

**Kiawah Island  
2006 East End Beach Restoration Project  
Survey Report No. 18**

**2024**  
**MONITORING REPORT**



Prepared for  
**Town of Kiawah Island**  
**Kiawah Island, South Carolina**

COASTAL SCIENCE & ENGINEERING



— THIS PAGE INTENTIONALLY LEFT BLANK —

# BEACH MONITORING PROGRAM SURVEY REPORT NO 18

## Kiawah Island – South Carolina

*Prepared for:*



4475 Betsy Kerrison Parkway, Kiawah Island, SC 29455

*Prepared by:*



160 Gills Creek Parkway, Columbia, SC 29209

[CSE 2597-YR1]  
April 2025

**COVER PHOTO:** Oblique aerial image of the Ocean Course and east end marshes in December 2024. The ongoing shoal bypass event has affected much of the area between the 2015 project site and the Ocean Course clubhouse. A pond created during the 2015 project is now filled with sediment, and a pair of drainage channels have opened between that pond and the incoming shoal. The western channel (center background) is scheduled to be realigned later in 2025 to avoid any potential damage to developed portions of the Ocean Course.

— THIS PAGE INTENTIONALLY LEFT BLANK —

## Synopsis

This report is the 18<sup>th</sup> in a series of annual monitoring reports initiated following the 2006 East End beach restoration project. It contains survey results from the oceanfront beach along Kiawah Island (SC), with a particular focus on the eastern third of the island around the Ocean Course and Stono Inlet. There, shoals and channels of Stono Inlet can create episodic erosional issues and deserve special attention.

The Town of Kiawah Island has completed two projects at the island's East End to address localized erosion and facilitate the flushing of a developing lagoon adjacent to the Ocean Course. The 2006 project moved about 550,000 cubic yards (cy) of sand and restored a wide, dry-sand beach in front of the Ocean Course while relocating a channel. By 2014, the flushing channel was again migrating toward the Ocean Course. Another channel relocation event was completed in the spring of 2015 and involved moving a total of 100,000 cy. Each project occurred in designated critical habitat for the piping plover and incorporated methods to reduce impacts and promote suitable habitat formation for protected species.

CSE tracks conditions by section of the island ('reaches' numbered 1 to 6) regarding sand volumes in the dunes, the visible beach, and the underwater zone. Between October 2023 and December 2024, a significant portion of the island was impacted by an ongoing shoal bypass event at the East End. The erosion observed along the Lagoon Reach (#5) and accretion observed along the Ocean Course Reach (#4) represent the vast majority of volume changes observed between October 2023 and December 2024.

Along the entire shoreline from Captain Sams Inlet to Stono Inlet, the island lost ~598,700 cy (-9.3 cy/ft) of sand from October 2023 to December 2024 (Table A). The East End Lagoon Reach accounts for most of the losses; downcoast reaches between the Beach Club and Beachwalker Park lost ~172,200 cy (-4.5 cy/ft) from October 2023 to December 2024. The central three reaches (West Beach, Turtle Point, and Ocean Course) lost a total of ~6,320 cy (1.5 cy/ft) between October 2023 and December 2024. At the island's western end, Kiawah Spit lost ~18,460 cy (-1.9 cy/ft).

Volume changes for each reach are provided in Table A. From 2011 to 2019, the Lagoon and Stono Inlet generally lost sand. Between 2020 and 2023, the Lagoon gained sediment (Stono Inlet continued eroding, except in 2020), but in 2024, both lost sediment while the Ocean Course gained. This trend in the East End likely reflects the influence of attaching shoals on prevailing patterns of longshore sediment transport. As the shoal continues to bypass, similar patterns of sediment distribution are expected in the future years.

Along Kiawah Island, a gain of 50 cy/ft equates to beach/dune widening of ~75 ft. These data support the long-held observation that Kiawah Island is healthy and growing, unlike many other beach communities. Figure A shows the change in dune position by monitoring station (Line Number) since August 2007. Positive values indicate a more seaward position of the dune crest, whereas negative

values mark erosion. The greatest dune movement since 2007 has occurred near the Beach Club and Captain Sams Inlet. Roughly half of the island’s oceanfront has experienced dune crest movement of less than 20 ft in either direction.

Figure B shows the average unit sand volumes (to -10 ft NAVD) by reach from 1999 or 2006 to 2024. The largest change in sand volumes occurred in Reach 5 around the island’s east end, where accreting shoals cause hot spots of erosion and accretion before spreading towards the downcoast reaches. The most important trends illustrated in the graph are along reaches 2, 3, and 4 (West Beach to the Ocean Course) – where much of the ocean front development lies. Since 1999, sediment volumes have gradually increased along those reaches, with minor erosion observed in Reach 2 (West Beach) and Reach 3 (Turtle Point) during 2024.

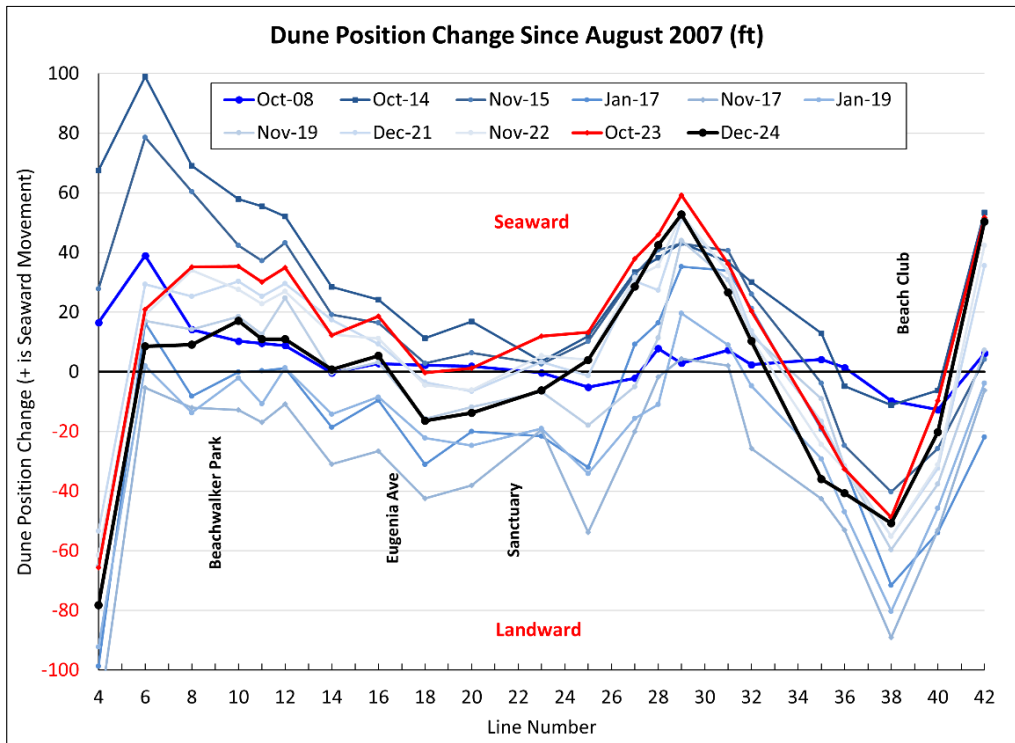
Hurricane impacts have been variable over the last two to three years, after several consecutive years featuring direct or near-miss impacts to Kiawah Island. Hurricane *Matthew* in 2016 caused dune recession of 15–40 feet along most of the residential beachfront, with even greater losses west of Beachwalker Park. While walkovers were damaged, property impacts were minimal. Subsequent storms—*Irma* (2017), *Florence* (2018), *Michael* (2018), and *Dorian* (2019)—produced high surf and winds but less beach erosion. Since 2019, hurricane seasons have been relatively quiet, except for *Ian* (2022) and *Idalia* (2023), which passed north of the island, bringing offshore winds but no severe impacts. From October 2023 to December 2024, the island experienced relatively calm weather, with no hurricanes impacting the area. Winter storms, featuring strong northeasterly winds, also impact Kiawah Island in some years more than tropical cyclones. Between October 2023 and December 2024, a strong nor’easter in December 2023 triggered the highest non-hurricane water level ever recorded at Charleston Harbor.

Despite the string of impacts from ~2016 through 2023, much of the island has exhibited stable or slightly accreting beach conditions since 2012, when CSE expanded its survey network from ~36 profiles to more than 60. From October 2012 to December 2024, portions of the island away from Captain Sams and Stono Inlets gained an average of ~16.8 cubic yards per linear foot of beach (cy/ft).

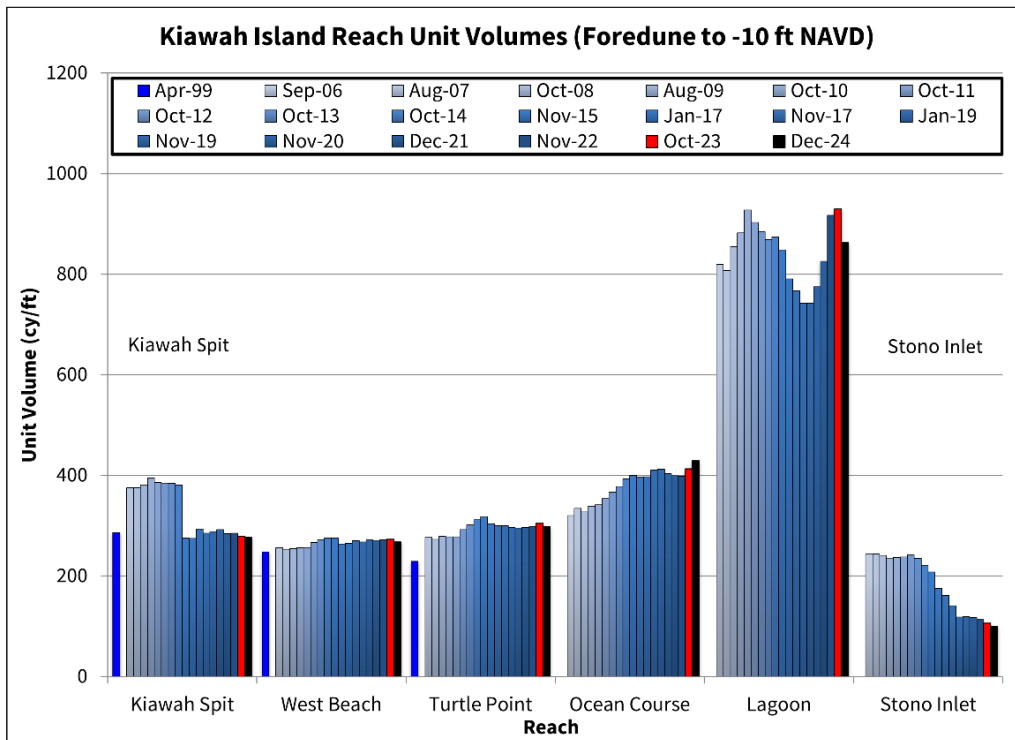
**TABLE A.** Beach volumes and unit volumes\*, along with respective changes for applicable time periods, for each reach and the entire island between 2007 and 2024. Volumes are to -10 ft NAVD. Reach boundaries are described in the report. Red indicates erosion since the prior survey. Average unit volumes for all reaches are weighted by the applicable reach length.

			Reach Total Volume (cy)																			
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820	2,527,960		3,309,434	3,308,176	3,360,442	3,482,539	3,403,430	3,385,060	3,387,780	3,365,774	2,426,028	2,421,235	2,587,554	2,516,429	2,546,308	2,574,957	2,505,765	2,513,897	2,460,921	2,442,459
2	West Beach	11,798	2,925,119		3,018,972	2,973,269	3,002,842	3,016,726	3,023,391	3,143,512	3,200,438	3,247,900	3,246,474	3,109,992	3,123,811	3,186,466	3,153,949	3,204,546	3,190,781	3,207,666	3,221,570	3,158,775
3	Turtle Point	13,614	3,119,193		3,788,036	3,711,347	3,791,866	3,780,710	3,769,778	3,973,563	4,103,336	4,242,815	4,338,658	4,133,108	4,083,240	4,087,595	4,041,965	4,019,325	4,035,192	4,088,888	4,149,913	4,059,050
4	Ocean Course	9,000		2,881,490	3,008,223	2,946,188	3,047,332	3,071,534	3,182,156	3,301,984	3,403,054	3,535,481	3,589,780	3,562,542	3,577,236	3,690,347	3,707,191	3,636,228	3,691,481	3,688,428	3,720,025	3,867,358
5	Lagoon	8,000		6,559,380	6,462,016	6,840,138	7,056,611	7,419,125	7,222,197	7,071,272	6,946,031	6,993,814	6,787,731	6,325,250	6,139,954	5,939,621	5,936,206	6,198,619	6,605,054	7,336,571	7,436,847	6,901,983
6	Stono Inlet	6,000		1,464,695	1,460,076	1,447,219	1,406,546	1,422,719	1,427,296	1,448,756	1,408,636	1,328,992	1,248,369	1,052,076	996,215	845,351	707,753	715,353	706,907	880,859	638,772	598,701
1-6	All	57,232			21,026,757	21,226,337	21,864,658	22,193,353	22,042,249	22,324,148	22,448,334	22,704,776	21,837,039	20,804,203	20,478,010	20,285,811	20,082,373	20,348,028	20,835,179	21,396,300	21,627,047	21,028,328
			Reach Unit Volume (cy/ft)																			
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820	296.6		375.2	375.1	391.0	394.8	385.9	383.8	384.1	380.5	275.1	274.5	293.4	285.3	289.6	291.9	284.1	285.0	279.0	276.9
2	West Beach	11,798	247.9		255.9	252.0	254.5	255.7	256.3	266.4	271.3	275.3	275.2	263.6	264.8	270.1	267.3	271.6	270.5	271.9	273.1	267.7
3	Turtle Point	13,614	229.1		276.8	272.6	278.5	277.7	277.9	291.9	301.4	311.7	318.0	303.6	299.9	300.2	296.9	296.2	296.4	298.9	304.8	298.2
4	Ocean Course	9,000		320.2	334.2	327.4	336.6	341.3	353.6	366.9	378.1	392.8	400.0	396.8	397.5	410.0	411.9	403.9	399.1	398.7	413.3	429.7
5	Lagoon	8,000		819.9	807.8	855.0	882.0	927.4	902.8	883.9	868.3	874.2	848.5	790.7	767.5	742.5	742.0	774.8	825.6	917.1	929.5	862.7
6	Stono Inlet	6,000		244.1	243.3	241.2	234.4	237.1	237.9	241.5	234.8	221.5	208.1	175.3	161.0	140.9	118.0	119.2	117.8	113.5	106.5	99.8
1-6	All	57,232			367.4	370.9	378.5	387.8	385.1	390.1	382.3	396.7	378.1	360.0	357.8	354.1	351.1	355.5	360.6	373.9	377.9	367.4
			Reach Volume Change Since Previous (cy)																			
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820				-1,268	52,266	122,097	-79,109	-18,370	2,719	-32,006	-929,746	-4,793	166,319	-71,125	28,879	29,649	-69,192	8,132	-52,977	-18,462
2	West Beach	11,798				-45,703	29,573	13,984	6,665	120,120	56,926	47,462	-1,426	-136,481	13,818	62,656	-32,517	50,596	-13,766	16,875	13,914	-62,756
3	Turtle Point	13,614				-56,689	80,539	-11,176	3,068	189,784	129,833	138,419	85,843	-195,550	-49,969	4,366	-45,630	-22,641	15,967	33,697	81,024	-90,982
4	Ocean Course	9,000			126,733	-62,036	101,144	24,202	110,622	119,808	101,070	132,427	64,299	-37,239	14,695	113,111	16,844	-71,963	-43,747	-3,053	131,597	147,333
5	Lagoon	8,000			-97,364	378,122	215,473	363,514	-196,928	-150,924	-125,241	47,784	-206,084	-462,481	-185,296	-200,333	-3,415	262,413	406,434	731,518	99,276	-533,864
6	Stono Inlet	6,000			-4,620	-12,857	-40,673	16,174	4,577	21,459	-40,119	-79,644	-80,624	-196,292	-85,861	-120,864	-137,598	7,600	-8,446	-26,048	-42,088	-40,071
1-6	All	57,232				199,580	438,321	528,685	-151,105	281,897	125,188	255,442	-1,067,737	-1,032,836	-126,194	-212,199	-173,437	255,655	287,151	761,120	230,747	-588,721
			Reach Unit Volume Change Since Previous (cy/ft)																			
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820			0.0	-0.1	5.9	13.8	-9.0	-2.1	0.3	-3.6	-105.4	-0.5	18.9	-8.1	3.3	3.4	-7.8	0.9	-6.0	-2.1
2	West Beach	11,798			0.0	-3.9	2.5	1.2	0.6	10.2	4.8	4.0	-0.1	-11.6	1.2	5.3	-2.8	4.3	-1.2	1.4	1.2	-5.3
3	Turtle Point	13,614			0.0	-4.2	5.9	-0.8	0.2	13.9	9.5	10.2	6.3	-14.4	-3.7	0.3	-3.4	-1.7	1.2	2.5	6.0	-6.7
4	Ocean Course	9,000			14.1	-6.9	11.2	2.7	12.3	13.3	11.2	14.7	7.1	-4.1	1.6	12.6	1.9	-8.0	-4.9	-0.3	14.6	16.4
5	Lagoon	8,000			-12.2	47.3	26.9	45.4	-24.6	-18.9	-15.7	6.0	-25.8	-57.8	-23.2	-25.0	-0.4	32.8	50.8	91.4	12.4	-66.7
6	Stono Inlet	6,000			-0.8	-2.1	-6.8	2.7	0.8	3.6	-6.7	-13.3	-13.4	-32.7	-14.3	-20.1	-22.9	1.3	-1.4	-4.3	-7.0	-6.7
1-6	All	57,232			0.0	3.5	7.7	9.2	-2.8	4.9	2.2	4.5	-18.7	-18.0	-2.2	-3.7	-3.0	4.5	5.0	13.3	4.0	-10.5

\*Shoreline change from year to year depends on which contour is chosen for comparison (eg – mean high water – MHW, mean sea level – MSL, mean lower low water – MLLW, etc.) and can vary greatly with some contours showing shoreline recession while others mark seaward movement over the same period. CSE uses beach volume measures because they provide a more objective result, integrating all small-scale changes between the foredune and some defined offshore depth representing the area over which nearly all sand movement occurs in the littoral zone. Unit volumes are derived from two-dimensional (2D) profiles by extrapolating changes in square feet by one-unit shore length, such as one foot. This yields a unit volume in cubic feet per foot of shoreline, which we convert to cubic yards per foot (cy/ft) by standard convention. Such results at individual profiles can then be extrapolated to the next profile to yield ‘beach volumes.’



Michael (2018), and Dorian (2019) all resulted in foredune erosion along Kiawah Island. Conditions since 2019 have stabilized compared to that relatively rough period.



**FIGURE B.** Unit volumes as measured by reach since April 1999 (September 2006 along the Ocean Course and East End). As of December 2024, much of the island had more sand on the beach above -10 ft NAVD than in September 2006 (April 1999 for the three westernmost reaches - Turtle Point, West Beach, and Kiawah Spit). The decrease in volumes measured along Reach 5 (Lagoon) during the October 2023 to December 2024 surveys reflect sand spreading alongshore from Reach 5, the attached shoal, which is expected to continue delivering sand to adjacent reaches for the next couple years.

