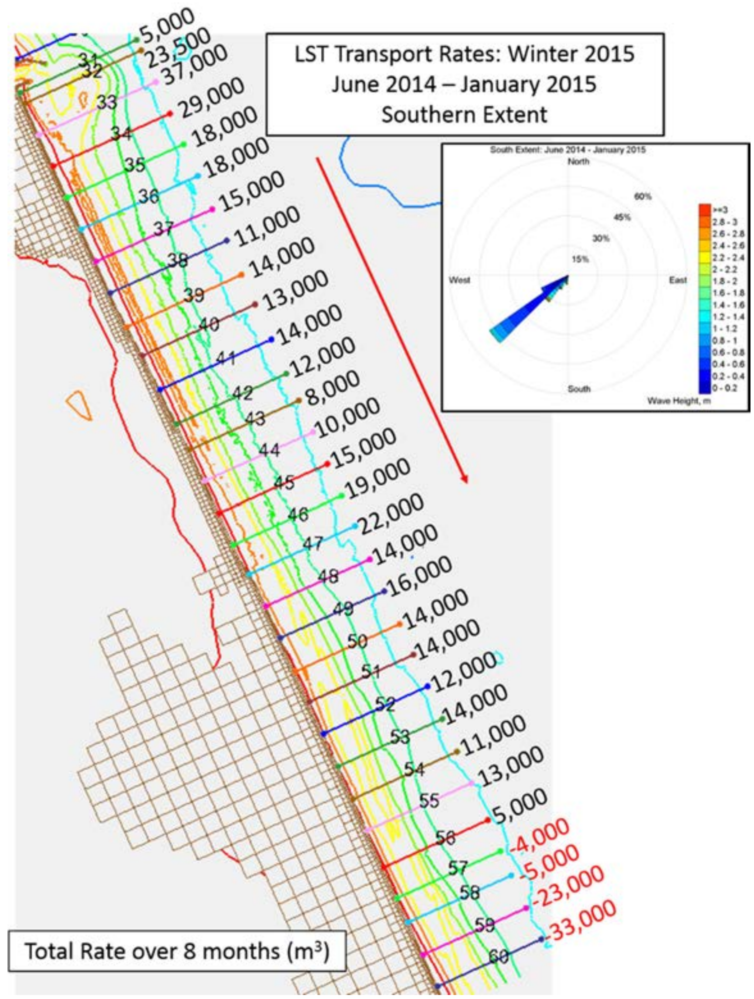


Figure 43. Calculated Longshore Sediment Transport Rates: Winter 2015 Model Run Southern Extent.

Figure 43 shows the computed longshore sediment transport volumes for the southern portion of the model domain extending from the south side of the inlet southward. The computed longshore sediment transport rates range from 5,000 cubic meters immediately southward of the south jetty and a maximum of 37,000 cubic meters across the downdrift attachment bar and ebb shield. Arcs 31 through 39 are also shown in the Inlet Extent (Figure 42). The longshore sediment transport decreases rapidly moving southward from the inlet and volumes match the Arcs shown in the Northern Extent (Figure 41). This analysis will be expanded into monthly rates. For brevity, July 2014 and December 2014 will be presented.

Monthly Longshore Sediment Transport: Winter 2014 Model Run

Calculated monthly sediment transport rates will be presented in the following section which will link the calculated longshore transport to the nearshore processes. For brevity, July 2014 will be used to illustrate movement of sand during quiescent periods and December 2014 will be used to examine the movement of sand during energetic periods.

The computed longshore sediment transport volumes for July 2014 are presented in Figure 44 with an accompanying wave rose inset. The wave rose indicates the direction towards which waves are traveling and show a near shore normal approach. A portion of the energy is directed slightly southward which drives the net sediment transport southward. Arc 21 is maintaining a northern movement of sediment which is consistent with the comprehensive model results over the 8 month run.

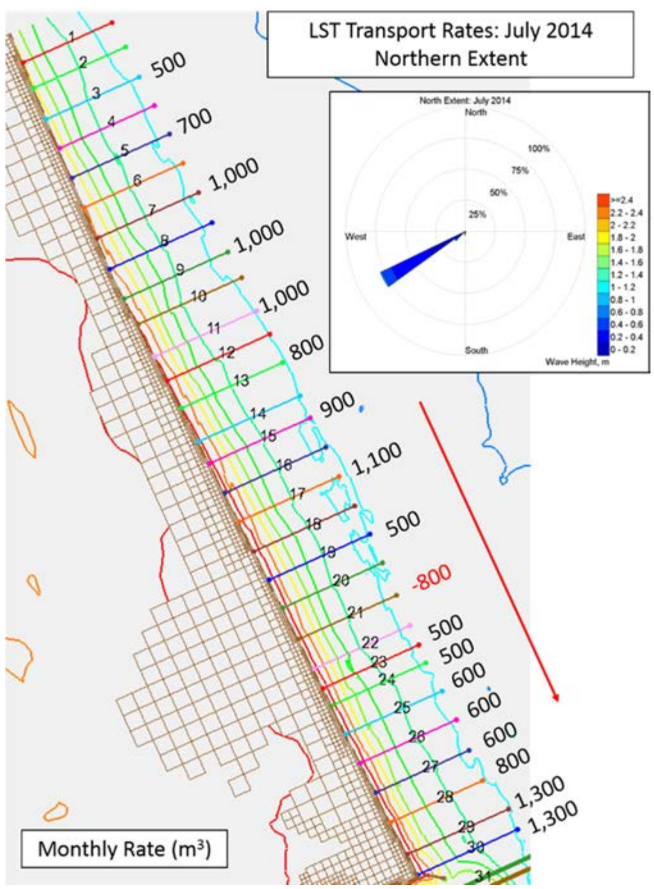


Figure 44. Calculated Longshore Sediment Transport Rates: July 2014 Model Run Northern Extent.

The calculated wave height and period time series is shown in Figure 45 for the July 2014 portion of the model run. Nearshore wave height, period and direction were extracted at a midpoint slightly offshore from the observational arcs.

