

**Year 2
Annual Monitoring Report
Sullivan's Island**

2024
MONITORING REPORT



Prepared for
Town of Sullivan's Island
Sullivan's Island, South Carolina

COASTAL SCIENCE & ENGINEERING



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2024 Year 2 Annual Monitoring Report

Sullivan's Island, South Carolina

Prepared for:



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[CSE 2585]

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EXECUTIVE SUMMARY

This is the Year 2 beach monitoring report for Sullivan’s Island under an agreement between the Town and Coastal Science & Engineering Inc (CSE) dated 21 July 2023. The report draws on prior studies and research by others, including CSE-SW-Dewberry (2010) and the University of South Carolina (eg – FitzGerald et al, 1978).

Prior surveys have generally been limited to a dozen or so profiles (eg – SCDHEC-OCRM 3000-series lines). As a result, the current effort is a significant increase in the amount of volume data collected along Sullivan’s Island. That data collection is important because much of what causes Sullivan’s Island to vary from station to station is occurring beyond MLW and is not readily apparent from the beach. Annual monitoring is designed to alert the community to developing changes and vulnerabilities before property is imminently threatened.

From August 2023 to September 2024, Sullivan’s Island lost sand below MLW (~82,500 cy or ~4.5 cy/ft) and between MLW and MHW (~21,100 cy or ~1.1 cy/ft) but gained sand above MHW (~6,700 cy or ~0.4 cy/ft). Island-wide averages mask the variation in accretion and erosion across individual profiles and reaches. In general, the central portions of the island (eg between the lighthouse and Sta 28) gained sand along the dry and intertidal beach while the ‘corners’ of the island (near Sta 17 in the west and Sta 30 in the east) lost sand.

Volume increases from 2023 to 2024 are primarily related to the onshore migration of shoals and bars associated with the inlet channels at either end of the island. As these shoals and bars attach to the beach and move up- or down-coast, sand volumes measured along particular sections of the beach or depths of the profile will oscillate between erosion and accretion. Because inlets in South Carolina tend to behave in a cyclical manner, the trends described herein may not continue indefinitely. Continued annual monitoring of the whole island will enable a better understanding of the inter-annual variations in these inlet cycles, which can be used to inform responsible project planning and scoping for potential remediation efforts in the future.

With this in mind, comparison of the 2023-2024 and 2024-2025 results will help establish a baseline of ‘normal’ year-to-year changes against which any future investigations can be compared. The Year 3 (2025) monitoring survey is currently scheduled for August 2025.

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1.0 SETTING & SHORELINE HISTORY

Sullivan’s Island is a 3.8-mile-long beach ridge barrier island bounded by Breach Inlet to the east, and Charleston Harbor to the west (Fig 1.1). The mean tide range is 5.1 feet (ft), and typical wave heights are approximately 2 ft (www.tidesandcurrents.noaa.gov). Net sand transport is east to west, into the Charleston Bight. Typical sediment size on the active beach is 0.2–0.25 millimeters (mm), and beach slopes are around 1 on 25. The wet-sand beach in the intertidal zone tends to be much wider than the dry-sand beach. Characteristic of South Carolina beaches, the backshore becomes vegetated with dune grasses soon after accreted land (beach ridges) forms (CSE 2011).

The north jetty into Charleston (completed in 1898) terminates near the center of Sullivan’s Island, but is generally not an obstruction across the beach. The jetties incorporate long weir sections close to shore, which are underwater sills designed to allow small craft to pass close to shore. Over the past century, sand has accumulated along the oceanfront and buried the section of the jetty that was above high water when it was constructed. Unlike many barrier islands on the east coast, Sullivan’s Island retains sand and is now much wider than it was during early development.

The principal source of sand to Sullivan’s Island is sand from the Isle of Palms, which is derived from “shoal bypassing” at Dewees Island and longshore transport down to Breach Inlet (Kana and Gaudiano 2001) (Fig 1.2). Shoal bypassing is the episodic release of large sand bars from an inlet’s ebb-tidal delta (seaward shoals). The bars migrate onshore on the downcoast side of the inlet, merge with the beach, and then spread laterally along the coast (Gaudiano and Kana 2001). This results in the shoreline jumping seaward in relation to the volume of sand bypassing the inlet. The same process occurs at Breach Inlet for the benefit of Sullivan’s Island, with certain important differences, which are outlined later.

The barrier islands of today’s central South Carolina coast are geologically young, having formed in the past 5,000 years or so (Colquhoun and Brooks 1986). Sea level and the general position of the shoreline have fluctuated hundreds of feet in elevation during the past half million years. Its present level is considered a “high stand” and is similar to levels 120,000 and 320,000 years ago (Fig 1.3) (Imbrie and Imbrie 1979). Approximately 20,000 years ago, sea level in the Charleston area was nearly 400 ft lower, and the ocean shoreline was dozens of miles offshore. These cycles of sea level change are related to global average temperatures and the expansion and contraction of continental glaciers. As glaciers melt and ocean water warms, sea levels rise.



FIGURE 1.1. Infrared aerial orthophoto of Sullivan's Island (2006) situated on the north side of Charleston Harbor. The green area is accreted land seaward of development. The east and west shorelines are armored to protect property. Sullivan's Island receives sand periodically from Breach Inlet and loses it to the Harbor entrance. [Source: SCDNR]



FIGURE 1.2. Isle of Palms, a classic “drumstick”-shaped barrier island, and Sullivan’s Island, another “beach-ridge” barrier island (Hayes 1976, 1979). Major sand transport pathways for Isle of Palms and Sullivan’s Island are indicated by the arrows. The ebb tidal delta (seaward shoals) of Dewees Inlet bypass sand to Isle of Palms. That sand is transported west to Breach Inlet. At Breach Inlet, sand builds up the spit causing it to overextend and overlap Sullivan’s Island. Periodically, the spit breaches and sand is released to the oceanfront of Sullivan’s Island. [Source: SCDNR 2006 and Research Planning Inc]

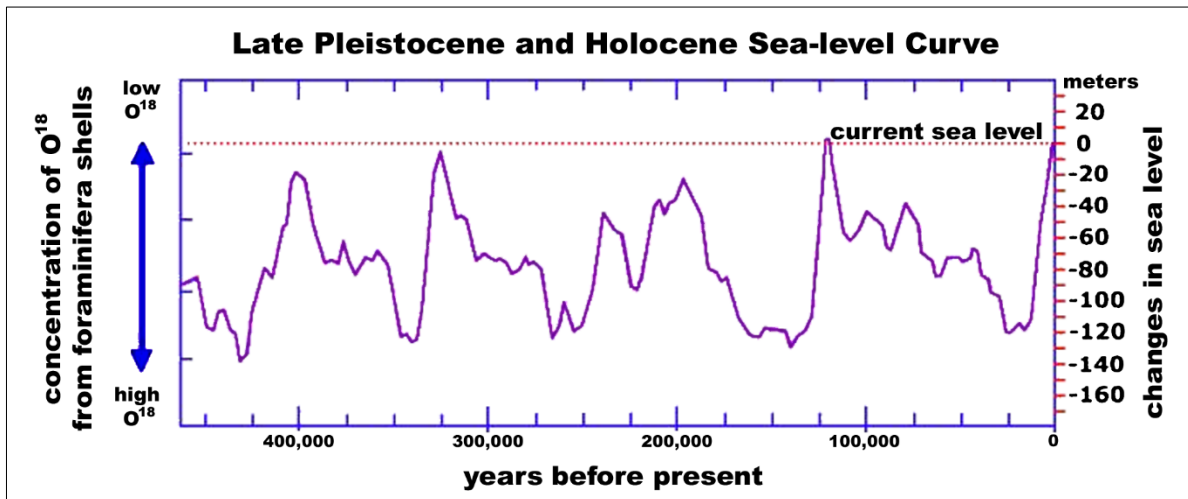


FIGURE 1.3. Global cycles of sea level change over the past half-million years as interpreted by Imbrie and Imbrie (1979). The present position of sea level is considered a “high stand,” similar to levels about 120,000 and 320,000 years ago.

Researchers have documented a relatively rapid rise in sea level from 20,000 to 5,000 years ago (Fig 1.4). Since then, sea levels have been relatively stable, allowing sediments to accumulate and be shaped by wave action at the coast. Waves winnow out fine-grain material (silts and clays) and shape sandy sediments into the beaches and dunes. Where sediment supply is sufficient, and dry-sand beaches occur, onshore winds build dunes above the normal wave runup level.

Over the past century, Charleston has experienced sea level rise (SLR) of approximately 24 centimeters (~0.8 ft) (Barth and Titus 1984). A portion of this rise is attributed to global warming, and about half of the rise is due to local subsidence of the land. This means Sullivan’s Island has already been subject to some measure of SLR over the past century. Section 3.2 of this report provides data on SLR in the Charleston area with implications for the next century. Recent evidence indicates the likelihood of a 2–3 ft SLR over the next century (IPCC 2021).

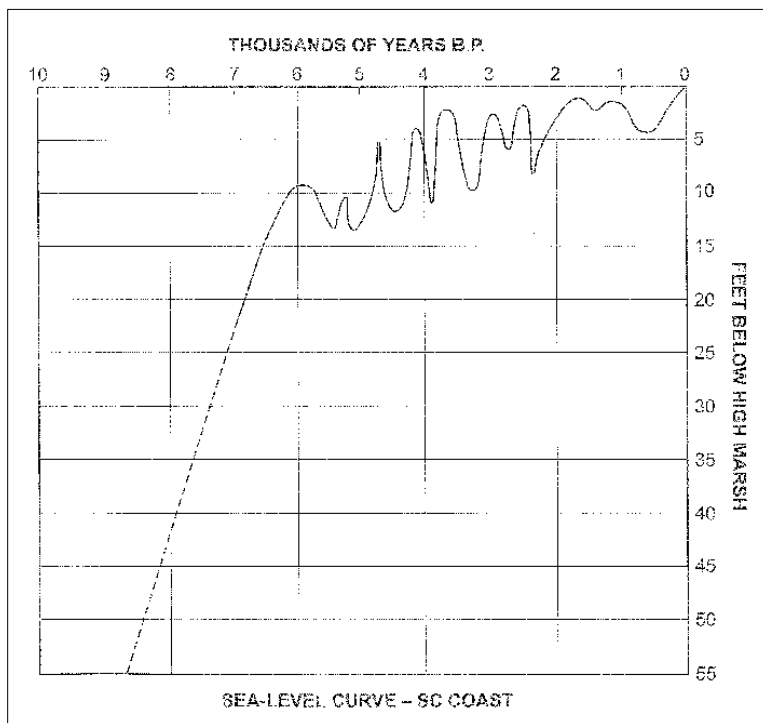


FIGURE 1.4. Fluctuations in sea level along the South Carolina coast over the past 6,000 years based on research by Colquhoun and Brooks (1986) as interpreted by Hayes and Michel (2008) (BP-Before Present). [Courtesy of RPI and Pandion Books, Columbia, SC – after Hayes and Sexton 1989]

1.1 Breach Inlet Processes

The health and stability of the beach along Sullivan’s Island depend on the continued bypassing of sand from Breach Inlet. This occurs episodically and by the process of “ebb tidal breaching” (FitzGerald 1978).

The central South Carolina coast has numerous large and deep tidal inlets (eg – Capers Inlet, Dewees Inlet, Charleston Harbor, Stono Inlet, and North Edisto River Inlet). These channels are situated in ancient riverbeds that flooded after sea level reached present conditions. The inlets

are positionally stable because they are anchored in semi-cemented rock (Cooper Marl) that underlies Charleston (Malde 1959). Ebb-tidal deltas associated with each inlet contain huge sand deposits. At the other extreme are small, unstable migrating inlets (eg – Pawleys Inlet and Capt Sams Inlet), which are shallow and cut into recent beach deposits. They migrate due to sand buildup and the extension of spits. Breach Inlet fits that category of small migratory inlets. However, shore protection structures along the Sullivan’s Island side of the inlet prevent further migration.

Each type of inlet bypasses sand to the adjacent beaches as described in geomorphic models by FitzGerald (1978 and 2001; Fig 1.5). Note that the “ebb-tidal delta breaching” model in Figure 1.5 was actually based on studies of Breach Inlet. As the diagram illustrates, a dominant longshore transport will cause the spit to grow and overlap the entrance, deflecting the channel downcoast. This is an unstable situation because it is less efficient for tides entering and exiting the inlet. Periodically, after the spit overextends too much, it will breach and allow the outgoing tide to “spill over” and initiate a new channel. This ebb delta breaching then leaves an isolated sand bar off the downdrift island. Waves then push those bars shoreward until they merge with the beach.

Figure 1.6 shows Breach Inlet and the north half of Sullivan’s Island in 2005, shortly after a breach of the overextended spit. The large sand bar to the left of the inlet opening had been part of the spit before the breach. After the breach, waves pushed the sand onshore and filled in the abandoned channel. This process has repeated itself numerous times over the past 50 years (Gaudiano and Kana 2001) and accounts for the buildup of accreted land highlighted in Figure 1.1. CSE’s shoreline monitoring for Sullivan’s Island is designed to track the sand bypassing events at Breach Inlet because they are the most critical process controlling shoreline movement in this setting (Kana and Gaudiano 2001).

About two years after the photo in Figure 1.6 was taken, the “bypassing shoal” (point A) extended to the middle of the island, nearly to the harbor jetty (Fig 1.7). As the bar migrates onshore, it often creates intertidal ponds between the bar and the beach. These ponds drain through small breaks in the bar. The high areas of the bar (white sand in the image) are initially overwash deposits but become the nucleus of a new foredune once they fully merge with the beach. The frequency of shoal bypassing and volumes of sand delivered to Sullivan’s Island have been so great that previous dune lines generally do not have time to build high dunes before the shoreline jumps seaward. Sheltering by new shoals allows dune grasses to propagate and stabilize the dunes at low elevations. This has important implications for Sullivan’s Island because it means dunes in the accreted lands tend to remain lower than an ideal elevation. Low dunes provide less protection during major storms like Hurricane *Hugo* (storm of record, 1989).

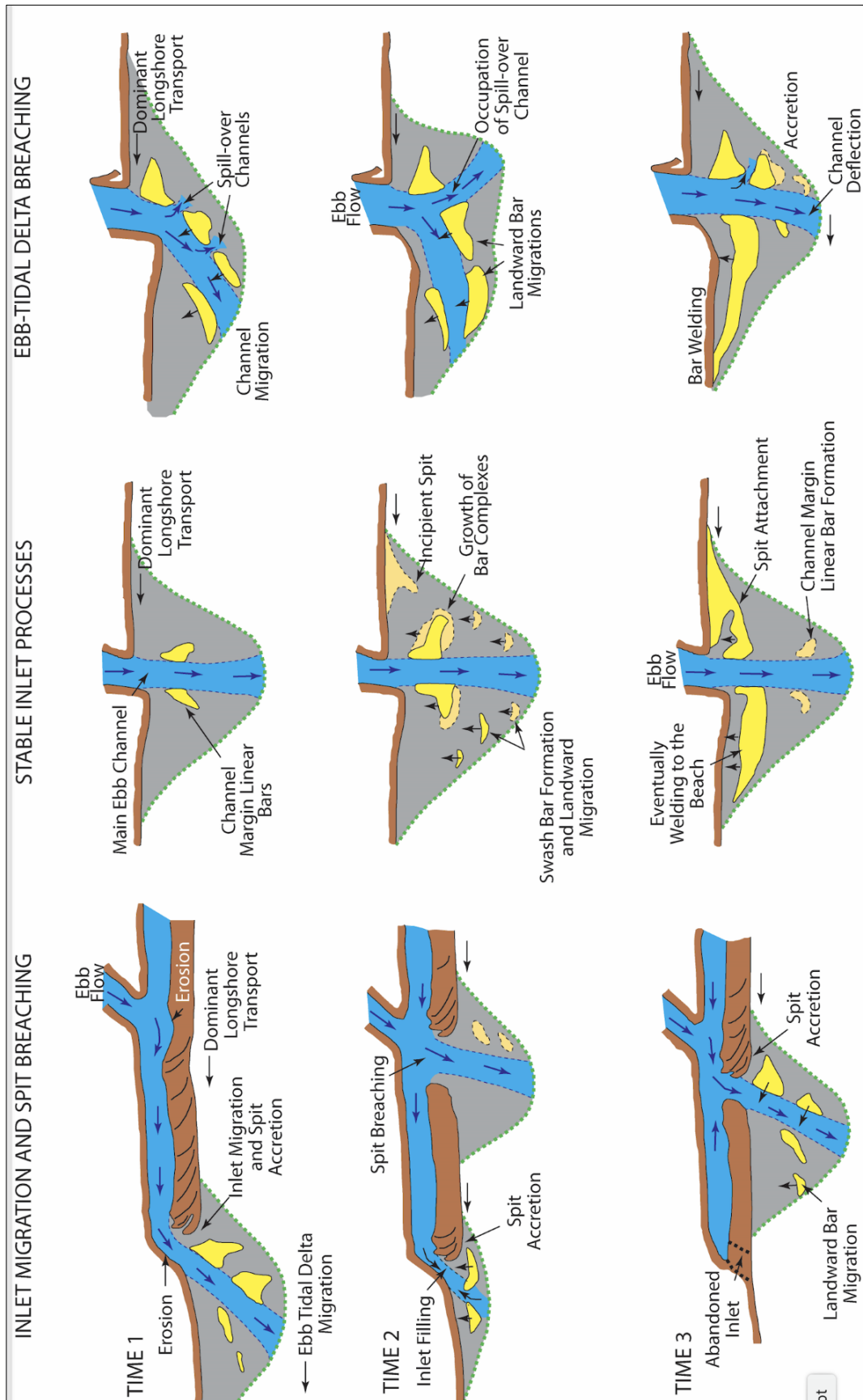


FIGURE 1.5. General models of inlet sediment bypassing for the South Carolina coast. Breach Inlet most closely matches the right hand model on the figure. Its channel is anchored by shore protection structures around the bridge to Isle of Palms. The outer portion of the channel is deflected west by sand moving into the inlet from Isle of Palms. Periodically, the outer bars breach through “spillover” channels, freeing sand to migrate onto Sullivan’s Island. [From FitzGerald et al 1978: 2001]



FIGURE 1.6. Oblique aerial photograph at low tide showing the deflection of Breach Inlet around shoals extending from Isle of Palms (right side of photo). Breaks in the shoals (B) allow the channel to shift, freeing sand further west (A) to move onshore and accrete along Sullivan's Island. [Photo circa 2005 by TW Kana]



FIGURE 1.7.

Oblique aerial photograph of Sullivan's Island looking north at low tide on 17 February 2007. The landward end of the north jetty for Charleston Harbor (arrow) is generally buried and nonfunctional. Sullivan's Island is accretional because of excess sand bypassing Breach Inlet and accumulating along the beach on both sides of the jetty — not because of sand trapping by the jetty. Its effect on sand trapping diminished soon after construction. Note the sand bars merging with the beach in the center of the photograph (Stations 23–29).

[Photo by TW Kana]

1.2 Historical Shorelines and Sand Volume Changes

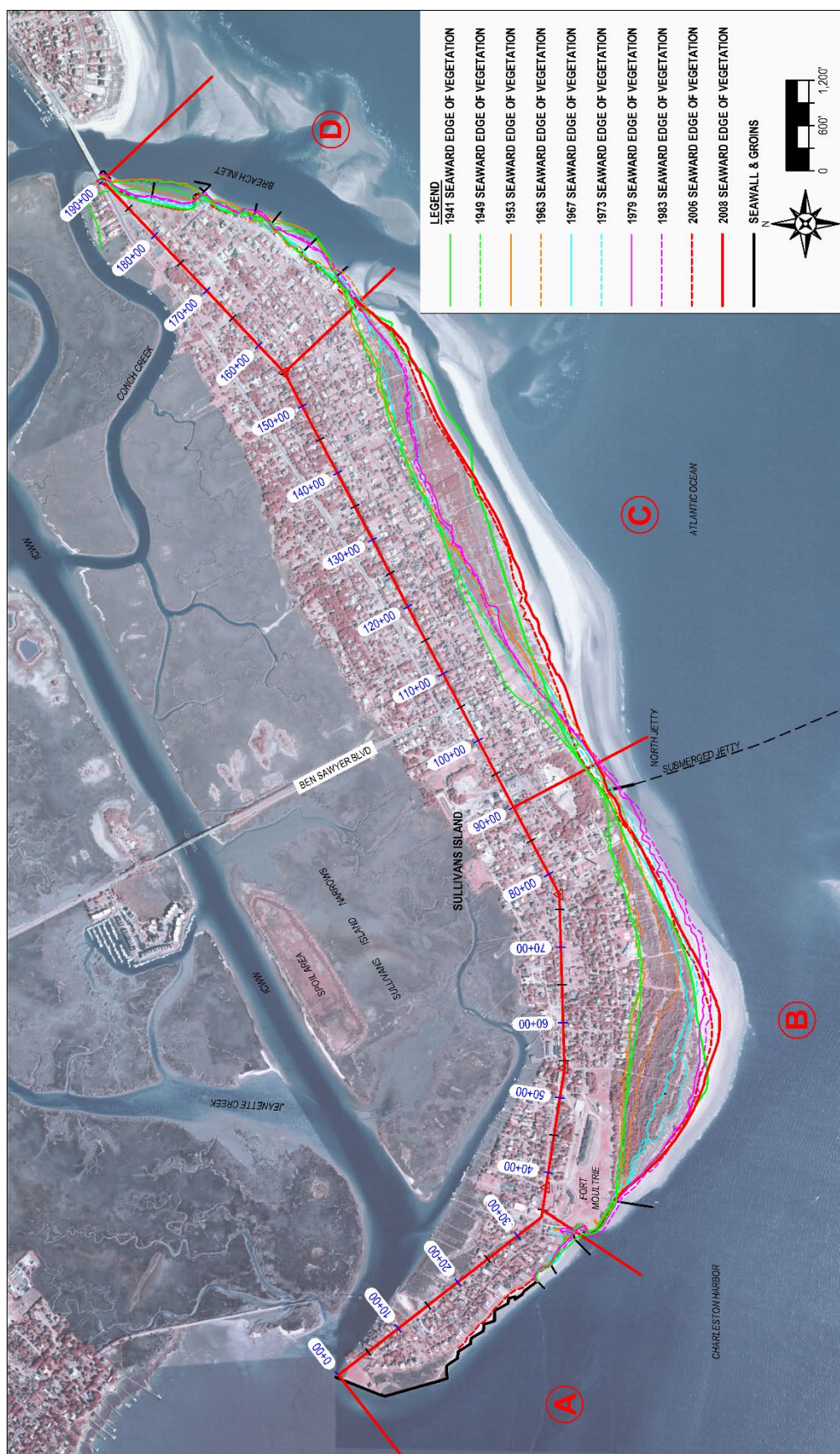
The shoreline history of Sullivan's Island was evaluated in detail by CSE-Sabine & Waters and Dewberry (CSE-SW-DEW 2010). The analysis was based on rectified vertical aerial photographs spanning 1941 through 2006. Two "shorelines" were interpreted on each image. First is the seaward-most vegetation line. This represents the highest, most landward tide and wave runup limit around the time of a particular aerial photo. The second line is the "dry sand/wet sand" contact line along the active beach. Experience has shown this line to be near normal mean high water along the open coast (Kana and Gaudiano 2001). This section summarizes the CSE-SW-DEW (2010) findings and provides background for the present monitoring results (Section 2.0).

Figure 1.8 shows the historical vegetation lines from 1941 to 2008. Four "reaches" are considered:

- A. Armored shoreline at the west end of the island facing Charleston Harbor (~3,500 linear feet [lf])
- B. West accreted land between Fort Moultrie and the Charleston Harbor jetty (~5,500 lf)
- C. East accreted land between the jetty and Breach Inlet (~6,500 lf)
- D. Armored shoreline along the west side of Breach Inlet (~3,500 lf)

The findings of CSE-SW-DEW (2010) included the following significant trends:

- Stable ends of the island (Reach A and Reach D).
- The western half of the accreted area (Reach B) was formed between 1953 and 1973, making most of the reach at least 50 years old.
- The eastern half of the accreted area (Reach C) formed between 1983 and 1999, making most of the reach less than 35 years old.



CSE-SW-DEW (2010) analyzed shoreline changes systematically by measuring distances from the survey control line to the seaward vegetation line by transect, reach, and date. Among the highlights to note:

1. Reach B and Reach C (main study area) have widened by an average of ~600 ft at the vegetation line.
2. Reach A and Reach D (ends of the island) have changed relatively little since 1941 because of shore-protection structures.
3. Reach B (western central accretion area) rapidly accreted between 1953 and 1983. Since 1983, there has been relatively little change along this reach.
4. Reach C (eastern central accretion area) gained about 150 ft between 1941 and 1963, then remained relatively stable for 20 years. Most of the accretion in this reach took place between 1983 and the present.

Figure 1.9 shows the average shoreline position by reach for the “1940–2010” period. The results confirm there was negligible change along the armored Reach A and relatively little change along the “stabilized” Breach Inlet shoreline (Reach D) after 1965. The central reaches advanced seaward by hundreds of feet during the same time period.

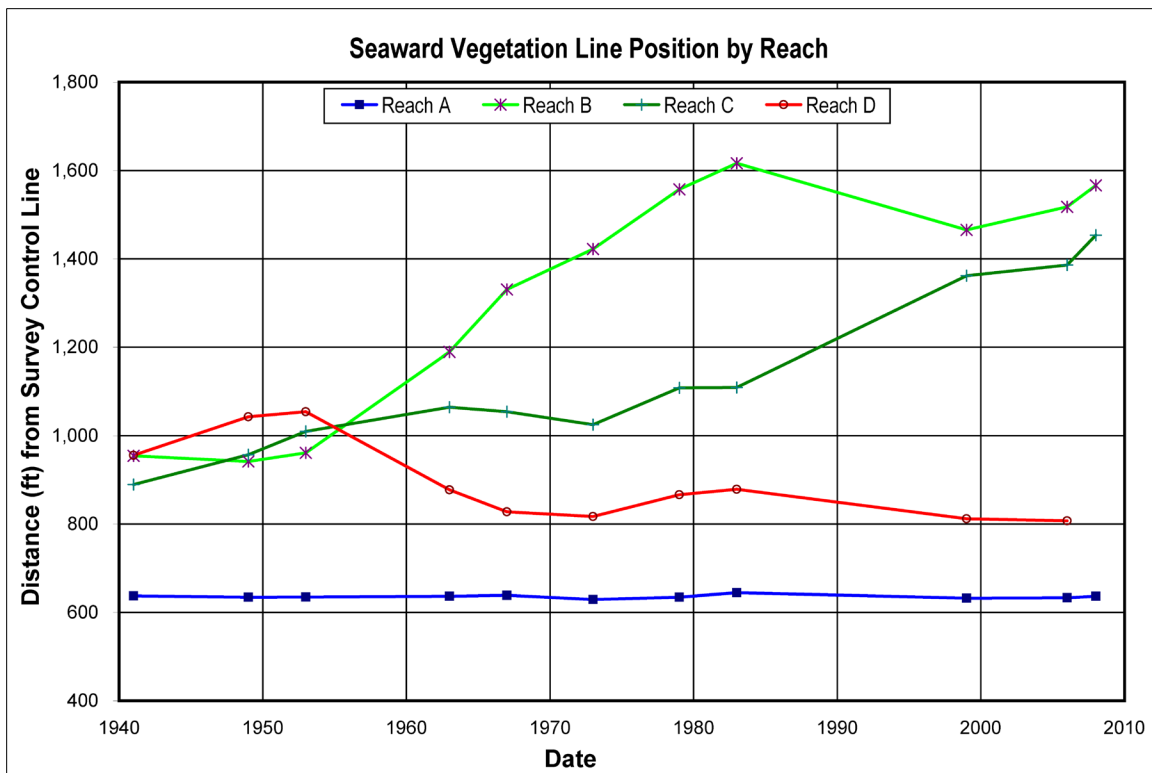


FIGURE 1.9. Average distance from Middle Street to the seaward vegetation line by reach between 1941 and 2008. [After CSE-SW-DEW-2010]

Figure 1.10 shows the average annual shoreline change rate by transect for the vegetation line and wet-sand/dry-sand line along Sullivan’s Island based on the CSE-SW-DEW 2010 analysis. Figure 1.10 indicates the rate of change varies along Sullivan’s Island—particularly the central accretion area—reaching a maximum near the middle of each reach (B and C) and minimum values at the ends of each reach. In Reach B, for example, the average annual change between 1941 and 2008 is over 15 feet per year (ft/yr) around transect 60+00 (~500 ft east of Station 16*). Accretion decreases to about 2 ft/yr at the ends of the reach (near transects 40+00 and 85+00 – north jetty). In Reach C, the average annual change peaks at ~12 ft/yr near transect 120+00 (~Station 25). The net result of prolonged accretion has been the development of two broad bulges in the shoreline along the oceanfront study area, separated by a narrow section of accreted land in the vicinity of the north jetty.

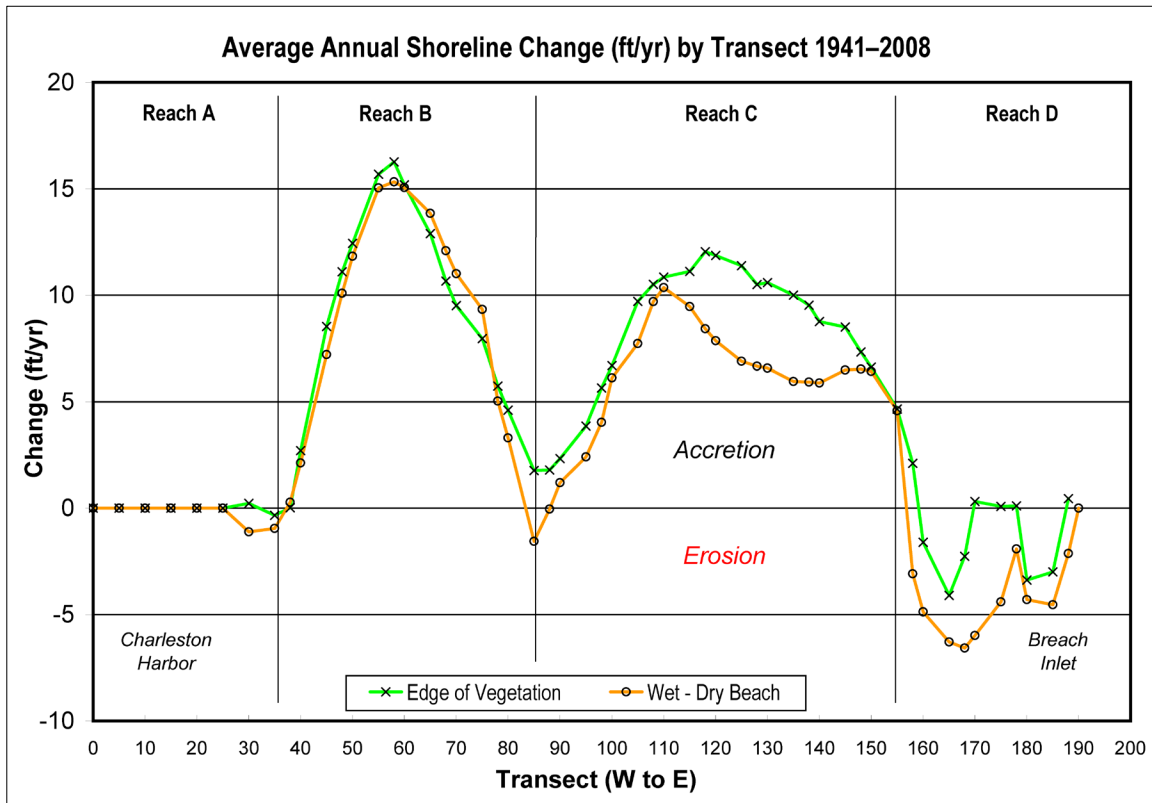


FIGURE 1.10. Average annual change in shoreline position by transect for the period 1941 to 2008. [After CSE-SW-DEW-2010]

* Cross streets along Sullivan’s Island are referred to as “Stations,” with Station 16 near Ft Moultrie and Station 29 near Breach Inlet. These are distinguished from CSE stations (measured in linear ft from Charleston Harbor)

It can be shown that linear shoreline change is equivalent to a “unit volume” change across the active profile of the beach, based on the typical elevation of the backbeach areas and depth of measurable sand transport and profile change offshore. Kana and Gaudiano (2001) determined that 1 ft of recession (or accretion) is equal to ~0.6 cubic yard per foot (cy/ft) at Sullivan’s Island.

Unit volumes (Fig 1.11) are a measure of the quantity of sand contained in a 1-ft length of beach between the foredune and outer limit of the littoral zone (referred to as the “depth of closure” where there is negligible change in the bottom elevation from one year or decade to the next). CSE-SW-DEW converted the linear shoreline changes to an equivalent unit volume change. The results were extrapolated from transect to transect using the “average-end-area method” to estimate the total volumes gained or lost from reach to reach.

Figure 1.12 averages the results by reach annually for the periods of 1941 to 1983, 1983 to 2008, and 1941 to 2008. Figure 1.12 shows the net change per year (upper) and the unit-width change per foot of shoreline per year (lower). The latter results normalize the data so they are not biased by different reach lengths. Rates of change for Reach B and Reach C show significant differences among the periods evaluated. From 1941 to 1983, for example, Reach B accreted at an average of over 19 cubic yards per foot per year (cy/ft/yr), while Reach C accreted one-third as fast (~5.9 cy/ft/yr). Then rates reversed from 1983 to 2008, with Reach B actually eroding (losses of ~2.6 cy/ft/yr), while Reach C accreted at over 15 cy/ft/yr. When averaged over 67 years (1941–2008), the average annual change for both reaches was very similar at ~10–11 cy/ft/yr. Reach D (Breach Inlet), during the same period of time (1941–2008), lost ~375,000 cy (~2 cy/ft/yr). Average annual losses along Breach Inlet have been about 5,600 cy/yr in contrast to annual gains of ~125,000 cy/yr along the central accretion area (Reach B and Reach C). Obviously, Reach A did not exhibit gains or losses because it is armored and generally lacks any wet or dry-sand beach area.

The sustained accretion along the Sullivan’s Island oceanfront at over 10 cy/ft/yr makes the island one of the healthiest, most rapidly accreting beaches along the US East Coast.

Between 1941 and 2008, Reach B gained upward of 3.7 million cubic yards, and Reach C gained about 4.7 million cubic yards. If these quantities were placed via hydraulic dredge in a traditional nourishment project, the cost to the community in today’s dollars would be in the order of \$75–100 million.

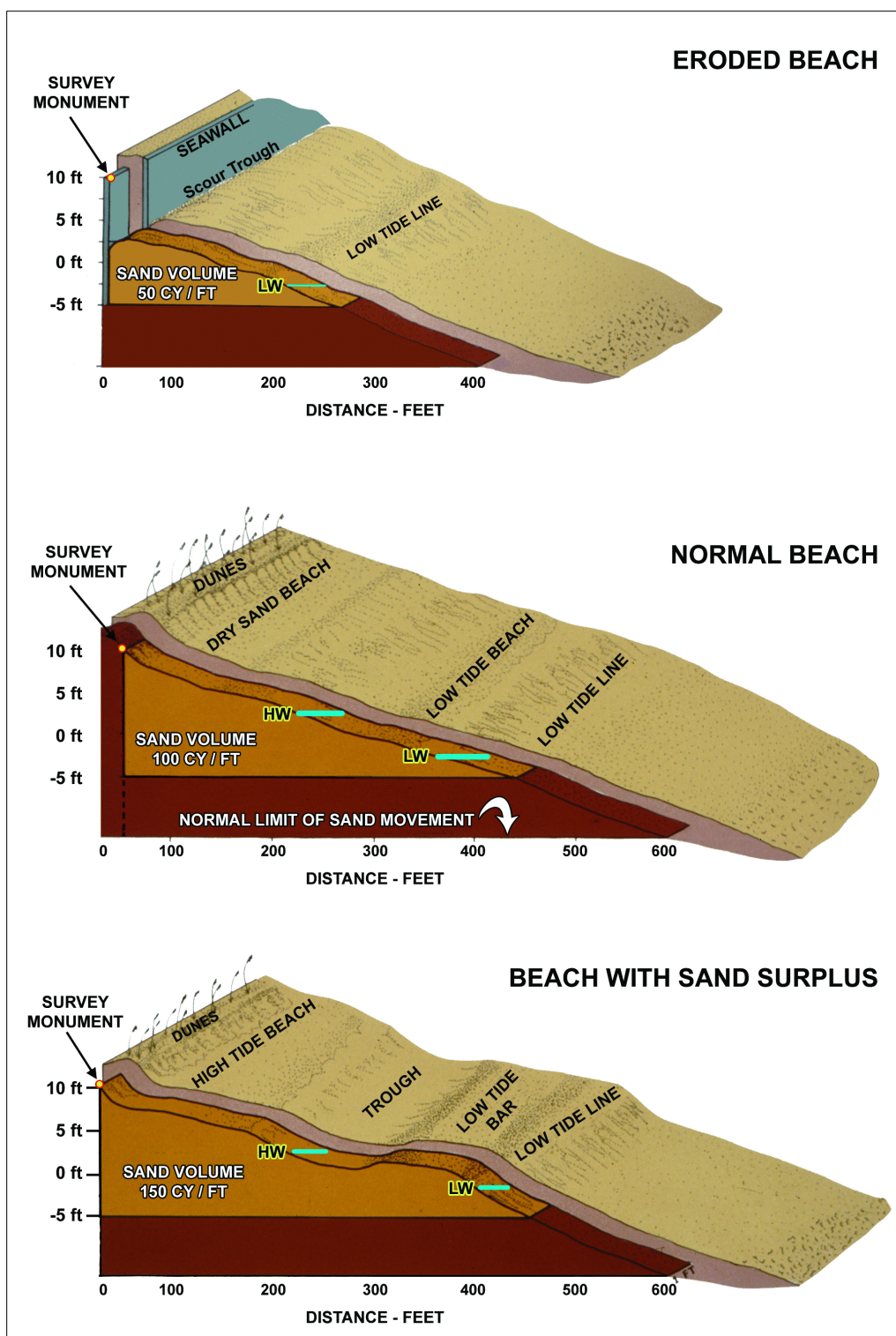


FIGURE 1.11. The concept of unit-width beach volumes, the quantity of sand contained within a 1-ft length of beach. [After Kana 1990]

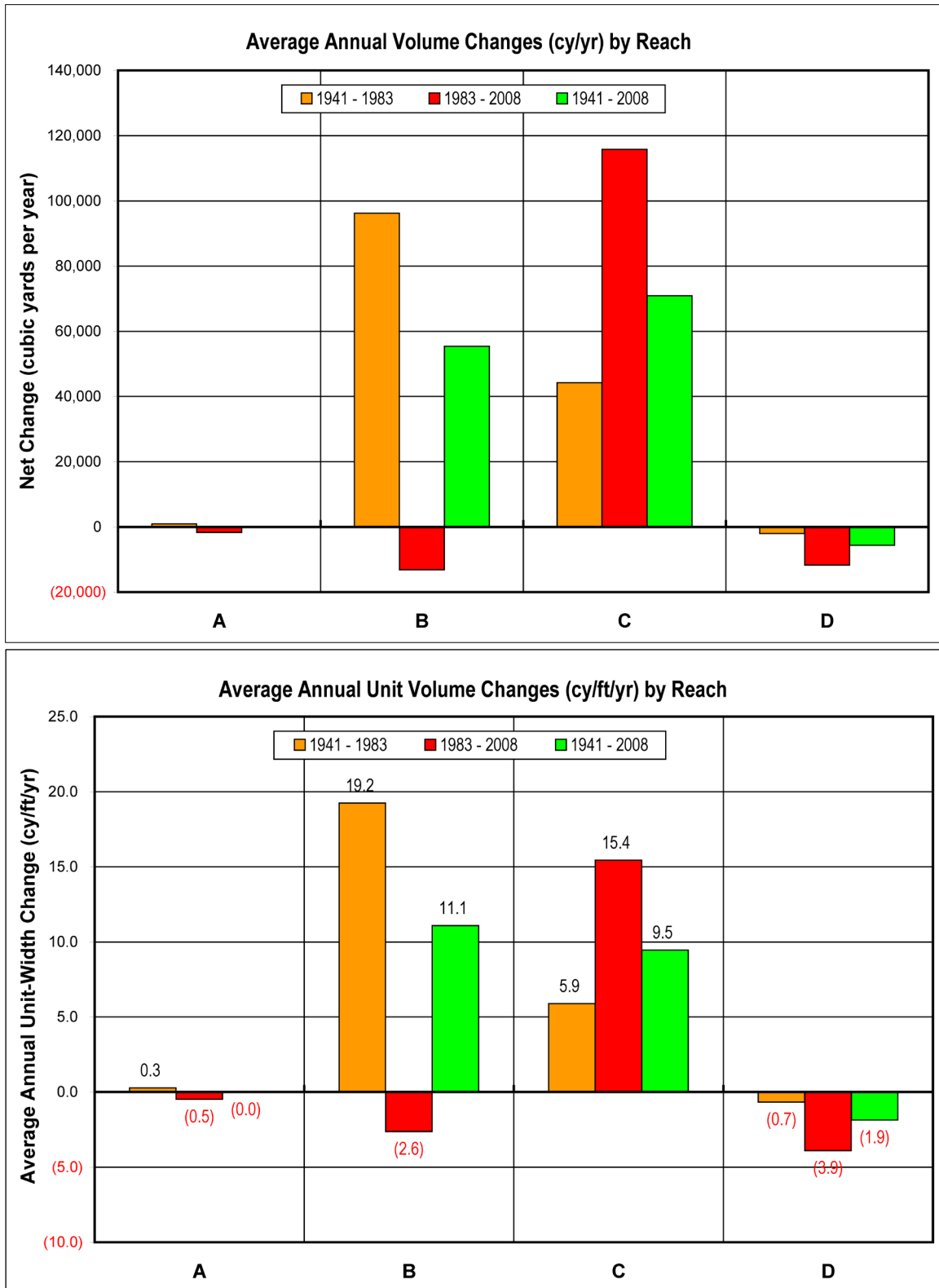


FIGURE 1.12. Average annual change in sand volume by reach for three periods 1941 to 2008 extrapolated from historical shoreline changes. **[UPPER]** Net change per year by reach. **[LOWER]** Average unit-width volume change per year by reach. [After CSE-SW-DEW-2010]

2.0 METHODS

Monitoring efforts for the present report were performed in September 2024. Sand volume changes in the active beach zone were evaluated by obtaining topographic and bathymetric data along shore-perpendicular transects at established locations (Fig 2.1).

Survey transects run from the 19th-century revetment just inside Charleston Harbor (Station 0+00) to the Breach Inlet bridge, northeastern end of the island (Station 182+50). Stationing relates to the distance along the shore, with the number before the “+” symbol representing 100 feet (ft). Therefore, Station 70+00 (near Station 18 ½ by the Lighthouse) is 7,000 ft from Station 0+00. The landward limit of volume calculations (shown in red in Fig 2.1) is set landward of the active beach to allow for future erosion/accretion, while the seaward limit of volume calculations (shown in blue in Fig 2.1) is set seaward of significant bottom elevation changes. These limits may be adjusted over time, but are designed to encompass volume changes over a number of years so that future reports can be easily compared.

Topographic data were collected via RTK-GPS (Trimble™ R12 GNSS), which provides position and elevation measurements at centimeter accuracy. Beach profiles were obtained by collecting data at low tide along the dunes, berm, and active beach to low-tide wading depth. Overwater work was then performed at high tide to overlap the land-based work (Fig 2.2) and was collected with RTK-GPS coupled with an Odom CV100™ precision echosounder mounted on CSE’s survey vessel, the *RV Southern Echo*.

Profiles were collected from the most landward accessible point in the dune system to a minimum of 2,500 ft from the baseline. Profiles along the northeast end of the island extended farther offshore to encompass the shoals associated with Breach Inlet. Alongshore spacing of the profiles ranged from 250 ft to 500 ft, averaging approximately 400 ft across the entire island. Comparative profiles from each of CSE’s monitoring efforts are shown in Appendix A. The complexity in volumetric changes around areas impacted by inlets requires a more detailed analysis (closer profile spacing) to fully incorporate volume changes associated with shoal-bypassing events and inlet migration.

The island is divided into compartments or ‘reaches’ to enable easier comparison of volumes within adjacent portions of the beach. Combining several profiles into a reach makes it easier to identify overall sediment gains and losses across the whole island. The reaches used for monitoring purposes are shown in Figure 2.1 and described in Table 2.1. These reaches are nearly identical to those used in earlier feasibility studies of Sullivan’s Island described in Section 1.2

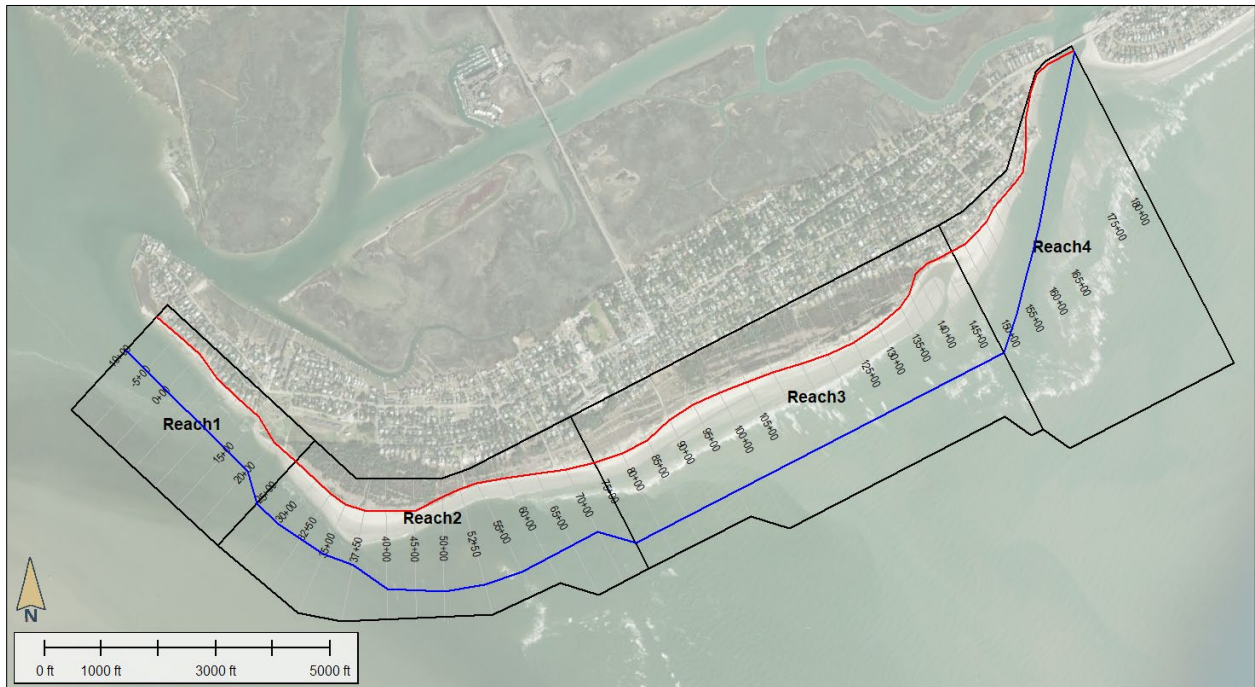


FIGURE 2.1. Baseline map of Sullivan's Island showing the landward (red) and seaward (blue) limits of volume calculations within each of the reaches (shown in black and labeled). Individual profiles are shown as well.



FIGURE 2.2.

Surveying beach profiles involves collection of land-based data at low tide (right) and hydrographic data collection at high tide (below).



TABLE 2.1. Reach boundaries, dimensions, and descriptions across Sullivans Island.

Reach	Name	Length (ft)	CSE Stations	Sullivan's "Stations"	Description
1	Charleston Harbor	4,000	-10+00 to 30+00	Sta 9 to Sta 14	Charleston Harbor to Fort Moultrie; armored, sheltered
2	Western Oceanfront	5,000	30+00 to 80+00	Sta 14 to Sta 20	Fort Moultrie to Elementary School; west of jetty, semi-sheltered
3	Eastern Oceanfront	7,000	80+00 to 150+00	Sta 20 to Sta 29	Elementary School to Dome House; east of jetty, exposed
4	Breach Inlet	2,500	150+00 to 175+00	Sta 29 to Sta 32	Dome House to Breach Inlet; armored, semi-sheltered

To determine changes in beach volume, beach profile data were entered into CSE's in-house custom software, Beach Profile Analysis System (BPAS), which converts 2D profile data in x-z (distance-elevation) format to 3D volumes. The software provides a quantitative and objective way of determining ideal minimum beach profiles and how the sand volume per unit length of shoreline compares with the desired condition. It also provides an accurate method of comparing historical profiles—as the volume method measures sand volumes in the active beach zone rather than extrapolating volumes based on single-contour shoreline position (ie – from aerial photography). Unit-volume calculations can distinguish the quantity of sediment in the dunes, on the dry beach, in the intertidal zone to wading depth, and in the remaining area offshore to the approximate limit of profile change (closure depth).

Sand volume was calculated between the primary dune and between Mean High Water (MHW; +2.03 ft NAVD88*), Mean Low Water (MLW; -2.91 NAVD88), and -15 ft NAVD (the approximate limit of measurable seafloor elevation changes in a 'normal' year for much of the island). Comparative volumes and volume changes were computed using standard procedures (average-end-area method, in which the average of the area under the profiles computed at the ends of each cell is multiplied by the length of the cell to determine the cell's sand volume). Certain adjustments were made to account for changes in the baseline direction and for volumes at the turn in the baseline at Charleston Harbor and Breach Inlet.

Sand volumes for offshore areas were calculated from digital terrain models (DTMs) produced by MATLAB® and GlobalMapper®. DTMs are digital 3D representations of the topography and bathymetry of an area and are useful for calculating changes in contour positions and sediment volumes. Position data were entered into the software as x-y-z coordinates and were processed to provide cross-section profiles and volumes. DTMs are compared with earlier collections to determine changes in shoal positions and volumes.

*North American Vertical Datum of 1988, which is ~0.5 ft above present mean sea level

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3.0 RECENT BEACH CHANGES AND PRESENT CONDITION

For this “Year 2” monitoring report, CSE re-established survey control and measured along the same stations as in 2023 (Fig 2.1). These data provide the first detailed year-over-year volumetric change estimates on Sullivan’s Island completed in many years and will serve as the initial frame of reference for future comparisons and erosion analyses. The set of Year 2 (September 2024) profiles is included in Appendix A. Tables depicting measured volumetric changes along individual profiles and within specific reaches are included in Appendix B.

3.1 Island-Wide Changes (2023–2024)

Shoal bypassing (Fig 3.1) is the episodic emergence and release of sand bars from the seaward shoals of an inlet and their subsequent onshore migration (Stage 1), attachment to the beach (Stage 2), and alongshore spreading (Stage 3). Each shoal bypassing event adds a new supply of sand to the beach and often causes the shoreline to “jump” to a new location, leaving a pond or swale between the previous dune line and the new dry beach. As the shoal bypassing cycle proceeds, the shorelines in the lee of the shoal undergo rapid changes, including accretion directly in the lee of the migrating bar and erosion at the flanks. Bulges in the beach are visibly apparent as areas of wider white sand. Salients produce the wavy shape of the beach, and over time, they tend to migrate from east to west (discussed in more detail below).

An elevation model of Sullivan’s Island beaches in August 2023 is illustrated in Figure 3.2; the same data for September 2024 are in Figure 3.3. The dashed white lines indicate the MHW and –15 ft NAVD contours as of August 2023, while the solid white lines indicate the same contours in September 2024. The most changes above MHW are located along the shifting Breach Inlet and Charleston Harbor shoals (red circles, Fig 3.2 and 3.3). Movement in the main channel and bars around Breach Inlet triggered changes above MHW along Reach 2 (blue arrows, Fig 3.2 and 3.3) while and 3 (highlights, Fig 3.3 and 3.4). Figure 3.4 shows the difference between the 2023 and 2024 surface; warmer colors indicate accretion and cooler colors indicate erosion. Alternating zones of accretion and erosion along the upper beach are caused by waves bending around incoming shoals on both ends of the island (Fig 3.5). Tables 3.1 and 3.2 contain unit and total (profile) volume survey results by profile and reach, using the same color scheme as Fig 3.5 for easier comparison.

In March 2023, the shoal west of the main Breach Inlet channel was nearly attached to Sullivan’s Island, which pushed the old channel up against the beach and created a shallow pond partially connected to the ocean. This condition is what Kana et al (1984) refer to as Stage 2 of the “Shoal Bypassing Cycle” (Fig 3.1). During Stage 2, erosion typically occurs where the shoal is attaching (eg – CSE stations 135+00 to 150+00) while accretion typically occurs along stations to the outside of the attachment zone (eg – CSE stations 120+00 to 135+00 and 150+00 to 165+00).

By September 2024, the shoal along Breach Inlet had largely attached to Sullivan’s Island and begun spreading towards the south and west (Stage 3). Along the central portions of the island, seaward movement in the MHW and MLW contours was observed. Volume increases measured to the –15 ft NAVD contour between CSE stations 55+00 and 110+00 evidence the downcoast spread of shoal sand that attached between March 2023 and September 2024. Knowing what stage of the shoal bypass cycle is occurring helps explain why certain areas are eroding while others are building up. This information is also useful for developing mitigation plans and managing short-term impacts of erosional arcs.

West of CSE station 55+00, near the entrance to Charleston Harbor, another shoal associated with that inlet channel shifted towards Sullivan’s Island between 2023 and 2024. As a result, volume increases measured above the –15 ft contour masked volume decreases above MLW, evidenced by dune scarping between the Station 18 and Station 16 beach access points. This erosional pressure along the upper portions of the beach profile is similar to the Stage 2 processes near Breach Inlet described above. However, the channel separating this shoal is only ~5 to 10 ft below MLW, while the Breach Inlet channel is >10 ft below MLW. Additionally, the Charleston Harbor entrance channel and jetties serve as anchors for this shoal, such that dramatic bypass events like those seen near Breach Inlet are less likely. As a result, although this shoal has encroached upon western Sullivan’s Island and caused some dune scarping (described and shown below), it is likely that sand will freely bypass from the shoal onto the beach in the next couple of years and mitigate the scarping observed since ~2022.