## TABLE OF CONTENTS

---

<b>SYNOPSIS</b> .....	<b>i</b>
<b>TABLE OF CONTENTS</b> .....	<b>v</b>
<b>1.0 INTRODUCTION</b> .....	<b>1</b>
<b>2.0 SETTING AND HISTORY</b> .....	<b>3</b>
2.1 Geologic History of Kiawah Island .....	4
2.2 Previous Shoreline Studies.....	5
2.2.1 Stono Inlet – Kiawah Island’s sand source .....	7
2.3 2006 and 2015 East End Projects.....	11
2.3.1 2006 East End Beach Restoration Project.....	11
2.4 2015 East End Channel Realignment Project.....	13
<b>3.0 METHODOLOGY</b> .....	<b>15</b>
3.1 Survey.....	15
3.2 Volume Calculations.....	17
<b>4.0 RESULTS</b> .....	<b>21</b>
4.1 Beach Volume Changes (October 2023 – December 2024).....	21
4.1.1 Reach 6 – Stono Inlet.....	21
4.1.2 Lagoon Reach .....	27
4.1.3 Reach 4 – Ocean Course .....	32
4.2 Downcoast Reaches.....	36
4.2.1 Turtle Point Reach.....	38
4.2.2 West Beach Reach .....	41
4.2.3 Kiawah Spit Reach.....	44
<b>5.0 COASTAL RESILIENCY UPDATE</b> .....	<b>47</b>
5.1 Weather and Climate Conditions, October 2023 to December 2024 .....	47
5.2 Sea Level Conditions and Trends .....	52
5.3 Flood Vulnerability.....	54
<b>6.0 FINDINGS AND RECOMMENDATIONS</b> .....	<b>59</b>
<b>7.0 ACKNOWLEDGEMENTS</b> .....	<b>61</b>
<b>8.0 REFERENCES AND BIBLIOGRAPHY</b> .....	<b>63</b>

### Appendix A) December 2024 Profiles

— THIS PAGE INTENTIONALLY LEFT BLANK —

## 1.0 INTRODUCTION

---

This report is part of a series of annual beach monitoring reports initiated following the 2006 East End restoration project (see CSE 2005, 2007). The Town of Kiawah Island (SC) sponsors annual surveys of the beach to determine rates and directions of sand movement within the project area and the remainder of the island. This eighteenth report of the series follows over a dozen shoreline erosion reports prepared by Research Planning Institute (RPI) and Coastal Science & Engineering (CSE) for Kiawah Island since the 1980s (eg – Kana et al 1983, CSE 1999). Annual post-project surveys have been conducted in the fall of every year between 2007 and 2023, in addition to periodic post-storm surveys in January 2017 (post-*Matthew*) and January 2019 (post-*Florence* and -*Michael*). The present survey was completed in December 2024 to provide a beach condition assessment since the last monitoring survey conducted in October 2023.

The purpose of annual beach monitoring reports is to compare current conditions in beach volumes along Kiawah Island to past conditions. To do so, survey data are collected along the entire island from Stono River Inlet to Captain Sams Inlet to document volume changes. Profile lines run from the landward side of the seaward-most dune to at least 2,500 feet (ft) offshore. Volume calculations are made within boundaries established using depths and range from 1,000 ft to 2,500 ft offshore. Most volume calculations represent the changes in sand volume above ~-10 ft NAVD\* elevation. A positive change indicates accretion, while a negative change indicates erosion. Over years, volumetric changes can be used to infer sediment transport patterns along the shoreline. This information is used to identify erosion hot spots and predict future areas of concern before hazardous situations arise.

The scope of work for the annual monitoring effort includes the following:

- Ground surveys of the dunes, beach, and inshore zone
- Oblique aerial photography
- Data analysis and production of a technical report describing beach volume changes

The next section of this report briefly describes Kiawah Island and its historical shoreline changes. A summary of the methods used during surveying and data analysis follows in Section 3. Section 4 includes the survey results, while Section 5 presents a meteorological and sea level summary to associate beach volume changes with particular weather events or water level increases. Section 6 discusses CSE's findings and recommendations for this year.

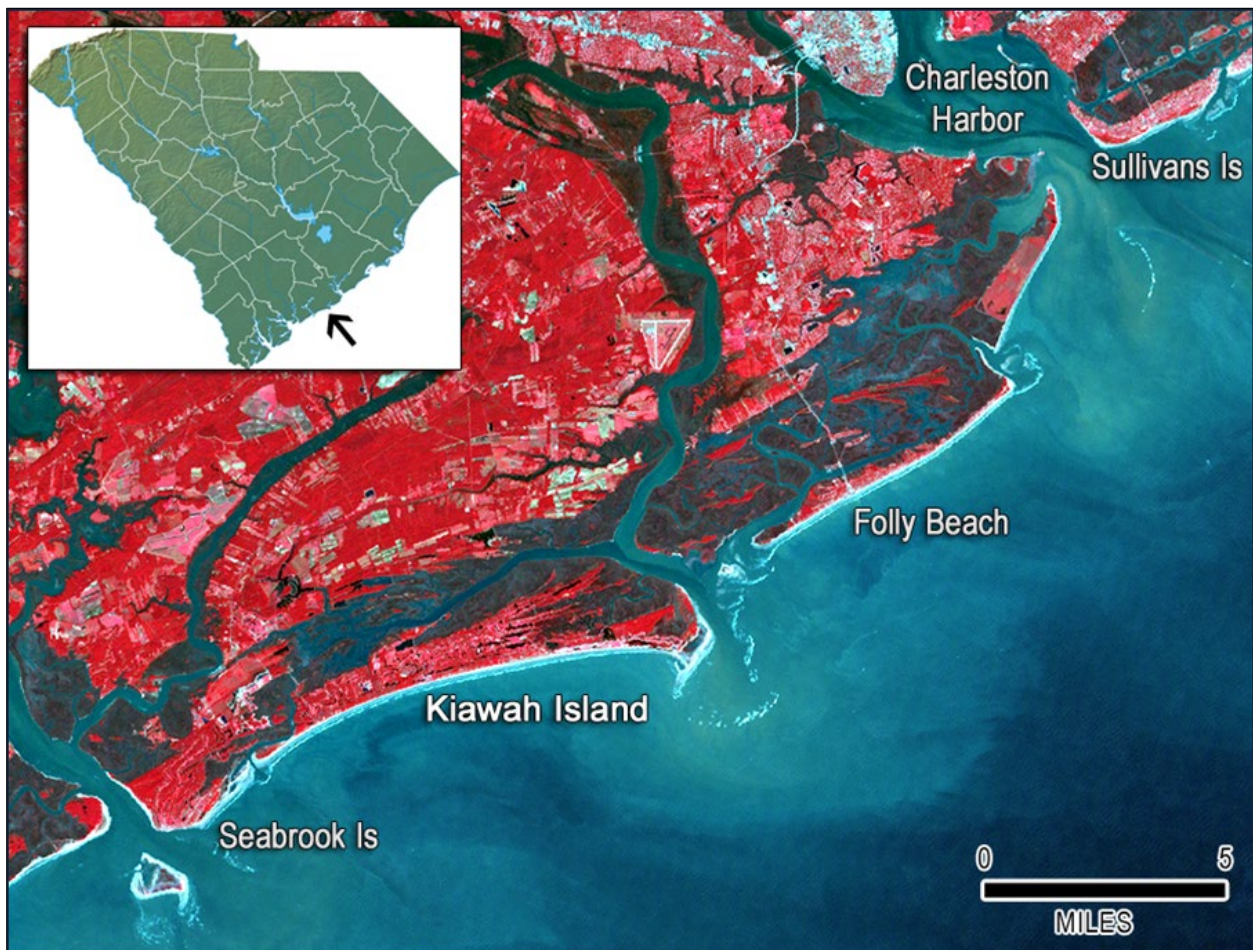
*\*NAVD – North American Vertical Datum of 1988, which is approximately 0.25 ft above present mean sea level (MSL)(<https://tidesandcurrents.noaa.gov/stationhome.html?id=8666467>). The datum provides a fixed reference plane for setting grades and 1<sup>st</sup>-floor elevations in the coastal zone regardless of tide range.*

— THIS PAGE INTENTIONALLY LEFT BLANK —

## 2.0 SETTING AND HISTORY

Kiawah Island is a ~10-mile-long barrier island situated ~10–15 miles southeast of Charleston, SC (Fig 2.1). The adjacent Stono Inlet has historically provided enough sand so that beach erosion occurs in minor, localized hotspots as sand migrates down the beach from Stono Inlet towards the west. Due to the long-term healthy sand supply, the island contains diverse habitats including marshes, maritime forests, and dunes. The diversity of native habitats and an adaptive beachfront management strategy make Kiawah one of the healthiest barrier islands in South Carolina.

Large quantities of sediment migrate onto the island’s eastern end from Stono Inlet, providing sand that sustains dunes and beaches along the entire shorefront (Fig 2.2). This sand supply and the foresight of the island’s developers to understand the processes and landforms of the island (see Hayes et al 1975, Hayes 1977) make Kiawah an excellent example of beachfront development and an aesthetically unique community along the South Carolina coast. The role of Stono Inlet in shaping the beach along Kiawah Island is explored in greater detail in Section 2.2.



**FIGURE 2.1.** South Carolina coastline from Seabrook Island to Charleston Harbor. [Circa 1999 image courtesy Research Planning Inc and SCDNR].



**FIGURE 2.2.** The East End of Kiawah Island in December 2024. A large shoal (volume >1 million cy) has attached to the island and is beginning to spread alongshore. Multiple sandbars are moving onshore and adding to the sand supply along the Ocean Course.

## 2.1 Geologic History of Kiawah Island

Kiawah Island was first studied in detail when Professor Miles O. Hayes and colleagues at the University of South Carolina initiated field investigations of the island’s geologic history in the 1970s. Hayes described the geologic evolution of ‘drumstick’ barrier islands along South Carolina as well as other ‘mixed-energy’ coasts like the Gulf of Alaska and the Netherlands using Kiawah as a prototype (see Hayes 1977, Hayes 1994, Hayes and Michel 2008, Hayes and FitzGerald 2013, FitzGerald et al 2018).

The island is bound by Stono Inlet on the east and Captain Sams Inlet on the west (see Fig 2.1). The eastern end episodically gains sand through shoal bypassing events (Williams & Kana 1986, Gaudiano 1998), and the sand eventually spreads to downcoast portions of the island towards Kiawah Spit. From there, smaller bypassing events transport the sand across Captain Sams Inlet towards Seabrook Island. The processes controlling sand movement along the island are discussed in greater detail in CSE (1999).

The oldest part of the island, adjacent to the Kiawah River, is at least ~4,000 years old (Moslow 1980). The most dynamic portion of the island is the northeastern end, where shoal bypassing and channel migration of the Stono River Inlet has caused the island to advance seaward by thousands of feet since

the mid-19<sup>th</sup> century. Such significant changes in shoreline position can have a cascading effect on nearshore wave patterns and may have influenced persistent erosion around Eugenia Avenue in the 1980s and 1990s (see CSE 1999).

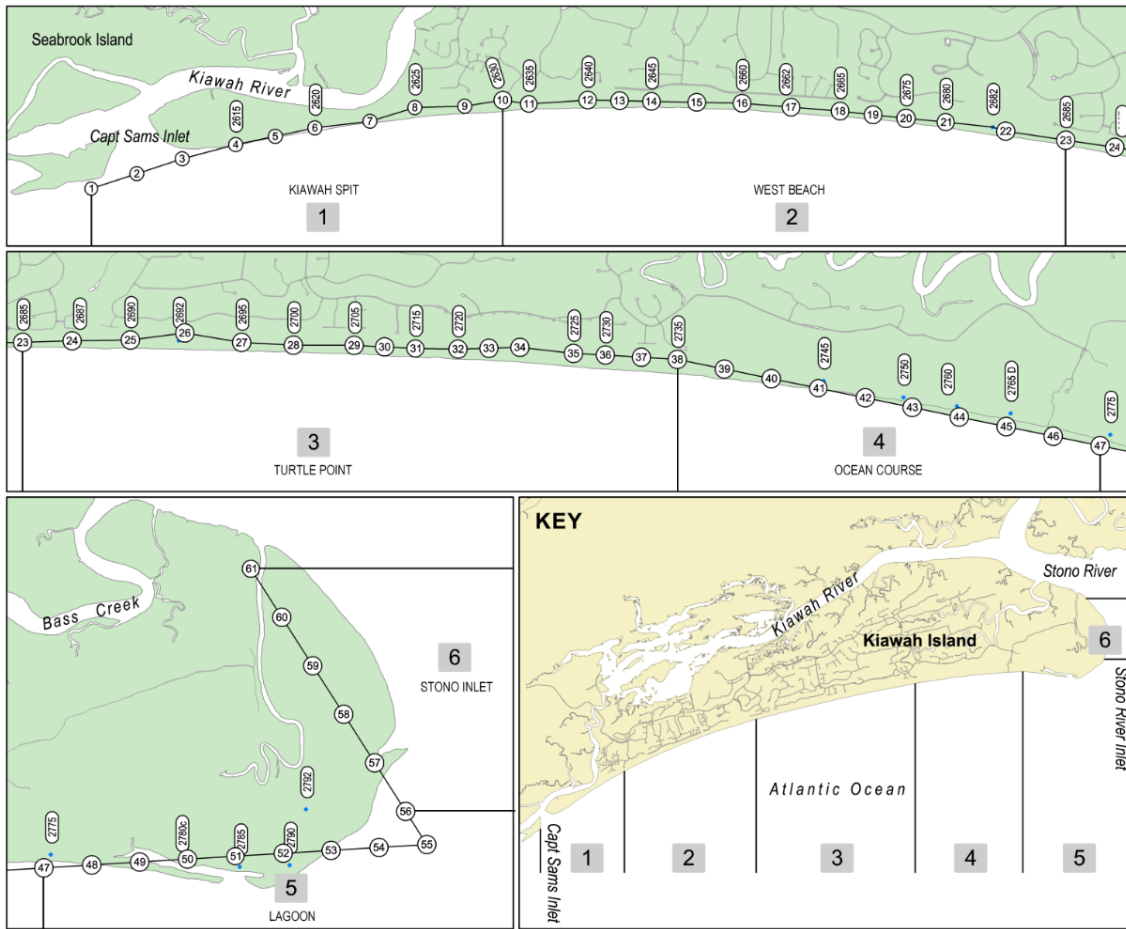
## 2.2 Previous Shoreline Studies

The first shoreline assessment of Kiawah Island was performed by Hayes and his students in the 1970s (Hayes et al 1975). Based on the island's geomorphology, Hayes identified five zones along the beach and recommended two middle zones (West Beach and Turtle Point) as suitable for development landward of the second dune ridge (Figs 2.3 and 2.4). Early development on the island was based on the findings of these studies, and it became one of the first localities in the state to implement rigorous setback lines.

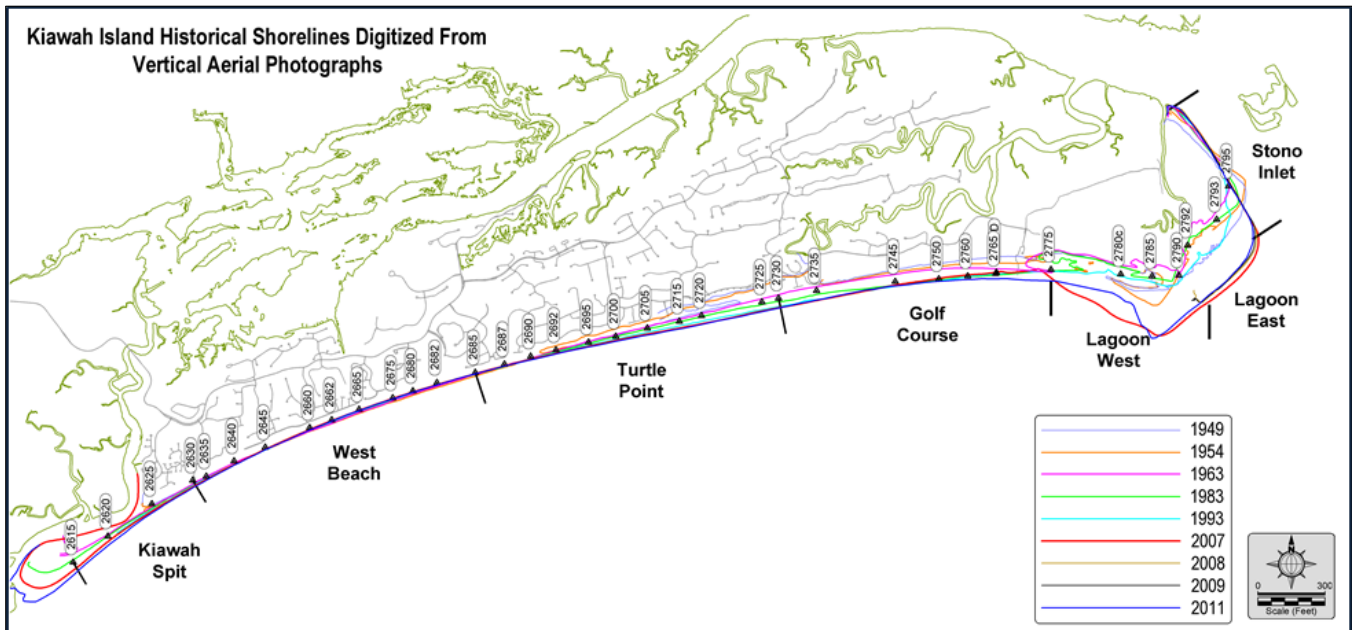
From 1981 to 1987, regular monitoring efforts were conducted by RPI and CSE (cf – Sexton et al 1981, Williams & Kana 1987). In July 1988, the Beach Management Act (BMA) of South Carolina was passed, and by 1989 the management of beach monitoring programs was taken over by the State. In 1994, CSE was again contracted by the Town of Kiawah Island and conducted monitoring through 1999. From 1981 to 1999, Kiawah Island either gained sand or remained stable. Isolated erosion did occur, but was generally small in magnitude.

The West Beach area (encompassing Windswept Villas, Mariners Watch Villas, Eugenia Avenue, West Beach Village, and Kiawah Inn) remained stable, losing only 0.21 cubic yards per foot per year (cy/ft/yr\*) from 1983 until 1999 (with episodic accretion and erosion events). All other areas showed gains in sand volume between 1983 and 1999. Details of volume change from 1983 to 1999 are provided in CSE (1999).

\* CSE's beach monitoring surveys emphasize volumetric changes rather than linear movement of the shoreline, because quantities of interest are the amounts of sand gained or lost across the entire beach zone. By breaking the measurements down on a per-foot, per-year basis, changes from one place to another are easy to compare and track over time. Along Kiawah Island, loss of ~1.0 cy/ft/yr is equivalent to ~1.5 ft of beach/dune recession.



**FIGURE 2.3.** General location of beach stations and reaches monitored for the present report. Line numbers are shown in circles. State surveys (c/o OCRM) are the 2700s profile markers.

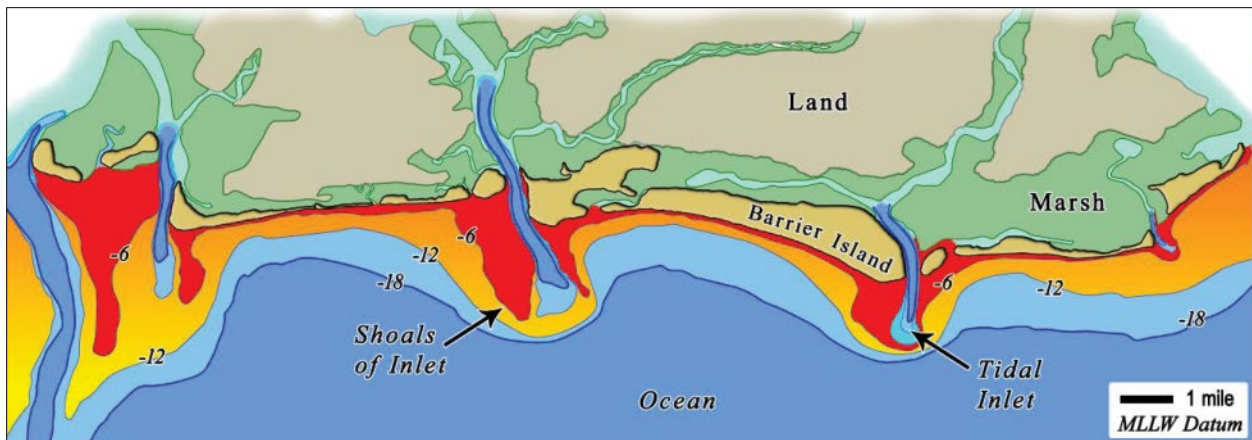


**FIGURE 2.4.** Historical shorelines (seaward vegetation lines). West Beach has been slightly erosional whereas all other reaches have been accretional since 1949. [Updated from CSE 1995]

### 2.2.1 Stono Inlet – Kiawah Island’s sand source

Sand from Stono Inlet is the primary source of beach sand for Kiawah Island (Kana et al 1981). Inlet ebb-tidal deltas often contain as much or more sand than the adjacent barrier islands along the South Carolina coast south of the Santee River mouth (Sexton & Hayes 1996). In this mixed energy environment (Hayes 1994), waves and tidal currents significantly impact morphology and processes. Powerful tidal currents with a dominant flow at ebb tide move sand seaward out of the inlet channel into the ebb delta (Fig 2.5). Waves then reshape the sands into shoals and bars, some breaking free from the delta and migrating onto the beach. This produces several characteristic features found along the South Carolina coast, including large delta complexes extending miles offshore, marginal flood channels (small channels near the beach flanking the main channel that are dominated by flood currents), and migrating shoals (cf – Fig 2.1 and Fig 2.2).