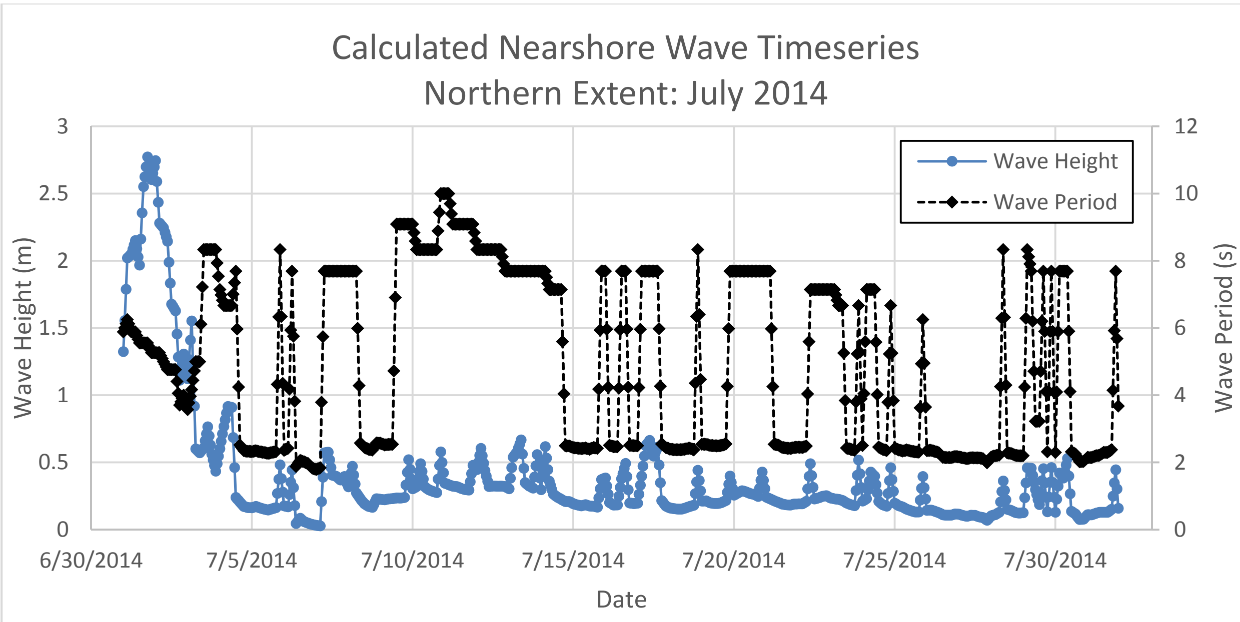


Figure 45. Calculated Nearshore Wave Time series: July 2014 Northern Extent.

The calculated wave heights in July are smaller waves with an average of significant wave height of 0.4 m and an average period of approximately 5 seconds. The maximum wave during this time period was calculated at 2.7 m at the beginning of the month. Average wave direction is directed onshore at 231 degrees. Figure 45 shows the calculated longshore sediment transport rates centered around the inlet during July 2014. The rates show an increase southward immediately north of the inlet and continue south past the ebb shield and downdrift attachment bar. The wave rose inset shows a slightly wider directional band of waves as compared to the northern region but still largely shore perpendicular.

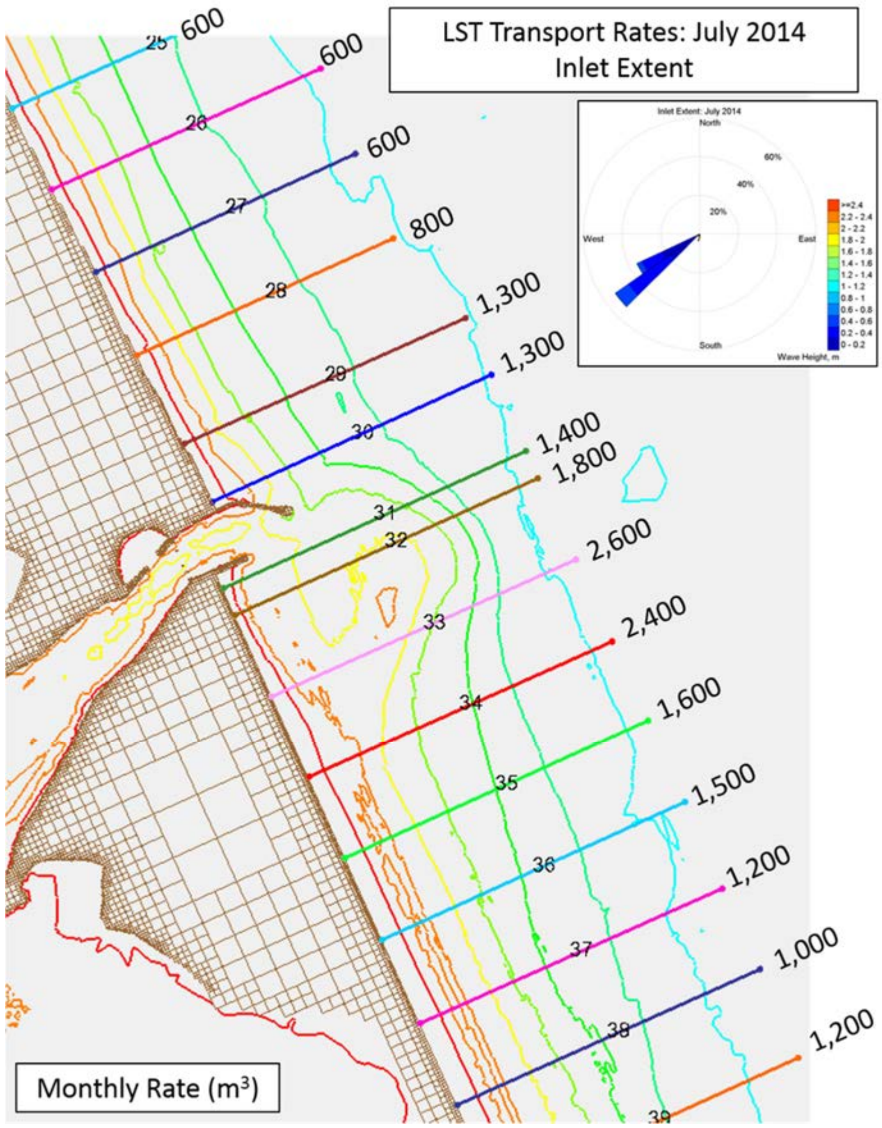


Figure 46. Calculated Longshore Sediment Transport Rates: July 2014 Model Run Inlet Extent.

Figure 47 shows the calculated nearshore wave time series for the inlet extent during the July 2014 portion of the model run. The average calculated significant wave height was 0.4 m with a period of 5 seconds and matches the waves in the northern portion of the domain. Average wave direction is directed onshore at 229 degrees.

