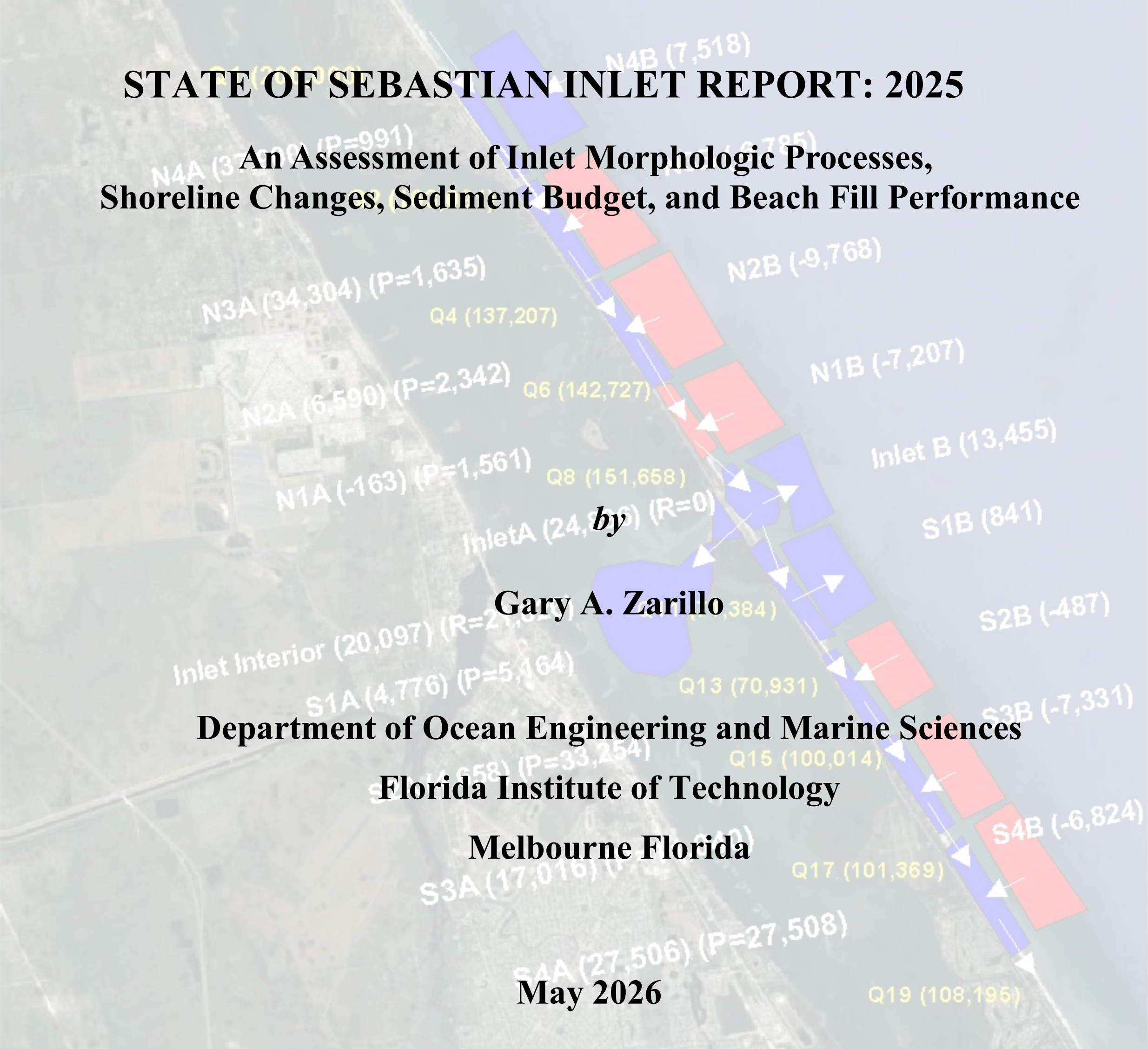

STATE OF SEBASTIAN INLET REPORT: 2025

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

by

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Executive Summary

The 2025 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 sand reservoirs of the inlet system, 2) analysis of morphologic changes within the inlet system, 3) calculation of the sand budget based on the results of the sand volume analysis, 4) an update of the shoreline change analysis, and 5) an update of the performance of the real time and forecast hydrodynamic model of Sebastian inlet and vicinity.

The sand volumetric analysis includes the major sand reservoirs within the immediate inlet area and sand volumes within the sand budget cells to the north and south of Sebastian Inlet. The volume analysis for each inlet sand reservoir extends from 2006 to 2025. Similar to the volumetric analysis described in previous state of the inlet reports, most inlet sand reservoirs are subject to a long-term trend of declining sand volume punctuated by occasional large seasonal changes in volume superimposed on the longer-term interannual trends. An examination of coastal sea level changes and sand volume changes between 2006 and 2025 revealed two important processes. First, it can be demonstrated that the Sebastian Inlet sand reservoirs and the sand budget cells areas to the north and to the south of the inlet undergo periods of regional volume losses and periods of volume gains. A comparison of interannual shifts in sea level with sand volume changes shows an inverse relationship in which sand volume decreases with rising sea level and increases during periods of falling sea level. Sand volume gains and losses cover the entire region rather than being inversely linked to gains or losses in adjacent subsections

The trends of sand volume change within the inlet sand reservoirs associated with Sebastian Inlet are also reflected in sediment budget calculations. In this report, the sand budget for the Sebastian Inlet region is calculated at 2-time scales, including a longer time scale of 17 to 18 years and a time scale of 10 years. Over the time period of 2007 to 2025, the benefits of sand bypassing from the sand trap and beach fill placement to the south of the inlet can be shown to mitigate sand volume losses on the south side of Sebastian Inlet, even when other areas are losing sand volume. In this report, the reader is referred to the 10-year sand budget based on volume changes between the winter 2015 and winter 2025 surveys. In this comparison, beach fill placement in sediment budget cells on the south side of Sebastian Inlet in combination with natural sand bypassing provided a net volume gain to beach and upper shoreface sand volumes at the 10-year time scale (See Figure 28, Section 3.2) Sediment volume bypass from the north side of Sebastian Inlet to the south side can be demonstrated for the 2023 to 2025 time period. Erosion on the north side of the inlet and transport to the south led to sand volume build-up in the inlet sand reservoirs (fillet areas and ebb shoal), but also increased natural sand bypass across the inlet to add sand volume to the upper shoreface in combination with fill projects.

Similar to the sand volume analysis, the results of shoreline mapping from survey data and aerial imagery vary considerably by time scale and by data sets from which they are derived. Differences between shoreline positions based on aerial imagery are compared with the shoreline

extracted from survey data. Over the 10-year time scale from 2015 to 2025, shoreline changes south of the inlet reflect the position of beach fill placement in 2011, 2012,2014, 2019 and 2025. These projects provided sections of advancing or stable shoreline. Guidance is provided for interpreting shoreline position versus sand volume analysis in terms of evaluating the stability of the beach and shoreface.

The performance of the forecast three-dimensional coastal processes model of Sebastian Inlet is described in this report. The model is based on the Deltares Delft3D numerical model code designed for shallow marine and estuarine environments. The model operates on a high-resolution computation grid nested in much larger basin-scale ocean and atmospheric models. Model forecasts are updated at hourly intervals. Deep learning methods (DLM) also known as machine learning, are applied to the Sebastian area model as method to provide model boundary conditions when measured or other model data are temporarily or permanently unavailable. Based on this analysis, recommendations are made for the management of sand resources by the Sebastian Inlet District

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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 2024 report through May of 2025 . Since the original analysis documented in the 2007 report, sand volume changes, sand budget, and morphological changes have been updated through winter 2025. Shoreline changes between 1958 and 2007 were documented in the 2007 Report using aerial images and between 1990 and 2007 using field survey data. The 2013 State-of-the-Inlet Report was expanded to provide an historical update of Sebastian Inlet and included a series of appendices updating the original 2007 analysis, as well as a description of ongoing numerical modeling experiments explaining the hydro- and sediment dynamics of Sebastian Inlet. The 2013 report documented presents a longer-term view of Sebastian Inlet's evolution and associated management strategies that have been applied over the years. The 2013 Report also presented a regional assessment of sediment types and textures as a basis of determining where to find beach compatible sand resources and sediment transport pathways around Sebastian Inlet. The more recent reports from 2016, through 2024 reports emphasize the sand volume calculations and sediments budgets of the Sebastian inlet area. In the present report the emphasis is on describing sand volume changes and related sediment budget calculations. A more detailed sediment budget template is developed consisting of beach and upper shoreface sediment budget cells and lower shoreface to inner continual shelf cells. The morphological analysis, sand budget analysis and the shoreline analysis are updated to 2025 and include a discussion of topographic changes within the sand budget cells in addition to the overall budget calculations

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 topography surveys and changes in the sand volume contained in the various shoals associated with Sebastian Inlet. In this section of the 2025 Inlet report, details of sand volume exchanges around the inlet are provided to support sand budget calculations.

The sandy shoals 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 2003 paper are the conceptual basis of littoral sand budgets in the vicinity of tidal inlets and beaches.

Sand volume changes within Sebastian Inlet shoals and sand budget cells over a 16-17, 10 year and 5-years intervals are used to annualize the sand budget in the inlet region. Sand budgets are presented as annualized terms, but calculated over intermediate to longer term time periods and compared to sea level changes in the Florida coastal ocean (Zarillo, 2023).

2.1 Sand volume analysis methods

Certified hydrographic surveys of the inlet system and the surrounding shoreface and beaches have been conducted by Sebastian Inlet District (SID) since the summer of 1989. Table 1 lists the surveys completed since 2006. Offshore elevation data are gathered by a combination of conventional boat/fathometer methods and multibeam acoustic surveying methods from -4 ft. to -40 ft.NAVD88 in accordance with the Engineering Manual for Hydrographic Surveys (USACE, 1994). Multibeam data are collected on the south side of Sebastian Inlet from FDEP Range Maker R1 through R17 in Indian River County, FL.

Figure 1 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. More recently, an additional 10,000 feet of survey coverage extended the survey area north of Sebastian Inlet to Brevard County R-179. Beach profiles are taken about every 1000 ft. Since 2011, survey methods have included multi-beam swath bathymetry on the south side of the inlet entrance. The multibeam data provide high spatial resolution in areas where reef rock outcrops occur. The dredged channel extension between the inlet and the Intracoastal Waterway (ICW) to the west has been surveyed semi-annually since it was constructed in 2007.

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 2025

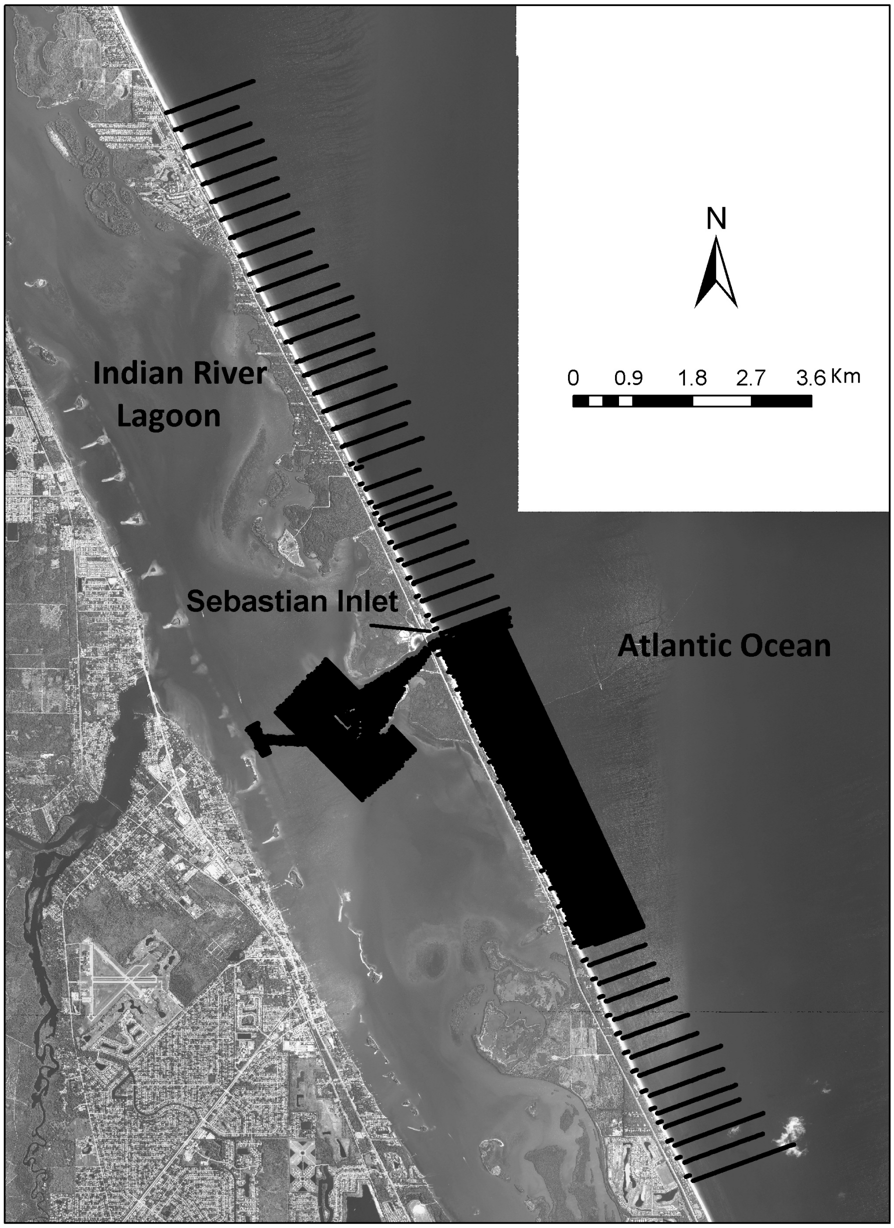

Figure 1. Typical Extent of hydrographic survey (2025 winter).

Table 1. Summary of Hydrographic Surveys completed since 2006

Survey Date	Ebb shoal	Channel	Sand trap	Channel Extension	Flood shoal	North beach (ft)	South beach (ft)
2006-2014	x	x	x	Begin 2008	x	30,000	30,000
Jan-14 *	x	x	x	x	x	30,000	30,000
Jul-14 *	x	x	x	x	x	30,000	30,000
Jan-15 *	x	x	x	x	x	30,000	30,000
Jul-15*	x	x	x	x	x	30,000	30,000
Winter 2016*	x	x	x	x	x	30,000	30,000
Summer 2016*	x	x	x	x	x	30,000	30,000
winter 2017*	x	x	x	x	x	30,000	30,000
Summer 2017*	x	x	x	x	x	30,000	30,000
Winter 2018*	x	x	x	x	x	30,000	30,000
Summer 2018*	x	x	x	x	x	30,000	30,000
Winter 2019*	x	x	x	x	x	30,000	30,000
Summer 2019	x	x	x	x	x	30,000	30,000
Winter 2020*	x	x	x	x	x	30,000	30,000
Summer 2020	x	x	x	x	x	30,000	30,000
Winter 2021*	x	x	x	x	x	30,000	30,000
Summer 2021*	x	x	x	x	x	30,000	30,000
Winter 2022*	x	x	x	x	x	30,000	30,000
Summer-Fall 22*	x	x	x	x	x	30,000	30,000
Winter 2023*	x	x	x	x	x	30,000	30,000
Summer-Fall 23*	x	x	x	x	x	30,000	30,000
Winter 24	x	x	x	x	x	40,000	30,000
Summer 24*	x	x	x	x	x	40,000	30,000
Winter 25*	x	x	x	x	x	40,000	30,000

* Multibeam data

Once each hydrographic survey is complete, volumetric data are added to the series of volume changes 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 2 shows the sand budget cells used to calculate the changes in sediment volume associated with alongshore littoral transport and cross-shore sediment exchanges between the upper and lower shoreface. The N4 and N3 cells are north of the inlet entrance. N4 is bounded by FDEP R-Markers R189 and R195 in south

Brevard County, whereas the N3 sand budget cell is bounded between R-195 and R-203. The N2 and N 3 cells are located between R-203 and R-216. The inlet cell includes all the sand reservoirs shown in Figure 4 and are bounded to the north by R-216 and to the south in Indian River County by R-4. On the south side of Sebastian Inlet sand budget cells are designated as S1, S2, S3 and S4. The S1 cell begins at R-4 and is bounded to the south by R-10 followed by the S2 cell bounded between R-10 and R-16. Sand budget cell S3 extend from R-16 to R-23 followed by cell S4, which terminates at R-30. All the cells extend seaward to an approximate depth of -40 feet, NAVD88

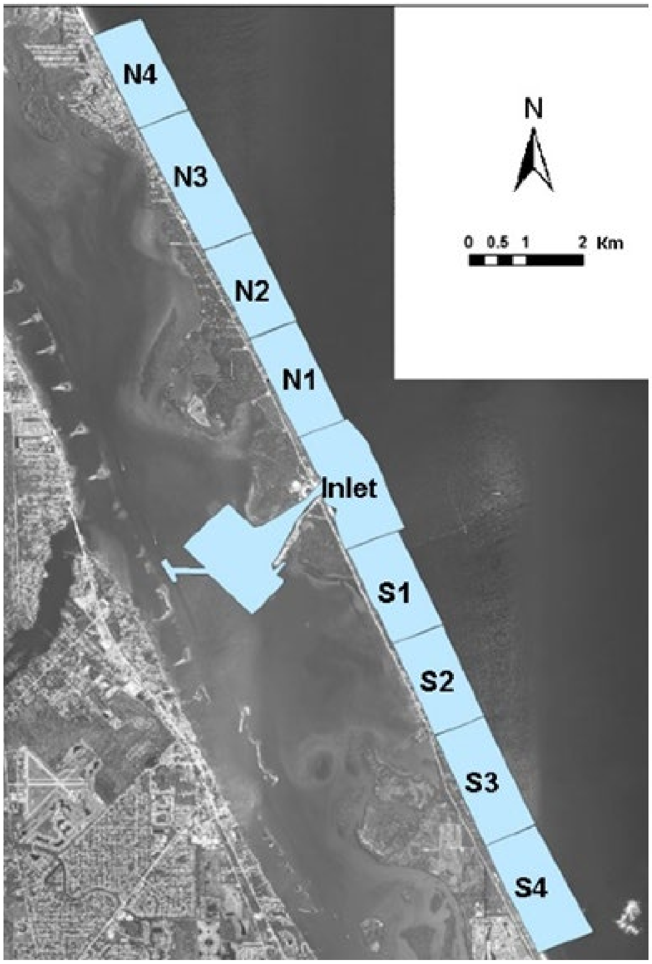

Figure 2. Sand budget cells.

Further subdivisions of the sediment budget cells shown in Figure 2 to consider sediment exchanges between the beach and upper shoreface and the lower shoreface and inner continental shelf. These subdivisions and shown in Figure 3 along with labels identifying the cell designation and the location of the Sebastian Inlet sand trap

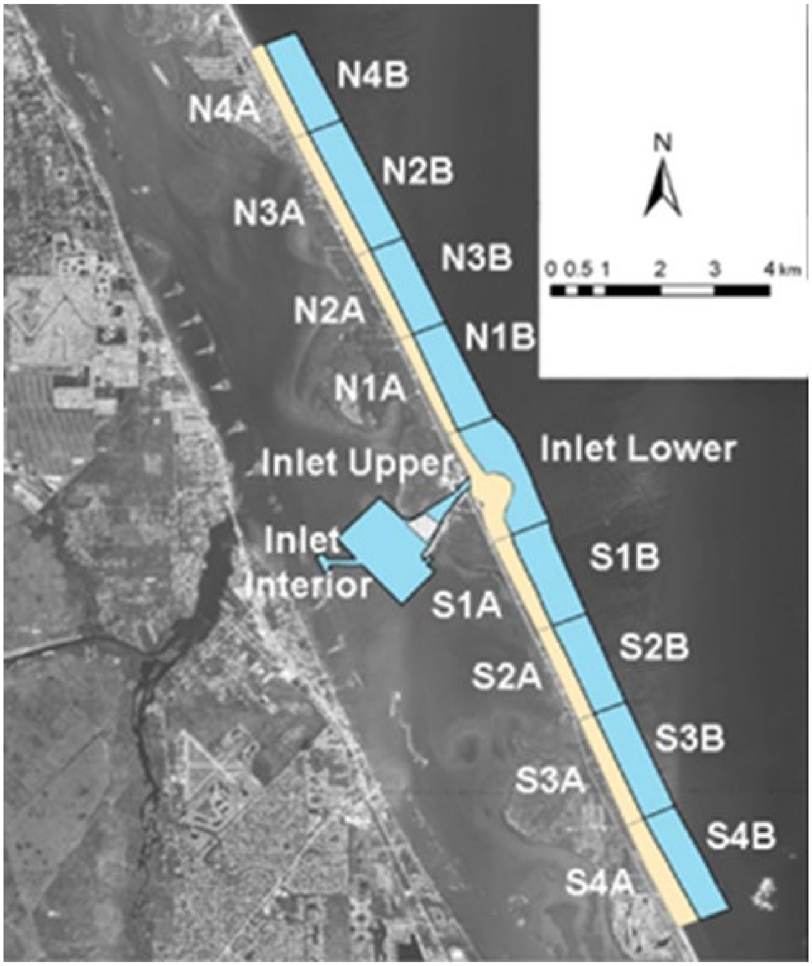

Figure 3. Upper and lower divisions of the sediment budget cells.

Within the immediate area of Sebastian Inlet further subdivisions are made to characterize sand reservoirs that exchange sand under a combination of strong tidal currents and wave action. These subdivisions are shown and identified in Figure 4. Two of the sand reservoirs, the flood shoal and the ebb shoal 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 sand trap, first excavated in 1962, re-established in 1972, and expanded in 2014, also influences the volume of the sand budget when it is periodically dredged. The most recent excavation of the sand trap covered in this report was completed in May 2025. Another sand bypass and beach fill project was completed in the Spring of 2026. Results of the 2026 project, including impacts on the regional sand budget will be covered in the next State of the Inlet Report to be issued in late 2026. A 2019 Project included approximately 166,220 cubic yards of material dredged from the sand trap of which 113, 500 cubic yards were placed and graded on the beaches to the south of the inlet between Indian River County R-Markers R-10 and -R17. Approximately 52,700 cubic yards of additional dredged material, balance of the sand trap and navigation channel volumes, were placed in the Sebastian Inlet dredge material management area (DMMA). In 2021, approximately 60,000 cubic yards of sand was trucked from the DMMA and placed on the beach between R-9 and R-17. Other sand reservoirs contain lower sand volume relative to the ebb and flood shoals and the sand trap, but may 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 most recent sand by-pass project covered in this report was completed in early 2025, included partial excavation of the sand trap of about 52,000 and placement in the R-6 to R17 areas. During this period, an additional 92,000 cubic yards of sand from an upland mine were placed between R-6 and R-17 boosting the placement total in this area to about 144,000 cubic yards.

The raw survey data in georeferenced to the NAVD88 vertical datum and Florida State Plane NAD83 horizontal datum are 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 among survey dates.