Periodically, sand stored in the ebb-tidal delta of Stono Inlet is released when the channel shifts position. Shoals on the downcoast (west) side of the channel are freed from the delta and pushed shoreward by wave action. During this process, the beach in the lee of the shoal builds due to decreased wave energy (‘Stage 1, Fig 2.6). Adjacent to the accreting beach, erosional arcs are formed by refracting wave crests bending shoreward around the offshore shoal (‘Stage 2’, Fig 2.6). This process continues until the shoal is fully attached, and sand moves laterally in both directions along the shoreline. The final stage of shoal bypassing (‘Stage 3’, Fig 2.6) occurs as waves continue to push the shoal landward and upward while sand spreads laterally along the beach. Shoal spreading provides natural nourishment with sand moving downcoast via longshore currents.



**FIGURE 2.5.** Nearshore bathymetry for a typical section of the central and southern South Carolina coast. Ebb-tidal deltas contain large amounts of sand, which alter the local bathymetry. This in turn directs wave energy and sediment transport patterns along the adjacent beaches. [From *Coastal Erosion and Solutions – A Primer* (Kana 2011) – CSE]

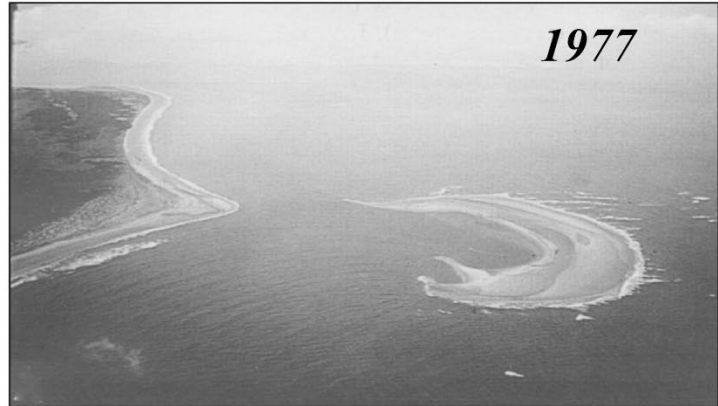
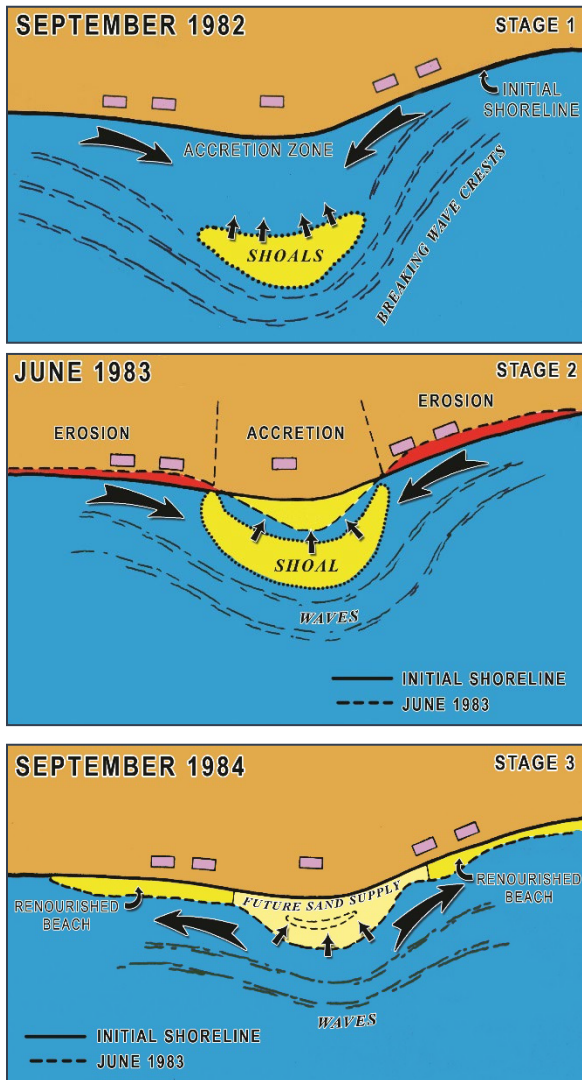
The time between episodic releases of sand by the inlet and subsequent attachment and spreading depends on the size of the inlet and its ebb-tidal delta. Large inlets like Stono Inlet tend to initiate shoal bypassing events every seven to eight years, with individual shoal volumes often exceeding 0.5 million cubic yards (Gaudio & Kana 2001).

Kiawah Island has experienced two impressively large shoal bypassing events over the past ~25 years. The first shoal formed offshore in 1994 and was completely attached by 1997. The second shoal began attaching in 1998 and continued until ~2004 (Fig 2.7). These two events were the largest ever documented in South Carolina (CSE 2005) and collectively contained such a large quantity of sand that wave action could not completely weld the shoal to the beach. As a result, a new beach-dune system developed up to ~2,000 ft seaward of the shoreline as measured in 1984. This created a lagoon between the 'new' and 'old' shorelines, along with a ~2-mile-long barrier beach (Fig 2.7). CSE (2005) estimates the two shoals added ~5 million cubic yards to Kiawah Island. With sheltering by the new outer beach, marsh grasses propagated naturally around the margins of the lagoon, where elevations were close to mean high water. What had been open ocean area just a few years before, became protected tidal wetlands (Kana 2002).

By 2004, the shoals had completely attached at their eastern edge but remained detached at the western end. Shoal sands were migrating westward and were reaching near the (old) Ocean Course Clubhouse (Fig 2.7), but tidal flushing maintained a natural channel between the main shoal complex and that point. Due to the overwhelming quantity of sand gained at the eastern end, the shoreline near the Ocean Course jumped seaward and changed orientation. This effectively paused the shoal-bypassing cycle somewhere between Stage 2 and Stage 3, altered the direction of approaching waves along the island's northeastern end, and caused focused erosion along the Ocean Course.

As longshore transport moved the shoal westward, the flushing channel migrated likewise and encroached on the 16<sup>th</sup> and 18<sup>th</sup> holes of the famed Kiawah Ocean Course. The beach at the original Ocean Course Clubhouse (near OCRM monument 2775) retreated over 500 ft between the years 2000 and 2005. The magnitude of the bypassing event was enough to generate severe erosion for several years before the cycle could be completed (Gaudio & Kana 2001). The Ocean Course remained vulnerable to erosion as the shoal and flushing channel migrated westward. This led to the plan for beach restoration proposed by CSE (2005).

## THE THREE STAGES OF SHOAL BYPASSING



**FIGURE 2.6.**

**[LEFT]**

Schematic of the shoal-bypass cycle originally modeled from a bypass event at Isle of Palms (SC). During Stages 1 and 2 of the cycle, accretion in the lee of the shoal is accompanied by erosion on either side of the attachment site. (After Kana et al 1985)

**[RIGHT]**

Shoal bypassing at the eastern end of Kiawah Island.

Stage 1 in 1977 [UPPER]. Stage 2 in January 1979 [UPPER MIDDLE] (courtesy of Research Planning Institute Inc). Stage 3 in 1983 [LOWER MIDDLE]. Stage 1 in 1986 [LOWER]. Note the similarity between the 1977 shoal and the 1986 shoal, but the additional sand accumulated on Kiawah in 1986. [After Kana et al 1999]



**FIGURE 2.7.** The eastern end of Kiawah Island in December 1998 [**UPPER**] and February 2005 [**LOWER**]. Note the 1989 shoreline situated well inland from the outer beach. Shoals 1 and 2 added upward of 5 million cubic yards to Kiawah in the 1990s. As waves pushed the new sand shoreward, an incipient barrier island/lagoon/marsh formed. The new lagoon was flushed via a channel at the western end of the accreted beach. [From CSE 2007]

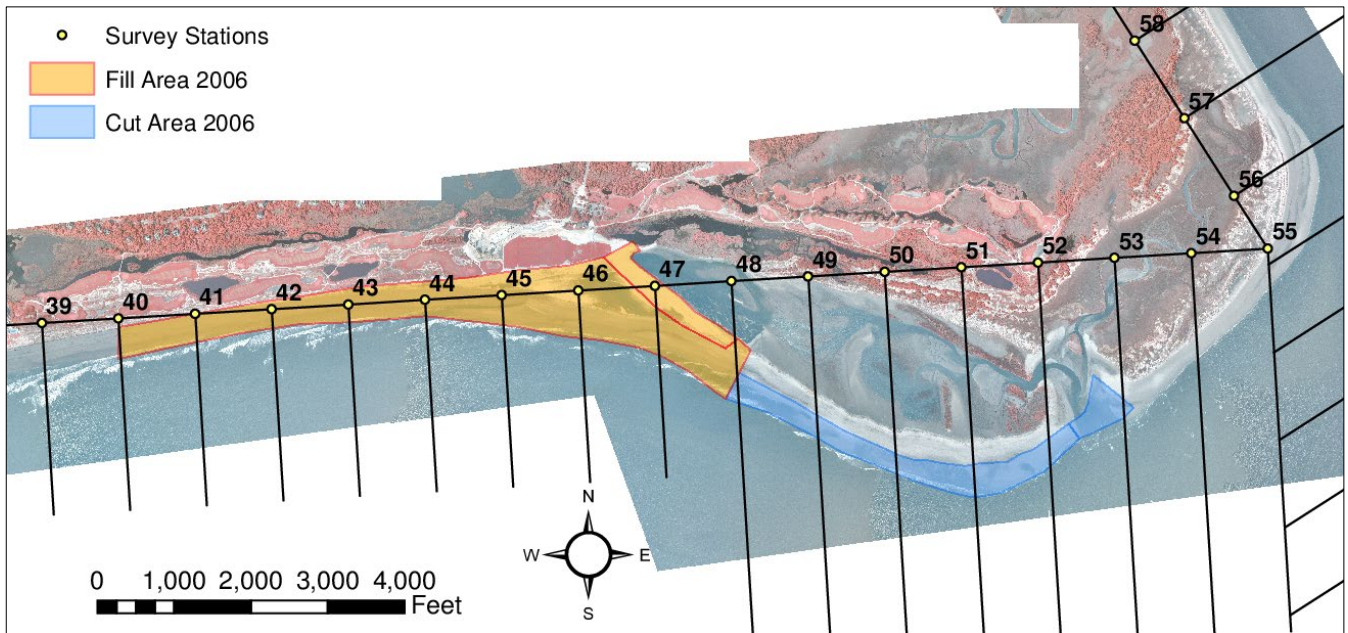
### **2.3 2006 and 2015 East End Projects**

Both the 2006 and 2015 East End projects were designed to manage highly unstable beach changes associated with shoal bypassing events. Realignment or relocation of ephemeral channels mimics natural processes while maintaining tidal flows into newly formed wetland areas. The channel closures triggered onshore migration of sand bars and accelerated downcoast sand spreading. Channel openings shifted the inlet upcoast and allowed a new cycle of inlet growth and migration to begin. In each case, wave action did much of the work of restoration, reducing the vulnerability of Kiawah resort facilities to storms.

#### **2.3.1 2006 East End Beach Restoration Project**

In June and July of 2006, the East End beach restoration project (SCDHEC–OCRM permit No P/N 2005–1W–310–P, USACE permit No 2005–1W–310) was completed by L. Dean Weaver Company Inc. The enclosure dike spanned ~2,000 ft towards the southeast from the Ocean Course driving range. The excavation area was along ~6,000 ft of shoreline between the dike and the new channel area (Fig 2.8). This project sought to artificially create Stage 3 of the shoal-bypassing cycle and avoid further erosion of the Ocean Course. The project details are in the final report, ‘2006 East End Erosion and Beach Restoration Project: Kiawah Island’ (CSE 2007). The objectives of the project were to:

- Accelerate the shoal-bypassing cycle to restore westerly sand transport along Kiawah Island
- Eliminate rapid erosion along the Ocean Course (particularly around the 16th, 17th, and 18th fairways and the driving range)
- Maintain viable piping plover beach habitat along the newly accreted barrier spit east of the Ocean Course, including areas of frequent washovers and the adjacent incipient dune habitat
- Preserve the environmental, cultural, and aquatic resources of the Town
- Protect oceanfront recreational facilities and community infrastructure as a resource of tax revenue and income
- Maintain the economic viability of tourism, the Town’s largest industry
- Make a new source of sand from the accreting shoal more readily available for natural nourishment along downcoast areas



**FIGURE 2.8.** Excavation and fill areas used in the 2006 project. Approximately 550,000 cy of sand was transferred from the excavation area to the fill. The background image was collected in September 2006 using an infrared camera, so vegetation appears red instead of green.



**FIGURE 2.9.** Before (February 2006) and after (July 2006) aerial photos of the 2006 East End beach restoration project. [After CSE 2007]

## 2.4 2015 East End Channel Realignment Project

The 2006 beach restoration project effectively restored the dry-sand beach along the Ocean Course. The new flushing channel relocated naturally in 2007 to a point in the middle of the open lagoon area. Between 2007 and 2013, the channel meandered across the intertidal beach; however, the throat of the channel remained east of the 2006 closure dike. In early 2014, the channel began to encroach on the closure dike, and the Town started to plan for another channel relocation in the event the channel continued to migrate west.

The plan called for periodic relocation of the flushing channel, using the minimal amount of sand necessary, if the channel migrated west beyond its position in February 2014. A permit application was submitted with the intended construction window of September/October; however, by the fall of 2014, the migration of the channel had quickened and eroded much of the dunes protecting the Ocean Course driving range. The Town applied for a one-time modification to the construction window to allow for construction during the spring-summer season, which regulatory agencies granted.

The 2015 project was constructed between May and June 2015 by Lake Moultrie Construction Company Inc, DBA Lake Moultrie Water Company, and Ashridge Inc, A Joint Venture (St Stephen SC) at a cost of \$538,000. A total of 100,000 cy of sand was transferred, and the new inlet was opened ~3,000 ft to the east. A closure dike was built across the original channel, connecting to the remaining portion of the 2006 closure dike (Fig 2.10). Excess sand was placed along the seaward edge of the driving range to facilitate the recovery of the eroded areas and protect the range. The completed project accomplished the goal of eliminating the cause of erosion along the Ocean Course while minimizing the construction impacts and manipulation of the beach. More recent aerial photographs and survey results from the current survey period are included in Section 4.1.1.



**FIGURE 2.10.** [UPPER] Excavation and fill areas used in the 2015 project. Approximately 100,000 cy of sand was transferred from the excavation area to the fill. [LOWER] Project area on 7 July 2015 after project completion showing closure dike in center of image and new flushing channel at upper right. Encroachment by the ‘erosional channel’ destroyed hundreds of feet of dunes, leaving no protection in front of the driving range.

### 3.0 METHODOLOGY

This section describes the methodologies of the topographic survey and habitat mapping used by CSE to monitor changes at Kiawah Island.

#### 3.1 Survey

The present survey was conducted by RTK-GPS\* (Trimble™ R12 GNSS system) in December 2024. Profiles along Kiawah are surveyed perpendicular to the local shoreline (CSE baseline) azimuth from the control points to at least -12 ft NAVD (equivalent to the seaward limit of sand exchange with the beach in this setting) or at least 3,000 ft from the primary dune ridge. Surveys were conducted by combining land-based surveys and bathymetric surveys (Fig 3.1). Land surveys were accomplished using an RTK-GPS between the foredune and low-tide wading depth (~-6 ft NAVD), whereas hydrographic surveys were collected by combining the RTK-GPS with a precision echo-sounder mounted on CSE's shallow-draft survey vessel, the *RV Southern Echo*.

[\*Real-time kinematic global positioning system]



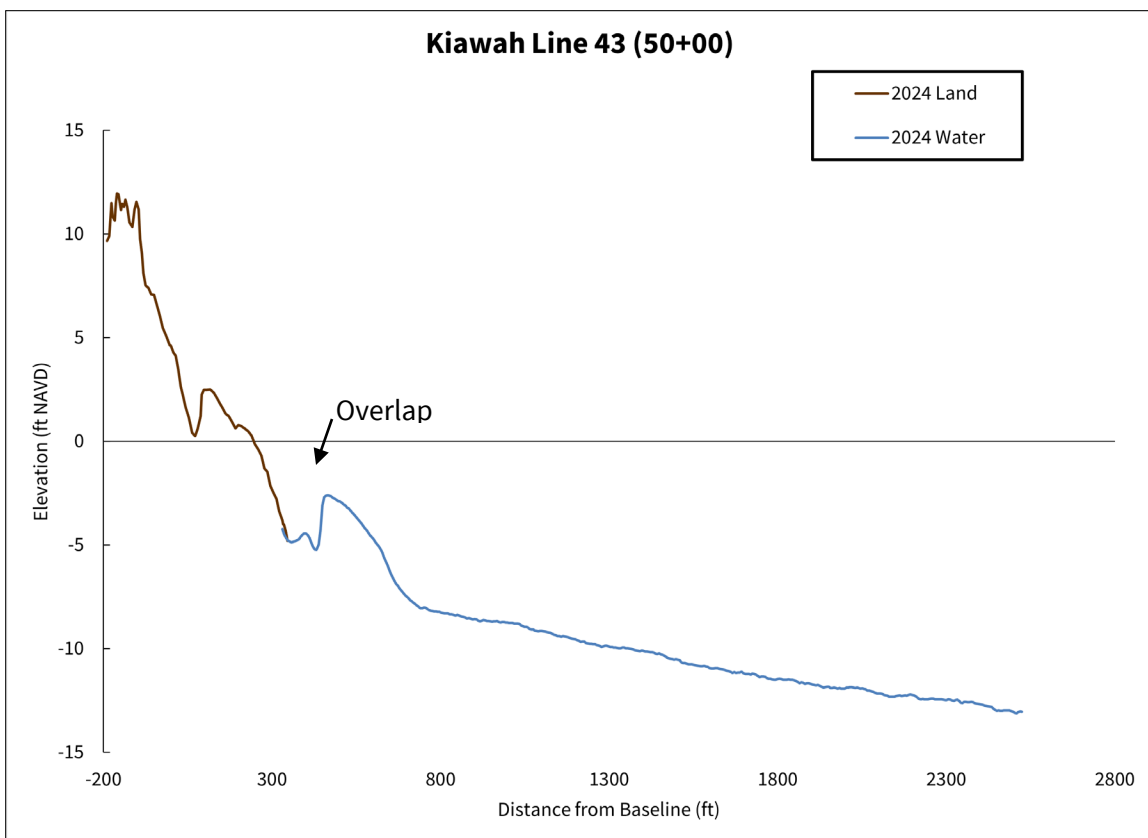
**FIGURE 3.1.**

CSE's monitoring methods include land-based data collection via RTK-GPS [UPPER LEFT] and hydrographic data collection via RTK-GPS linked to a precision echo-sounder. CSE's shallow-draft vessel, the *R/V Southern Echo*, is shown in the lower image.



Working around the tidal cycle, data collected on land extended into shallow depths at low tide. Data were collected from the boat at high tide to ensure overlap of the two surveys close to shore (Fig 3.2). Appendix A includes profiles for the most recent survey compared to earlier surveys. CSE has updated profile sheets to include profile volumes and aerial images showing profile locations.

Surveys conducted from 2007 to 2011 involved 23 stations west of the East End project area (using existing OCRM monuments spaced ~1,000 to 2,500 ft apart) and 64 stations in the project area spaced 400 ft apart. The present baseline reduces the maximum spacing in the downcoast profiles to ~1,000 ft. CSE also reduced the number of lines in the project area from 64 to 24 by increasing the spacing from 400 ft to between 1,000 and 1,200 ft. The baseline was also modified at the East End to reduce the number of azimuth changes, to simplify volume calculations.



**FIGURE 3.2.** CSE combines land-based and hydrographic data collection to produce continuous profiles of the beach. Land-based work is accomplished at low tide, while hydrographic work is performed at high tide. This allows for overlap of the two data collection methods and ensures quality data and a complete profile.

The present baseline anchors 61 profiles, with Lines 1–37 representing the shoreline west of the 2006 project and Lines 38–61 representing the project area and eastern end of the island (Table 3.1). The baseline is shown in Figure 2.3. Line numbering increases from west to east – Line 1 is near Captain Sams Inlet ~1.2 miles southwest of the Beachwalker Park vehicle access. Line 61 is at the tip of the sand spit at the junction of the Stono River and Penny’s Creek. OCRM monument names and CSE project stationing are indicated where the new profile lines coincide with previous stations (ie – Line 35 is OCRM station 2725). The current reaches (see Fig 2.3) are defined in Table 3.2.