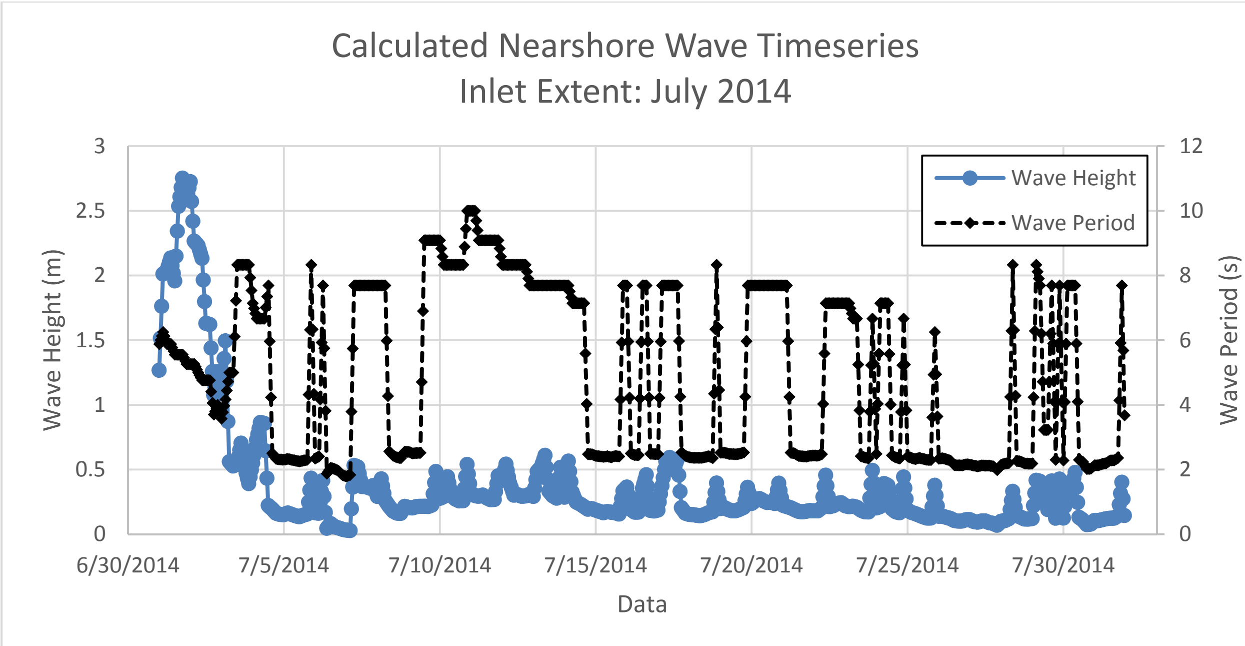


Figure 47. Calculated Nearshore Wave Time series: July 2014 Inlet Extent.

Figure 48 depicts the calculated longshore sediment transport rates for July 2014 across the southern portion of the model domain. The volumes range from 3,200 cubic meters over the month to 800 cubic meters. The volumes decrease dramatically in the southernmost portion of the domain. The wave rose inset indicates the direction towards which the waves are traveling showing a primarily shore normal wave approach.

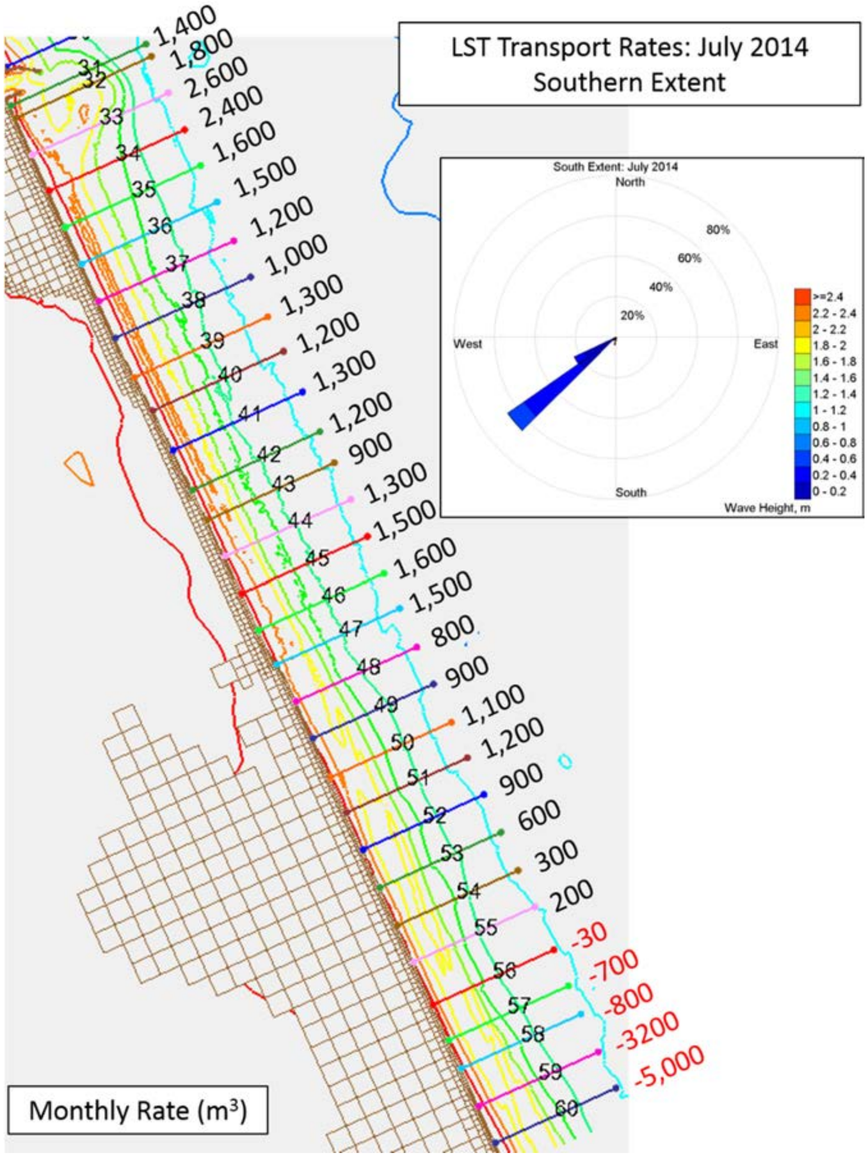


Figure 48. Calculated Longshore Sediment Transport Rates: July 2014 Model Run Southern Extent.

Figure 49 shows the calculated nearshore time series for the southern extent of the model domain which closely matches the waves in the other portions of the model domain with an average wave height of 0.4 m, average period of 5 seconds and an onshore average wave direction of 228 degrees.

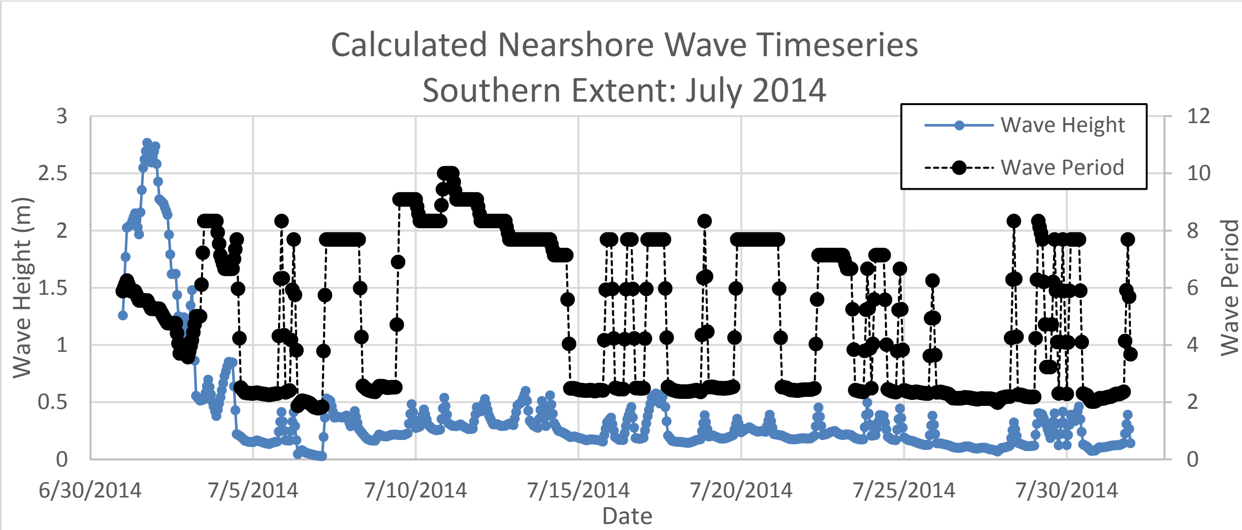


Figure 49. Calculated Nearshore Wave Time series: July 2014 Southern Extent.