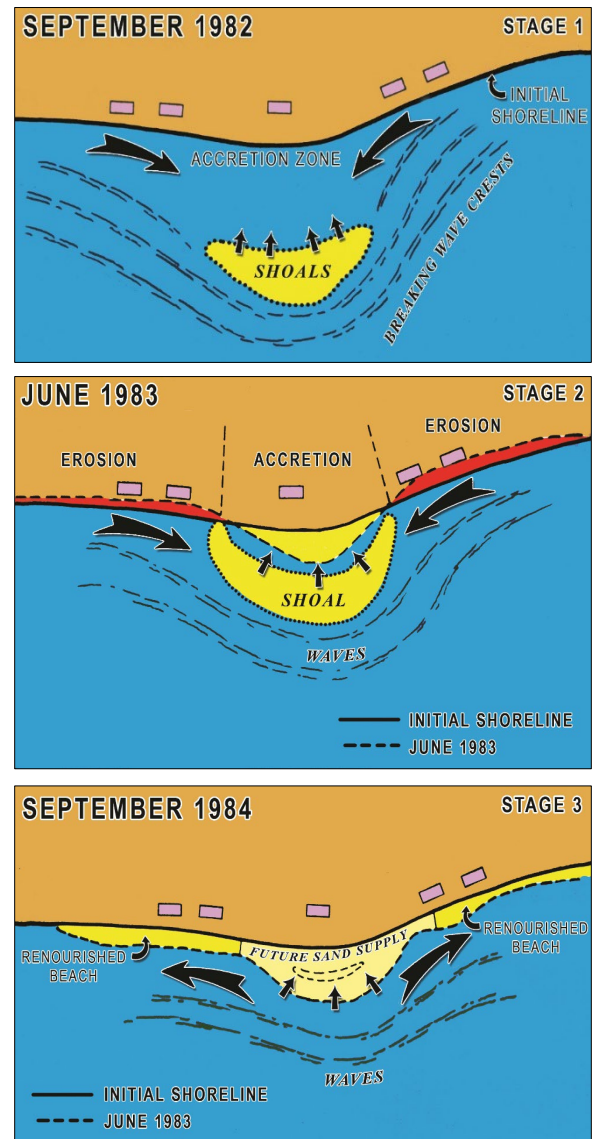


FIGURE 3.1. The “shoal bypassing” cycle is the episodic emergence and release of sand bars from inlet deltas (Stage 1) and their subsequent onshore migration by waves and attachment to the beach (Stage 2). Stage 3 is a period of lateral spreading onshore. Each event adds larger volumes to the beach and causes the shoreline to “jump seaward” and form new dry beach and dunes. The model was based on an event at the east end of the Isle of Palms in the 1980s. [After Kana et al 1984]

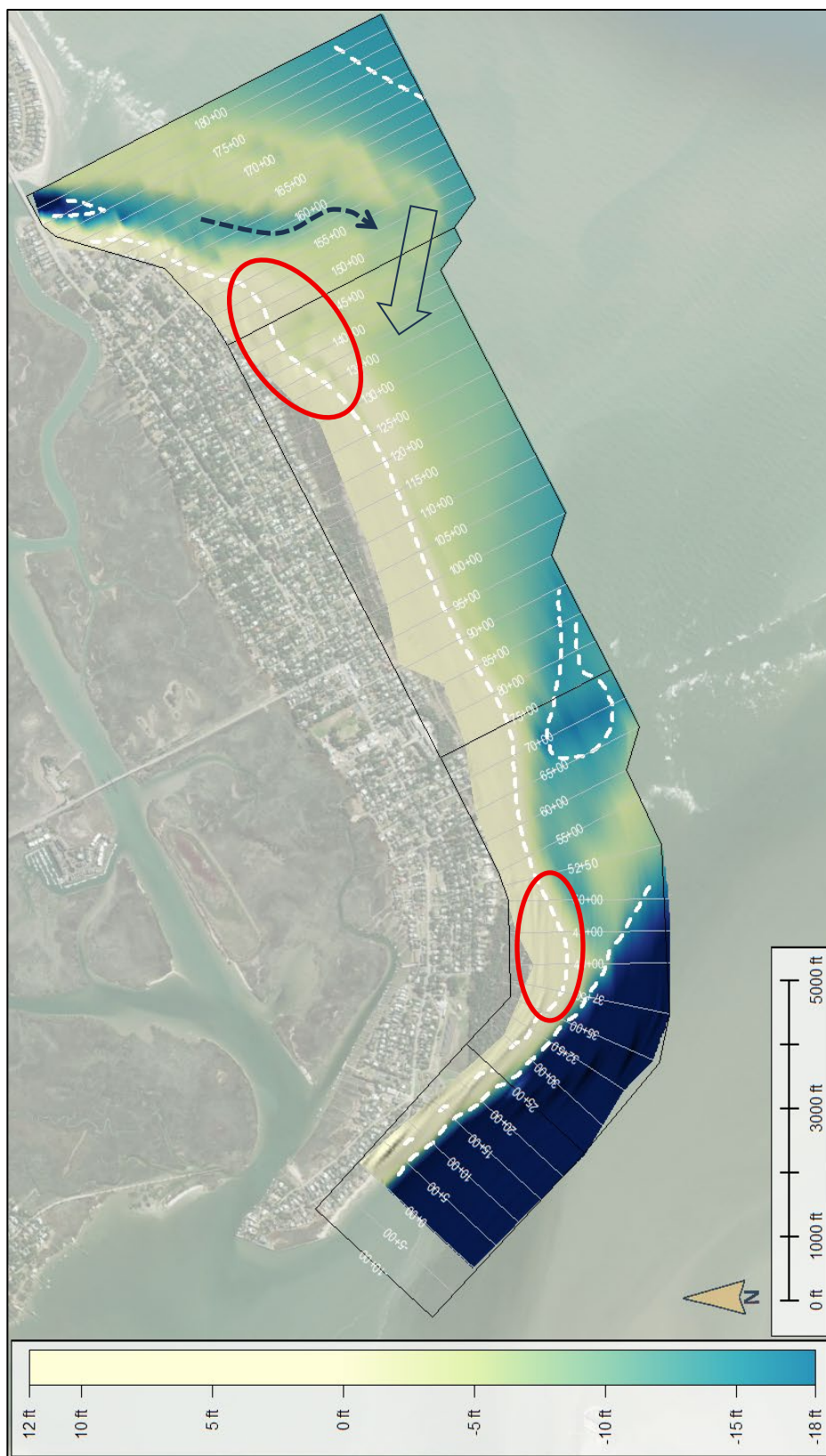


FIGURE 3.2. Surface elevations as measured in August 2023. Reference contours include MHW and the -15 ft depth. Areas of interest include the shoal attachment zones (red circles), the main channel of Breach Inlet (dashed line arrow), and the incoming shoal at the mouth of Breach Inlet (block arrow).



FIGURE 3.3. Surface elevations as measured in September 2024. The red circles in Fig 3.3 match the location and dimension of the red circles in Fig 3.2, and highlight the most notable changes to dry beach volumes between the survey years. The exact orientation of the main channel of Breach Inlet and the location of the incoming shoal at the mouth of that channel are adjusted to reflect morphological changes between 2023 and 2024.

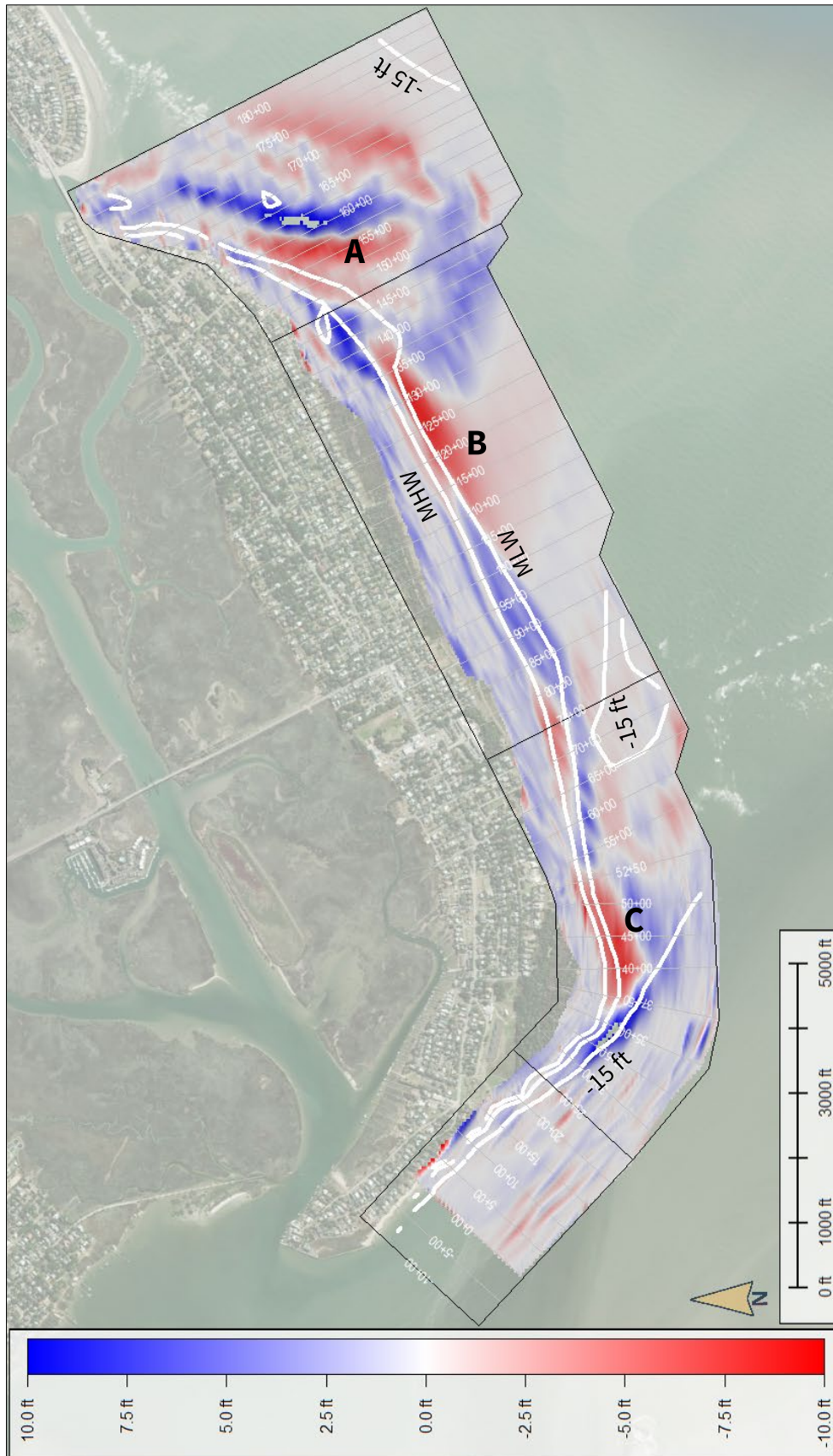


FIGURE 3.4. Changes in surface elevation between August 2023 and September 2024. The color scheme here is designed to match that of Table 3.1, wherein red shades indicate erosion and blue shades indicate accretion. The most significant changes between 2023 and 2024 occurred near the inlets on either side of the island, which have cascading impacts on beach widths and volumes along the entirety of the beachfront. Alternating bands of blue and red in Reaches 2 and 3 are due to the alongshore migration of shoals and bars associated with either inlet. Notations matching locations shown in Tables 3.1 and 3.2 are provided for reference.

TABLE 3.1. [UPPER] Unit volume changes along individual stations and lens depths across Sullivan’s Island from August 2023 to September 2024 **[LOWER]** The same results averaged by reach.

Results by Profile						Unit Volume (cy/ft)						Unit Volume Change (cy/ft)		
						Aug-23			Sep-24			Aug-23 to Sep-24		
Reach	Name	Station	Distance to Next (ft)	Offset (ft)	Cutoff (ft)	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW
1	Charleston Harbor	-10+00	0	292	1,000				120.1	21.1	7.6			
		-5+00	500	260	1,000				128.0	21.8	9.1			
		0+00	500	277	1,000	127.8	21.3	7.7	128.9	22.7	9.2	1.1	1.4	1.5
		5+00	500	366	1,000	98.1	18.0	7.0	100.4	17.7	6.3	2.3	-0.3	-0.7
		10+00	500	375	1,000	119.6	29.5	9.9	121.4	31.5	10.0	1.7	2.0	0.1
		15+00	500	360	1,000	122.6	39.3	8.1	124.8	42.6	10.6	2.1	3.3	2.5
		20+00	500	512	1,000	121.7	20.2	5.3	122.4	21.4	4.5	0.7	1.2	-0.8
		25+00	500	504	1,500	139.2	32.5	11.8	141.8	36.5	9.3	2.6	4.0	-2.6
2	Western Oceanfront	30+00	500	506	1,500	164.9	34.9	11.8	180.7	47.8	17.6	15.8	12.8	5.8
		32+50	250	515	1,500	163.7	38.8	12.4	198.9	66.2	29.8	35.2	27.5	17.3
		35+00	250	504	1,500	183.6	50.8	18.2	221.0	72.2	29.2	37.4	21.4	11.0
		37+50	250	569	1,600	271.1	84.8	39.5	307.9	62.6	24.8	36.8	-22.2	-14.6
		40+00	500	569	2,000	396.7	102.6	49.8	352.7	51.2	22.8	-44.0	-51.4	-27.0
		45+00	500	568	2,000	351.2	68.6	36.3	357.5	32.9	8.8	6.3	-35.7	-27.5
		50+00	250	347	2,000	444.2	61.7	41.8	479.4	35.0	9.6	35.2	-26.7	-32.3
		52+50	250	288	2,000	507.6	54.8	34.5	493.2	43.5	14.2	-14.4	-11.2	-20.3
		55+00	500	301	2,000	390.3	47.6	18.0	416.4	62.4	21.2	26.1	14.8	3.2
		60+00	500	450	2,000	325.1	50.5	18.1	347.2	52.5	20.4	22.1	2.0	2.2
		65+00	500	590	2,000	296.8	60.6	25.6	312.2	55.3	21.2	15.5	-5.3	-4.4
		70+00	500	791	2,000	276.2	66.1	26.6	294.5	47.3	11.5	18.3	-18.7	-15.1
75+00	500	924	2,500	335.1	71.1	41.0	337.7	52.1	13.9	2.7	-18.9	-27.1		
3	Eastern Oceanfront	80+00	500	995	2,500	390.7	60.0	32.1	405.8	67.2	25.8	15.1	7.2	-6.3
		85+00	500	997	2,500	431.1	47.1	10.2	475.1	75.3	21.3	44.1	28.2	11.1
		90+00	500	860	2,500	501.6	60.9	20.4	559.9	100.8	31.5	58.2	39.8	11.1
		95+00	500	809	2,500	557.9	75.9	29.3	595.4	116.8	40.1	37.5	40.9	10.8
		100+00	500	830	2,500	579.3	79.9	31.2	589.4	113.1	45.2	10.0	33.3	14.0
		105+00	500	890	2,500	589.4	77.2	31.1	569.5	100.0	44.7	-19.9	22.8	13.6
		110+00	500	946	2,500	592.5	78.8	31.3	540.3	84.2	37.0	-52.1	5.4	5.7
		115+00	500	1,036	2,500	575.0	79.0	30.1	494.3	63.6	27.0	-80.7	-15.4	-3.1
		120+00	500	1,098	2,500	553.8	92.4	18.8	460.3	43.0	14.9	-93.5	-49.4	-3.8
		125+00	500	1,132	2,500	540.1	95.3	18.1	459.1	33.6	10.4	-80.9	-61.7	-7.7
		130+00	500	1,064	2,500	561.2	104.9	30.3	559.8	48.2	22.6	-1.4	-56.7	-7.7
		135+00	250	943	2,500	604.5	116.2	30.3	674.7	86.6	45.2	70.2	-29.5	14.9
		137+50	250	823	2,500	653.8	99.4	16.4	727.4	103.9	43.5	73.6	4.4	27.1
		140+00	250	500	2,500	845.3	119.8	45.8	876.8	157.0	68.4	31.5	37.3	22.6
		142+50	250	507	2,500	830.9	47.7	31.1	853.0	153.1	40.0	22.1	105.3	8.9
145+00	250	510	2,500	830.4	38.7	22.4	841.3	113.0	34.0	11.0	74.3	11.6		
147+50	250	487	2,500	859.5	119.7	30.1	853.9	140.3	59.1	-5.6	20.6	29.0		
4	Breach Inlet	150+00	250	500	2,000	757.9	143.1	42.3	734.2	113.3	58.6	-23.6	-29.8	16.4
		152+50	250	432	2,000	688.9	137.5	39.1	629.1	98.9	57.0	-59.8	-38.6	17.9
		155+00	250	403	2,000	693.1	123.3	40.7	524.1	78.7	43.5	-169.0	-44.5	2.8
		157+50	250	345	1,600	539.9	83.6	19.3	381.2	64.7	36.5	-158.6	-18.9	17.2
		160+00	250	309	1,200	323.8	22.9	3.4	254.9	46.2	17.3	-68.9	23.3	13.9
		162+50	250	294	1,000	200.8	14.0	10.0	165.9	31.9	9.0	-34.9	17.9	-1.0
		165+00	400	326	1,000	132.3	8.1	6.4	131.8	11.0	3.8	-0.4	2.9	-2.6
		167+50	370	243	1,000	200.7	24.1	11.2	182.3	29.9	10.7	-18.5	5.8	-0.5
		170+00	380	270	1,000	196.1	45.3	55.3	196.1	43.9	53.5	0.0	-1.4	-1.8
		172+50	0	12	1,000	272.9	39.4	13.4	271.9	42.2	9.8	-1.0	2.8	-3.6

Results by Reach				Unit Volume (cy/ft)						Unit Volume Change (cy/ft)			
Reach	Name	Length		Aug-23			Sep-24			Aug-23 to Sep-24			
				-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW	
1	Charleston Harbor	4,000		93.5	20.9	6.5	95.7	23.1	6.8	2.2	2.2	0.3	
2	Western Oceanfront	5,000		330.7	62.9	30.1	344.4	51.9	18.2	13.7	-11.0	-11.9	
3	Eastern Oceanfront	7,000		595.0	82.6	26.6	590.8	88.5	34.2	-4.1	5.9	7.5	
4	Breach Inlet	2,500		376.4	58.9	22.6	324.0	52.5	27.5	-52.3	-6.4	4.9	
ALL				18,500	385.6	60.8	22.7	381.1	59.6	23.0	-4.5	-1.1	0.4

TABLE 3.2. [UPPER] Total volume changes along individual stations and lens depths across Sullivan’s Island from August 2023 to September 2024 **[LOWER]** The same results calculated by reach.

Results by Profile						Profile Volume (cy)						Profile Volume Change (cy)		
						Aug-23			Sep-24			Aug-23 to Sep-24		
Reach	Name	Station	Distance to Next (ft)	Offset (ft)	Cutoff (ft)	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW
1	Charleston Harbor	-10+00	0	292	1,000				62,032	10,719	4,178			
		-5+00	500	260	1,000				64,228	11,131	4,584			
		0+00	500	277	1,000	56,480	9,825	3,672	57,326	10,106	3,885	845	281	213
		5+00	500	366	1,000	54,442	11,860	4,211	55,447	12,301	4,080	1,006	441	-131
		10+00	500	375	1,000	60,570	17,190	4,498	61,536	18,531	5,150	965	1,341	652
		15+00	500	360	1,000	61,089	14,860	3,358	61,804	16,001	3,774	715	1,141	416
		20+00	500	512	1,000	65,216	13,165	4,286	66,053	14,482	3,436	836	1,316	-849
25+00	500	504	1,500	76,021	16,861	5,904	80,614	21,078	6,718	4,593	4,218	814		
2	Western Oceanfront	30+00	500	506	1,500	41,074	9,217	3,025	47,446	14,255	5,922	6,372	5,038	2,897
		32+50	250	515	1,500	43,405	11,200	3,832	52,483	17,304	7,370	9,078	6,104	3,538
		35+00	250	504	1,500	56,840	16,952	7,211	66,114	16,850	6,752	9,274	-102	-459
		37+50	250	569	1,600	83,483	23,421	11,161	82,581	14,227	5,958	-902	-9,194	-5,202
		40+00	500	569	2,000	186,970	42,794	21,535	177,556	21,019	7,917	-9,413	-21,775	-13,618
		45+00	500	568	2,000	198,838	32,572	19,538	209,220	16,965	4,597	10,383	-15,607	-14,941
		50+00	250	347	2,000	118,972	14,556	9,538	121,573	9,816	2,966	2,601	-4,740	-6,572
		52+50	250	288	2,000	112,235	12,801	6,555	113,702	13,247	4,417	1,467	446	-2,138
		55+00	500	301	2,000	178,847	24,541	9,023	190,895	28,741	10,380	12,048	4,199	1,357
		60+00	500	450	2,000	155,472	27,778	10,923	164,856	26,948	10,381	9,384	-829	-542
		65+00	500	590	2,000	143,236	31,661	13,041	151,681	25,652	8,165	8,444	-6,009	-4,875
		70+00	500	791	2,000	152,804	34,281	16,909	158,049	24,871	6,349	5,245	-9,410	-10,559
75+00	500	924	2,500	181,441	32,759	18,289	185,879	29,830	9,938	4,438	-2,929	-8,351		
3	Eastern Oceanfront	80+00	500	995	2,500	205,440	26,759	10,576	220,231	35,611	11,779	14,791	8,851	1,203
		85+00	500	997	2,500	233,172	26,998	7,659	258,750	44,006	13,197	25,578	17,009	5,538
		90+00	500	860	2,500	264,883	34,203	12,436	288,824	54,394	17,911	23,941	20,191	5,475
		95+00	500	809	2,500	284,311	38,942	15,134	296,201	57,488	21,329	11,890	18,547	6,195
		100+00	500	830	2,500	292,192	39,261	15,575	289,732	53,278	22,466	-2,461	14,017	6,890
		105+00	500	890	2,500	295,472	38,982	15,589	277,465	46,039	20,412	-18,007	7,057	4,824
		110+00	500	946	2,500	291,866	39,448	15,354	258,665	36,948	16,003	-33,201	-2,500	649
		115+00	500	1,036	2,500	282,190	42,866	12,220	238,654	26,660	10,496	-43,536	-16,206	-1,723
		120+00	500	1,098	2,500	273,454	46,940	9,207	229,852	19,157	6,324	-43,601	-27,783	-2,883
		125+00	500	1,132	2,500	275,316	50,047	12,097	254,733	20,444	8,240	-20,583	-29,603	-3,857
		130+00	500	1,064	2,500	291,414	55,253	15,157	308,623	33,699	16,963	17,209	-21,554	1,806
		135+00	250	943	2,500	157,275	26,948	5,839	175,258	23,809	11,094	17,982	-3,139	5,254
		137+50	250	823	2,500	187,377	27,398	7,781	200,516	32,608	13,990	13,139	5,210	6,209
		140+00	250	500	2,500	209,516	20,936	9,621	216,221	38,758	13,551	6,705	17,822	3,929
		142+50	250	507	2,500	207,657	10,808	6,688	211,794	33,261	9,245	4,137	22,453	2,556
145+00	250	510	2,500	211,233	19,797	6,563	211,900	31,661	11,634	668	11,863	5,072		
147+50	250	487	2,500	202,166	32,838	9,047	198,508	31,689	14,720	-3,658	-1,149	5,672		
4	Breach Inlet	150+00	250	500	2,000	180,844	35,072	10,169	170,418	26,518	14,451	-10,426	-8,555	4,283
		152+50	250	432	2,000	172,743	32,600	9,968	144,149	22,202	12,559	-28,594	-10,398	2,591
		155+00	250	403	2,000	154,113	25,858	7,490	113,159	17,928	9,997	-40,954	-7,930	2,507
		157+50	250	345	1,600	107,958	13,313	2,831	79,512	13,864	6,718	-28,446	551	3,887
		160+00	250	309	1,200	65,573	4,610	1,672	52,597	9,763	3,285	-12,976	5,153	1,613
		162+50	250	294	1,000	41,629	2,757	2,048	37,218	5,357	1,601	-4,411	2,600	-447
		165+00	400	326	1,000	41,623	4,020	2,195	39,264	5,103	1,808	-2,359	1,082	-387
		167+50	370	243	1,000	49,604	8,668	8,308	47,295	9,219	8,016	-2,309	551	-292
		170+00	380	270	1,000	58,632	10,581	8,583	58,500	10,759	7,907	-132	178	-676
		172+50	0	12	1,000	68,236	9,845	3,343	67,978	10,545	2,448	-258	700	-895
Results by Reach						Profile Volume (cy)						Profile Volume Change (cy)		
						Aug-23			Sep-24			Aug-23 to Sep-24		
Reach	Name		Length	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW	-15 to MLW	MLW to MHW	MHW		
1	Charleston Harbor		4,000	373,819	83,761	25,929	382,778	92,499	27,043	8,959	8,738	1,114		
2	Western Oceanfront		5,000	1,653,617	314,533	150,578	1,722,036	259,725	91,112	68,419	-54,808	-59,466		
3	Eastern Oceanfront		7,000	4,164,933	578,421	186,543	4,135,928	619,509	239,354	-29,005	41,088	52,811		
4	Breach Inlet		2,500	940,956	147,325	56,607	810,090	131,257	68,792	-130,866	-16,068	12,185		
ALL				7,133,324	1,124,040	419,657	7,050,831	1,102,990	426,301	-82,493	-21,050	6,644		

Unit volumes by Reach for selected depth contours are shown in Figure 3.5. Between the -15 ft contour and MLW – in other words, the part of the active beach profile that nearly always remains under water – Reach 3 contains approximately twice as much sand (~600 cy/ft) as the other three reaches. Reaches 2 and 4, located along relatively shallow inlet channels, contain ~300 cy/ft. Reach 1, located within the entrance to Charleston Harbor and therefore much closer to deep water than the other reaches, contains ~100 cy/ft in the underwater profile. Along shallower lens depths, the four reaches exhibit similar trends in beach volumes, whereby Reach 3 contains the most sand, Reaches 2 and 4 are roughly equivalent, and Reach 1 contains the least sand.

Lens depths between the MLW and MHW contours represent the intertidal beach exposed to varying degrees as water levels decrease and increase twice daily. As described in Section 1.2, it is possible to convert between unit volumes and linear dry beach widths by using a few simple assumptions (see Gaudio and Kana 2001). A 1-ft difference in beach width is equivalent to a 0.6 cy/ft difference on Sullivan’s Island, so a 1 cy/ft difference is equivalent to approximately 1.7 ft of dry beach width. In other words, dry beach widths in Reach 3 are approximately 30 ft greater than in Reach 2 ($34.2 \text{ cy/ft} - 18.2 \text{ cy/ft} = 16 \text{ cy/ft} \times 1.7 \text{ ft/cy} = 30$), 10 ft greater than Reach 4, and 40 ft greater than Reach 1.

Unit volume changes by Reach from 2023 to 2024 for selected depth contours are shown in Figure 3.6. Between March 2023 and September 2024, Reach 4 lost the most volume from any lens or reach (-52.3 cy/ft between the -15 ft contour and MLW) while Reach 2 gained the most volume from any lens or reach (+13.7 cy/ft between the -15 ft contour and MLW). Changes to the intertidal beach were relatively minor across most of the island, with the exception of Reach 2 (-11.0 cy/ft between MHW and MLW). Reach 3 tended to gain sand above MLW, while Reach 2 tended to lose sand above MLW, while Reach 1 gained relatively minor volumes of sand. These trends are explained in greater detail in Section 3.2.

Examining trends between individual profiles and lens depths at an island-wide scale can help clarify some of the trends of Reach-averaged values described above. Figure 3.7 depicts the unit volume changes to selected lens depths from 2023 to 2024, but plots results from individual stations without averaging by Reach. This offers a more nuanced picture of the volume changes measured in the year-to-year surveys. The relatively minor changes and volumes presented for Reach 1 above are reflected in the individual station results shown in Figure 3.6. This portion of the island is armored and within the entrance to Charleston Harbor, and therefore represents a very different type of beach setting than the other three reaches.

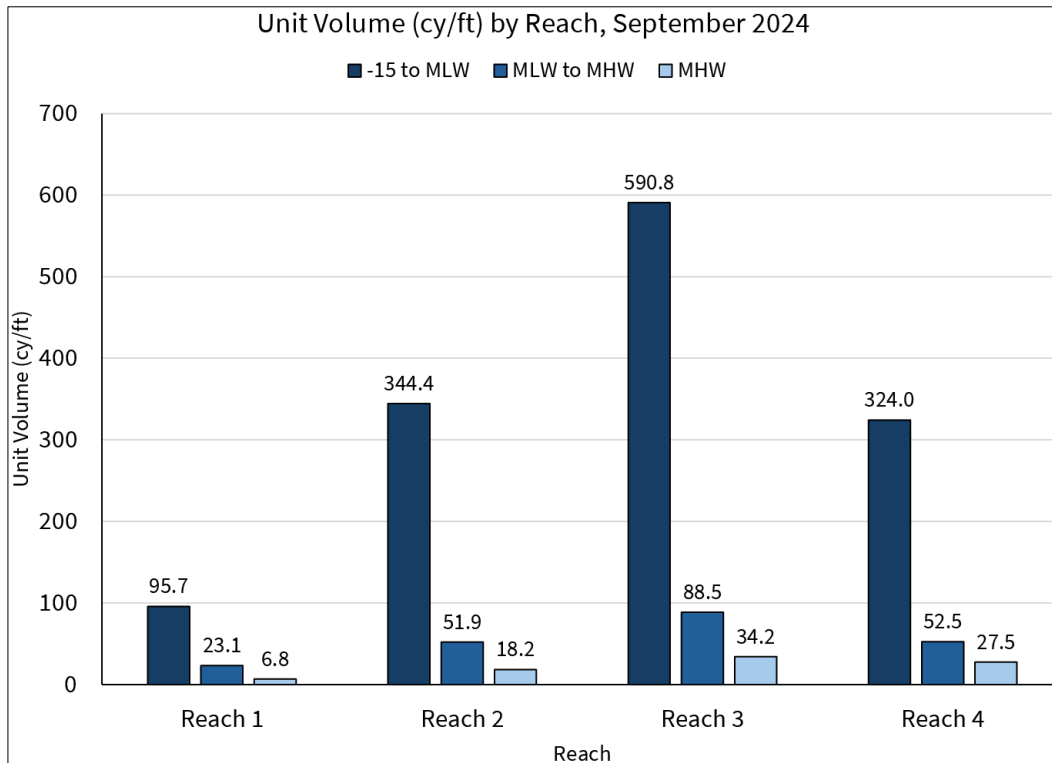


FIGURE 3.5. Unit volumes across the four reaches on Sullivan’s Island as measured in September 2024.

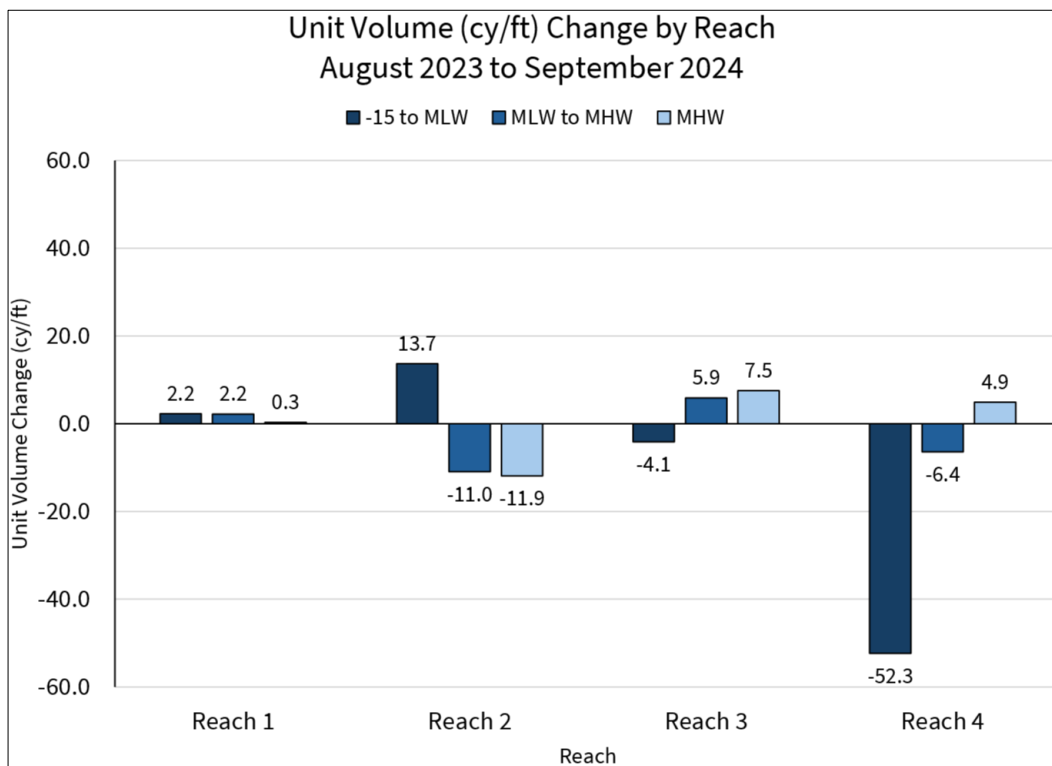


FIGURE 3.6. Unit volume changes across the four reaches of Sullivan’s Island from August 2023 to September 2024.

Waves of erosion and accretion propagating west and south from Breach Inlet in Reach 4 are evident in the volume changes measured between the -15 ft and MLW contours. Encroachment of the Breach Inlet channel on the survey area is reflected in the losses exceeding 100 cy/ft along Reach 4. At least two waves of volume increases, centered near CSE stations 135+00 and 95+00 in Fig 3.7, represent underwater sand transport moving away from the attachment zone of the Breach Inlet shoal.

Because that portion of the profile remains underwater nearly always, it is more continuously exposed to wave-driven transport. As a result, those salients of volume increase have moved slightly farther than the same patterns higher on the profile. For instance, volume increases measured between MLW and MHW were greatest, approximately 1,000 ft upcoast (eg – east and north) from the volume increases measured below MLW. Changes to the dry beach measured above MHW follow a similar pattern.

The losses measured above MLW along Reach 2 are more closely related to the shifting shoal at the mouth of Charleston Harbor than the alongshore spreading of sand from Breach Inlet. The channel separating that shoal from Sullivan’s Island is squeezed against the beach as the shoal moves landward, triggering dune scarping (a classic diagnostic signature of erosion along the upper beach profile). However, volume increases below MLW reflect the additional shoal sand that has migrated landward at the same time.

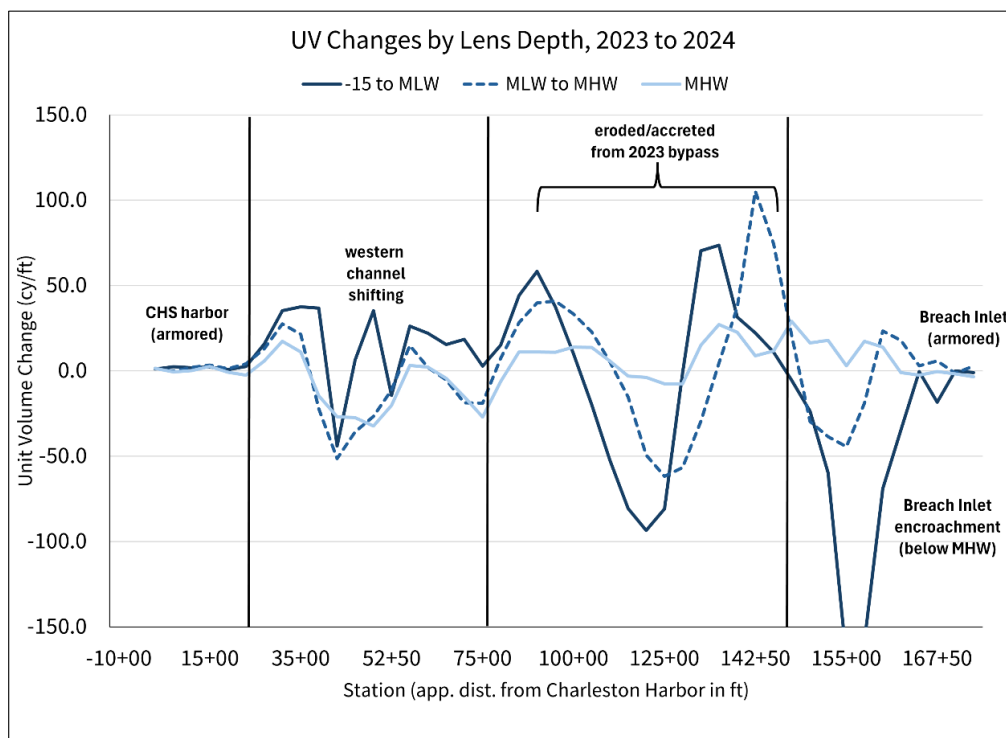


FIGURE 3.7. Unit volume changes, plotted by individual stations, across Sullivan’s Island from August 2023 to September 2024.

3.2 Changes by Reach (2023–2024)

Reach 1 – Charleston Harbor

The portion of Sullivan’s Island adjacent to Charleston Harbor (Reach 1) gained minor volume increases across all lens depths between August 2023 and September 2024. Below MLW, the reach gained ~2.2 cy/ft (~9,000 cy) while the intertidal beach gained ~2.2 cy/ft (~8,700 cy) and the dry beach gained ~0.3 cy/ft (~1,100 cy). These changes are virtually indistinguishable in site photos comparing the visible condition of the intertidal and dry beaches between the survey events (Fig 3.8).

This reach is located adjacent to the Charleston Harbor entrance channel, deeper than 50 ft within 800 ft of the first row on Sullivan’s Island. Additionally, the entire reach contains hardened structures along the upper dry beach. Sediment supply and beach conditions in Reach 1 are dependent on sediment availability in Reach 2. When Reach 2 is healthy, more sand is available to move into Reach 1, and the beach condition tends to improve. A ‘typical’ profile and ground photo are included in Figure 3.9

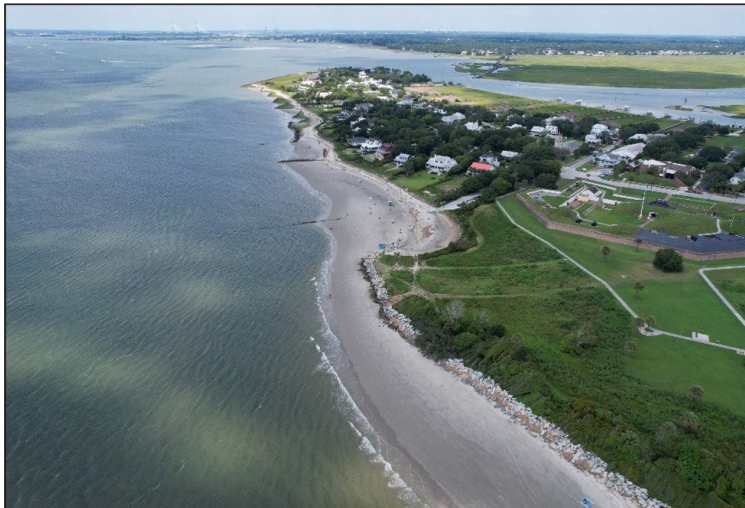


FIGURE 3.8. Aerial photos on Reach 1 looking northwest towards Charleston Harbor. Volumetric changes along the beach above MLW between August 2023 (upper) and September 2024 (lower) were relatively minor. As a result, beach widths did not change significantly between the two survey events.



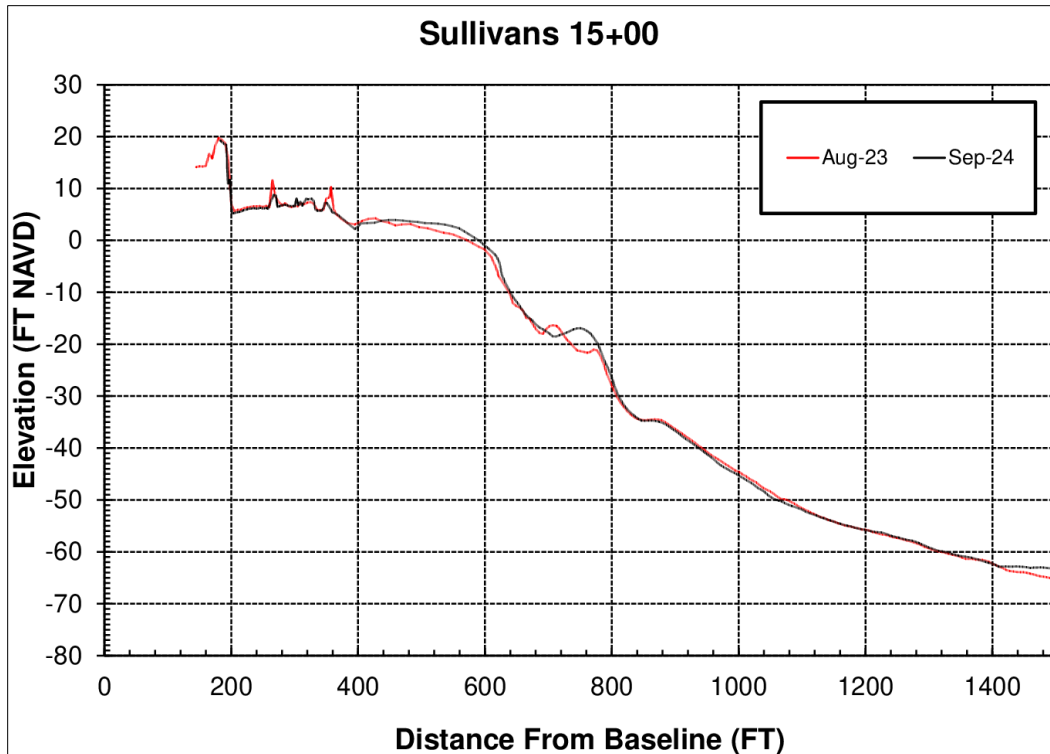


FIGURE 3.9. Profile and ground photo from Station 12 beach access in September 2024. At this time, there was little dry-sand beach present at this location. However, the position of the MLW line changed relatively little between 2023 and 2024 – most of the volume changes measured here occurred in ~15 to 20 feet of water. The proximity of most profiles in Reach 1 to much deeper water (note water depths exceed 50 ft within 1,000 ft of MLW) makes this reach particularly dependent on sand supplied from Reach 2 along the intertidal and dry-sand beach.

Reach 2 – Western Oceanfront

The western section of the oceanfront (Reach 2) gained ~13.7 cy/ft (~68,400 cy) below MLW, but lost ~22.9 cy/ft above MLW on the intertidal and dry-sand beaches. Losses above MLW were nearly evenly split between the intertidal beach (MLW to MHW lost ~11.0 cy/ft, or ~54,800 cy) and the dry-sand beach (above MHW lost ~11.9 cy/ft, or ~59,500 cy). These changes are evident in site photographs, which reflect a narrow band of the intertidal and dry-sand beaches from 2023 to 2024 (Fig 3.10). Erosion of the visible beach exceeded 100 linear feet in some areas, with MHW encroaching into densely vegetated uplands. Scarping and upland loss was most severe between CSE stations 60+00 and 45+00.

Ground photos from September 2024 also reflect the eroded condition of the dry-sand beach in Reach 2. CSE station 50+00 is located just west of the Sand Dunes club, and lost ~32.3 cy/ft above MHW (Fig 3.11). However, landward movement in the shoal brought ~35.2 cy/ft of accretion between the -15 ft and MLW contours. This is a typical – though perhaps slightly dramatic – example of the changes along Reach 2 from 2023 to 2024. With this in mind, and considering the continued downshore migration of sand from the Breach Inlet bypass in the last year, it is likely that the dune scarping observed in Reach 2 from 2023 to 2024 is temporary, and sand from the shoal attachment to the east will begin to restore the area in the next 1 to 2 years.



FIGURE 3.10. Aerial imagery indicating the extent of upland encroachment by the MHW line between August 2023 (upper) and September 2024 (lower).

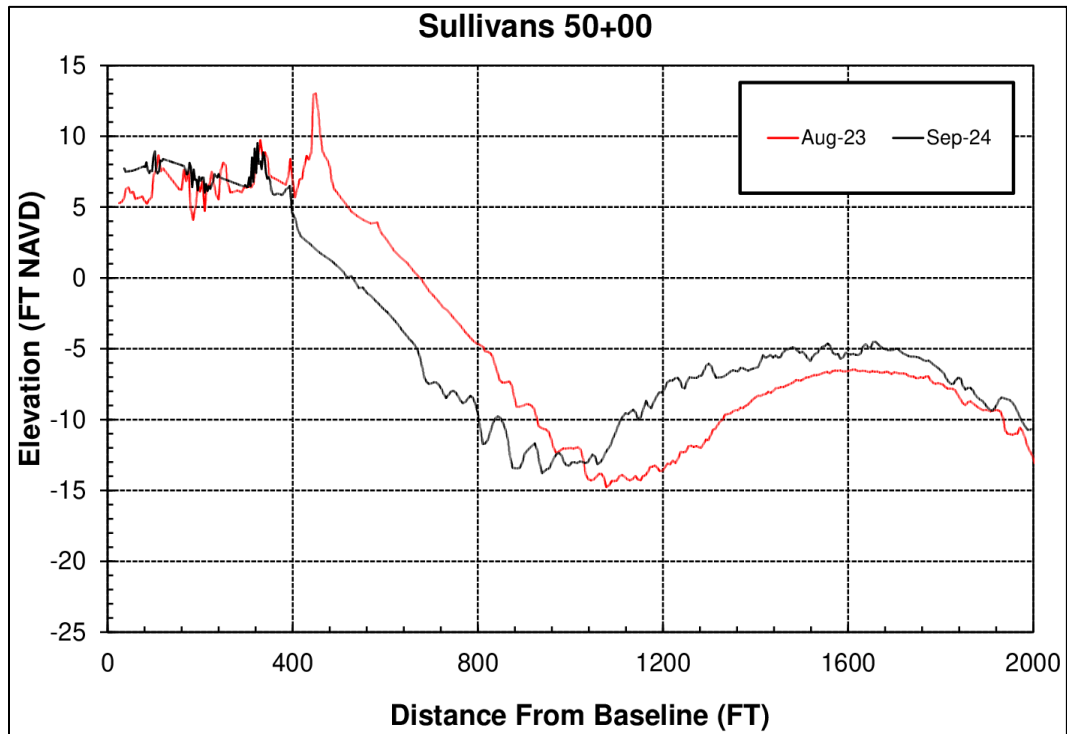


FIGURE 3.11. Profile and ground photo from the Sand Dunes Club beach access in September 2024. The MHW line (~2 ft NAVD) moved approximately 150 ft landward in this location, one of the most severe losses of dry-sand beach on Sullivan's Island between August 2023 and September 2024. Despite these losses, an incoming shoal located ~1,000 to 2,000 ft seaward of the Sand Dunes Club is expected to feed sand from deeper water to the dry-sand beach in the next 1 to 2 years.

Reach 3 – Eastern Oceanfront

The eastern section of the oceanfront (Reach 3) contains the largest average beach volumes seaward of the dune on Sullivan’s Island. This reach also exhibited a reverse pattern in lens depth volume changes compared to Reach 2 between 2023 and 2024. Whereas Reach 2 gained sand below MLW and lost sand above MLW, Reach 1 lost sand below MLW and gained sand above MLW (see Fig 3.12). Below MLW, the reach lost ~4.1 cy/ft (~29,000 cy) while the intertidal beach gained ~5.9 cy/ft (~41,100 cy) and the dry beach gained ~7.5 cy/ft (~52,800 cy).

Much of this change is due to the attachment and spreading of a shoal from Breach Inlet, which bypassed the channel between August 2023 and September 2024. The landward, upward, and down-coast movement of shoal sand helps build the upper portions of the beach at the expense of the underwater portions of the beach. CSE station 105+00 is near the middle of Reach 3 (closest to the Sta 24 access point) and reflects these changes as a typical profile (Fig 3.13). Troughs between emergent shoals in 2023 have filled with sand, while additional excess volume has moved to the west and south, where CSE stations 80+00 to 100+00 all gained more than 10 cy/ft above MHW. If there are no major storm impacts between 2024 and 2025, it is likely the dune toe will be colonized with grasses and begin moving seaward due to the volume increase.



FIGURE 3.12. Aerial imagery between August 2023 (upper) and September 2024 (lower) reflects the attachment of a shoal released via ‘bypass’ from Breach Inlet. As the shoal attached to Sullivan’s Island near CSE station 142+50 (Sta 28 ½), its crest elevation increased, and the onshore migration rate slowed. As a result, a ‘cat-eye’ pond was formed near the attachment zone.

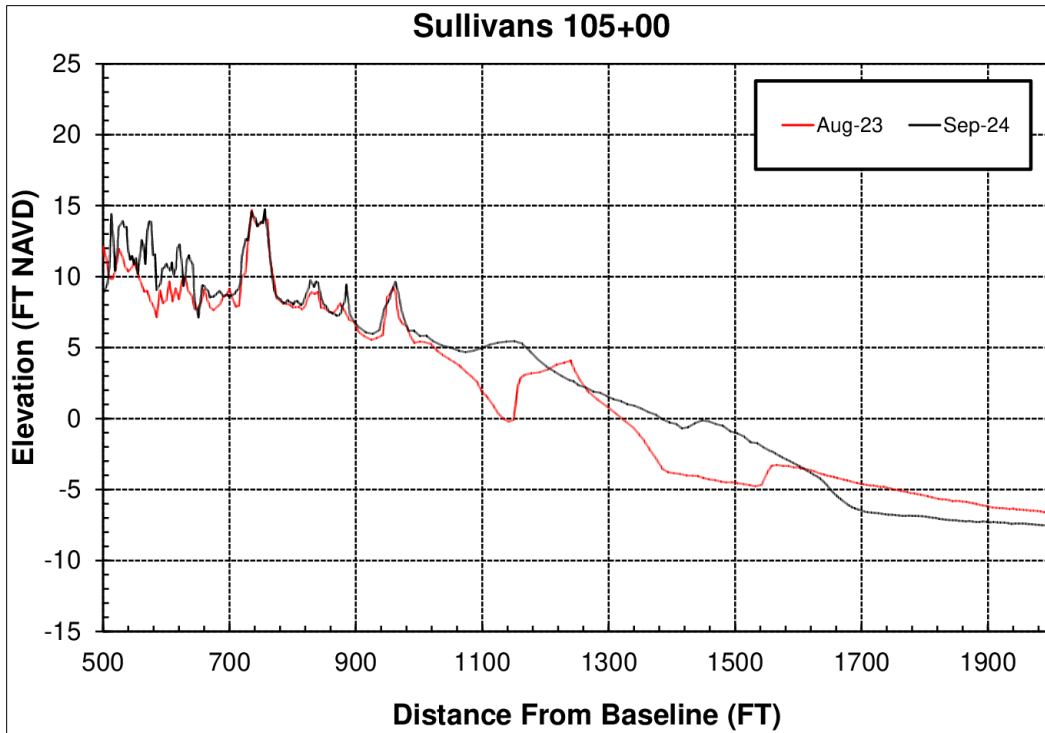


FIGURE 3.13. Profile and ground photo from CSE station 105+00 in September 2024. The MHW line (~2 ft NAVD) moved approximately 100 ft seaward in this location, as a shoal released from Breach Inlet via bypassing attached to Sullivans Island between August 2023 and September 2024.

Reach 4 – Breach Inlet

At the eastern end of Sullivan’s Island, there are a series of revetments and groins armoring the beach against encroachment from the primary channel of Breach Inlet. As a result, volume changes above MHW do not always change in a similar manner to volumes below MHW or certainly below MLW. From 2023 to 2024, the reach lost ~52.3 cy/ft (~130,900 cy) below MLW while the intertidal beach lost ~6.4 cy/ft (~16,100 cy) and the dry beach gained ~4.9 cy/ft (~12,200 cy). Because the majority of the change occurred below MLW, and the upper dry beach is held in place with hardened structures, photos of the site do not necessarily communicate the degree of volumetric change over the past year (Fig 3.14).

However, a representative profile (CSE station 160+00) coupled with a site photo at the same location helps clarify the story. Changes below MLW, a result of the Breach Inlet channel migrating toward Sullivan’s Island, constitute the vast majority of measured volume losses along Reach 4 (Fig 3.15). Additionally, due to the bypass and attachment of the Breach Inlet shoal last year, the upper portions of the profile are relatively wide, particularly along the southern portion of the reach. A sand recycling project placed in Fall 2024 along Reach 4 will help mitigate the flood hazard for properties along Breach Inlet (Fig 3.15 lower). The USACE plans to place over 200,000 cubic yards along the low-tide beach in Reach 4 as part of a beneficial use project. The Town intends to relocate up to 75,000 cy of this sand into the dunes and dry-sand beach to increase resilience and improve public access.



FIGURE 3.14. Beach volume and width changes around Breach Inlet are strongly impacted by shifts in the position of the primary inlet channel seen here. Aerial imagery between August 2023 (upper) and September 2024 (lower) documents the attachment of a shoal just west of Reach 4, and the static nature of the beach-upland boundary along the reach due to the presence of armor stone revetments. A USACE beneficial use project scheduled for 2024–2025 is expected to place more than 200,000 cy below MLW along the reach. Coupled with a Town-sponsored effort to recycle some of that sand into the dune, the beach condition of Reach 4 should improve between September 2024 and the 2025 annual survey.

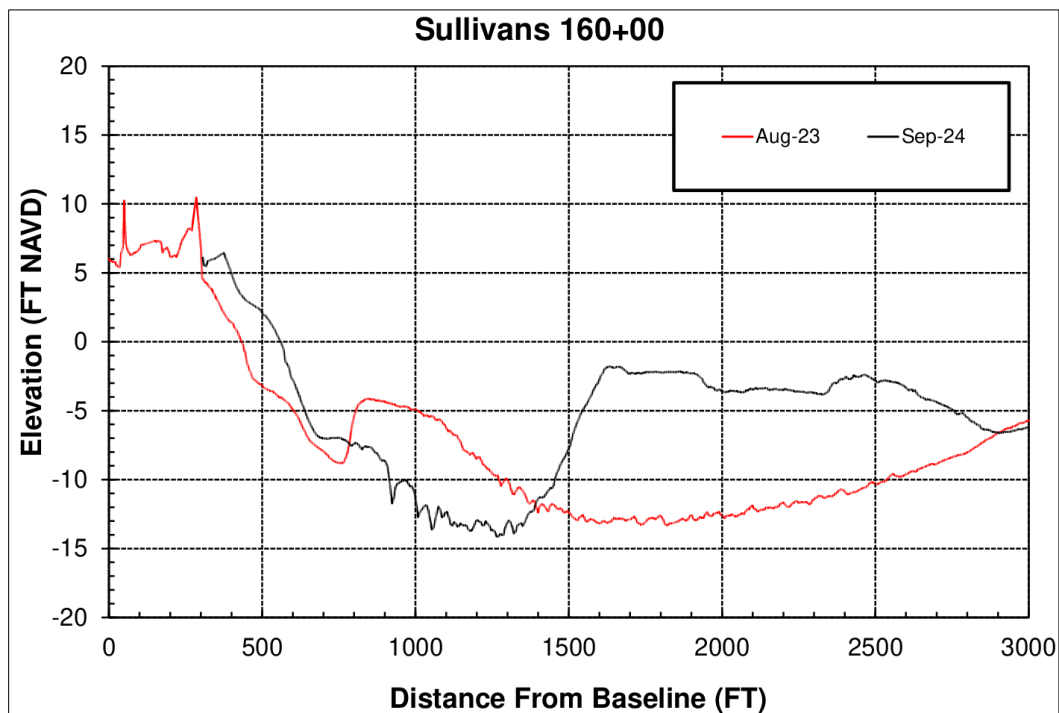


FIGURE 3.15. Profile and ground photo from CSE station 160+00 in September 2024. The MHW line (~2 ft NAVD) moved approximately 100 ft seaward in this location, as a shoal released from Breach Inlet attached and the primary channel of the inlet moved seaward.