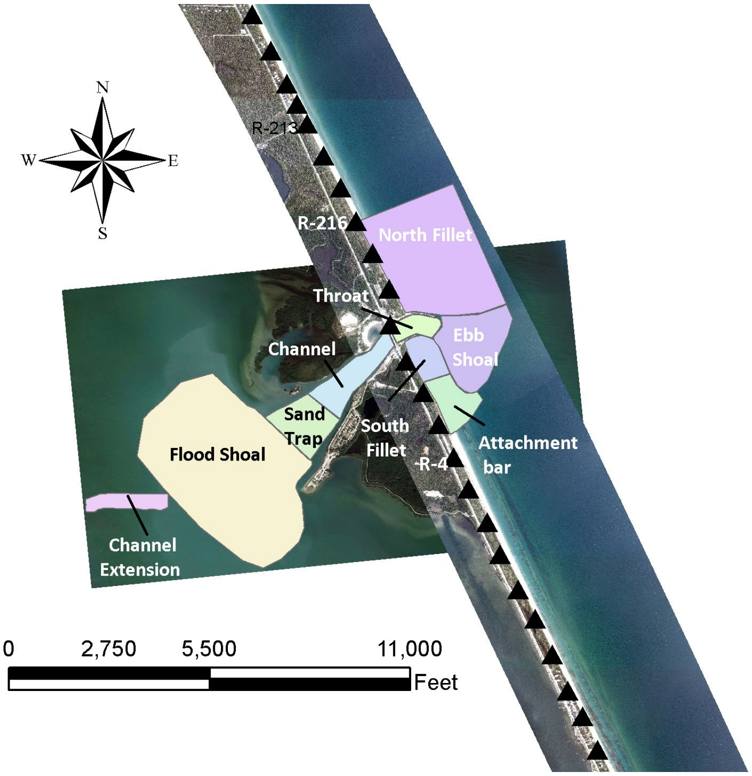

Figure 4. Morphological features forming the inlet sand reservoirs.

2.2 Sebastian Inlet sand reservoir volume analysis

The sand reservoirs are contained within the inlet sand budget cell (Figure 2 and Figure 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 cell

(Figure 4) with plots of net seasonal and cumulative volume change over time. Section 3.2 presents the volumetric evolution of the consolidated inlet littoral cells, which are then sub-divided into upper and lower shoreface cells (Figure 3) used for the sand budget computation. 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 compared to large sand bodies such as the flood shoal.

The volumetric evolution of the ebb shoal from 2005 to 2025 is illustrated in Figure 5. Integrated seasonal volume changes over time provide a net volume change and visualization of trends. Seasonal volume gains or losses are most often followed by counterbalancing volume losses or gains. For instance, 12 months of sand volume gains totaling about 89,000 cubic yards on the ebb shoal from July 2013 to July 2014 were followed by about a 50,000 cubic yard sand volume loss from July 2014 to winter 2015. This was followed by about 85,000 cubic yards of column gain though the summer of 2016 (Figure 5). Little net change occurred from the summer of 2016 to the summer and winter survey of 2024. Over this period, the ebb shoal seasonal volume varied over a maximum range of about 75,000 cubic yards. Since winter 2004 the ebb shoal has added about 50,000 cubic yards of sand volume. As seen in Figure 5, a trend of increasing ebb shoal sand volume occurred over an approximate 5-year period between 2005 and 2010 that totaled about 150,000 cubic yards. The recent trend of rising sea level and associated sediment processes may have contributed to the loss of ebb shoal volume between 2018 and the winter survey of 2021. A comparison of the cumulative sand volume changes in the ebb and flood shoal is shown in Figure 6. Volume changes in the 2005 to 2020 periods are not highly correlated between these two sand reservoirs, but the longer-term volume trends are opposite. Since the summer 2021 survey, volume changes of the ebb and flood shoal are inversely correlated. The ebb shoal volume increased since 2005, punctuated by shorter variations of up to 75,000 cubic yards. In contrast, the total volume of the flood shoal has declined by about 177,000 cubic yards since 2007, but is subject to shorter-term variations of 100,000 cubic yards or more. Larger variations in flood shoal volume are linked to the dredging of the Sebastian Inlet sand trap. Each sand trap excavation temporarily disrupts the sediment balance within the interior of the inlet, resulting in a temporary sharp decline in flood shoal volume. The ebb shoal volume, changes in the flood shoal volume, and sand excavations from the sand trap dominate the sand budget changes linked to the inlet. These interactions are discussed under Section 4 of the report.

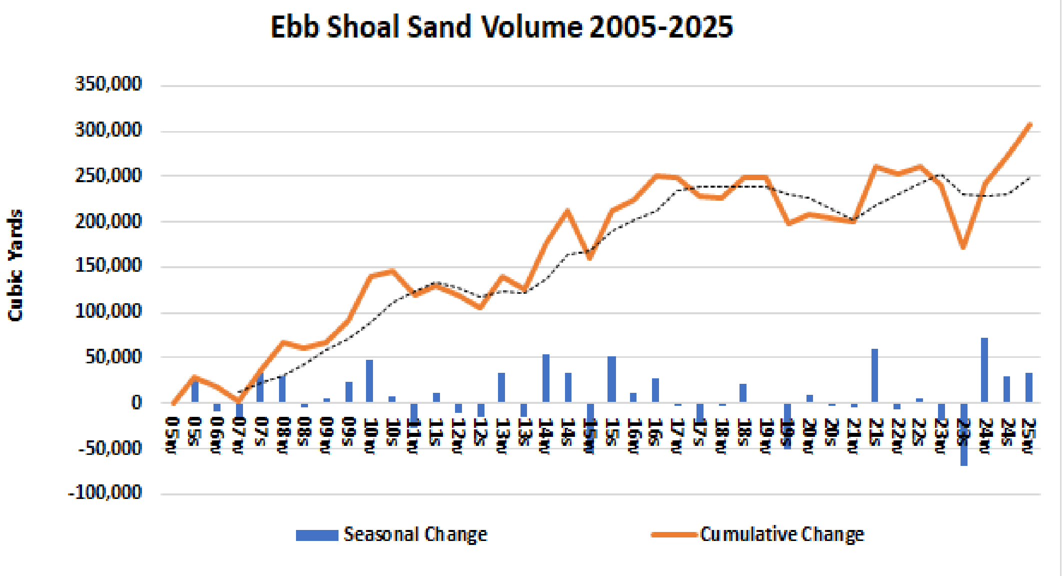

Figure 5. Volumetric evolution of the ebb shoal from summer 2005 to winter 2025.

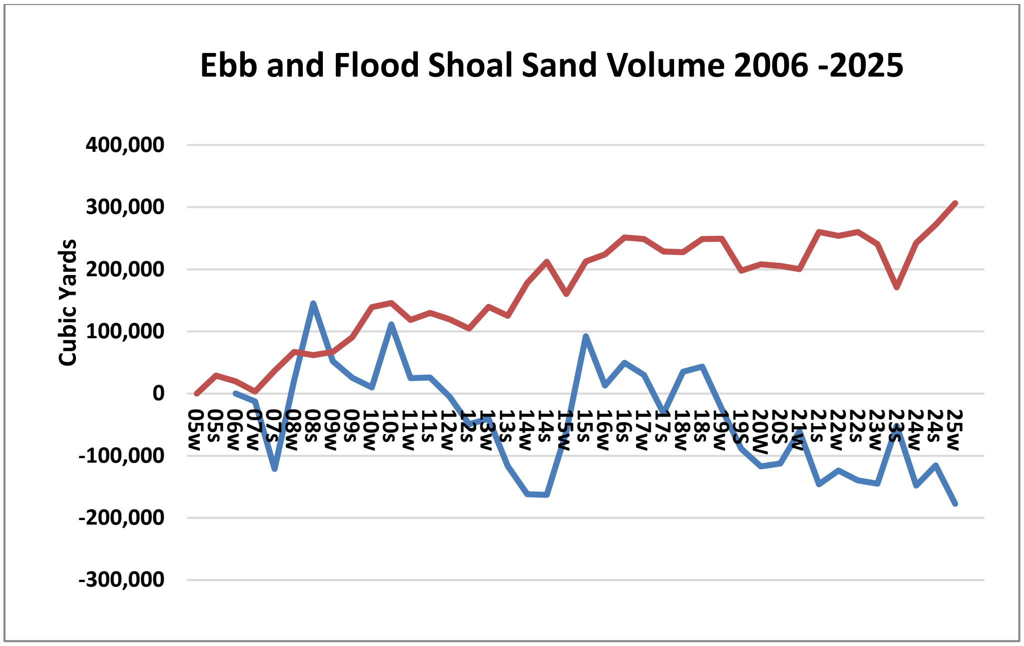

Figure 6. Cumulative sand volume changes of the Sebastian Inlet ebb shoal and flood shoal 2006-2024.

The sand volume changes of the attachment bar are small due to its role as a sediment redistribution zone rather than an accumulation or storage zone (Zarillo et al., 2007). As seen in Figure 7, volume changes alternately between positive and negative on a seasonal basis. Increases in sand volume usually occur during the winter season of higher wave energy, whereas volume losses from the attachment bar typically occur during the summer season. The winter sand volume increases due to sand bypassing around the inlet entrance by higher energy winter wave conditions. Losses in the summer are due to the movement of sand further south or back to the inlet entrance during the lower energy conditions of the summer season and north-directed littoral sand transport by wave energy from the southeast in the summer. An increase in bar volume of about 70,000 cubic yards seen in the summer 2019 survey may be related to partial back passing of sand placed between R-10 and R-17 from the sand trap in the winter of 2019. This was partially balanced by a volume loss of about 40,000 cubic yards by winter of 2020. Sand volume in the attachment bar is little changed between the summer of 2020 and 2022 despite seasonal fluctuations. However, a large seasonal change over a range of about 110,000 cubic yards was documented from the sequential winter and summer surveys of 2023. This was followed by a volume decline of about 35,00 cubic yards documented in the winter 2024 survey and 5,000 cubic yards in the summer 2025 survey data. As of winter 2025, the attachment bar gained about 12,000 cubic yard of sediment. The 2023 and 2025 seasonal sediment volume gains indicate episodes of sand bypassing from the ebb shoal to the attachment bar. Sand volume in the attachment bar has increased by about 41,000 cubic yards since 2005.

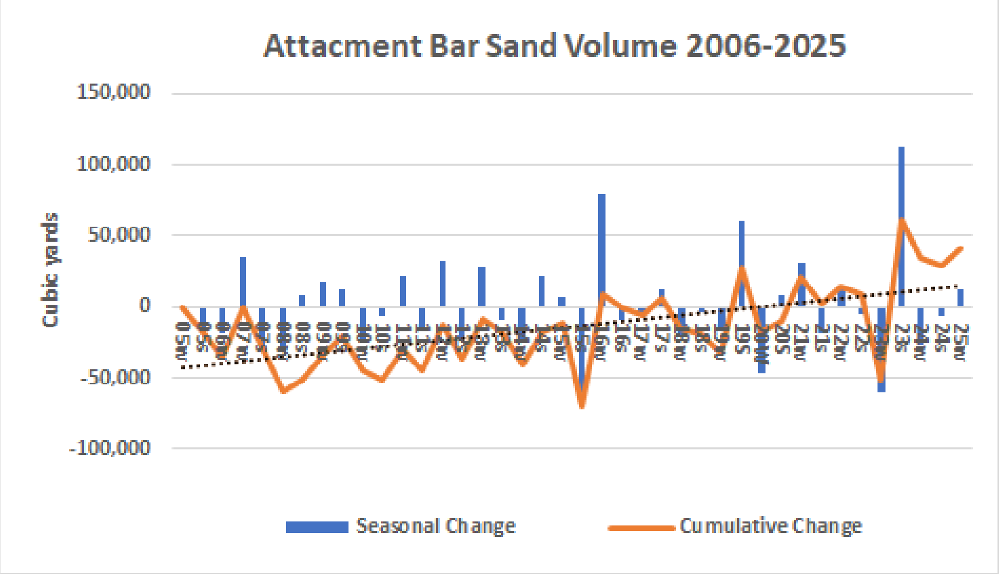

Figure 7. Volumetric evolution of the attachment bar from summer 2005 to winter 2025.

The volumetric evolution of the sand trap is presented in Figure 8. The trends and patterns of volume change are dominated by excavation from the sand trap in 2007, 2012, 2014, and 2019. Post dredge annual sand volume gains are about 30,000 to 40,000 cubic yards, averaging 15,000 to 20,000 cubic yards every 6 months. The pattern in Figure 8 shows that the highest rate of sand volume gains usually occurs in the first 6 months after dredging followed by smaller gains or small loss of volume thereafter until the next dredging cycle. The record from January, 2012 to July, 2014 clearly marks the recent dredging projects to bypass and expand the sand trap in 2014. Figure 7 illustrates the mechanical bypassing of spring 2012 with the removal of approximately 122,000 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 total about 121,000 cubic yards through the summer of 2018. The gains include about 43,000 cubic yards in the first six months after dredging followed by smaller gains of less than about 6,000 cubic yards per year through the winter of 2016. Analysis of surveys in summer 2016 and winter 2017 indicate a total gain of about 37,000 cubic yards of sand. Sand volume gains in the second half of 2017 were minimal, but followed by a gain of about 28,000 cubic yards by the winter survey of 2018. The winter survey of 2019 showed a sand volume loss of about 90,000 cubic yards related to dredging of the sand trap. The final as-built survey indicated 124,000 cubic yards of sediment was removed from the sand trap. Between the 2019 bypass project and winter 2024, the sand trap gained approximately 180,000 cubic yards of new sediment (Figure 8). The winter 2025 sand trap excavation removed about 52,000 cubic yards of sand and sent the sediment to beaches on the south side of Sebastian Inlet.

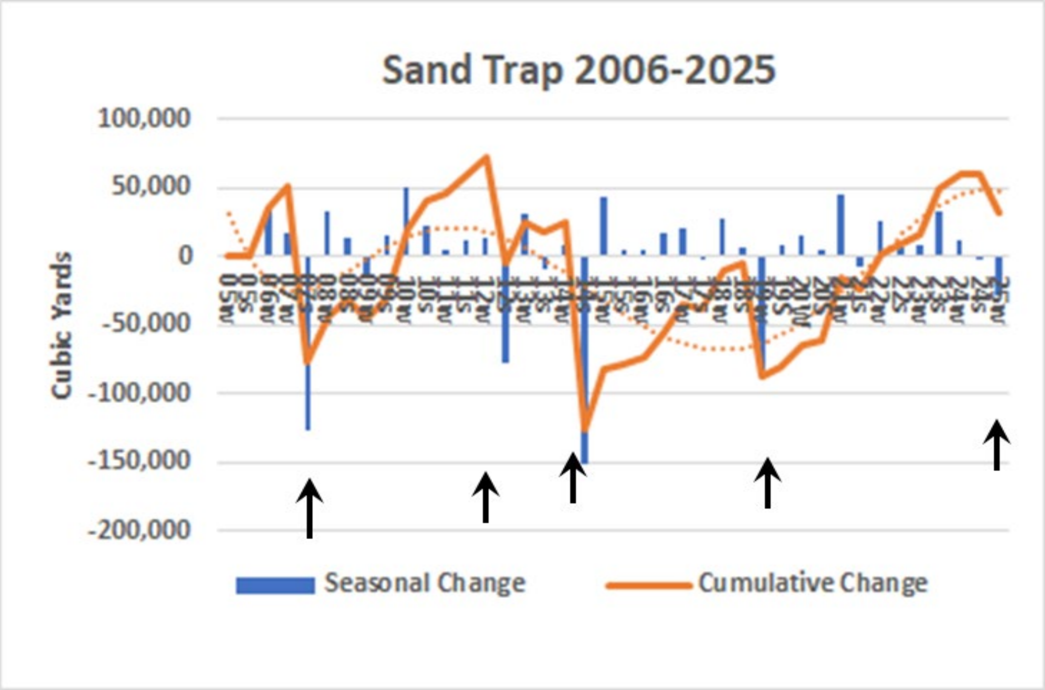

Figure 8. Volumetric evolution of the sand trap from winter 2005 to winter 2025. Arrows indicate sand trap excavation and sand by-pass projects.

Changes in flood shoal volume (Figure 9) can be more than 100,000 cubic yards on a seasonal basis. Temporary losses of sand volume of more than 50,000 cubic yards from the flood shoal are 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 and increased its volume by the summer of 2008. A period of continuing relatively large sand volume loss began in January, 2011 and continued through 2014 when the sand trap was expanded. Initial losses may have been due to loss of sea grass coverage beginning in 2011, which helps to stabilize the flood shoal. After the expansion of the sand trap in 2014, the flood shoal entered a period of recovery and expansion, which continued through the summer of 2015 as seen in Figure 9. Seasonal variations in the ebb shoal volume were about

25,000 to 50,000 cubic yards through 2018, followed by a sand volume losses exceeding 100,000 cubic yards through the summer of 2021   The sand volume loss beginning in winter 2019 survey is linked to dredging of the Sebastian Inlet Sand Trap as described in this, and previous State of the Inlet Reports. The flood shoal volume reached a minimum by the winter 2023 survey due to the impacts of sant trap dredging. This was followed by a seasonal recovery of about 100,000 cubic yards according to the summer 2023 survey. This volume recovery was reversed according to the winter 2024 survey, followed by another recovery of about 32,000 cubic yards (Figure 9). The decline of about 52,000 cubic yards of sediment registered in the winter 2025 survey can be linked to dredging in the sand trap area during the winter of 2025.

Net volume change of the flood shoal in the 17-year period since 2006 is approximately a loss of 177,000 cubic yards. Intra-annual sand volume fluctuations of 50,000 to 100,000 cubic yards can occur in any year.

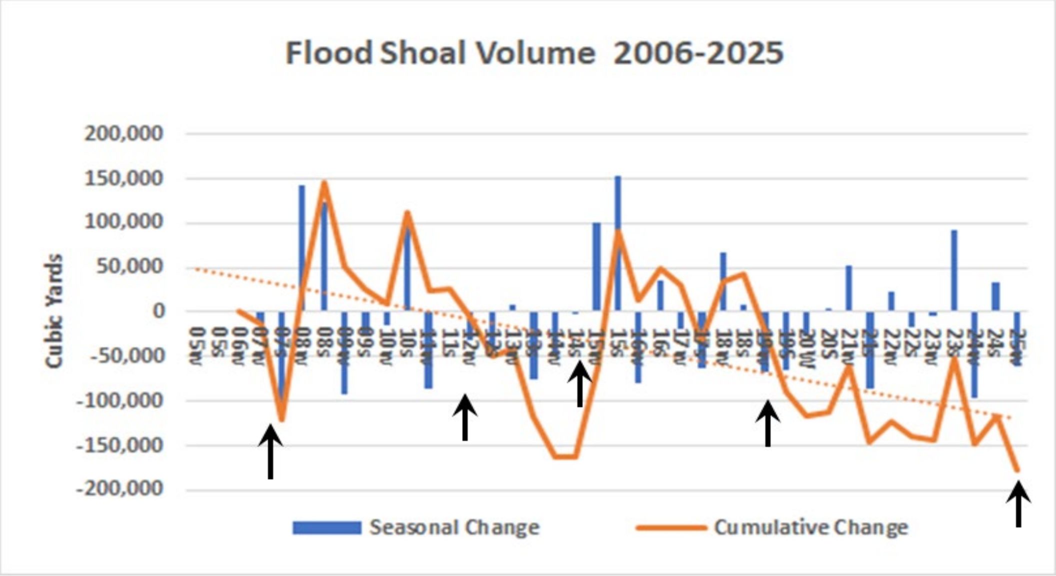

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Figure 9. Volumetric evolution of the flood shoal from winter 2006 to winter 2025. Arrows indicate sand trap excavation and sand bypass projects.

The record of changes in sand volume in the channel extension to the Intracoastal Waterway is shown in Figure 10. This area, first dredged for navigation in 2008, is dynamically linked to the sand trap and flood shoal sand exchanges. Sharp declines in sand volume occurred in 2012 and 2014 as the channel extension areas was dredged along with the sand trap. These declines may have also been influenced by sand volume losses in the adjacent flood shoal area and linked to losses of sea grasses. Like the flood shoal, sand volume sharply increased within the channel in 2015 followed by a loss of about 10,000 cubic yards in the 2016. A sand volume decline of about 13,000 cubic yards between summer 2018 and summer 2019 is linked to dredging of the channel extension during the 2019 sand trap bypass project. Between summer 2019 and summer 2021, the channel extension gained about 13,000 cubic yards of sediment (Figure 10). Since 2021 the sediment volume in the channel extension has increased by about 11,000 cubic yards, most of which was a seasonal accumulation measured in the summer 2023 and winter 2025 surveys. Since 2023 sand volume changes in the channel extension have been reversed in sign compared to volume changes of the flood shoal. This could demonstrate the dynamic sand transport linkage between the flood shoal and channel. As of the winter 2025 survey the Channel extension gained about 8,500 cubic yards of sediment. This is expected to be reversed in the summer 2025 survey and winter 2026 survey.

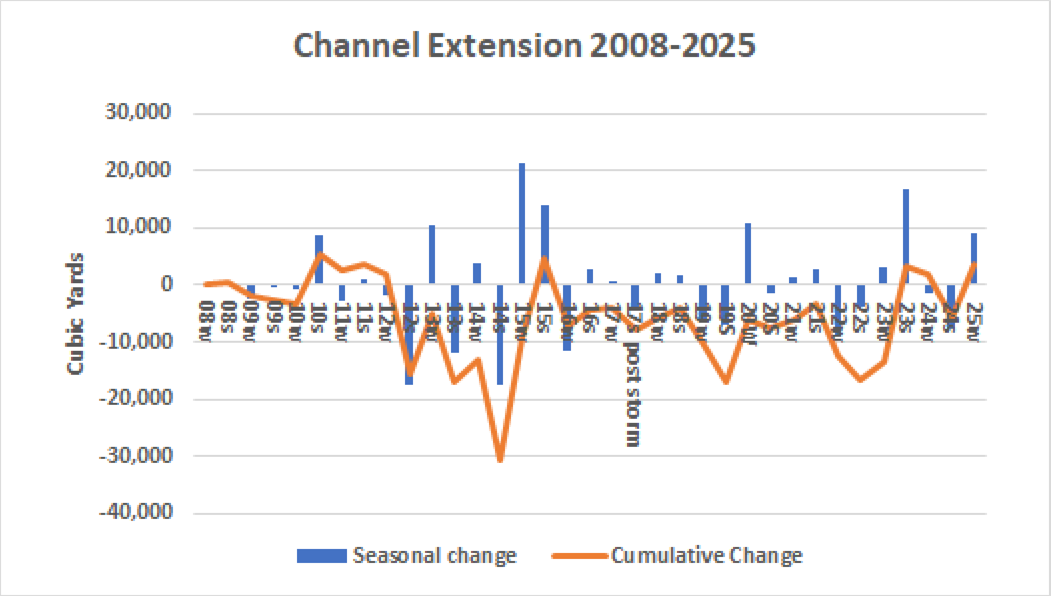

Figure 10. Volumetric evolution of the channel from winter 2008 to winter 2025.

2.3 Sand budget cells

Sediment budget calculations discussed in this report depend on the analysis of individual sand budget cells. The sand budget computational cells are shown in Figure 2 and Figure 3. The inlet sand budget cell encompassing the nearshore zone from R-216 in Brevard County to R-4 in Indian River County, includes the ebb shoal, flood shoal, attachment bar and all other reservoirs shown in Figure 4. This cell is further subdivided into upper and lower inlet components and an interior inlet component, as shown in Figure 3. The interior cell also includes the Sebastian Inlet sand trap (Figure 3). Annualized volume changes (ΔV) for each cell are calculated over different time periods and 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 are also included to account for dredging/mechanical bypassing and beach fill activities in the cells concerned. Time series of volumetric change since 2006 for the nine sand budget cells including upper beach/shoreface and lower shoreface components (Figure 3) are shown in Figure 11 through Figure 18, ranging from the northernmost to the southernmost cells. Under Section 3 of this report, volume changes in the upper beach/shoreface and lower shoreface components of these cells are used to calculate sediment budgets over different time periods.