The previous set of figures and plots demonstrates the behavior of sediment transport along the domain during a quiescent period of the model run (July 2014). The following figures and plots will demonstrate the behavior of sediment transport during a more energetic time period (December 2014).

Figure 50 shows the calculated sediment transport volumes during the December 2014 portion of the model run for the northern portion of the model domain. Positive values are indicating a net southern direction movement of sediment while the negative numbers (red) are indicating a net northern movement of sediment movement computed during December 2014. The absolute values of sediment volume ranges from 2,200 cubic meters to 40 cubic meters. The largest volume is adjacent to the north jetty and is directed northward. The sediment movement in the northern portion of the domain away from the inlet is directed southward and are similar in volume to the July 2014.

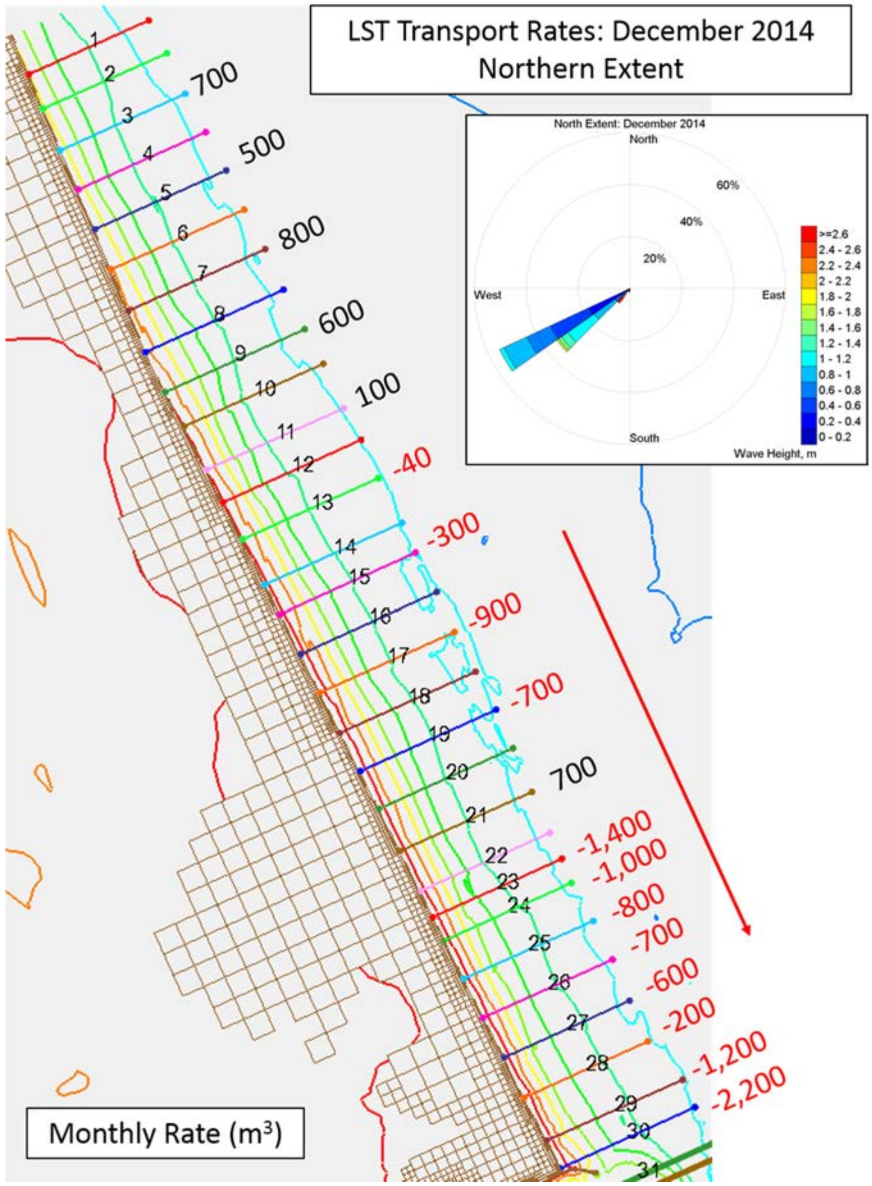


Figure 50. Calculated Longshore Sediment Transport Rates: December 2014 Model Run Northern Extent.

Figure 51 shows the calculated nearshore time series for the northern extent during December 2014 of the model run. In contrast to the wave series calculated for July 2014, the wave height and periods are consistently higher. The calculated average wave height during this time period was 0.82 m with an accompanying wave period of 10 seconds. The calculated average wave direction was directed onshore at 233 degrees. The maximum wave height during this period was computed at 2.87 m.

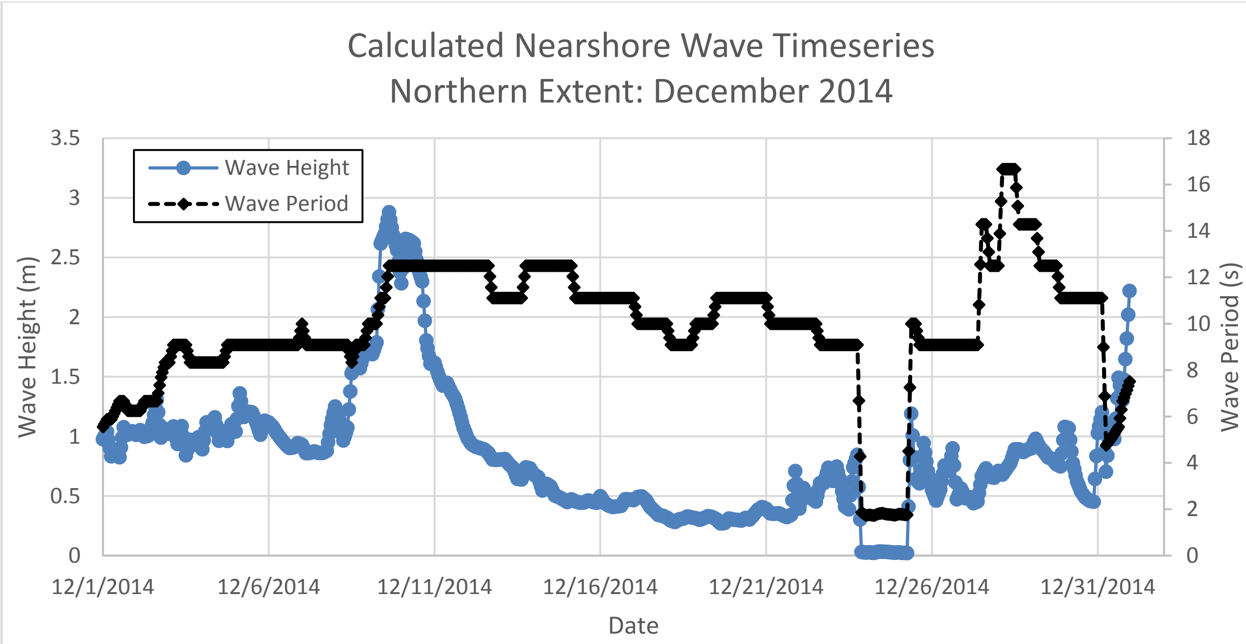


Figure 51. Calculated Nearshore Wave Time series: December 2014 Northern Extent.