Volume calculations for the lagoon were obtained via digital terrain models (DTMs) produced from CSE survey data. This eliminates the need for volume adjustments due to differing baseline and beach configurations. However, profiles are still used for inferring changes to the beach shape, position of shoals and channels, and berm elevations in this area.

### **3.2 Volume Calculations**

To estimate changes in the sand volume along Kiawah Island, survey data (collected in x-y-z format) were entered into CSE’s in-house custom software, Beach Profile Analysis System (BPAS), which calculates volumes based on 2D data (converted to x-z format along profiles) and distances between survey lines. The resulting volumes provide a quantitative method of determining beach condition, including the ideal minimum beach profile and how sand quantities at a site (volume per unit length of shoreline) compare with some desired condition (Kana 1993). Volume results calculated this way integrate all the small-scale perturbations across the beach and yield a simple measure of its condition. This measure is less susceptible to seasonal fluctuations in the profile, which is a common problem with shoreline change studies derived from a single contour or interpreted from aerial photos (like a wet-dry line or mean high water).

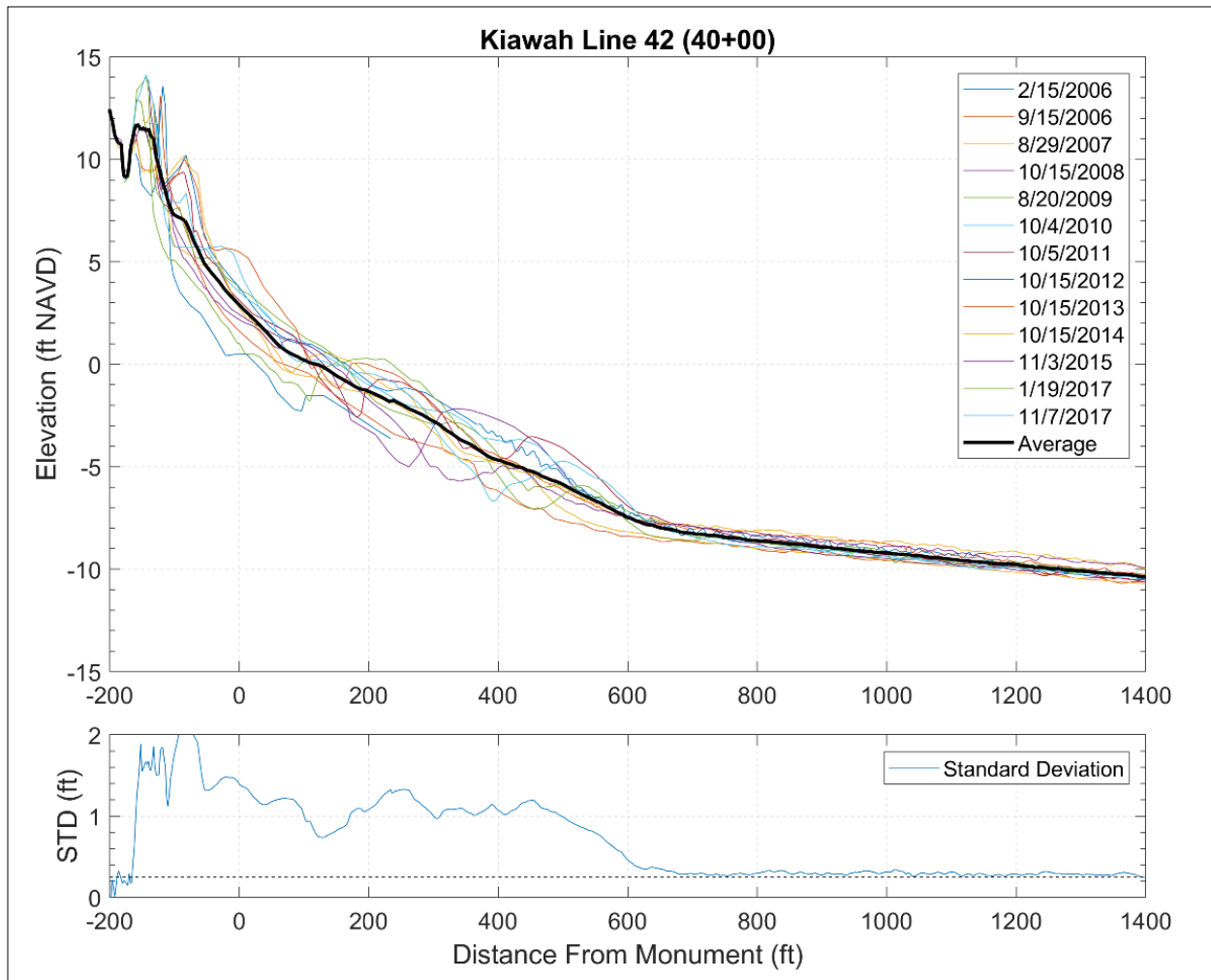
For the present survey, sand volumes were calculated between the primary dune and –10 ft NAVD. The –6 ft NAVD contour has been included in some reports for the sake of consistency with earlier studies and data collection limitations in reports before 2007. While most sand movement on Kiawah occurs above –6 ft NAVD, some profile changes do occur between –6 ft and –10 ft NAVD. Significant changes can occur within this lens when underwater bars form or change and as shoals move onshore and alter morphology. Especially along the dynamic northeastern end of the Island, volume calculations are cut off at a set distance due to data coverage or morphological considerations (ie – the profile flattens over the ebb-tidal delta before reaching –10 ft NAVD). Profiles and calculation limits are shown in Appendix A.

**TABLE 3.1.** Kiawah Island beach monitoring stations referenced in the present report. Order is generally west to east. Offset and cutoff refer to distances in feet from the benchmark/baseline for the start and end of beach volume calculations.

Reach	Line	Name	Offset	Cutoff	Distance to Next	Easting	Northing	Reach	Line	Name	Offset	Cutoff	Distance to Next	Easting	Northing	
1	1		-200	2,500	1,000	2262721.7	271034.2	3	32	OCRM 2720	208	1,500	645	2289526.0	282752.7	
	2		0	2,500	997	2263451.4	271718.0		33			309	1,700	646	2290143.9	282937.6
	3		250	2,500	1,153	2264178.6	272399.3		34	OCRM 2722		390	1,600	1,125	2290763.1	283122.9
	4	OCRM 2615	140	1,500	844	2265064.0	273138.6		35	OCRM 2725		322	1,600	666	2291875.6	283288.9
	5		93	2,500	845	2265739.8	273644.8		36	OCRM 2730		316	1,600	666	2292526.8	283430.6
	6	OCRM 2620	86	1,500	1,157	2266414.9	274152.4		37			300	1,700	752	2293263.8	283580.0
	7		95	2,500	978	2267397.7	274763.4		38	0+00		300	1,600	1,000	2294001.1	283729.5
	8	OCRM 2625	189	1,500	1,040	2268125.0	275417.0		39	10+00		165	1,700	1,000	2294999.2	283790.2
	9		100	1,500	806	2269055.6	275882.0		40	20+00		30	1,500	1,000	2295997.4	283850.9
	10	OCRM 2630	152	1,500	547	2269723.8	276332.8		41	30+00		-55	1,500	1,000	2296995.5	283911.6
2	11	OCRM 2635	41	1,500	1,232	2270247.2	276490.7	42	40+00		-140	1,500	1,000	2297993.6	283972.3	
	12	OCRM 2640	94	1,500	665	2271326.8	277083.3	43	50+00		-219	1,500	1,000	2298991.7	284033.0	
	13		67	1,400	665	2271935.3	277351.5	44	60+00		-295	1,500	1,000	2299989.8	284093.8	
	14	OCRM 2645	47	1,200	945	2272943.9	277619.7	45	70+00		-370	1,500	1,000	2300988.0	284154.5	
	15		27	1,400	946	2273408.4	278001.2	46	80+00		-300	1,500	1,000	2301986.1	284215.2	
	16	OCRM 2660	28	1,100	1,025	2274273.9	278383.2	47	90+00		-374	1,800	1,000	2302984.2	284275.9	
	17		15	1,400	1,026	2275234.5	278740.9	48	100+00		-250	2,000	1,000	2303982.3	284336.6	
	18	OCRM 2665	5	1,000	691	2276196.1	279099.0	49	110+00		0	2,500	1,000	2304980.4	284397.3	
	19		0	1,400	692	2276850.6	279320.6	50	120+00		350	3,200	1,000	2305978.6	284458.0	
	20	OCRM 2675	0	1,100	831	2277505.6	279542.3	51	130+00		780	3,500	1,000	2306976.7	284518.8	
3	21	OCRM 2680	46	1,300	1,266	2278288.1	279822.4	52	140+00		1100	3,500	1,000	2307974.8	284579.5	
	22		0	1,400	1,267	2279502.6	280179.9	53	150+00		500	2,800	1,000	2308972.9	284640.2	
	23	OCRM 2685	10	1,200	1,033	2280718.1	280537.6	54	160+00		65	1,500	1,000	2309971.0	284700.9	
	24	OCRM 2687	40	1,500	1,215	2281707.1	280837.2	55	170+00		-775	1,000	0	2310969.2	284761.6	
	25	OCRM 2690	80	1,300	1,145	2282876.3	281167.0	56	Inlet 0+00		300	1,300	1,200	2310528.3	285452.3	
	26	OCRM 2692	279	1,500	1,205	2283935.3	281602.5	57	Inlet 12+00		700	1,420	1,200	2309882.6	286463.7	
	27	OCRM 2695	119	1,400	1,080	2285131.1	281719.2	58	Inlet 24+00		900	1,420	1,200	2309237.0	287475.2	
	28	OCRM 2700	100	1,400	1,269	2286187.8	281943.8	59	Inlet 36+00		920	1,420	1,200	2308591.3	288486.6	
	29	OCRM 2705	130	1,500	635	2287413.8	282268.9	60	Inlet 48+00		912	1,720	1,200	2307945.7	289498.1	
	30		143	1,500	643	2288034.7	282401.8	61	Inlet 60+00		640	1,520	0	2307300.1	290509.5	
31	OCRM 2715	145	1,500	889	2288663.4	282536.4										

**TABLE 3.2.** Kiawah Island reaches referenced in the present report.

Reach	Approximate Geographic Boundaries	Line Numbers	Reach Length (ft)
Kiawah Spit	West end of Kiawah Island to Beachwalker Park	1-10	8,820
West Beach	Beachwalker Park to Turtle Point	10-23	11,798
Turtle Point	Turtle Point Area	23-38	13,614
Ocean Course	Ocean Course Area	38-47	9,000
Lagoon	Lagoon Area	47-55	8,000
Stono Inlet	Stono Inlet Shoreline	56-61	6,000



**FIGURE 3.3.** Comparison of repetitive profiles at a monitoring station along Kiawah Island and computation of standard deviation. Where the profiles converge, the standard deviation is low and is an indicator of little sediment exchange (approximate closure depth).

Figure 3.3 shows a representative profile from Kiawah Island over an approximate 12-year period. The lower portion of the graph tracks the standard deviation in elevation based on the mean profile elevation of the set of profiles at the station. A standard deviation of <0.25 ft over several hundred feet at the outer end of a profile is evidence of little change in bottom elevation over the data collection period. This statistically confirms nearly all measurable volume changes along Kiawah occur above -10 ft NAVD, and a realistic value for depth of closure (DOC) at decadal-or-longer time scales is ~-10 ft NAVD (see Barrineau et al., 2019 for a more detailed discussion).

DOC is the depth where little sand movement to or from the beach occurs. At longer time scales (eg - 10 yrs), or under storm conditions with rough waves, DOC may become deeper. However, our surveys account for the vast majority of sand movement under 'normal' conditions. Unit-volume calculations allow us to distinguish the quantity of sediment at different lens depths, for instance in the dunes, on the dry beach, in the intertidal zone, and beyond wading depth. Reference boundaries are site-specific but ideally encompass the entire zone over which sand moves in a given year. This means the survey data incorporate all changes from the dune to the DOC, which constitutes the 'active beach system' under normal conditions.

Unit volumes for each survey date and unit volume changes between selected dates were used to calculate the net volume between stations (called the 'profile volume'). Profile volumes are generated using the average-end-area method. In this method, the average of the area under two profiles at either end of a length of shoreline is multiplied by the length of the cell to determine the total volume between the two stations. When these profile volumes are added for discrete portions of the shoreline, they represent sub-reach and reach volumes and, finally, the net volume for the entire project area.

These net volumes by reach can be subdivided by applicable reach lengths to yield weighted average unit volumes. The weighting considers the variations in applicable shoreline distances between individual stations. If they are not evenly spaced, the station-to-station net volumes will be proportional to the distance between stations, and some accuracy in reach- or project-wide profile volumes will be lost. Changes in unit volume can be determined by comparing individual surveyed profiles and computing differences in cross-sectional areas. The change in cross-section can be extrapolated (1) over a 1-ft length of shoreline to yield unit volume changes (in cy/ft) and (2) over a much longer section of beach to yield net volume changes in that particular section of shoreline.

## 4.0 RESULTS

---

### 4.1 Beach Volume Changes (October 2023 – December 2024)

Reach volume changes are reported from the island's eastern end (Reach 6 – Stono Inlet) to the western end (Reach 1 – Captain Sams Spit). Unit volumes for each station are provided in Table 4.1, and volumes for each reach are provided in Table 4.2. Between October 2023 and December 2024, portions of Kiawah Island along the East End lost sand as part of the shoal bypass mentioned in Section 2.1.1. The Ocean Course Reach gained significant sand volume over the last year, and the downcoast reaches lost sand at moderate rates.

#### 4.1.1 Reach 6 – Stono Inlet

Stono Inlet (Reach 6) spans ~6,000 ft from Line 56 to Line 61 (see Fig 2.3). Beach profiles in this reach are steeper than the oceanfront reaches due to the presence of Stono Inlet and sheltering from large waves—beach steepness is inversely proportional to wave energy and directly proportional to sediment grain size (Komar 1998). Unit volumes from Stono Inlet are shown in Figure 4.1. Between October 2023 and December 2024, the Stono Inlet Reach lost ~40,100 cy (–6.7 cy/ft) of volume (Table 4.2).

Erosion along Stono Inlet generally decreases and transitions to accretion moving from the 'corner' of the island inland (~northwest) up Stono River as exposure to larger northeasterly waves decreases. Unit volumes decreased by 371.4 cy/ft since August 2007 at Line 56 and increased by 117 cy/ft at Line 61 over the same period. Erosion at Station 56 is related to shifting bars and shoals around the northeastern 'corner' of Kiawah Island, while eroded material makes its way north and west toward Line 61 inside the inlet. From November 2019 to November 2022, volume increases observed at Line 56 likely reflected additions of sand from a shoal migrating onshore near that location. Since October 2023, that trend reversed, and Line 56 has started eroding. As of December 2024, the erosion trend continued at 48.2 cy/ft—at a higher rate than other lines in Reach 6 to the east and Lines 54 and 55 in the adjacent Reach 5 (Lagoon Reach) to the west.

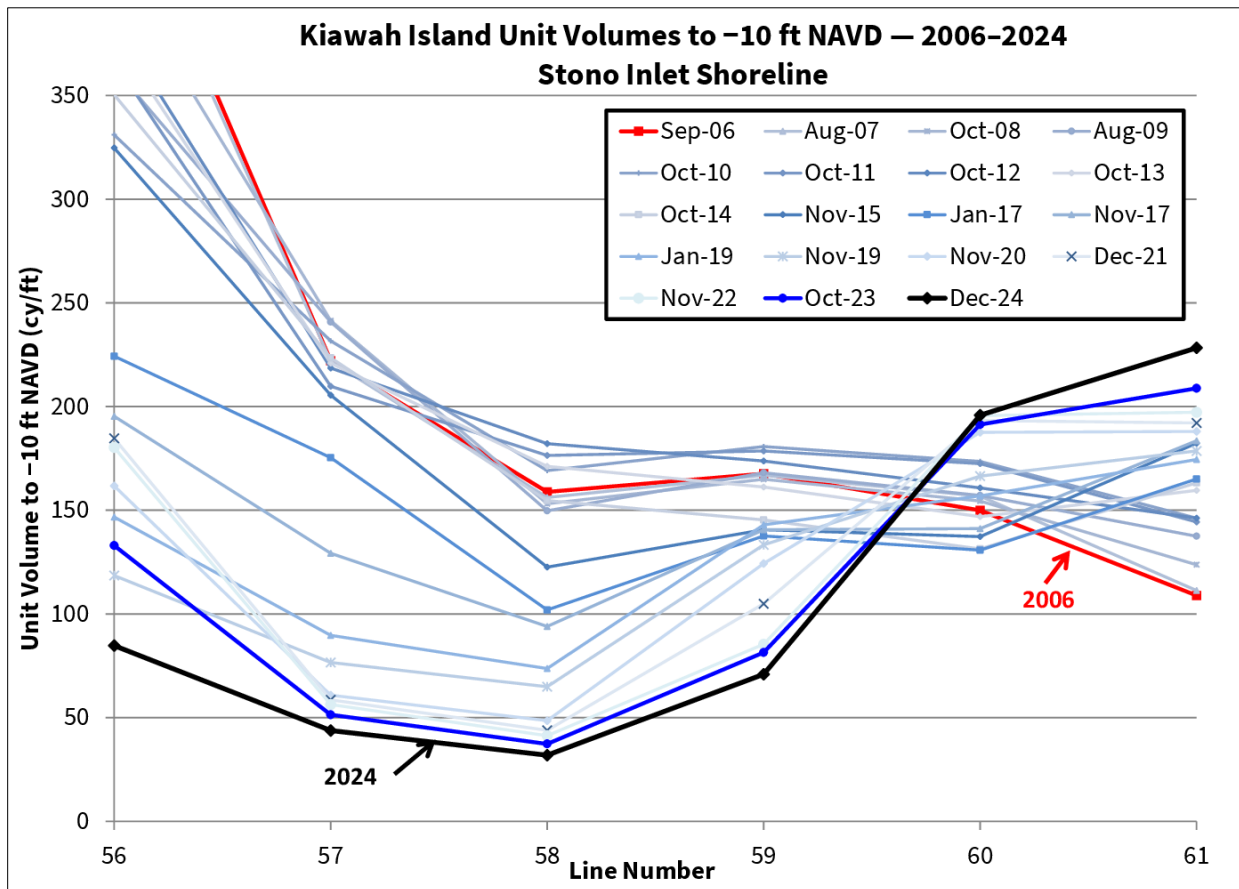
The occurrence of erosion and accretion in close proximity, and transitions between those states in successive survey years, is due to the movement of shoals around Stono Inlet along this reach. The magnitude of changes associated with shoal attachments is proportional to the size of the shoal and proximity to the area where the shoal attaches to the beach. This influence tends to decrease over time as the shoals fully attach, with periods of both accretion and erosion depending on the size and alongshore extent of the shoal. This is why the rates of change observed in Reach 6 tend to be smaller than those in Reach 5 and Reach 4 (discussed below). The largest shoals tend to attach along those reaches rather than along Reach 6.