Volume changes in the N4 cell (R-189 and R-195, (Figure 11) indicate a net sand volume loss of about 400,000 cubic yards from 2006 to 2023, most of which is accounted for by volumes losses since the summer of 2017 after Hurricane Irma impacted Florida. A 550,000 cubic yard rebound occurred between winter 2023 and summer 2023, after losses totaling about 200,000 cubic yards between winter 2022 and winter 2023 due to Hurricanes Ian and Nicole that impacted Florida. The large sand volume rebound of more than 500,000 cubic yards occurred between the winter and summer surveys of 2023 may be linked to onshore sand recovery after the 2022 hurricanes. This recovery was followed by a volume loss within N4 of 100,000 cubic yards observed in the post-winter survey of 2024. Since 2024 sand volume remained stable into the winter 2025 survey results.

Volume changes in the N3 cell, (R195 - R203, Figure 2), are shown in Figure 12. Like the N4 cell, large volume changes in N3 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 N4 and N3 cells from the nourished beaches and shoreface to the north in Brevard County. This usual pattern of seasonal volume shifts has changed since summer of 2017 survey, which was characterized by a gain in sand volume in the N3 cell corresponding with a large gain in the N4 cell to the north. Conversely, large sand volume losses were recorded in the N2 and N1 cell to the south of N3.

This was due to the impacts of Hurricane Irma in September of 2017 that were recorded in the post-storm survey completed in late September. Storm waves approaching the southeast may have caused event-scale erosion in the N2 and N1 cells, transporting sand into the N3 and N4 cells to the north. The Sebastian Inlet wave gage measured wave heights up to 17 feet at periods of 12s or more. Between the summer survey of 2018 and the winter survey of 2021, sand volume declined by about 250,000 cubic yards in N3, followed by a seasonal gain of about 100, 000 cubic yards, as shown in the winter 2022 survey in a pattern like that of N4. Sand volume declines continued through the winter survey of 2023, the result of impacts from Hurricanes Ian and Nicole in late 2022. This was followed by a large gain of more than 400,000 cubic yards, correlating with a gain of similar volume in Cell N4 to the north. A sand volume loss of about 90,000 cubic yards was recorded in the winter 2024 survey. The sand volume pattern into the winter 2025 survey was a period of volumetric stability similar to the pattern in N4. Given the volume rebound in 2023 sand volume losses in N3 since 2006 are about 85,000 cubic yards

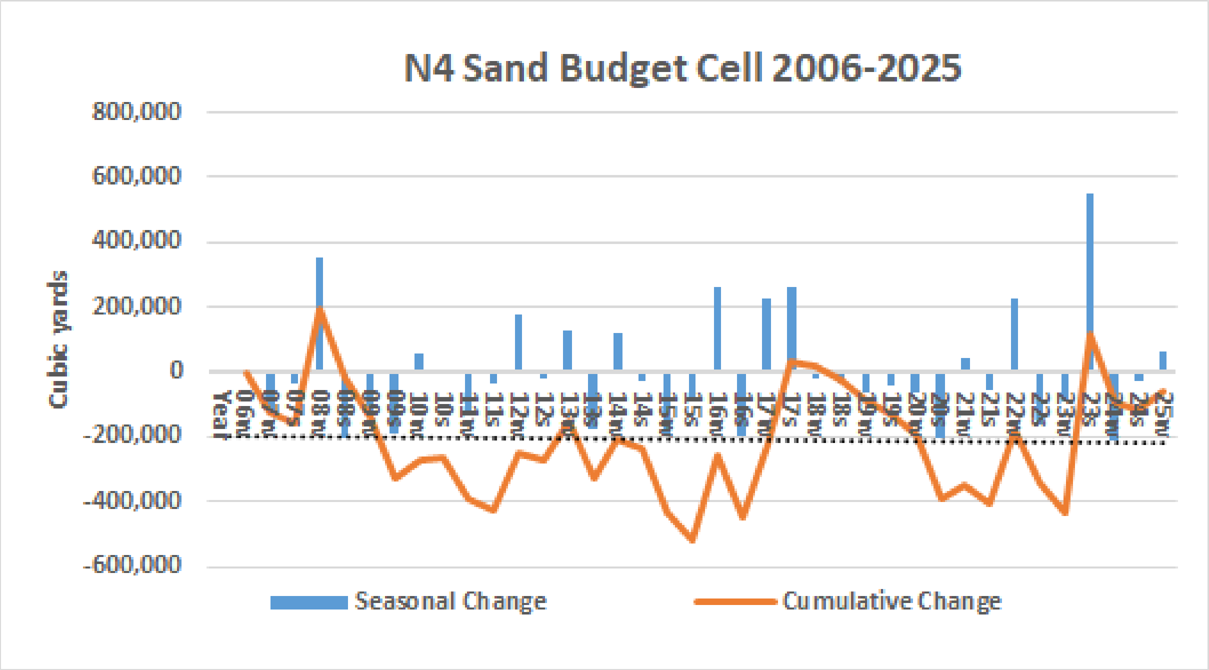

Figure 11. Volumetric evolution of the N4 sand budget cell 2006-2025

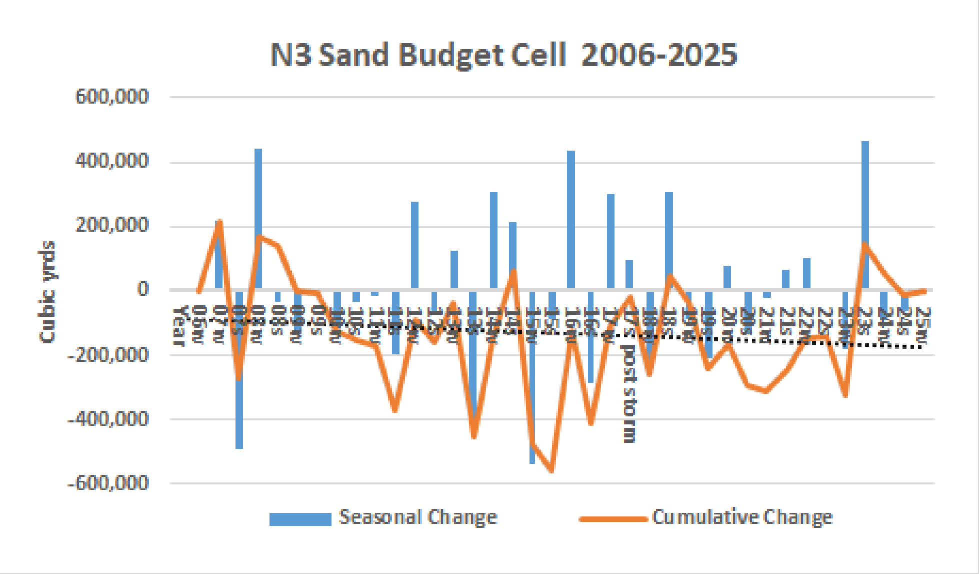

Figure 12.Volumetric evolution of the N3 sand budget cell 2006-2025.

Seasonal volume changes found in the N2 sand budget cell (Figure 13) are similar in magnitude and pattern to those recorded in the N3 cell, including large seasonal changes. In the post-Hurricane Irma period, a large volume gain was recorded in the Summer 2018 survey, along with similar gains in the N3 cell to the north and the N1 cell to the south. After 2018, sand volume losses were recorded through the end of 2019, after which the seasonal volume change pattern was re-established and was marked by a large sand volume gain of about 165,000 cubic yards between summer 2019 and winter 2020. This was followed by smaller seasonal losses through the winter survey of 2022. A gain of 200,000 cubic yards occurred between winter and the summer/fall survey of 2022. The large sand volume loss of about 200,000 cubic yards recorded in the winter 2023 survey is likely the impact of the fall 2022 hurricanes. Large seasonal sand volume gains and losses followed. Similar to volume changes in the N4 and N3 sand budget cells, a strong sand volume rebound was recorded in the summer 2023 survey. After a sand volume loss of about 150,000 cubic yards moderate sand volume changes of 50,000 to about 75,000 cubic yards were recorded in the summer 2025 and winter 2025 surveys. Integration over all the interannual and seasonal shifts since 2006 has resulted in a net sand volume loss of about 160,000 cubic yards It is noteworthy that a single session oscillation of sand volume gain can offset the longer-term trend.

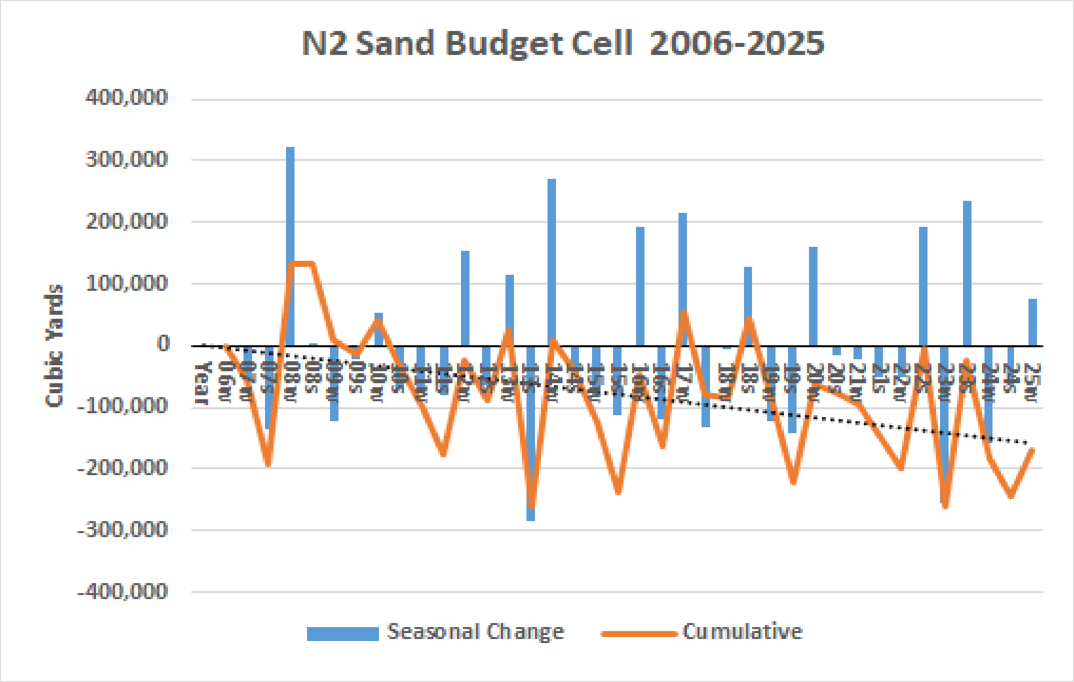

Figure 13. Volumetric evolution of the N2 sand budget cell 2006-2025

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Net sand volume change in the N1 Cell (R209-R216) followed the pattern of the N2 budget cell marked by large sand volume loses and gains of 100,000 cubic yards and more at seasonal intervals. The largest recent seasonal sand volume change is a gain of about 250,000 cubic yards between the winter and summer survey of 2023 in the post-storm recovery period after Hurricanes Ian and Nicole. Among the large seasonal variations, there is no long-term trend of either sand volume gain or loss. The 150,000 cubic yard gain of sediment recorded in the winter 2025 survey returned the long-term trend to a near zero change in sediment volume since 2006.

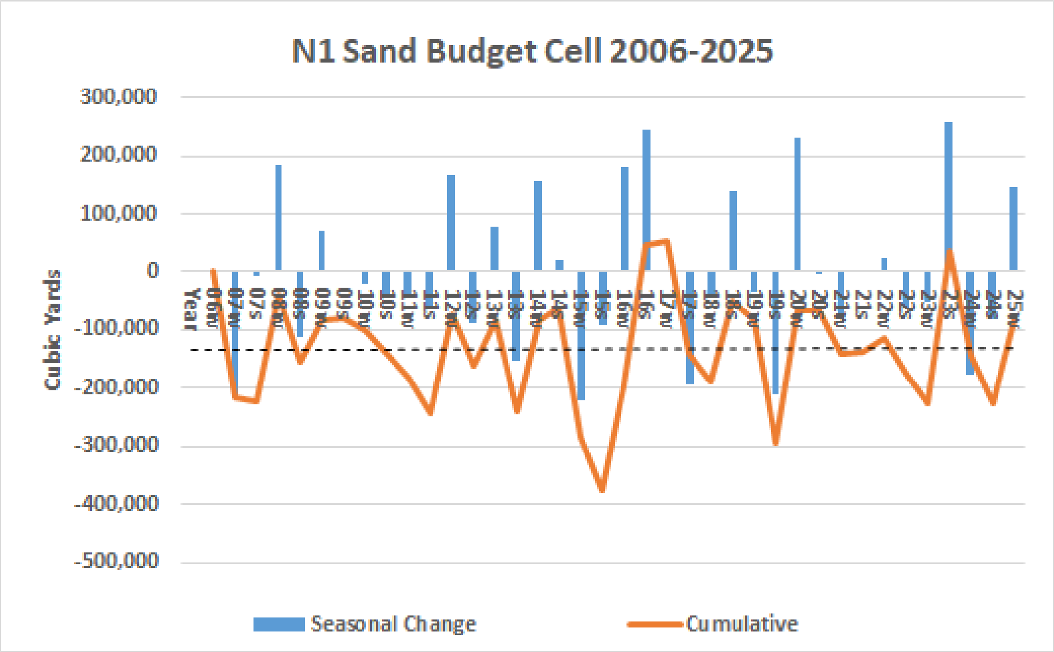


Figure 14. Volumetric evolution of the N1 sand budget cell 2006-2022.

In summary, seasonal changes in all of the sand budget cells to the north of Sebastian Inlet are about, or greater than net longer term net changes. As emphasized by the trend lines shown in volume losses among the N1 to N4 cells north of the inlet Figure 11 to Figure 14, increase to the north with distance from Sebastian inlet. The N1 sediment budget cell adjacent to the inlet budget cell shows no trend compared to the N2 to N4 cells further north of Sebastian Inlet, which have longer-term trends of sand volume loss.

Volume changes for the inlet sand budget cell (Figure 2, Figure 15) are a combination of volume changes in the ebb and flood shoals, as well as the sand trap and main inlet channel (conveyance channel). Sand is also 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 as can be seen in 2007, 2012, 2014 and 2019. This cycle of abrupt sand loss followed by a period of sand volume gain is due to a combination of sand removal by dredging the sand trap and responding losses from the flood shoal followed by recovery of sand volume in the trap and rebound of the flood shoal. The influence of the ebb shoal sand volume within the inlet budget cell is independent of the sand trap excavation, but linked to accumulations of sand volume from the south directed littoral drift.

Over the past 18 years, net sand volume gain in this cell is about 800,000 cubic yards (Figure 15). Within the overall inlet sand budget cell volume gains in the ebb shoal are partially balanced by sand volume losses in the flood shoal, which are largely driven by sand trap dredging at approximate 5-year intervals. An episode of sand volume losses of about 200,000 cubic yards is balanced some of sand volume accumulations of about 400,000 cubic yards between 2013 and 2018. A volume gain of 300,000 cubic yards was recorded in the winter 2022 survey followed by balancing annual volume losses and gains of about 250,000 cubic yards through 2023 and 2024. Sand volume gains during 2024 and recorded in the winter survey of 2025 added approximately 400,000 cubic yards of sediment to the inlet budget cell.

The interaction among the various sand reservoir components included in the overall inlet sand budget cells is further explained under Section 3 of this report dealing with sediment budget calculations. Sediment budget calculations consider the balance among the interior, upper inlet and lower inlet sand budget cells as shown in   Figure 3

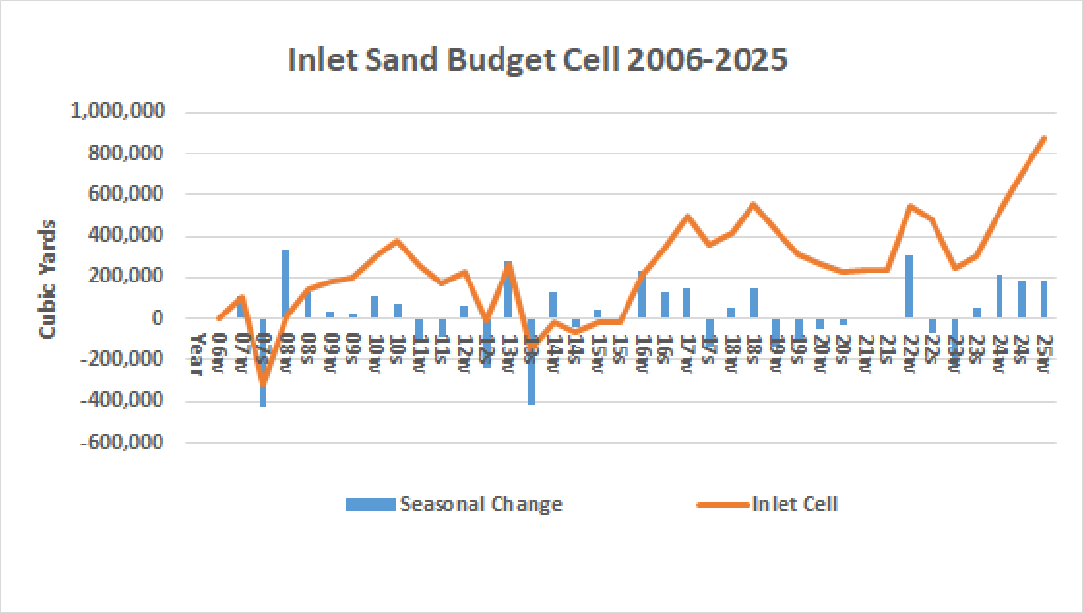


Figure 15. Volumetric evolution of the inlet sand budget cell 2006-2025

Inspecting the volume changes in the sand trap, flood shoal, and ebb shoal, as well as volume losses in the N1 cell just to the north of the inlet cell, shows that the post sand bypass volume gains in the inlet are due to a combination of sand trap infilling, flood shoal rebound, and sand releases from the N1 cell to the inlet. In addition to the link with excavation of the Sebastian Inlet sand trap, interannual variations in sand volume within the inlet budget cell may be influenced by interannual sea level fluctuations. Periods of decreasing sand volume correspond to periods of rising sea level, whereas period of sand volume increase correspond to periods of falling sea level along the Florida coast

The volumetric evolution of the S1 cell, situated between R4 and R10 immediately south of the inlet cell, is shown in Figure 16. The normal volume change pattern in this cell is a seasonal variation marked by volume gains in the winter and volume loss in the summer. A portion of this pattern is due to sand placement from the sand trap. Seasonal losses of about 100,000 cubic yards occurred in this cell though the summer of 2011 followed by a gain of about 150,000 cubic yards recorded in the winter survey of 2012 and another gain of about 50,000 cubic yards by the summer of 2012. These gains are, in part, due to 122,000 cubic yards of sand placed within the budget cell from the Sebastian Inlet sand trap. The volume gains of 2013 then dissipated by the summer of 2013 followed by a large volume gain in 2014 in the cell, again in part, due to sand bypass from the inlet sand trap. Large sand volume gains in all sand budget cells observed in the winter survey of 2014 indicate that there was a regional depositional event in this period that may be caused by onshore movement of sand from the lower shoreface. Sand volume gains of 2014 in the S1 cell were then passed to the S4 cell by the summer of 2015 as shown in Figure 19. Losses during this period from S2 and S3 were also passed to the S4 cell (Figure 17 and Figure 18). The S1 cell regained about 380,000 cubic yards of sand by the winter of 2018 due to large volume increases recorded by the winter 2016 survey and the post Irma survey of 2017, which served as the summer survey. Like 2014, there was a regional depositional event during this period as seen in the records of all sand budget cells from N4 to S4. A gain recorded in the 2019 winter survey captures some of the fill material bypassed form the sand trap. Although the official placement location for the fill was between R10 and R17, some of this material may have spread into the S1 cell as indicated by sand volume losses recorded in the S2 sand budget cell located between R10 and R17. A sand volume gain of about 81,500 cubic yards was measured between the late summer survey of 2018 and the late winter survey of 2019. The winter 2019 sand trap bypass project was followed by a large seasonal fluctuation in sand volume consisting of an approximate volume loss of 300,000 cubic yards recorded in the summer 2019 survey and a volume gain of more than 200,000 cubic yards recorded in the winter 2020 survey. A similar large sand volume fluctuation occurred within the N1 and N2 cells on the north side of Inlet sand budget cell (Figure 13 and Figure 14) and to some extend in the S2 and S3 cells to the south (Figure 17 and Figure 18). Seasonal sand volume changes in S1 between the winter survey of 2020 and winter survey of 2022 have been less than 100,000 cubic yards until the summer/fall survey of 2022 in which a sand volume gain of about 190,000 cubic yards was recorded. The source of this volume is likely a combination of bypassing across Sebastian Inlet of sand eroded from the N1 cell (Figure 14), volume loss from the flood shoal (Figure 9) and potentially onshore movement of sand from the effects of long period, but low waves along the east coast of Florida produced by Hurricane Ian.

After summer 2022, a large sand volume loss of about 200,000 cubic yards was recorded in   the winter 2023 survey after the two hurricanes of late 2022. Since that time, cell S1 has gained back about 270,000 cubic yards of sand volume largely due to gains between summer 2024 and winter 2025. Similar gains in the seasonal also occurred in the S2, S3 and s4 sand budget cells. Net volume change in the S1 cell from 2006 to 2025 is a gain of about 30,000 cubic yards due to natural sand bypassing across Sebastian Inlet and Sand Trap bypass projects.

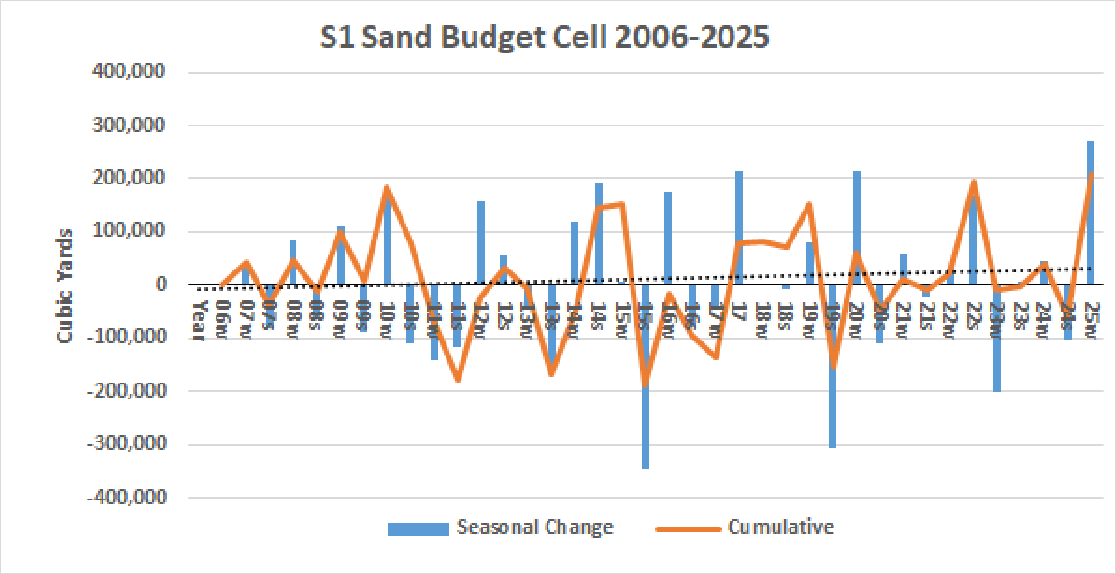


Figure 16. Volumetric evolution of the S1 sand budget cell 2006-2025

Sand volume changes in the S2 cell (Figure 17, R-10 – R16) are a combination of regional and littoral drift gains and sand placement by the SID and Indian River County (IRC). . Gains the in 2010, 2014 and 2016 are part of regional depositional events followed by sand volume losses over the following year. Sand volume losses sequentially recorded by three surveys between the summer of 2018 and summer 2019 totaling about 380,000 cubic yards were balanced by sand volume gains totaling about 330,000 cubic yards in the 2020 surveys. The 2019 sand bypass project placed approximately 113,500 cubic yards of sand excavated from the sand trap in the S2 budget cell. Apparently, a substantial portion of this volume was back-passed to the S1 cell where a gain of approximately 80,000 cubic yards was recorded in the winter 2019 survey. The large 2020 sand volume gains in the S2 cell may indicate that much of the sand trap material eventually returned to the S2 cell. Sand volume losses continued in this cell between summer 2020 and the summer survey of 2024 totaling about 300,00 cubic yards. Sand losses were a combination of seasonal losses of up to 100,000 cubic yards that were not completely balanced by seasonal gains. However, the large sand volume gain recorded in the winter 2025 survey in this cell and the other adjacent cells helped to offset the multiyear trend of loss. Over the 18-year period between 2006 and 2025, the volume change in the S2 cell was a net loss of about 270,000 cubic yards.