Figure 52 shows the calculated sediment transport during the December 2014 portion of the winter model run. Positive values are indicating a net southern direction movement of sediment while the negative numbers (red) are indicating a net northern movement of sediment movement computed during December 2014. The absolute values of sediment volume ranges from 3,000 cubic meters to 200 cubic meters. Most of the observation arcs in this portion of the model domain are indicating a net northward movement of sediment transport. Only 3 arcs are showing a net southward movement of sediment; all of which are located on the southern portion of the ebb shield and the downdrift attachment point. The wave rose inset is indicating an onshore wave direction similar in spread to the July 2014 portion of the model run but with greater intensity. Figure 53 plots the computed nearshore wave time series for both wave height and period. The wave form is similar to the northern extent and has an average calculated wave height of 0.8 m with an accompanying average wave period of 10 seconds and an average wave direction of 232 degrees directed onshore.

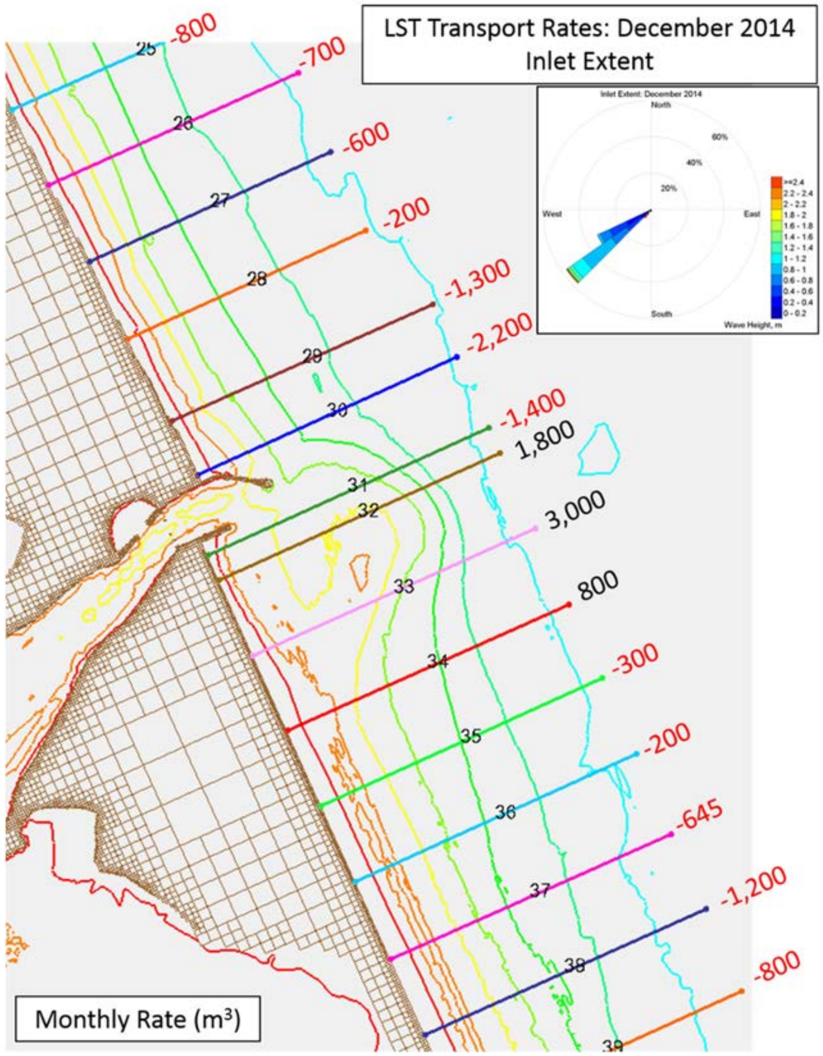


Figure 52. Calculated Longshore Sediment Transport Rates: December 2014 Model Run Inlet Extent.

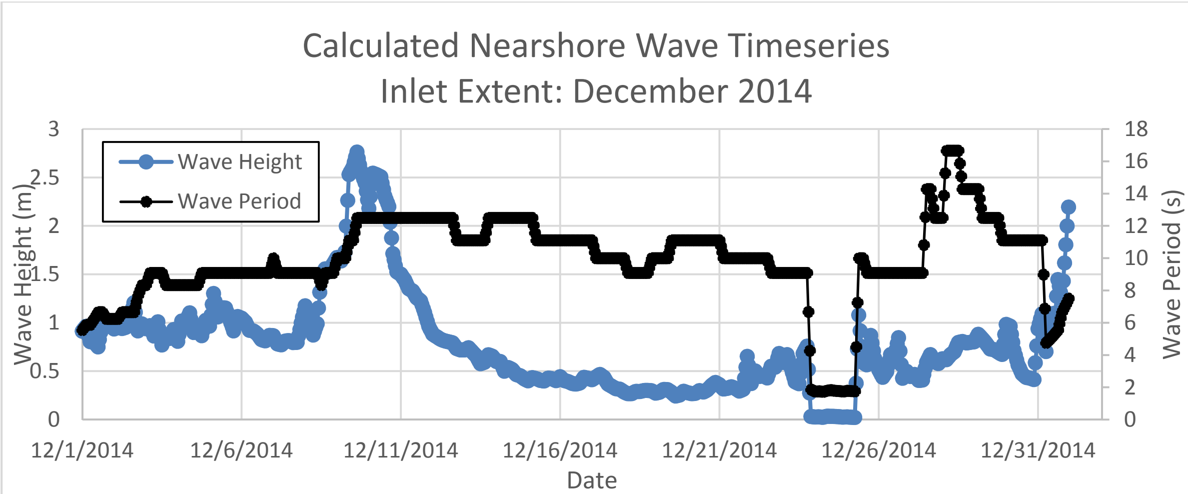


Figure 53. Calculated Nearshore Wave Time series: December 2014 Inlet Extent.

Figure 54 shows the sediment transport volumes computed over the December 2014 portion of the model run. The absolute volume ranges from 10,000 cubic meters at the southern portion of the domain to 300 south of the inlet at arc 36. Most of the sediment transport is directed northward as indicated by the negative sign convention on the majority of the volumes. Sediment transport is directed southward immediately south of the inlet over arcs 32 through 34 which are situated over the ebb shoal and downdrift attachment bar. The wave rose inset is indicating an onshore direction of wave energy. Figure 55 shows the time series of wave height and wave period during December 2014 portion of the winter model run in the southern extent. This is similar to other locations in the model domain.