**TABLE 4.1.** Unit volumes\* for monitoring profiles at Kiawah Island (measured to -10 ft NAVD).

Kiawah Island 2024 (Dec) Monitoring Survey			Unit Volume (cy/ft)																							
Reach	Line	Distance to Next (ft)	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24				
1 - Kiawah Spit	1	1,000	465.5		608.4	608.5	607.7	630.6	607.9	601.9	577.7	576.6	694.4	667.9	592.4	479.6	485.4	573.7	537.6	584.3	528.3	604.1				
	2	997	378.4		494.6	494.7	494.0	512.7	494.2	489.3	494.0	477.6	362.0	406.0	435.3	379.0	400.6	422.6	378.3	419.4	395.6	406.7				
	3	1,153	262.7		343.4	343.4	342.9	355.9	343.1	339.7	346.1	337.0	252.8	256.5	302.0	296.9	278.0	271.2	266.2	275.2	253.6	256.1				
	4	844	300.2		392.4	392.4	391.9	406.7	392.1	388.2	384.7	387.0	360.9	330.5	325.6	340.4	331.9	336.2	327.3	325.8	308.5	308.9				
	5	845									384.3	384.5	386.4	372.2	351.2	341.0	292.9	342.9	349.5	340.4	336.9	333.3	328.5			
	6	1,157	252.5		361.9	361.1	375.2	384.1	380.9	384.5	384.0	386.0	378.2	357.1	349.6	340.4	350.3	357.5	345.9	339.4	337.2	328.2				
	7	978									316.7	315.3	312.7	310.8	300.4	293.9	296.0	292.6	296.0	289.1	290.4	287.4	283.4			
	8	1,040	240.1		309.0	309.9	321.6	334.7	331.0	347.6	353.8	346.8	340.1	334.3	337.0	332.1	326.9	331.6	328.9	325.0	325.7	323.4				
	9	806									334.9	335.6	334.6	329.3	320.7	321.5	321.7	324.5	326.3	322.9	314.5	322.2	319.7			
2 - West Beach	10	547	260.3		300.9	299.1	303.6	318.7	317.3	335.8	339.8	339.1	333.3	323.1	328.4	328.4	330.9	328.3	327.5	326.0	325.6	312.9				
	11	1,232	255.0		289.3	290.4	300.2	307.1	312.3	323.8	324.3	325.1	320.0	314.6	317.4	326.1	318.2	325.7	324.2	316.3	318.0	303.0				
	12	665	232.5		261.1	257.9	273.1	273.1	275.4	284.8	293.0	294.6	292.5	278.8	285.4	292.5	285.8	298.7	297.0	290.7	291.3	281.4				
	13	665								277.8	281.6	287.8	287.3	276.7	274.0	285.3	285.2	287.6	288.2	283.7	283.1	276.6				
	14	945	251.9		252.3	248.5	257.7	258.2	259.3	270.8	278.3	280.9	276.1	272.5	269.5	273.8	273.0	280.8	278.2	277.8	274.2	269.1				
	15	946								268.1	273.7	279.5	273.5	269.0	264.9	271.1	269.4	274.3	273.3	276.9	276.3	263.4				
	16	1,025	235.6		254.5	252.6	258.3	260.3	253.0	265.4	269.6	278.3	277.4	268.6	270.2	267.8	270.5	273.4	271.6	277.8	278.0	273.3				
	17	1,026								251.7	256.6	261.8	257.4	251.9	251.3	249.7	250.6	250.1	252.9	253.7	260.0	259.1				
	18	691	242.2		251.2	243.9	245.2	246.7	242.8	252.0	262.1	267.4	259.9	252.8	249.7	254.3	248.2	261.7	257.8	262.1	261.6	256.8				
	19	692								252.1	254.6	257.9	261.7	233.2	245.0	251.3	249.1	252.4	252.5	255.3	255.3	256.6				
	20	831	272.6		243.8	239.0	239.3	238.1	239.8	248.2	253.0	260.3	261.7	240.6	240.5	252.9	247.4	250.9	245.9	251.2	250.1	250.5				
	21	1,266				222.0	220.0	226.8	234.0	238.9	235.1	243.8	231.8	231.4	240.2	228.5	234.1	233.0	234.1	241.3	240.3					
22	1,627								258.2	257.5	267.0	271.9	252.0	267.4	262.2	265.1	263.8	260.1	267.7	269.8	265.4					
3 - Turtle Point	23	1,033	234.3		253.9	249.0	252.2	253.0	257.3	261.3	271.3	270.5	285.4	272.7	271.5	275.0	272.4	267.2	273.5	278.0	278.1	277.0				
	24	1,215				257.1	255.4	259.3	265.6	274.8	285.7	291.6	273.7	273.4	286.8	282.1	281.3	288.1	288.5	292.3	294.7					
	25	1,145	229.2		260.3	254.0				271.9	280.7	291.7	299.0	274.0	278.7	283.9	284.5	290.1	287.4	288.1	295.9	294.1				
	26	1,205				259.9	251.5	258.0	265.2	278.2	294.2	291.0	276.1	279.9	283.0	276.7	290.2	287.8	288.2	298.0	282.9					
	27	1,080	266.2		262.7	274.3	279.7	270.2	277.2	287.6	304.5	314.5	324.5	307.8	306.5	311.6	302.3	304.8	302.2	307.8	317.6	313.1				
	28	1,269	299.2		278.2	291.8	295.2	292.3	300.8	307.4	323.9	336.5	343.9	333.2	323.5	327.5	321.7	322.6	319.8	331.8	331.5	332.7				
	29	635	268.3		321.9	313.4	325.8	323.1	322.1	344.5	360.4	370.5	381.7	368.2	365.6	358.8	359.6	354.2	360.6	371.1	376.8	364.7				
	30	643								345.7	354.7	369.1	384.0	364.4	360.7	361.3	358.7	348.9	349.5	359.8	371.3	354.3				
	31	889	265.3		322.6	325.1	326.1	331.3	326.6	346.8	353.7	373.8	382.8	372.2	360.9	355.5	348.3	352.7	352.9	352.9	361.3	352.9				
	32	645	286.4		306.2	302.0	306.9	309.3	305.3	323.3	330.2	351.9	354.5	349.2	335.1	334.6	329.6	332.3	321.3	325.7	334.5	324.6				
	33	646								282.4	289.6	310.3	318.6	289.1	297.4	294.2	289.4	295.1	287.3	292.5	295.8	288.1				
	34	1,125				254.9	260.5	256.0	272.8	280.6	287.1	296.6	281.3	272.9	268.3	272.7	259.4	262.5	260.1	263.7	258.4					
	35	666	217.0		252.1	250.3	253.3	254.3	245.3	269.3	267.0	273.8	277.2	273.3	264.2	256.2	258.5	239.5	253.3	240.9	247.8	241.3				
	36	666	252.2		257.4	204.3	259.9	263.7	258.2	275.8	275.7	276.7	279.8	275.0	265.2	259.1	261.3	251.0	255.3	252.8	252.4	248.5				
	37	752								283.9	288.2	285.3	288.7	267.7	269.4	262.6	250.4	245.1	254.5	252.2	260.6	247.5				
4 - Ocean Course	38	1,000		255.8	260.4	261.1	264.7	269.7	264.0	280.1	279.4	282.8	273.3	260.4	260.7	260.8	259.7	249.4	248.0	254.4	259.1	244.8				
	39	1,000								277.5	276.9	271.5	270.5	256.5	258.4	257.2	250.7	255.2	249.3	249.8	265.9	248.6				
	40	1,000		253.1	251.6	257.3	276.6	279.3	277.3	288.9	291.4	286.3	279.5	255.7	266.1	276.5	273.9	266.0	264.0	278.1	287.2	276.6				
	41	1,000								285.1	274.2	289.1	264.9	235.5	263.2	273.5	274.8	265.4	268.0	282.1	289.6	275.7				
	42	1,000		231.3	247.4	262.8	273.9	287.0	288.0	297.0	297.7	291.4	262.4	255.0	269.6	295.4	296.1	290.1	302.1	311.1	317.3	302.6				
	43	1,000								326.2	311.1	325.0	299.5	310.0	312.8	345.6	353.5	346.7	368.3	370.5	381.0	386.0				
	44	1,000		294.9	355.1	346.9	351.5	362.9	356.3	371.2	364.1	424.1	514.2	429.6	419.1	441.0	454.0	473.0	447.9	461.2	469.6	480.1				
	45	1,000								454.2	527.4	531.0	524.0	547.2	547.7	573.0	593.8	584.5	572.6	572.2	530.1	577.4				
	46	1,000		505.6	500.1	453.5	465.3	441.4	486.7	537.7	572.5	551.5	581.0	651.8	633.4	646.9	651.6	621.5	601.1	560.7	572.9	709.5				
5 - Lagoon	47	1,000							647.9	686.4	848.6	934.2	982.2	953.1	901.7	858.0	816.2	788.1	751.1	954.0	977.0					
	48	1,000		617.4	578.8	541.8	561.5	562.6	689.5	758.3	839.2	879.5	903.6	898.4	904.3	862.9	830.8	819.7	786.8	955.6	1489.2	1475.1				
	49	1,000							980.1	978.1	959.2	921.1	959.7	932.6	887.6	938.1	1003.5	1034.3	1044.1	1230.1	1186.9					
	50	1,000							1012.4	1005.7	1025.4	1025.9	957.2	896.5	891.2	859.9	1011.1	1207.9	1267.9	1282.0	1096.0					
	51	1,000							929.1	838.9	799.5	779.4	733.9	734.8	698.8	703.6	689.6	752.4	784.3	865.0	789.0					
	52	1,000							708.2	622.4	561.9	541.3	480.5	472.6	465.6	414.7	349.6	344.6	426.6	434.2	409.1					
	53	1,000							761.9	711.5	636.9	529.2	472.9	455.8	429.1	426.6	414.2	379.5	401.8	411.7	441.0					
	54	1,000							574.6	563.2	519.3	414.7	357.1	342.5	330.6	319.4	306.0	266.9	252.3	263.2	234.6					
	55	0								588.4	621.0	602.3	579.0	560.6	537.3	463.4	436.5	399.6	371.1	340.4	348.9	339.0				
6 - Stano Inlet	56	1,200		465.8	456.2	413.3	363.2	331.0	366.5	385.7	378.6	350.4	324.7	224.3	195.3	146.7	118.5	161.8	184.7	180.3	132.9	84.7				
	57	1,200		222.1	221.9	241.5	240.8	231.6	209.8	218.6	220.9	223.5	205.4	175.3	129.3	89.7	76.6	60.9	58.6	56.3	51.4	43.8				
	58	1,200		158.9	156.1	153.2	149.7	169.2	176.4	182.1	171.1	154.6	122.6	101.9	94.0	73.7	64.9	48.5	43.9	41.3	37.3	31.9				
	59	1,200		167.6	166.9	164.9	168.1	180.7	178.6	173.7	161.1	145.3	140.6	137.7	140.6	142.9	133.3	124.3	104.9	85.4	81.4	70.9				
	60	1,200		150.0	156.8	154.5	157.1	173.5	172.5	160.8	146.9	131.3	137.2	130.8	141.2	156.9	166.5	187.6	1							

**TABLE 4.2.** Total reach volumes, weighted unit volume, by volume by reach, net reach volume changes and weighted average unit volume changes since the previous survey.

Reach	Name	Length	Reach Total Volume (cy)																			
			Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820	2,527,990		3,309,434	3,308,176	3,300,442	3,360,442	3,482,539	3,403,430	3,385,060	3,387,780	3,355,774	2,425,028	2,421,235	2,587,554	2,516,429	2,574,957	2,505,765	2,513,897	2,460,921	2,442,459
2	West Beach	11,798	2,925,119		3,018,972	2,973,269	3,002,942	3,016,726	3,023,391	3,143,512	3,200,438	3,247,900	3,246,474	3,103,992	3,123,811	3,186,466	3,153,949	3,204,546	3,190,781	3,207,666	3,221,570	3,188,775
3	Turtle Point	13,614	3,119,193		3,789,036	3,711,347	3,791,866	3,780,710	3,783,778	3,973,563	4,103,355	4,242,815	4,133,108	4,063,240	4,087,555	4,041,965	4,019,325	4,036,192	4,068,888	4,149,913	4,149,913	4,089,060
4	Ocean Course	9,000		2,881,490	3,009,223	2,946,188	3,047,330	3,071,534	3,182,156	3,301,984	3,403,064	3,536,481	3,562,542	3,577,236	3,690,347	3,707,191	3,656,228	3,591,481	3,588,428	3,588,428	3,720,025	3,667,368
5	Lagoon	8,000		6,559,380	6,462,016	6,840,138	7,055,611	7,419,125	7,222,197	7,071,272	6,946,031	6,963,814	6,787,731	6,325,250	6,139,964	5,939,621	5,936,206	6,198,619	6,005,064	6,198,619	7,436,847	6,901,983
6	Stono Inlet	6,000		1,454,655	1,467,076	1,447,219	1,406,546	1,422,719	1,427,296	1,448,765	1,408,636	1,328,592	1,248,369	1,082,076	965,215	845,351	707,763	715,353	706,507	880,859	638,772	598,701
1-6	All	57,232	21,028,157		21,664,658	22,193,353	22,042,249	22,324,146	22,483,334	22,704,776	21,637,039	20,604,203	20,478,010	20,265,811	20,092,373	20,348,028	20,635,179	21,396,500	21,627,047	21,028,326		
Reach Unit Volume (cy/ft)																						
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820	286.6		375.2	375.1	381.0	394.8	385.9	368.8	384.1	380.5	275.1	274.5	293.4	285.3	288.6	291.9	284.1	285.0	279.0	276.9
2	West Beach	11,798	247.9		259.9	262.0	254.5	257.7	266.3	266.4	271.3	275.3	275.2	263.6	264.8	270.1	267.3	271.6	270.5	271.9	273.1	267.7
3	Turtle Point	13,614	229.1		276.8	272.6	278.5	277.7	277.9	291.9	301.4	311.7	318.0	303.6	299.9	300.2	296.9	296.2	266.4	298.9	304.8	288.2
4	Ocean Course	9,000		320.2	334.2	327.4	338.6	341.3	353.6	366.9	378.1	382.8	400.0	365.8	367.5	410.0	411.9	403.9	366.1	368.7	413.3	429.7
5	Lagoon	8,000		819.9	807.8	855.0	882.0	927.4	902.8	889.9	888.3	874.2	848.5	790.7	767.5	742.5	742.0	774.8	825.6	917.1	929.5	862.7
6	Stono Inlet	6,000		244.1	243.3	241.2	234.4	237.1	237.9	241.5	234.8	221.5	208.1	176.3	161.0	140.9	118.0	119.2	117.8	113.5	106.5	99.8
1-6	All	57,232	367.4		370.9	378.5	387.8	385.1	385.1	390.1	392.3	396.7	378.1	380.0	367.8	354.1	351.1	355.5	380.6	373.9	371.9	367.4
Reach Volume Change Since Previous (cy)																						
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820			-1,268	52,295	122,097	-79,109	-18,370	-18,370	2,719	-32,006	-929,746	-4,793	166,319	-71,125	28,879	29,649	-69,192	8,132	-52,977	-18,462
2	West Beach	11,798			-45,703	29,573	13,884	13,884	6,655	120,120	56,926	47,462	-1,426	-136,481	13,818	62,656	-32,517	50,588	-13,765	16,875	13,914	-62,795
3	Turtle Point	13,614			-56,889	80,539	-11,776	3,068	1,068	189,784	129,833	136,419	85,943	-195,560	-49,889	4,366	-45,630	-22,641	15,867	33,697	81,024	-90,882
4	Ocean Course	9,000			126,733	-62,036	101,144	24,202	110,622	119,828	101,070	132,427	64,299	-37,239	14,695	113,111	16,844	-71,993	-43,747	-3,063	131,597	147,333
5	Lagoon	8,000			378,122	215,473	363,514	-196,328	-160,924	-125,241	-125,241	47,784	-206,084	-462,481	-185,256	-200,333	-3,415	262,413	406,434	731,518	99,276	-538,864
6	Stono Inlet	6,000			-12,867	-4,620	16,174	4,577	21,459	21,459	-40,119	-75,644	-80,624	-196,292	-85,861	-120,864	-137,598	7,600	-8,446	-26,048	-42,088	-40,071
1-6	All	57,232			199,890	438,321	528,695	-151,105	281,897	281,897	125,188	255,442	-1,067,737	-1,032,836	-128,194	-212,199	-173,437	255,655	287,151	761,120	230,747	-588,721
Reach Unit Volume Change Since Previous (cy/ft)																						
Reach	Name	Length	Apr-99	Sep-06	Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15	Jan-17	Nov-17	Jan-19	Nov-19	Nov-20	Dec-21	Nov-22	Oct-23	Dec-24
1	Kiawah Spit	8,820			0.0	-0.1	5.9	13.8	-9.0	-2.1	0.3	-3.6	-106.4	-0.5	18.9	-8.1	3.3	3.4	-7.8	0.9	-6.0	-2.1
2	West Beach	11,798			0.0	-3.9	2.5	1.2	0.6	10.2	4.8	4.0	-0.1	-11.6	1.2	5.3	-2.8	4.3	-1.2	1.4	1.2	-5.3
3	Turtle Point	13,614			0.0	-4.2	5.9	-0.8	0.2	13.9	9.5	10.2	6.3	-14.4	-3.7	0.3	-3.4	-1.7	1.2	2.5	6.0	-6.7
4	Ocean Course	9,000			14.1	-6.9	11.2	2.7	12.3	13.3	11.2	14.7	7.1	-4.1	1.6	12.6	1.9	-8.0	-4.9	-0.3	14.6	16.4
5	Lagoon	8,000			-12.2	47.3	26.9	45.4	-24.6	-18.9	-15.7	6.0	-26.8	-57.8	-23.2	-25.0	-0.4	32.8	50.8	91.4	12.4	-66.7
6	Stono Inlet	6,000			-0.8	-2.1	-6.8	2.7	0.8	3.6	-6.7	-13.3	-13.4	-32.7	-14.3	-20.1	-22.9	1.3	-1.4	-4.3	-7.0	-6.7
1-6	All	57,232			0.0	3.5	7.7	9.2	-2.6	4.9	2.2	4.5	-18.7	-18.0	-2.2	-3.7	-3.0	4.5	5.0	13.3	4.0	-10.5



**FIGURE 4.1.** Unit volumes for stations along the Stono Inlet Reach. Line numbers run east to west, into the inlet along this reach.

Overwash has shifted the dry beach landward over the last few years. As beach sand is transported into the marsh and out of the active beach-dune system, the shoreline recedes. Since ~2019, some overwash deposits have begun encroaching upon uplands located along the 1989 shoreline ('A,' Fig 4.2). As the deposits have 'run out of room,' they have been redistributed alongshore, and some minor dune scarping has been observed. At the same time, some of these overwash deposits continue to move landward over lower-elevation marsh ('B,' Fig 4.2). This phenomenon can result in uneven rates of shoreline retreat and offsets in the position of mean high water.

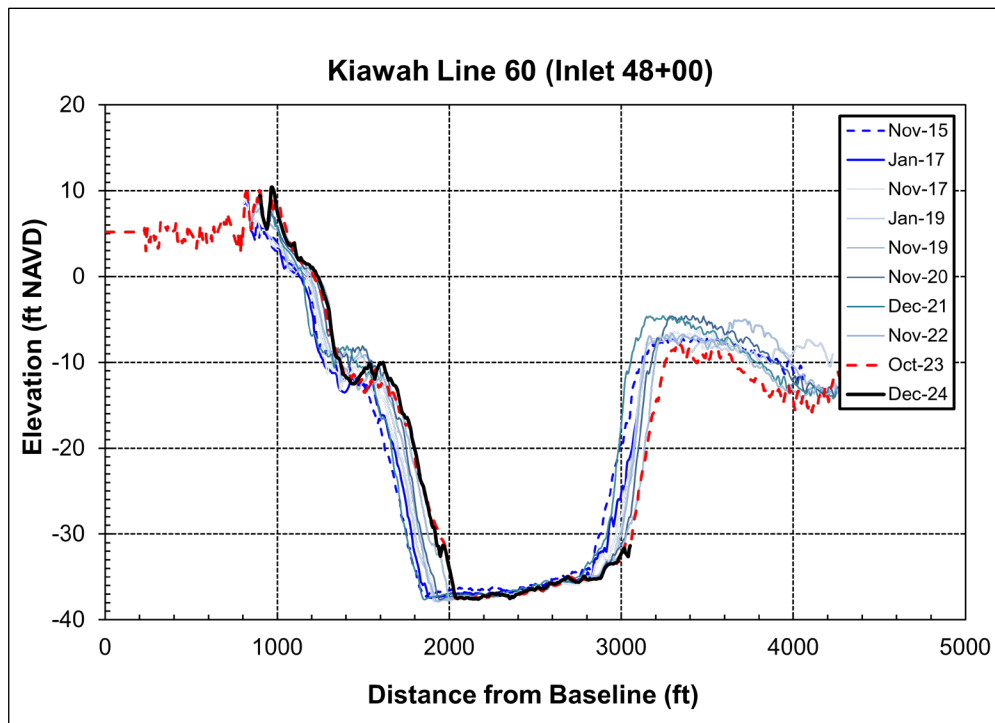
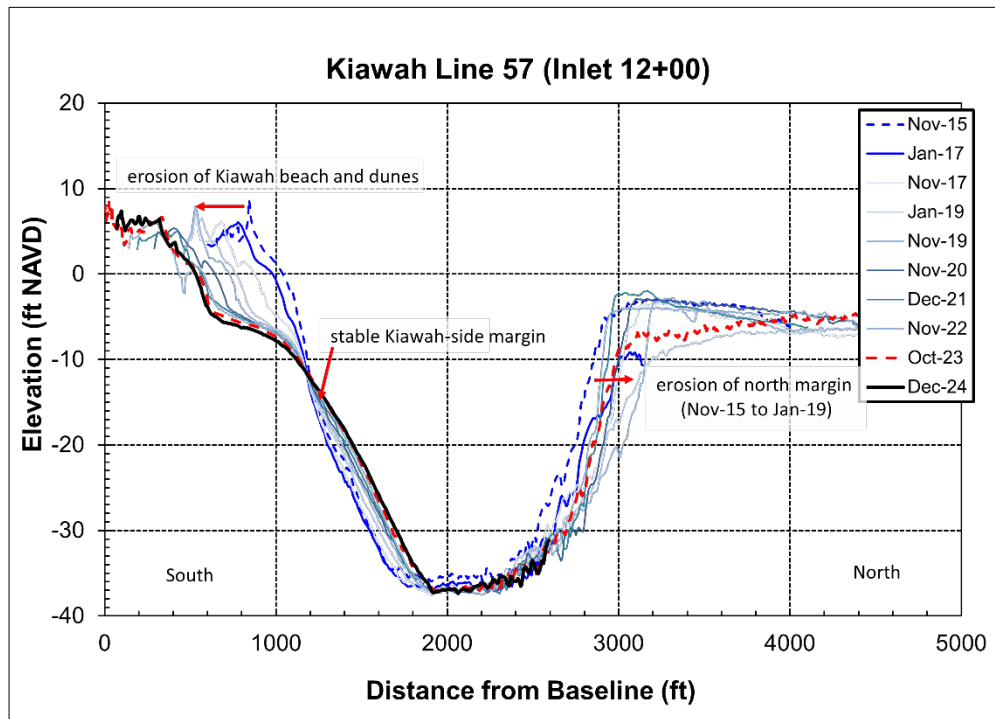
As the shoal along Lagoon Reach continues attaching to the East End, sand has spread laterally into Stono Inlet and the Ocean Course Reach. Accretion along Reach 6 since November 2020 reflects this ongoing process (see Fig 4.1).