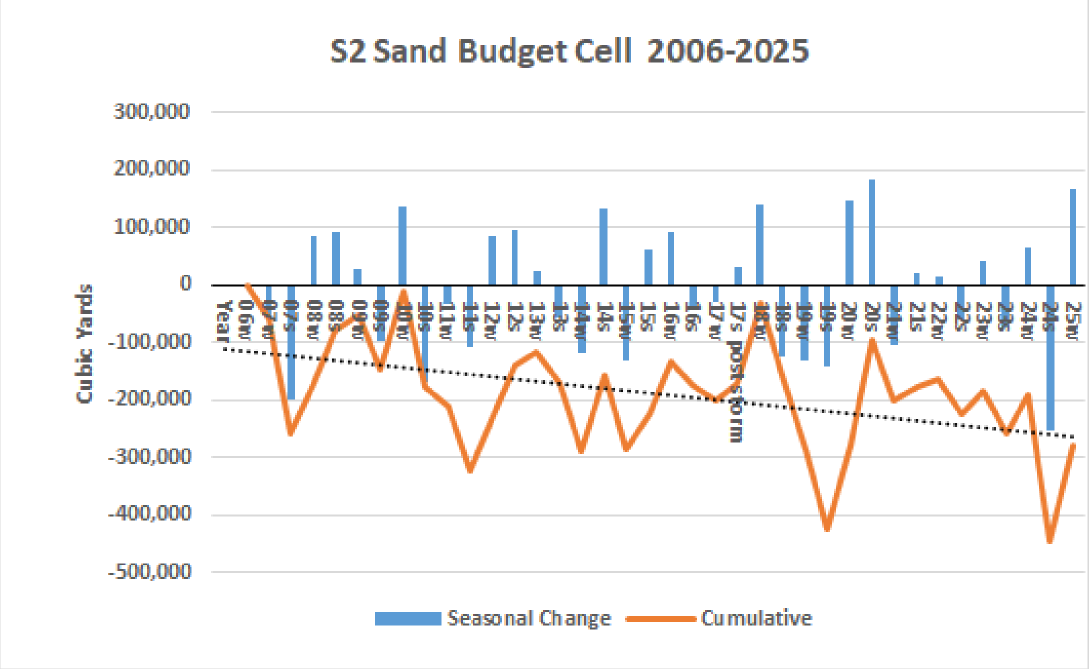


Figure 17. Volumetric evolution of the S2 sand budget cell 2006-2025.

Sand volume changes in the S3 cell (Figure 18) located between R16 and R23 have a more consistent seasonal pattern of gains followed by losses compared to S2 sand budget cells. However, gains are not always in the winter and losses in the summer. The regional sand volume gains of 2010, 2014, and 2016 and 2020 are noted in the S3 record. Some of the gains in the S3 cell are offset by one season from a sand gain-loss cycle in cells father to the north indicating transfer of sand to the south by littoral drift. A net sand volume loss of about 318,000 cubic yards between 2006 and winter 2018 is attributed to a series of seasonal losses not completely balanced by sand volume gains in the following season. This was partially offset by a large seasonal gain of about 194,00 cubic yards between the winter and summer surveys of 2018. This was followed by a sand volume loss of about 168,000 cubic yards as recorded in the winter 2019 topographic survey data. One of the larger seasonal losses of sand volume occurred in the winter of 2015 of about 350,000 cubic yards. This event was also seen in most of the other sand budget cells. Sand volume losses totaling about 270,000 cubic yards was partially balanced by sand volume gains in S2 of about 110,000 cubic yards recorded in the winter 2020 survey. As suggested for 2020 volume gains in the S2 cell, 2020 gains in S3 may be the result of sand drifting south that included beach fill from the 2019 sand trap project. Sand volume change between summer of 2020 and summer/fall 2022 surveys included a net decline of about 150,000 cubic yards including balancing seasonal fluctuations of more than 200,000 cubic yards. Both 2023 surveys show a sand volume gain of about 100,000 cubic yards each. This was followed by a balancing sand volume decline of about 270,00 cubic yards recorded in the winter 2024 survey. The 300,000 cubic yard gain recorded in the 2025 winter survey more than offset the 2024 loss. Net volume change in this cell between 2006 and 2024 is a decline of about 260,000 cubic yards.

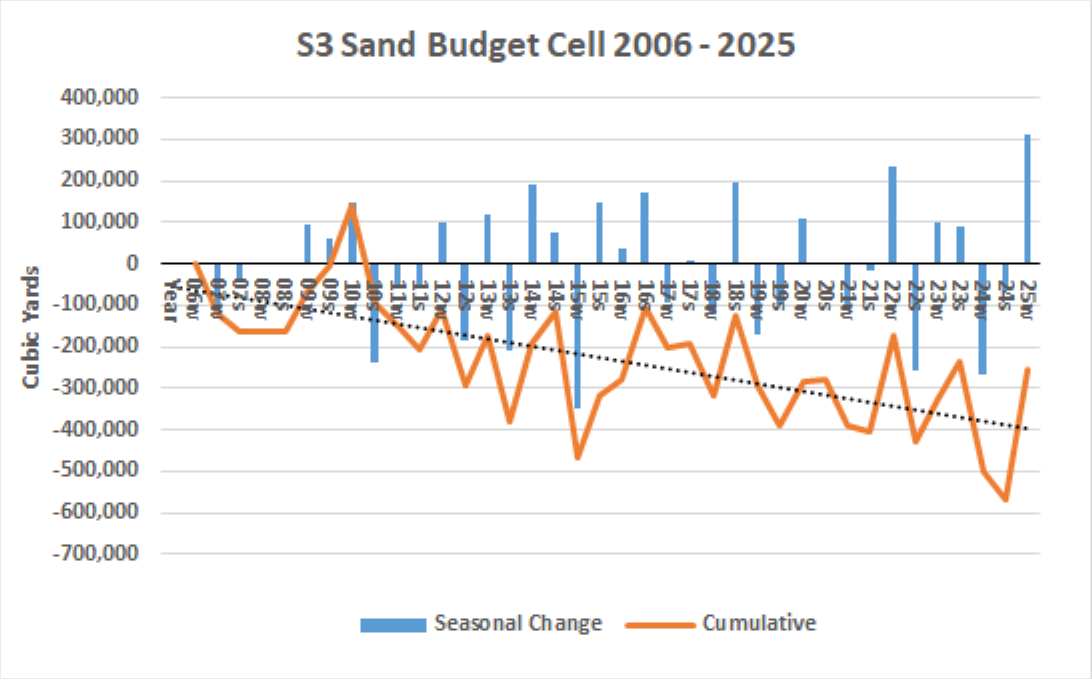


Figure 18. Volumetric evolution of the S3 sand budget cell 2006-2025.

The S4 sand budget cell (Figure 17, located between R23 and R30 (Figure 2) like S3, has an imbalance between seasonal gains and losses that add up to a net cumulative volume loss of about 480,000 cubic yards between 2006 and 2025. The seasonal pattern of sequential gains and losses is not as consistent as seen in the S2 and S3 cell. Seasonal offsets between S4 and sand budget cells to the north indicate the role of sand movement in the littoral drift system.

The regional sand volume gains of 2010, 2014, 2016, 2018 in some cases 2020 are not apparent in S4. However, the magnitude of the regional and seasonal gain recorded by the winter 2025 survey was 270,000 cubic yards. Summing all of the seasonal gains and losses of sand over the 18-year period of record yields a net sand volume loss in the budget cell of about 475,000 cubic yards,

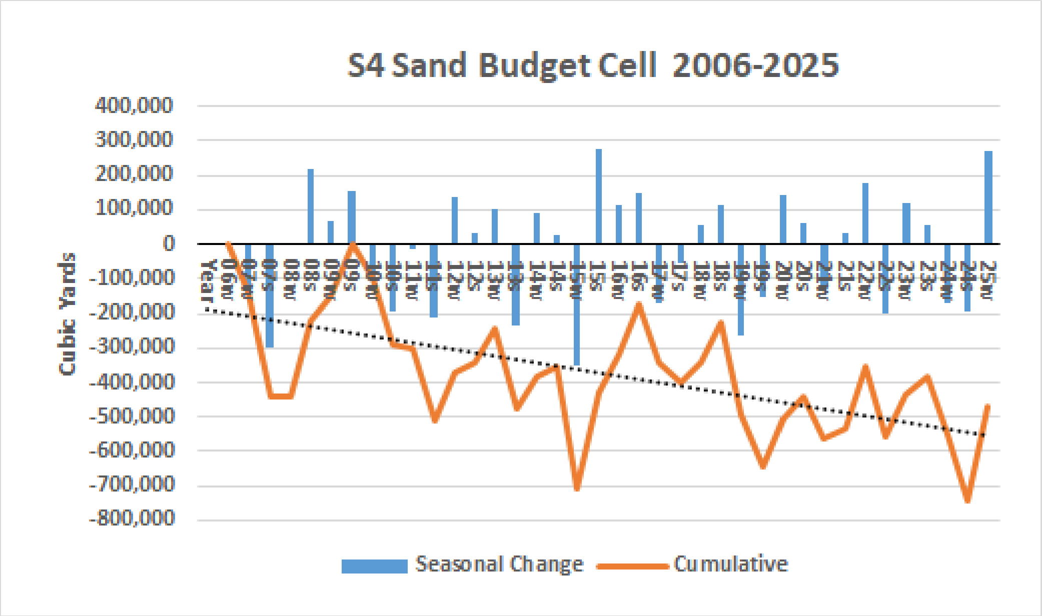


Figure 19. Volumetric evolution of the S4 sand budget cell 2006-2025.

2.4 Analysis of Sand Volume Changes, 2006 – 2025

To view trends among the sediment budget cells Figure 20 compares sand volume changes in sediment budget cells on the north side of Sebastian Inlet (N4 – N1) along with the inlet sediment budget cell. The overall pattern of trends is the same for all four sand budget cells on the north side of Sebastian inlet and includes declining sand volume from winter 2009 through summer 2016 (Figure 20), punctuated by seasonal gains and losses. In cells N4 through N2, sand volume declines reverse to volume gains through summer 2019, followed by sand volume declines in 2020 through the winter survey of 2021 . In the N1 cell just north of the Inlet sand budget cell, the sand volume gains end with the summer 2017 survey, followed by a net loss of sand volume through the summer of 2020. These trends reversed in the winter 2021 survey, followed by net volume declines into the winter survey of 2023 in all 4 budget cells due to the hurricane impacts of late 2022. Over the next year, the north budget cells registered large volume gains of up to 170,000 cubic yards (summer 2023 survey), followed by sand volume losses in all north cells. This corresponded to the large sand volume gains in the overall inlet budget cell that reached more than 550,000 cubic yards.. The volume pattern between the inlet call and the north cells was inversely correlated from the summer 2023 survey to the winter 2025 survey. This indicates the passing of sediment volume from the north into the inlet area.

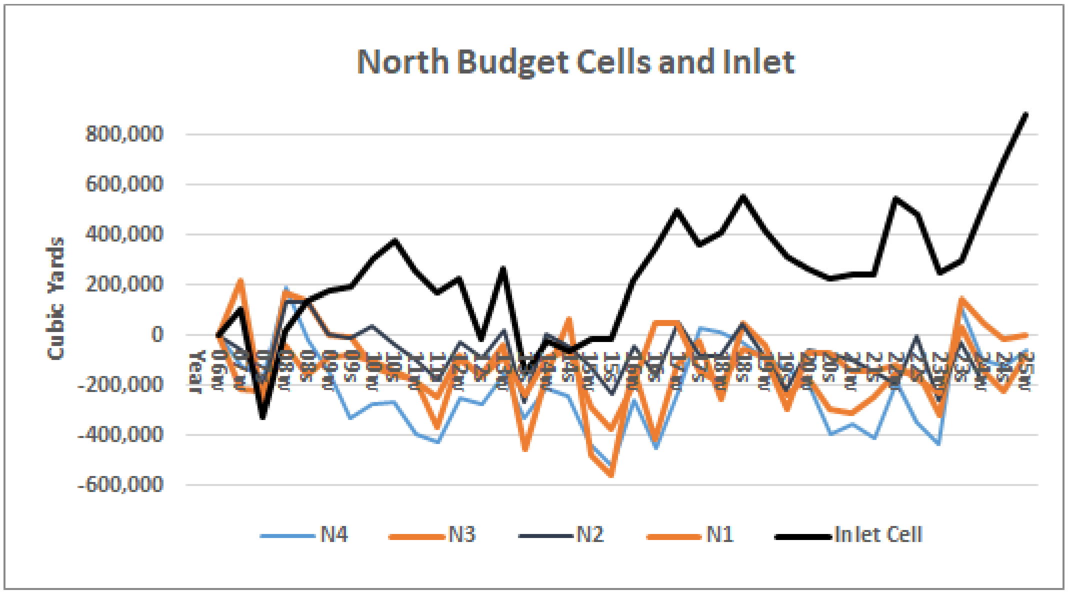


Figure 20. Comparison of sand volume changes within the Sebastian Inlet sediment budget cells N4 to N1 and in the inlet budget cell from 2006 to 2024.

Figure 21 compares sand volume changes among sand budget cells on the south side of Sebastian Inlet (S1 – S4). Trends and patterns on the south side of Sebastian inlet in each of the sand budget cells are similar to those in budget cells on the north side of the Inlet, with the exception of the 2024-2025 period. From summer 2024 to winter 2025 all of the sand budget cells to the south of Sebastian Inlet registered strong volume gains on the order of 200,000 cubic yards in each cell. This is evidence that sand volume losses from summer 2023 to summer 2024 in the N4- N1 cells that produced sand volume gains.

to the inlet cell, produced the 2024-2025 sand volume gains in the south cells.

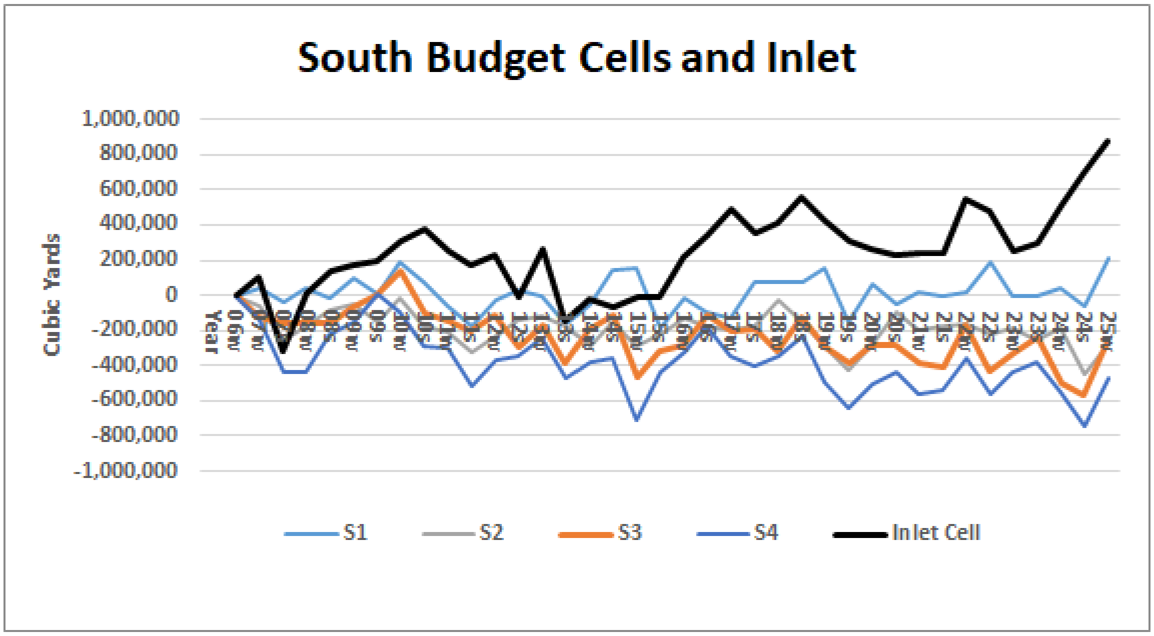


Figure 21. Comparison of sand volume changes within the Sebastian Inlet sediment budget cells S1 to S4 along with the inlet budget cell from 2006 to 2025.

As stated in the 2024 State of the Sebastian Inlet report (Zarillo et al, 2024) there is correlation between interannual sea level trends and changes in shoreface sand volumes. Figure 22 compares the 2006 to 2025 sea level record, filtered to emphasize interannual trends, and with the sand volume records from the S2 budget cell. There is an inverse relationship between sand volume and sea level. Higher sea levels correspond to lower sand volume contained within the S3 cell. Likewise, lower sea levels correspond with intervals of higher sand volume. The interannual trends of rising sea levels from 2010 to 2015 correspond to a 6-year trend of declining sand volume in the S2 budget cell. Sand volume in S2 increased from 2015 to 2018 in a period of falling sea level. This was followed by a large sediment volume decline from 2018 to 2020 due to a jump in sea level. Another period of rapid sea level rise from mid-2021 through the winter of 2024 corresponded to an approximate 50,000 cubic yard decline in sediment volume within S2. The correspondence in time is not exact and can be offset by a season due to the data filter methods and lag time between sea-level changes and shoreface sediment volume response.

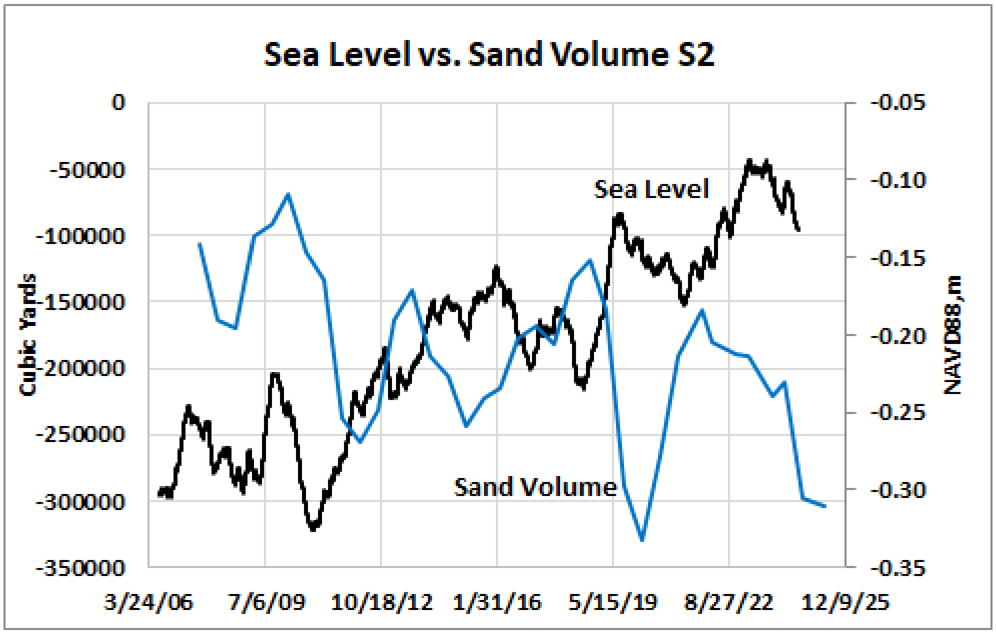


Figure 22. Comparison of the 2006 to 2025 sea level record with the filtered sand volume change record of the S2 budget cell.

The example shown in Figure 22 indicates that sea level change is a primary control over periods of sand volume increase or decrease within the central Florida coast surrounding Sebastian Inlet. Figure 23 compares the central Florida coast sea level record from 2006 to 2024 with measured cumulative volume changes in each sand budget cell over the same period. Sand volume versus sea level change is shown in pairs of sand budget cells beginning with cells N1 and S1 and progressively with distance from Sebastian Inlet. Overall, the relationship is like that shown in Figure 22. Sand volume increase in sand budget cells corresponds to lower sea levels, whereas periods of sea level rise correspond to trends of sand volume loss.

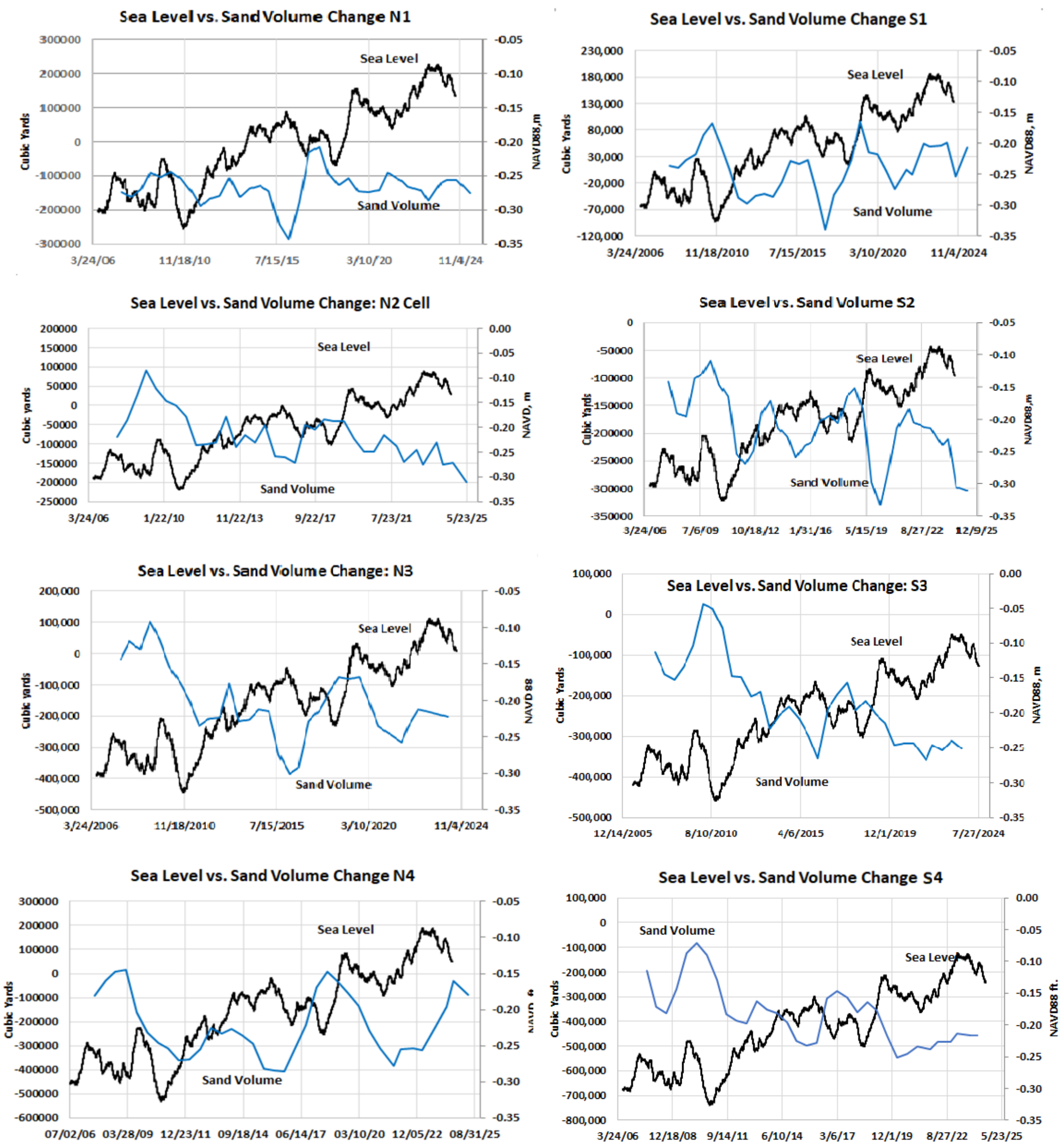


Figure 23. Comparison of sea level changes, cumulative sand volume changes within the sand budget cells to the north and south of Sebastian Inlet

3.0 Sand Budget: Sebastian Inlet and Surrounding Barrier Segments

3.1 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:

$$\Sigma Q_{source} - \Sigma Q_{\sin k} - \Delta V + P - R = residual$$

Equation 1

The sources (Qsource) and sinks (Qsink) 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). Figure 24 schematically shows how calculations are made within each cell of the sediment budget model.