4.0 COASTAL RESILIENCY AND SEA LEVEL RISE

4.1 Weather and Climate Conditions, August 2023 to September 2024

CSE gathered weather and climate data from outside sources (all NOAA-supported) to evaluate observed changes to the beach with respect to environmental conditions. Wind and wave data reported here cover the time period from August 2023 to September 2024 (the time in between the Year 1 and Year 2 surveys). Wind data are compared to historical data covering the period from 1945 to 2024 (Fig 4.1). Real-time and historical hourly wind data from across the United States are aggregated by the Midwestern Regional Climate Center (MRCC), a cooperative program between offices of the National Oceanic and Atmospheric Administration (NOAA) and Purdue University (MRCC 2022, <http://mrcc.purdue.edu/>). The closest operational station is located at Charleston International Airport (FAA Identifier – CHS) in North Charleston, ~15 miles northwest of Sullivan’s Island.

The average wind speed and direction* was 14.8 miles per hour (mph) from ~166° (approximately south southeast, Fig 4.1). The peak observed wind speed was a gust to 69.8 mph from ~189° (approximately south) on 9 January 2024 during the passage of a strong cold front. According to data from MRCC-NOAA, wind data over the study period were similar to the long-term trends. The proportion of winds from the southeast (90°–180°) and southwest (180°–270°) quadrants represent ~48 percent of the total from 1945 to 2023; between August 2022 and August 2023, these have represented ~47.0 percent of the total incoming winds. Northerly winds were consistent with long-term trends, as well.

Wave data are recorded by the National Data Buoy Center (NDBC) Station 41004 (“Edisto”), 41 nautical miles (nm) southeast of Charleston (SC) (NOAA 2025, http://www.ndbc.noaa.gov/station_page.php?station=41004). The average wave height at Station 41004 from August 2023 to September 2024 was ~4.5 ft, with an average dominant wave period of ~7.6 seconds. The maximum observed wave height was ~27.2 ft on 17 December 2023 during the passage of a nor’easter. The average wave direction** was ~164° (approximately south southeast).

From January 2010 to September 2024, Station 41004 experienced similar wave conditions compared to recent years. Data from Station 41004 have been collected nearly continuously since January 2010, and in the period from then until September 2024, wave height exceeded 10 ft ~190 times per year and 15 ft ~25 times per year. Between August 2023 and September 2024, wave height exceeded 10 ft an average of ~375 times per year and exceeded 15 ft ~13 times per year.

* Herein, wind and wave direction is either given in degrees north or in terms of the direction from which it propagates.

** The direction from which waves propagate toward NDBC Station 41004.

Atmospheric pressure dropped below 1000 millibars (mb) ~84 times per year from 2010 to 2024 and was detected ~191 times below 1000 mb from August 2023 to September 2024 (Fig 4.2). Most Category 1 hurricanes have a central pressure of ~980–990 mb, and many nor’easter-type storms will feature central pressures below 1000 mb.

Similarly, wave height is an easy parameter for the relative intensity of storm events. However, atmospheric pressure and wave height are imperfect measures because these are simply proxies for the physical processes that result in beach erosion (eg – a more energetic surf zone with alongshore transport in a particular direction occurring in phase with high tide).

The work of erosion is fundamentally a sand transport problem. An increase in erosion indicates more sand is being transported away from a location than is being transported to replace lost volume. Sand transport increases exponentially with current velocity, and wave energy increases by the square of the wave height. So, in tidal channels, a doubling of velocity will result in an eight-fold increase in net transport, while a doubling of wave heights produces a four-fold increase in erosive force. This helps explain why even minor storms can do significant damage along the coast. A four-foot wave impacting a structure or the foredune will be much more impactful than a normal two-foot wave.

Wind Rose, Charleston Intl Airport January 1945 to August 2023

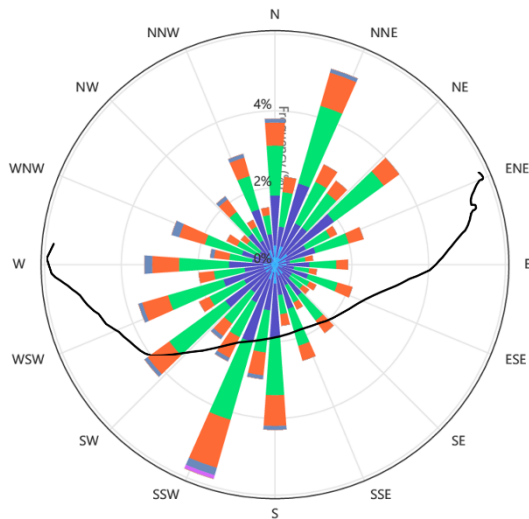
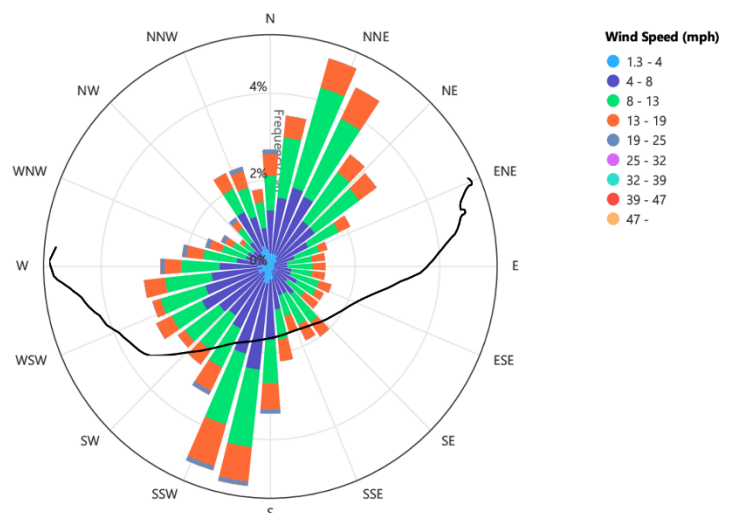


FIGURE 4.1. Wind roses showing the direction and magnitude of winds measured at Charleston International Airport from January 1945 to September 2024 [UPPER] and from August 2023 to September 2024 [LOWER]. The line across the wind rose indicates the orientation of the oceanfront shoreline along Sullivan’s Island.

Wind Rose, Charleston Intl Airport August 2022 to August 2023



We use measurements of wave properties like height, wavelength, and speed to estimate the magnitude of energy exerted by a wave striking the beach. The estimate is expressed as “wave power” in kilowatts per meter of crest length (kW/m). Because sand can migrate in either direction along a beach, wave power must be adjusted so that waves producing southerly transport (ie – north to south) and northerly transport (ie – south to north) can be differentiated. To accomplish this, wave power can be calculated so that northerly transport is measured above zero (positive) while southerly transport is measured below zero (negative). Wave power at Station 41004 is presented in Figure 4.2 with wave height. The larger-magnitude wave power values from late August and December 2023 and January 2024 represent the passage of Tropical Storm Idalia (2023), a nor’easter (2023), and a strong convective system (2024). In the spring and summer, lower-magnitude positive values tend to dominate.

The most powerful waves mentioned above exhibited more than ~11 kW/m of wave power dominant in southerly direction (Fig 4.3). However, the average power of a northerly-directed wave from August 2023 to September 2024 was 1.59 kW/m, and the average southerly-directed wave power was -0.58 kW/m. Calculating the average of all wave power indicates that more individual waves moved in a southerly direction than in a northerly direction over the same period.

These results indicate that most waves at Sullivan’s Island approach from the south, but the strongest waves approach from the north. Since 2010, a similar pattern has been observed wherein approximately three to four times more total energy is expended moving waves in a northerly direction compared to a southerly direction. However, individual southerly-directed waves are roughly twice as powerful. This result corroborates long-term observations along Sullivan’s Island documenting southeasterly-directed drift. It is important to note that Station 41004 is several dozen miles off the coast with slightly different exposure to northerly winds. Thus, the net total wave power exhibited at Station 41004 may be somewhat different from the inshore zone off Sullivan’s Island, but the general trends in long-term wave climate should be similar. There is ample evidence of net southerly transport along Sullivan’s Island because of spit growth and overextension of shoals at Breach Inlet. Nearly all islands situated at the mouth of a major inlet like Charleston Harbor will tend to exhibit net sand transport “into the bight.” Thus, transport at Sullivan’s Island is east to west, whereas Morris Island, on the other side of Charleston Harbor, exhibits transport from south to north.

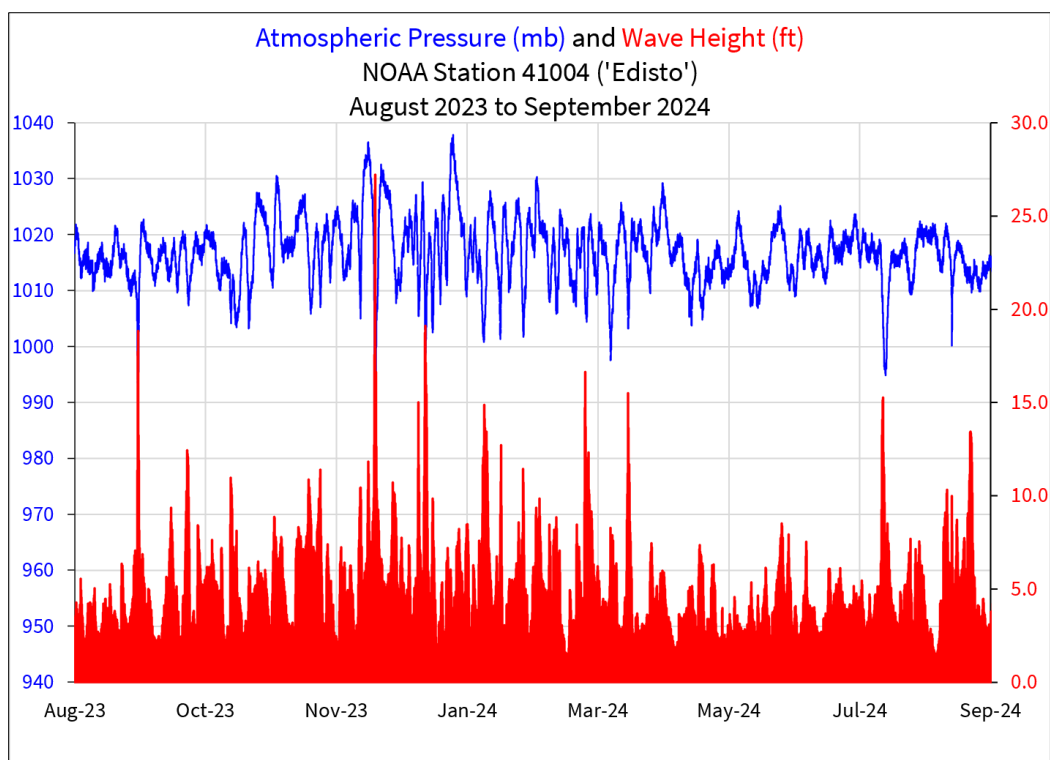


FIGURE 4.2. Atmospheric pressure and wave height at NDBC 41004 from August 2023 to September 2024. Wave heights exceeded 20 ft only once during the study period; however, wave heights exceeded 10 ft and the pressure dropped below 1000 mb more times than the 2022–2023 survey. These two parameters indicate conditions have been relatively rough compared to previous.

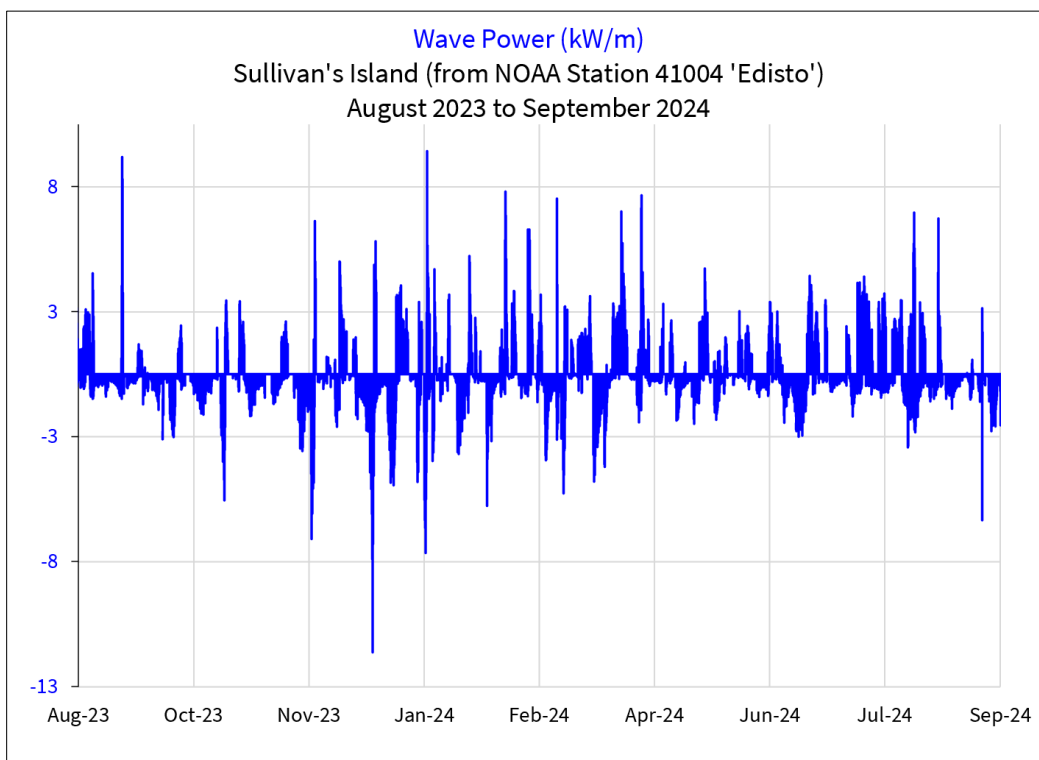


FIGURE 4.3. Wave power (in kW/m) and wave height (in m) for NDBC 41004 from August 2023 to September 2024. Wave power is a useful parameter for determining the relative magnitude and direction of wave energy in an alongshore direction along a beach. Positive values indicate waves move from south to north (ie – northerly transport), while negative values indicate predominance of north-to-south (ie – southerly) transport.

4.2 Flood Vulnerability

Regional projections of average sea level rise (SLR) through 2100 within the Southeast US range from ~1 ft to ~10 ft (Sweet et al 2022). These projections are based on modeled values of future greenhouse gas emissions, shifts in ocean circulation, vertical movements in the Earth’s crust, and changes to Earth’s gravitational field and rotation. They range from “Low” – ~1 ft by 2100 to “Extreme” – ~10 ft by 2100, with a “High” scenario at 8 ft and three “Intermediate” values averaging ~4 ft (Fig 3.4; NOAA 2021).

For reference, the highest astronomical tide (aka “King Tide”) expected at Sullivan’s Island would bring water levels ~3 ft above mean sea level (MSL). So, the water levels observed during those King Tide events represent the higher range of projected MSL by ~2060 and the lower-intermediate projected MSL by ~2100 (Fig 4.4).

Relative to 1995–2014 conditions, the likely global mean sea level rise by 2100 is ~1 to 2 ft under the lowest emissions scenario. This scenario calls for warming to be held at or below 1.5 °C by 2100 compared to 1900 and for “net-zero” CO2 emissions by 2100. “Net-zero” emissions represent the condition in which removals of atmospheric carbon exceed emissions. The “intermediate” scenarios are approximately in line with the upper (eg – higher-emitting) end of reduced emissions and project ~3 ft of SLR by 2100, while the “very high” scenario assumes no policy changes and projects ~5 to 6 ft of SLR by 2100.

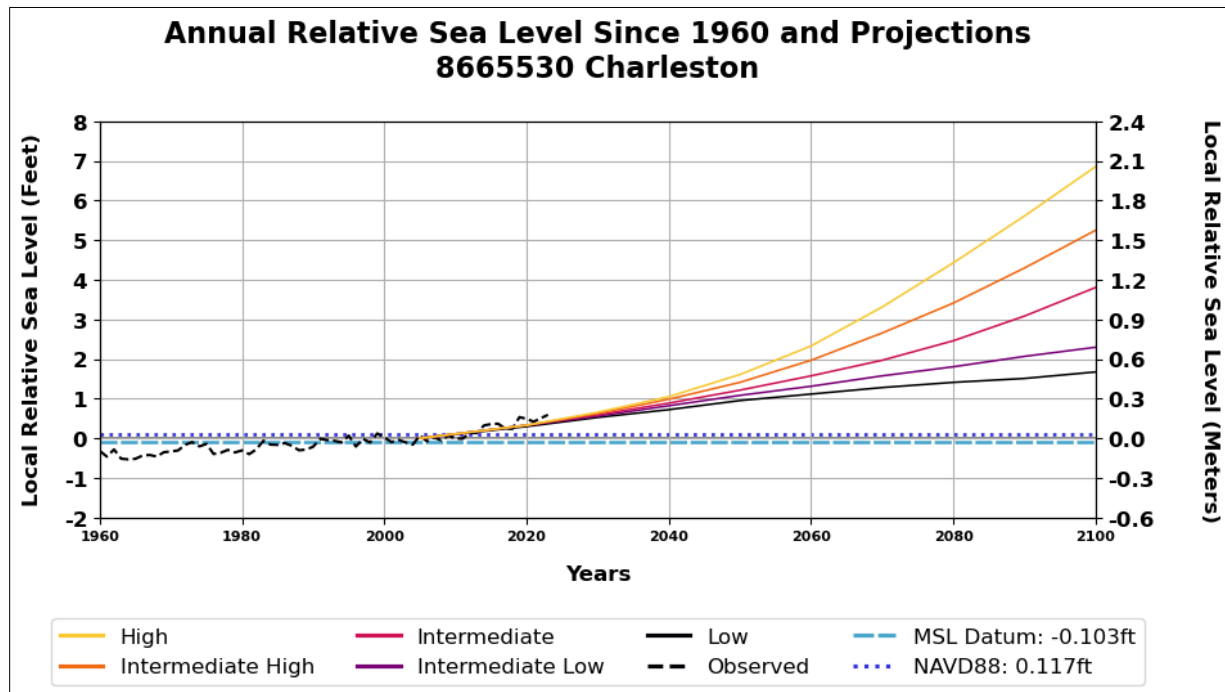


FIGURE 4.4. Projected MSL values under an ‘Intermediate’ emissions scenario average ~2 ft by 2060, and ~4 ft by 2100 at Charleston Harbor. These projections are global-scale predictions of future water levels (based largely on emissions) adapted to the Lowcountry by accounting for regional and localized changes in ocean circulation, vertical movement in the ground surface, and other factors (NOAA 2025).

Keep in mind that any rise in *mean* sea level in the future is accompanied by a corresponding rise in mean high tide. So, in simple terms, today's high tide level would become a future mean tide level, and a future normal high tide level could be the equivalent of the storm tides Sullivan's Island experienced during hurricanes *Matthew* (2016) or *Dorian* (2019).

Coastal communities are becoming more aware of the subtle differences in these impacts as they begin to feel pressure from sunny-day 'nuisance' floods (see Sweet et al 2018, Sweet et al 2020, Sweet et al 2022). Such floods will tend to impact low-lying sheltered shorelines, such as causeways over the marsh or creek-front backyards. Just a small increase in sea level can quickly overtop a road that is barely above normal spring tide levels. On the other hand, locations on the open ocean generally do not experience nuisance floods in the same way. This is because dunes just inland from the beach lie at higher elevations than the mainland-facing 'back side' of barrier islands, where the shoreline transitions more gradually into marsh and creek habitats.

NOAA provides a 'Sea Level Rise Viewer' (SLRV; see <https://coast.noaa.gov/digitalcoast/tools/slr.html>) to help people identify local variations in flood impacts under different SLR scenarios. This tool allows users to specify water levels and generate inundation maps showing MSL and depth in previously dry areas. The NOAA viewer is a handy tool for determining which SLR scenarios have begun to impact a particular property.

Figure 4.5a,b shows a range of SLR scenarios between 1 ft and 4 ft above mean higher high water (MHHW). MHHW is presently 2.62 ft above 0 ft NAVD at the Charleston Harbor entrance. So, ~2 feet of SLR would bring MSL up to present-day MHHW and likewise move MHHW upwards. These visualizations do not distinguish between MSL and MHHW; however, they indicate the water level at 1, 2, 3, and 4 ft above MHHW. This means the maps show where the highest astronomical tide would flood under these scenarios. It is apparent that with increasing SLR, flooding will be more impactful along the backside of the island.

At **present**, all properties on the island remain above MHHW. Under a SLR scenario of 1 ft (Fig 4.5), some of the marsh edge along the back side of the island would be inundated. Certain roads could be threatened by nuisance flooding more frequently than at present. This scenario is equivalent to projected MHHW in ~2040 under an 'Intermediate' scenario (see Fig 4.4).

A 2-ft increase in MHHW would lead to further marsh creep and periodic inundation along the north marsh edge, especially at the west end of the island. According to NOAA projections under an ‘Intermediate’ scenario, this increase would occur by ~2070 (see Fig 4.4). Kiawah Island has begun strategic planning to address the impacts of this SLR rate and magnitude (see Town of Kiawah Island 2018).

The SLRV indicates that the most significant changes could occur when MHHW increases from 2 ft to >3 ft above present (Fig 4.5 – orange areas). Many properties would be permanently inundated, including:

- The western tip of the island
- Numerous properties north of Middle Street in the west-central part of the island
- All properties north of Raven Drive in the east-central part of the island
- Many properties on the north side of Jasper Blvd (State Rd 703) at the east end of the island

Almost no properties would be impacted along the oceanfront by the 1–4 ft SLR stillwater flooding. However, properties along Breach Inlet will be vulnerable to wave attack at higher elevations due to the negligible setbacks of buildings. Existing seawalls and revetments will be too low to provide protection during even minor wave uprush events. While these future impacts are significant, the vast majority of properties on Sullivan’s Island are presently situated more than 4 ft above MHHW.

SLR of 3 ft and 4 ft on the oceanfront could trigger a mixture of impacts. If sufficient sand volumes are maintained along the oceanfront, the first 1 or 2 rows of beachfront homes would likely remain high and dry even with a 4-ft rise in MHHW. This is because most oceanfront properties are elevated higher than back-barrier buildings to accommodate surge and wave runup. Keep in mind that such properties may be safe from normal conditions, but will still be exposed to higher water levels in storms. Houses presently elevated to the 100-yr flood level standard will become more vulnerable to lower return-period storm surges – perhaps as frequently as a 30-yr interval – under the likely SLR scenarios in the next 80 years (see Marsooli et al 2019).

A 3 ft increase in MHHW is possible under the ‘Intermediate’ scenario by ~2090 (see Fig 3.4), whereas a 4 ft SLR under the same scenario is not expected until after 2100. Folly Beach plans to adapt to SLR of 3 ft by ~2060 (see SC Sea Grant 2017). Extensive research is being conducted worldwide to improve future sea-level predictions and ramifications for individual locations. A key finding of the August 2021 IPCC* report is that regardless of any level of reduction in atmospheric CO₂, sea levels will rise through 2100 by at least 2 to 3 ft.

** IPCC – the Intergovernmental Panel on Climate Change was formed by the United Nations to provide regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. The panel currently has 195 members worldwide, with dozens of additional scientists contributing to each report.*



FIGURE 4.5a,b. Sea level inundation models around the Sullivan's Island generated using data from NOAA (<https://coast.noaa.gov/digitalcoast/tools/slr.html>). Shades of yellow, orange, red, and maroon are used to signify SLR of 1, 2, 3, and 4 ft above present-day MHHW.

5.0 SUMMARY AND RELATED PROJECTS

This Year 2 (2024) beach monitoring report provides comparative analysis of the beach volume changes along Sullivan’s Island between August 2023 and September 2024. It is one of the first-ever comprehensive year-to-year surveys of Sullivan’s Island, including the entire beachfront as well as the entire active shoreface from the foredune to deep water.

From 2023 to 2024, Sullivan’s Island lost ~82,500 cy (~4.5 cy/ft) below MLW and ~21,100 cy (~1.1 cy/ft) between MLW and MHW, but gained ~6,600 cy (~0.4 cy/ft) above MHW. The channels of Charleston Harbor and Breach Inlet, on the west and east ends of the island, respectively, drove most of the volume changes measured over the second year of monitoring.

As shoals and bars associated with these inlets approach Sullivan’s Island and attach, they tend to trigger alternating zones of accretion and erosion depending on the dimension, volume, and speed of attachment. As a result, island-wide average changes mask the more dramatic changes occurring between individual profiles or lens depths along the island.

For instance, a shifting shoal along the central-western portion of Sullivan’s Island caused significant scarping and upland erosion in the vicinity of the Sand Dunes Club. However, these losses along the upper beach are balanced by volume increases below MLW as a shoal migrates landward and is expected to attach to that area in the next year or two.

Along the eastern half of the island, a shoal bypass event related to Breach Inlet has brought volume increases above MLW as that sand has attached and begun to spread downcoast—generally towards Charleston Harbor. Those changes along the intertidal and dry beach are outpaced, however, by volume losses below MLW where the Breach Inlet channel has re-established a deeper thalweg following the bypass event.

Site photographs and profiles presented herein indicate areas along the Western Oceanfront (Reach 2) and Breach Inlet (Reach 4) that may require some dune remediation to mitigate losses of upland ecosystems due to these shoal/inlet dynamics. Such work is currently scheduled to occur in 2024–2025 and will be documented in the Year 3 (2025) report.

Sullivan’s Island is strongly affected by inlets on either end of the barrier island. Because inlets in South Carolina tend to behave in a cyclical manner, the trends described herein may not continue indefinitely. Continued annual monitoring of the whole island will enable a better understanding of the inter-annual variations in these inlet cycles, which can be used to inform responsible project planning and scoping for potential remediation efforts in the future.

The Year 3 (2025) annual monitoring survey is currently scheduled for August 2025.

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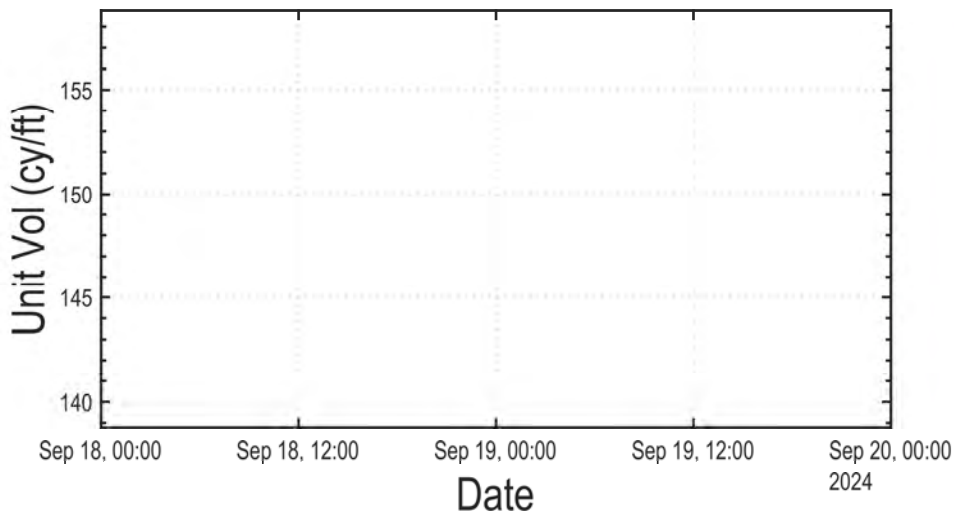
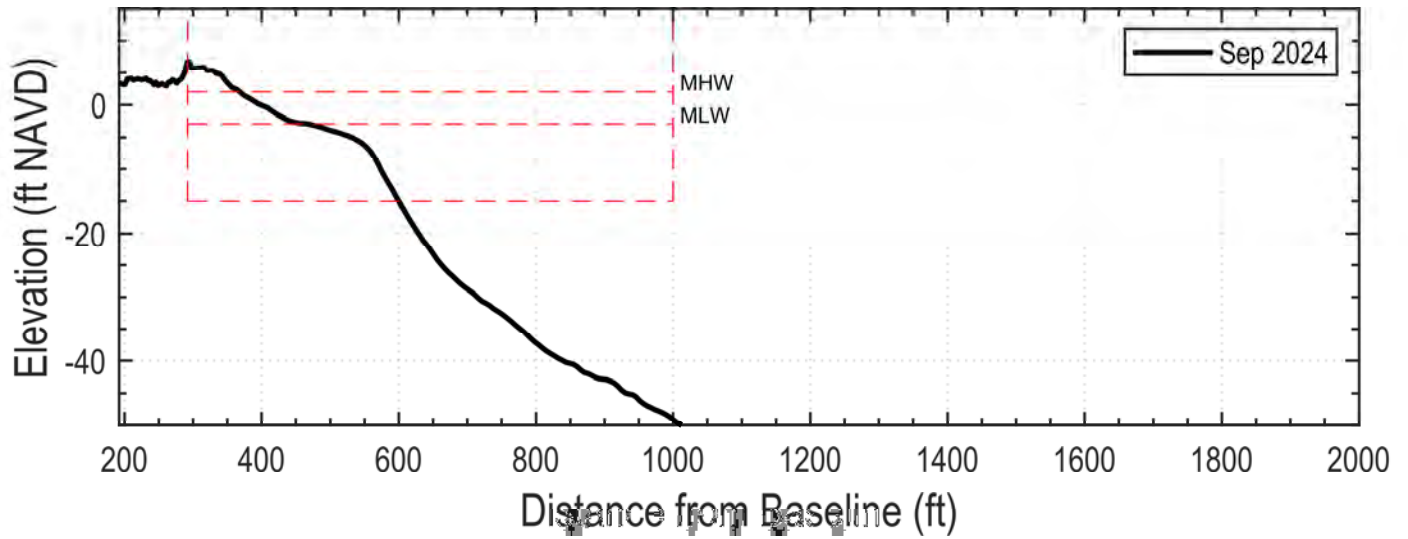
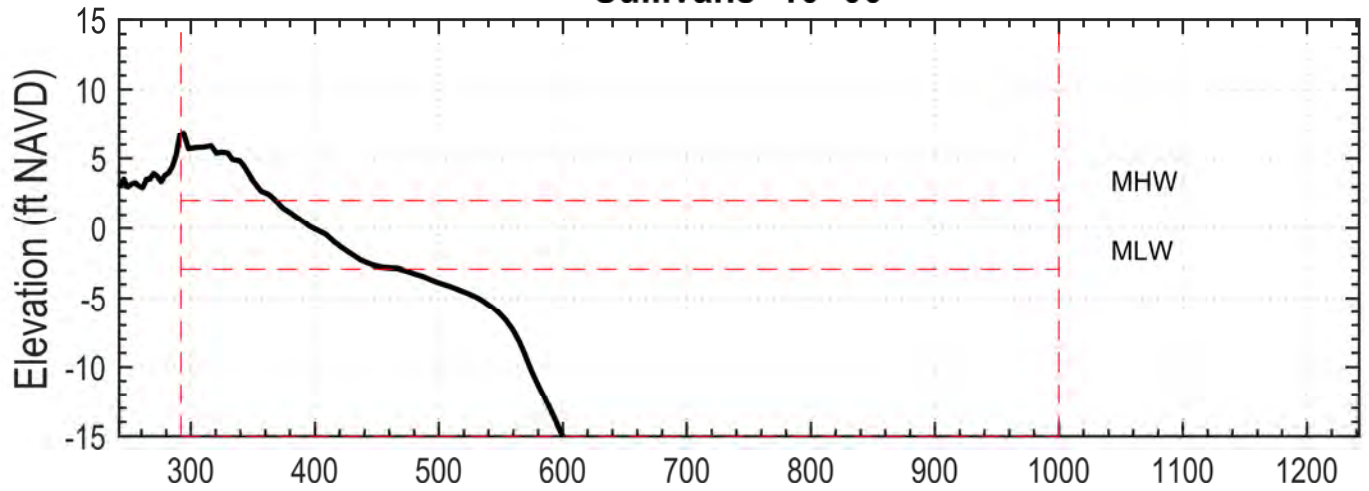
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APPENDIX A