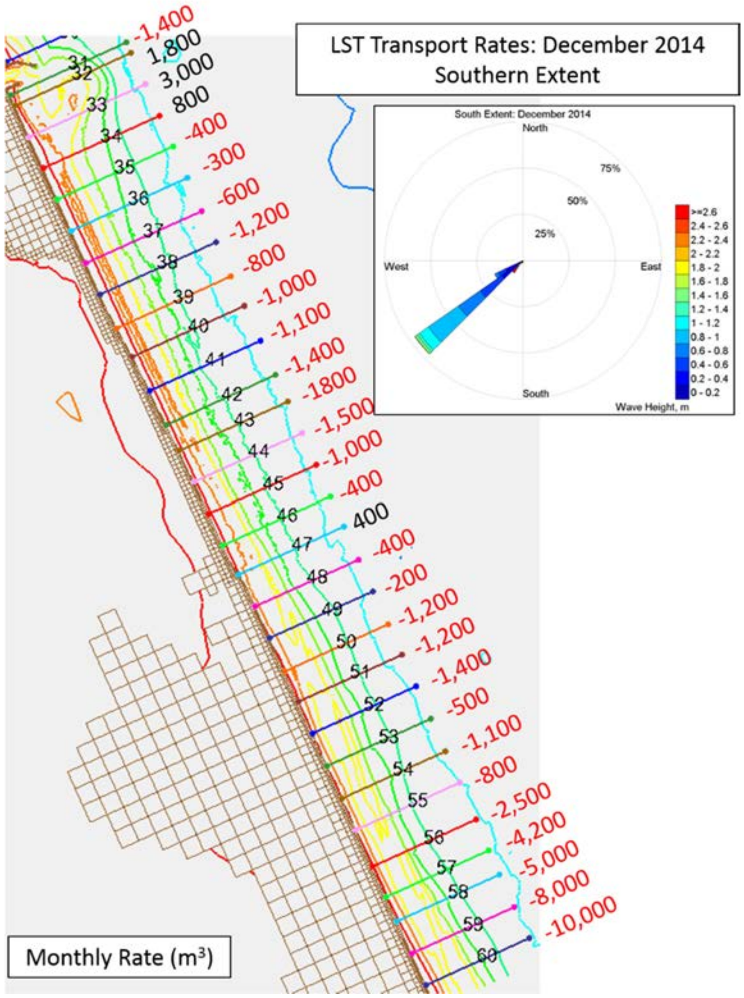


Figure 54. Calculated Longshore Sediment Transport Rates: December 2014 Model Run Southern Extent.

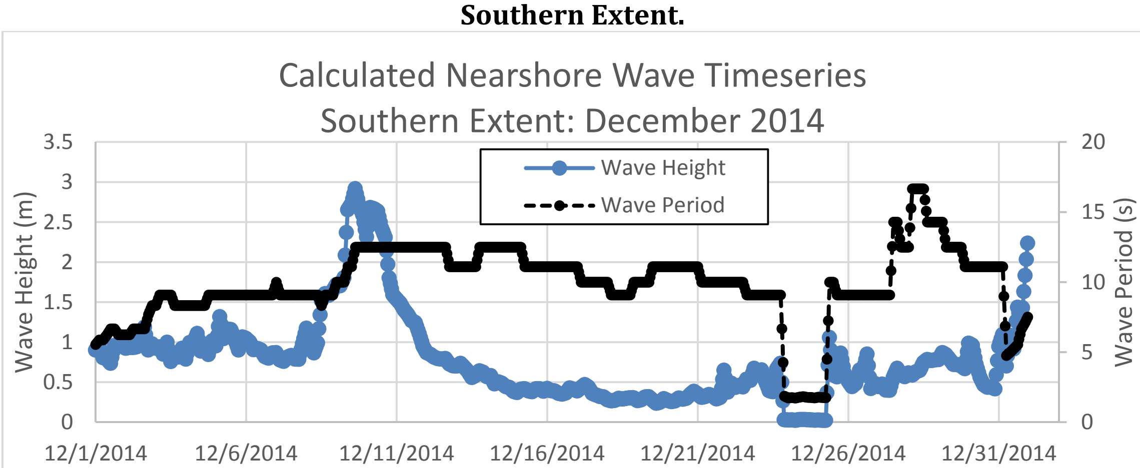


Figure 55. Calculated nearshore times series of wave height and wave period, December 2014.

Spring 2015 Model Run: January 2015 – July 2015

The following section presents the longshore sediment transport rates over the 7 month spring model run between January 2015 and the end of July 2015. The figures will follow the same conventions as those for the winter model run. Figure 56 shows the longshore sediment transport rates in the northern portion of the model domain with a wave rose inset. During this period, the transport direction was mostly northward except for the areas closest to the inlet in Arcs 24 through 30. The transport rates range from 36,000 cubic meters immediately north of the north jetty to 1,000 cubic meters at the northern portion of the domain.