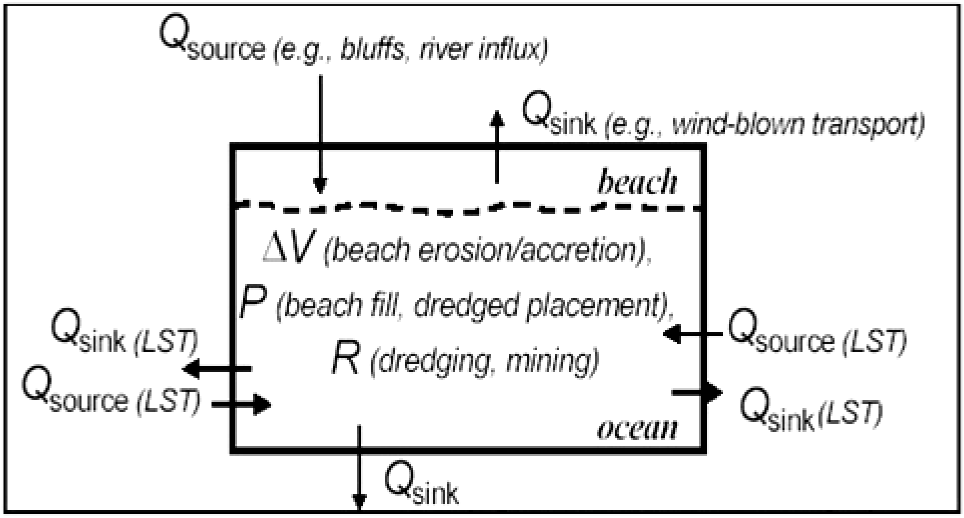


Figure 24. Schematics of a littoral sediment budget analysis (from Rosati, 2005).

The determination of net volume change for the local sediment budgets for Sebastian Inlet was based on volumetric analysis masks presented in section 2, of this report. The sediment budget encompasses the area between Monument R189 in Brevard County to Monument R30 in Indian River County. Since variability of the seasonal sand volume changes can be larger than the average range of values in the sediment budget, the temporal scale of the calculations is based on time periods of 10 and 18 years between 2007 and 2025. The computational cells (masks) that were used to establish the local sediment budget are shown in the Figure

3. As described in Section 2 and shown in Figure 3, the consolidated sediment cells are divided into beach/shoreface and lower shoreface components. Accordingly, 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 (SBAS) program provided by the U.S. Army Corps of Engineers 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, an initial input value (Qsource) of 150,000 yd3/yr. was specified. The placement values (P) correspond to the beach fill projects that were included in the calculations. Most of sand placement is to the south of Sebastian inlet in the S2 and S3 sand budget cells from either the Sebastian Inlet sand trap or from upland sources accessed by Indian River County. However, beginning in 2016, placement in the N1 to N4 cells are associated with post-hurricane repair of beaches in south Brevard County. Removal of sand (R) through mechanical bypassing was included to account for the 2012, 2014, 2019, and winter 2025 dredging projects within the sand trap. Placement and removal values are annualized and presented in Table 2.

Table 2. Annualized placement (P) and removal (R) volumes for sand budget calculations. Units are in cubic yards per year.

Time Period	Season	N4	N3	N2	N1	Inlet (R)	S1	S2	S3	S4
2007-24	**Summer**	**1,960P**	**451P**	**1,378P**	**918P**	**26,276R**	**16,840P**	**17,695P**	**8,911P**	**22,006P**
2007-25	**Winter**	**1,851P**	**426P**	**1,301P**	**867P**	**32,428R**	**21,153 P**	**21,809P**	**8,472P**	**24,478P**
2014 –24	**Summer**	**991P**	**766P**	**2,342P**	**1,561P**	**0 R**	**11,120P**	**25,508P**	**10.938P**	**18,014P**
2015–25	**Winter**	**991P**	**1,635P**	**P**	**1,561P**	**21,826R**	**5,165P**	**33,254P**	**11,040P**	**27,508P**

3.2 Sand budget results

The sand budget is presented in two distinct time scales of 10 years of 17and 18 The budget uses calculated annualized volume change per cell as inputs (see Figure 2). Annualized beach fill material is accounted for in the N4 to N1 cell on the north side of Sebastian Inlet, the inlet cell, and the S1 to S4 cells a shown in Figure 2. Interpretation of the fluxes, especially those leaving the southernmost cell (S4, R16-R30) must consider that the sand budget assumes a fixed input rate of either +150,000 or +200,000 cubic yards per year entering the first north cell (N4). Net sand transport was assumed to flow north to south. However, over shorter seasonal time scales, local reversals of littoral drift can occur, especially in the vicinity of the entrance of Sebastian Inlet. The overall sand volume loss from the beach/upper shoreface cells, which extend to a depth of about -20 feet NAVD88 is attributed to an extended period of rapidly rising sea level combined with tropical storms in this period, which facilitate episodes of erosion.

Figure 25 Illustrates results of the 18-year sand budget analysis bounded by the winter surveys of 2007 and 2025. The upper beach/shoreface sand budget cells on the north side of the inlet registered annualized sand volume gains, except for the N1 cell adjacent to the Sebastian Inlet. . The calculation begins with an input of 150,000 cu/yd per year into cell N4 and assumes net south littoral transport. In order keep the littoral transport rate of about 150,000 cu/yd, cross shore sand transport to and from the lower shoreface cells are applied Lower shoreface sand budget cells near Sebastian Inlet registered net volume gains and are balanced by cross-shore transport from the upper beach/shoreface cells or upper inlet cell to the lower shoreface. An additional source for deposition on the lower shoreface surrounding the inlet could be sediments from the multiple sand bypass projects from the sand trap conducted between 2007 and 2019. The texture of these lower shoreface sands is in the fine to very fine sand range compatible with lower shoreface energy environment and with the fine sand textures of the sand trap material.

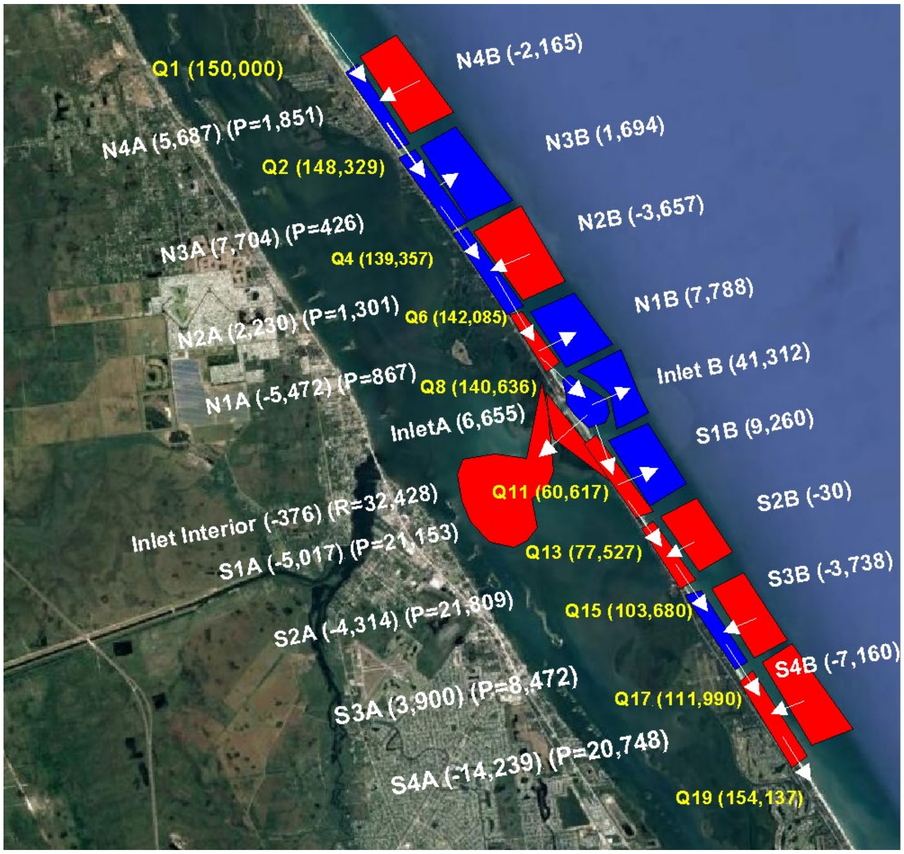


Figure 25. Annualized 18-year sediment budget for the winter 2007 to winter 2025. Values on the west of the barrier island indicate sand volume changes and values on the east indicate calculated sand flux rate in cubic yards per year. P= annualized placement quantities and R = annualized value of sand removed from the sand trap. Blue cells indicate sand volume increase whereas red cells indicate sand volume loss.

The sand retention rate over the 18-year period can be computed by adding annualized and volume changes across the lower, upper, and interior inlet sediment budget cells and accounting for the difference in annualized volume changes in the interior of the inlet and annualized volume removed from the sand trap. In the winter 2007 to 2025 sediment budget, the annualized sand volume accumulation among the inlet-related sediment reservoirs is about 47,600 cubic yards per year. On the south side of Sebastian Inlet, the upper shoreface/beach sand budget cells mostly registered moderate annualized sand volume losses that were mitigated by sand bypass projects from the Sebastin Inlet Sand Trap and other episodic beach projects over the 18-year period. Budget cell 3A, however registered sand annualized volume gain of about 4,000 cubic yards. The lower shoreface cell 1B adjacent to the inlet had an annualized gain of about 9,300 cubic yards, which may be partially due to the finer fractions of beach fill sand being transported to the lower shoreface. Lower shoreface budget cells register moderate annualized volume losses, which in this analysis were assumed to be transported to the upper shoreface cells, in order to balance the sand budget and provide appropriate rates of littoral and transport along the upper shoreface and beach. Given these assumptions and observed sediment volume changes over the 18-year analysis period , the calculated littoral drift rate out of the south end of the sand budget is approximately 154,000 cubic years per year or nearly the same as the initial assumed annual rate arriving at the north end of the sand budget.

The 17-year summer-to-summer sand budget is shown in Figure 26. In this sand budget calculation, based on annualize sand volume changes in the beach/upper shoreface and lower shoreface cells most of the lower shoreface cells registered a net volume loss. However, these losses were applied to the beach/upper shoreface cell to maintain sand volume balance and provider realistic rates of littoral transport (Q-values). The beach/upper shoreface and budget cells north of Sebastian Inlet all registered sand volume gains derived from littoral sand moving in from the north and some onshore movement from the lower shoreface. The inlet budget cells all registered sand volume gains for the period, amounting to an annualized gain of about 61,000 cubic yards per year. The majority of Sediment budget cells on the south side of Sebastian Inlet registered sand volume losses, except for the lower shoreface S1 cell and the beach/upper shoreface S4 cell at the south end of the sand budget. Sand volume losses on the lower shoreface were assumed to be added to the upper shoreface to keep the littoral transport from reversing in the transport (Q-value) calculations. The net transport rated leaving the sand budget at the south end was calculated at about 147,000 cubic yards per year, which is close to the transport rate arriving at the north end of the calculation.

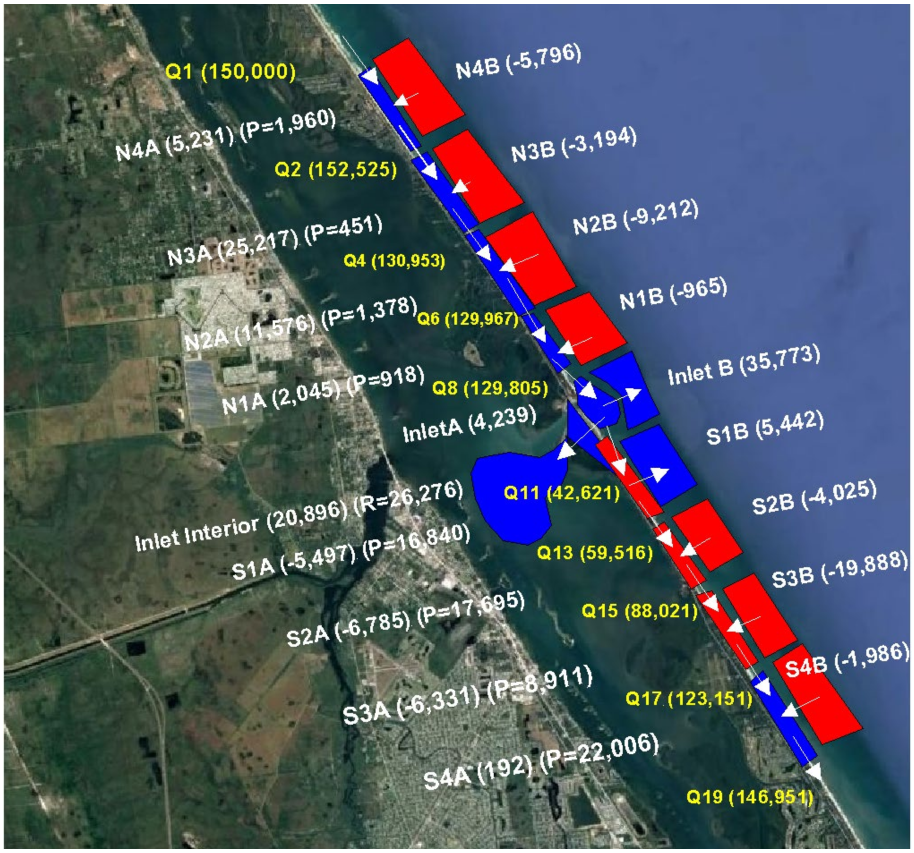


Figure 26. Annualized 17-year sediment budget for the summer 2007 to summer 2024. Values on the west of the barrier island indicate sand volume changes and values on the east indicate calculated sand flux rate in cubic yards per year. P= annualized placement quantities and R = annualized value of sand removed from the sand trap. Blue cells indicate sand volume increase whereas red cells indicate sand volume loss.

The summer-to-summer 10-year sand budget between 2014 and 2024 except for the budget cells including and adjacent to Sebastian Inlet . This 10-year budget was initiated with a higher rate of annualized littoral drift at 200,000 cubic yards in order to accommodate the larger annualized volume changes recorded in many of the upper and lower shoreface cells. In this interpretation, sand volume losses from the lower shoreface cells are directed offshore to balance the volume budget and keep the upper shoreface cells from having unreasonably large net littoral drift rates. The annualized sand volume accumulation rate included in the inlet sand budget cells was calculated at about 72,000 cubic yards per year. On the south side of Sebastian Inlet, several of the beach/upper shoreface cells required seaward-directed cross-shore transport, along with longshore sand transport to keep the littoral drift (Q) values) from becoming unreasonably large. Calculated net longshore drift at the southern end of the region was nearly equal to the 200,000 cubic yards of littoral drift assumed to arrive at the north end and directed south.

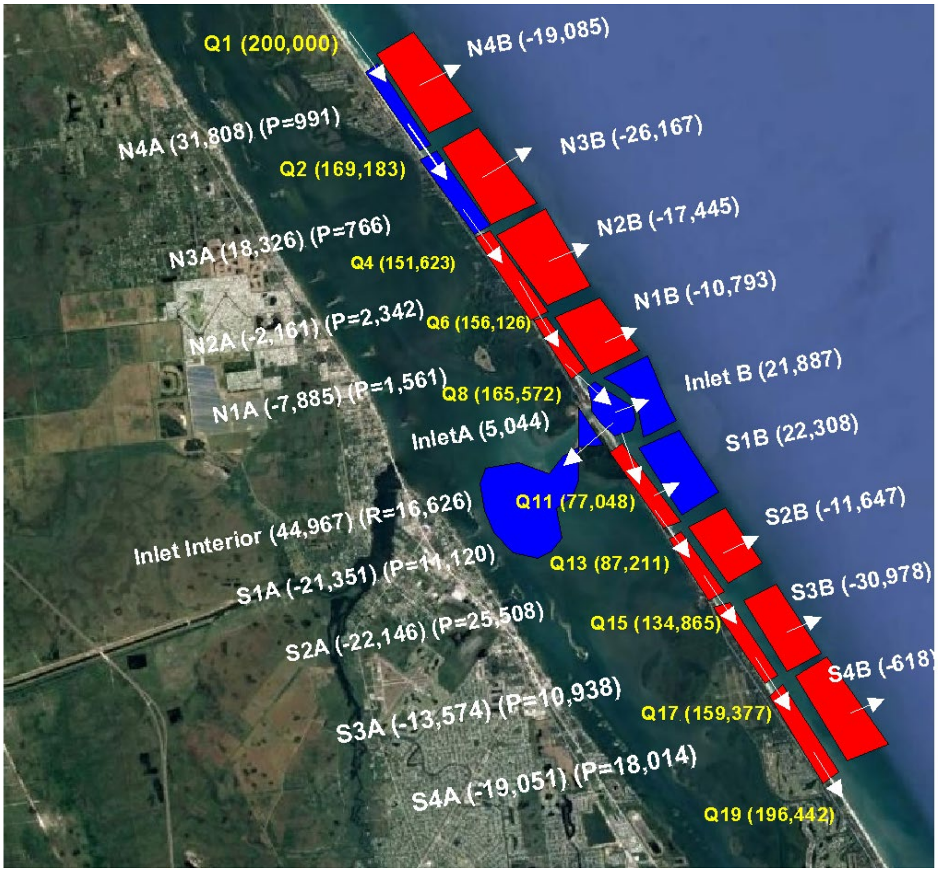


Figure 27. Annualized 10-year sediment budget for the winter 2014 to winter 2024 period. Values on the west of the barrier island indicate sand volume changes and values on the east indicate calculated sand flux rate in cubic yards per year. P= annualized placement quantities and R = annualized value of sand removed from the sand trap. Blue cells indicate sand volume increase whereas red cells indicate sand volume loss.

The analysis results for a 10-year sand budget based on the winter-to-winter period between 2015 and 2025 show a period of volume recovery among the beach/upper shoreface cells amplified by strong sand volume gains in the S1 to S4 cells on the south side of the inlet. There were also periods of sea level drop from 2014 to 2017, 2019 to 2021, and 2022 to 2025. However, as seen in Figure 28, annualized sand volume gains in the beach and upper shoreface cells are similar in magnitude to annualized placement volumes in this 10-year period. Any volume contributions by onshore movement from the lower shoreface would be of secondary importance to the upper shoreface gains. In sand budget cells on the north side of the inlet contributions from the lower shoreface would also be of secondary importance along with the small amount of beach fill placed by Brevard County in this 10-year period. The initial littoral transport rate into the sediment budget calculations was set to 200,000 cubic yards per year in recognition of the over 1,000,000 cubic yards of beach fill placement by Brevard County in beach areas to the north. Between 2015 and 2025, approximately 1.1 million cubic yards of sand were placed directly on Brevard County's c beaches through federal and local beach nourishment projects. Some of this fill material is likely moving southward, ultimately reaching the Sebastian Inlet area. Sand budget cells within and adjacent to Sebastian Inlet accumulated sand volume at a rate of about 80,000 cubic feet per year as calculated in this budget.

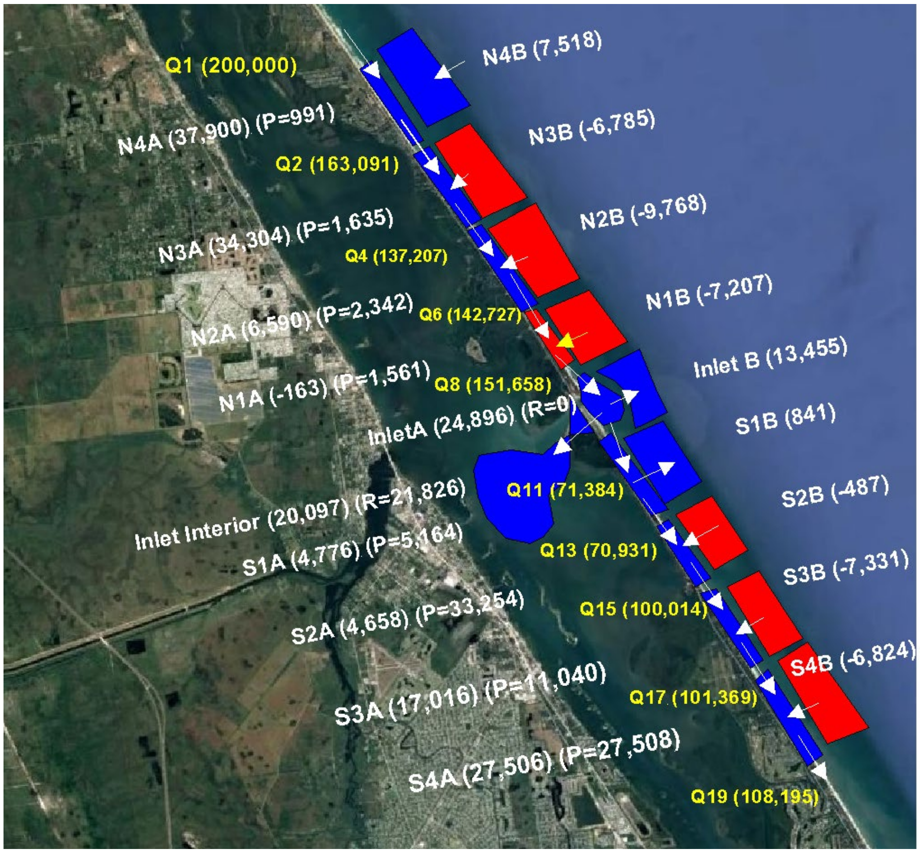


Figure 28. Annualized 10-year sediment budget for the 2015 to winter 2025 time period. Values on the west of the barrier island indicate sand volume changes and values on the east indicate calculated sand flux rate in cubic yards per year. P= annualized placement quantities and R = annualized value of sand removed from the sand trap. Blue cells indicate sand volume increase whereas red cells indicate sand volume loss.