Survey Control Points

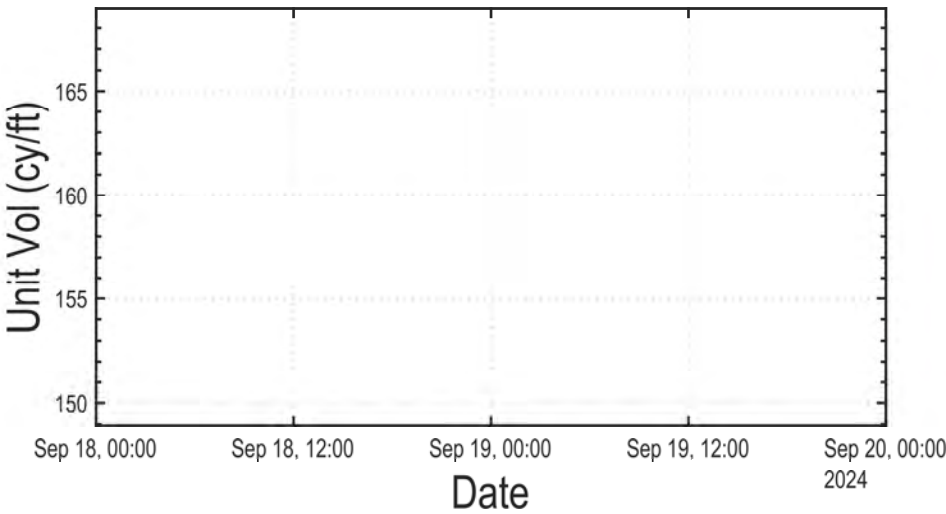
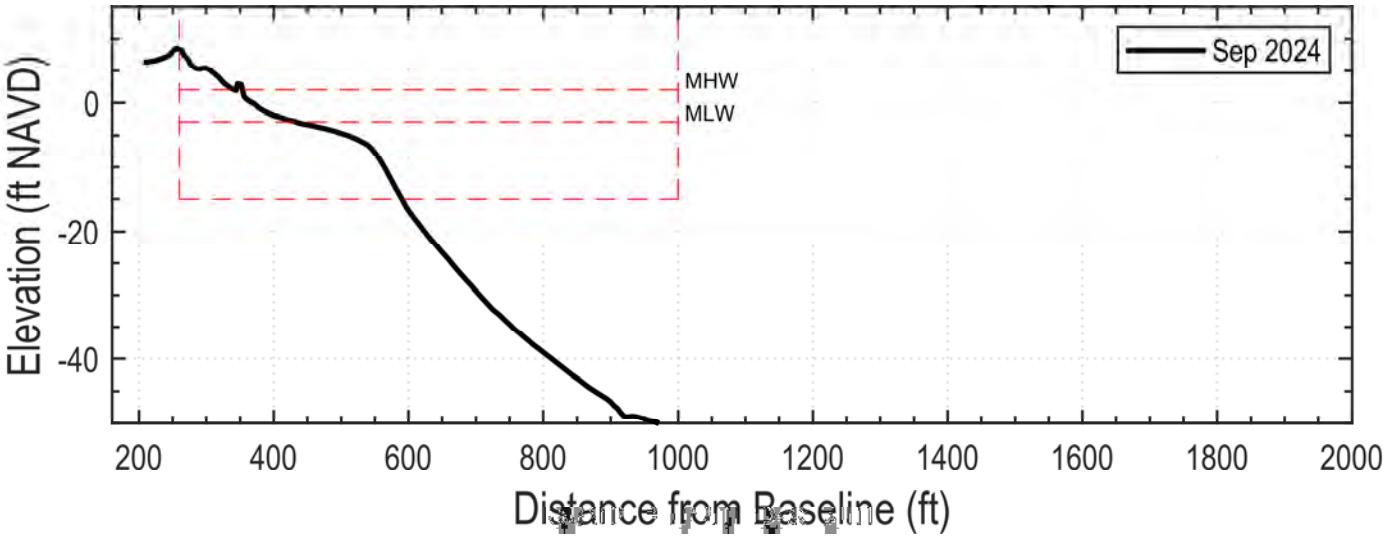
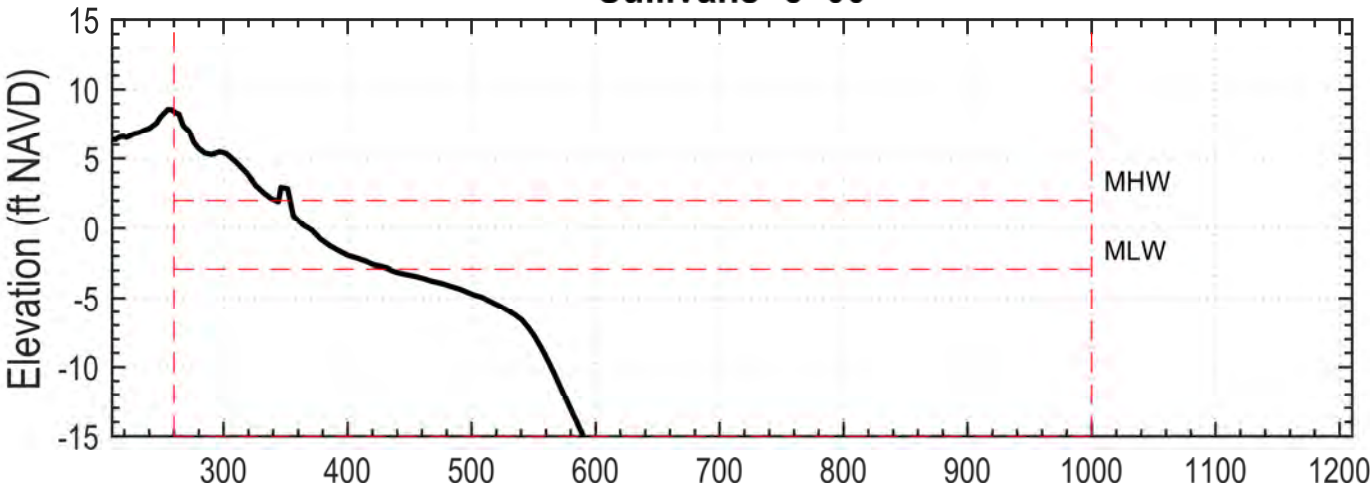
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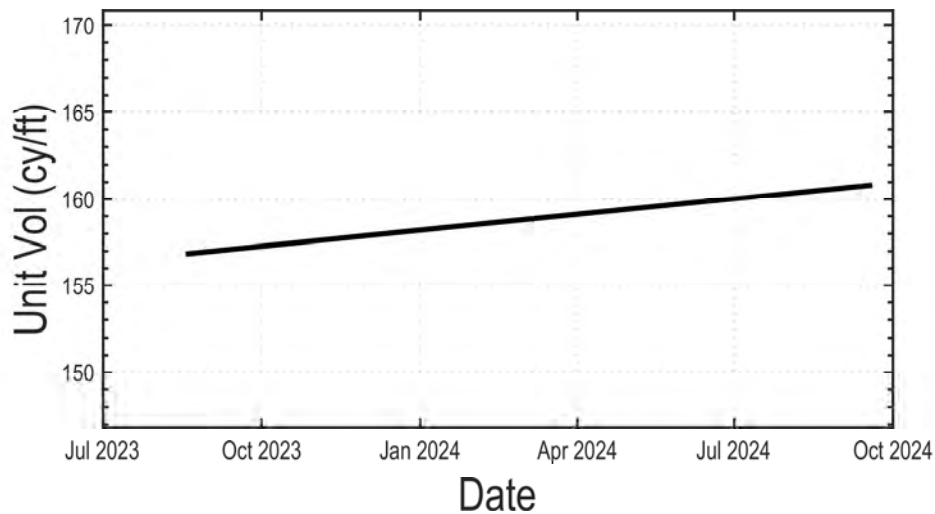
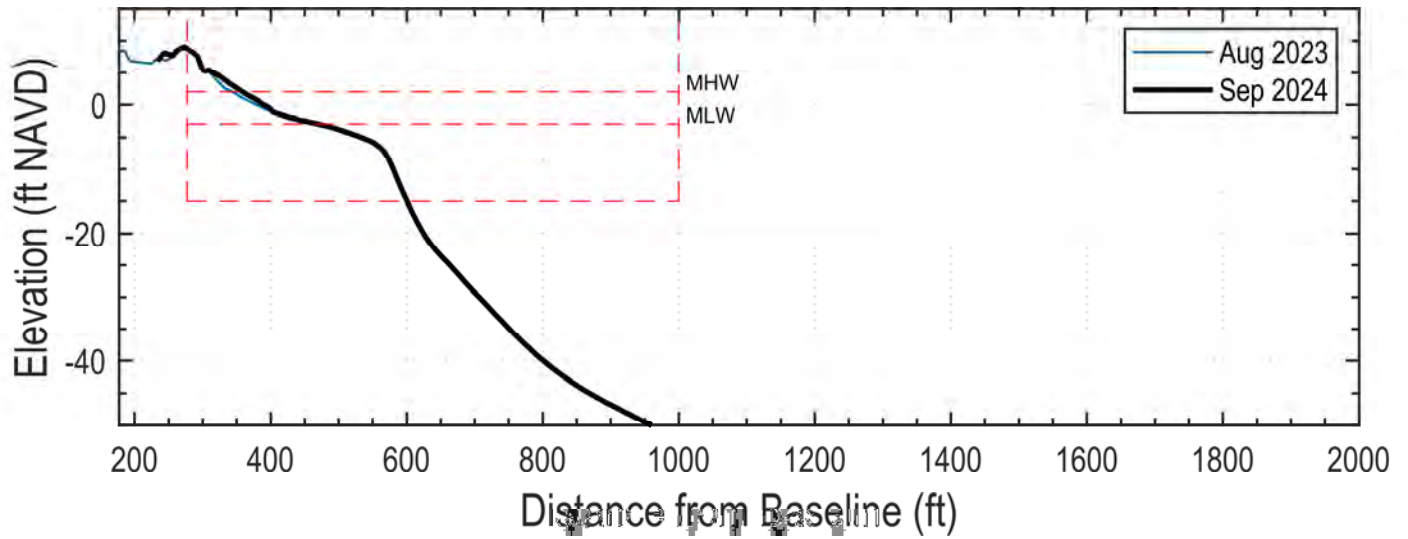
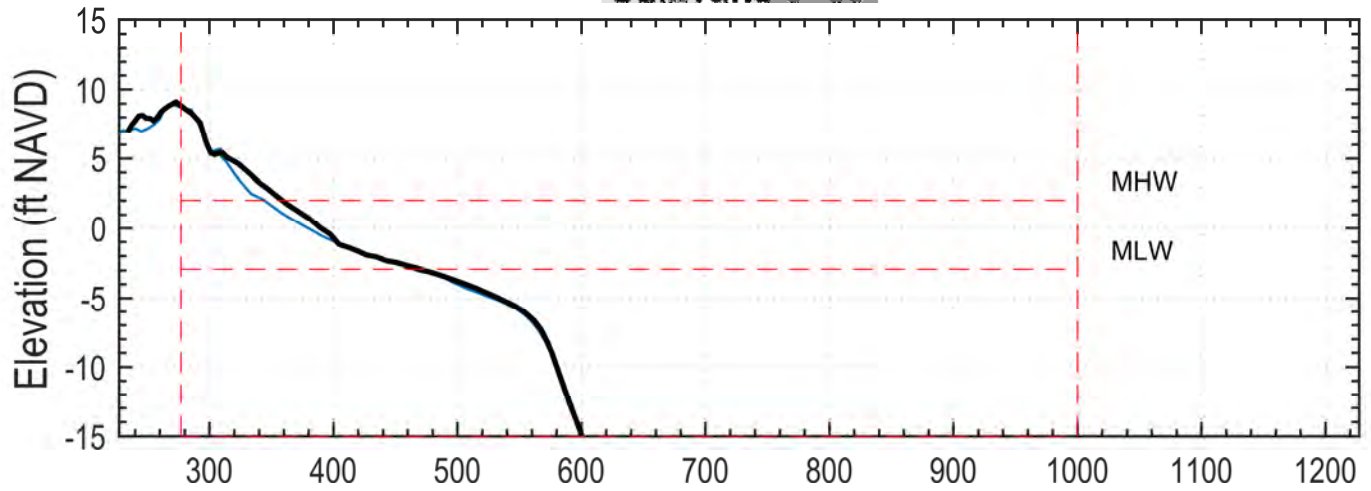
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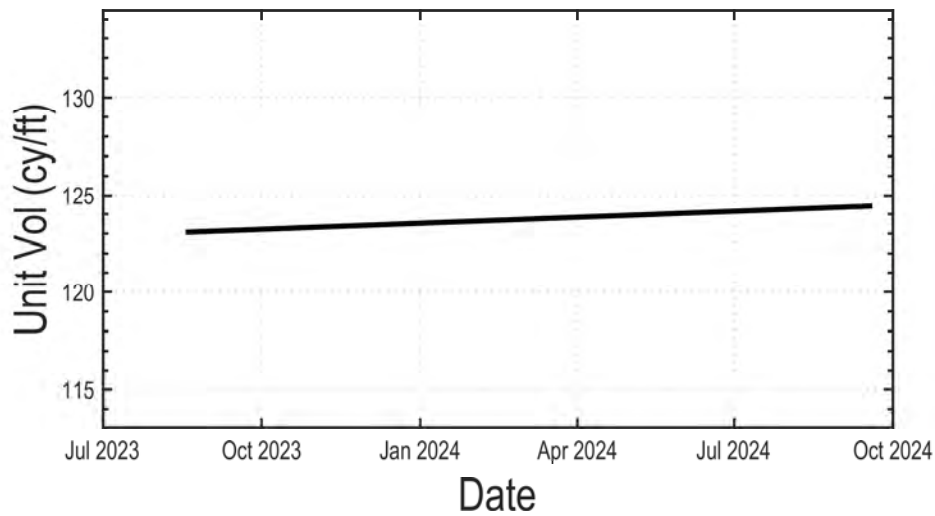
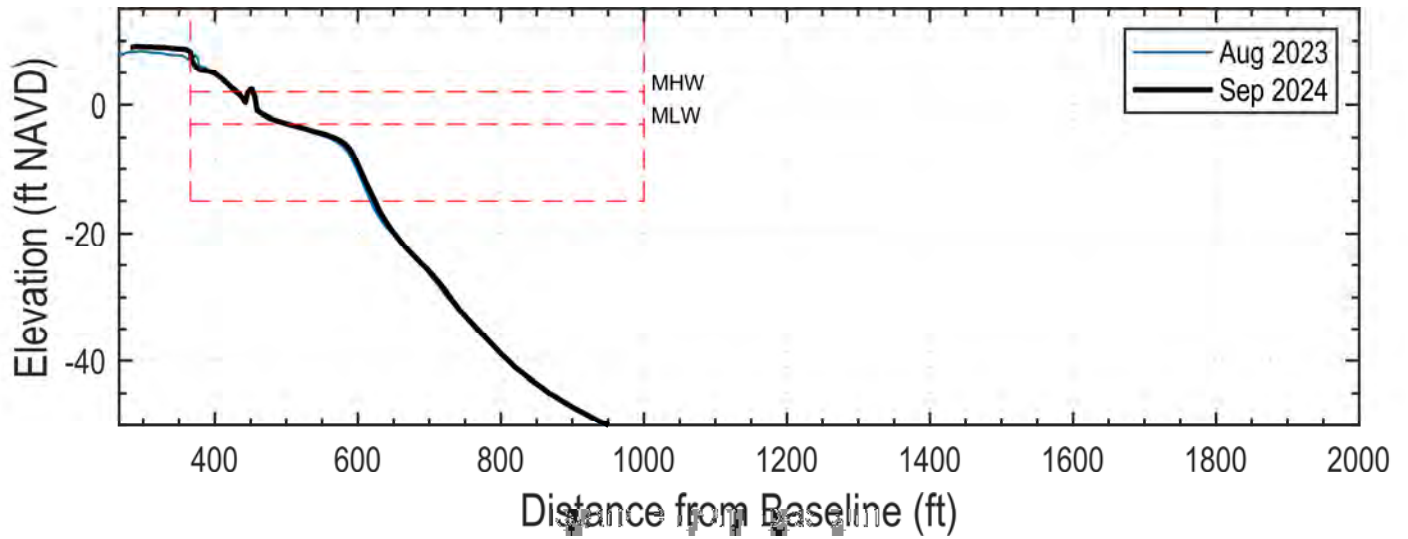
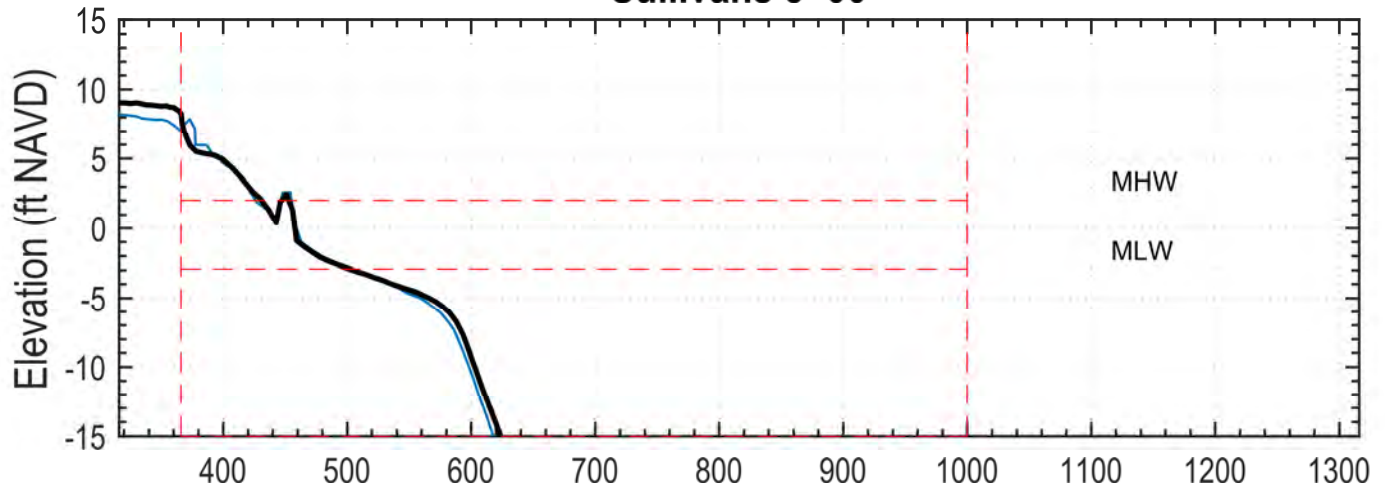
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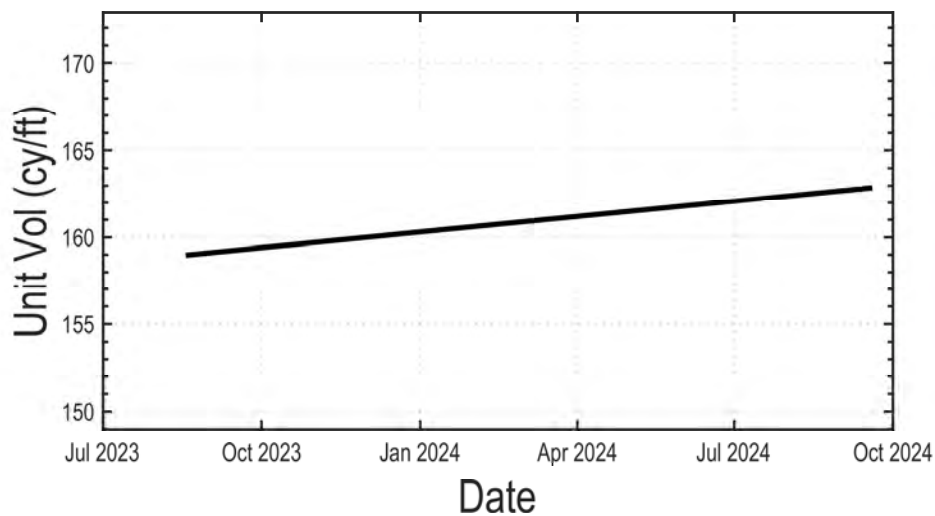
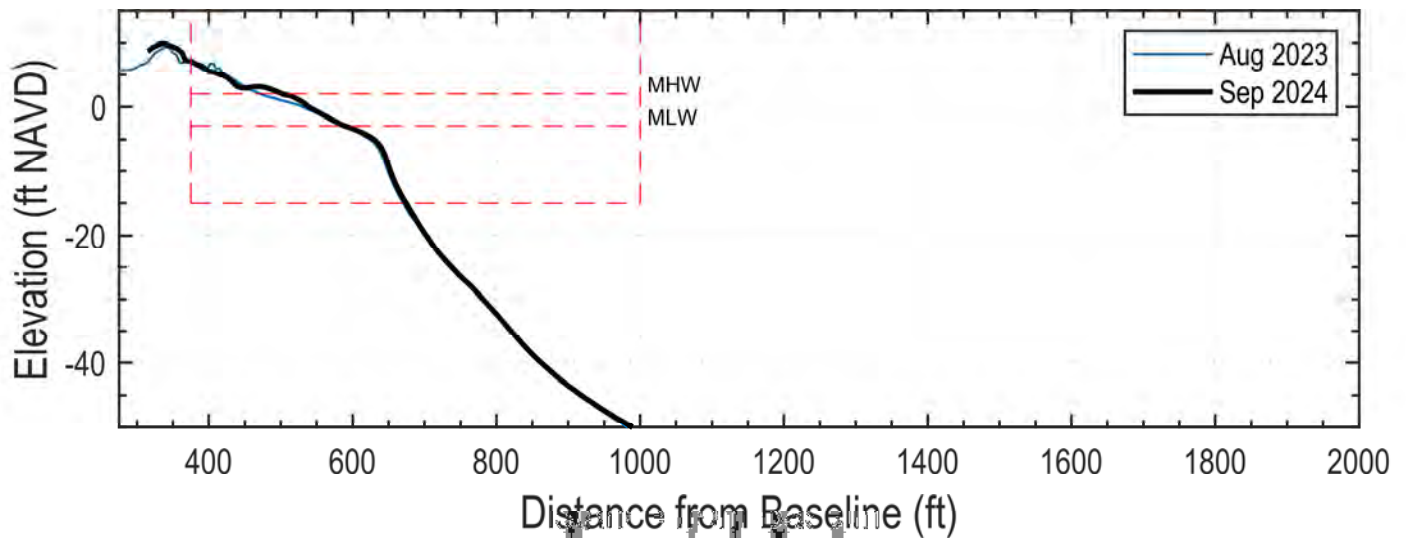
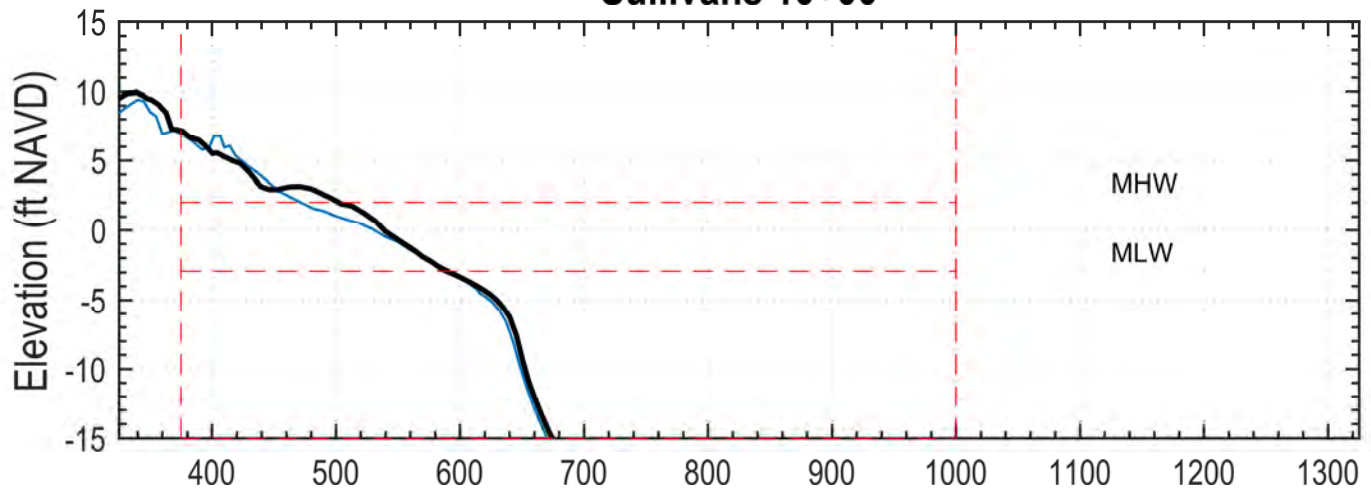
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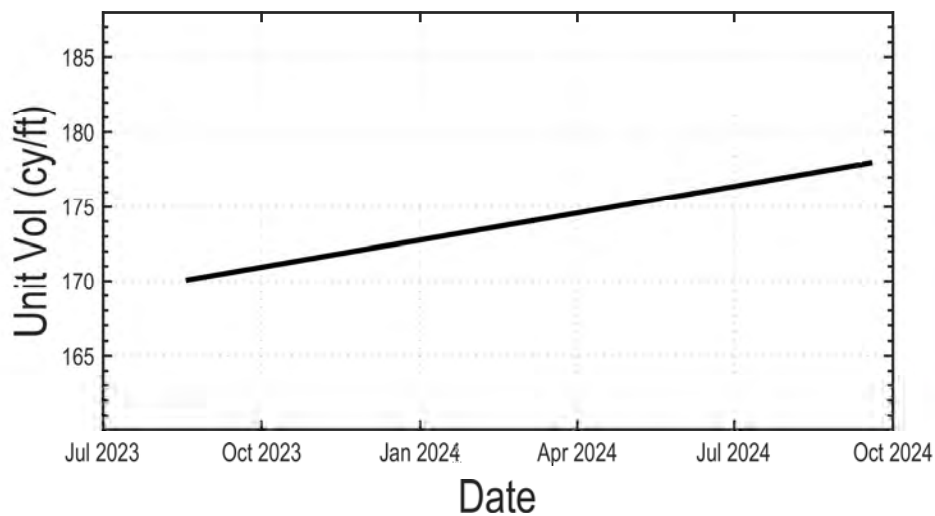
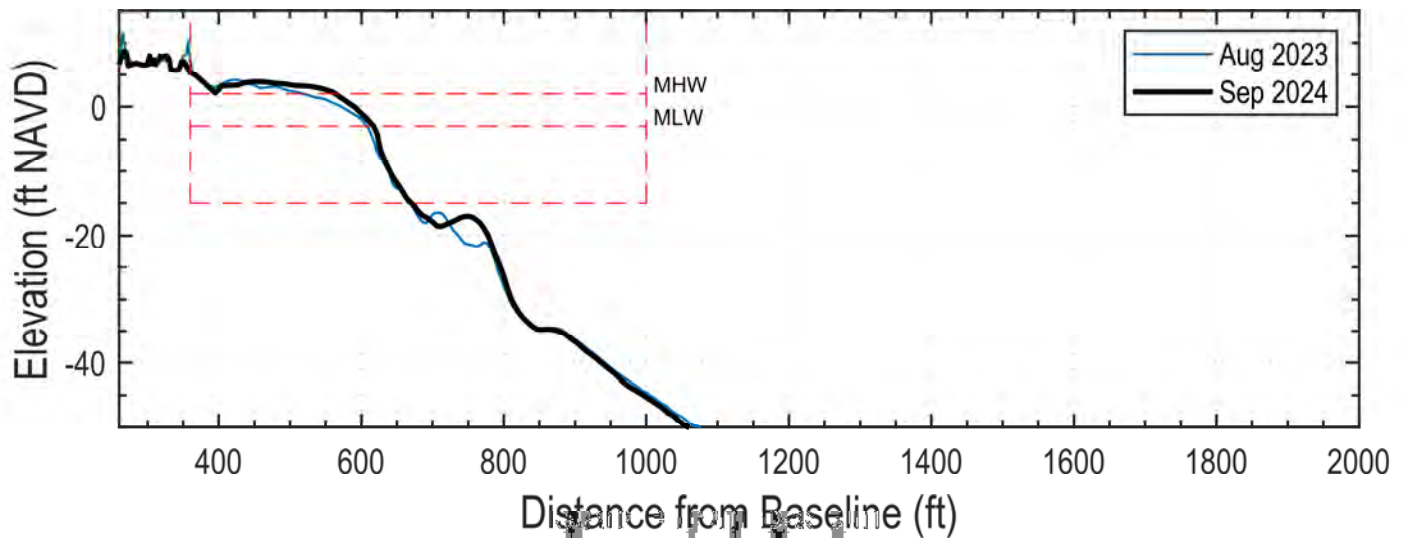
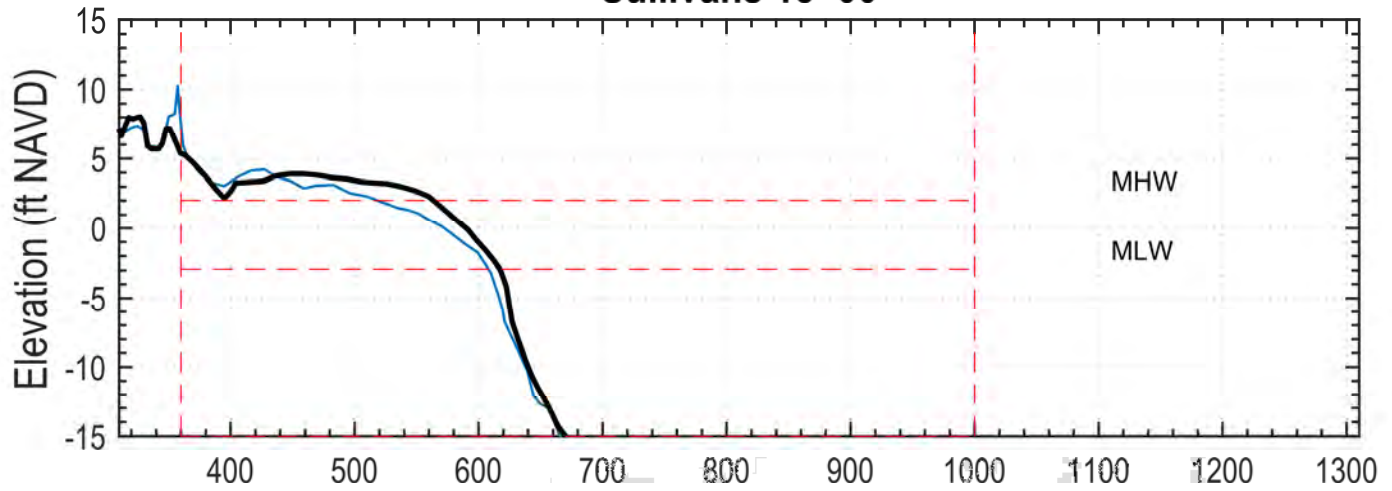
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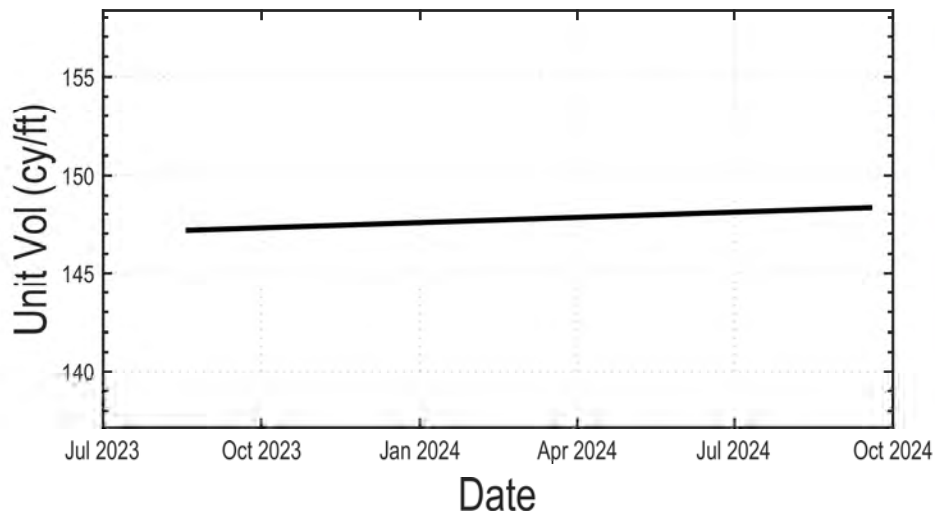
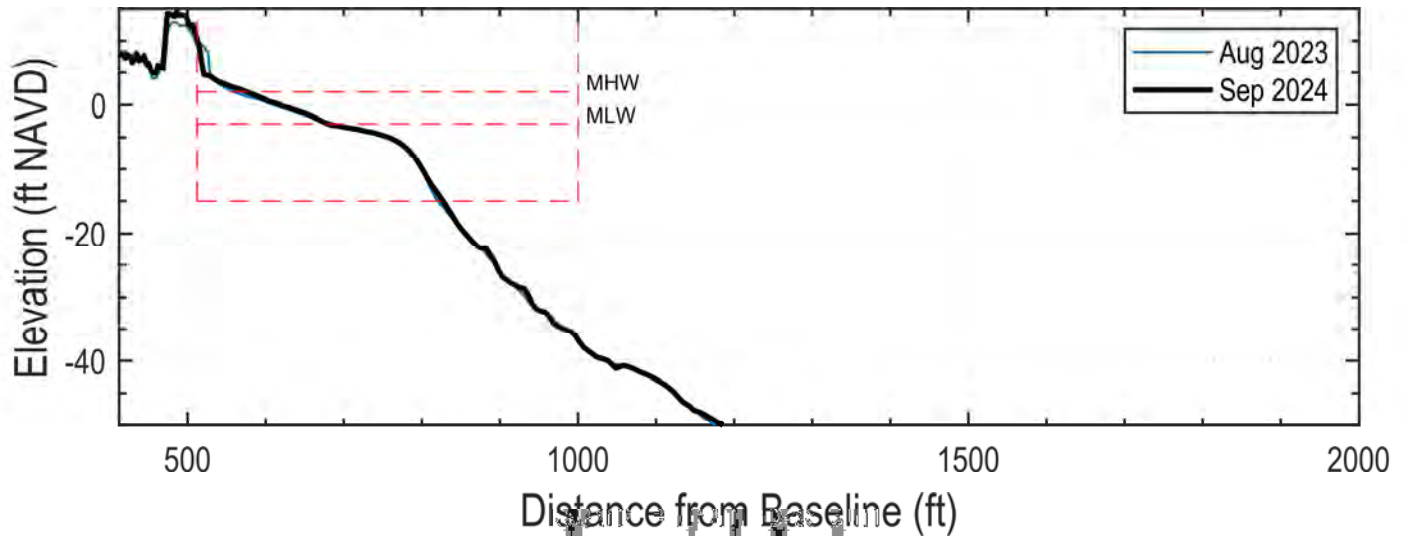
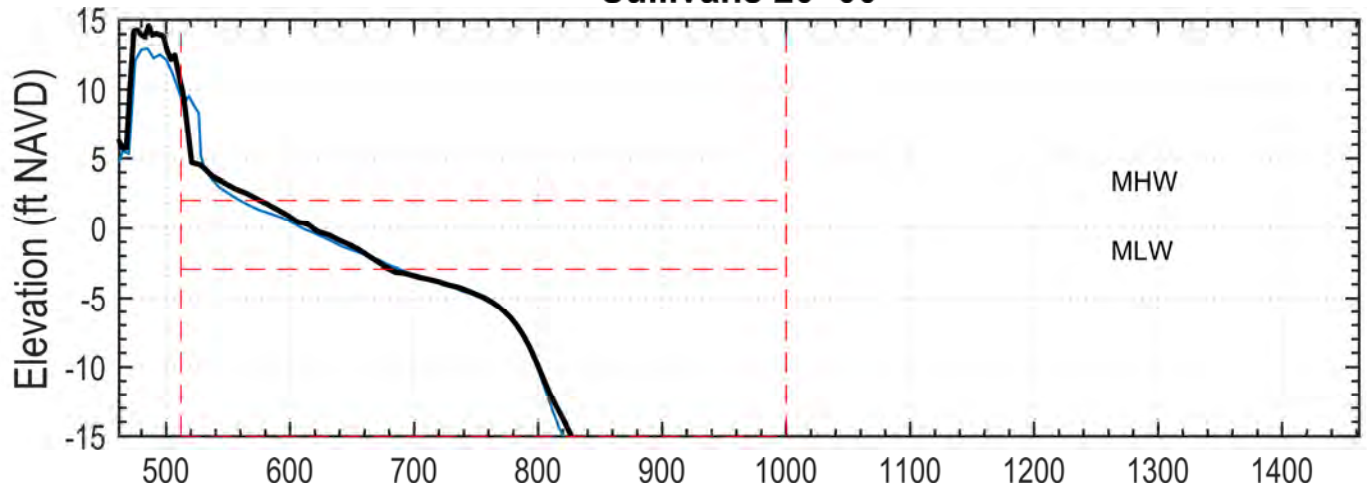
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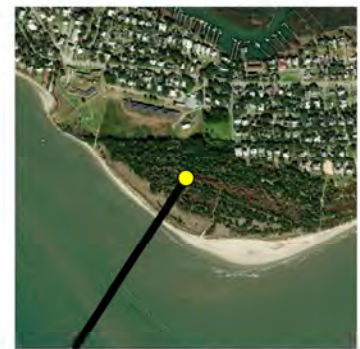
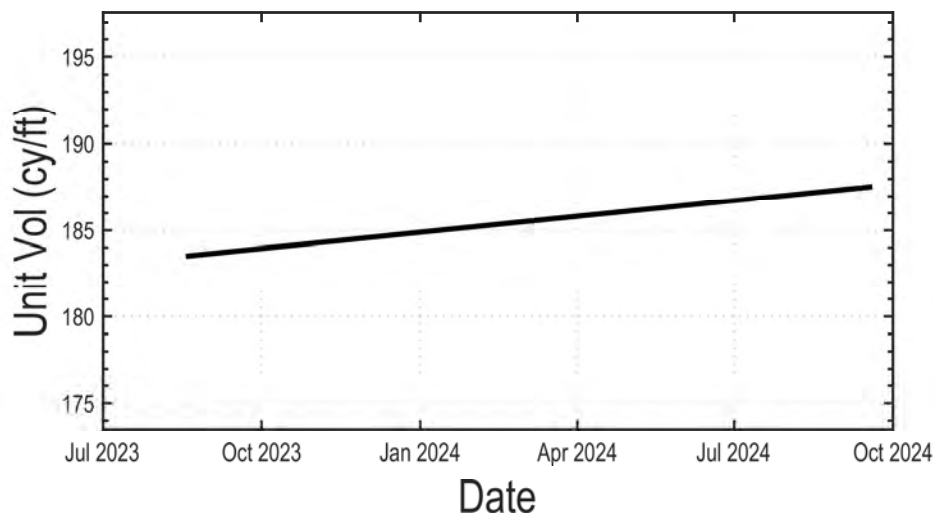
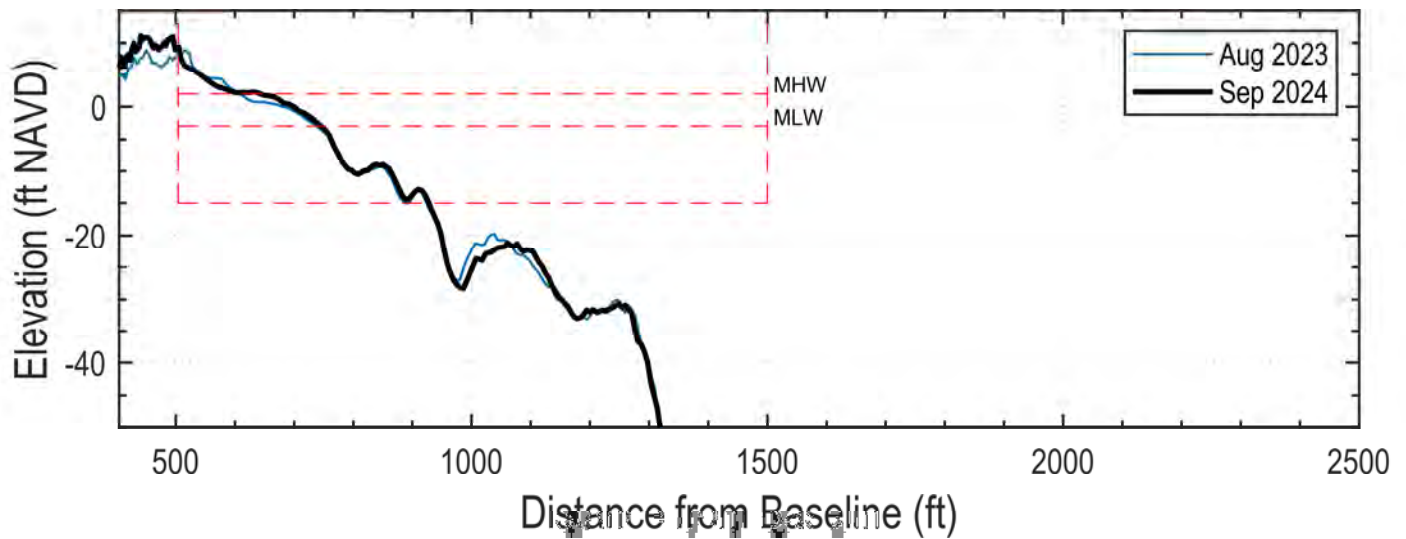
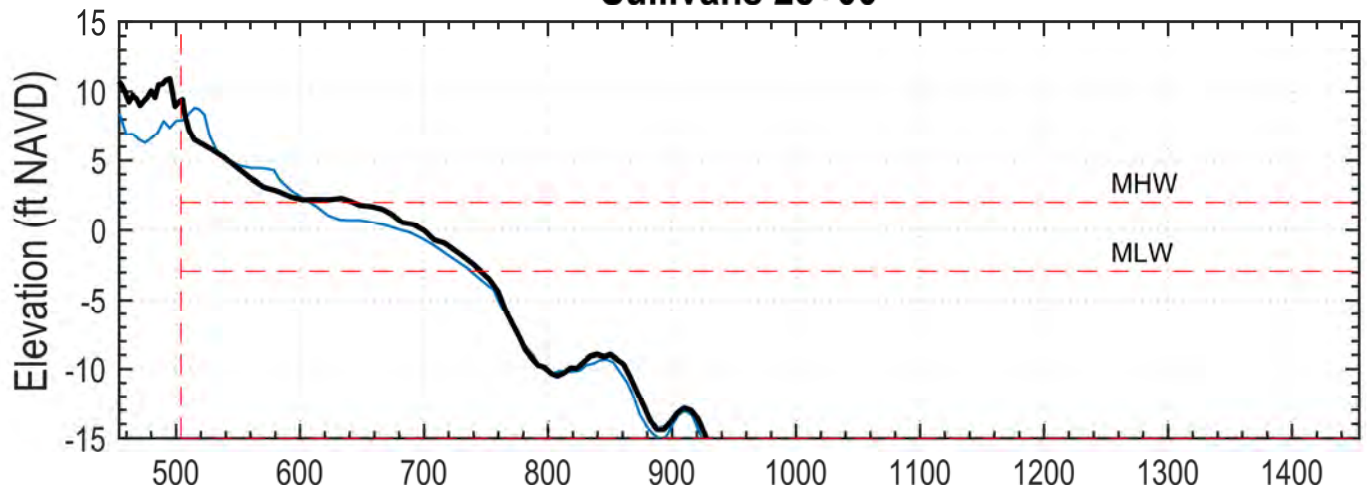
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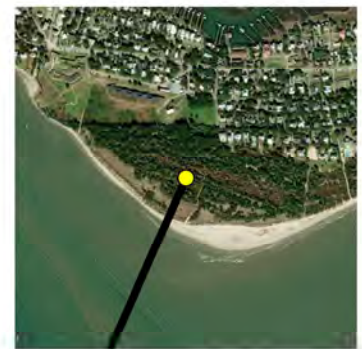
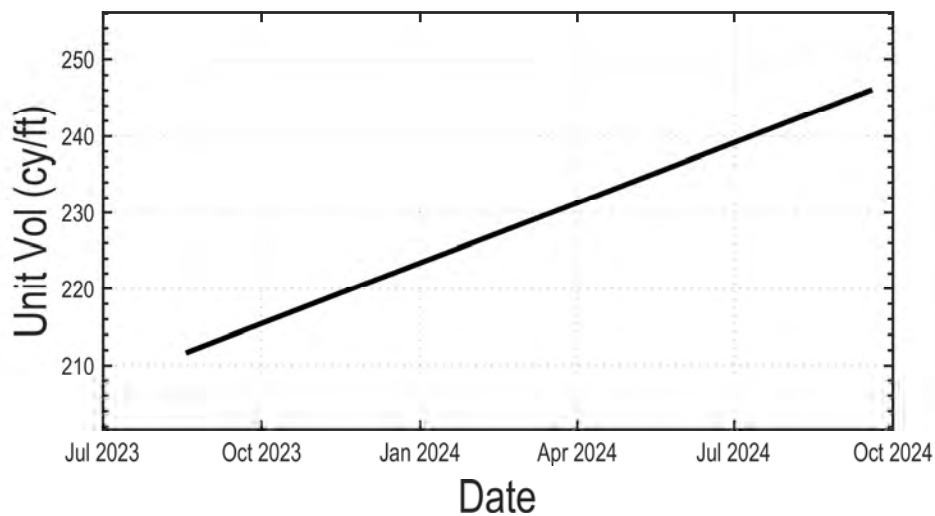
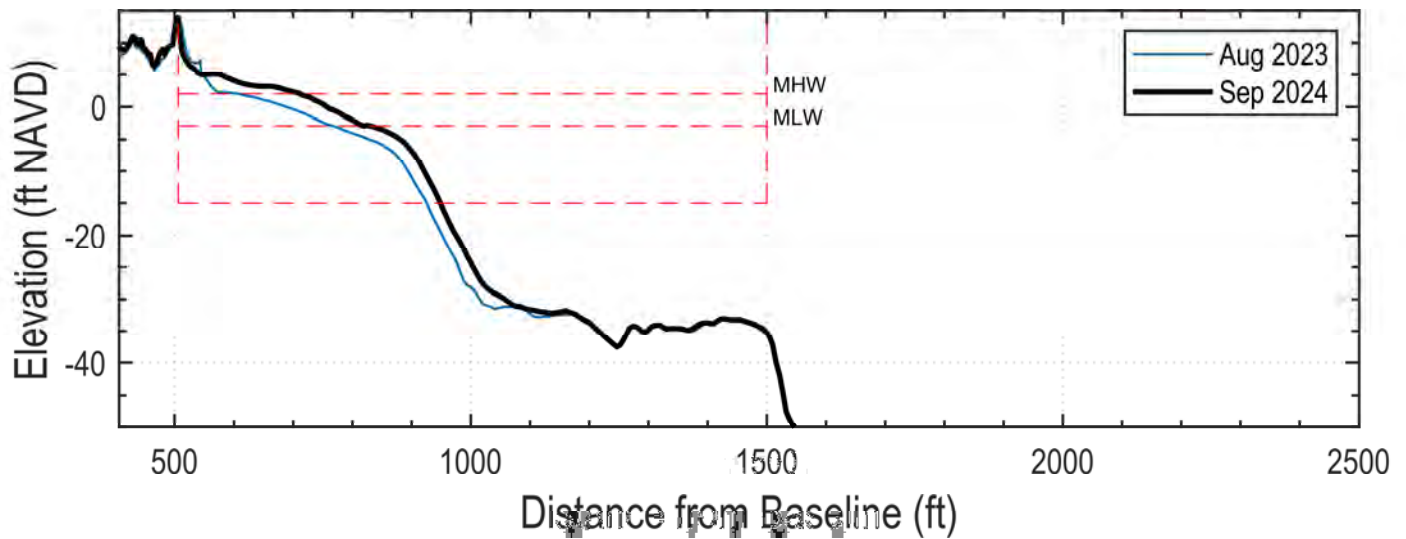
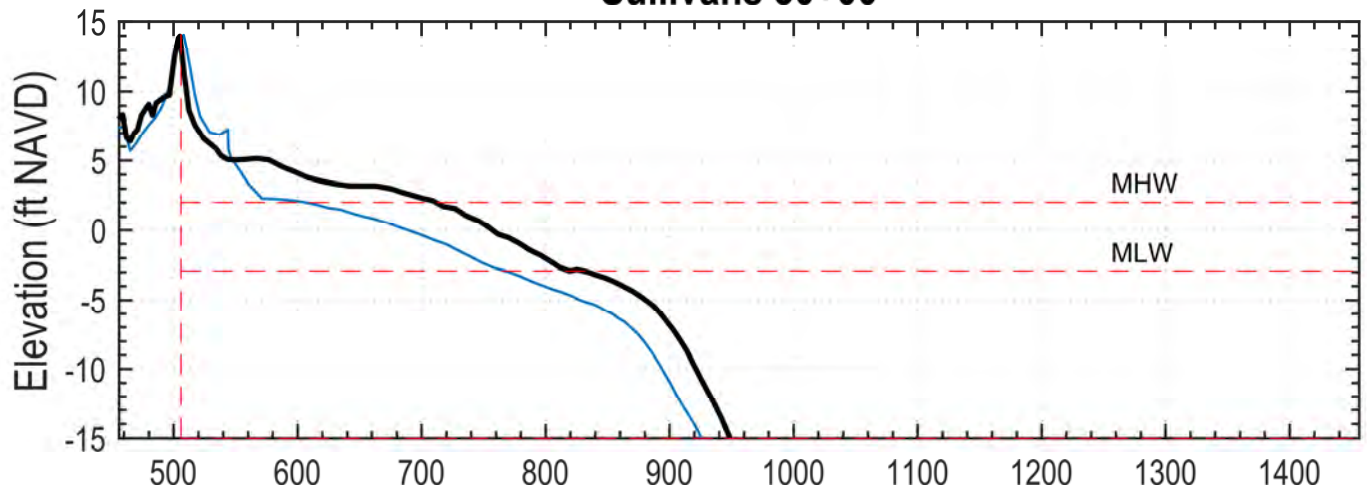
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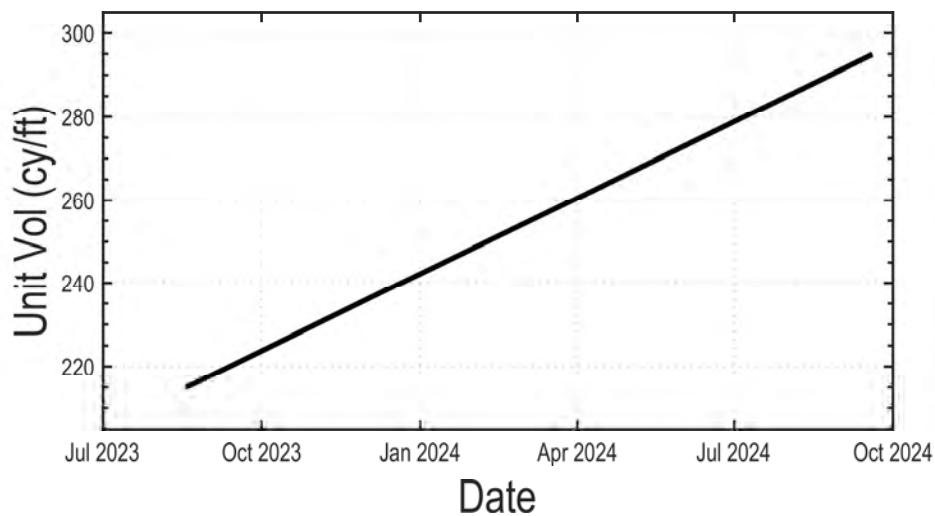
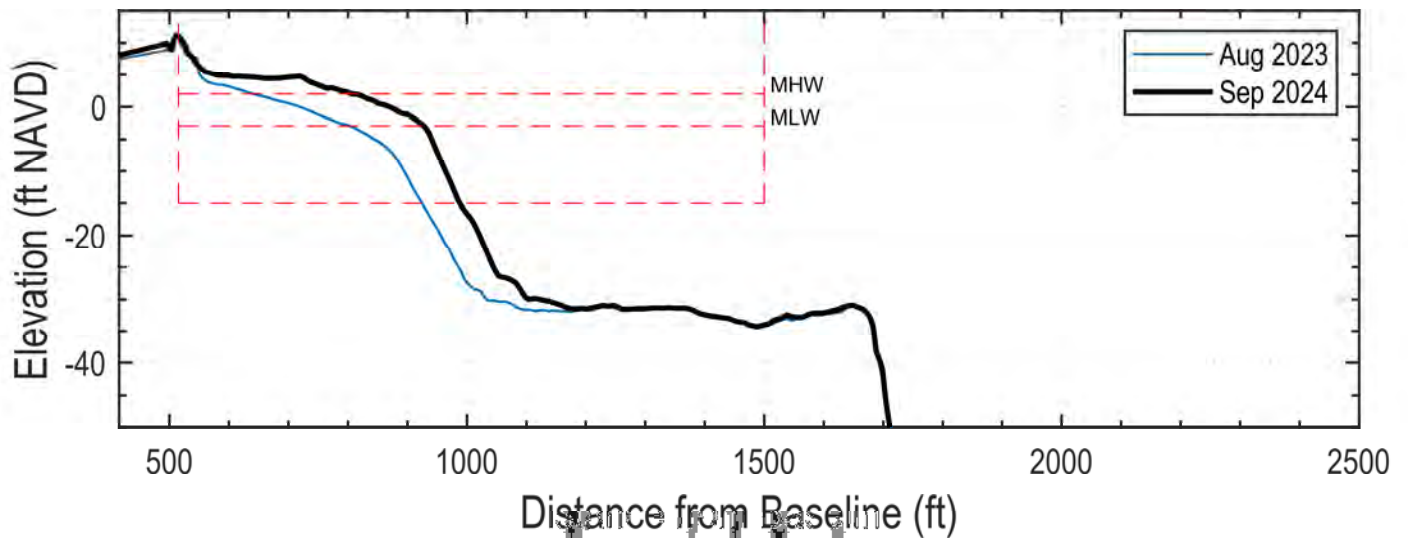
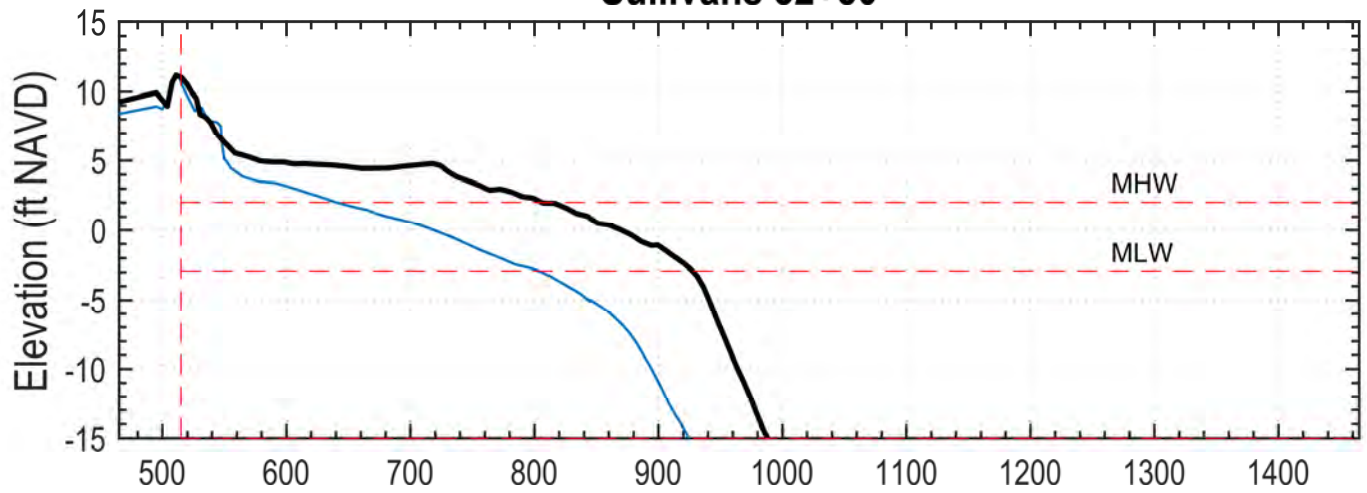
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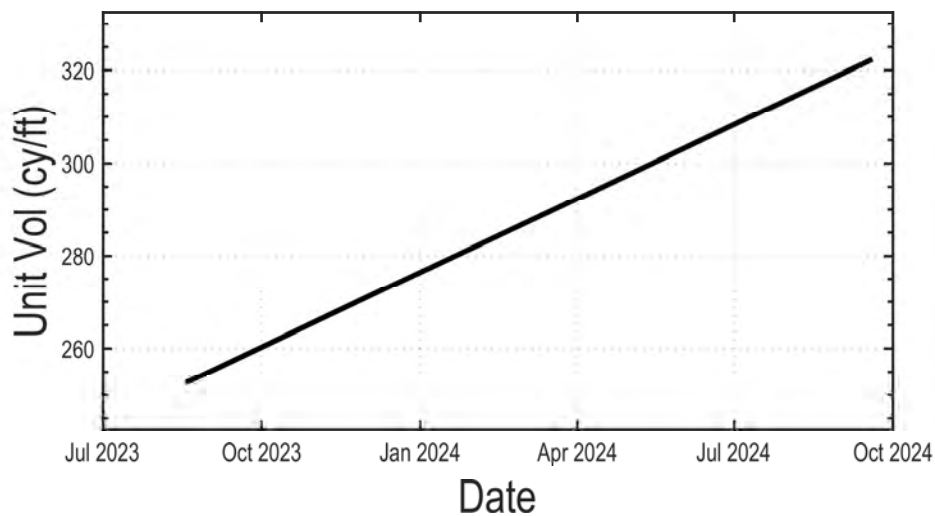
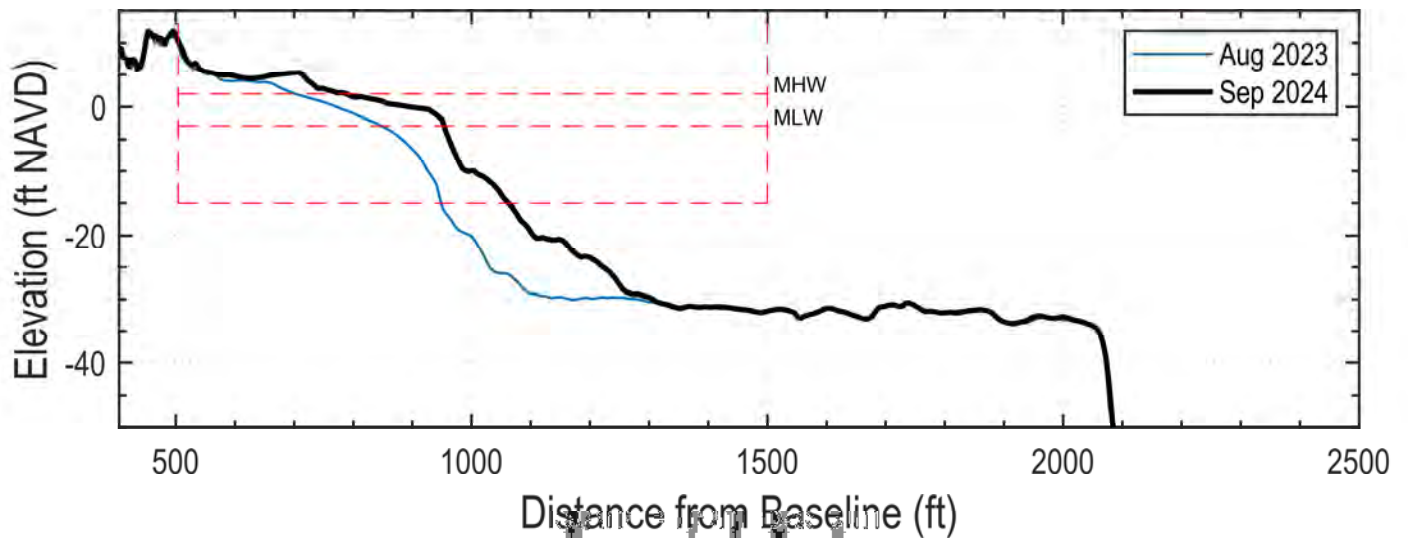
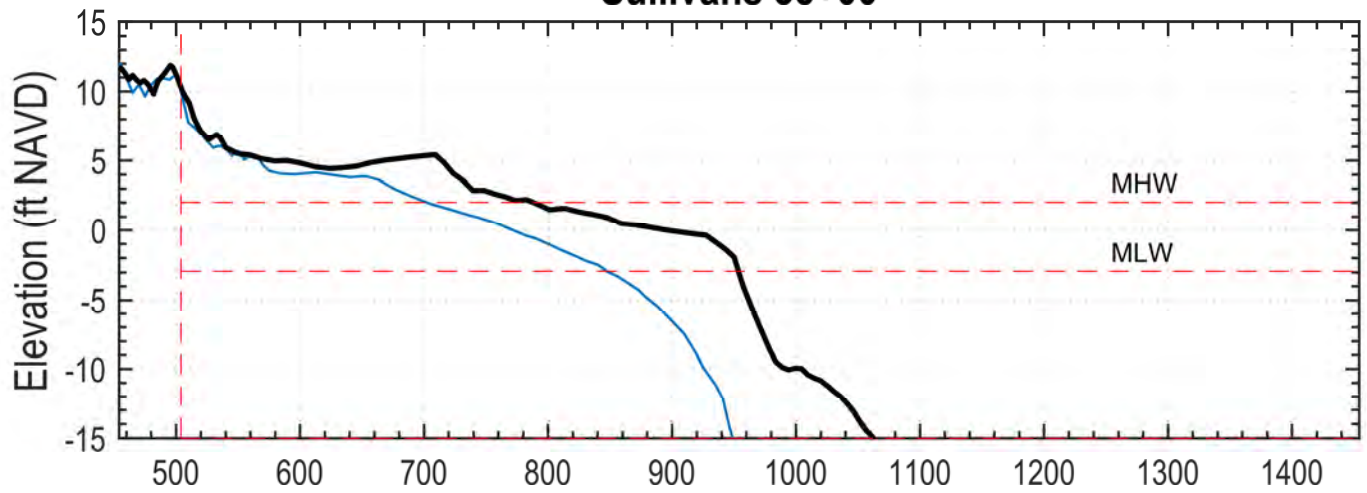
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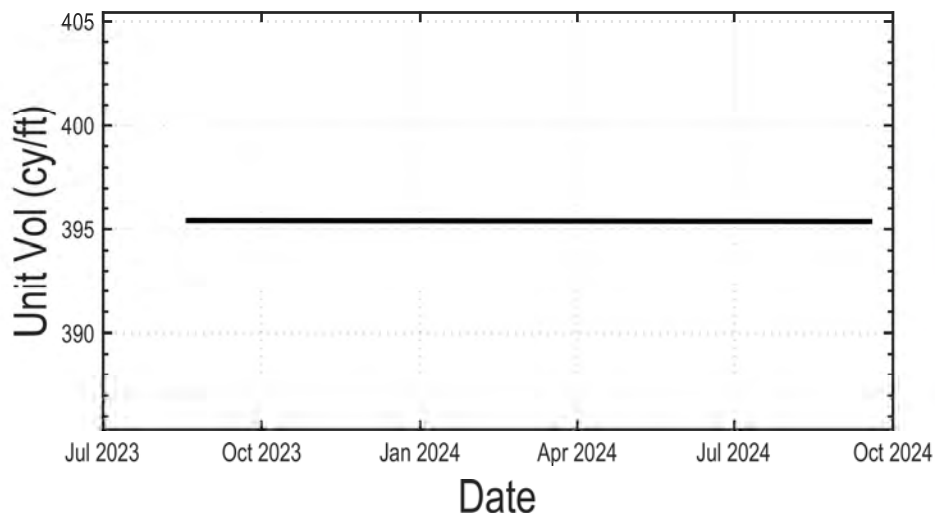
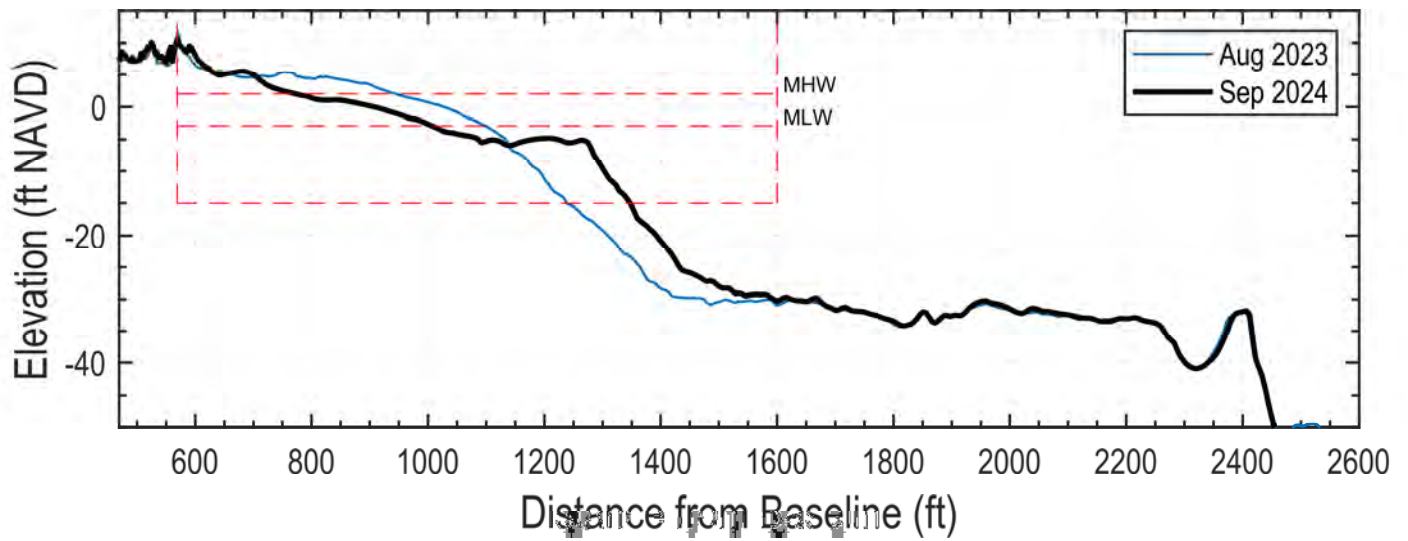
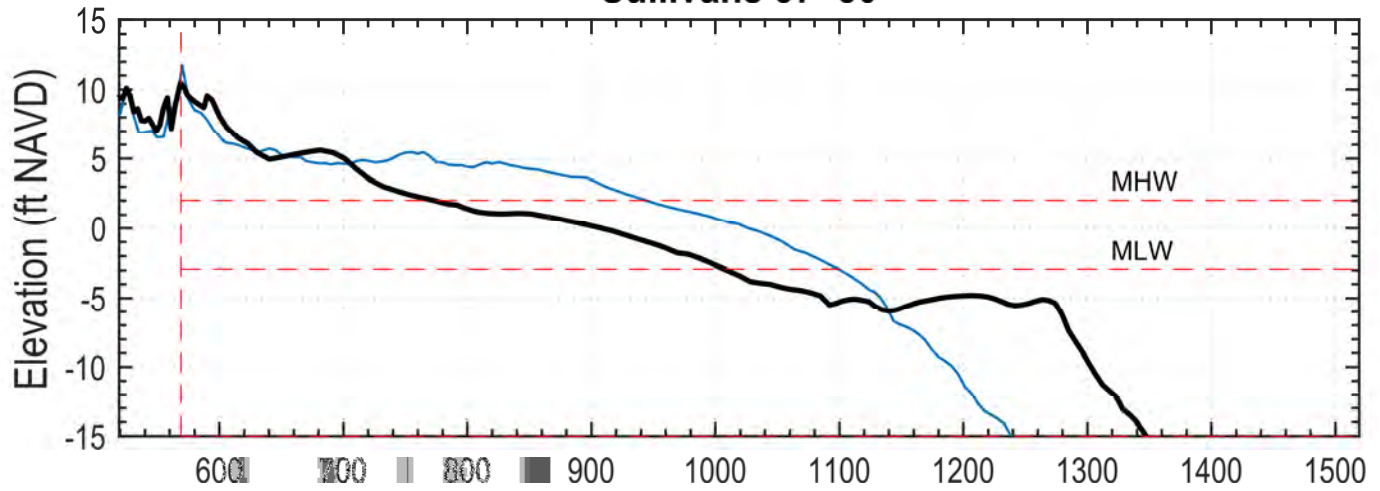
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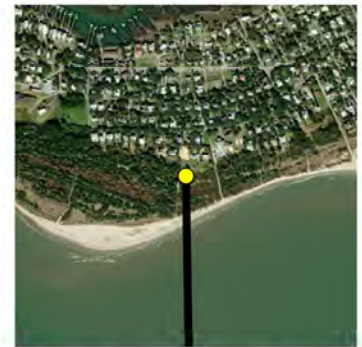
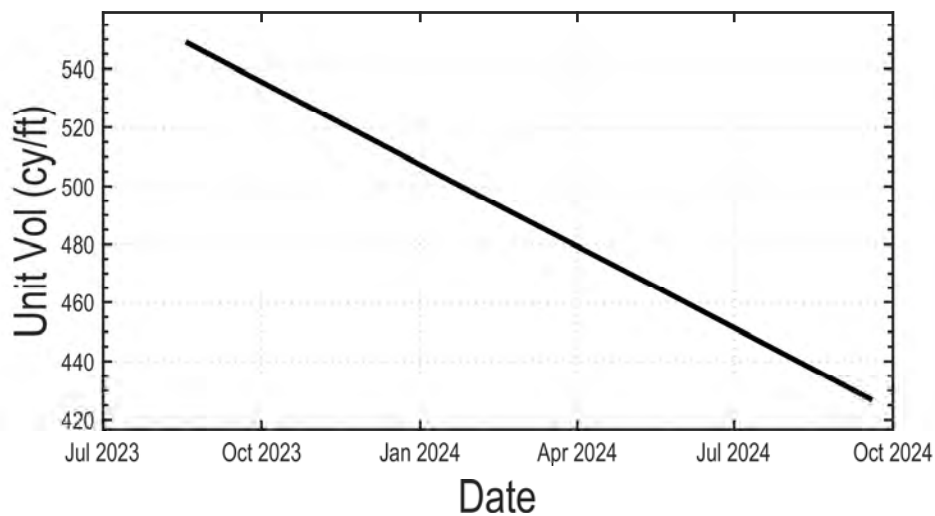
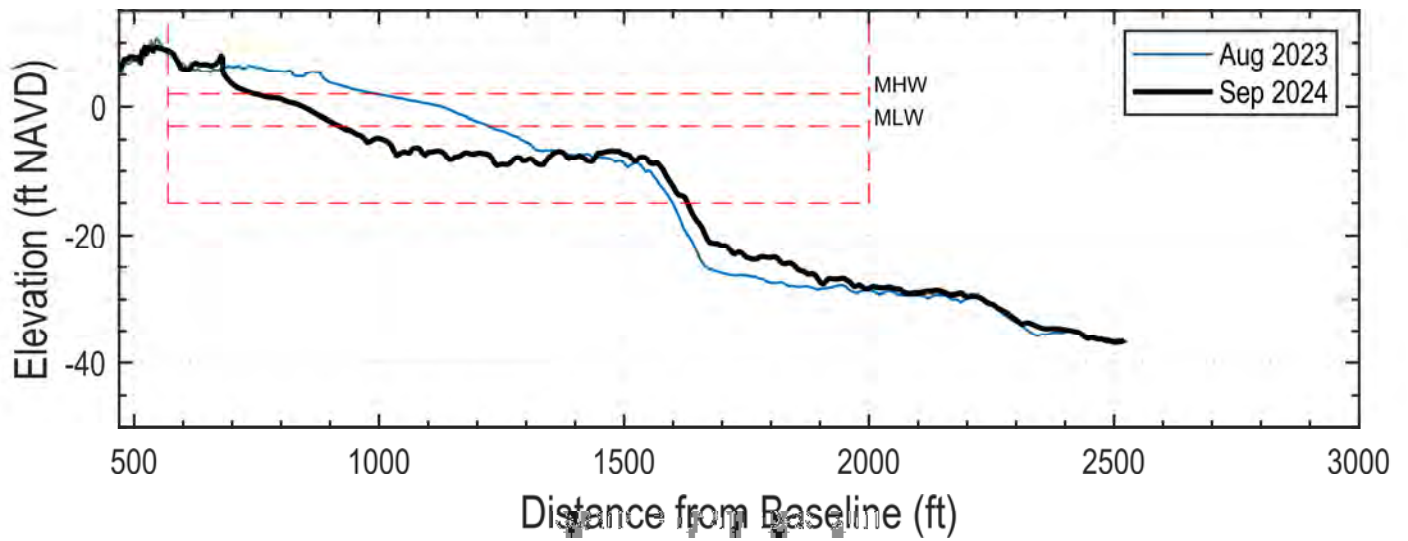
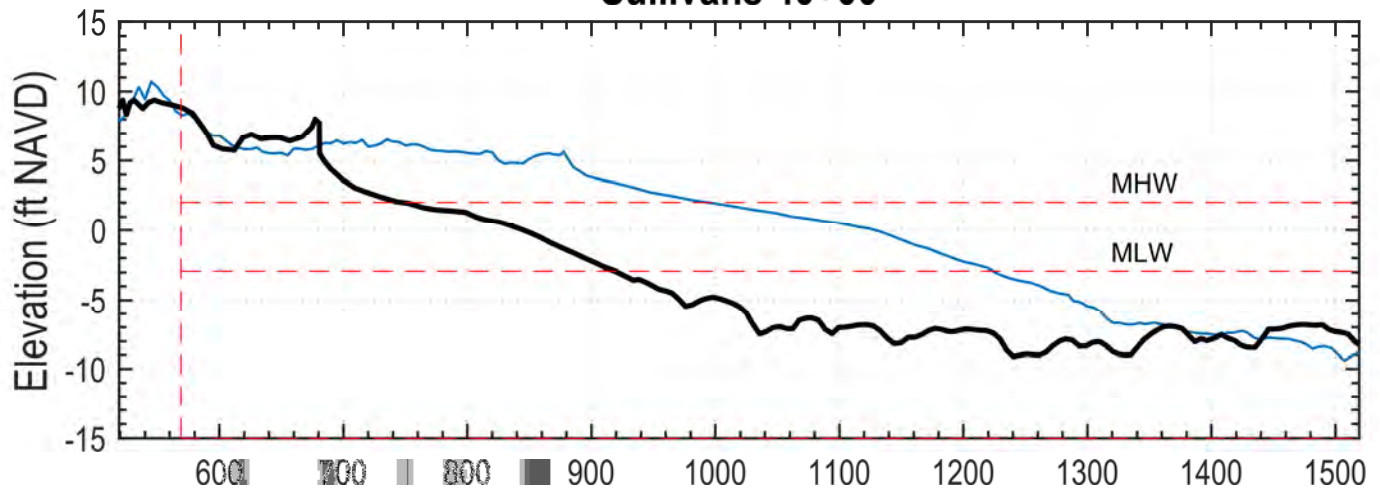
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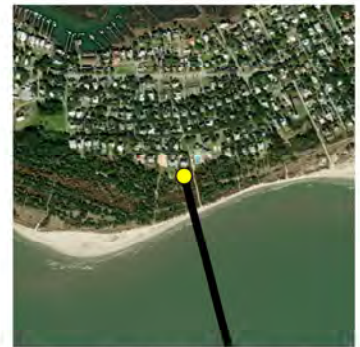
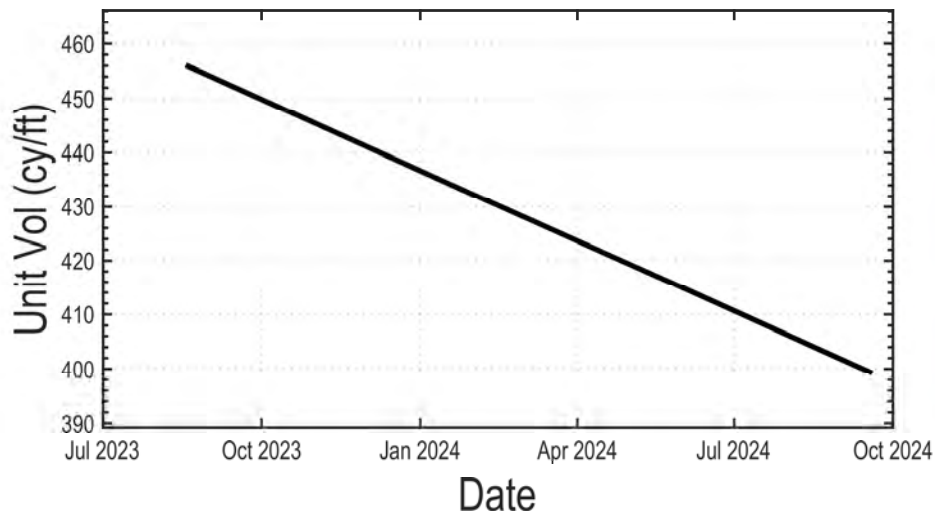
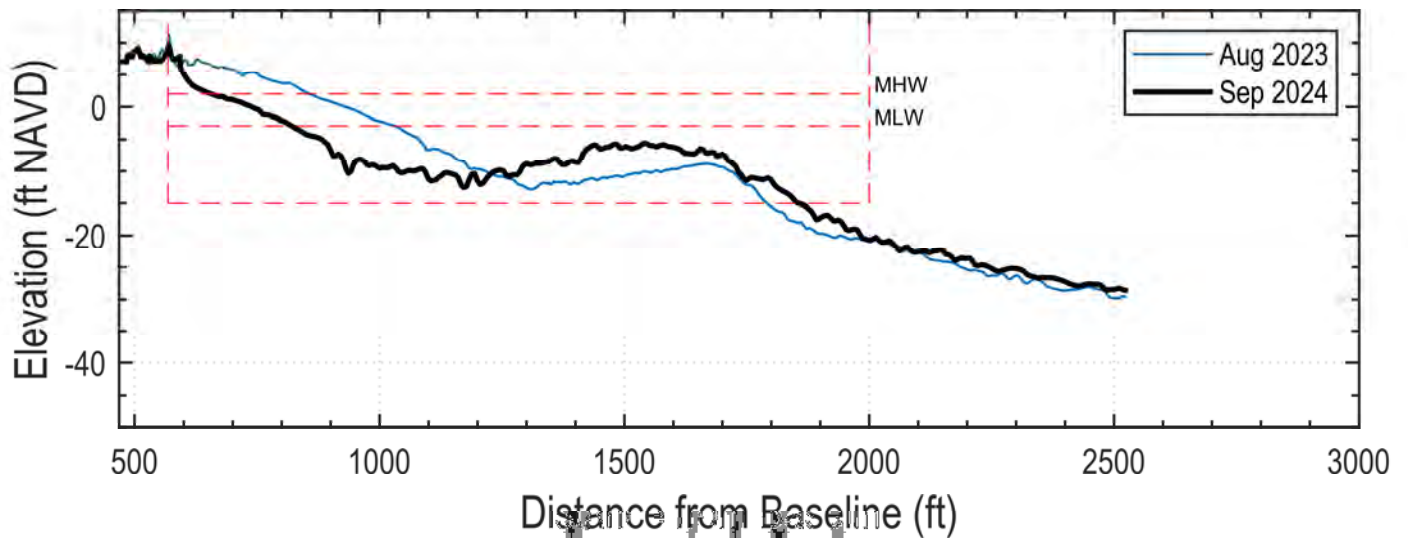
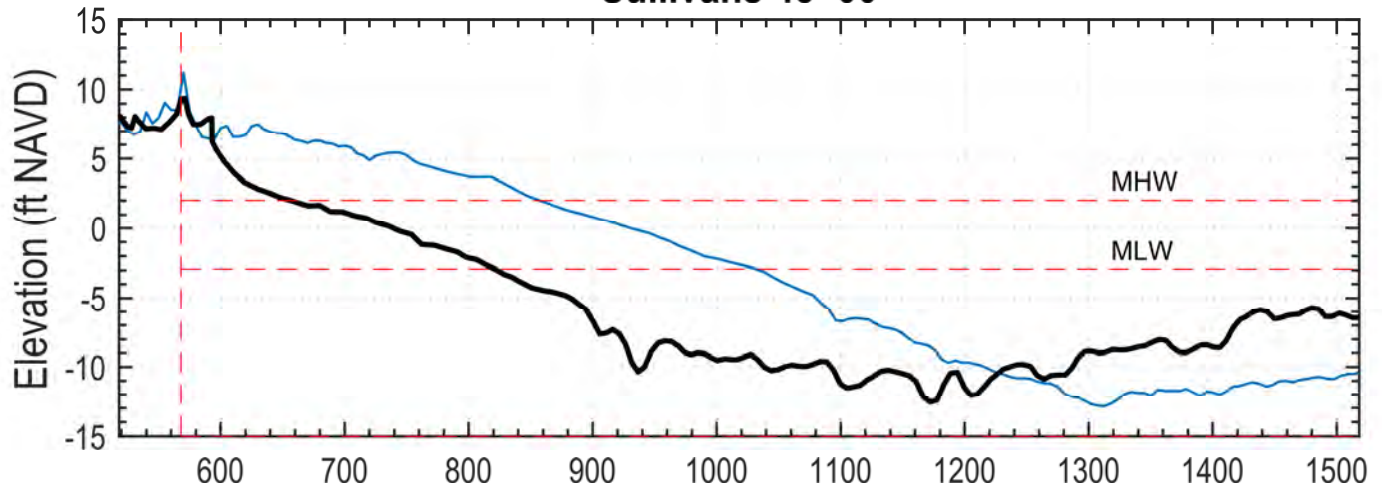
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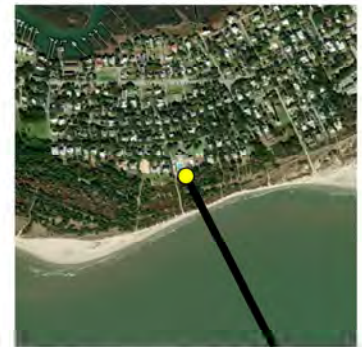
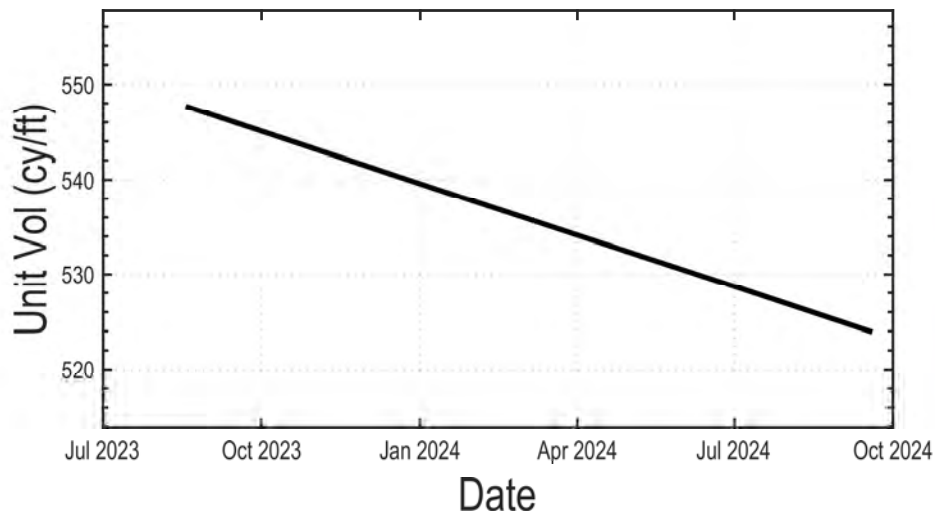
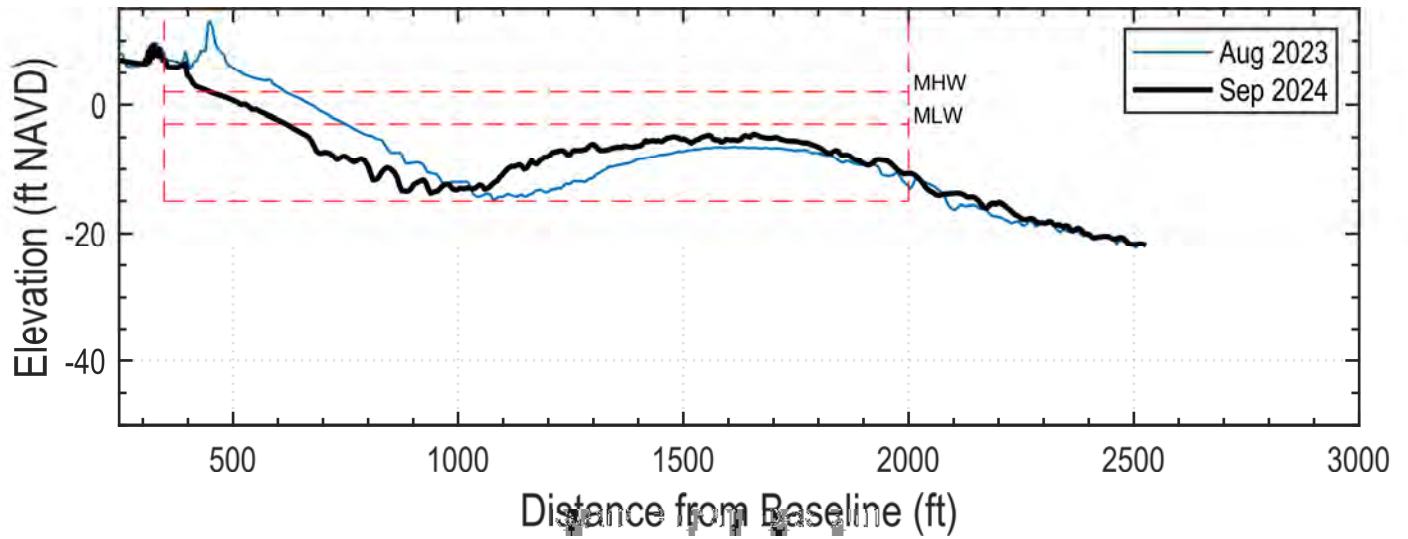
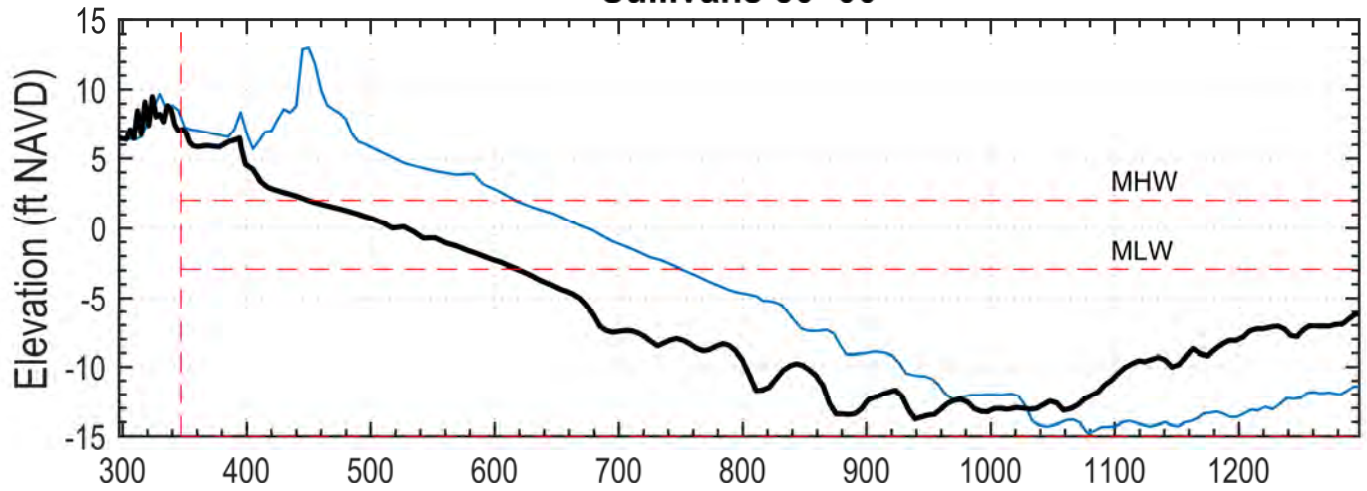
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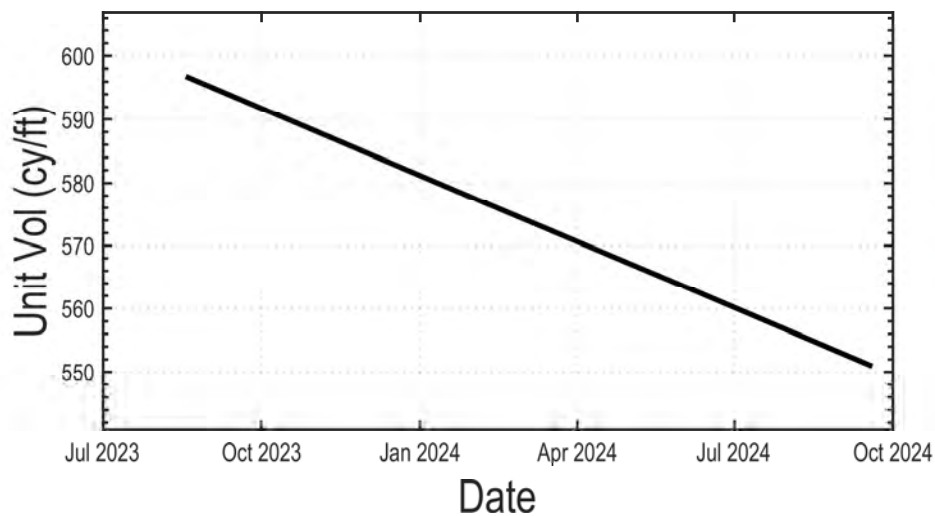
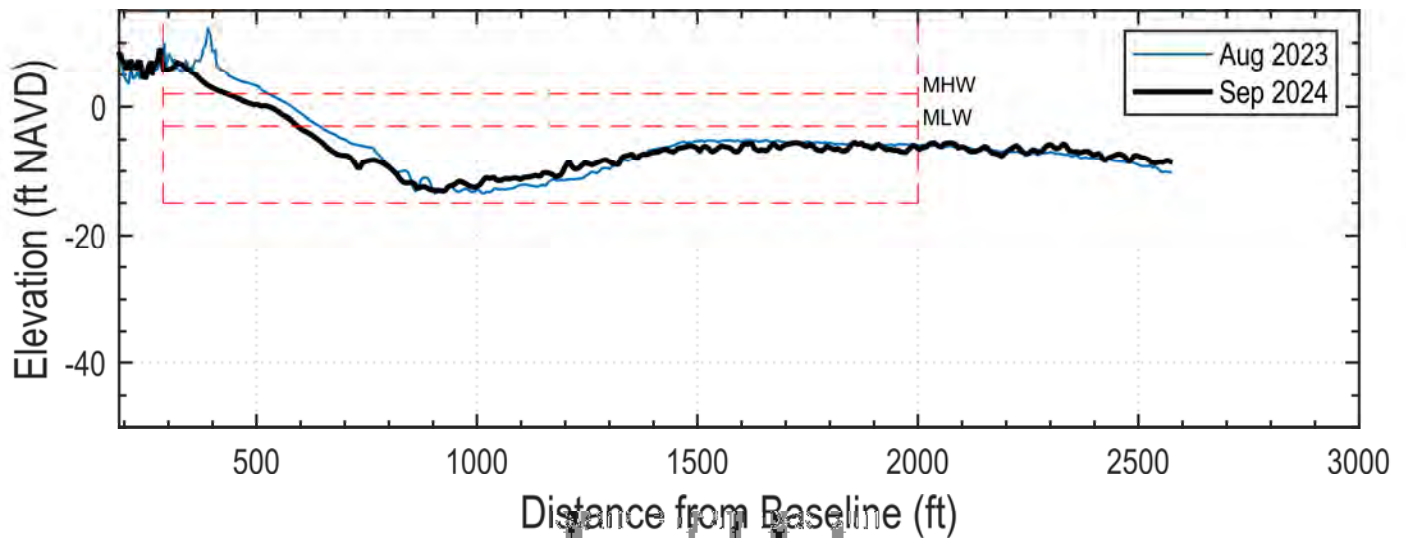
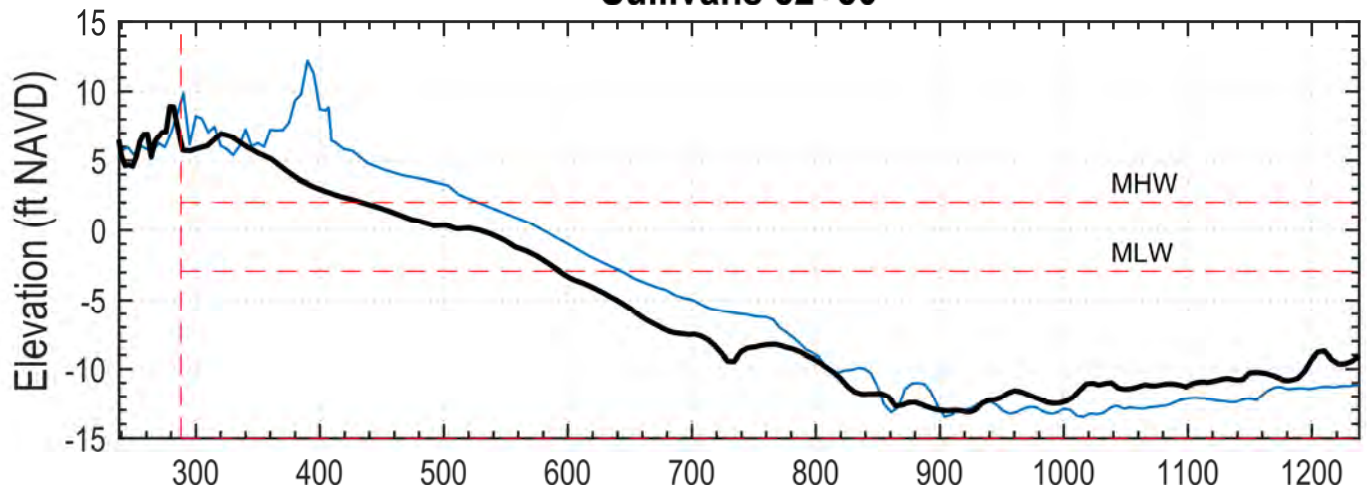
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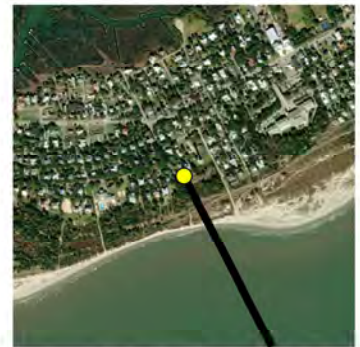
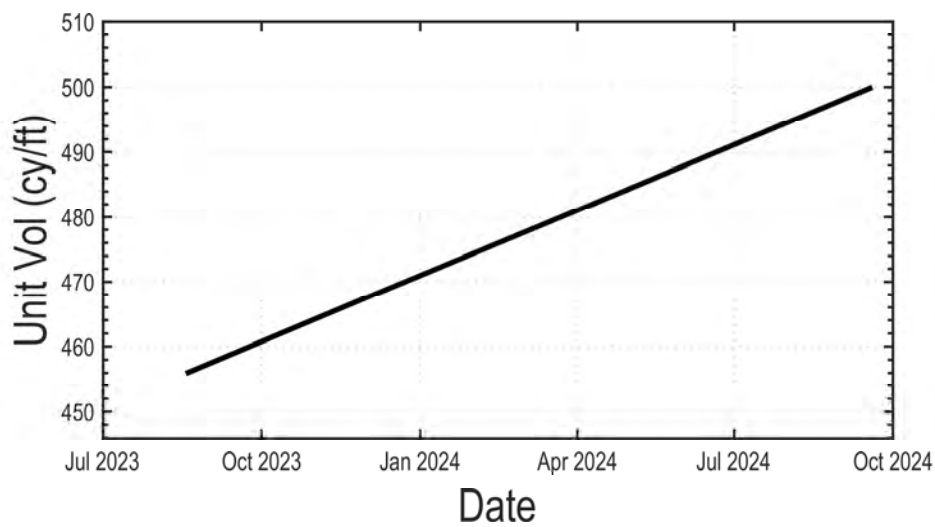
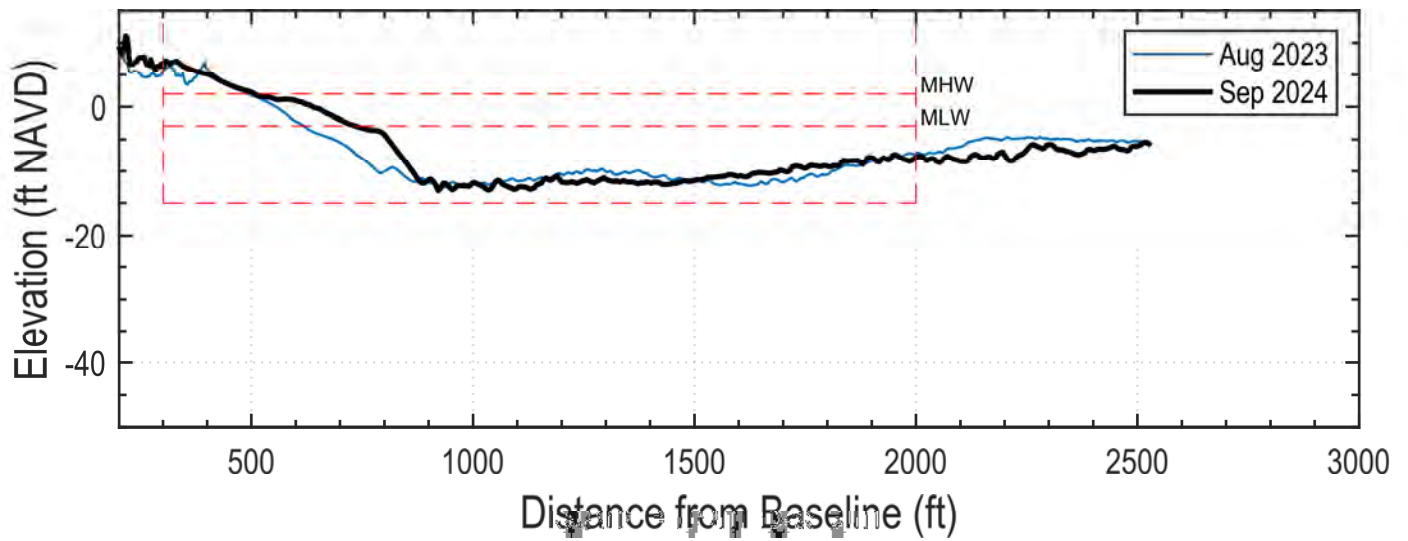
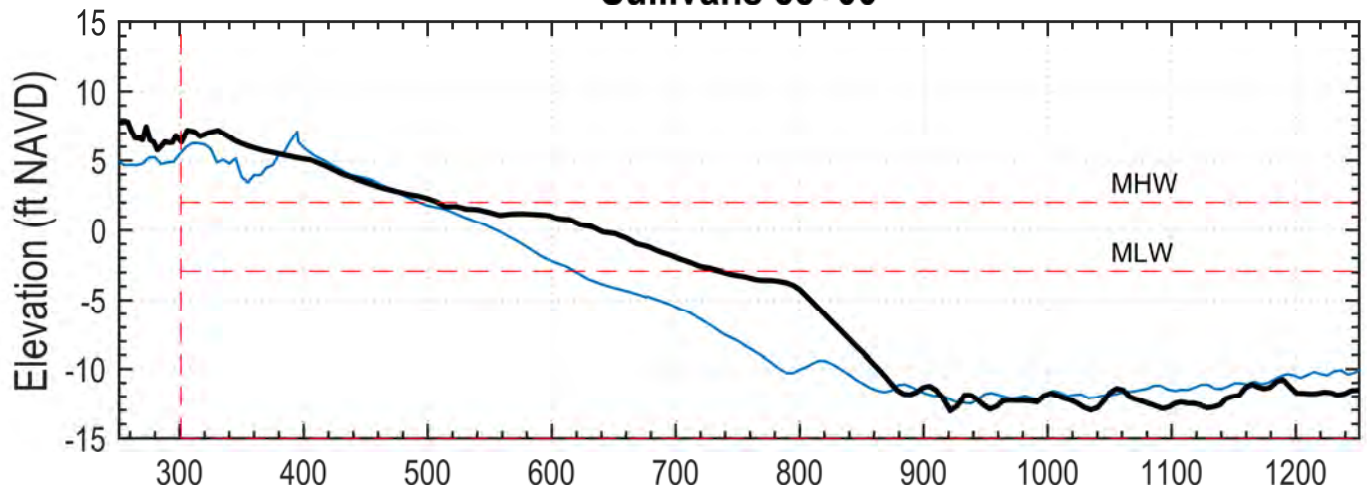
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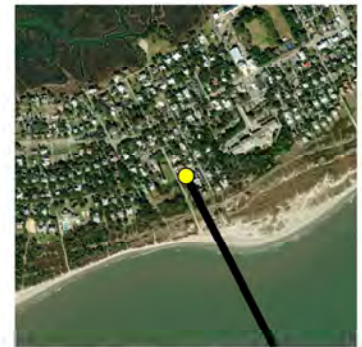
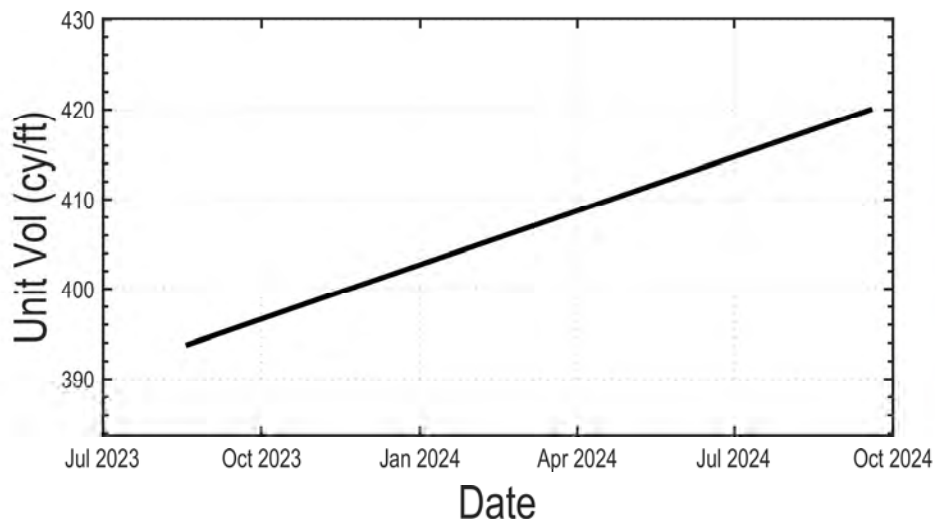
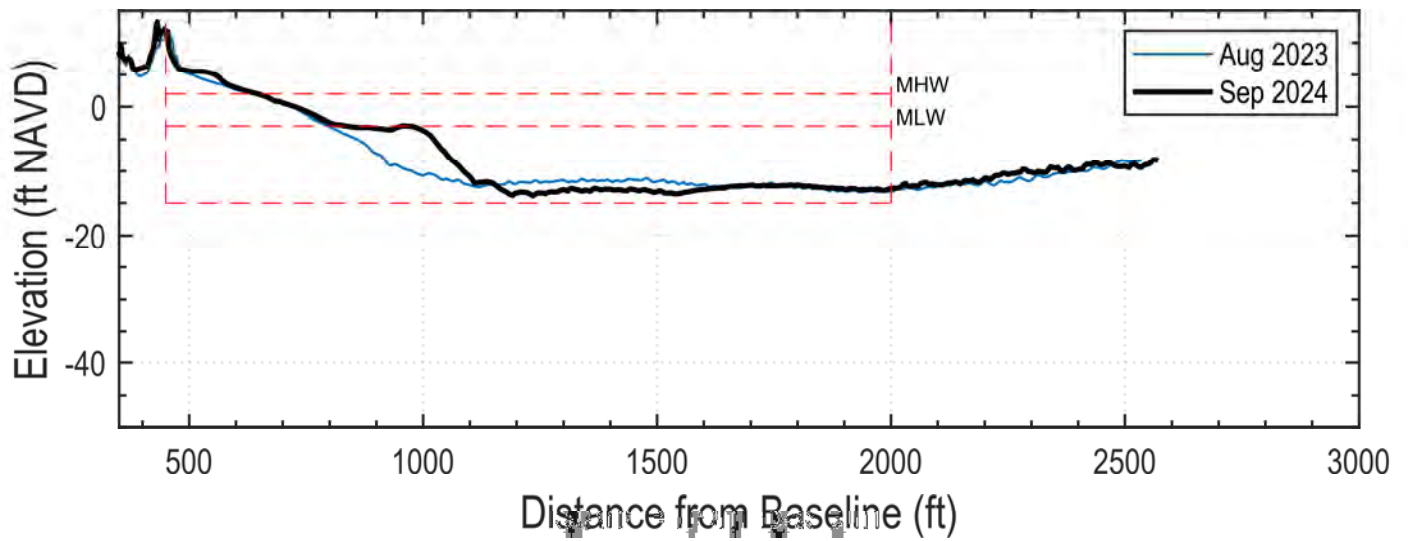
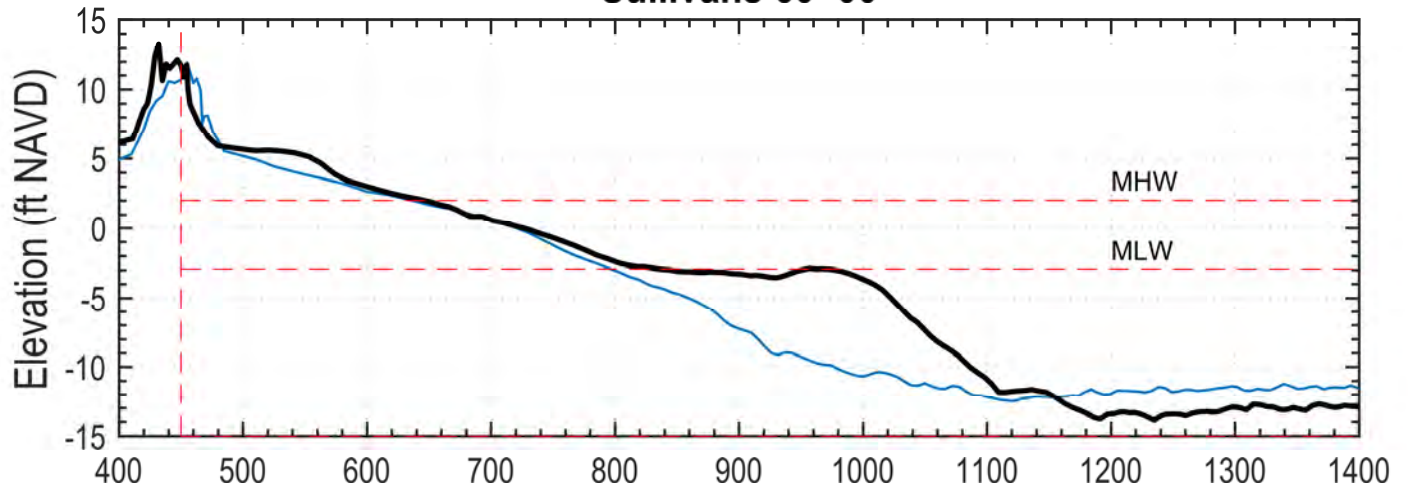
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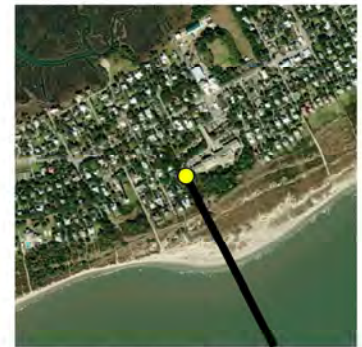
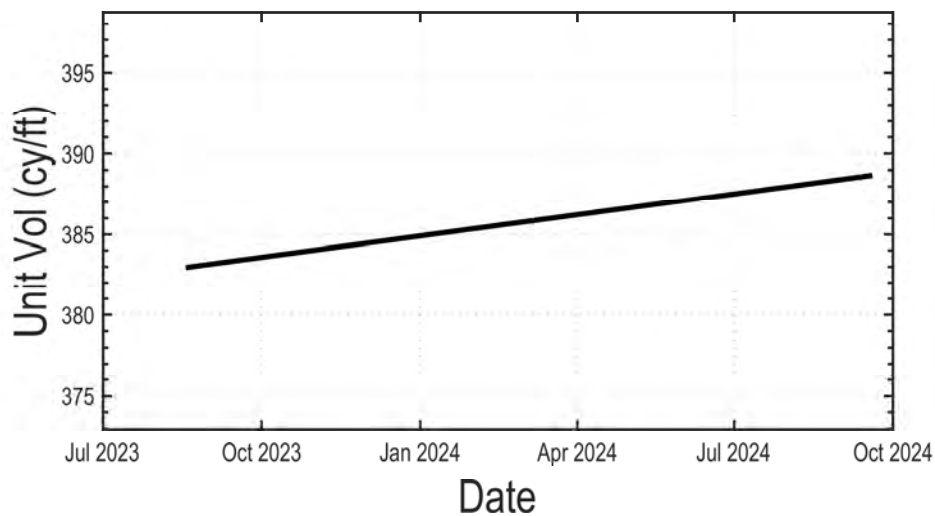
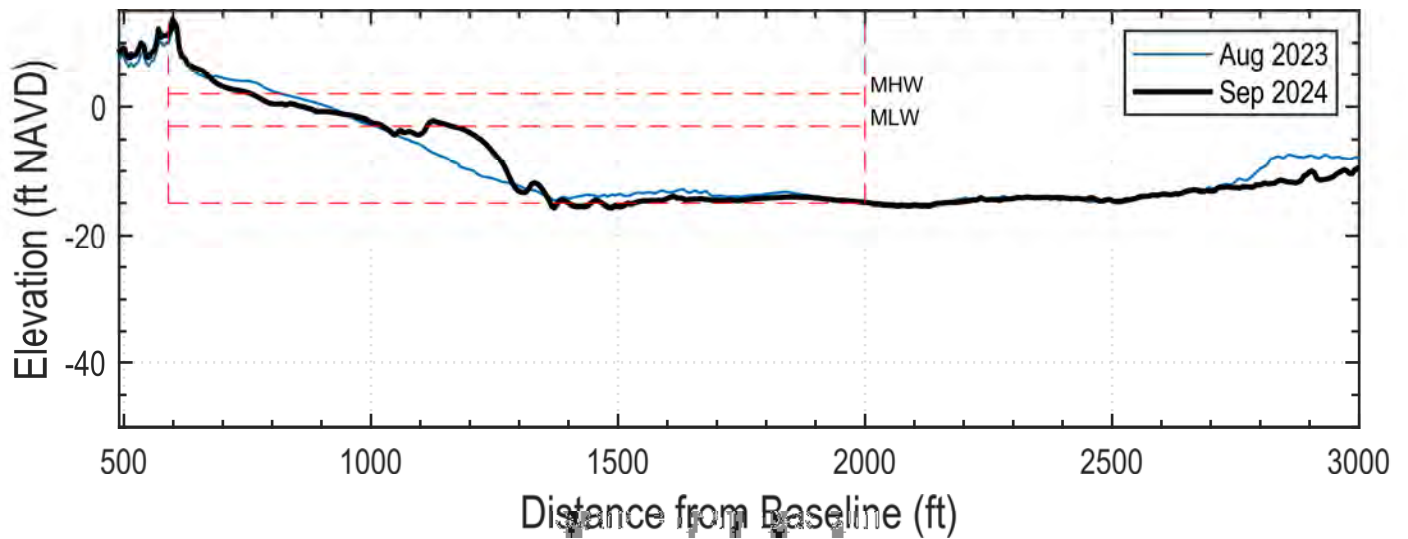
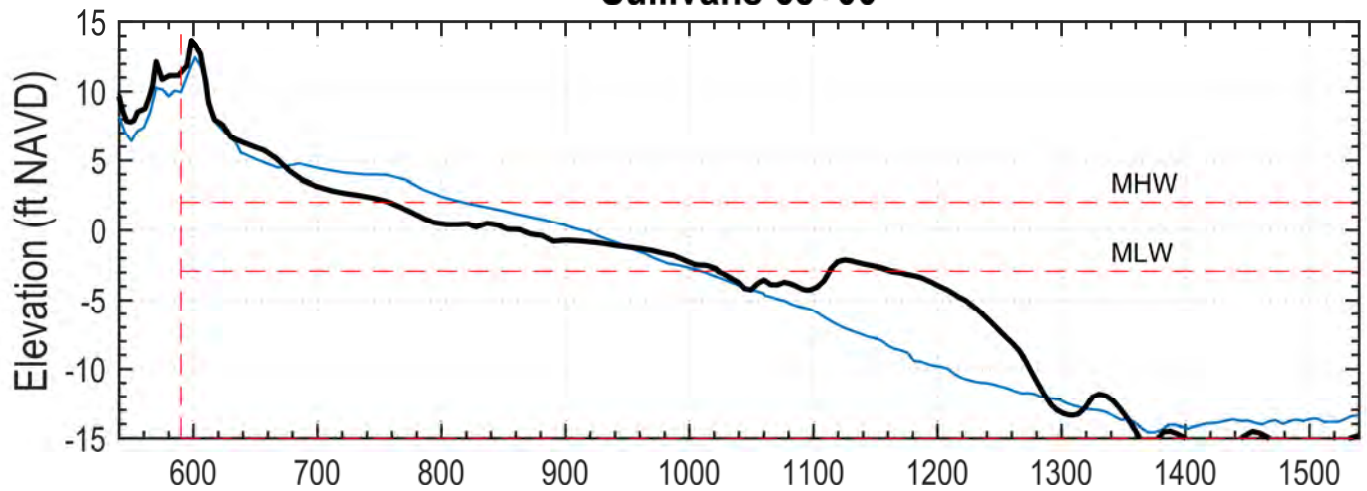
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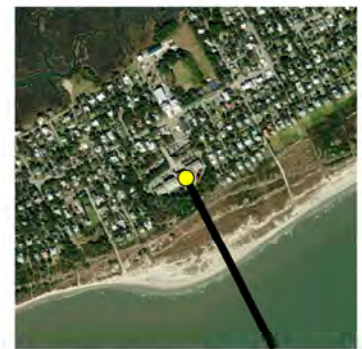
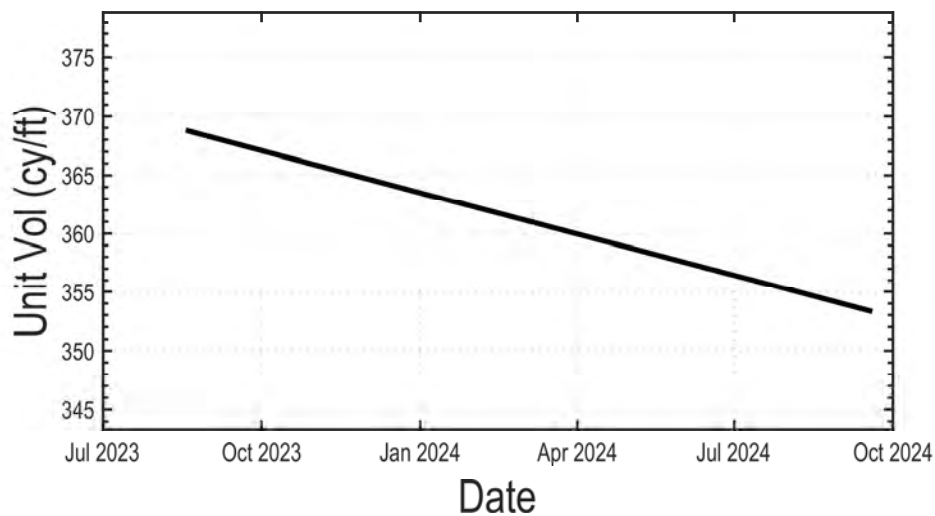
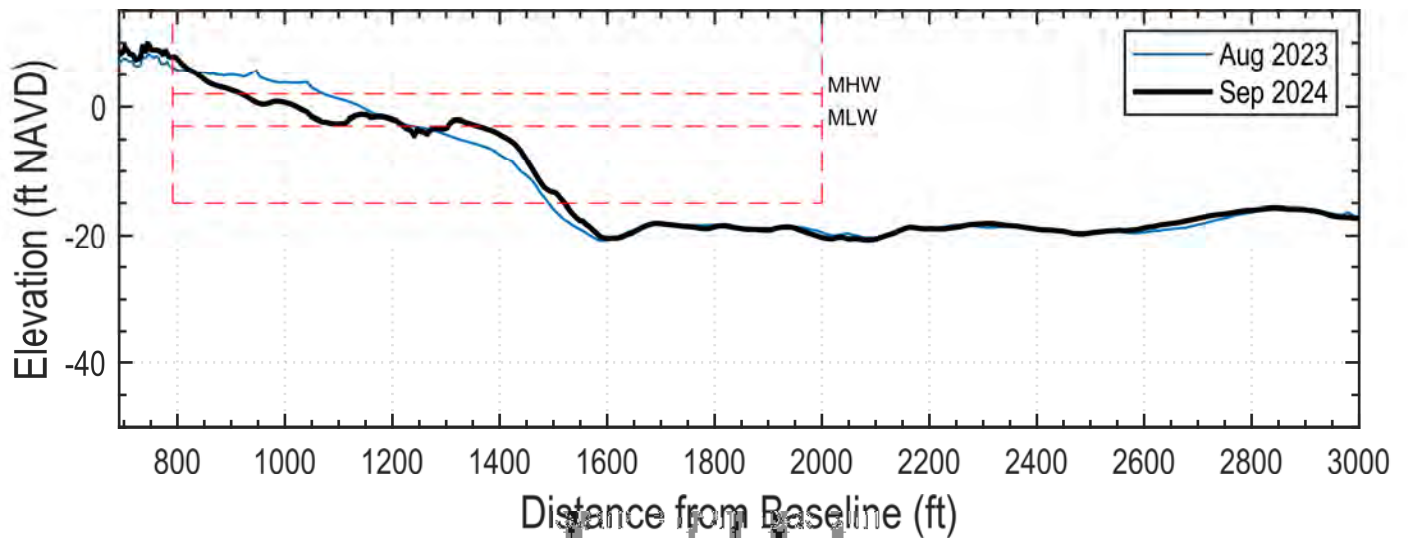
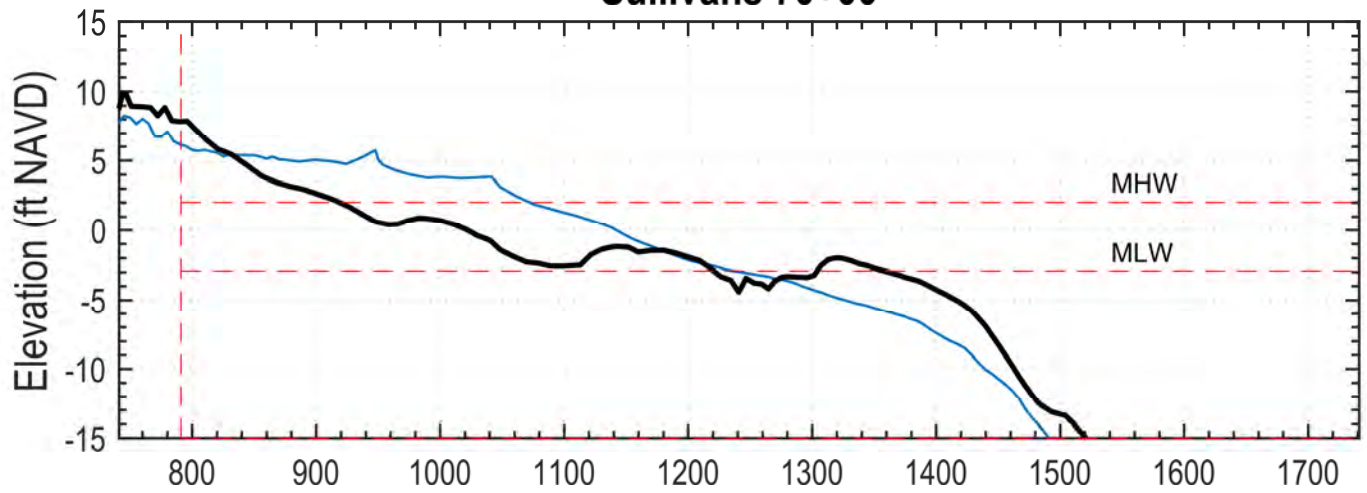
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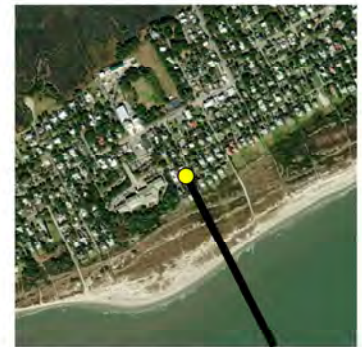
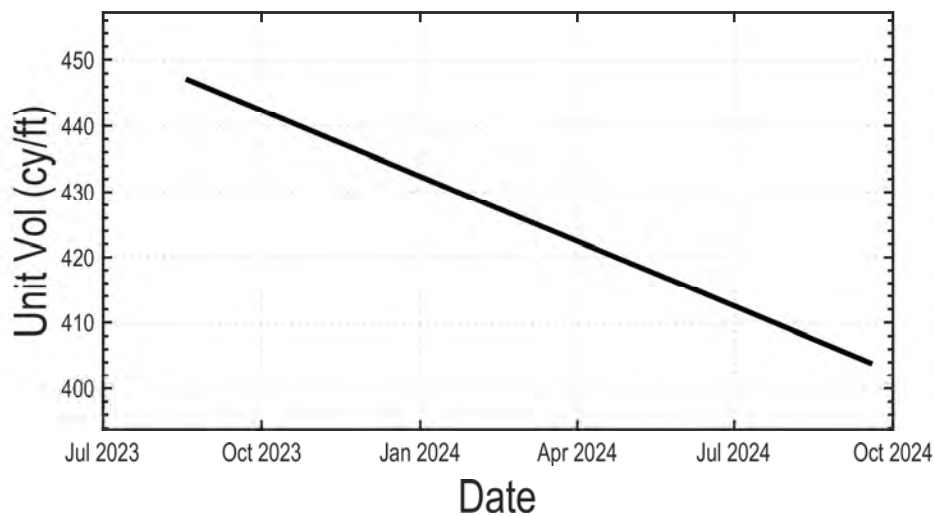
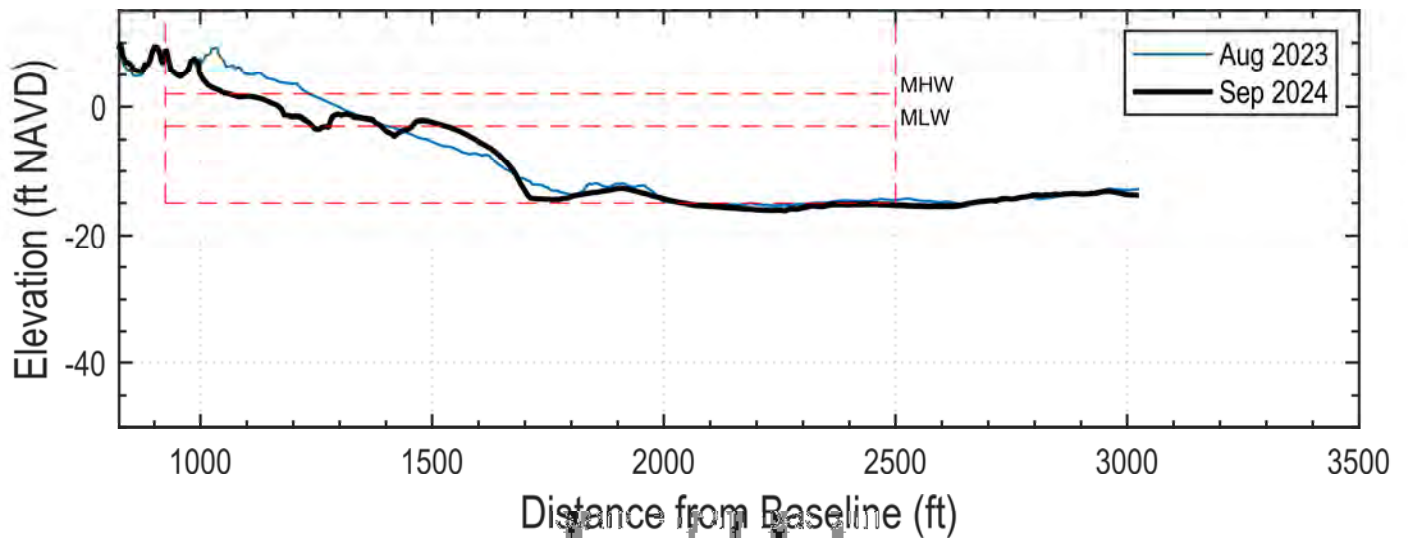
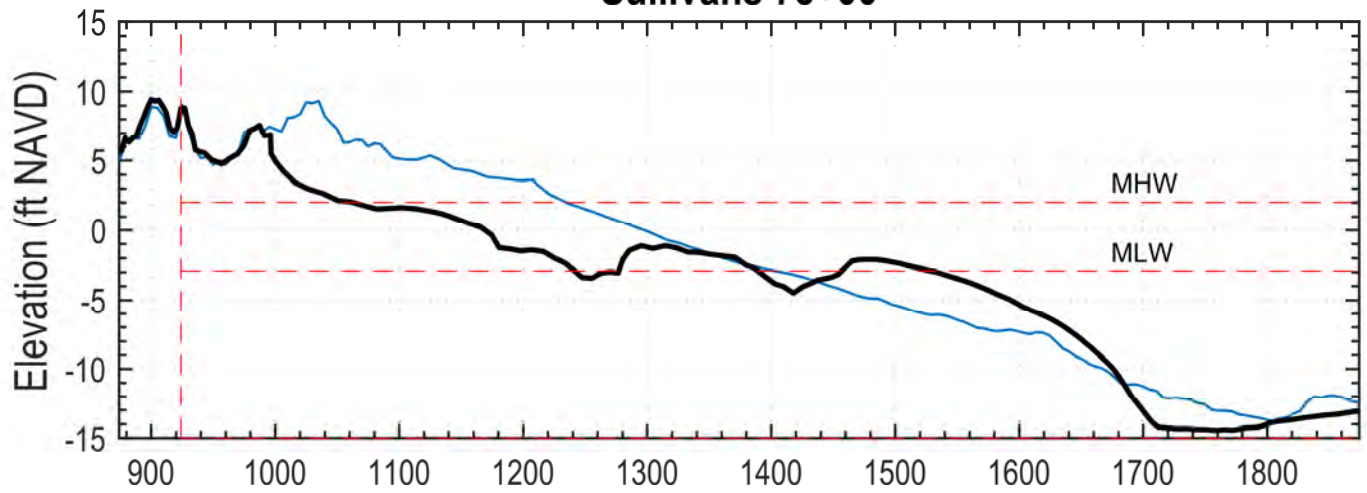
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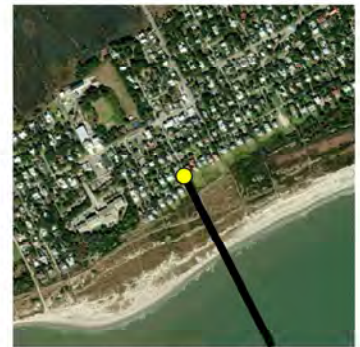
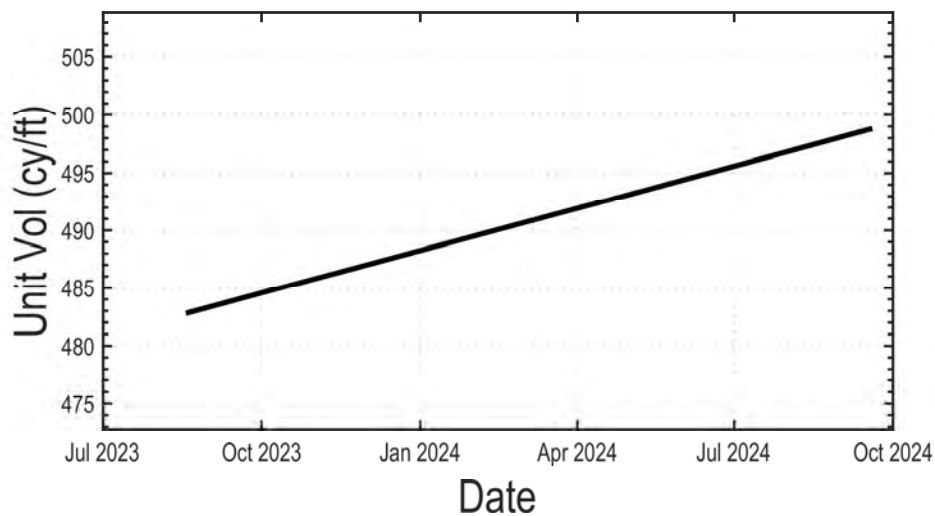
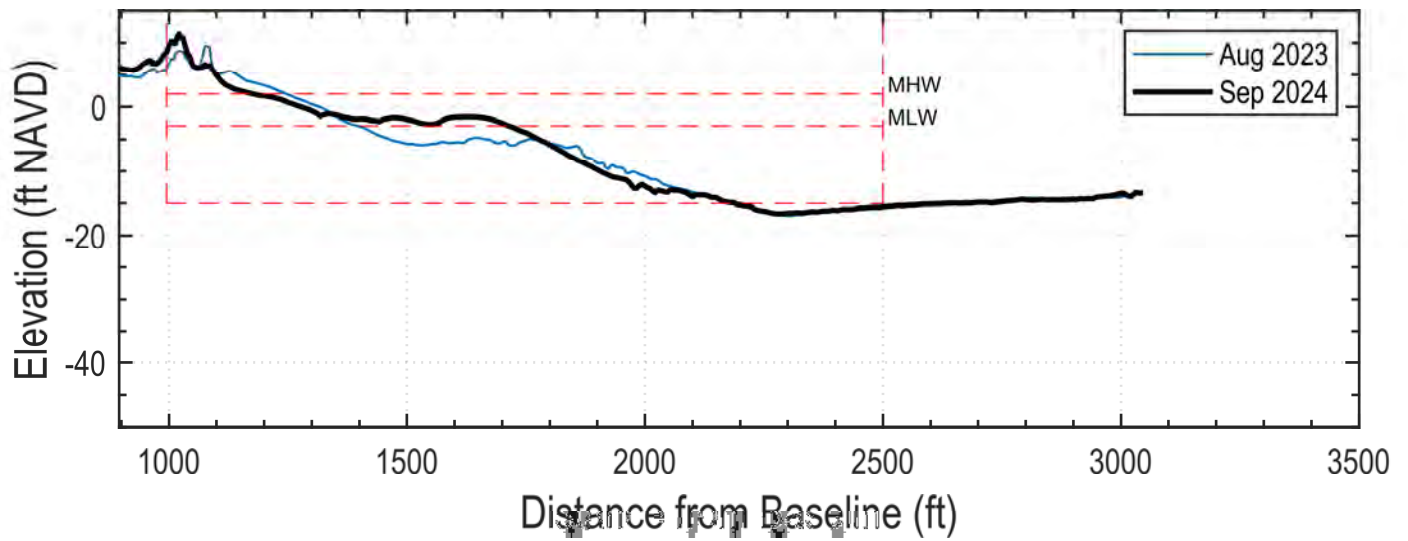
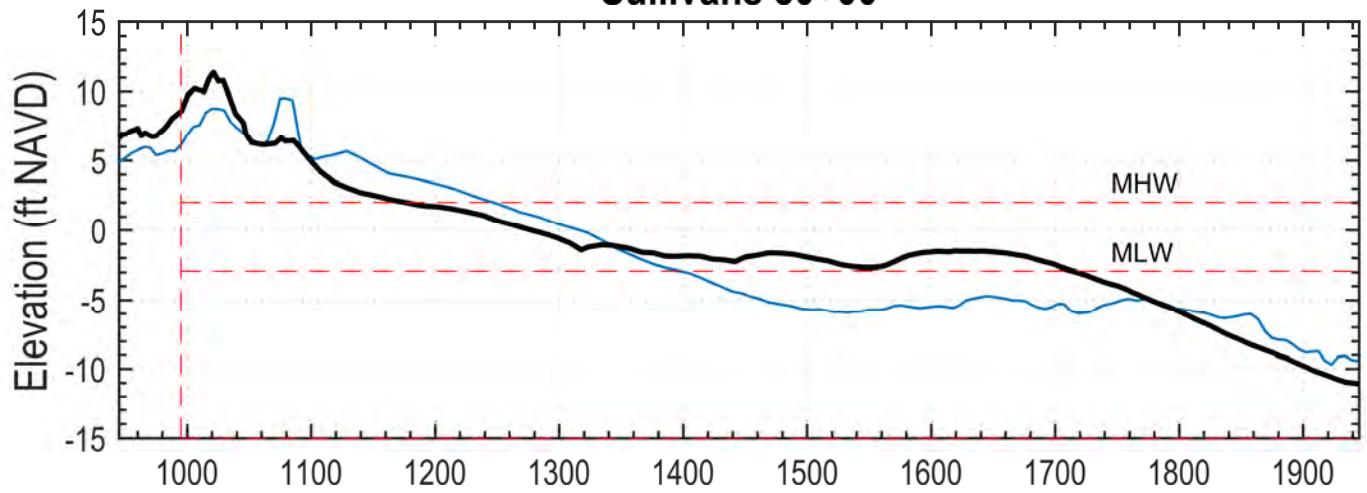
X: 2356720.41
Y: 338926.43