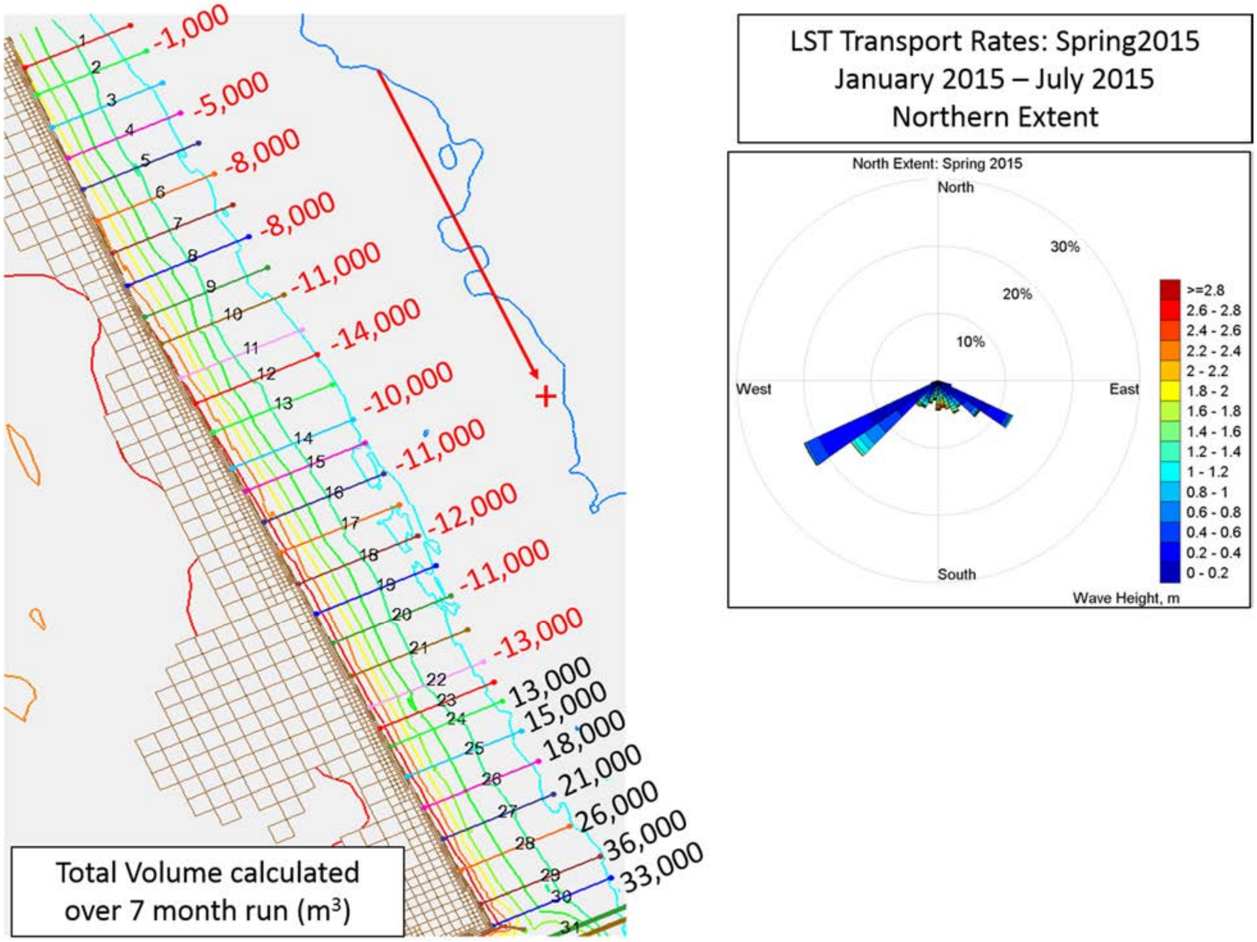


Figure 56. Calculated Longshore Sediment Transport Rates: Spring 2015 Model Run Northern Extent.

Figure 57 shows the calculated longshore sediment transport rates during the spring 2015 model run over the inlet. A local reversal is present over Arcs 36 through 38 just south of the attachment bar. The volumes range from 110,000 cubic meters over the ebb shoal to 400 cubic meters just south of the attachment bar. Wave rose inset indicates a greater variability of wave height and direction during the model run.

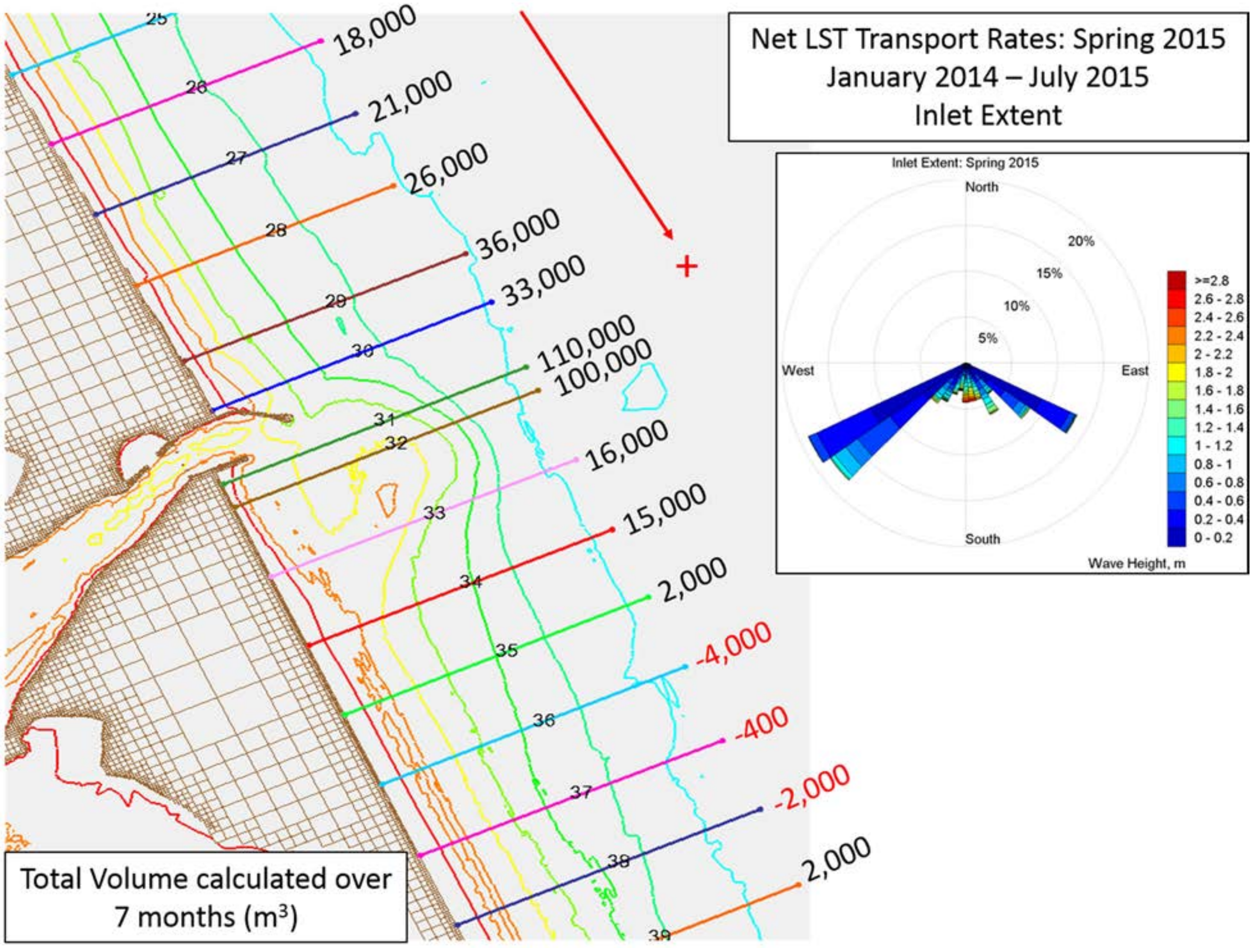


Figure 57. Calculated Longshore Sediment Transport Rates: Spring 2015 Model Run Inlet Extent.

Figure 58 details the longshore sediment transport rates for the southern portion of the model domain over the spring 2015 model run. This portion of the domain is more variable with regards to direction of sediment transport as well as volumes. Transported volumes are lower immediately after the inlet but then increase to 25,000 cubic meters at Arc 48 and again to nearly 400,000 cubic meters at the southern portion of the domain. The wave rose inset is consistent with the inlet and northern portions of the model domain showing a portion of wave energy directed onshore as well as alongshore. A northern direction sediment movement is observed at the southern boundary.