4.0 Morphologic Changes

4.1 Methods

The analysis uses the same datasets and overall methodology applied to the sand volume analysis and sand budget analysis described under Sections 2 and 3 . The morphologic change section is subdivided according to the periods associated with sediment budget calculations presented in Section 3. In the color convention for figures depicting topographic change; blue spectrum colors are assigned to erosion, whereas red and orange colors indicate deposition areas. Topographic changes were combined with results from shoreline changes and sand budget calculations for a better understanding of the sedimentation processes. The overall conclusion is that larger topographic changes occur on the sediment-rich upper shoreface, combined with much smaller changes at depths of 15 to 40 feet NAVD88.

4.2 Topographic Change 2007 to 2025

A perspective view of the regional topography is shown in Figure 29 based on the winter 2025 topographic survey. On the north side of Sebastian Inlet, the slope of the shoreface is steeper compared to the shoreface configuration to the south side of Sebastian Inlet. The width of the active shoreface profile to the south of Sebastian Inlet is set by an elevated rock terrace composed of lithified late Pleistocene carbonate- rich coastal sediments. Sebastian inlet is located at the elevation change in the rock surface, and the history of its position before being stabilized by the present jetties may have been controlled by the step-up in the elevation of the rock terrace.

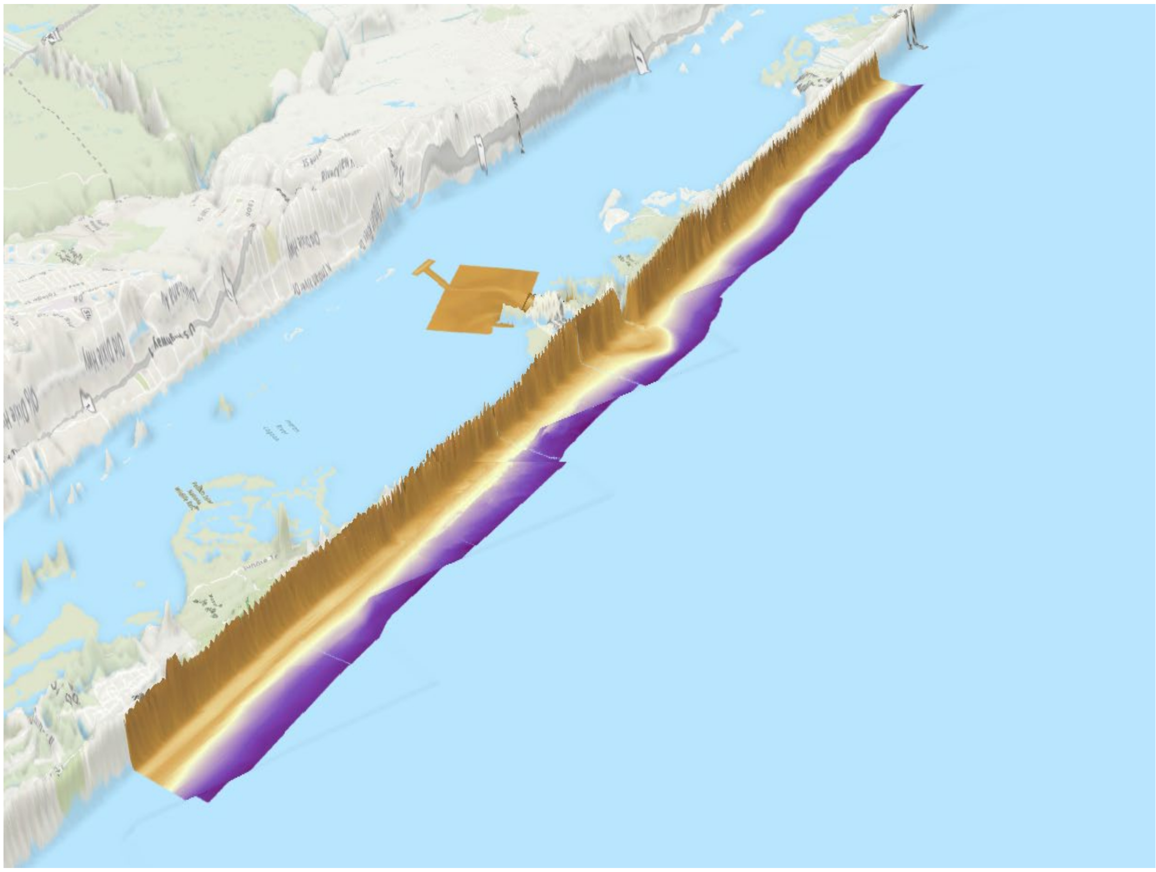


Figure 29. Perspective view of regional topography near Sebastian Inlet. Vertical exaggeration is 30x,

Calculated Net topographic changes between 2006 and 2025 are shown in Figure 30. The pattern of topographic changes indicates that the largest topographic changes take place on the shoreface at depths shallower than about 15 feet, which is the approximate wave base along the central Florida coast. Deposition and an increase in topographic elevation are also apparent over the ebb shoal area along with broader areas wrapping around the crest of the ebb shoal. The Blue spectrum patterns increase in coverage with increasing distance north and south of Sebastian Inlet, which is consistent with sand budget calculations seen in Figure 25 Inspection of topographic changes within each of the sand budget cells suggests the need to subdivide the existing cells into upper shoreface and beach components, and a separate set of sand budget cells that extends from the base of the shoreface onto the inner continental shelf.

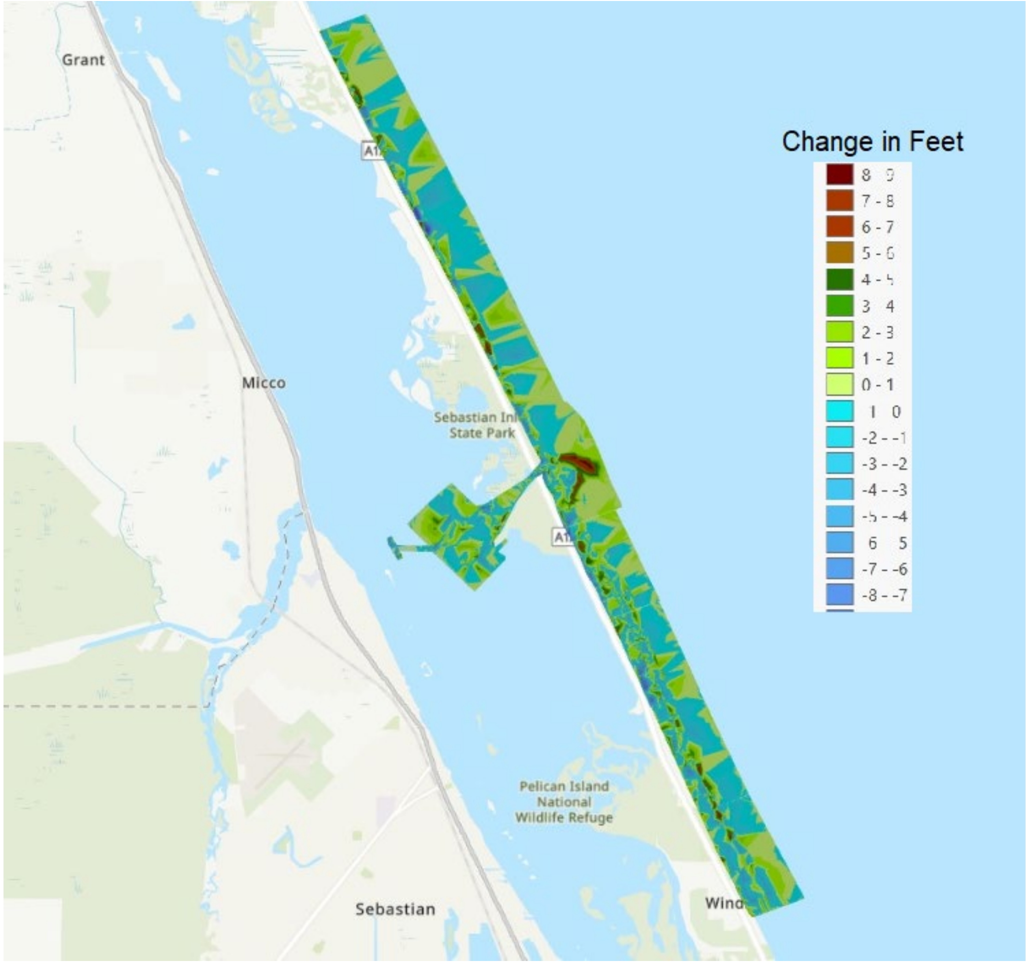


Figure 30. Net topographic (elevation) changes between 2007 winter to 2025 winter associated with the 17-year sediment budget calculation

Figure 31 shows the net topographic change between 2006 and 2024 in a summer-to-summer comparison. The patterns of deposition and erosion are similar to the 18-year winter-to-winter analysis, except that the flood shoal and sand trap areas have greater topographic elevations in terms of deposition and infilling

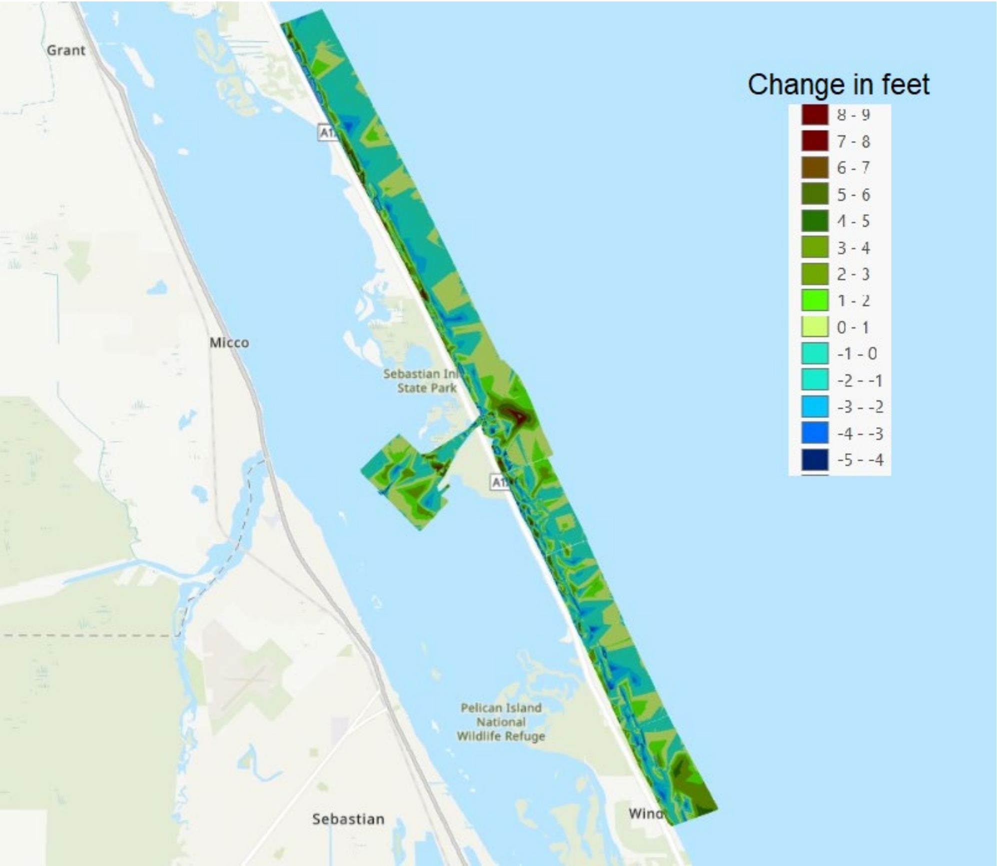


Figure 31. Net topographic (elevation) changes between 2007 summer to 2024 summer associated with the 17-year sediment budget calculation

Topographic changes associated with the 10-year summer-to-summer 2014-2024 sand budget are shown in Figure 32. Blue spectrum patterns are more dominant on the lower shoreface except in the area of deposition around the inlet entrance, including the ebb shoal. In the flood shoal area, deposition is apparent along with the blue spectrum linear features that are the signature of the shallow channels. The 2014 to 2024 period includes the use of multibeam topographic data collection from the inlet entrance southward to approximately R-20. The linear blue spectrum features at approximately fair-weather wave base indicate erosions along the rock reef outcrops. The topographic pattern is consistent with sediment budget calculations shown in Figure 27 showing erosion in the upper and lower shoreface sand budget cells and deposition in, and around the inlet budget cells.

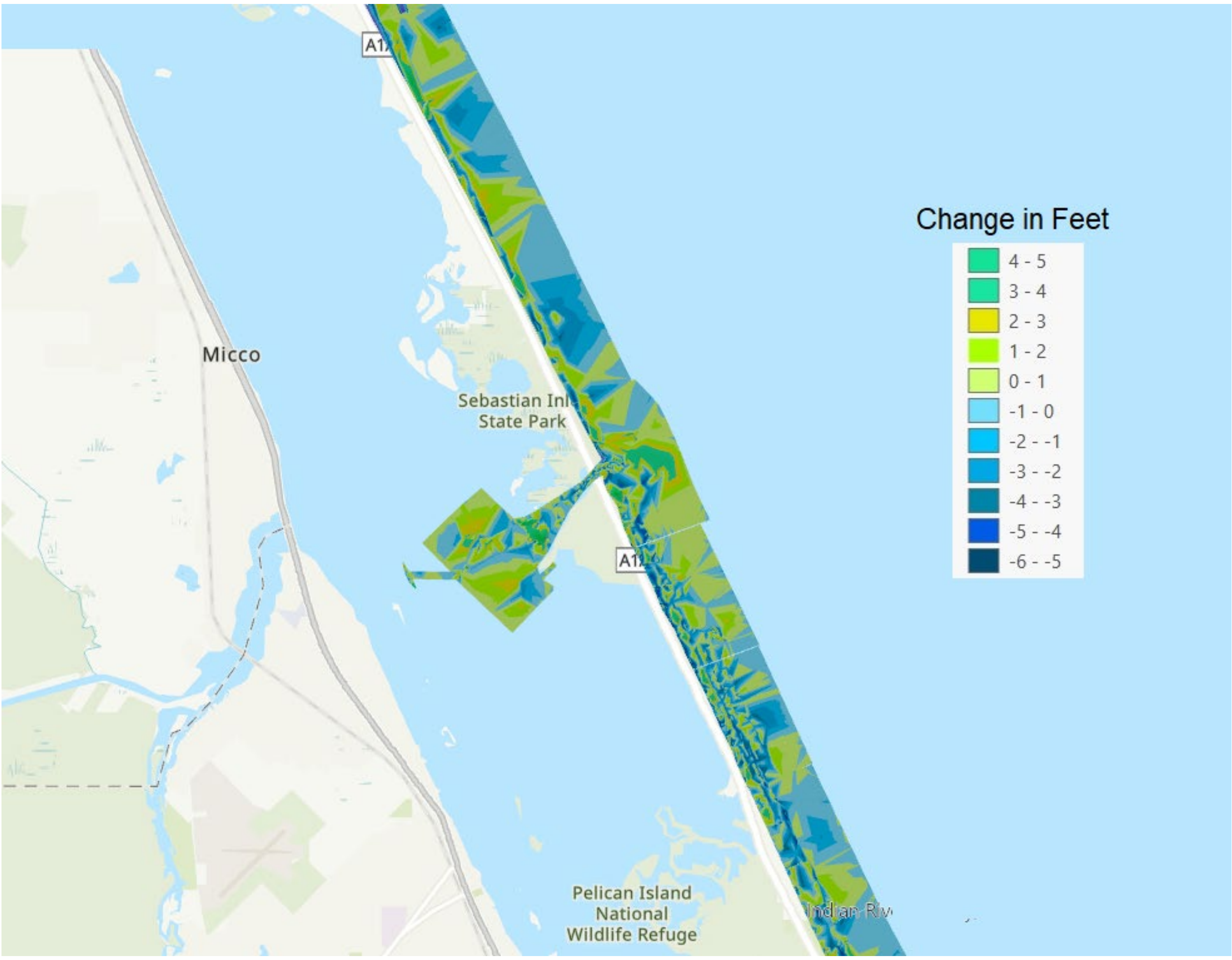


Figure 32. Net topographic (elevation) changes associated with the 2014 summer to 2024 summer associated with the 10-year winter to winter sediment budget calculation

Figure 33 shows the net topographic change from the winter-to-winter comparisons of 2015 to 2025. The correlation with the sediment budget calculation for this period (Figure 28) is most recognizable north of Sebastian Inlet, where deposition dominates the upper shoreface and segments of the beach, whereas sand volume loss dominates the lower shoreface. Depositional areas wrap around the entrance of Sebastian Inlet and extend into the interior over the flood shoal areas. On the south side of the inlet. Topographic elevation increase (red spectrum colors) dominate the upper and lower shoreface between R-2 and R-10 (Figure 34), which is consistent with the sand budget cells shown in Figure 28. Further south, erosion (blue spectrum) becomes more apparent on the lower shoreface, where sand volume loss is evident in the sand budget cells. The upper shoreface, to the south of R-10, maintains enough deposition (red spectrum colors) to render upper shoreface as a net deposition area in the sand budget calculation.

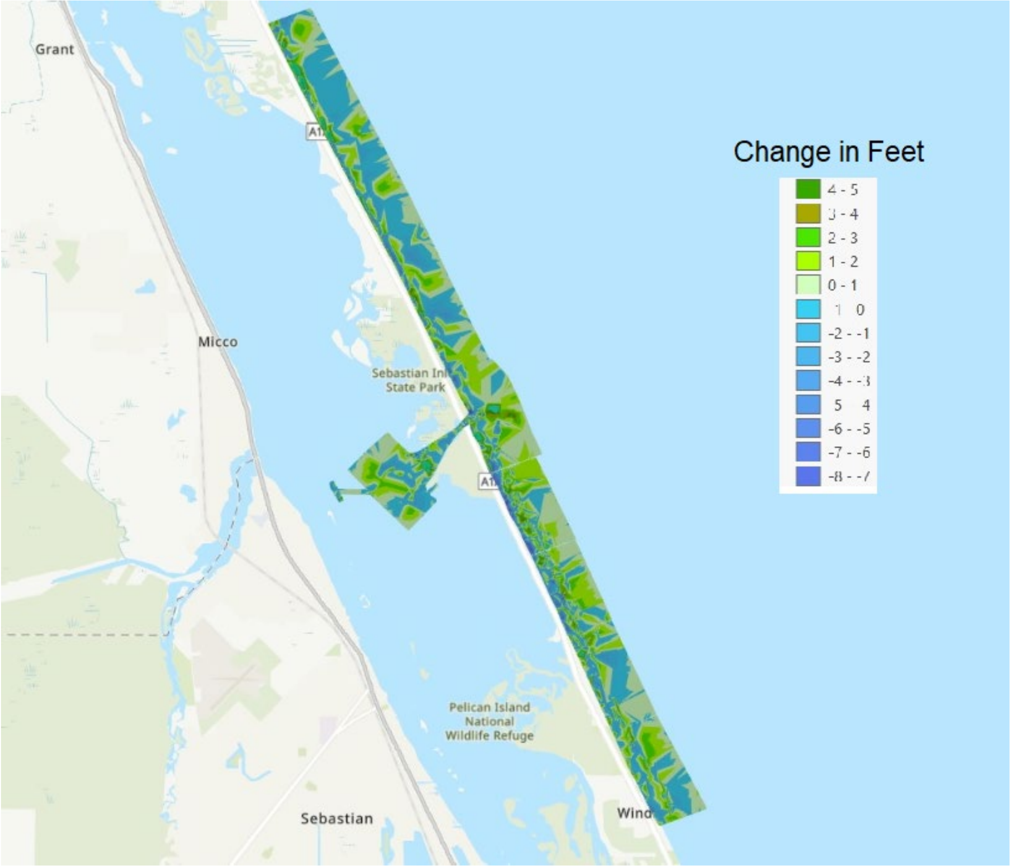


Figure 33 Net topographic (elevation) changes from winter 2015 to winter 2025 associated with the 10-year winter-to-winter budget calculation

Figure 34 shows the annual difference in topography calculated from the winter surveys of 2024 and 2025. A sand budget calculation is not attempted for these short intervals, but the deposition and erosion patterns reflect the large short-term seasonal volume changes that can occur, as seen in the seasonal volume change calculations shown in Section 2 of this report. A patchwork of deposition and erosion of up to several feet in topographic expression is noticeable at the entrance of Sebastian Inlet extending across the ebb shoal and to the base of the shoreline, at depth of -40 feet.

A small zone of blue in the inlet interior marks an area that was dredged during the winter 2025 sand bypass project. The deposition on the beach and upper shoreface between R4 and R10, corresponding to sand buffer cell S1 is the signature of sand placement during the bypass project, which was supplemented with beach fill from upland resources. South of S1 in an area corresponding to sediment budget cell S2 and a portion of S3, a zone of segmented blue patterns indicates erosion of several feet of topography on the beach and upper shoreface. Offshore along the lower shoreface, a persistent pattern of red-spectrum colors indicates deposition. Along with smaller zones of erosion. The continuous color pattern is related to the fact that the lower shoreface is covered by high-resolution multibeam surveys. North of Sebastian inlet, surveys are single-beam profiles spaced at 1000-foot intervals corresponding to Brevard County R-Markers. Even at this lower spatial resolution, zones of deposition and erosion are continuous. Most of the blue pattern indicating erosions occurred on the upper shoreface, where strong seasonal sand volume changes result in significant volume changes that can equal or exceed long-term trends as described in Section 2 of this report.

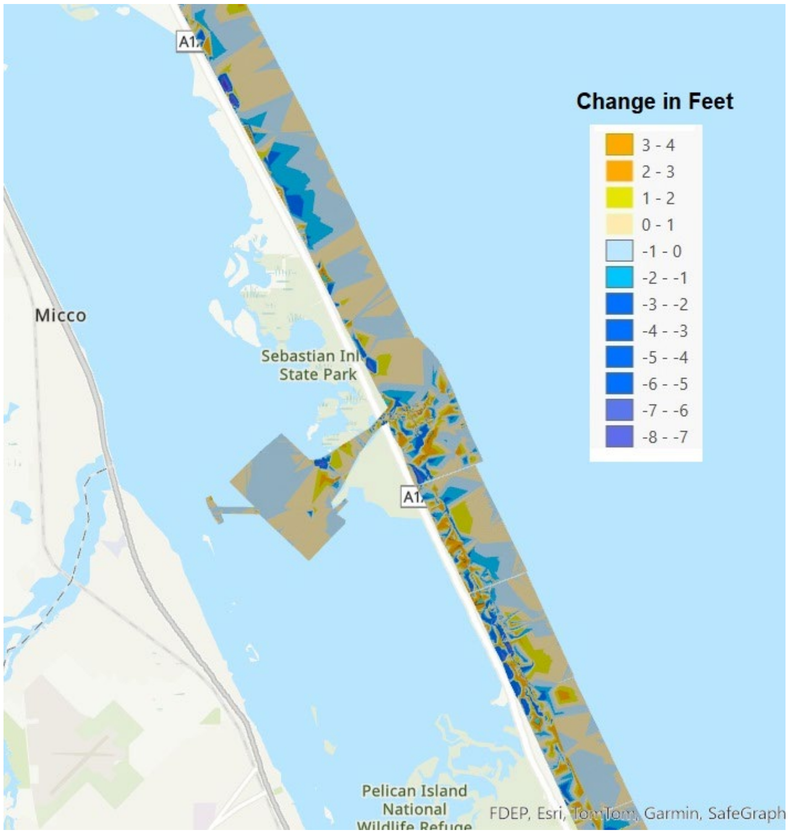


Figure 34. Topographic change between the winter surveys of 2024 and 2025.