While the predominant shoreline trend along the Stono Inlet Reach has been erosion out to the -10 ft contour, the main channel of the inlet has not encroached further into Kiawah Island. Figure 4.3 shows cross-inlet profiles for Stations 57 and 60 for the period of November 2015 to December 2024.

The underwater margin of the channel has shifted over 100 ft northward. However, the flow cross-section and maximum depth have generally remained constant. Like many drowned coastal plain rivers along the South Carolina coast, Stono Inlet has remained “positionally stable” and deeply incised into the consolidated sediments underlying Charleston. Major shoreline recession at Line 57 is confined to the upper part of the profile.



**FIGURE 4.2. [UPPER]** November 2024 aerial image of Stono Inlet Reach, showing the easternmost tidal creek (upper right corner) draining the marsh as well as portions of overwash and non-overwash beach in close proximity (to either side of Point A). It is likely the oncoming shoal will help to mitigate some of this variation and provide a reservoir of beach sand to help re-establish a dune and beach ridge to protect the marshes around Stono Inlet Reach. **[LOWER]** Ground photos reflect the difference in beach condition along scarped and overwashed portions of the reach.

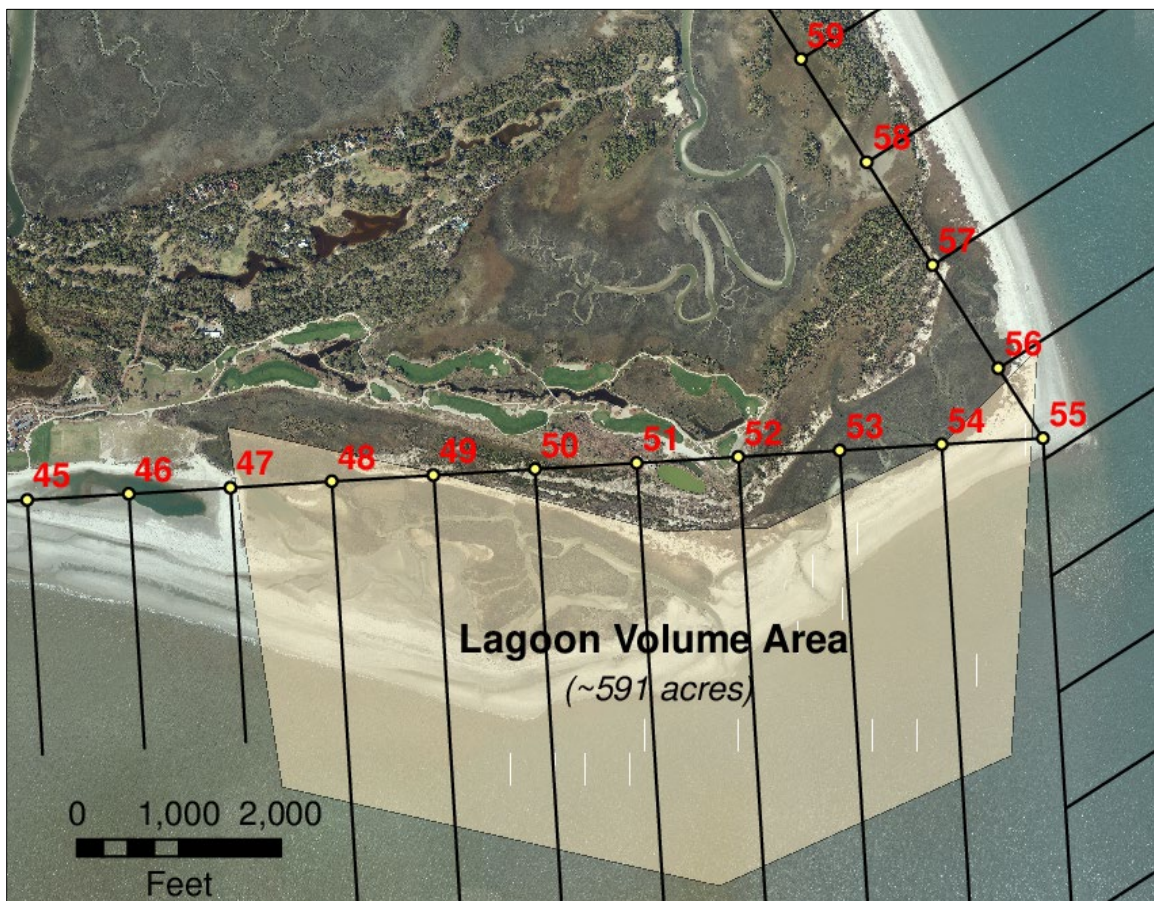


**FIGURE 4.3.** Profiles from Line 57 [UPPER] and Line 60 [LOWER] along the Stono Inlet shoreline. Hurricane *Matthew* eroded all of the remaining dunes in 2016. The berm shifted over 100 ft landward in 2017 (due largely to impacts of Hurricane *Irma*).

#### 4.1.2 Lagoon Reach

The Lagoon Reach spans 8,000 ft from Line 47 to Line 55 at the eastern point of the island (Fig 4.4). Monitoring reports for the 2007–2011 surveys subdivided this reach into the eastern and western lagoons. The 2012 report combined these reaches and adjusted the baseline to simplify data collection and reporting, and the present report continues this method. This reach encompasses the area of the island most influenced by shoal bypass events (see Section 1 and Fig 4.5). The Lagoon Reach lost ~533,900 cy (-66.7 cy/ft) above -10 ft NAVD between October 2023 and December 2024.

Due to technical and logistical limitations in this reach, CSE computes beach volumes using digital terrain models (DTMs) created from survey data. These volumes represent the volume of sand within the established boundaries and to a set depth. The analogy of a sandbox is often used to describe this method, whereby the volume of sand is measured within the same sandbox each year. DTMs are also used to create contours at specified elevations for each survey, which can then be compared to provide a visual representation of horizontal shoreline change.



**FIGURE 4.4.** The Lagoon Reach extends from Line 47 to Line 55. Due to the dynamic nature of the area, the total volume for this reach is calculated from DTMs within the boundaries shown here (image: March 2018).



**FIGURE 4.5.** October 2024 aerial images of the Lagoon Reach. The 2015 dike is visible in the foreground of the upper image, while only one of the two channels created during hurricanes *Matthew* and *Irma* is visible in the lower image.

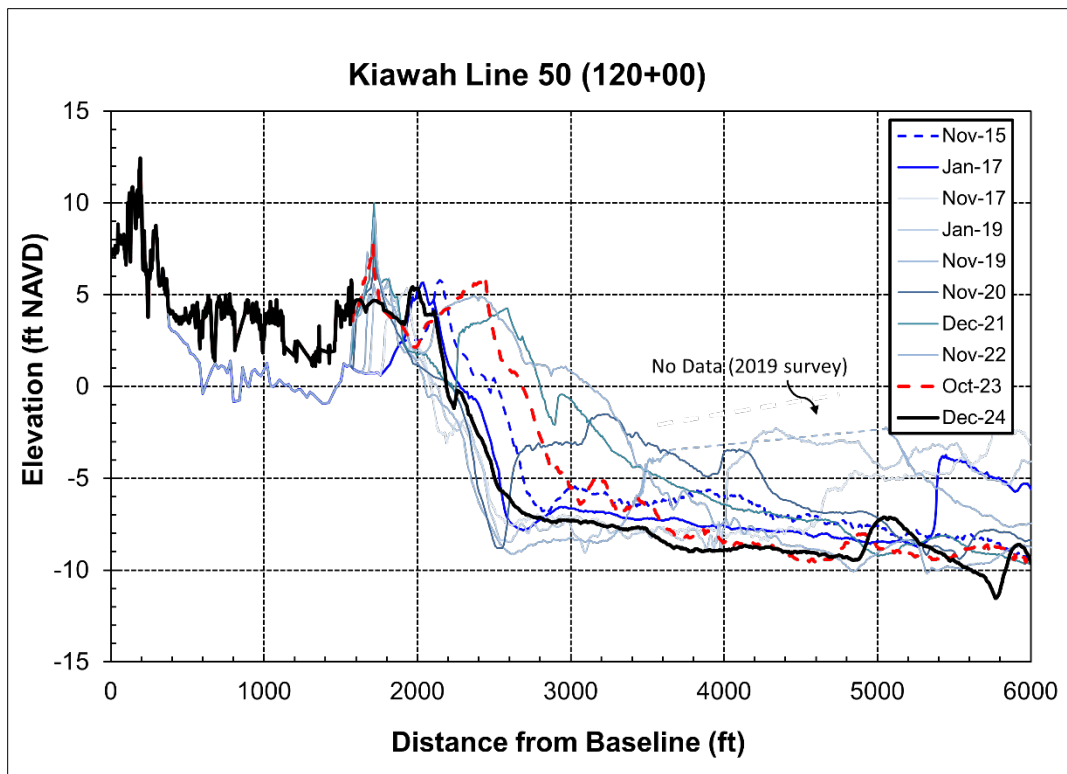
The reach gained a net total of ~439,970 cy (~55.0 cy/ft) between August 2007 and December 2024 but has oscillated between erosion and accretion through three cycles of shoal bypass events over that period. Bypass events along the Lagoon Reach occurred between 2007 and 2010, and 2020 and 2023. The event culminating in 2010 delivered ~957,100 cy (~119.6 cy/ft) of sand, while the most recent event delivered ~1,499,600 cy (~187.5 cy/ft) to the Lagoon Reach.

It is possible to track shoal bypass events in real time using CSE's survey data and generally predict the distribution of erosion and accretion around the shoal itself as sand migrates onshore. In the two bypass events mentioned above, shoals formed around one mile offshore and migrated ~1,000 ft/yr towards the main beach. The sand delivered to the main beach through these events is redistributed to the rest of Kiawah Island via longshore transport to the southwest and northeast.

As the most recent shoal bypass sand migrates away from the attachment point in Reach 5, volume increases are expected along the Stono Inlet and Ocean Course reaches. The eastern flank of the shoal has already attached to the main beach ~1,500 ft from the 5<sup>th</sup> hole green in the vicinity of Lines 51 and 52 and is actively feeding sand towards the northeast. The western flank of the shoal remains separated from the main beach by a narrow channel ~1,500 ft east of the containment dike constructed during the 2015 East End realignment project. A small flushing channel has been cut between the East End marsh and the ocean near where the western flank of the shoal will eventually attach to the main beach (Figures 4.6 and 4.7).

Other than the attachment of the new shoal at Stono Inlet, a notable observation in the lagoon area is the persistence of channels created by hurricanes *Matthew* and *Irma* and shoaling of the 2015 constructed channel. One of the 2015 channels (east-end channel) remains open as of December 2024, and it continues to shoal with sand and may be closed by the increase in longshore transport expected with the ongoing shoal bypass event. The channels to the east seem to be providing most of the drainage for the east-end marshes, and as of December 2024, the channel remained in the same configuration as observed in October 2023 (Figure 4.8).

As the shoal bypass sand migrates away from the Lagoon Reach, CSE expects continued erosion of the lagoon area. That said, the reach contains ~434,000 cubic yards **more** sand than the August 2007 condition due to bypass events over the years. Based on observations at Stono Inlet and similar systems on the South Carolina coast, the recurrence interval of these events is on the order of ~10 years. CSE has initiated a permit application for the Channel Realignment in the vicinity of the Ocean Course at the eastern end of the Island to mitigate this erosion.



**FIGURE 4.6.** Profiles from Line 50 showing ~350 ft of dune recession over the past five to six years. Peak elevations of 4–5 ft are insufficient to prevent overwash during storms and spring tides, thus inhibiting dune growth. On a positive note, overwash helps maintain unvegetated beach habitat favored by the piping plover, a threatened species that utilizes the area. This profile line also marks the emergence of the next bypassing shoal approximately 5,000 ft from the baseline. As of December 2024, the “2020” shoal is fully attached to the beach.



**FIGURE 4.7.** December 2024 aerial photo over the East End marshes showing the shoal is attaching and feeding sand to the beach between the East End and Stono Inlet (center background). Sand making up the spit on the west side of the shoal will eventually attach to the Lagoon Reach and migrate towards the Ocean Course. A small shallow channel separates the main body of the shoal from the beach as of December 2024, (red line) but it is not expected to inhibit downcoast sand transport over the next several years.



**FIGURE 4.8.** [UPPER] October 2023 and [LOWER] December 2024 aerial images of the Lagoon Reach. The outer beach is retreating across the salt marsh of the lagoon, occasionally exposing mud outcrops along the wet-sand beach (highlighted in foreground and center of image). The dashed line is the approximate 1989 shoreline. The two flushing channels created by Hurricanes *Matthew* (2016) and *Irma* (2017) remained open until October 2023. As of December 2024, the channel on the west end has closed (former position shown with red circle), while the east-end channel has shifted westward but continues to flow in roughly the same locations observed in October 2023 (red line).

### 4.1.3 Reach 4 – Ocean Course

Ocean Course Reach is the transition zone between the developed shoreline with a typical strand beach and a dynamic lagoon area (Fig 4.9). It spans ~9,000 ft between Line 38 (Kiawah Beach Club) and Line 47 (closure dike). The Ocean Course Reach gained ~147,300 cy (16.4 cy/ft) of sand between October 2023 and December 2024. The reach has generally gained sand since August 2007, with a total volume increase of ~859,130 cy (95.5 cy/ft) over that period (Fig 4.10).

However, due to the proximity of the Stono Inlet system and Lagoon Reach—where shoals often attach to Kiawah Island and influence adjacent beaches—the Ocean Course Reach is subject to wide oscillations in beach volumes. The reach tends to gain and lose volumes with the accretion and erosion cycles associated with shoal bypass events, but its shoreline trends tend to lag behind those of the Lagoon Reach by one or two years.

From 2019 to 2022 the reach eroded as a large shoal approached the Lagoon Reach, ~5,000 ft southeast of the Ocean Course driving range. Annualized sand losses over that period averaged around 10 cy/ft/yr. Volumes started to increase in 2021 as sand from the Lagoon Reach began spreading toward the Ocean Course.

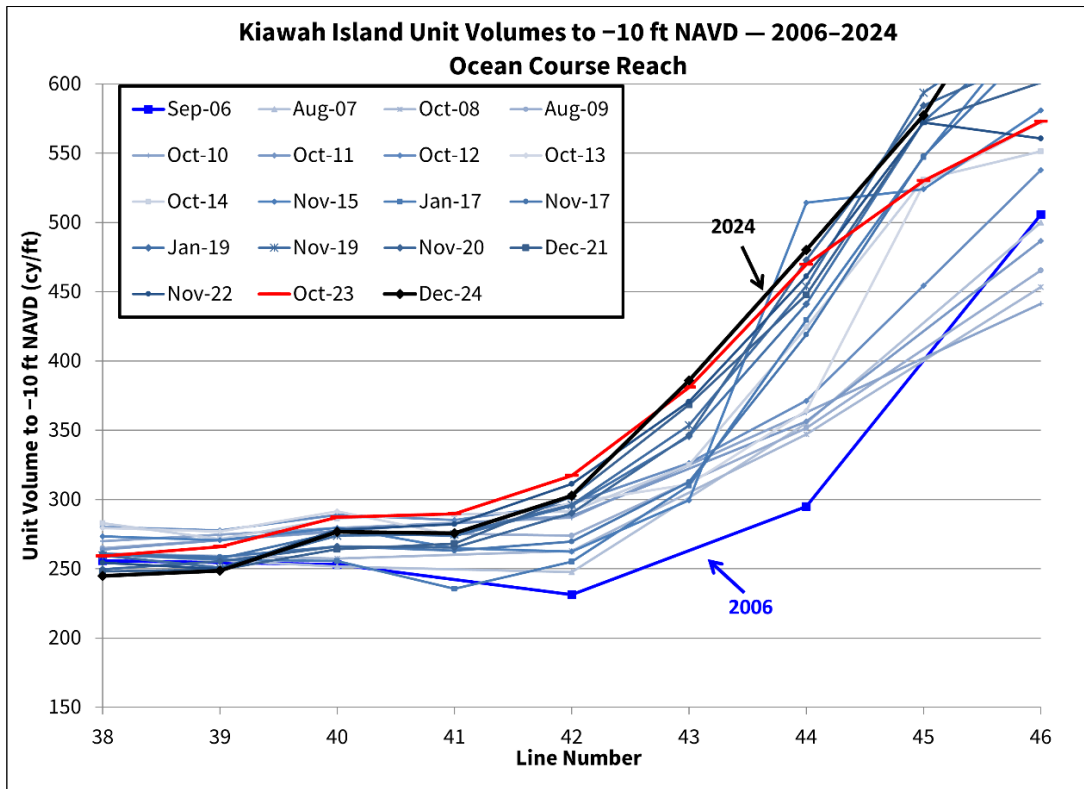
From October 2023 to December 2024, volume losses along the Ocean Course were observed between Line 38 to Line 42 and volume gains were observed between Line 43 to Line 46. The erosional arc adjacent to the attaching shoal moved ~2,000 ft toward the Ocean Course Club House over the last year. Line 46 experienced the greatest volume increases along an individual profile from October 2023 to December 2024 (Fig 4.11). A December 2024 aerial image is compared to the post-project condition in Figure 4.12.

As shoals attach to a barrier island, areas immediately ‘behind’ the shoal (see Fig 2.6) will accrete as the sand migrates onto the submerged beach. During this period of the bypassing process, adjacent beaches will erode due to the refraction of wave crests around the seaward edge of the shoal. Erosion measured from 2019 through 2022 along the Ocean Course reach is probably due to this phenomenon. Accretion observed from October 2023 to December 2024 along the eastern portions of the reach reflect the transition from erosion to accretion as shoal spreads laterally away from the attachment zone.