Sullivans 75+00



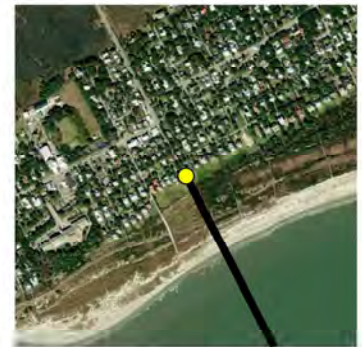
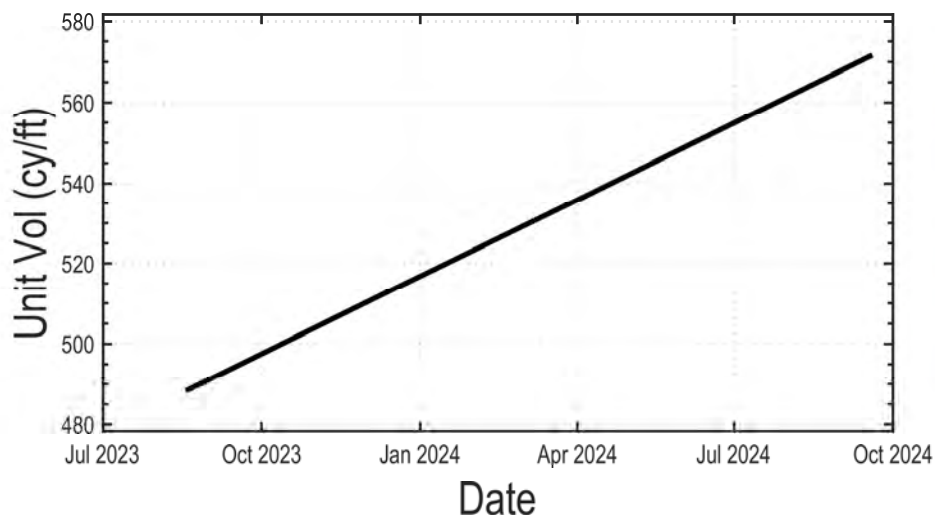
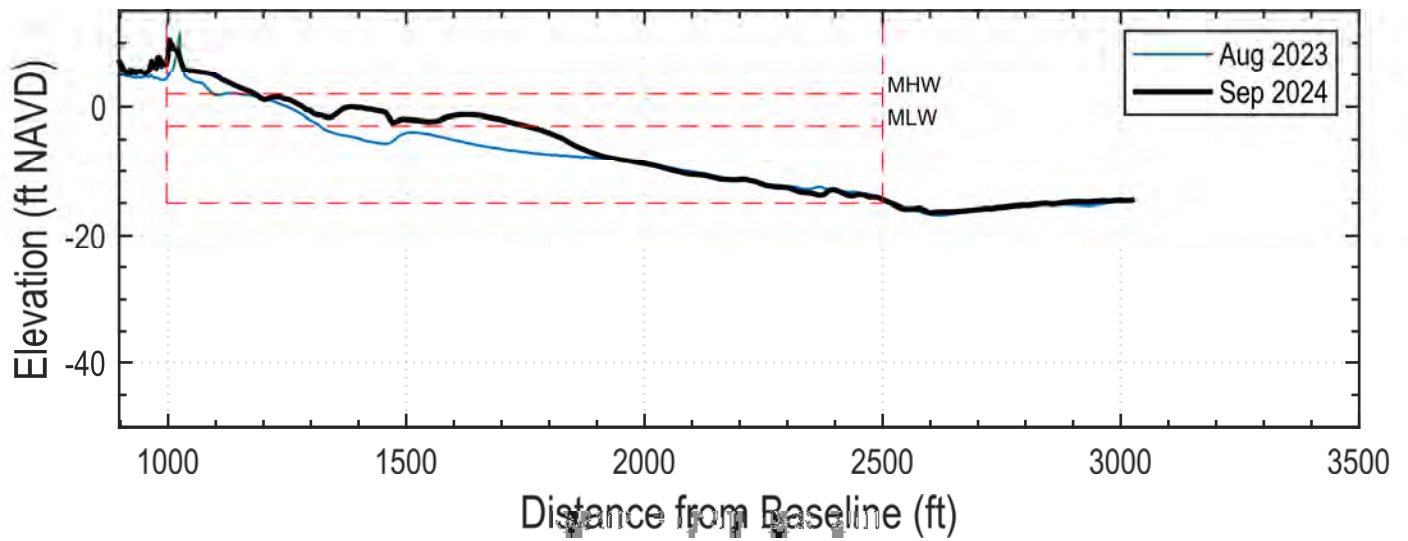
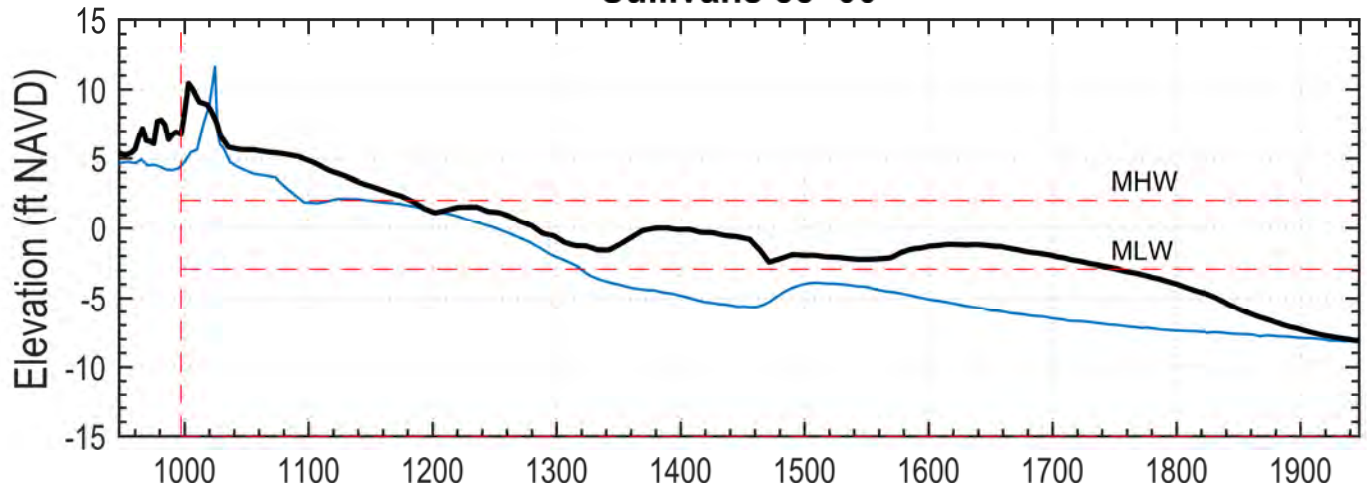
X: 2357164.67
Y: 339155.84