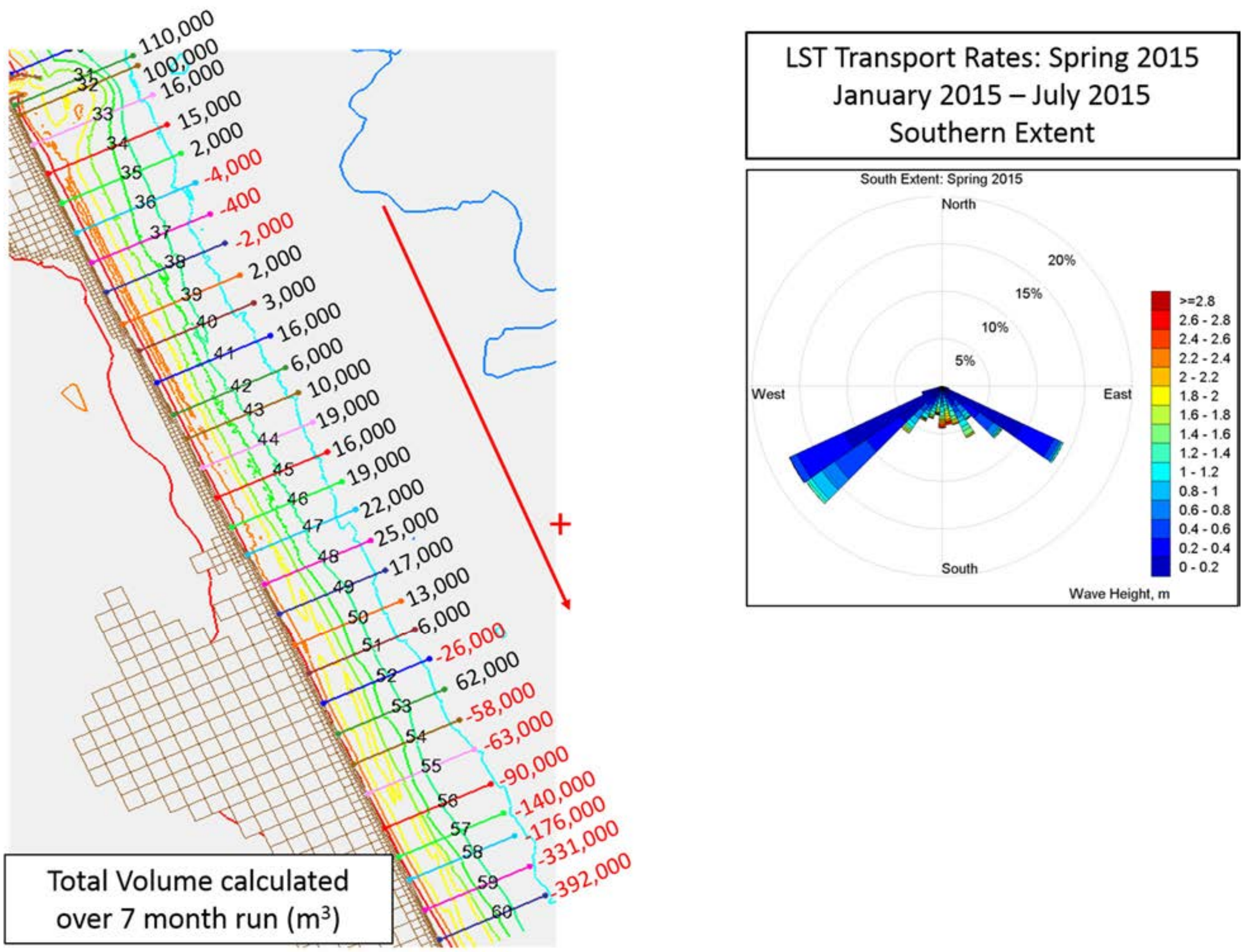


Figure 58. Calculated Longshore Sediment Transport Rates: Spring 2015 Model Run Southern Extent.

Discussion

A brief literature review was conducted to find a measured sediment transport rate near Sebastian Inlet. Wang, 1998 performed an extensive field study across Florida using streamer traps to measured longshore sediment transport rate in the surf zone. Melbourne Beach was one of their study areas but measurements were difficult due to rough waves and only the inner surf zone was measured. Because the lack of outer surf zone measurements, the measured sediment transport for this site is most likely underestimated. A longshore sediment transport rate of 19,000 cubic meters per year was determined using the field data. It is not clear in the paper when the measurements were made (during what season) or how long a duration. The average longshore sediment transport rate over the winter 2014 8-month run in the Northern Extent is approximately 13,000 cubic meters ranging from a minimum of 7,500 cubic meters just north of the Inlet to 19,000 cubic meters at Arc 7 in the northern most portion of the domain. Additional field measurements should be investigated for comparison.

Figure 41 shows the net longshore sediment transport rates along the northern extent for the Winter 2014 model run and indicates that the majority of the sediment transport is directed southward towards the inlet. Arc 21 indicates a net sediment movement to the north which may indicate a nodal point or a local reversal. Further analysis is needed to confirm this behavior.

During the winter 2014 model run, backpassing does occur in the southern portion of the domain during energetic periods as demonstrated by the December 2014 portion of the model run. Backpassing is not observed occurring during quiescent periods of the model run. In contrast, the spring 2015 model run showed northward sediment transport during a variety of time periods and spatially varying across the entire model domain.

Figure 59 illustrates the complex relationship between wave height, direction, current direction and sediment transport pathways. The left panel shows the wave direction vectors with lower wave height indicated by warmer colors with higher wave heights represented by cooler colors. Higher wave heights were computed over the ebb shoal. The middle panel shows the wave height color scheme with current direction vectors. The right panel shows the resulting sediment transport vectors with depth contours. Warmer colors indicating shallower depths while cooler colors are representing deeper depths in this third panel. All three panels are from the same time step within the winter run. Sediment transport vectors at this time period are directed into the inlet and recirculating northward over the ebb shoal.

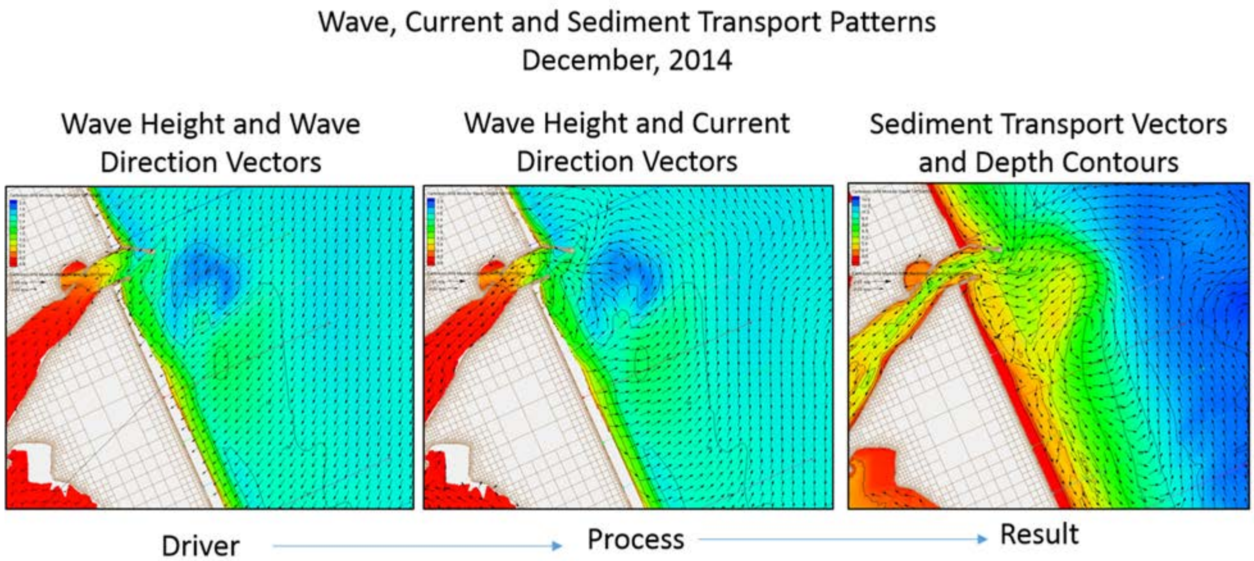


Figure 59. Relationship between Waves, Currents and Sediment Transport Pathways.

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