5.0 Image-Based Shoreline Change Analysis

This section of the report provides an update of the shoreline change analysis from aerial imagery taken from 2023 to 2024. A complete analysis of shoreline changes mapped from georeferenced aerial imagery is provided in Appendix A, which covers the 1958 to 2024 period.

Shoreline positions were digitized from the geo-referenced aerial imagery for a domain covering approximately 14 miles from north to south of Sebastian Inlet, FL. Changes to the shoreline position were determined by comparing time series of transects generated every 25 ft along the coast. Transects were generated using the BeachTools© extension for ArcGIS © from a standardized baseline (see Figure 37) that runs parallel to Florida State Road A1A (SR-A1A) to the wet/dry line (low-tide terrace). More detailed information about the methodology and extent of the sub-domains referenced in this report can be found in a series of annual "State of the Inlet" reports issued since 2007.

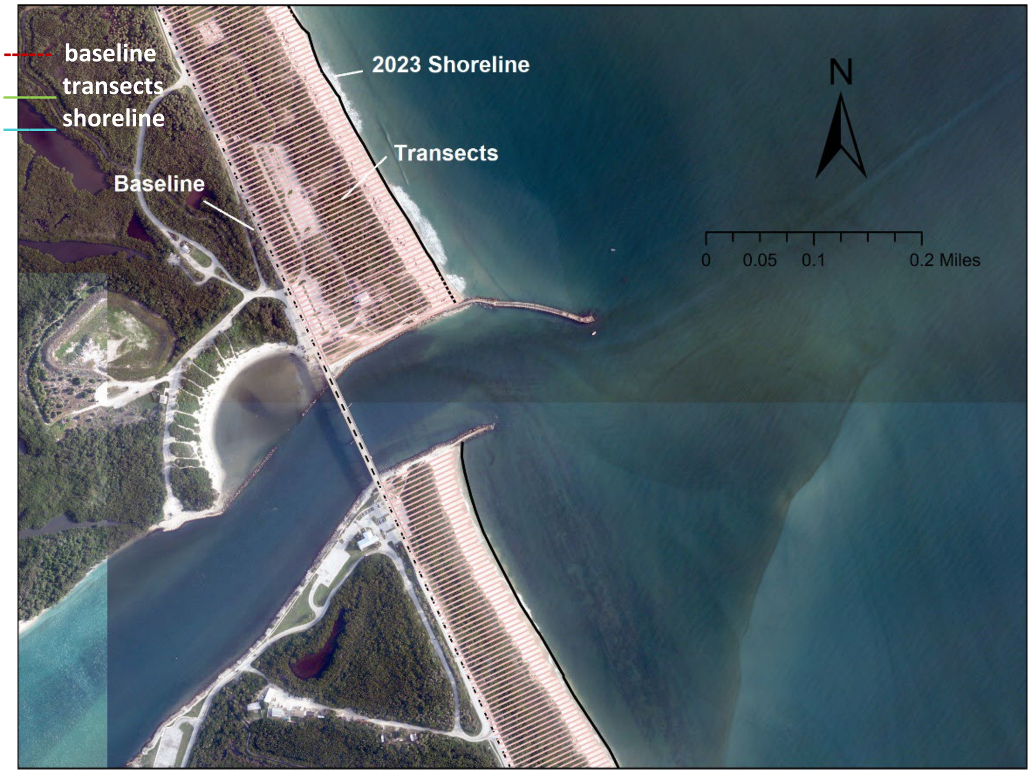


Figure 35. Baseline transects (green lines) and the image-based 2023 shoreline immediately to Sebastian Inlet.

The change in shoreline position was determined by subtracting the distances along each transect between time-series of interest. Shoreline change analysis included the use of the End

Point Rate (EPR) and the Linear Regression (LR) methods (Crowell et al., 1993; Morton et al., 2002). In this report, the shoreline change values were calculated from the direct comparison of the two years of interest. In other words, the most recent year, which is 2024 is compared directly with 1958, 2014, 2019, and 2023, respectively. Thus, the results from the EPR and LR methods yielded almost identical values and even though the EPR method would have suffice to explain the change in the shoreline position, it is the value of the slope of the line calculated from the LR method which allowed us to explain the rate at which the shoreline is changing. For details on the EPR and LR methodologies the reader is referred to State of Sebastian Inlet Technical Report 2007-1.

The results presented and discussed in this section focus on an image-based shoreline change. Table 5 shows the extent of coverage of the full study domain and of the assigned sub-cells (e.g., N1, S2, North) used in the shoreline analysis. The rates of change have been updated for an historical time period of sixty-four years (1958-2023), an intermediate period of ten years (2013-2023), and short-term analyses that account for recent changes from 2018-2023 (five years), as well as those occurring more recently from 2022 to 2023 (annual). Comparisons here are made for the most recent period, whereas a complete listing of comparisons reaching back to 1958 are listed in Appendix A.

Table 3. Summary of transect coverage to extract shoreline data from aerial imagery

Domain	Transect ID	Sub-Domains	R Marker	Transect ID	Extent Coverage in Miles
North	**0** ***to*** **1480**	**N3**	180.5 - 203	0 - 1480	4.2
		N2	203 - 216	880 - 1364	2.3
		N1	216 - 219	1364 - 1480	0.6
		Inlet	BC216 - IRC4	1365 - 1645	1.3
South	**1508** ***to*** **2974**	**S1**	0 - 3.5	1508 - 1627	0.6
		S2	3.5 - 16	1627 - 2120	2.3
		S3	16 - 37.5	2120 - 2974	4.0

5.1 Annual Update (2023-2024)

The shoreline changes occurring between 2023 and 2024 (Figure 36) show shifts ranging from -70 feet to +15 feet. Most of the shoreline underwent retreat. Table 4 lists shoreline change statistics for 2023-24, including maximum and minimum change rates, sector average rates, and the percentage of sectors' lengths under shoreline erosion or accretion for the period. Over the entire coastal reach, approximately 95% experienced shoreline retreat, whereas about 4% experienced accretion. In the context of shoreline retreat derived from comparisons of the 2023 and 2024 image-based shorelines, the shorelines based on the summer 2024 and winter 2025 surveys are located seaward of the 2024 image-based shoreline by up to 75feet (see Section 6.0)

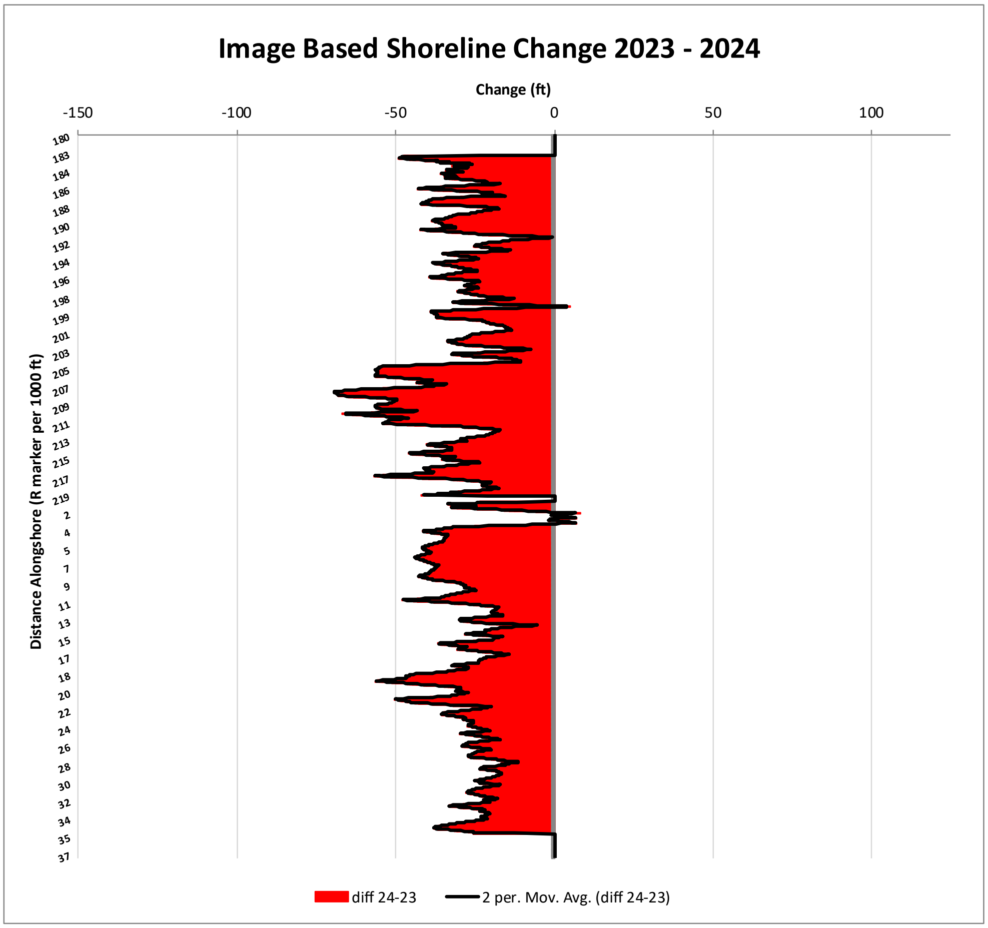


Figure 36. Change (ft) in shoreline position from 2023-2024.

Table 4. Summary of short-term changes for the recent period (2023-2024)

Extent	Range (ft/yr) *Max Erosion to Max Accretion*	Rate of Change (ft/yr)	Erosion %	Accretion %
North to South	-69.3600 to 8.0500	-22.2854	69.98	1.21
North	-69.3600 to 4.9200	-28.9644	89.26	0.27
N3	-43.3900 to 4.9200	-22.0571	81.95	0.45
N2	-69.3600 to -7.2400	-40.5072	100	0.21
N1	-57.0900 to -17.4600	-33.0178	100	0.85
Inlet	-57.0900 to 8.0500	-24.0711	79	11.39
S1	-40.8500 to 8.0500	-13.477	72.13	26.23
S2	-48.0300 to -5.3000	-31.2088	100	0.2
S3	-56.5300 to 0.0000	-6.8159	21.05	0.12
South	-56.5300 to 8.0500	-15.5366	51.74	2.18

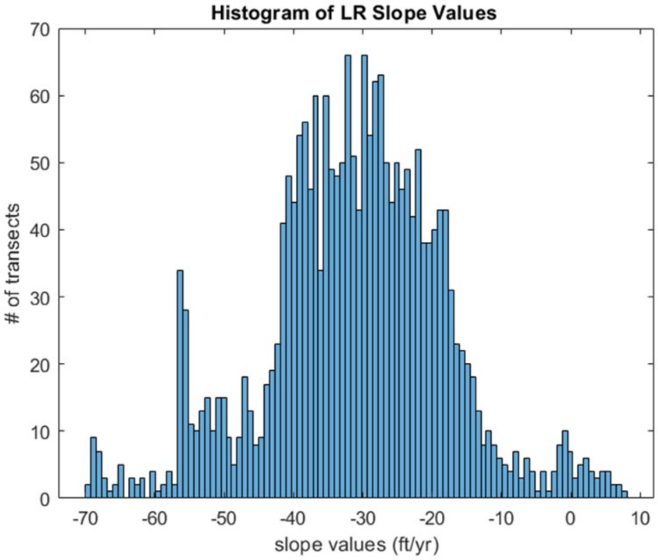
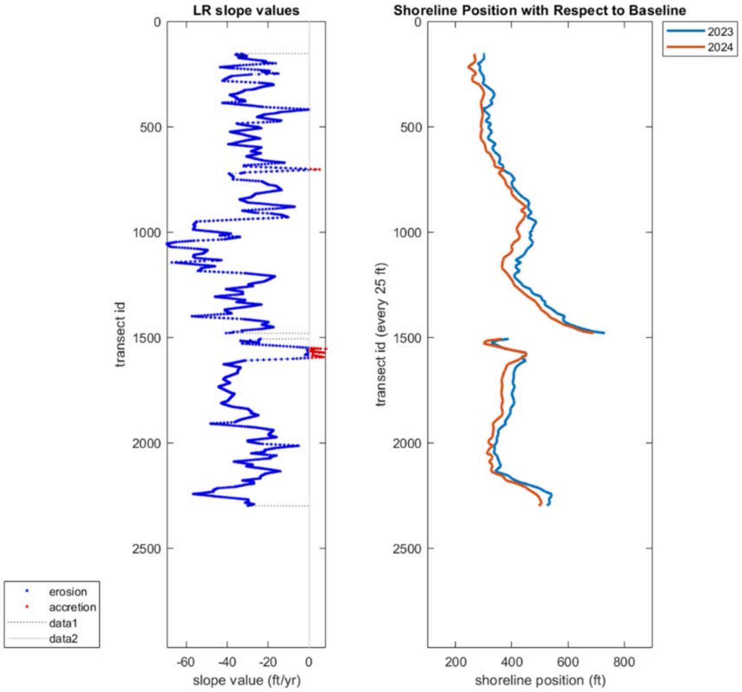


Figure 37. Histogram indicating the number of transects per slope value (ft/yr) for 2023-2024.

Figure 38 compares the 2023-2024 rate of shoreline change along the project area with the 2023-24 shoreline positions relative to the same baseline. The 2023 and 2024 shorelines are remarkably correlated and mostly within 50 feet of each other. However, shoreline segments north and south of Sebastian inlet near the south jetty reached a year-to-year offset of about of up to 75 feet (Figure 36). The shorelines in other areas are within what can be expected for a seasonal range of shoreline position for a tidally influenced coast of moderate wave energy.



(a) **(b)**

Figure 38. Period of 2023-2024. (a) Shoreline change rate in ft/yr (according to LR method calculated for each transect); (b) Shoreline position in feet (from baseline to wet/dry line).

6.0 Survey vs. Image Based Shorelines

The 0-contour survey lines on which the shoreline is based is usually measured every 500 to 1000 ft, whereas the raw shoreline data is captured every 100 ft in the aerial images. Even though the survey-based and the image-based shorelines are digitized and re-sampled at a 25 feet interval, due to a much lower spatial resolution of the raw survey data when compared to the image-based shoreline, the image-based pattern is spatially more variable.

The comparison between survey-based and image-based shoreline position is presented in Figure 38 for 2024 image (black line), 2025 winter (blue line), and 2024 summer (red line). While spatial variability exists in the shoreline profile and some reversals occur along the domain, the main trend (pattern) of the shoreline position is analogous in both methods and years. Results indicate that both survey-based shorelines (25w and 24s) are predominantly positioned seaward from the 2024 image-based shoreline up to 75 feet. The trends are well correlated with the fundamental difference being that the imaged shoreline is extracted from the wet-dry line along the beach, and the surveyed shoreline is relative to the NAVD88 vertical datum. The wet-dry line approximates mean high water when imaged near low tide.

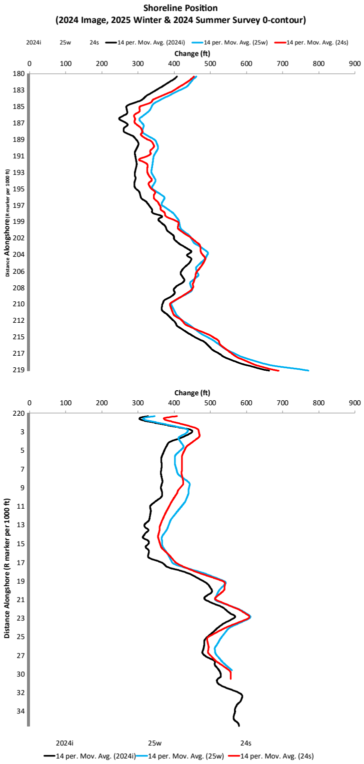


Figure 39. Shoreline positions for image-based and survey-based. Black line is 2024 Aerial image; Blue line is 2025 Winter survey; and red line is 2024 Summer survey.

7.0 Real- Time and Forecast Model of Sebastian Inlet: Update

A coastal processes model application provides real-time and forecast predictions of water levels, currents, wave height and direction, salinity, and water temperature around Sebastian Inlet. The real-time simulation is based on the Deltares, Inc. Delft3D modeling system, which has been widely applied in the US and Europe. Eventually, this model will include predictions of sand transport and morphological change.

Major model features that make Delft3D appliable to the Sebastian Inlet area is modular structure including hydrodynamics (Delft3D-Flow), surface waves (Delft3D-Wave), morphology (Delft3D-Mor), and water quality (Delft3D-WAQ). The Delft3D-Flow module solves the unsteady shallow water equations including the horizontal equations of motion, the continuity equation, and the transport equations for conservative constituents. The model can be used to simulate both two-dimensional and three-dimensional non-steady flow and transport phenomena driven by river discharges, tidal and meteorological forcing. The model grid must be orthogonal and can be boundary fitted, on either curvilinear or spherical coordinate systems. The flow model can be used to predict the flow in shallow coastal areas, estuaries, lagoons, rivers, and lakes. The presently operational model forecast can be viewed at https://realtimefl.githsub.io/Sebastian_Inlet.

Model setup and calibration procedures have been described in previous State of the Inlet Reports. These include development of the model grid or mesh and examples of model calibration for water level at Sebastian Inlet. Details of the model formulation can be found in Roelving and Banning,(1995).

7.1 Model Investigation of Gulf Stream Effects on Coastal Sea Level

In this report we briefly describe the application of the Sebastian Inlet coastal processes model to understanding the effects of the Gulf Stream on local coastal ocean sea level. The published paper can be found in Habin and Zarillo, 2024, which is cited in the reference list of this report.

This model study investigated the effects of the Gulf Stream (GS) on sea level oscillations across various time scales and assessed the performance of a Delft3D coastal and estuarine model nested within a global model in simulating these variations. It was aimed at improving boundary conditions to simulate sea level oscillations more accurately by considering the influence of GS flow. An inverse correlation is observed between observed sea level oscillation and GS flow, which becomes more pronounced over longer time scales. Using Delft3D, a high-resolution coastal and estuarine model is developed to simulate circulation dynamics in the central Indian River Lagoon (IRL), FL, and adjacent coastal areas on the Florida east coast. The model is nested within the HYCOM (Hybrid Coordinate Ocean Model), whereas meteorological data are obtained from the NARR (North American Regional Reanalysis) model. The model demonstrates satisfactory performance across major parameters, including tide, salinity, water temperature, and currents. However, a noticeable difference remains between modeled and observed sea level data. To address this, the model is executed with modified flow boundary conditions at eastern boundary nodes, integrating HYCOM tide and observed low-frequency sea level variations. Implementing the new boundary conditions results in an improved simulation of sea level oscillations. This study provides comprehensive documentation of the concepts and detailed methods involved in developing a high-resolution model for estuarine and coastal regions nested within Global models, capable of satisfactorily simulating sea level oscillations even when the Global model does not represent GS effects.

8.0 Conclusions and Recommendations

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 sand reservoirs of the inlet system, 2) analysis of the sand budget based on the results of the sand volume analysis, 3) analysis of morphologic changes within the inlet system associated with the sand budget analysis, 4) an update of the shoreline change analysis, and 5) an update of the real-time and forecast coastal processes numerical model described the importance of Gulf Strean dynamic in determining coastal sea level,

- The Sebastian 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.

- It can be demonstrated that the Sebastian Inlet sand reservoirs and the beach and shoreface areas both to the north and to the south of the inlet undergo extended periods of regional sand volume declines and periods of volume gains upon which large seasonal and year to year volume changes are superimposed

- Large sand volume gains and losses occur over the entire region rather than being inversely linked to gains or losses in adjacent subsections of the coast.

- Examples of regional changes include sand volume declines on the shoreface of extending from 2011 through 2023 that corresponded to a multiyear trend of rapidly rising sea level along the central Florida coast.

- When the sea level record measured at Sebastian Inlet is examined over the 18-year period between 2006 and 2025, it can be demonstrated that periods of increasing cumulative sand volume losses correspond to periods of rising sea level

- The sand budget for the Sebastian Inlet region is reported at two-time scales, including a longer time scales of 17/18 years, and 10 years to demonstrate the ability of the coastal sand reservoir to respond to rapid and abrupt sea level fluctuations.

- Over the time period of 2006-2025, the benefits of sand by-passing from the sand trap and beach fill placement projects to the south of the inlet can be shown to mitigate sand volume losses that extend over the region

- Based on topographic change patterns the Sebastian Inlet ebb shoal is serving as a local sand source similar to a river delta-front sand bodies adding sand to adjacent beach and shoreface environments.

- The ebb shoal accumulates sand from southernly net littoral drift that carries excess sand due to recent beach fill projects in Brevard Couty that exceed 1 million cubic yards of sand

- Buildup of sand volume in the ebb shoal is being released and bypassed to Indian River Couty beached at intervals of about 12-months

- Sebastian Inlet Management District should continue the use of beach/upper shoreface and lower shoreface inner continental shelf sediment budget cell subdivisions to better resolve cross-shore sand transport and littoral drift of sand being bypassed across the inlet.

- Similar to the sand volume analysis, the results of shoreline mapping from survey data and aerial imagery vary considerably by time scale.

- Shorelines mapped at any point in time may be more indicative of recent impacts of wave energy and storm activity and not necessarily indicate the overall stability of the coast over longer time periods.

- The ongoing coastal processes numerical model provides a day-to-day forecast and forecasts over 72 hours (three days) of energy conditions of the central Florida coast including the inner coastal ocean , within Sebastian Inlet , and in the Indian River Lagoon.
- It is recommended that the Sebastian District plan for time scales of 10 years and beyond when sea level is projected to continue rising at higher rates and more extreme interannual variations in sea level amplify the impact of rising seas along the coast
- Based on the correlation between interannual sea level shifts and sand volume on the shoreface, the Sebastian Inlet District should develop additional resources for beach-quality sand to mitigate sea level-driven coastal erosion.

Acknowledgments:

The project team acknowledges the Sebastian Inlet District Commissioners, the District Executive Director James Gray for their support.

9 .0 References

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Appendix A: Historical Shoreline Analysis

A1: Image-Based Shoreline Change

This section of the report provides an update of the shoreline change analysis from aerial imagery taken in 2024. Shoreline positions were digitized from the geo-referenced aerial imagery for a domain covering approximately 14 miles from north to south of Sebastian Inlet, FL. Changes to the shoreline position were determined by comparing time series of transects generated every 25 ft along the coast. Transects were generated using the BeachTools© extension for ArcGIS © from a standardized baseline (see Figure 35) that runs parallel to Florida State Road A1A (SR-A1A) to the wet/dry line (low-tide terrace). More detailed information about the methodology and extent of the sub-domains referenced in this report can be found in a series of annual “State of the Inlet” reports issued since 2007.

The change in shoreline position was determined by subtracting the distances along each transect between time-series of interest. Shoreline change analysis included the use of the End Point Rate (EPR) and the Linear Regression (LR) methods (Crowell et al., 1993; Morton et al., 2002). In this report, the shoreline change values were calculated from the direct comparison of the two years of interest. In other words, the most recent year, which is 2024 is compared directly with 1958, 2014, 2019, and 2023, respectively. Thus, the results from the EPR and LR methods yielded almost identical values and even though the EPR method would have suffice to explain the change in the shoreline position, it is the value of the slope of the line calculated from the LR method which allowed us to explain the rate at which the shoreline is changing. For details on the EPR and LR methodologies the reader is referred to State of Sebastian Inlet Technical Report 2007-1.

The results presented and discussed in this section focus on an image-based shoreline change. Table 5 shows the extent of coverage of the full study domain and of the assigned sub-cells (e.g., N1, S2, North) used in the shoreline analysis. The rates of change have been updated for a historical time period of sixty-four years (1958-2024), an intermediate period of ten years (2014-2024), and short-term analyses that account for recent changes from 2019-2024 (five years), as well as those occurring most recently from 2023 to 2024 (annual).