Sullivans 80+00



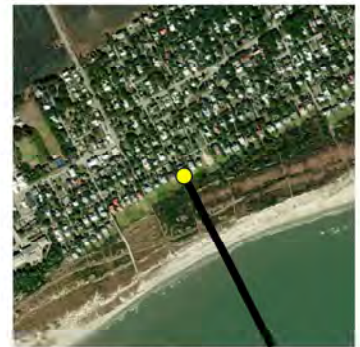
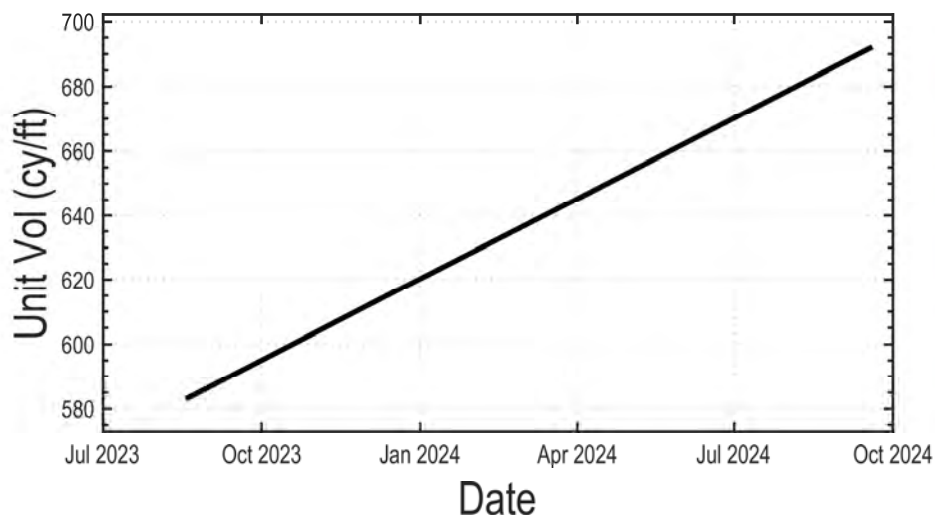
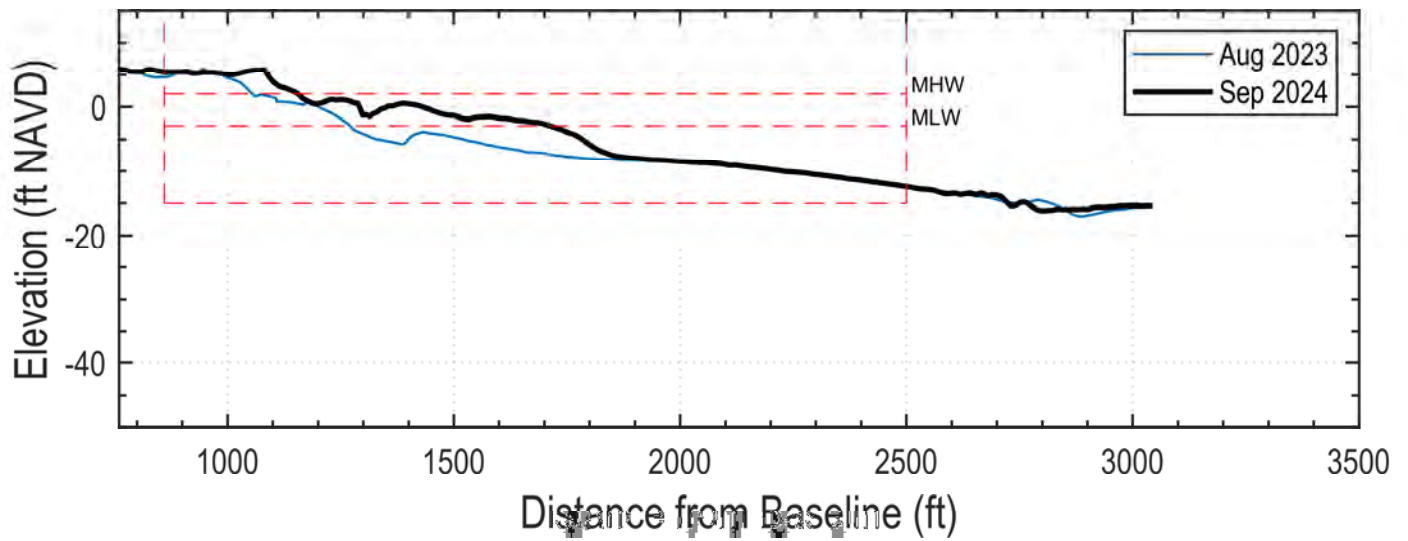
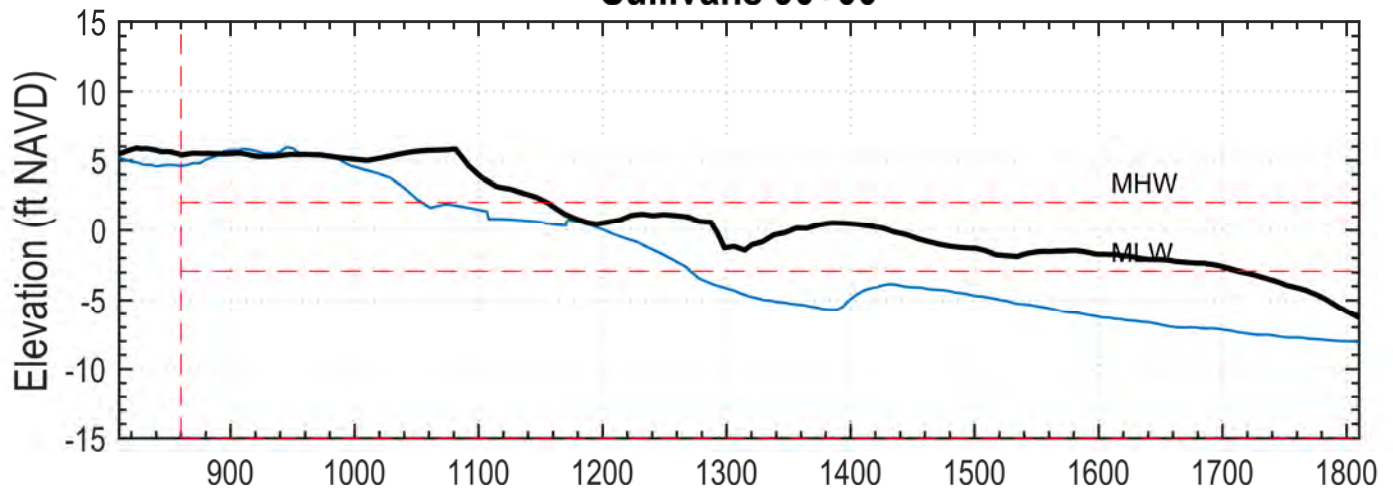
X: 2357608.93
Y: 339385.25

Sullivans 85+00



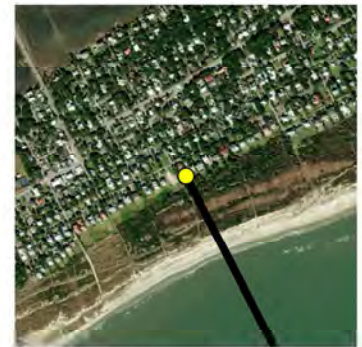
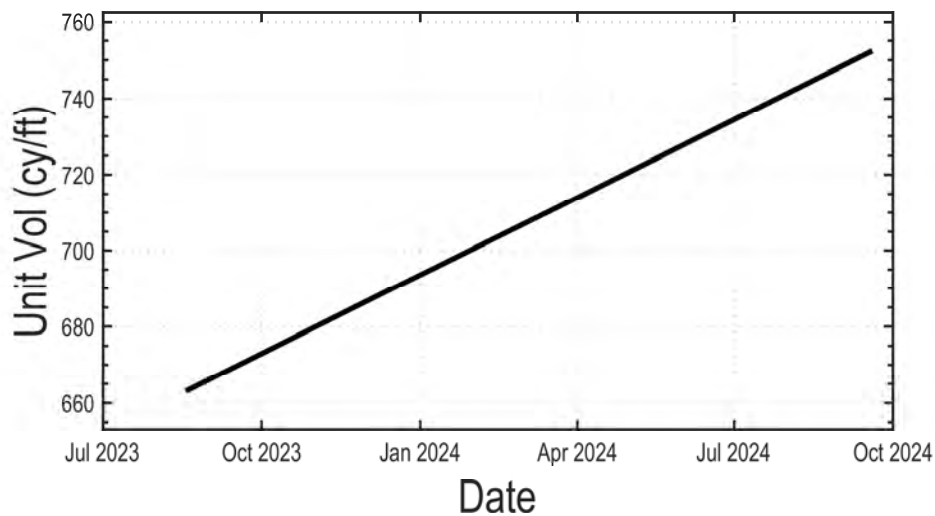
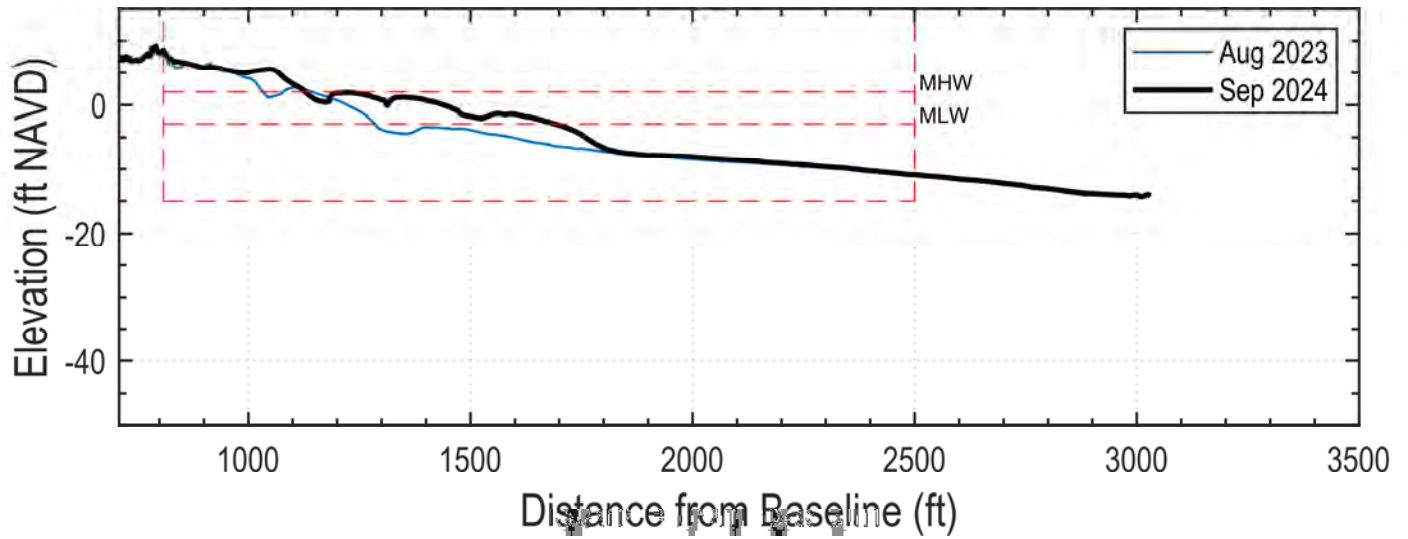
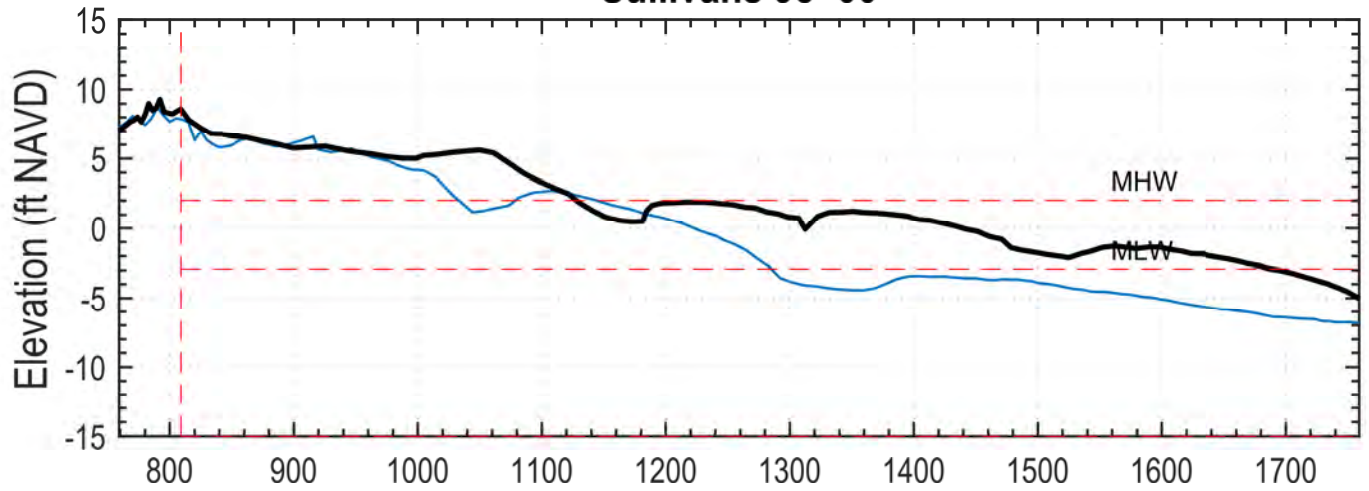
X: 2358053.19
Y: 339614.66

Sullivans 90+00



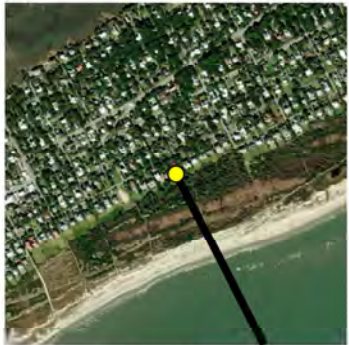
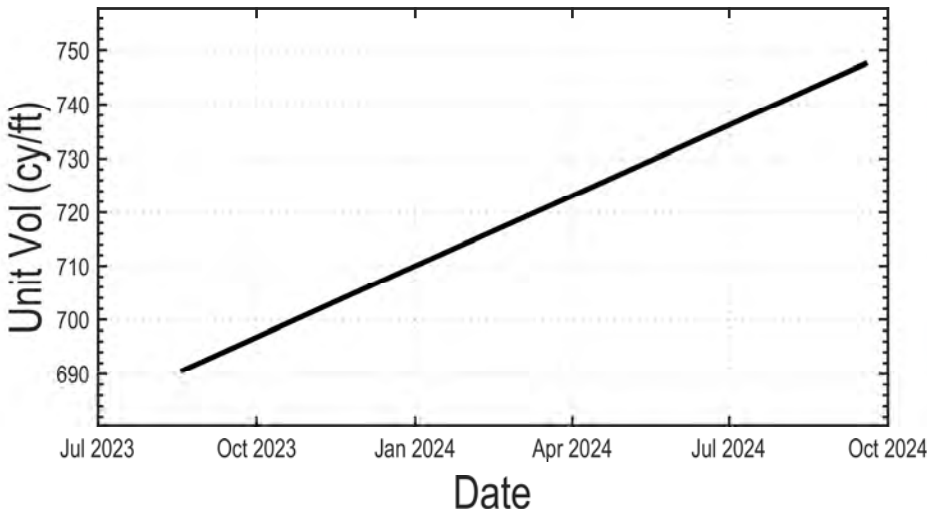
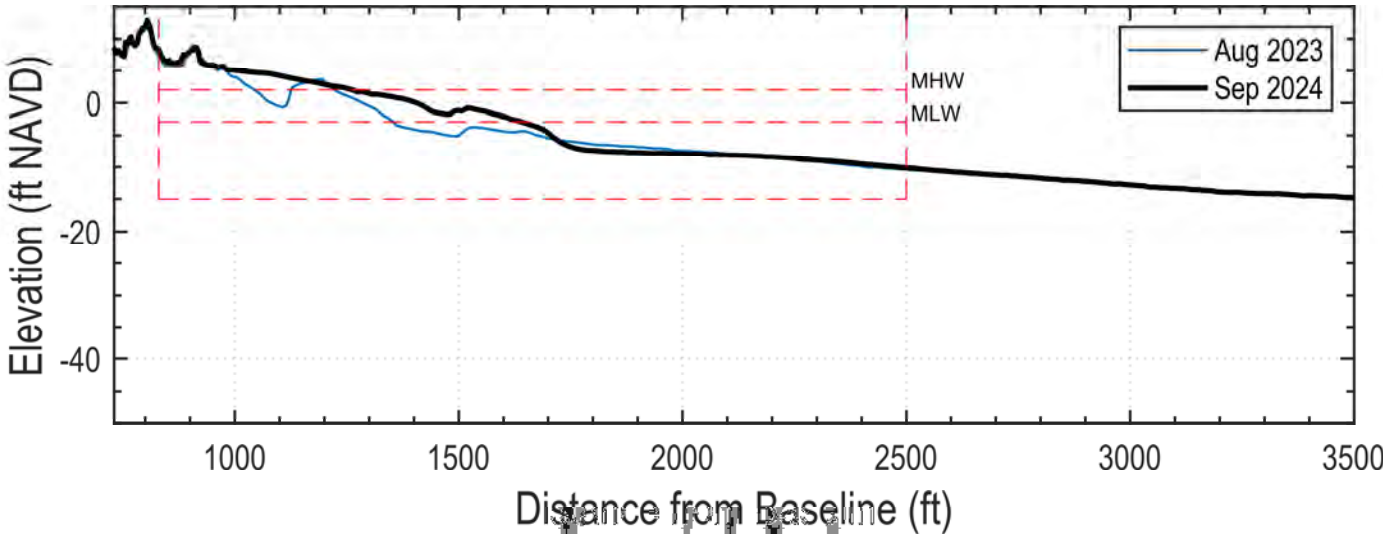
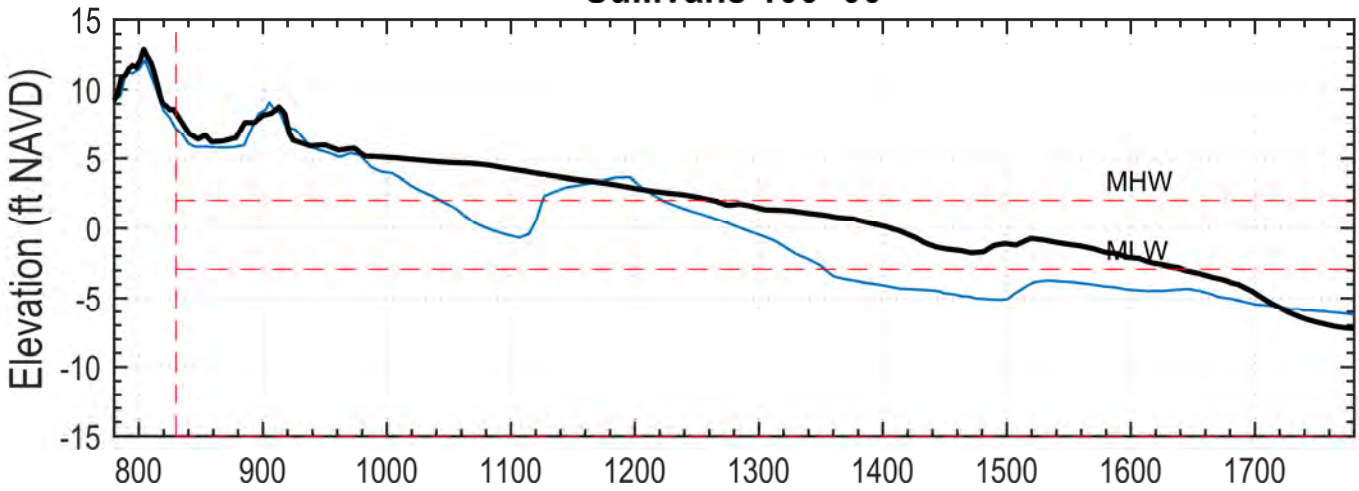
X: 2358497.46
Y: 339844.08

Sullivans 95+00



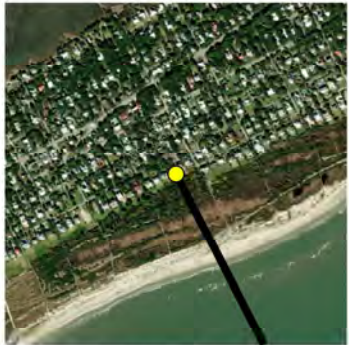
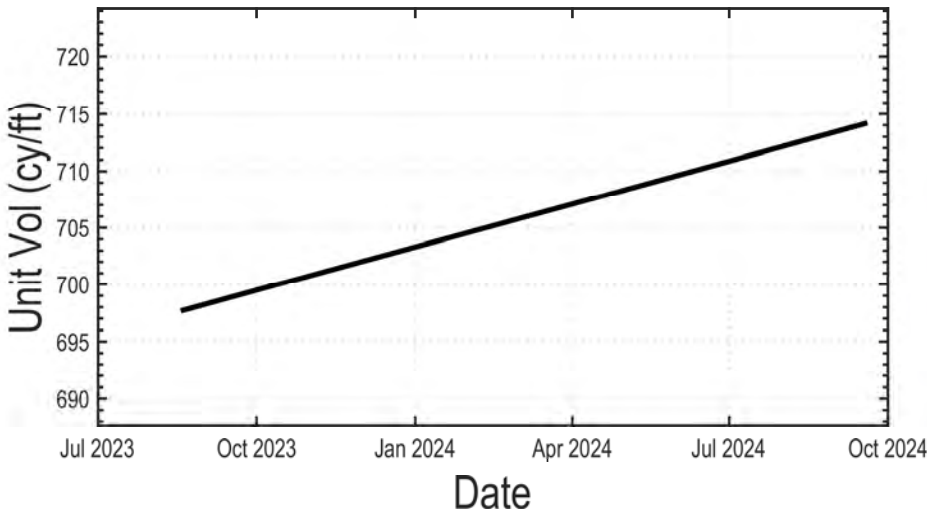
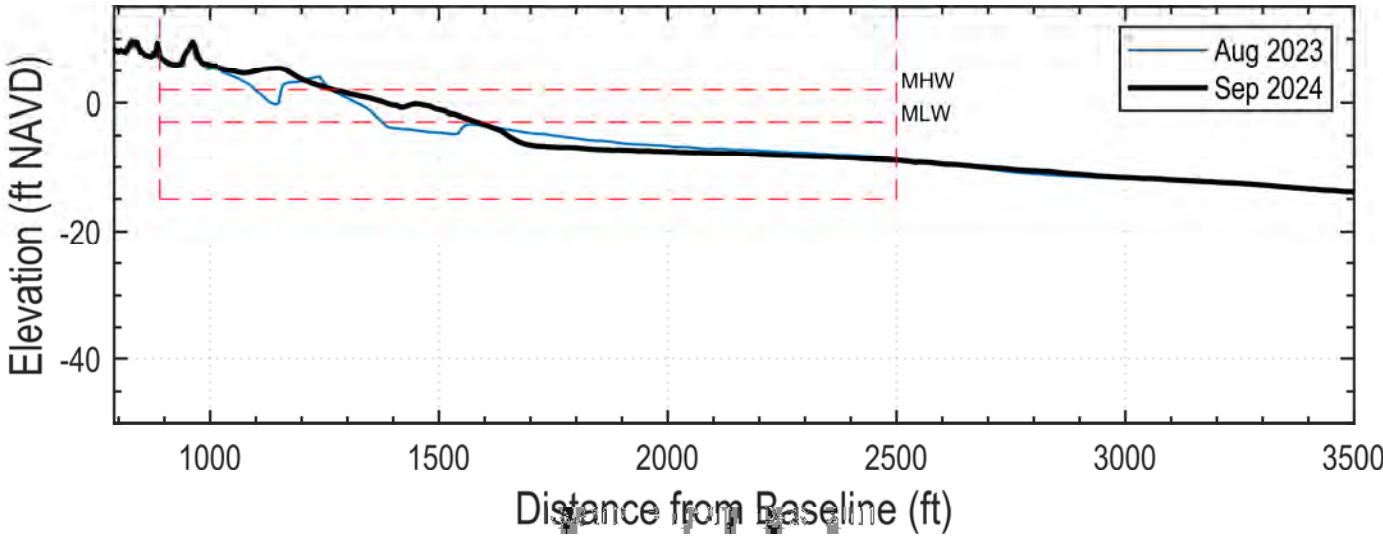
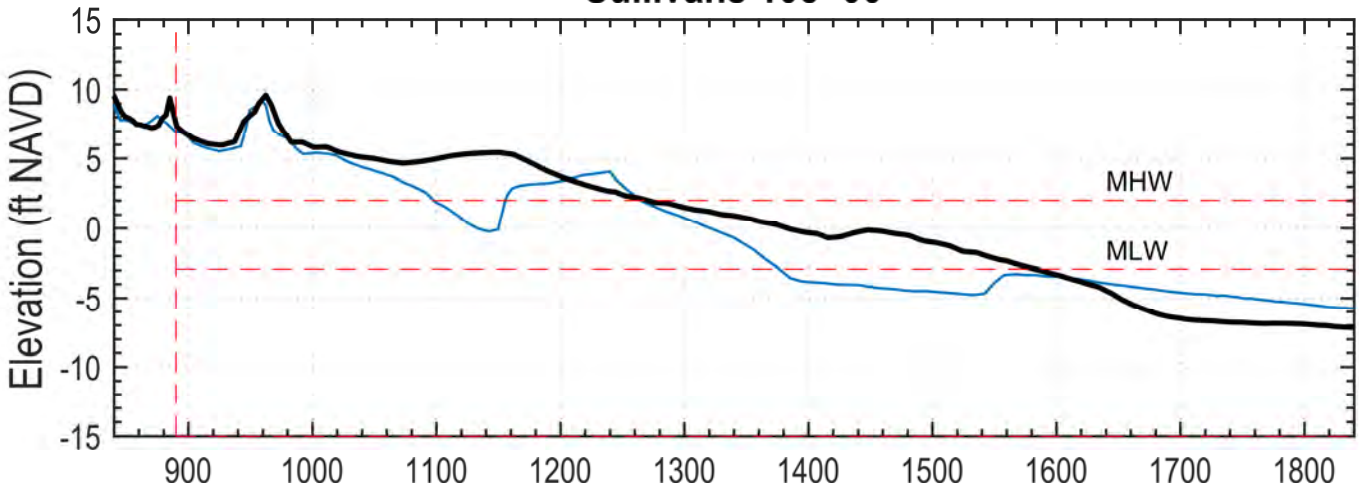
X: 2358941.72
Y: 340073.49

Sullivans 100+00



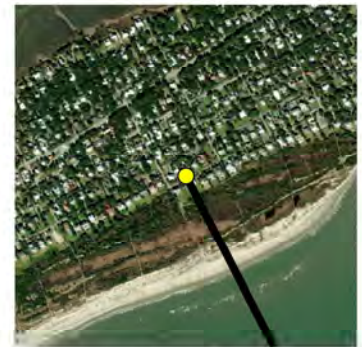
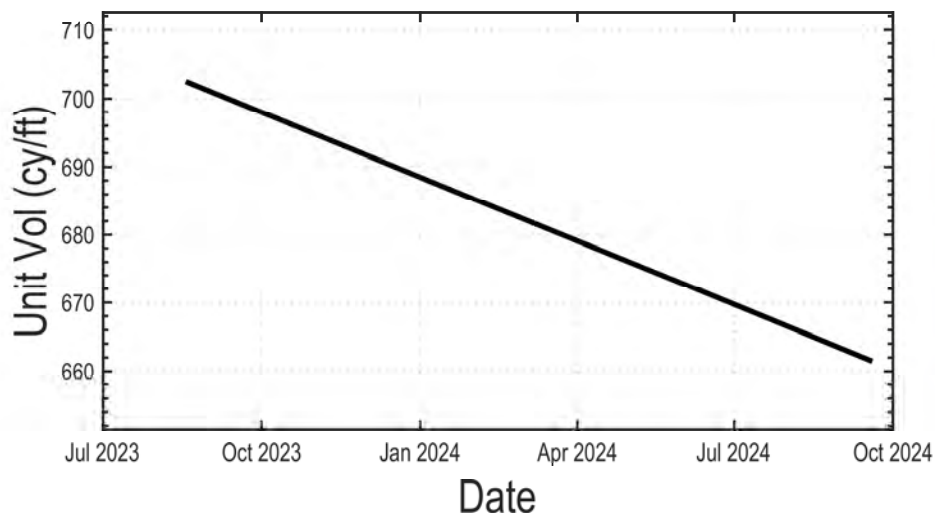
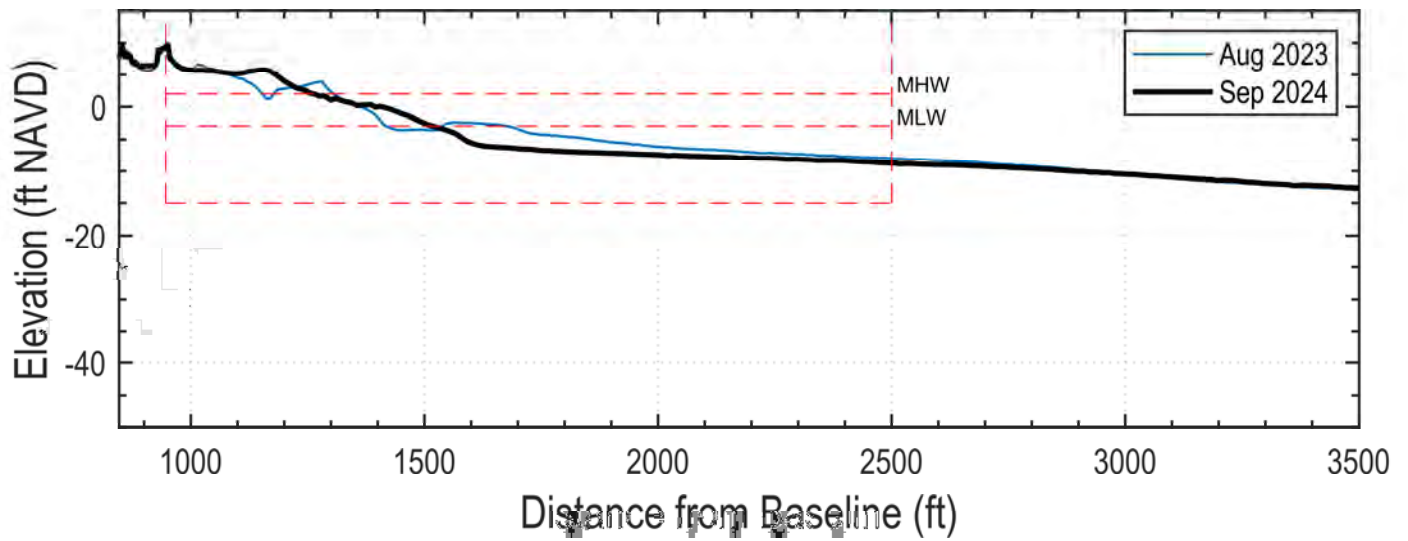
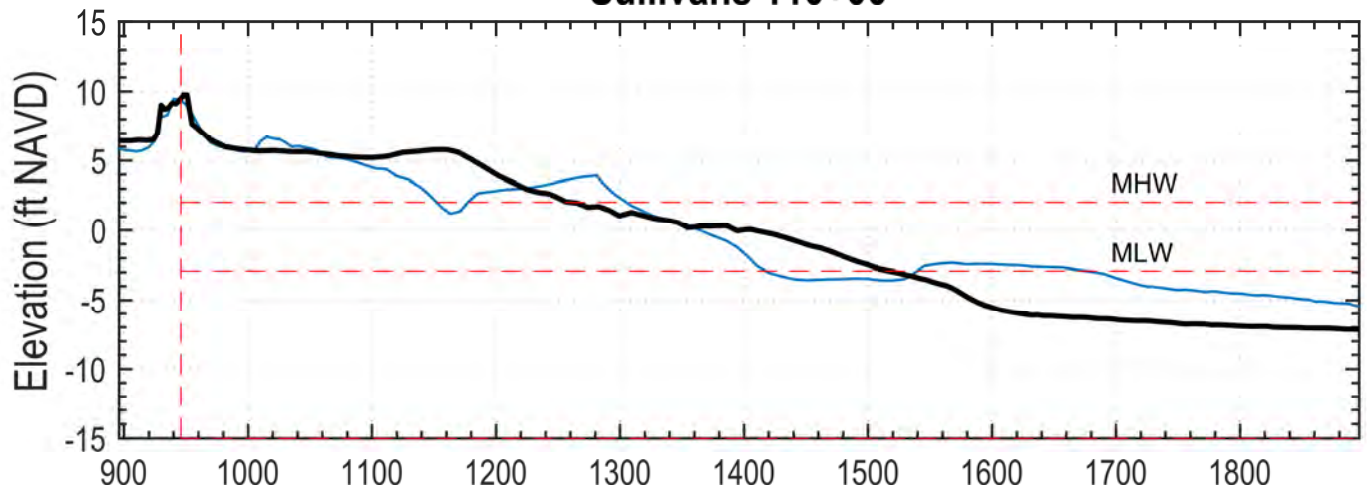
X: 2359385.98
Y: 340302.9

Sullivans 105+00



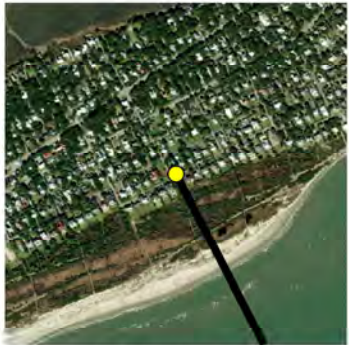
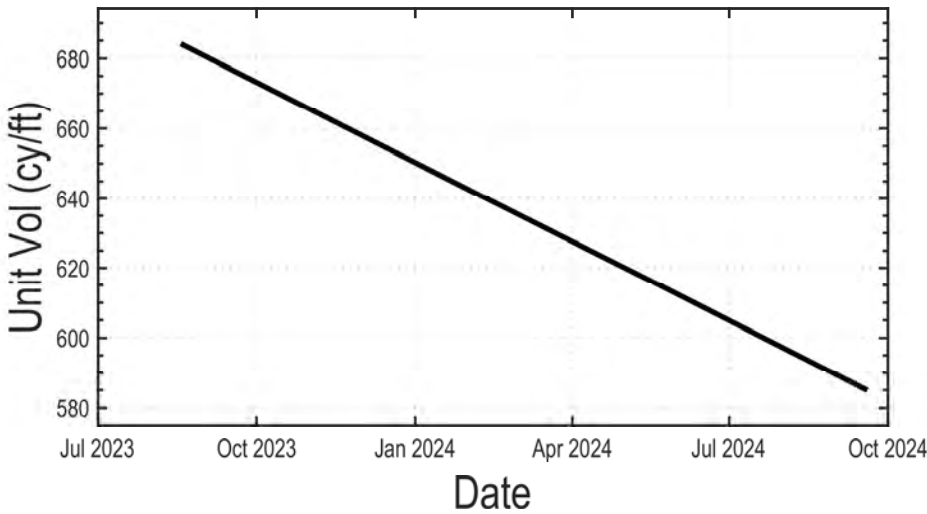
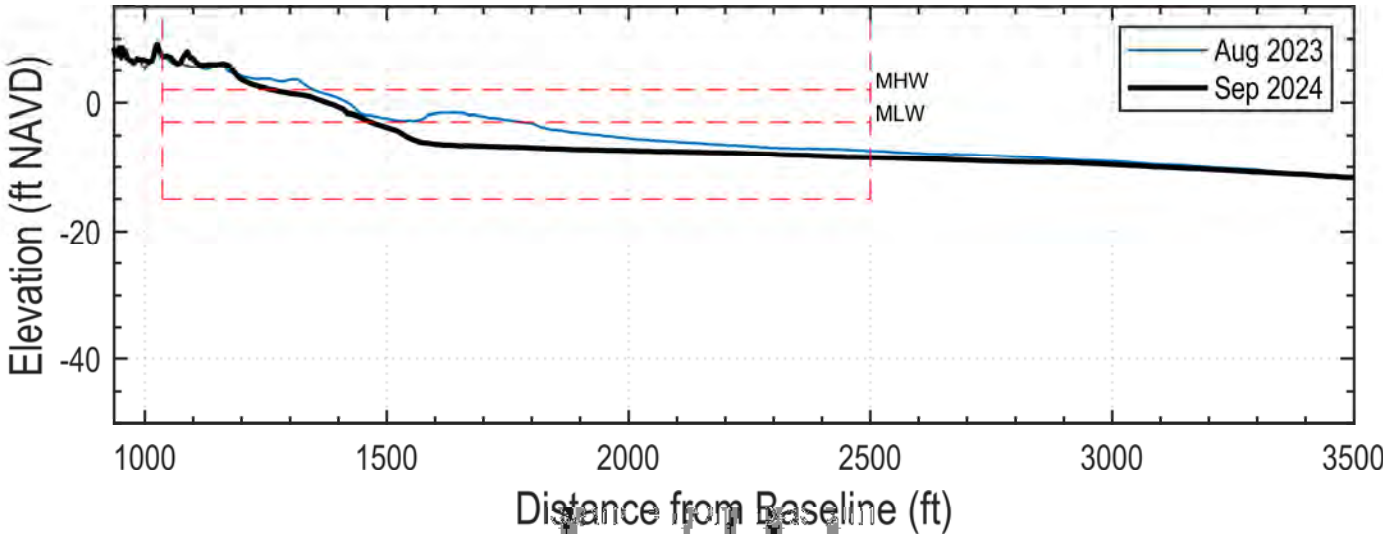
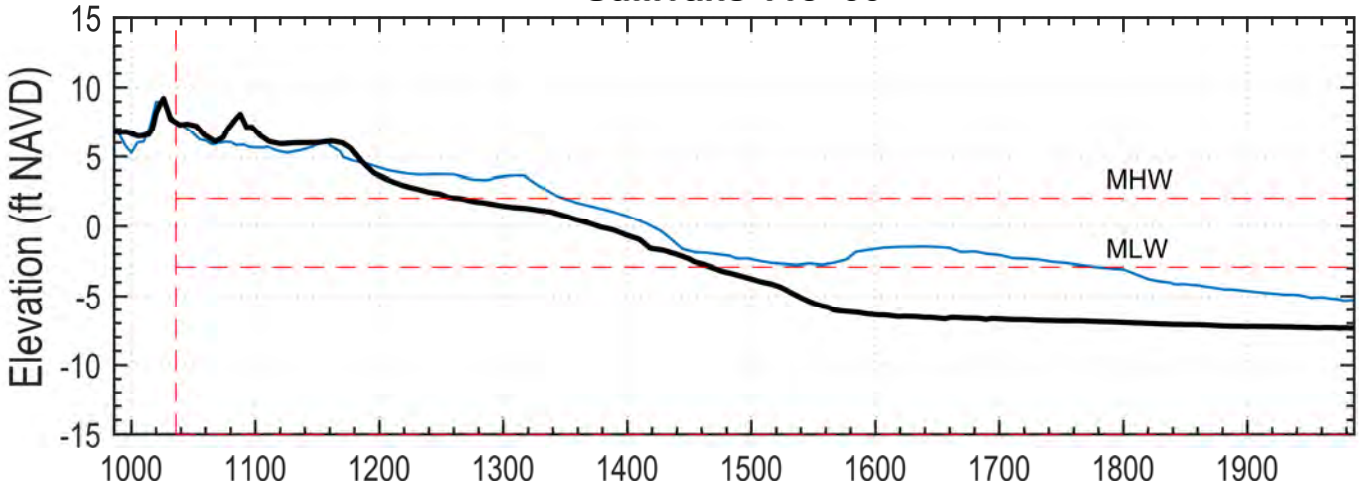
X: 2359830.25
Y: 340532.32

Sullivans 110+00



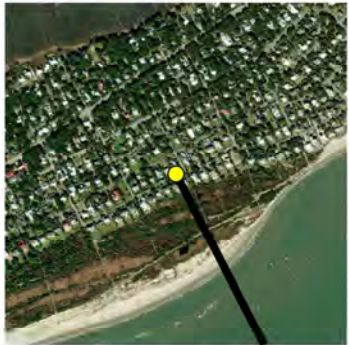
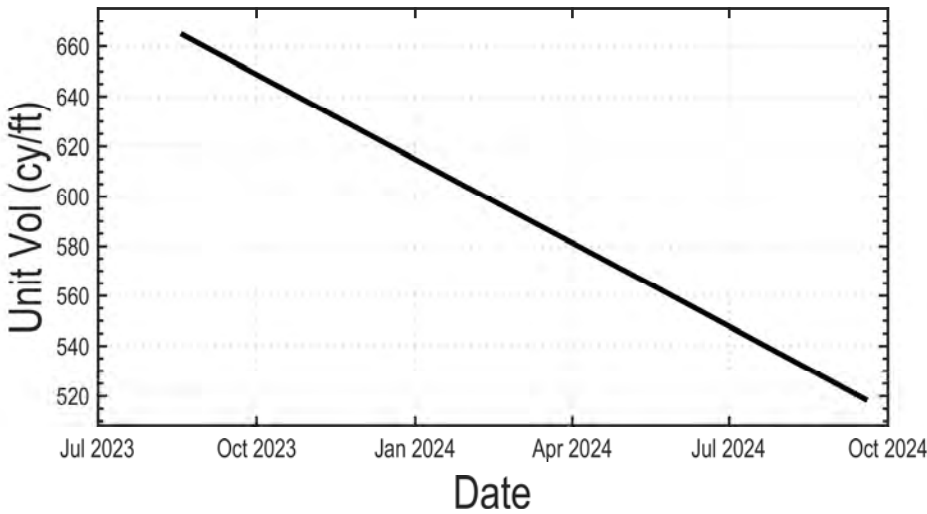
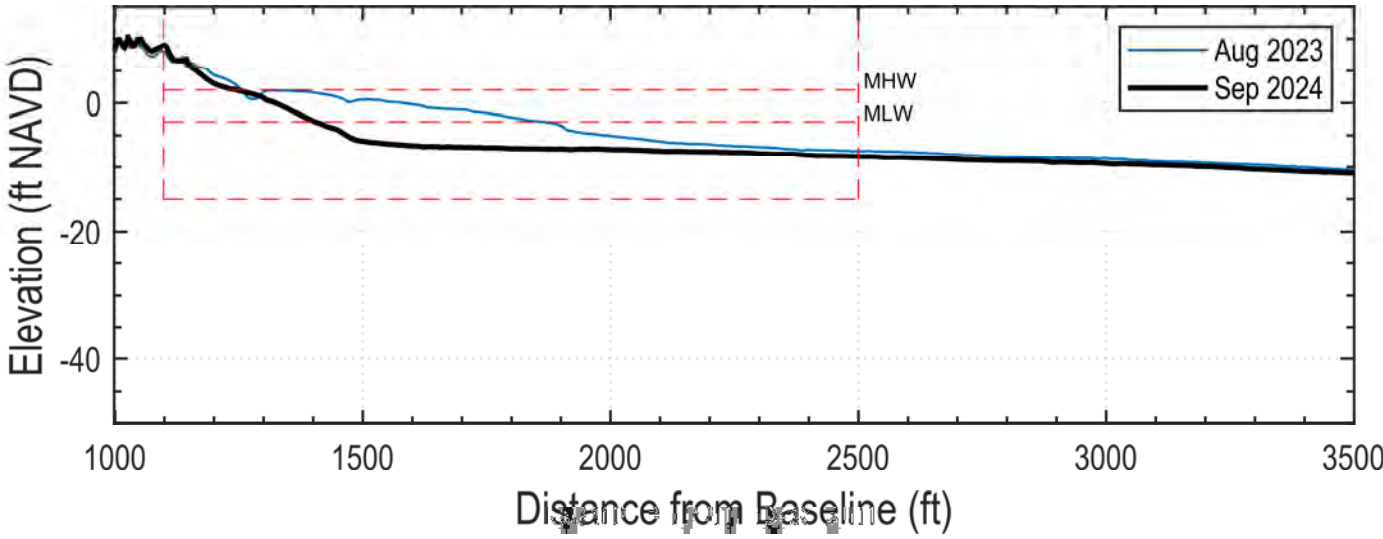
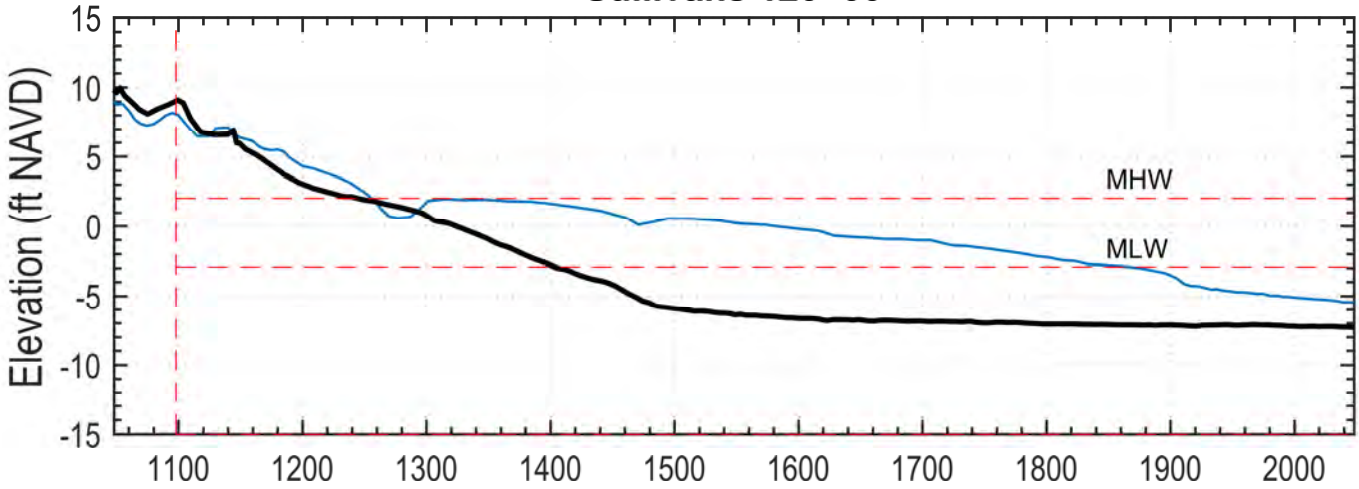
X: 2360274.51
Y: 340761.73