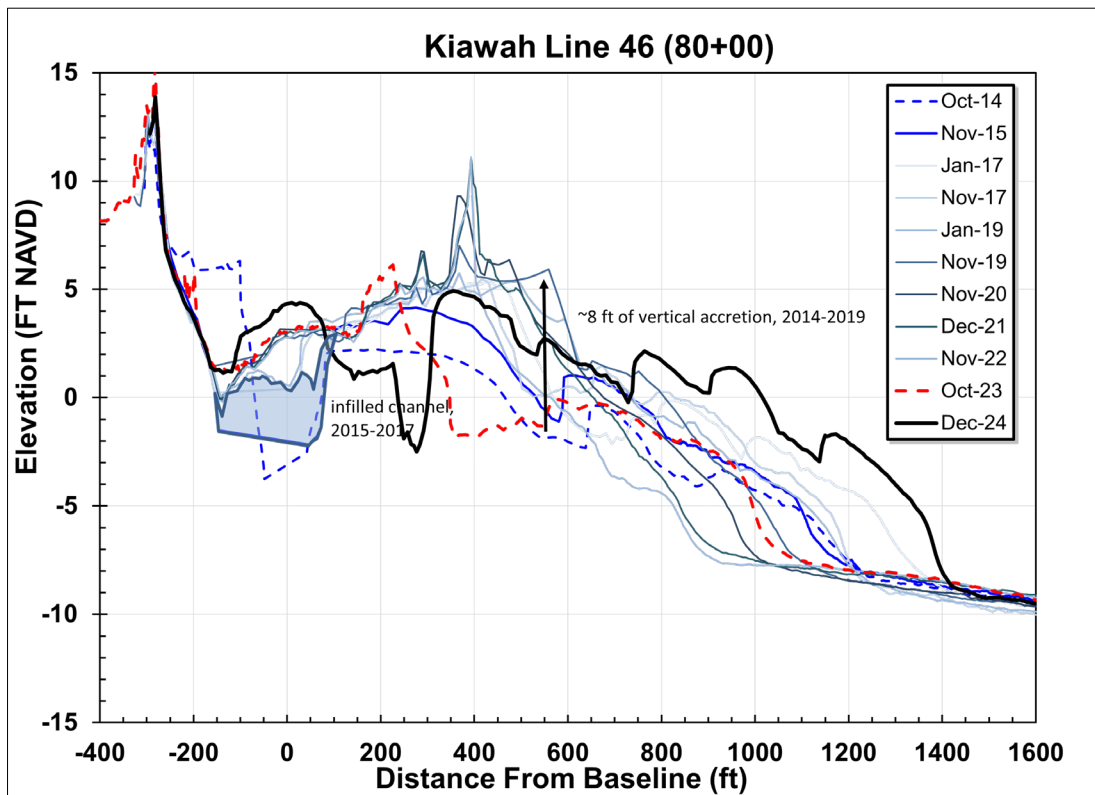
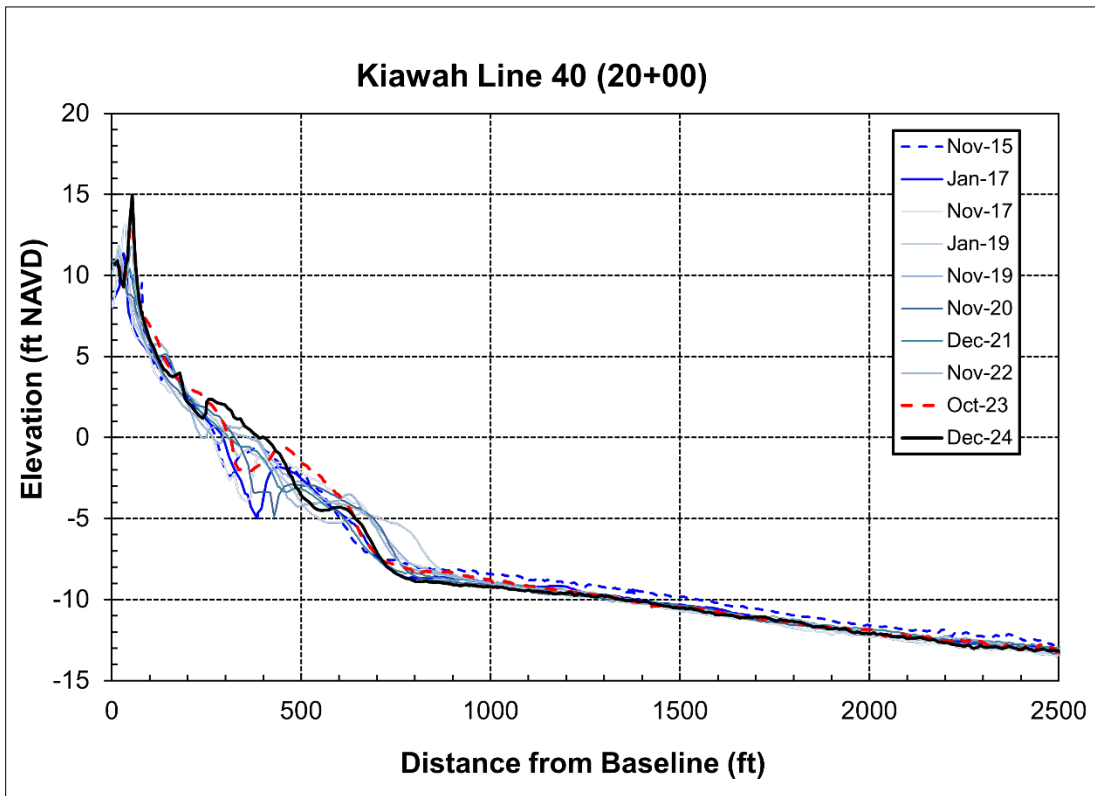
As the channel separating the western flank of the shoal from the main beach infills with sand, there will be volume increases along the Ocean Course Reach. However, it is also possible this channel can encroach on high ground around the Ocean Course itself. During the previous shoal bypassing event, individual profiles gained between 40 and 50 cy/ft in a given survey period. The current bypass event appears larger than the previous one, so even greater volume increases are expected in this case.



**FIGURE 4.9.** The Ocean Course Reach lies along the transition zone from the ‘strand’ beach to the east end of the driving range. In January 2019, the lagoon and flushing channel fronting the Ocean Course Club House was nearly cut off from the ocean. However, between January 2019 and November 2020, a new flushing channel opened naturally (red circle) and presently is draining the lagoon. (photo via UAV December 2024)



**FIGURE 4.10.** Unit volumes for the profiles of the Ocean Course Reach illustrating the transition between the ‘strand beach’ of Kiawah away from inlets (volumes ~250–300 cy/ft to the -10 ft NAVD contour) and the inlet-influenced zone where extensive intertidal bars add to volumes.



**FIGURE 4.11.** Profiles from Lines 40 [UPPER] and 46 [LOWER]. At Line 40, the dunes have remained relatively stable with only a slight decrease in elevation since 2017; however, the dune at Line 46 was more developed in 2024 than it was in 2017.

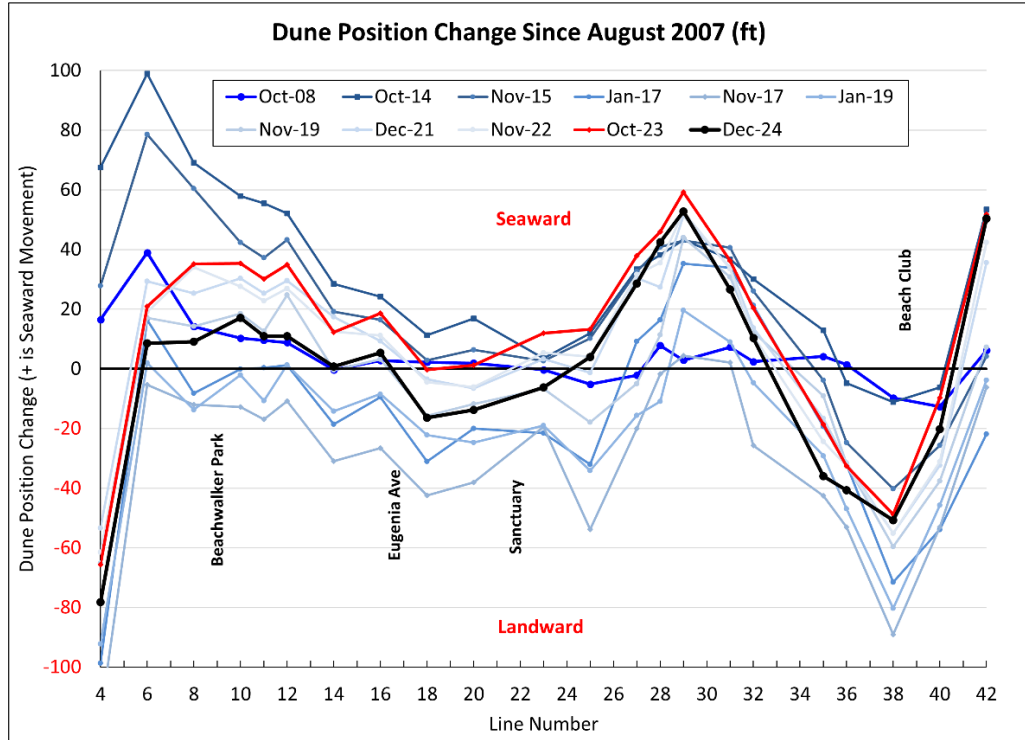
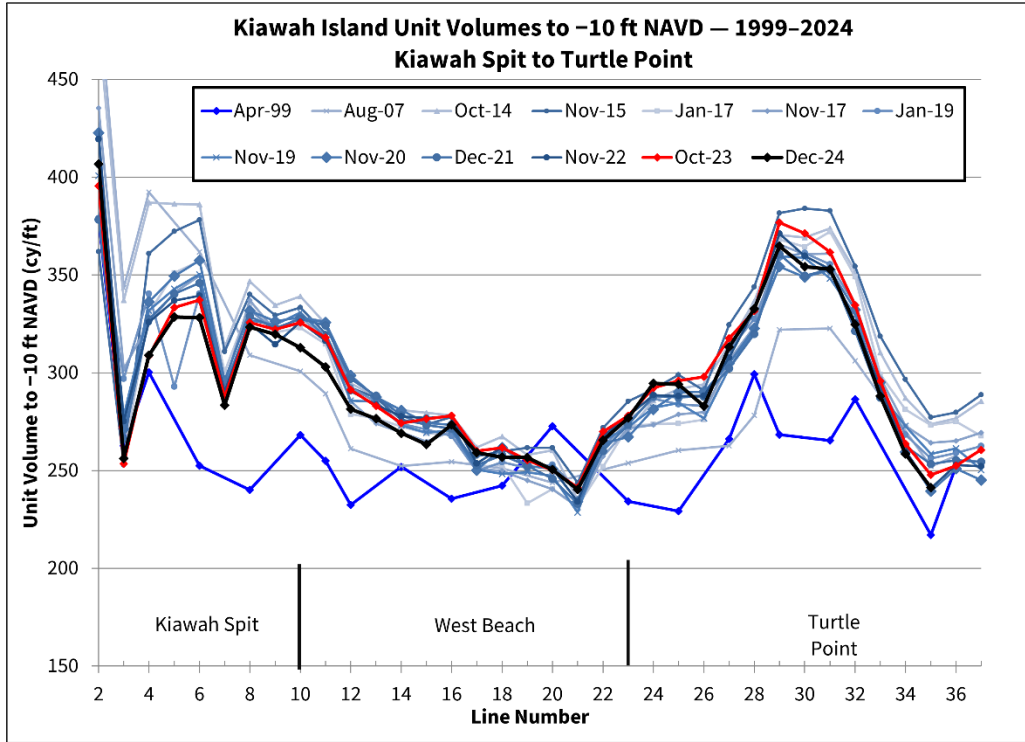


**FIGURE 4.12.** October 2017 aerial image [UPPER] compared to December 2024 aerial image [LOWER] of the Ocean Course Reach (eastern half). The ponded area is the relict channel basin from the 2015 project, formed before the closure dike was constructed. By December 2024, a similar flushing channel has formed close to the 2015 channel location, which triggered remedial work to close it. The present channel may have to be redirected similarly in the next 2–3 years.

## 4.2 Downcoast Reaches

The December 2024 monitoring data for reaches downcoast (west) of the East End project area are compared to 1999 and 2006–2021 data. Profiles in these areas use OCRM monuments and newly created profiles (2012) so that profile spacing does not exceed 1,267 ft. CSE added these new lines to better monitor local beach changes along the ‘populated’ beach. CSE has collected data at certain downcoast stations since the early 1980s. Historically, the West Beach Reach has been stable, while the Turtle Point Reach and Kiawah Spit Reach have been accretional. Profiles are given in Appendix A.

Figure 4.13 (upper) shows unit volumes for each station in the downcoast reaches. While the typical trend along this area is accretion, yearly volume changes can vary in magnitude, and periods of erosion in some areas are common. From October 2023 to December 2024, the downcoast reaches lost ~172,100 cy (-5.0 cy/ft) but ranged from -17.0 cy/ft to +75.8 cy/ft for individual stations. Due to the mixture of accretion and erosion, some areas of beach and dunes have receded landward while others grew seaward. Despite this variability, most stations that were surveyed in April 1999 or August 2007 contain more sand in December 2024. Stations that have lost any appreciable volume are located within the 2015 Captain Sams Inlet relocation project area and are likely more related to changes around the inlet than other causes.



**FIGURE 4.13.** Unit volumes in the downcoast reaches between 1999 and 2024 [UPPER] and dune-line linear change (measured at the +7-ft NAVD contour) [LOWER]. Line 1 is on the Seabrook side of Captain Sams Inlet following the 2015 relocation project.

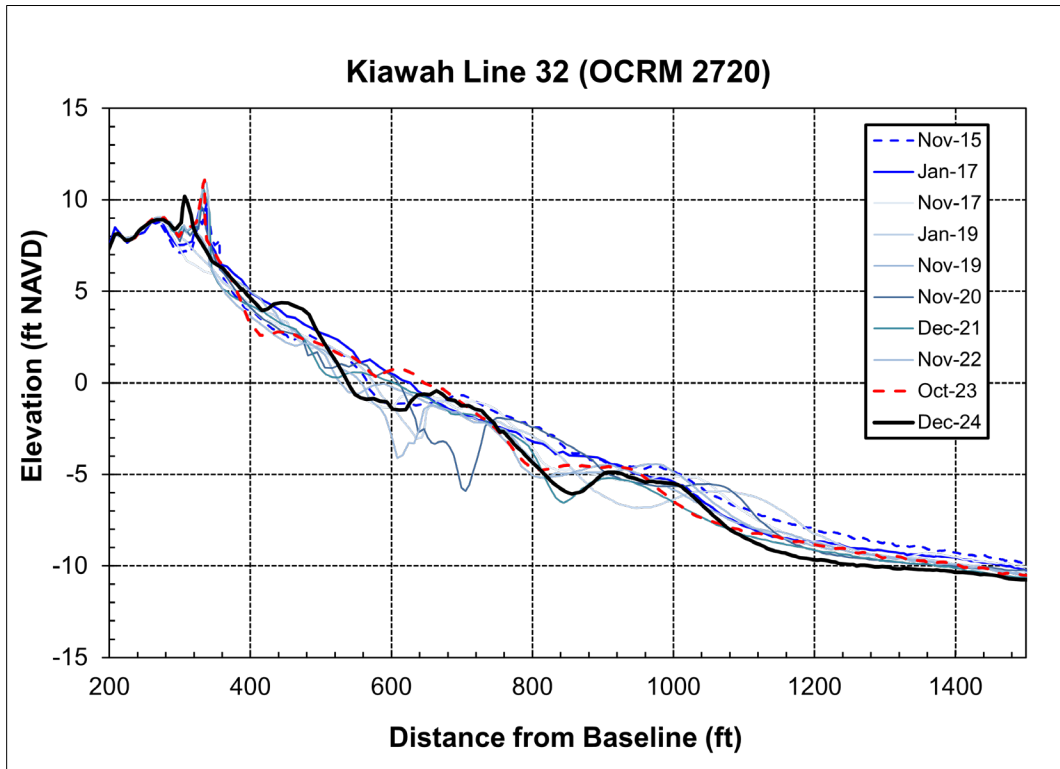
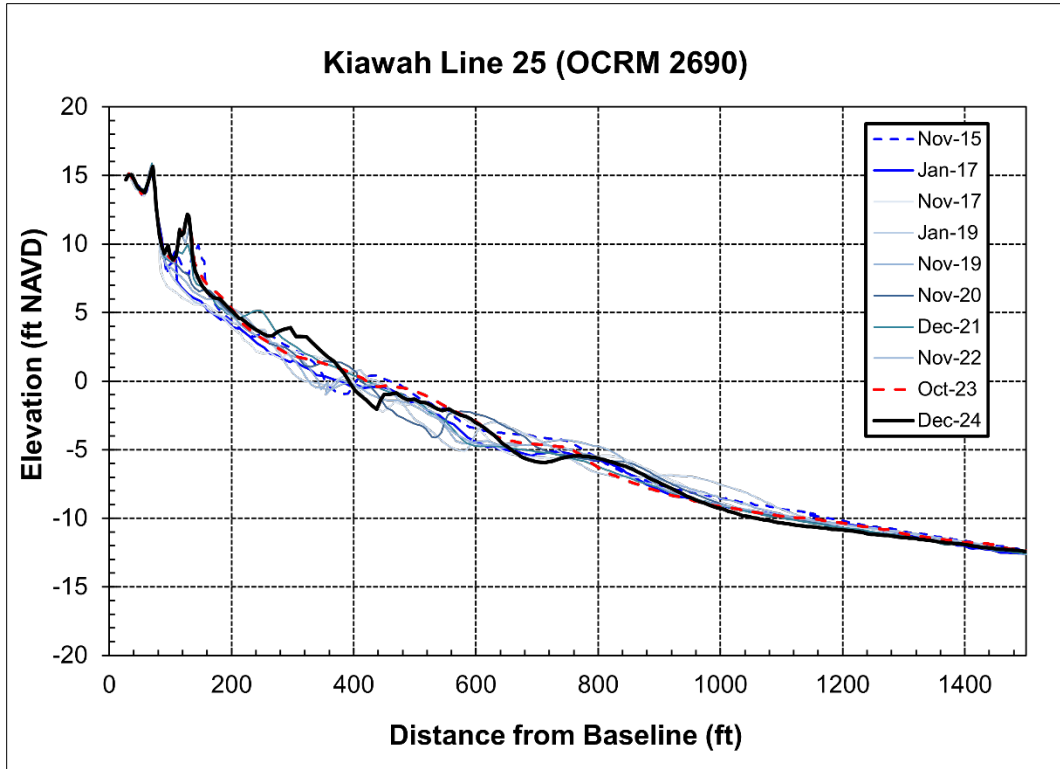
#### 4.2.1 Turtle Point Reach

Turtle Point Reach extends 13,614 ft from Line 23 (16th hole of Turtle Point Golf Course) to Line 38 (Kiawah Beach Club). Between October 2023 and December 2024, the reach lost ~90,900 cy (-6.7 cy/ft) of sand. Like the Ocean Course Reach, Turtle Point is the recipient of bypassed sand once shoals fully attach to the main beach.

The relationship between shoal bypass events and volume changes along Turtle Point is evident in measured volume changes since 2007. A shoal attached to the Lagoon Reach between 2007 and 2010, and volumes increased along Turtle Point from 2011 to 2015. From 2015 to 2020, as sand from that bypass eventually made its way towards Capt Sams Inlet and the island was impacted by multiple named storms, Turtle Point tended to lose sand. A new shoal bypass event started in 2019, attached to the Lagoon Reach by ~2023 and had begun spreading alongshore by the December 2024 survey. As of that survey, the zone of volume increases from the newly attached shoal were less than 1 mile from the boundary between the Ocean Course and Turtle Point Reaches. As sand from that shoal spreads alongshore, volumes along Turtle Point are expected to increase.

Unit volume changes within the reach ranged from -17.0 cy/ft to +2.4 cy/ft between October 2023 and December 2024. The beach has generally recovered from losses experienced between November 2015 and November 2017. Ground photos (Fig 4.15) reflect recovery along most of the reach following Hurricane *Irma*. A dune was reconstructed along the Turtle Point Golf Course before the November 2017 survey because this area was within the state's definition of an emergency condition following *Irma*. Since November 2017, the escarpments and dune damages from *Irma* have healed naturally via wind-blown sand and revegetation.

The significant building setbacks and historical accretion trend around Turtle Point suggest that the reach can recover without any additional action by the Town. Over the past several years, repeated storms have eroded the primary dune along most of the reach; however, overall sand losses have been relatively low (especially during *Irma*). Every profile still shows a higher sand volume than the August 2007 condition; the entire reach contained ~291,000 cy (21.4 cy/ft) more sand in December 2024 than in August 2007.



**FIGURE 4.14.** Profiles from the Turtle Point Reach. In recent years, most of the profiles lost sand along the upper beach, but gained sand in the lower beach. Note the difference between blue (November 2015 – January 2017) and red/black (October 2023 – December 2024) profiles; the dune ridge was washed away, but a new bar is forming around low tide wading depth. These profile changes are typical of winter or storm beaches.



**FIGURE 4.15.** Ground photos near Line 28 post-*Irma* September 2017 [UPPER] November 2019 [MIDDLE] and December 2024 [LOWER]. The ramp (red circle) exposed by *Irma* is now hidden behind tall stands of sea oats.