Table 5. Summary of transect coverage to extract shoreline data from aerial imagery

Domain	Transect ID	Sub-Domains	R Marker	Transect ID	Extent Coverage in Miles
North	**0** *to* **1480**	**N3**	180.5 - 203	0 - 1480	4.2
		N2	203 - 216	880 - 1364	2.3
		N1	216 - 219	1364 - 1480	0.6
		Inlet	BC216 - IRC4	1365 - 1645	1.3
South	**1508** *to* **2974**	**S1**	0 - 3.5	1508 - 1627	0.6
		S2	3.5 - 16	1627 - 2120	2.3
		S3	16 - 37.5	2120 - 2974	4.0

A2: Historical Period (1958-2024)

The shoreline changes between the period of 1958 to 2024 (Figure 40) show shifts ranging from -130 feet (near R-marker 12) to +125 feet (south of R-marker 2). Two major sections of shoreline advancement are noticeable along the north-to-south domain flanked by one noticeable area of shoreline retreat in the north and a major area of recession dominating the southern extent. Interspersed there are smaller areas that alternate between landward and seaward shoreline migration.

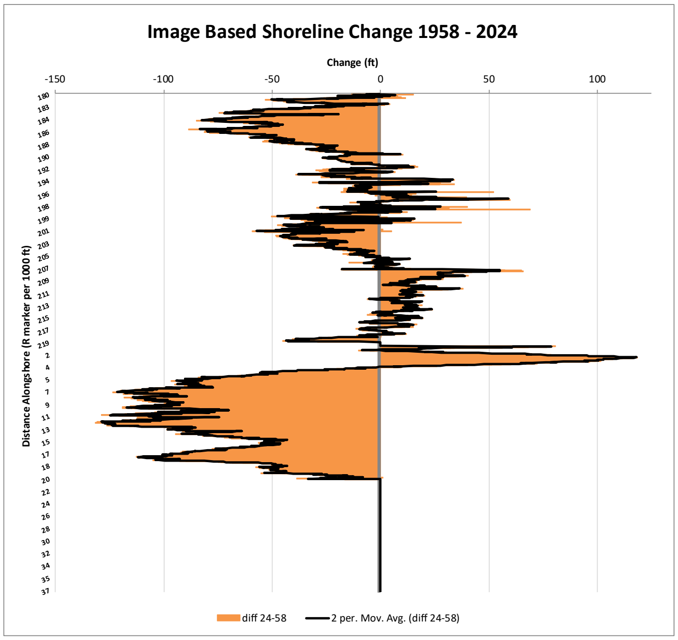


Figure 40. Change (ft) in shoreline position from 1958-2024

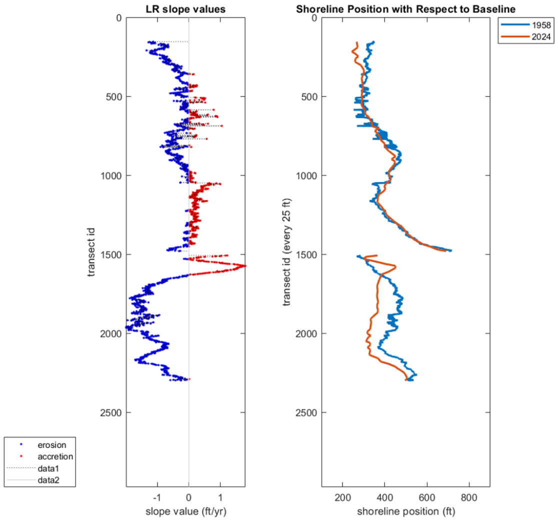
In segment N3, the northernmost area denoting landward migration is close to -75 feet and is centered around R-187, within the same N3 segment the first section denoting seaward migration shows a maximum value of close to +70 feet is centered around R-marker 196. The second area of shoreline advancement is found along segments N2 and N1, where the maximum seaward migration can be seen around R-208 with a value of close to +70 feet. Approaching the north side of Sebastian Inlet, a small section of shoreline retreat is noticeable with a value of close to -12 feet at R-219. Immediately south of Sebastian Inlet, the area of shoreline showing maximum advancement reaching +125 feet while the widest contiguous section of landward migration (retreating shoreline) of up to -130 feet at R-12 dominates most of S2 and the part of S3 that has data available for this analysis.

The range of the shoreline change rates, the average shoreline change rate for a segment or extent, and the percentage of the shoreline undergoing erosion or accretion within each segment are summarized in Table 6. Overall, the entire extent (North to South) for the 1958-2024 period presents mostly retreat at 49.8% compared to 21.4 percent accretion. The North segment shows four sections where erosion occurs (55%), with an average rate of change of -0.14 ft/yr. The South extent is where the maximum retreat rate occurs (-1.99 ft/yr) dominating segment S2.

Table 6. Summary shoreline changes for the historical period (1958-2024)

Extent	Range (ft/yr) *Max Erosion to Max Accretion*	Rate of Change (ft/yr)	Erosion %	Accretion %
North to South	-1.9926 to 1.7921	-0.3027	49.82	21.38
North	-1.3441 to 1.0474	-0.1399	54.69	34.84
N3	-1.3441 to 1.0474	-0.278	67.76	14.64
N2	-0.6117 to 0.9973	0.1008	30.1	69.9
N1	-0.6835 to 0.2526	-0.0995	58.97	41.03
Inlet	-0.6835 to 1.7921	0.3822	30.96	59.43
S1	-0.1553 to 1.7921	0.9078	3.28	95.08
S2	-1.9926 to 0.1955	-1.2653	99.19	0.81
S3	-1.7044 to 0.0129	-0.2014	20.94	0.12
South	-1.9926 to 1.7921	-0.4667	45.75	8.17

Another way to visualize the results presented in Figure 41(a) is with a histogram plot (Figure 42), which shows the frequency at which a particular value of the rate of change occurs throughout the study domain for the particular time period considered. Most of the frequency distribution is on the negative, but with modal frequencies near 0 and 0.1 ft/yr/



(a) **(b)**

Figure 41. Period of 1958-2024 (a) Shoreline change rate in ft/yr (according to LR method calculated for each transect); (b) Shoreline position in feet (from baseline to wet/dry line).

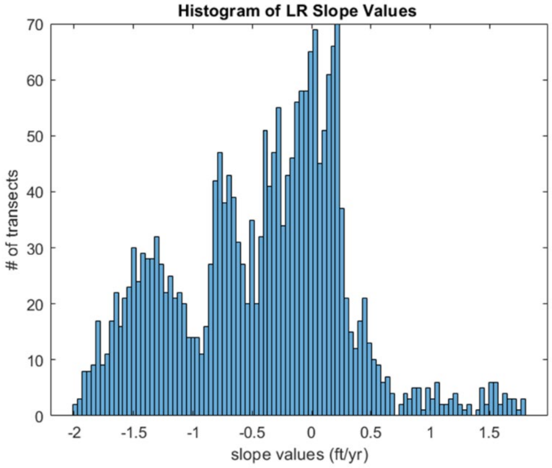


Figure 42. Frequency of rate of change (slope value in ft/yr) for entire domain (1958-2024).

A3: Intermediate Period (2014-2024)

The changes in shoreline position from 2014 to 2024 (Figure 43) show retreat through most of the domain with a maximum retreat of about -80 feet near R-7 in Indian River County.

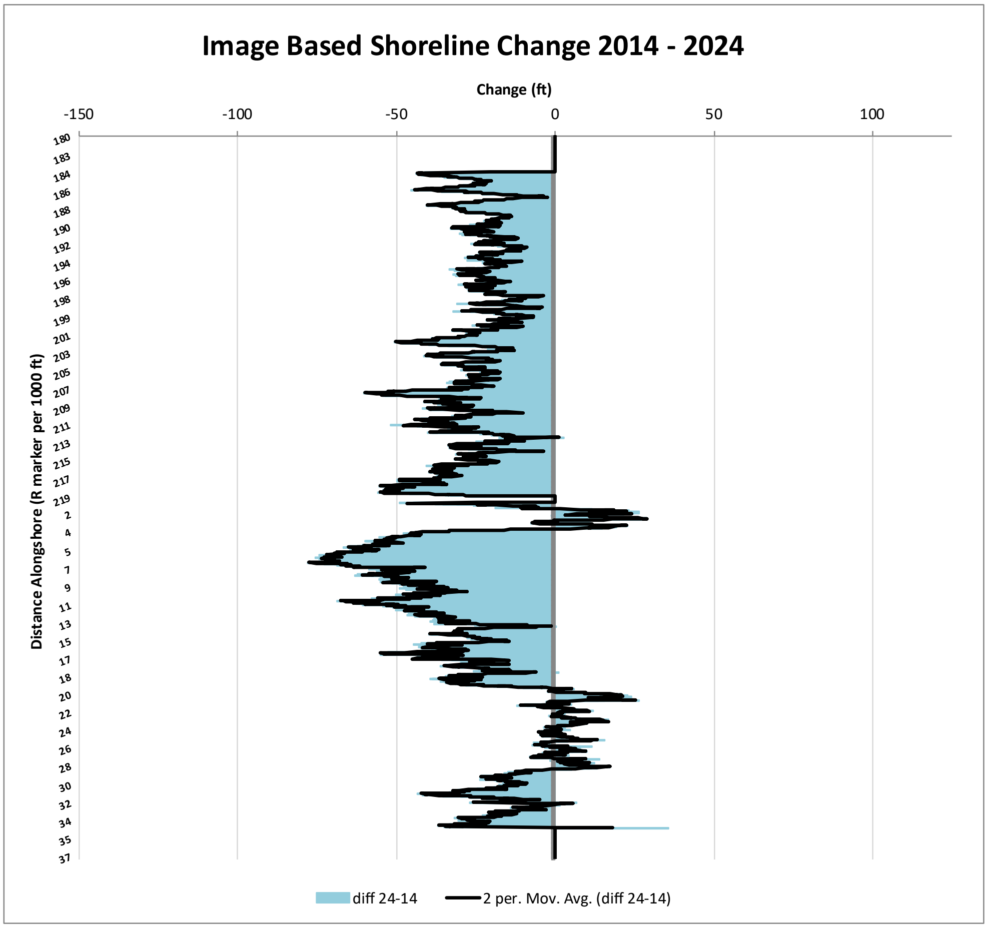


Figure 43. Change (ft) in shoreline position from 2014-2024.

The full extent from North to South shows about 68% shoreline retreat and 3% accretion with an average rate of change of about -2 ft/yr (Table 7). Similarly, most segments show retreat ranging from 18% (S3) to 99% (S2). In general, the average rate of change is about -2.3 ft/yr for the North and around -1.7 ft/yr for the South,

Table 7. Summary of short-term changes for the recent period (2014-2024)

Extent	Range (ft/yr) *Max Erosion to Max Accretion*	Rate of Change (ft/yr)	Erosion %	Accretion %
North to South	-7.7920 to 2.8930	-2.0431	68	3.19
North	-6.0180 to 0.2580	-2.322	89.47	0.07
N3	-5.0790 to 0.0000	-1.8225	82.41	0.11
N2	-6.0180 to 0.2580	-2.7989	99.79	0.21
N1	-5.5910 to -2.6760	-4.1056	100	0.85
Inlet	-5.5910 to 2.8930	-2.1022	65.48	24.91
S1	-4.9050 to 2.8930	0.1687	40.98	57.38
S2	-7.7920 to 0.0490	-4.5036	99.8	0.2
S3	-5.5320 to 2.3000	-0.4551	18.36	2.69
South	-7.7920 to 2.8930	-1.7606	47.52	6.4

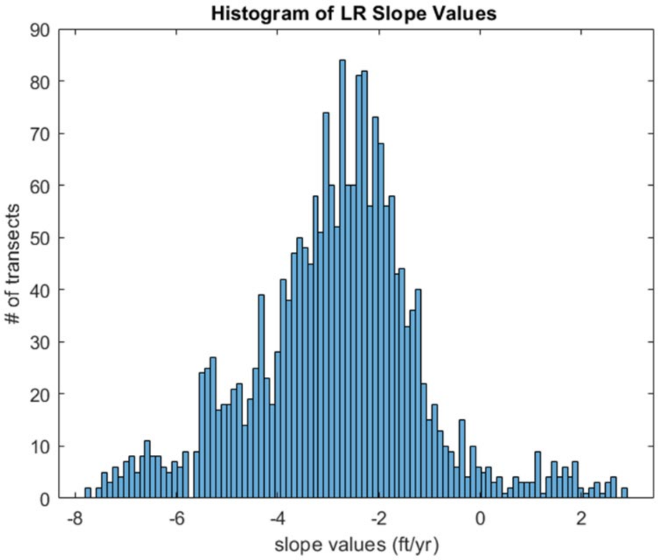
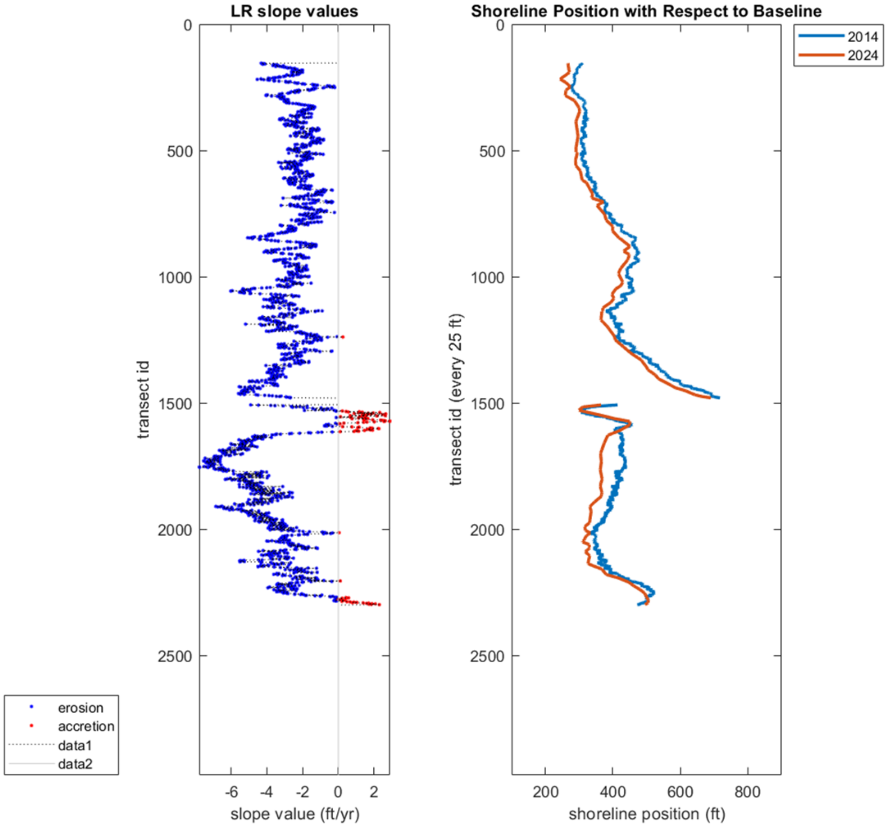


Figure 44. Histogram indicating the number of transects per slope value (ft/yr) for 2014-2024.



(a) (b)

Figure 45. Period of 2014-2024. (a) Shoreline change rate in ft/yr (according to LR method calculated for each transect); (b) Shoreline position in feet (from baseline to wet/dry line).

A4: Recent Changes (2019-2024)

Shoreline changes from 2019 to 2024 (Figure 46) experienced mostly landward migration (retreat) throughout the entire domain. A maximum change of -90 feet is found immediately north of the inlet in N1. The range of shoreline change in segment S1 is from -16.8 ft/yr to +2.3 ft/yr (Table 8).

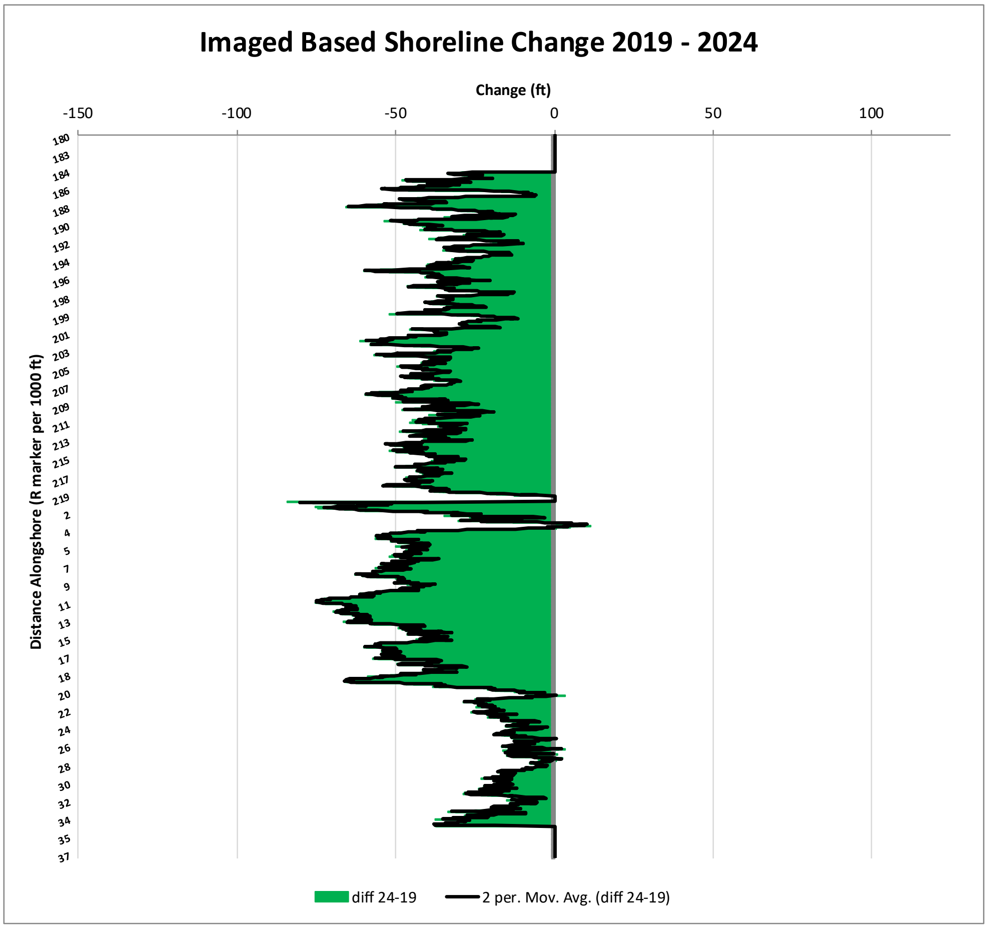


Figure 46. Change (ft) in shoreline position from 2019-2024.

Table 8. Summary of short-term changes for the latest update (2019-2024)

Extent	Range (ft/yr) *Max Erosion to Max Accretion*	Rate of Change (ft/yr)	Erosion %	Accretion %
North to South	-16.8360 to 2.2720	-5.6212	70.59	0.61
North	-13.1900 to 0.0000	-6.3018	89.53	0.07
N3	-13.1900 to 0.0000	-5.321	82.41	0.11
N2	-11.9220 to -3.8120	-7.7821	100	0.21
N1	-10.7980 to -0.8380	-7.5718	100	0.85
Inlet	-16.8360 to 2.2720	-6.9688	83.99	6.41
S1	-16.8360 to 2.2720	-5.9346	83.61	14.75
S2	-15.0420 to -5.8320	-10.2937	100	0.2
S3	-13.2440 to 0.0000	-1.7008	21.05	0.12
South	-16.8360 to 2.2720	-4.9312	52.69	1.23

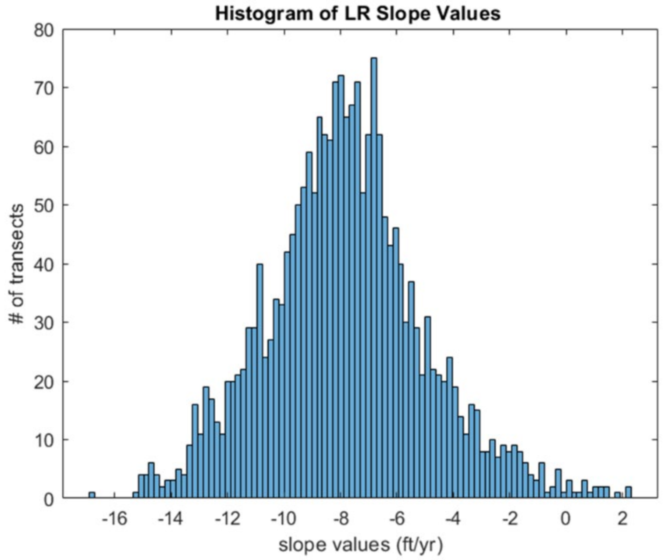
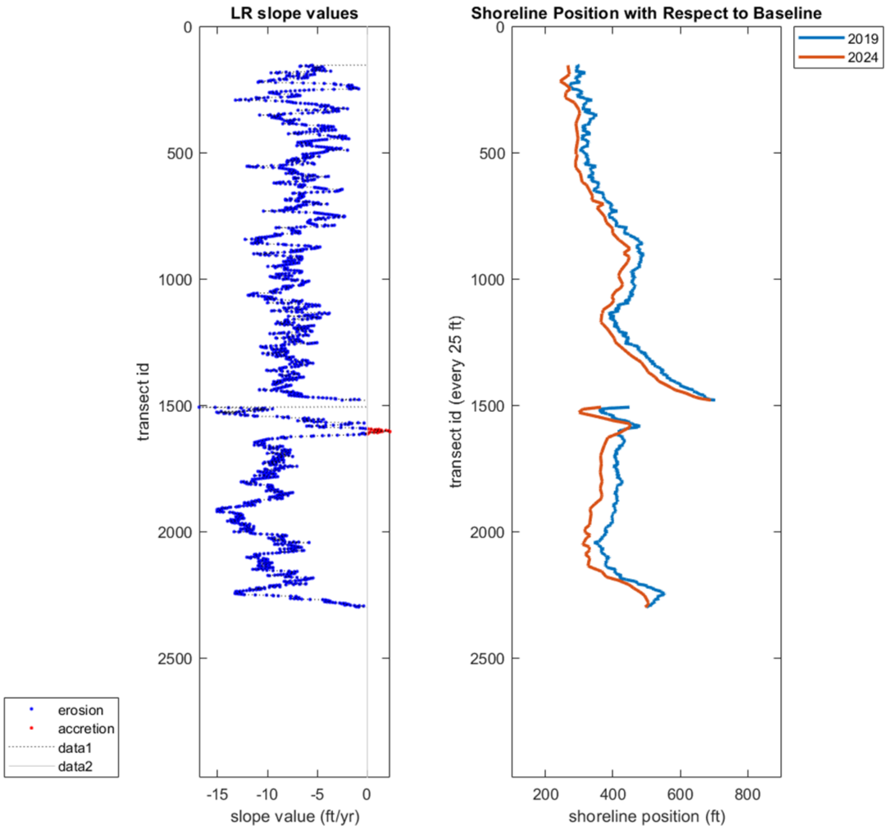


Figure 47. Histogram indicating number of transects per slope value (ft/yr) for 2019-2024.

The full extent from North to South show 70% erosion and about 1% accretion (Table 8). In all segments, the percent shoreline length in retreat exceeds the percent accretion by order of magnitude. In general, the average rate of change is centered around a value close to -5.6 ft/yr (Figure 47)



(a) (b)

Figure 48. Period of 2019-2024. (a) Shoreline change rate in ft/yr (according to LR method calculated for each transect); (b) Shoreline position in feet (from baseline to wet/dry line).