Sullivans 115+00



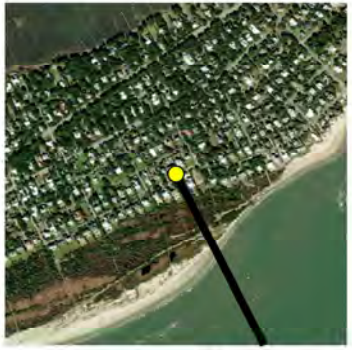
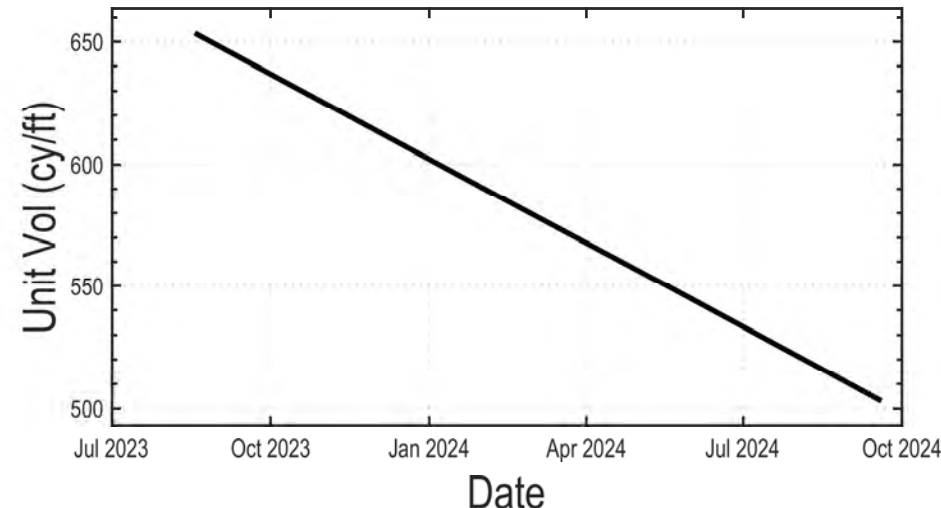
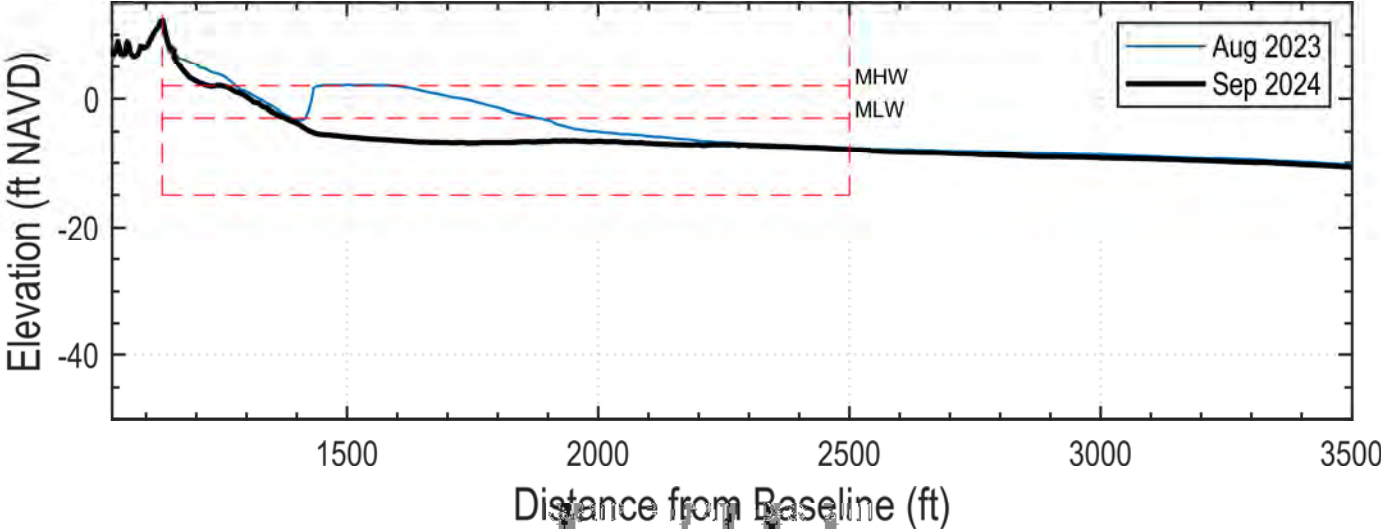
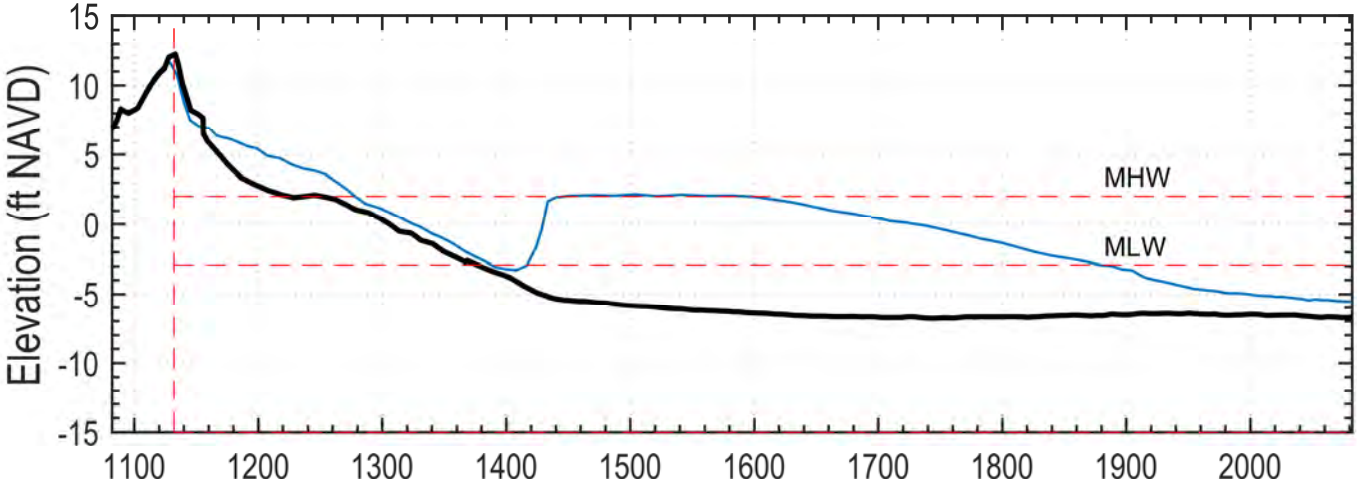
X: 2360718.77
Y: 340991.14

Sullivans 120+00



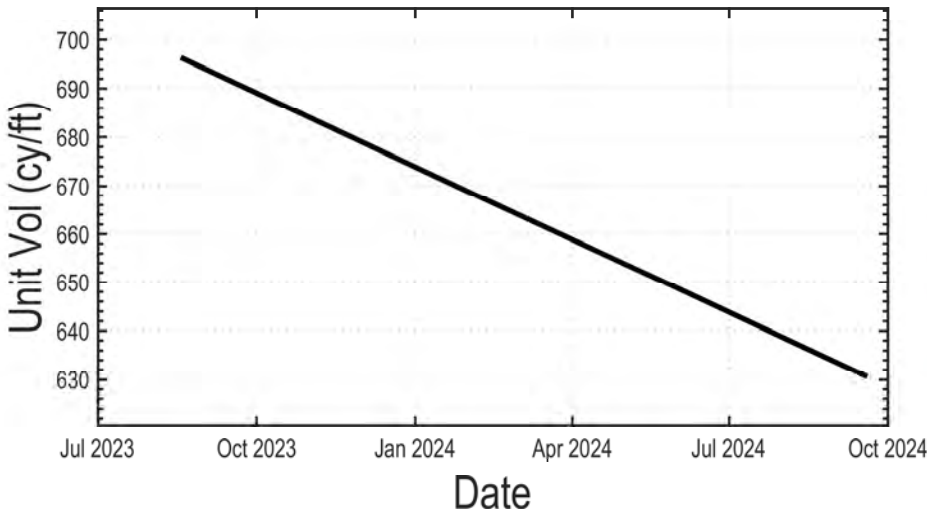
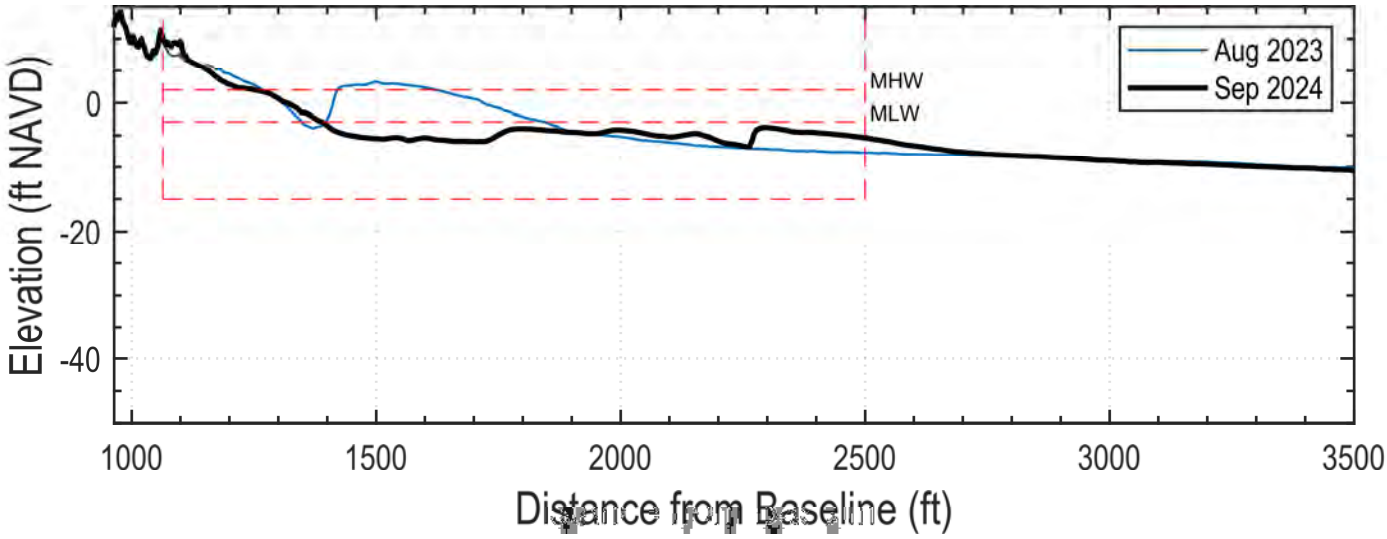
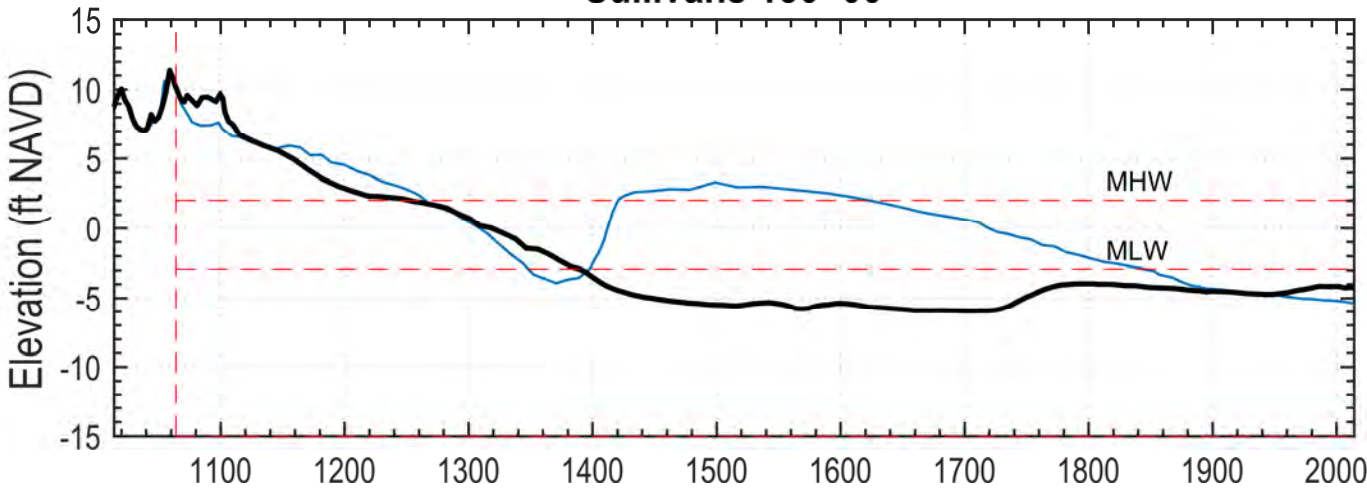
X: 2361163.04
Y: 341220.56

Sullivans 125+00

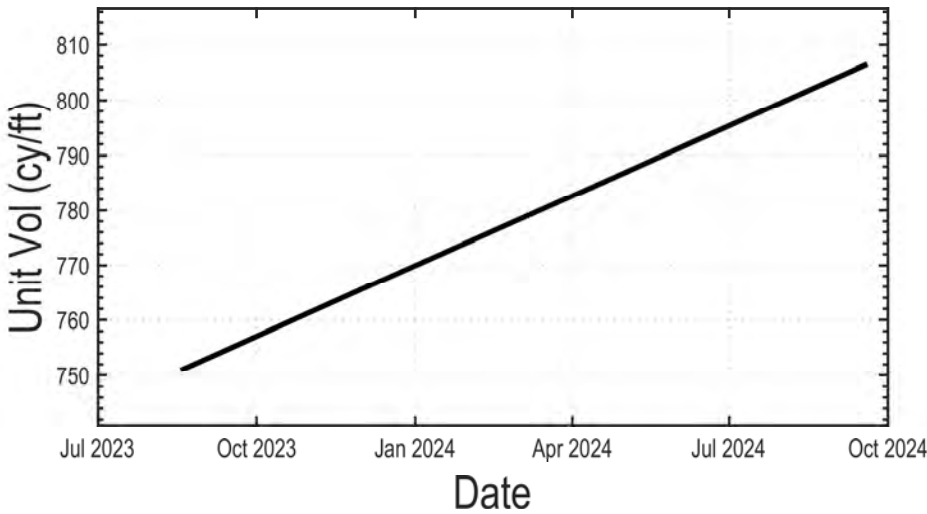
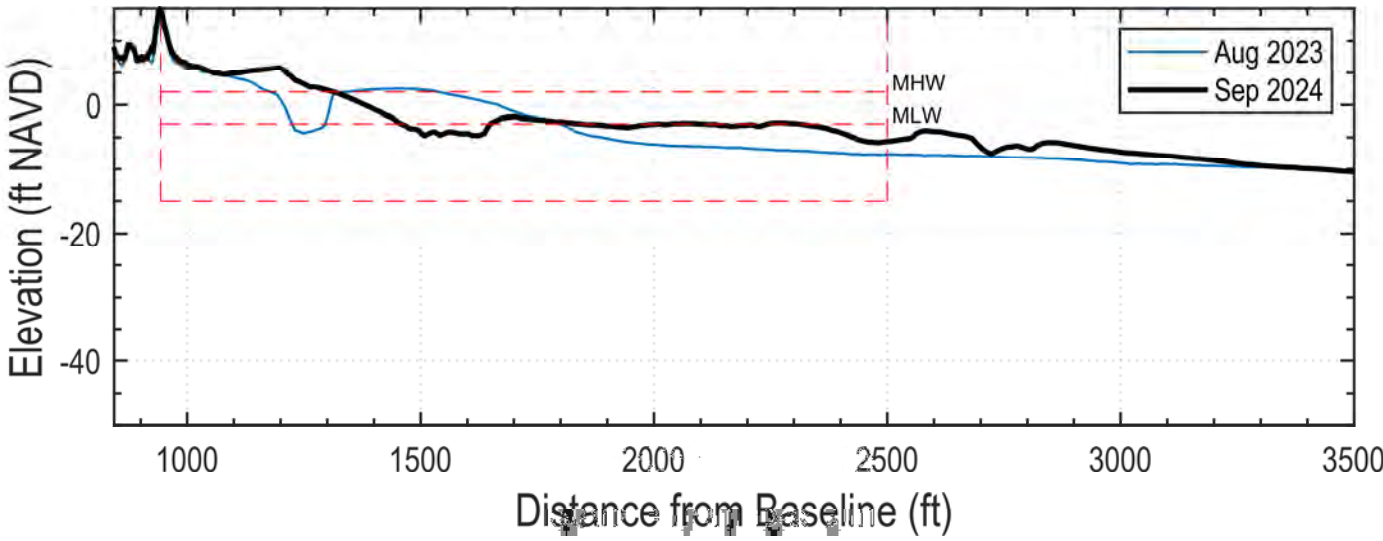
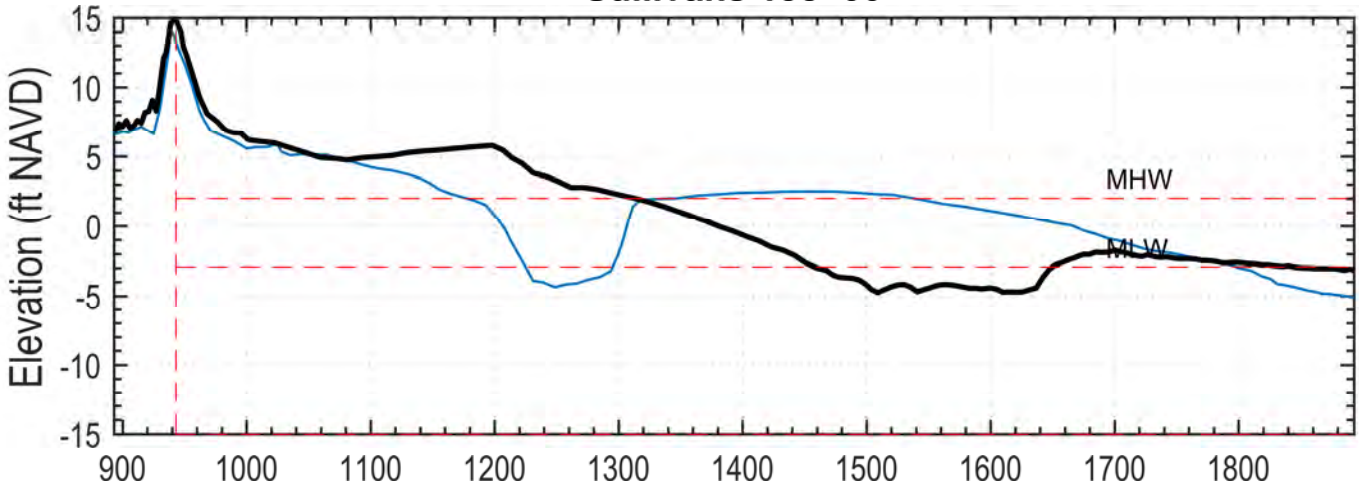


X: 2361607.3
Y: 341449.97

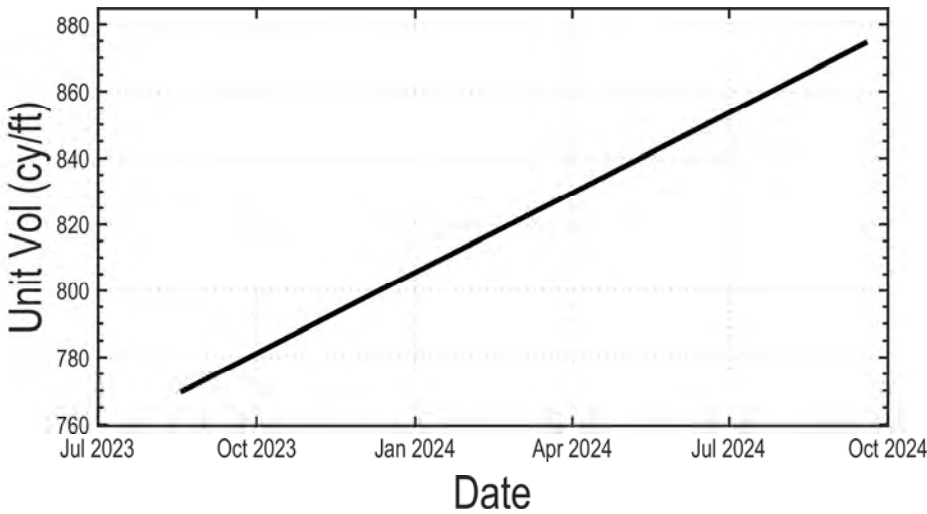
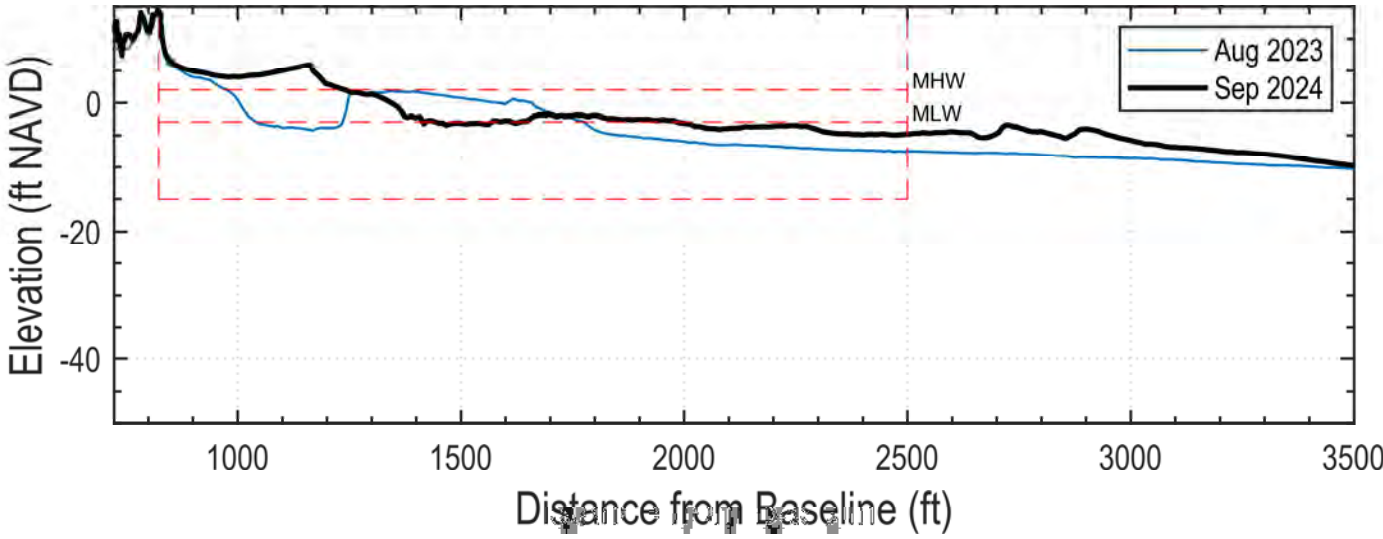
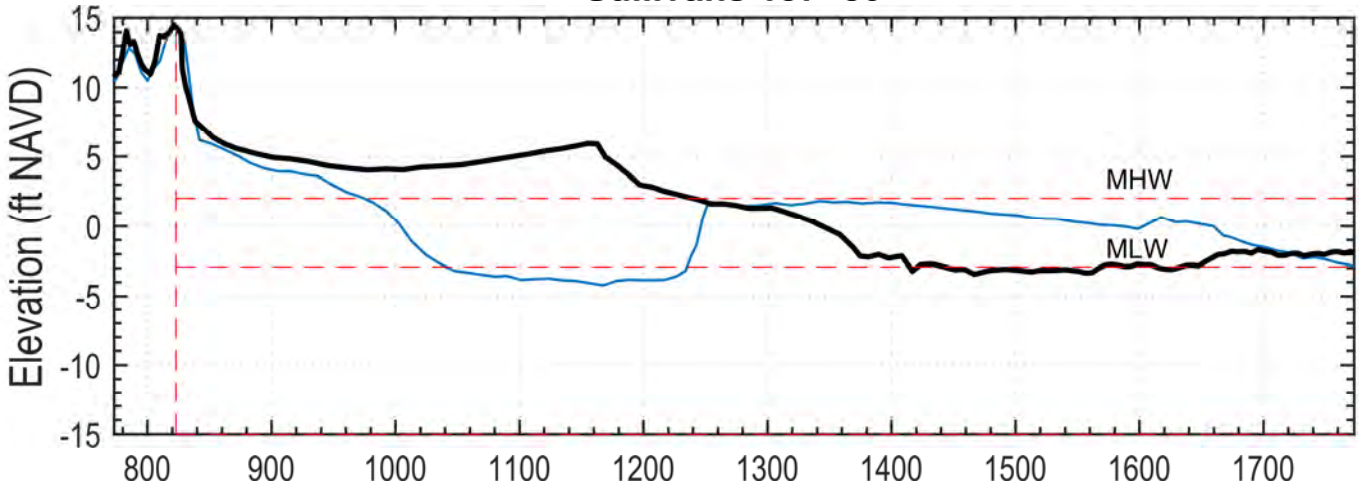
Sullivans 130+00



Sullivans 135+00

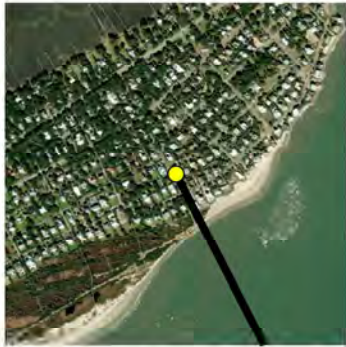
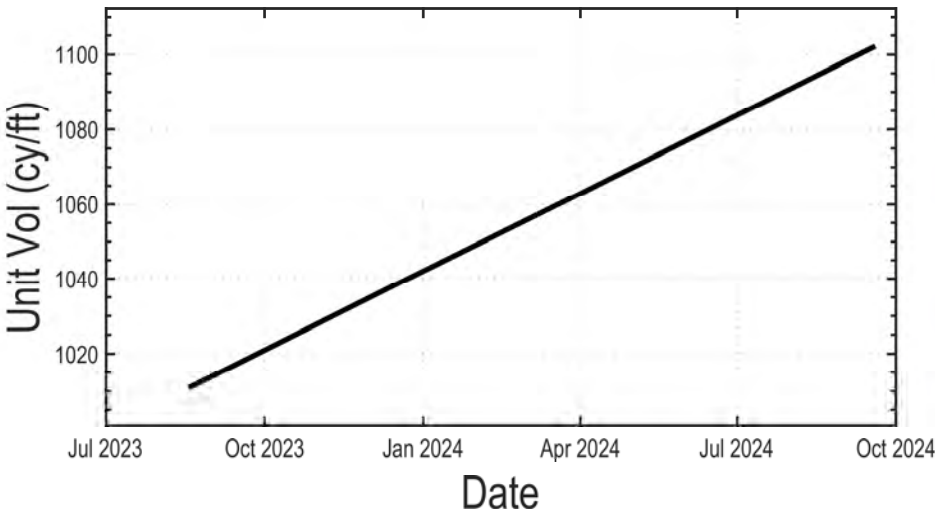
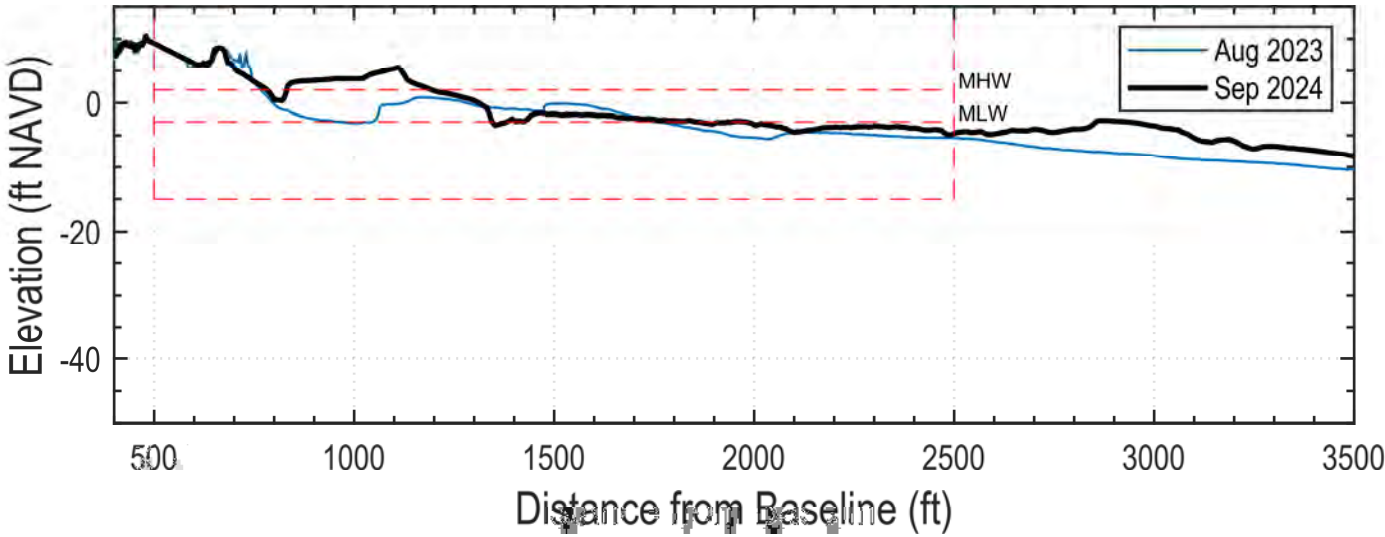
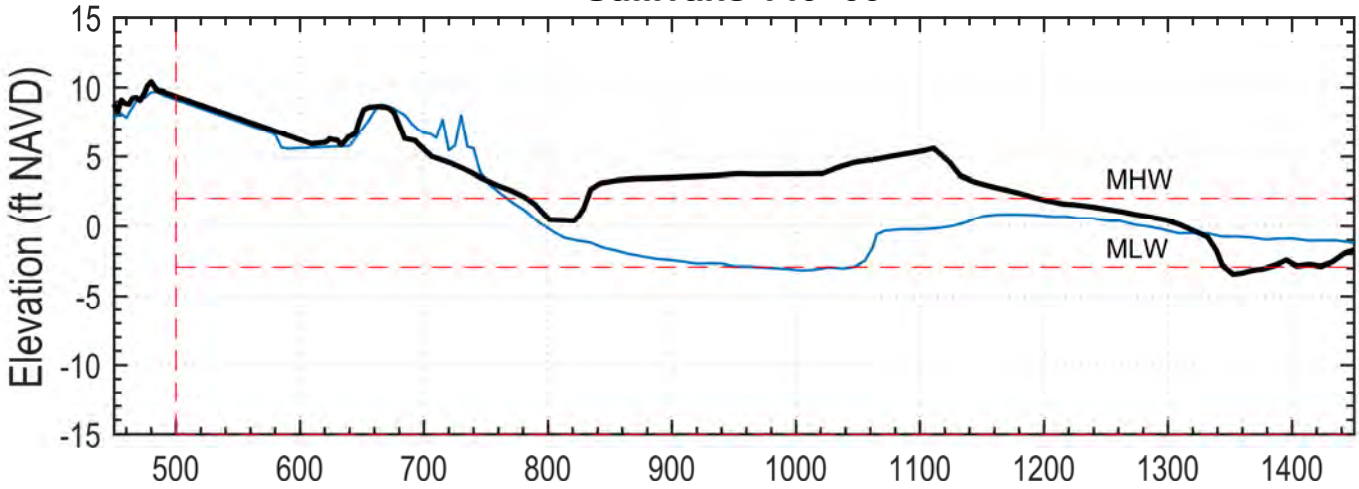


Sullivans 137+50



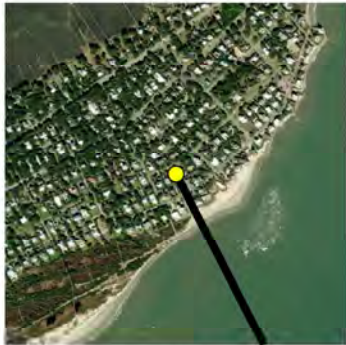
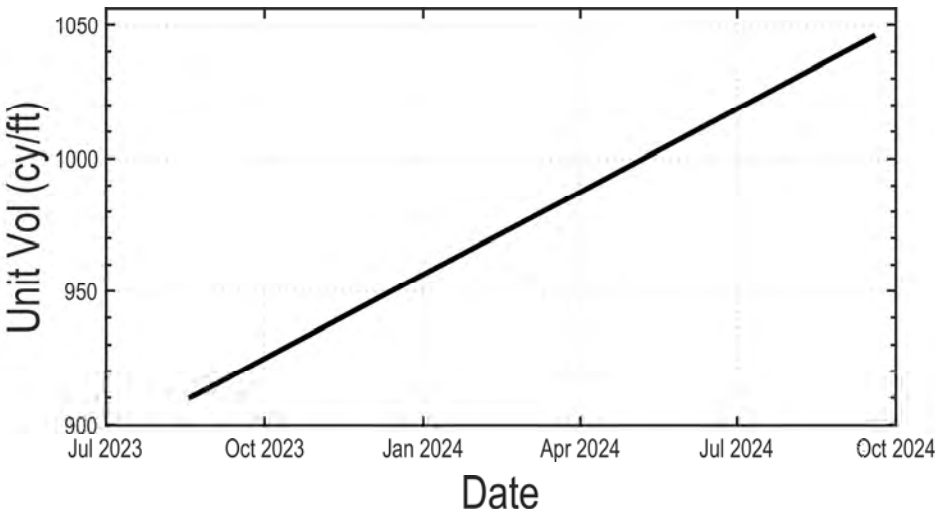
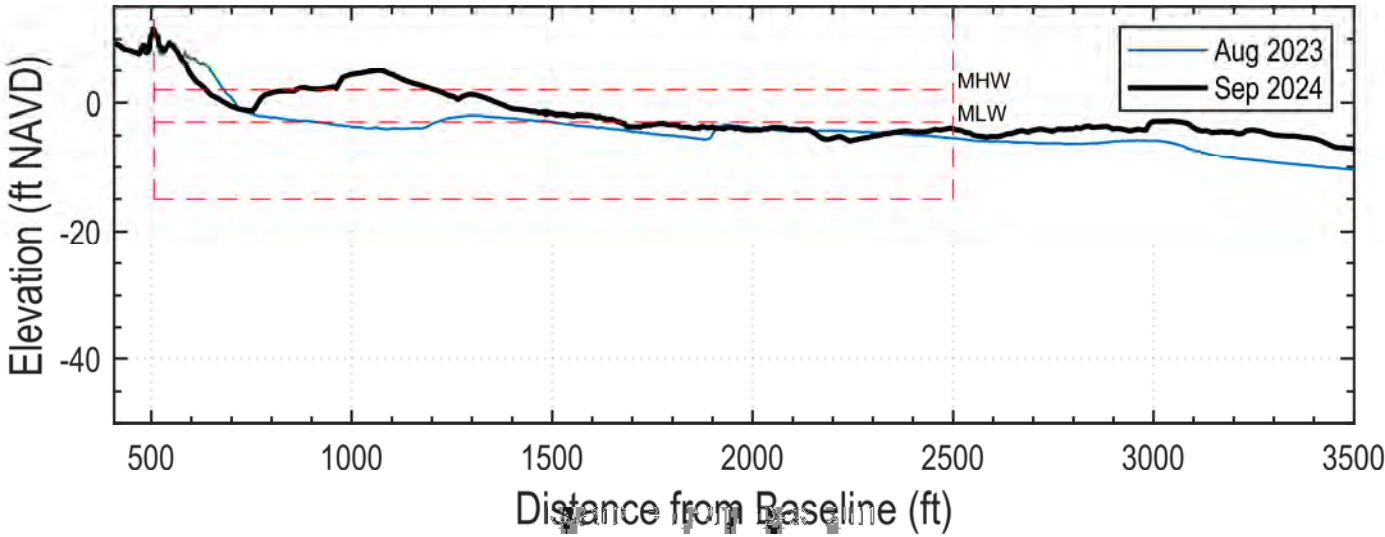
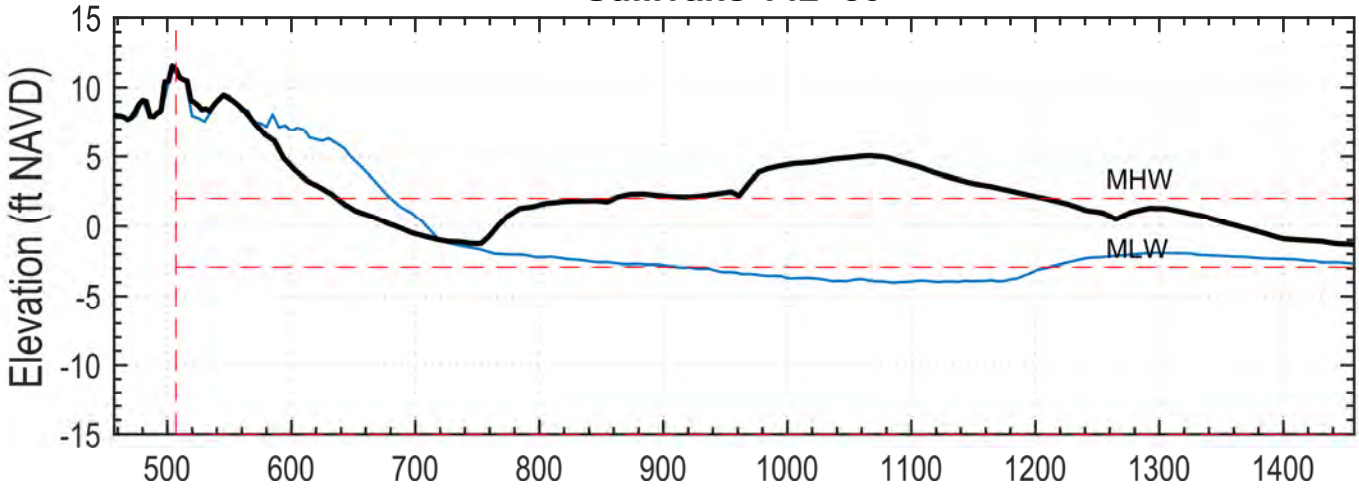
X: 2362273.69
Y: 341794.09

Sullivans 140+00



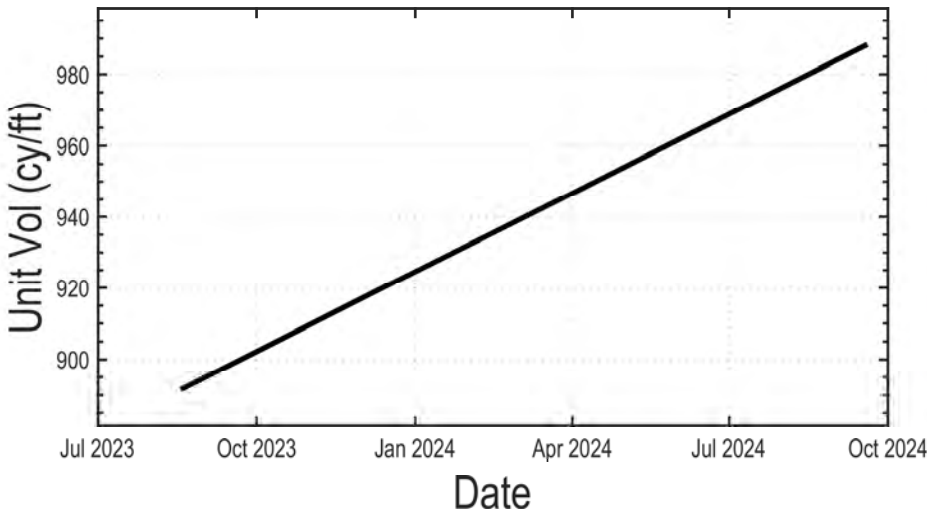
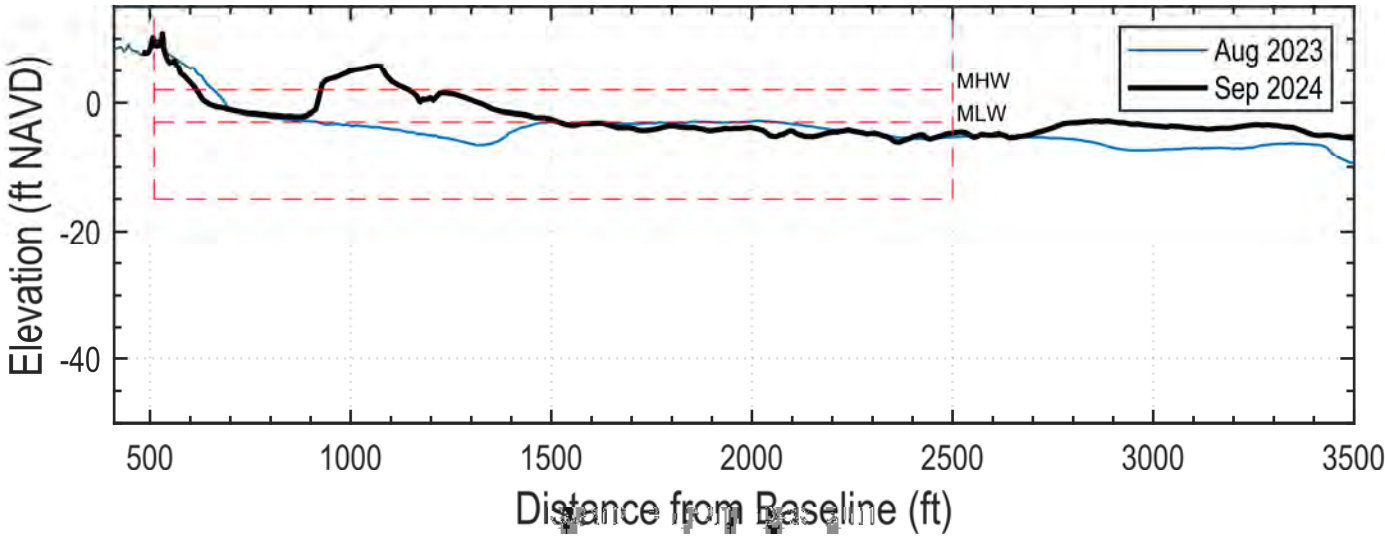
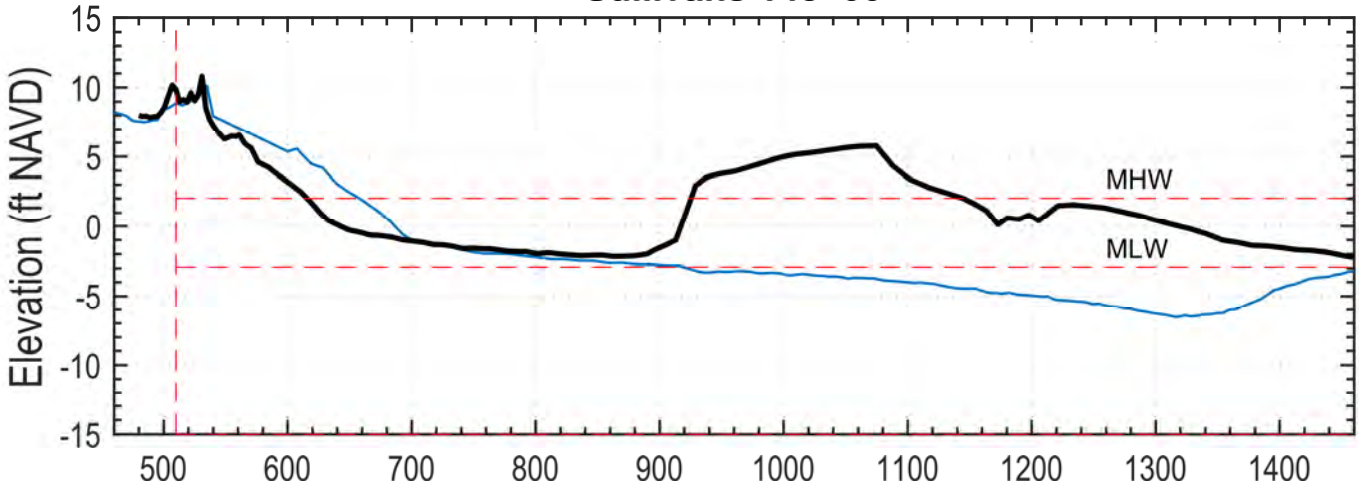
X: 2362495.83
Y: 341908.79

Sullivans 142+50

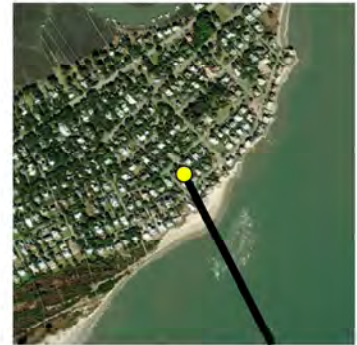
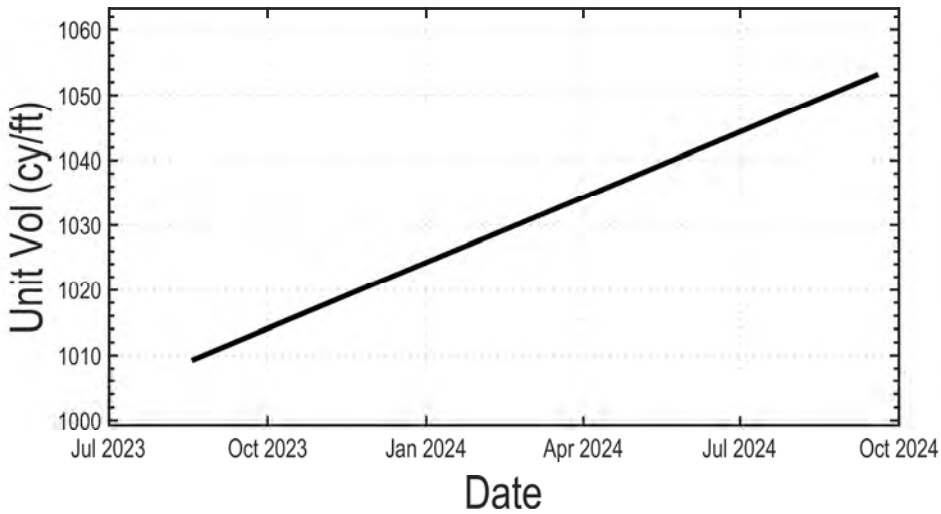
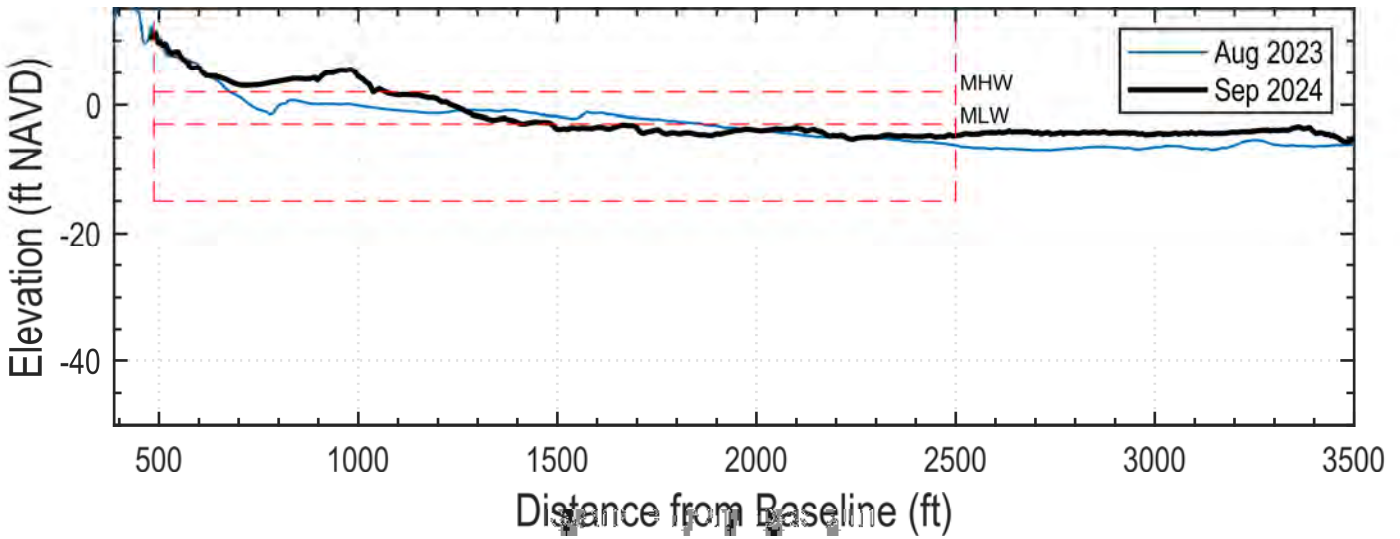
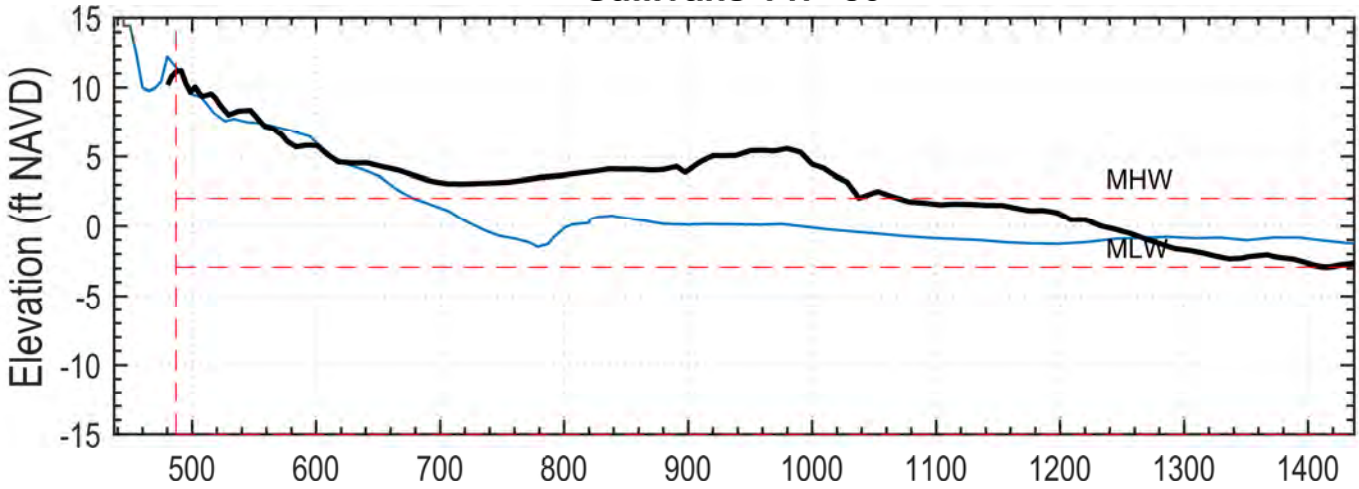


X: 2362717.96
Y: 342023.5

Sullivans 145+00

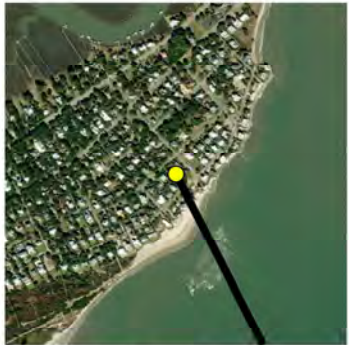
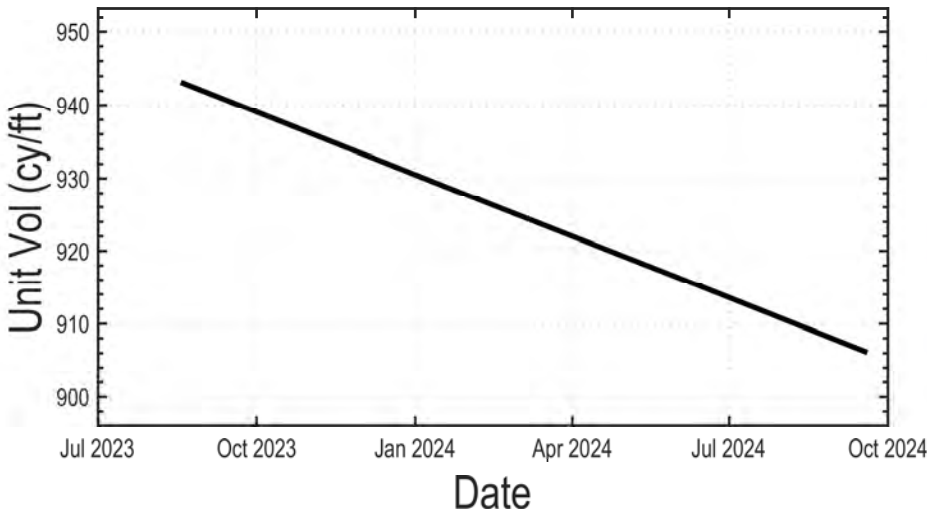
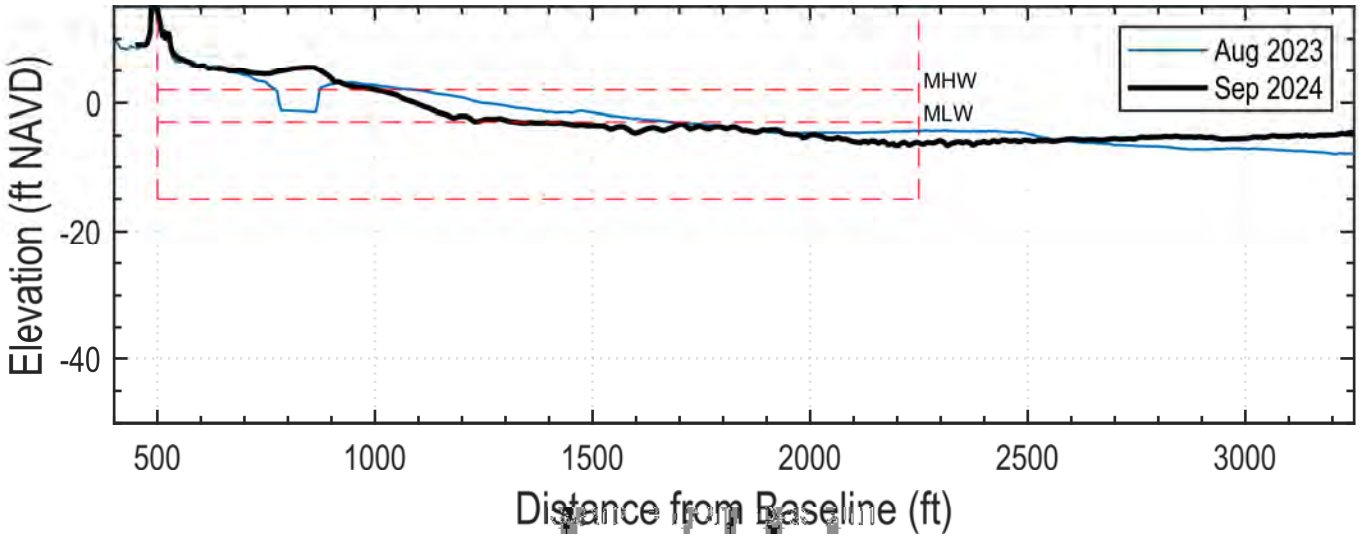
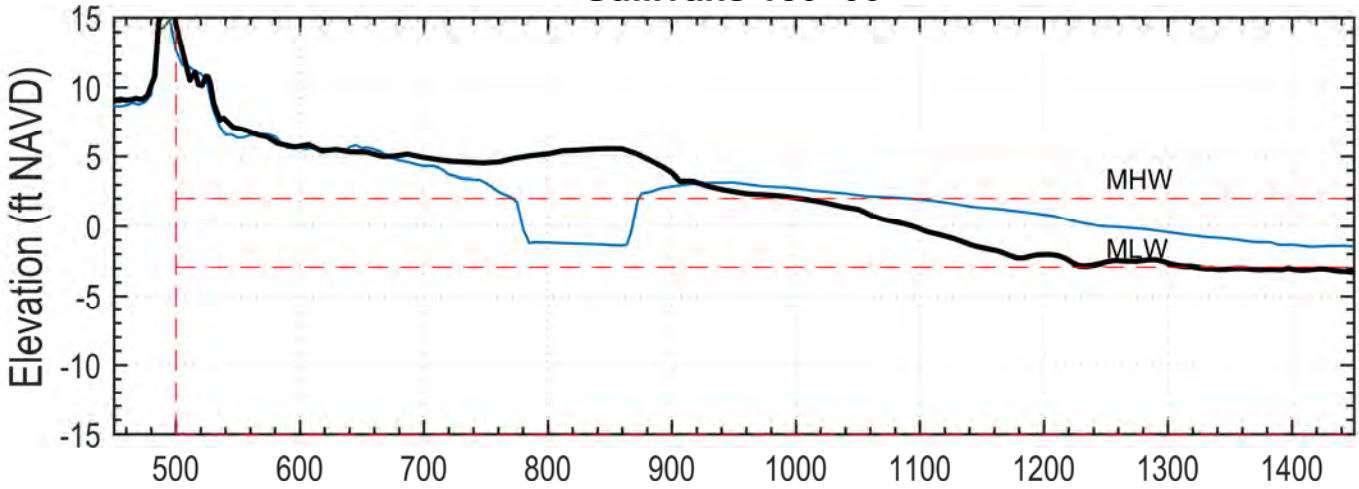


Sullivans 147+50



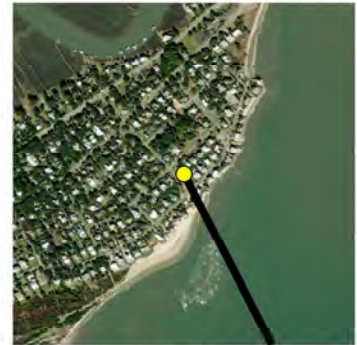
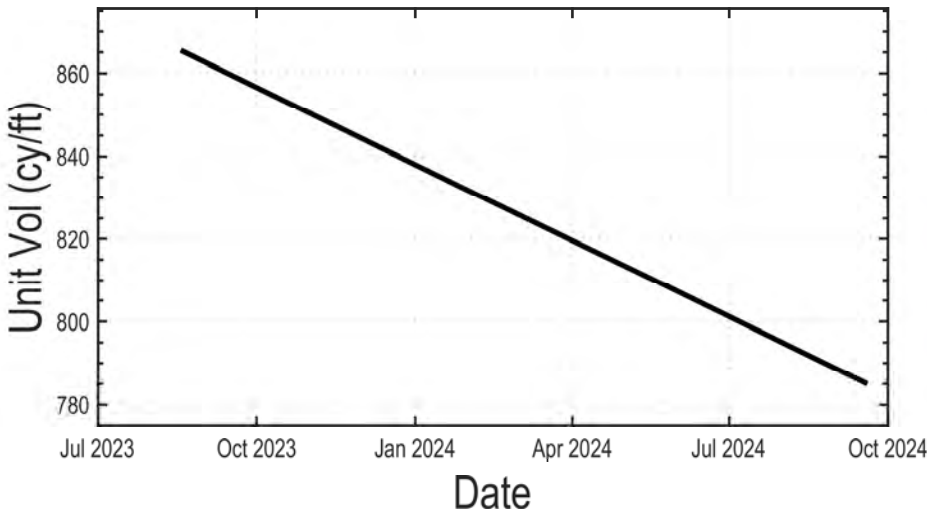
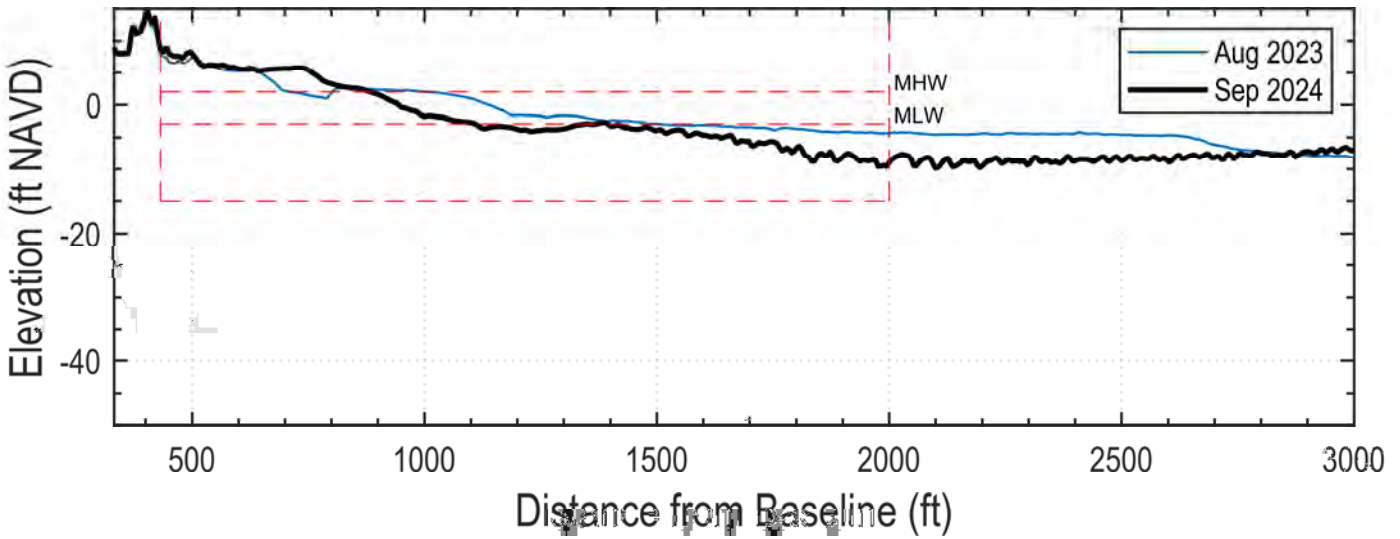
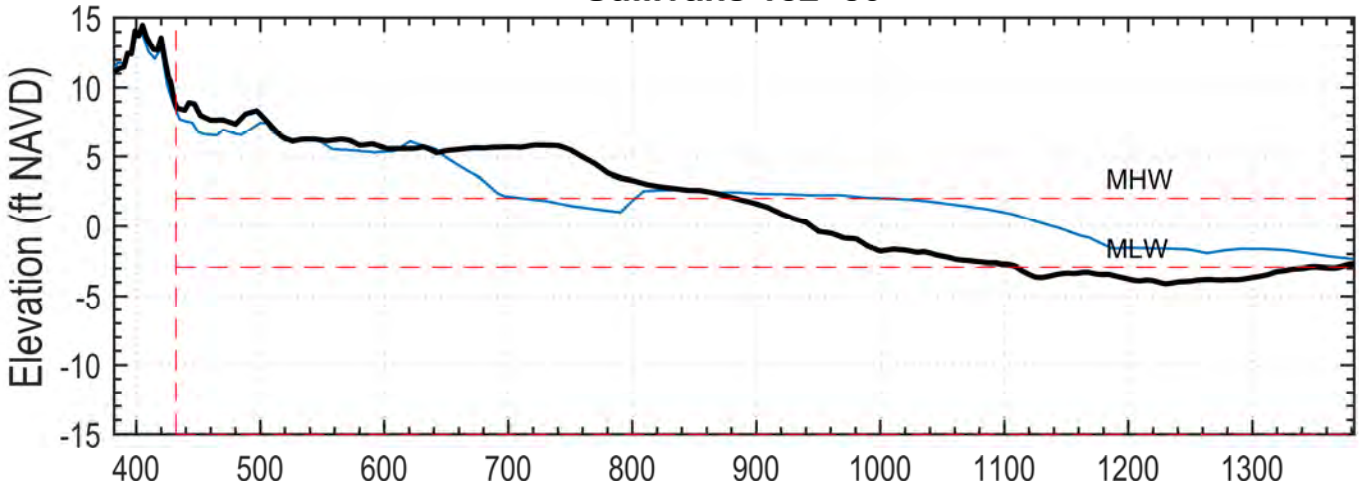
X: 2363149.25
Y: 342274.97

Sullivans 150+00



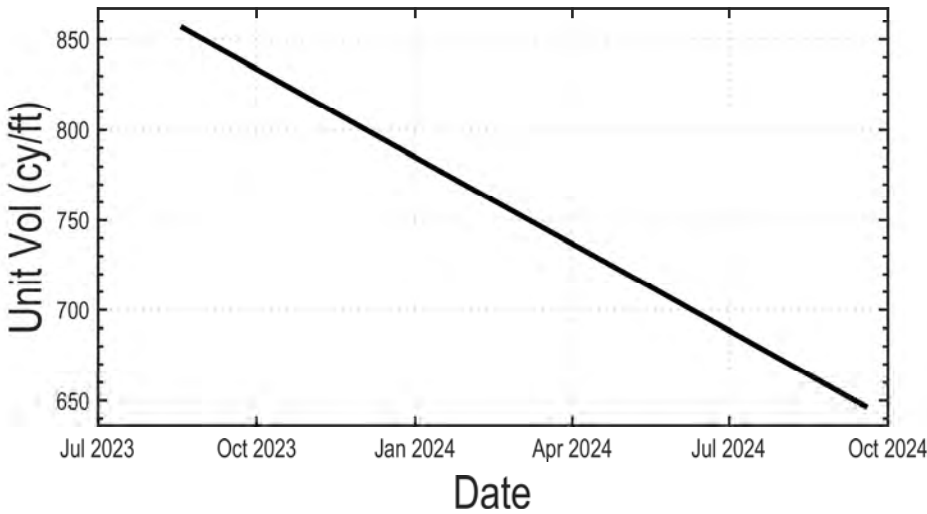
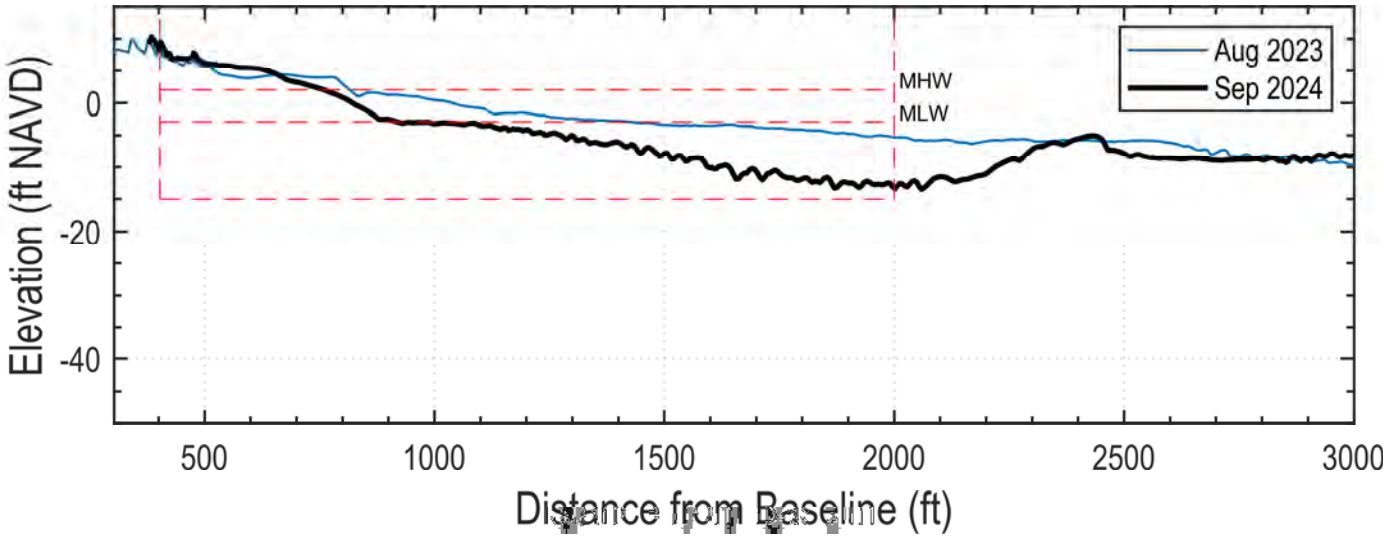
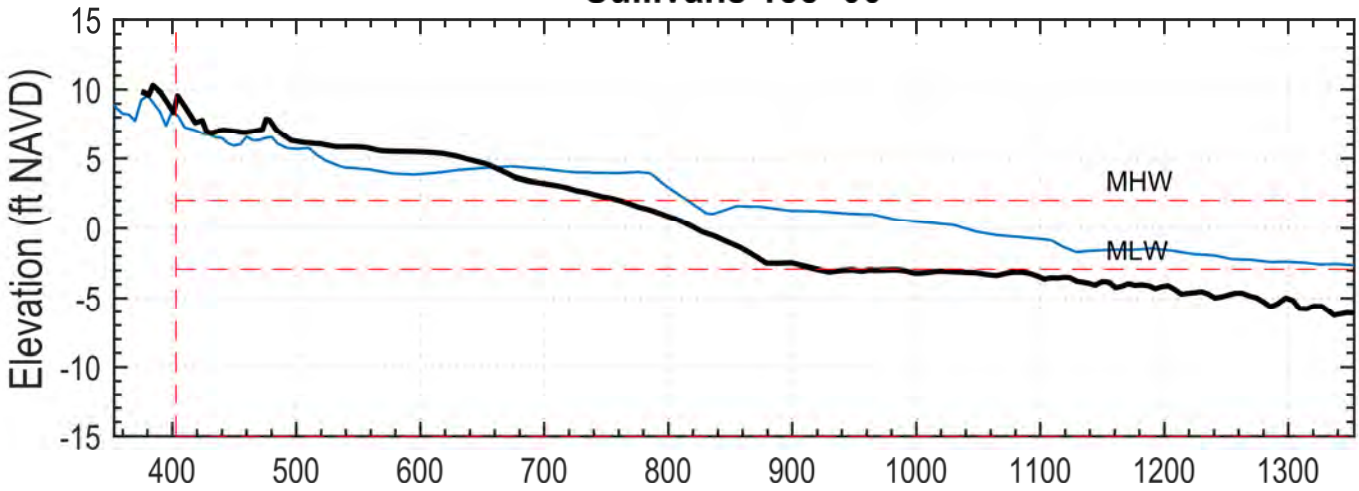
X: 2363349.07
Y: 342464.12

Sullivans 152+50

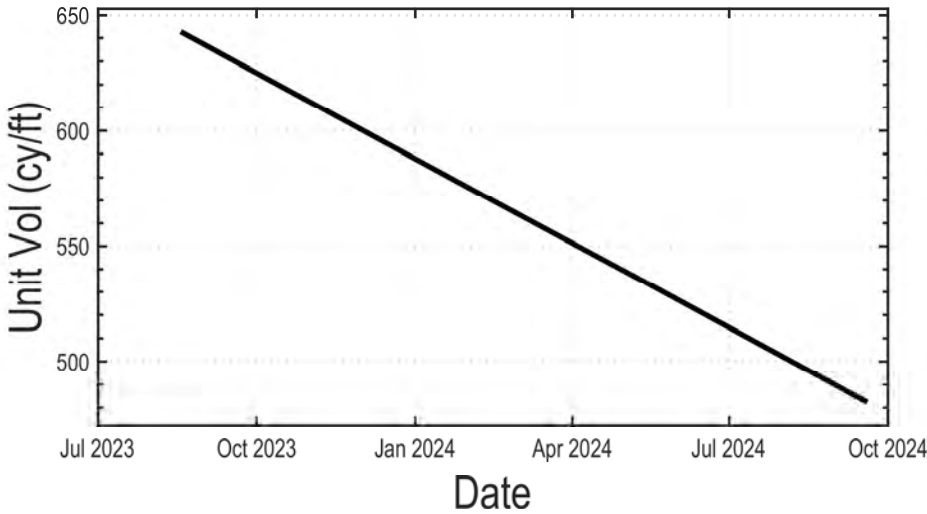
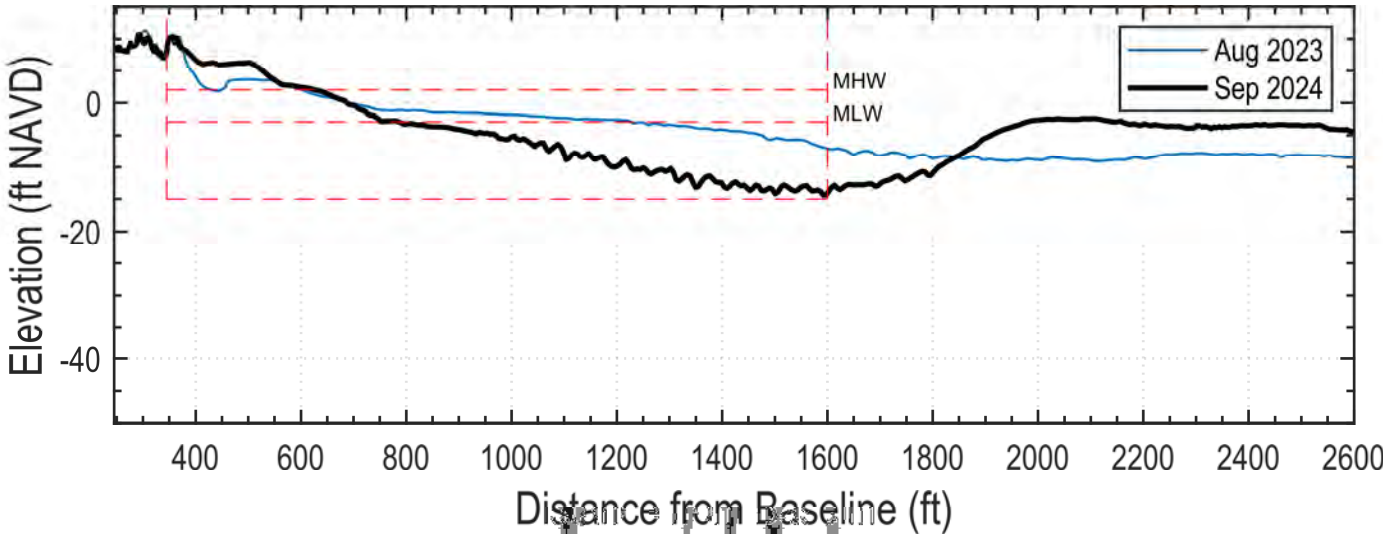
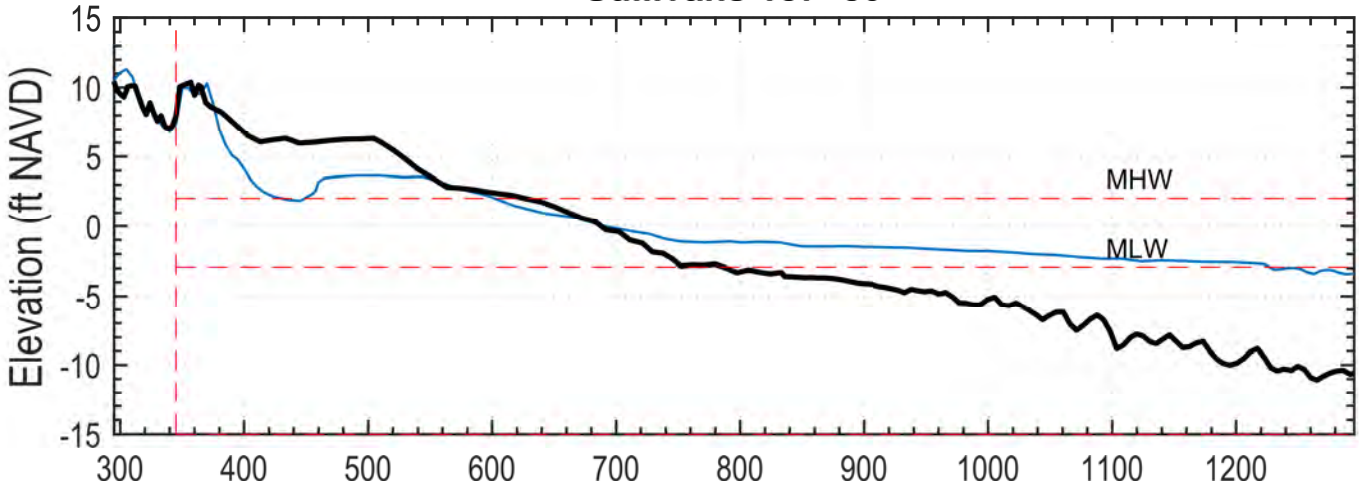


X: 2363528.86
Y: 342634.42

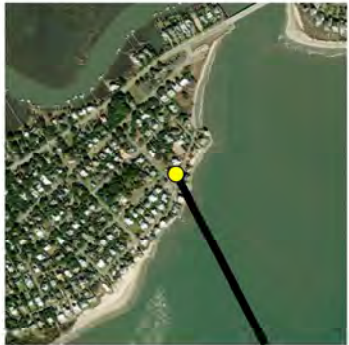
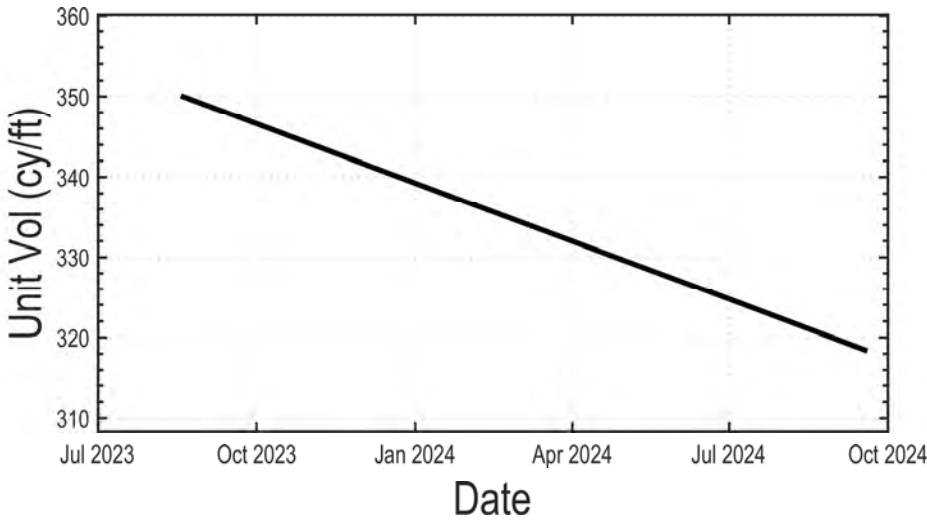
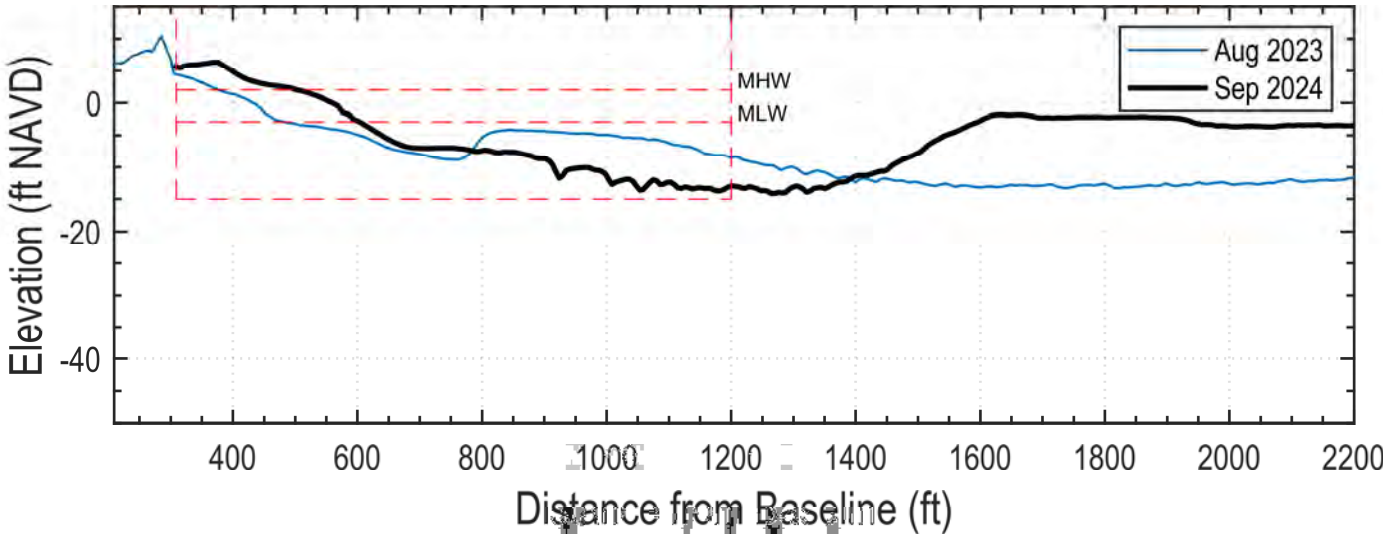
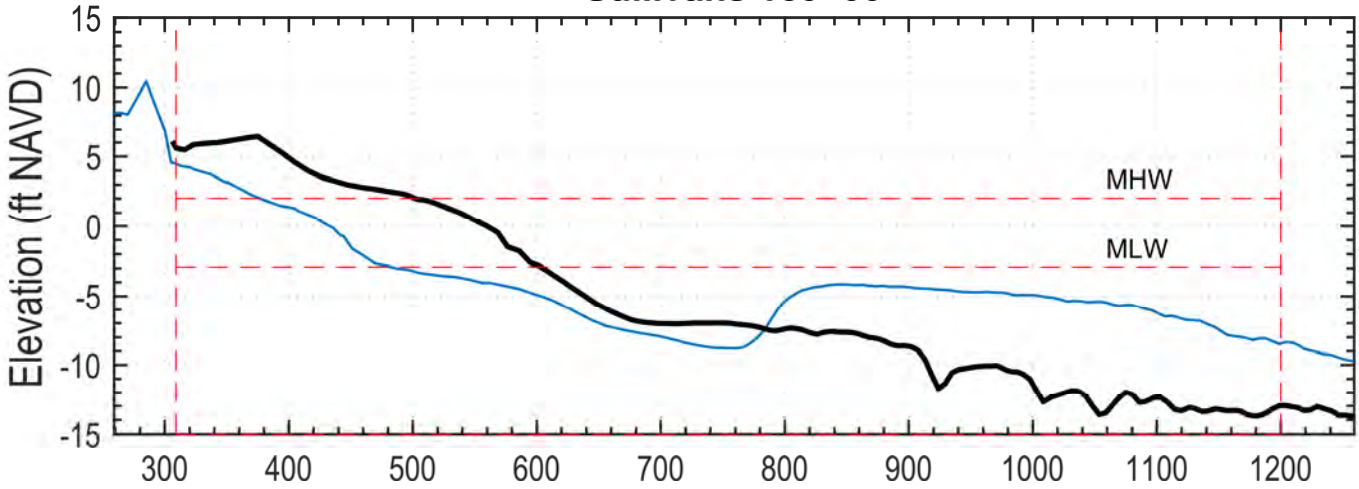
Sullivans 155+00



Sullivans 157+50

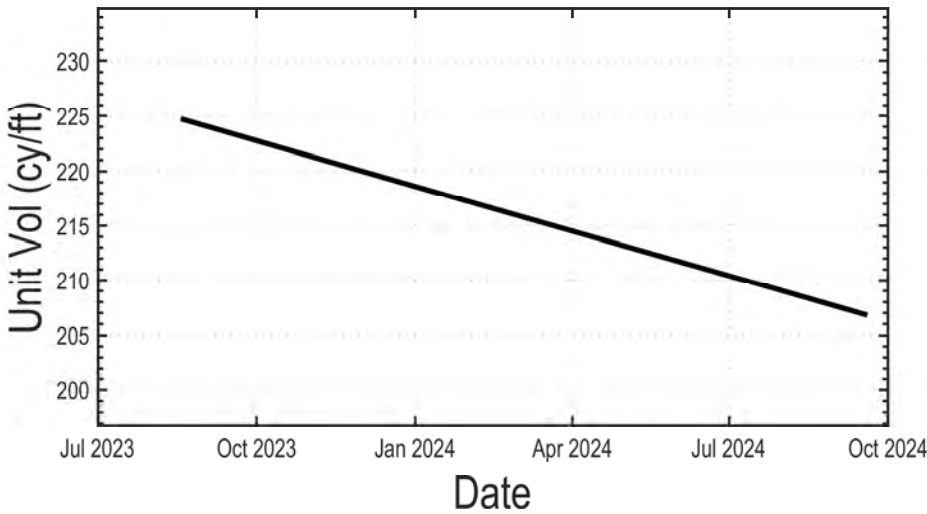
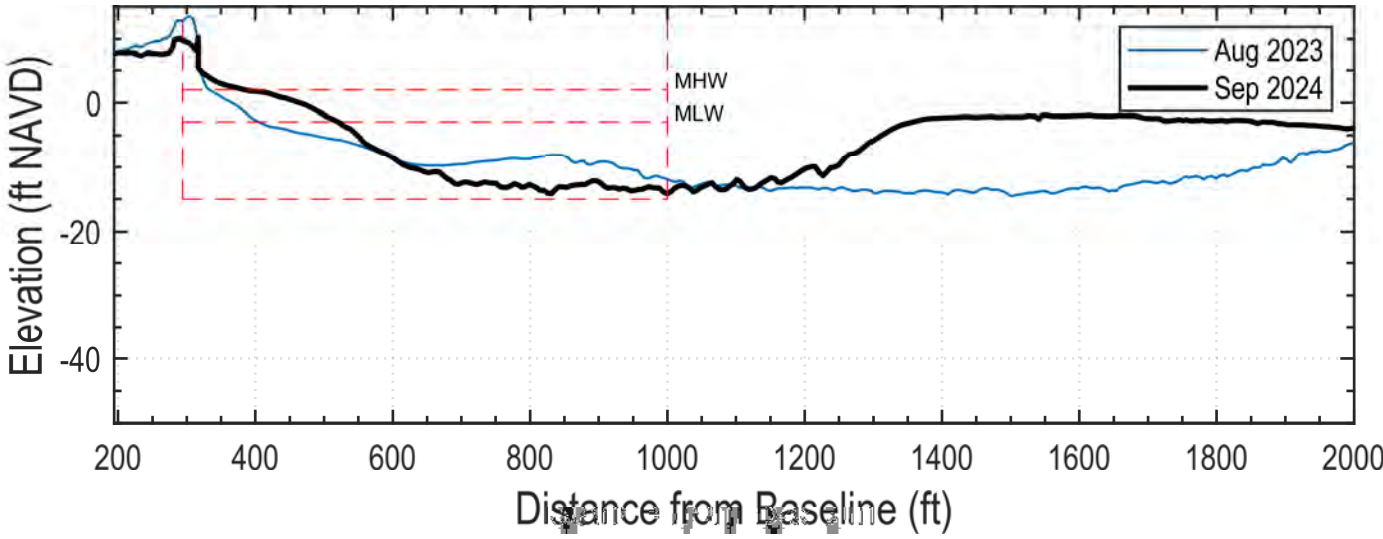
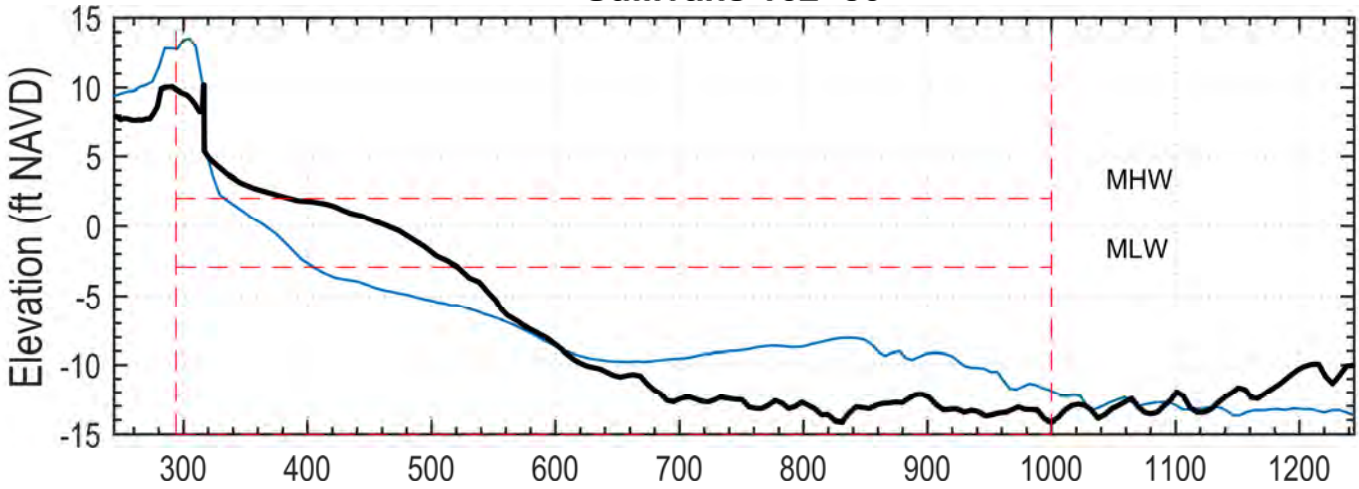


Sullivans 160+00

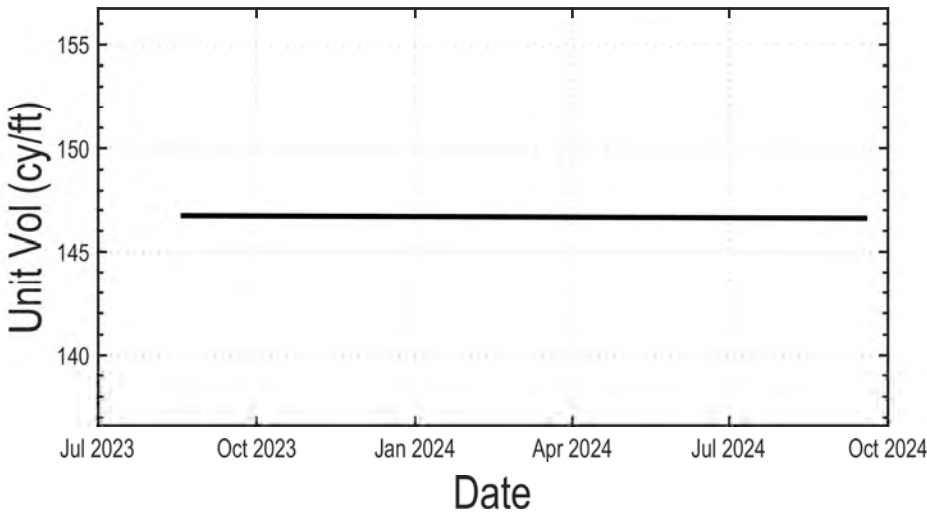
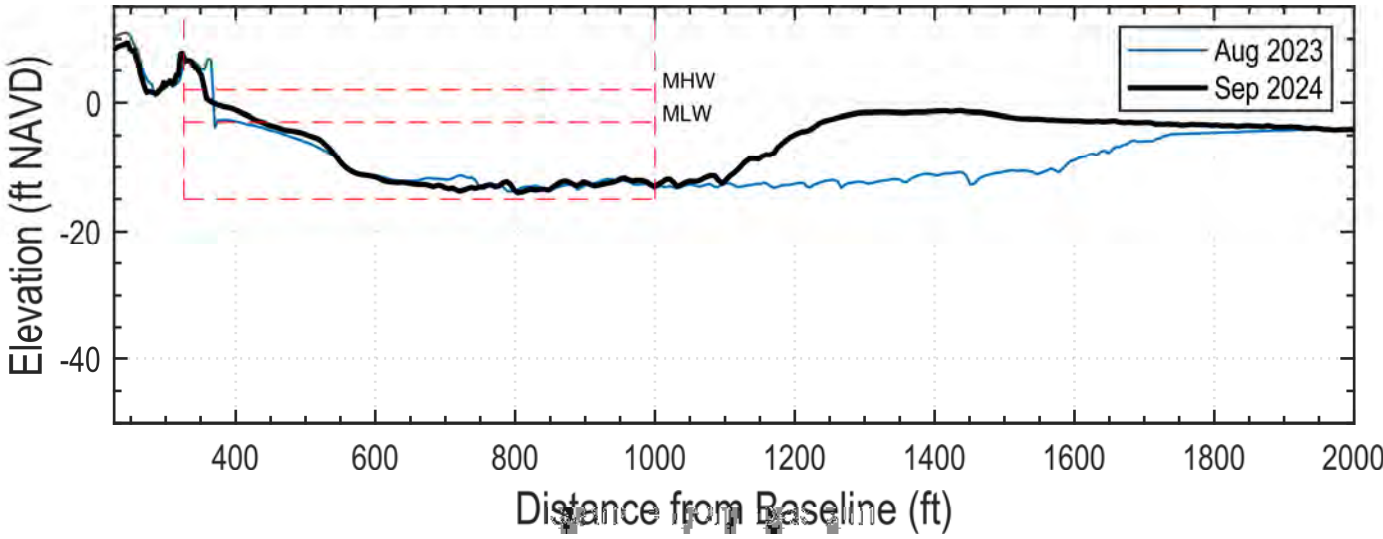
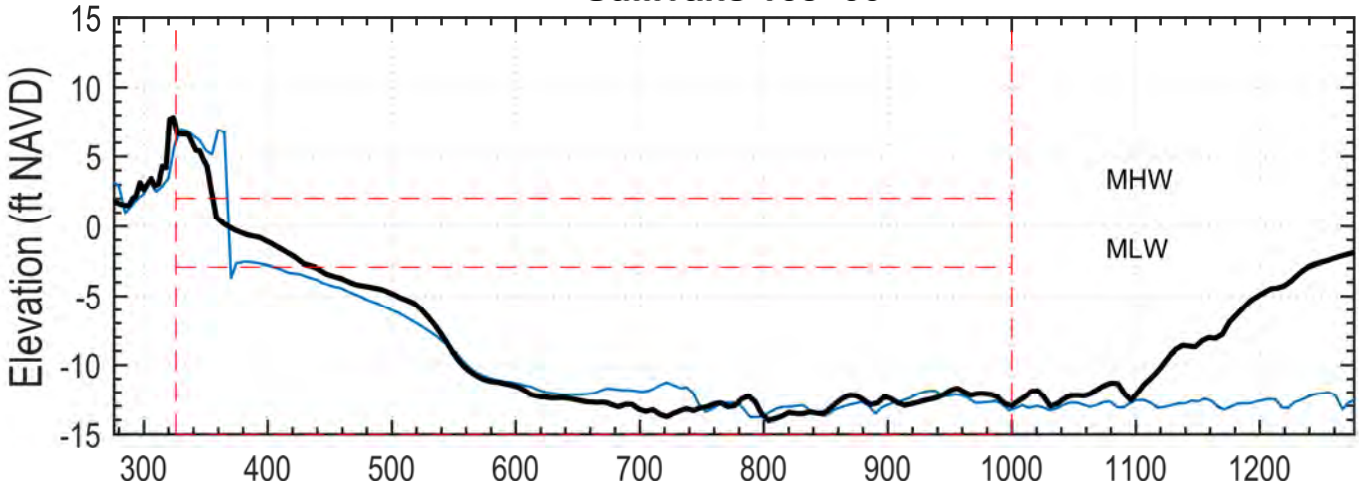


X: 2364053.12
Y: 343218.7

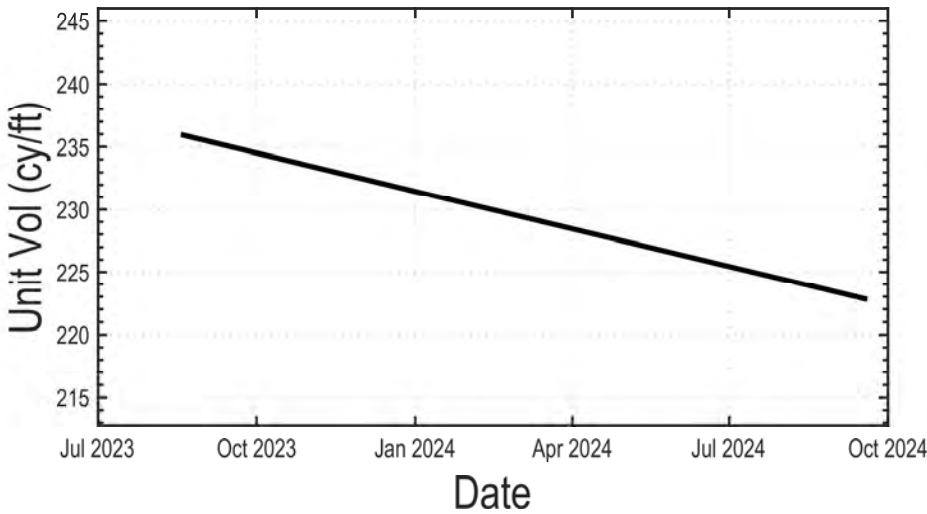
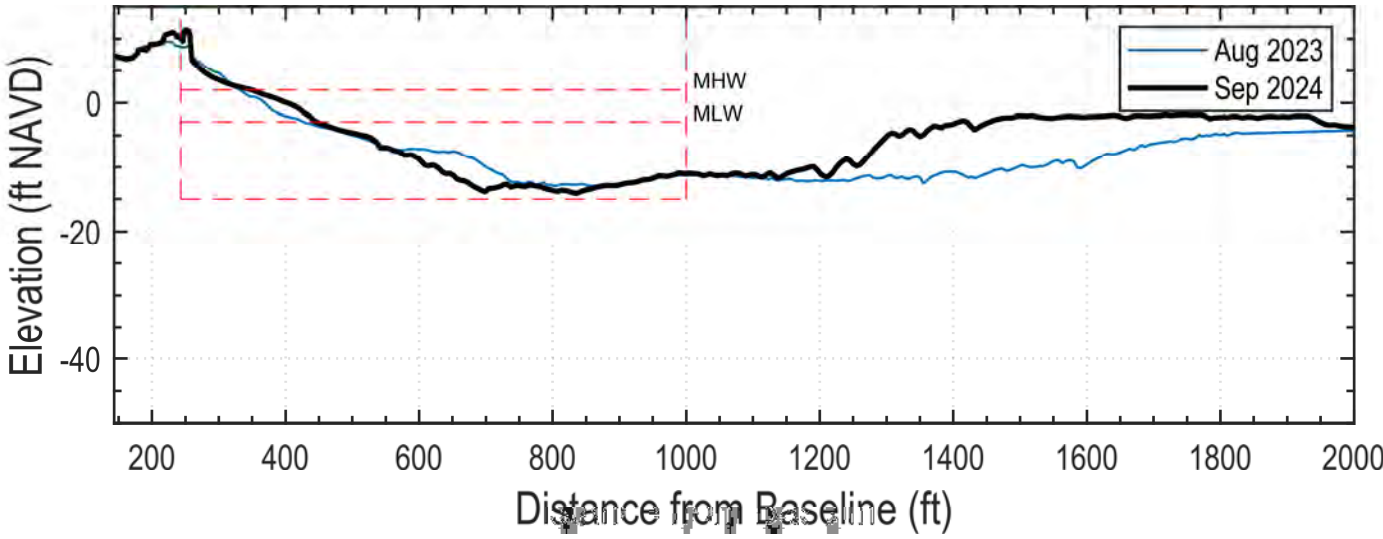
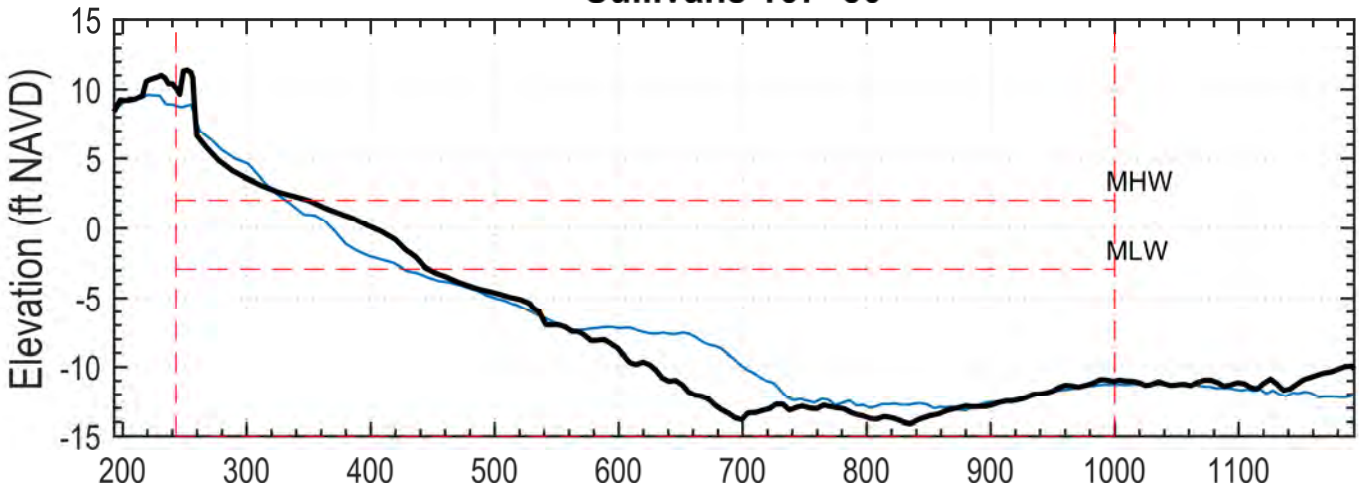
Sullivans 162+50



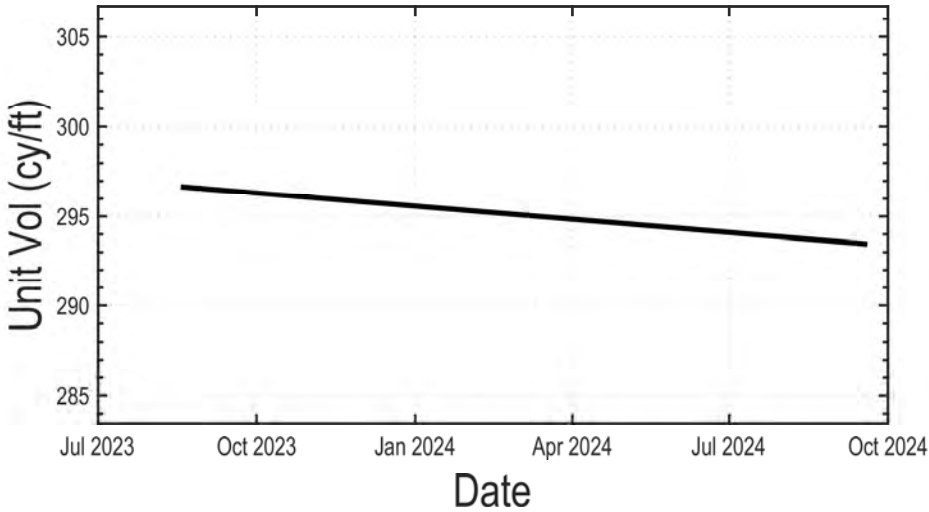
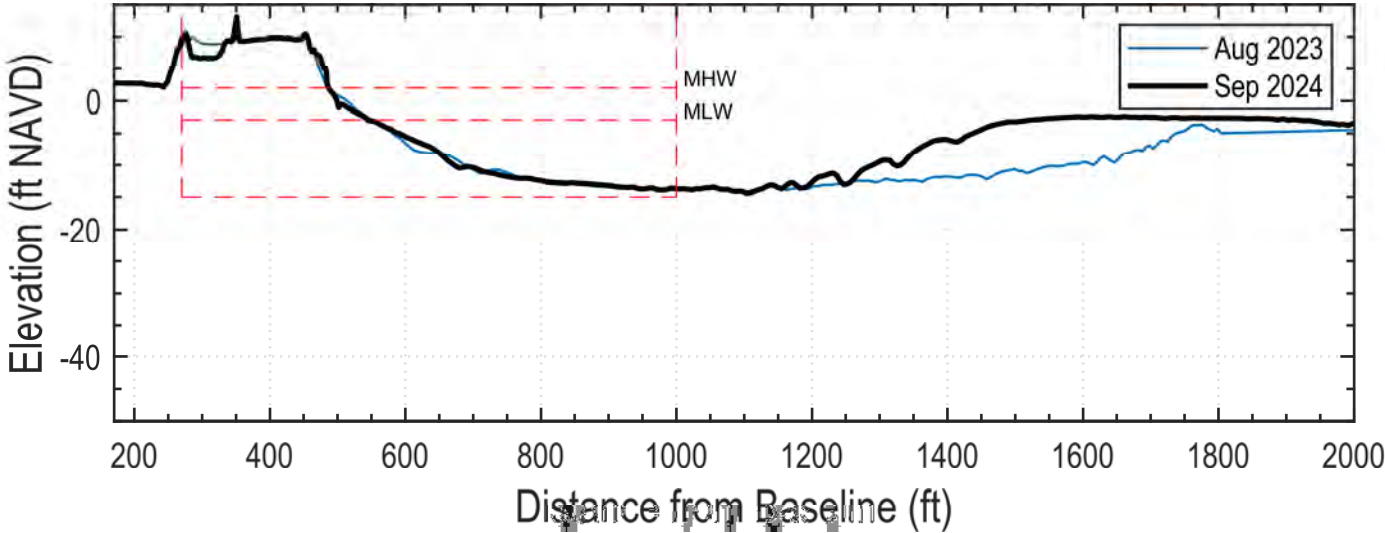
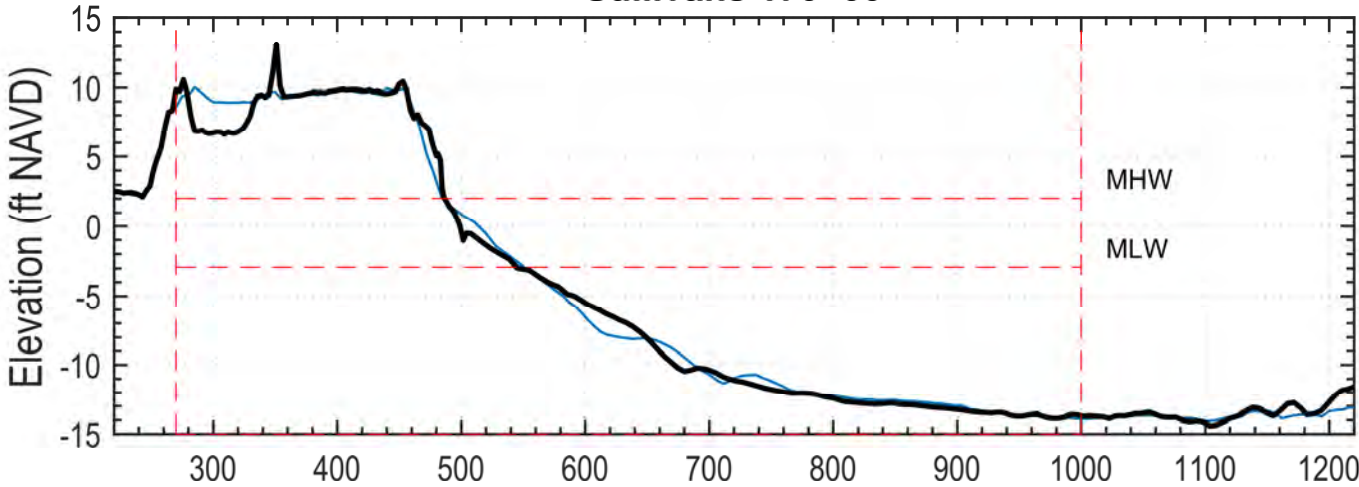
Sullivans 165+00



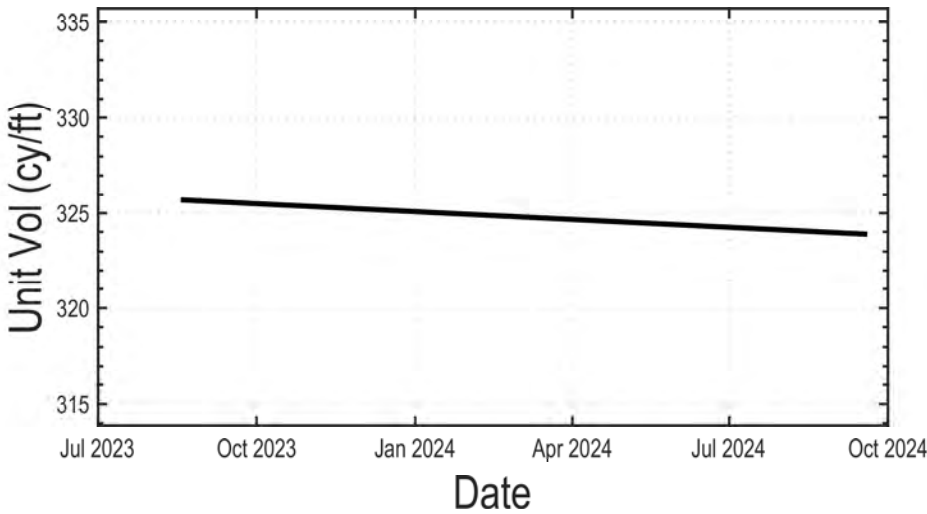
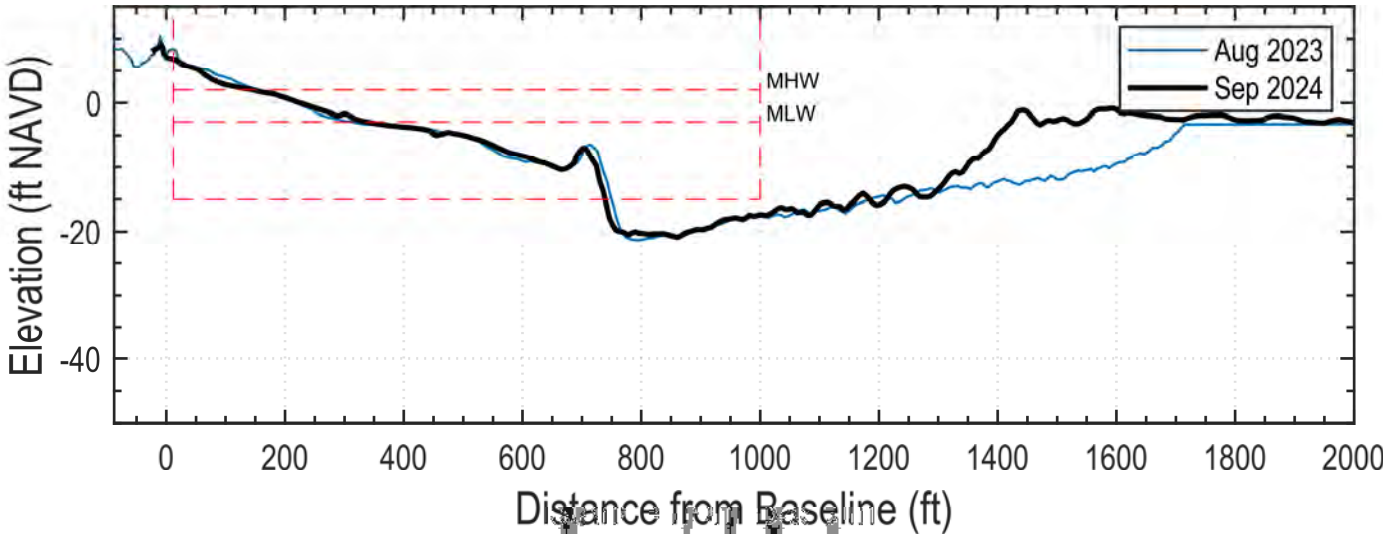
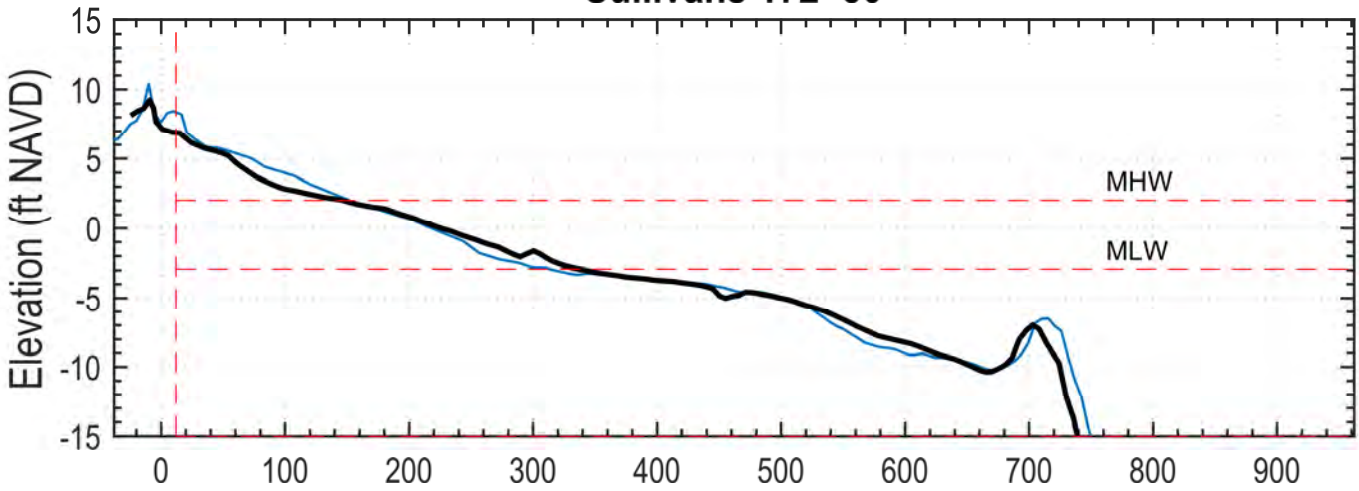
Sullivans 167+50



Sullivans 170+00



Sullivans 172+50



APPENDIX B

CSE Survey Profiles

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Station	Distance		Unit Volumes (cy/ft)												Profile Volumes (cy)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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