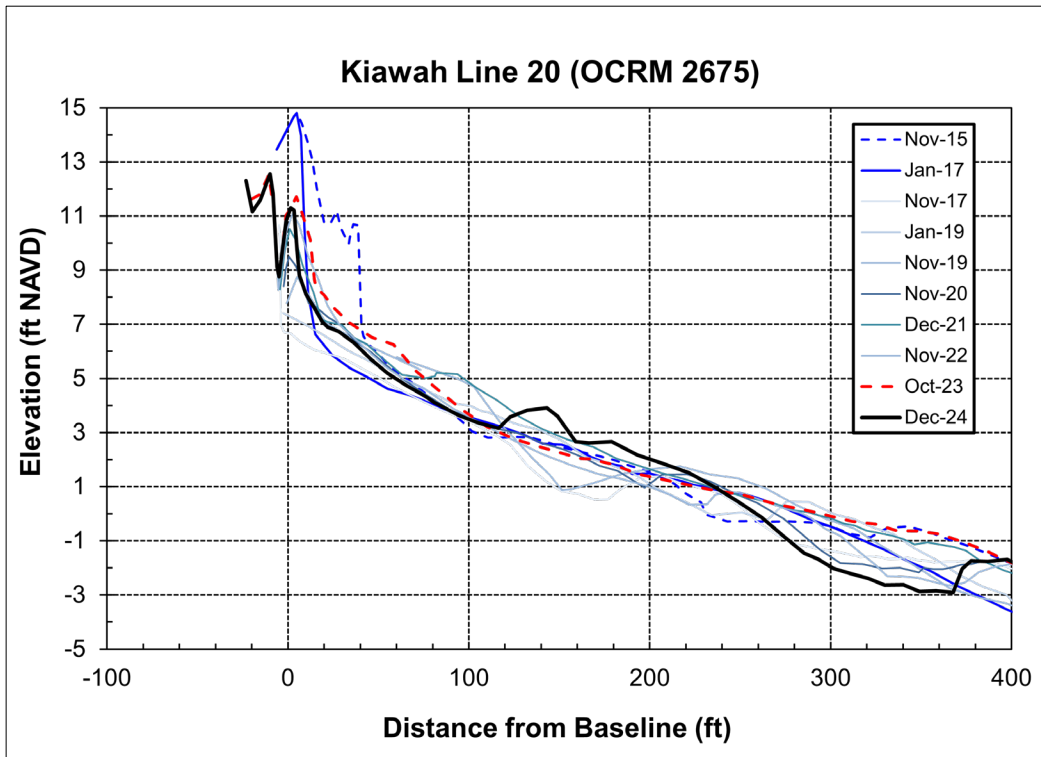
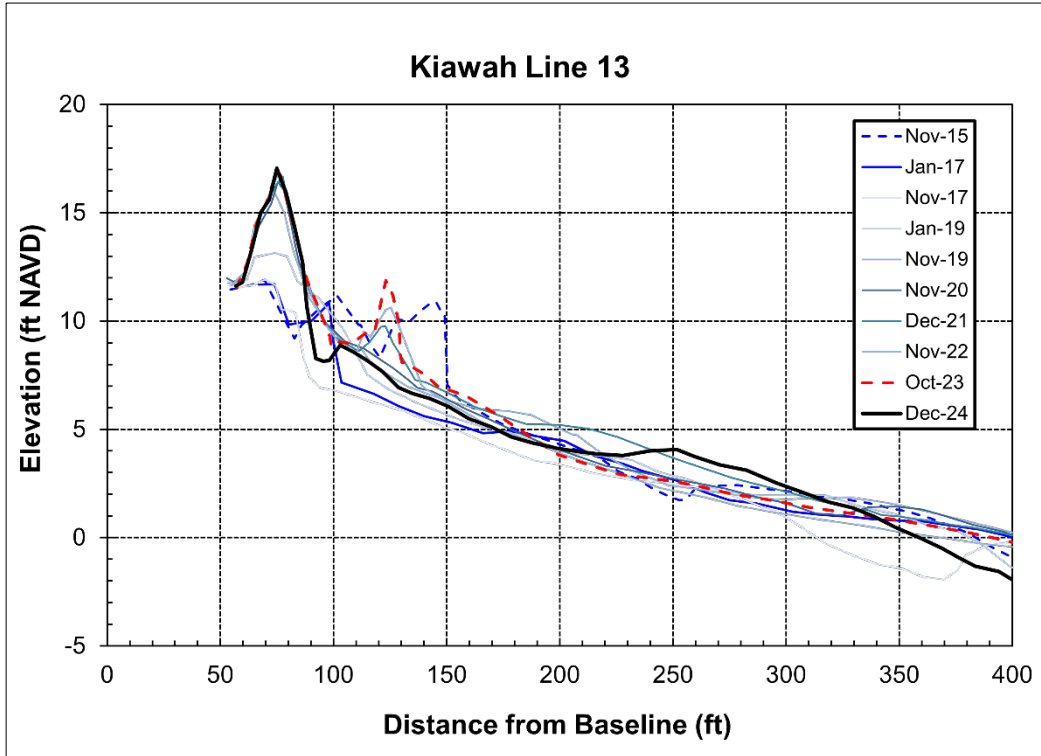
#### 4.2.2 West Beach Reach

West Beach Reach encompasses 8,820 ft of beach between Lines 10 and 23 (Sand Alley to the 16th tee of Turtle Point Golf Course). Historically, this reach has been relatively stable compared to the other reaches. However, between October 2023 and December 2024, West Beach lost ~62,800 cy (-5.3 cy/ft).

Although West Beach has experienced periods of erosion, properties within the reach are sufficiently set back to allow for a substantial vegetated buffer between the ocean and the structures. The reach lost 3.9 cy/ft of sand from 2007 to 2008 but accreted during every monitoring interval between 2008 and 2014. From 2014 to 2015, the reach was stable overall, although within the reach, the western half eroded and the eastern half accreted. The reach was highly erosional from November 2015 to January 2017 (Hurricane *Matthew*), losing ~136,500 cy (-11.6 cy/ft).

Since January 2017, reach-wide volume changes have oscillated between erosion and accretion, ranging from -5.3 cy/ft (October 2023 to December 2024) to +5.3 cy/ft (November 2017 to January 2019). Individual profiles oscillate between accretion and erosion at moderate rates ranging from -11.6 cy/ft at Line 21 between January 2019 and November 2019 to +13.4 cy/ft at Line 18 between November 2019 and November 2020. There was a significant loss of sand following Hurricane *Irma* (September 2019), such that between January 2019 and November 2019, the reach lost ~32,500 cy (-2.8 cy/ft). As previously mentioned, sand from the dune shifted lower in the beach profile during the storm but has since migrated back to the upper beach during calmer weather conditions. Between October 2023 and December 2024, most of the lines in the reach lost sand. However, the reach contained ~139,800 cy (11.8 cy/ft) more sand as of December 2024 than in August 2007.

Recent profiles from the reach (Fig 4.16) show a consistent pattern of erosion of the foredune from 2015 through 2020–2021, leaving a pronounced escarpment on the seaward side of the foredune. As shown in Figure 4.17, the dune receded ~20 ft along the reach. With the combined effects of hurricanes *Joaquin*, *Matthew*, and *Irma*, and the pre-existing narrower setbacks of structures in the reach, several properties were left vulnerable to erosion. The Town obtained a permit for beach scraping to rebuild the dunes along Eugenia Avenue and seaward of The Sanctuary. This effort restored the storm protection offered by the foredune and improved recreational access to the beach via walkovers. Additionally, these efforts provided a healthier habitat for nesting turtles. CSE generally recommends sand scraping only after significant storm events because these efforts do not add new sand to the system; rather, it is a means to shift eroded sand back to the upper profile and accelerate natural recovery of the dry-sand beach.



**FIGURE 4.16.** Representative profiles from West Beach Reach. Much of the reach has experienced erosion of the dune ridge in recent years. The eastern end of the reach (Lines 18–21) has shown the least amount of accretion over the past two decades. Line 20 is the only line showing less volume than the 1999 condition.



**FIGURE 4.17.** The West Beach Reach (Line 18 shown here) experienced dune erosion from relatively busy hurricane seasons and nor'easters between 2015 and 2017. Hurricane *Irma* left a particularly noticeable scarp in the dune (see left-hand portion of the top panel above, November 2017). The Town of Kiawah Island elected to scrape the beach to rebuild a protective foredune, and the project has performed well. The scraped dune (top right panel, January 2019) now appears as a gentle sand ramp with colonizing dune grasses beginning to grow seaward (see bottom left panel, November 2019). This indicates longer-term recovery from post-storm conditions. As of December 2024 (bottom right panel), the dune face scarp slightly by the wind. However, dune grasses helping to hold the sediments in place.

### 4.2.3 Kiawah Spit Reach

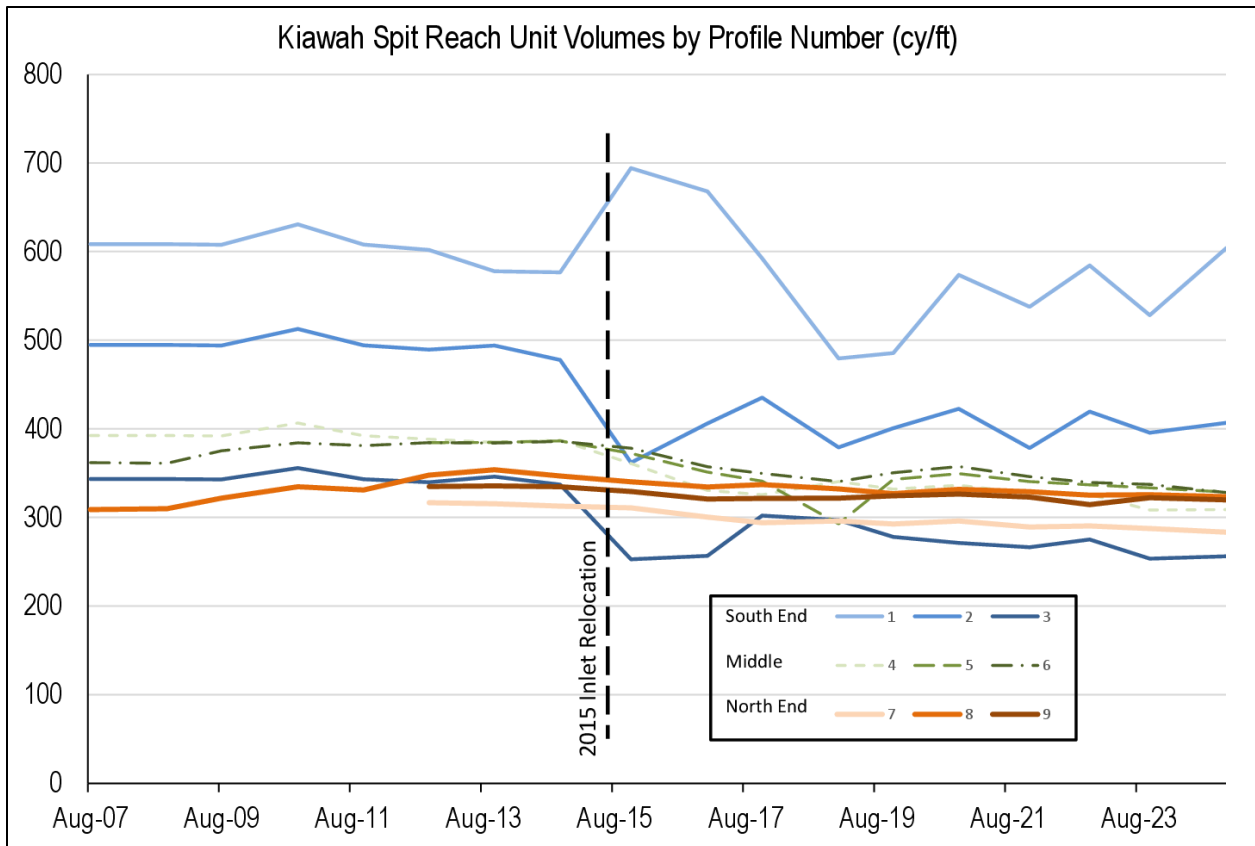
Kiawah Spit Reach encompasses the downdrift end of the island. It acts as a sink for sand transported by longshore currents from upcoast areas and a source for sand exported away towards Seabrook Island. As wave action transports sand to the west, it feeds the spit, causing growth into Captain Sams Inlet and forcing the inlet to migrate toward Seabrook Island (Fig 4.18). Between October 2023 and December 2024, Kiawah Spit lost ~18,460 cy (-2.1 cy/ft). It is likely these observed losses were related to underwater shifts in the position of the main inlet channel between lines 1 and 3 and do not indicate any cause for immediate concern.

As mentioned in Section 4.1.2, Captain Sams Inlet was relocated ~3,000 ft to the east in June 2015. This placed the eastern margin of the inlet ~450 ft west of Line 3. The end of Kiawah Spit is growing to the west as Captain Sams Inlet continues its natural migration toward Seabrook Island. Immediately after the relocation project, the inlet channel was steeply sloped on the Kiawah side with minimal wet-sand beach. Since then, intertidal bars have formed along the inlet margin and seaward on the Kiawah side of the channel in conjunction with the growth of a new ebb-tidal delta. The evolution of New Captain Sams Inlet and Kiawah Spit generally follows the same historical trends observed after the 1983 and 1996 inlet relocations: initially, upon relocation, there is some sand loss along the downcoast end of the spit near the new channel. As sand accumulates around the new inlet, the ebb-tidal delta grows seaward and erosion transitions into accretion.

Since 2007, the volume of sand seaward of the foredune has remained relatively constant along the spit. Nine profiles are monitored each year along Kiawah Spit and nearly all maintain a healthy volume of about 300 cy/ft or greater (Fig 4.19). Profiles 7-8 at the north end, where most activity with Beachwalker Park occurs, change little from year to year. The visible beach has receded during storms like *Irma* (2017), but volumes have been retained close to shore and gradually returned to the upper beach. This has helped protect the neck of Kiawah Spit and reduced the threat of a breach. The central part of the spit (green dashed lines in Figure 4.19) has similarly maintained a fairly steady profile volume. The south end comes under direct influence of Captain Sams Inlet and therefore exhibits the greatest changes in sand volume. Each inlet relocation (1983, 1996, 2015) starts a new cycle of beach adjustment, delta growth, and spit elongation. This instability is reflected in Profiles 1-3 on Figure 4.19. Despite major changes, associated with the inlet movement, the volume of sand seaward of the dune line has remained high and relatively stable.



**FIGURE 4.18.** West end of the Kiawah Spit Reach in December 2024. Wave crests breaking over the low bars and shoals around Capt Sams Inlet drive sand onshore and toward Seabrook Island (red arrows). The 1983 channel, before inlet migration (yellow arrow), was encroaching on developed uplands and led to the initiation of an inlet relocation program. The containment dike used to seal off the old channel (black arrow) in 2015 is highlighted in the blue circle.



**FIG 4.19.** Unit volumes by profile for the Kiawah Spit Reach, showing general stability over time around the neck and Beachwalker Park (Lines 7–9) and the central spit (Lines 4–6). Each relocation of Captain Sams Inlet (Lines 1–3) produces larger changes, but volumes have generally remained healthy.

— THIS PAGE INTENTIONALLY LEFT BLANK —

## 5.0 COASTAL RESILIENCY UPDATE

---

### 5.1 Weather and Climate Conditions, October 2023 to December 2024

Weather and climate data are gathered from outside sources (all NOAA-supported) to compare observed changes to the beach and environmental conditions. Data reported in this document cover the period from October 2023 to December 2024 (the same as the survey data presented herein). Wind data are compared to historical data covering the period from 1945 to 2024.

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 (<http://mrcc.isws.purdue.edu/>). The closest operational station to Kiawah Island is Charleston International Airport (FAA identifier – CHS) in North Charleston.

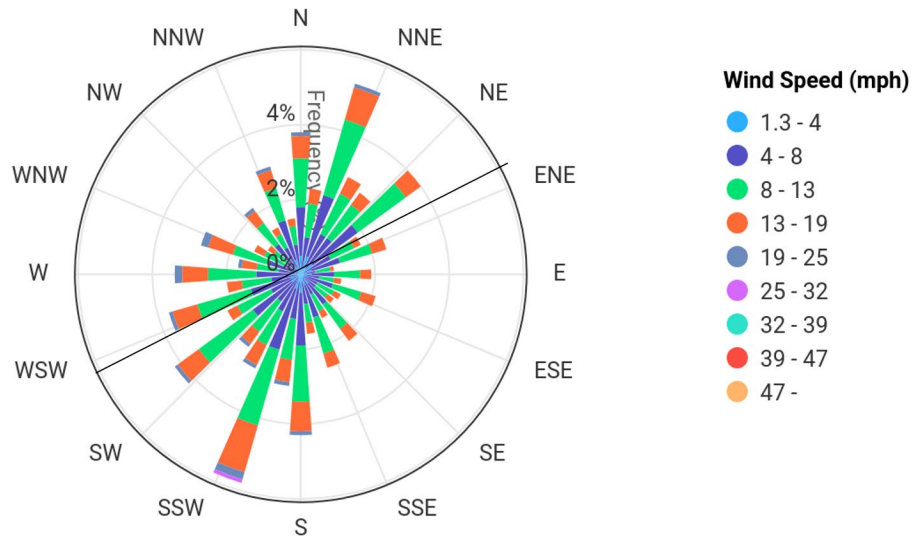
Winds along Kiawah are bimodal (typical for the southeastern coast), with predominant winds from the north northeast and prevailing winds from the south southwest. After averaging the wind data, it yields easterly winds from  $\sim 104^\circ$ . Relative to the shoreline azimuth (see Fig 5.1), these drive more wave energy from easterly components, leading to net westerly transport along the beach. Nor'easters, which generate the highest frequency of strong winds, are partially sheltered by the shoals of Stono Inlet, lessening wave exposure along the oceanfront. The peak observed wind speed was on 9 January 2024 with a gust to 69.8 mph. The maximum wind speed from 2010 to 2024 was 99.3 mph, observed during Hurricane *Dorrian* in September 2019.

According to the data from MRCC-NOAA, between October 2023 and December 2024, there was a weaker northerly component of the winds than typically occurs in the Lowcountry. The typical proportion of winds from that half of the compass represents  $\sim 47$  percent of the total observed from 1945 to 2024, while from October 2023 to December 2024, these winds represent about  $\sim 46$  percent of the observations. Compared to long-term observations, this suggests there may have been slightly weaker storm winds between October 2023 and December 2024. NOAA buoy data also show a weak northerly component during the same period.

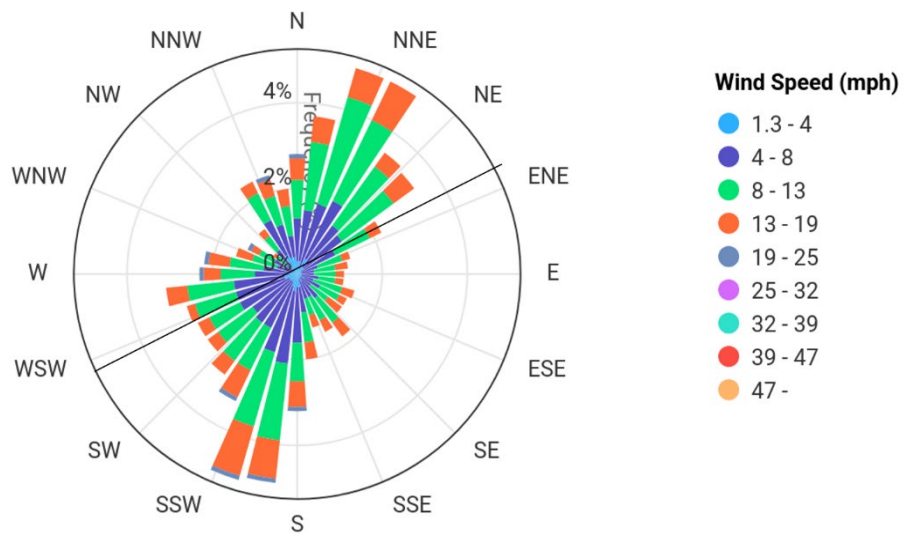
Meteorological and oceanographic data are recorded by the National Data Buoy Center (NDBC) Station 41004 ('Edisto'),  $\sim 50$  miles due east of Kiawah Island. This is the closest station recording continuous wave data for the entire period.

\*The normal convention for wave direction is the direction of propagation, whereas winds are recorded by the direction of origin. Thus, waves at  $\sim 132^\circ$  are moving to the southeast, whereas winds from  $132^\circ$  are blowing toward the northwest.

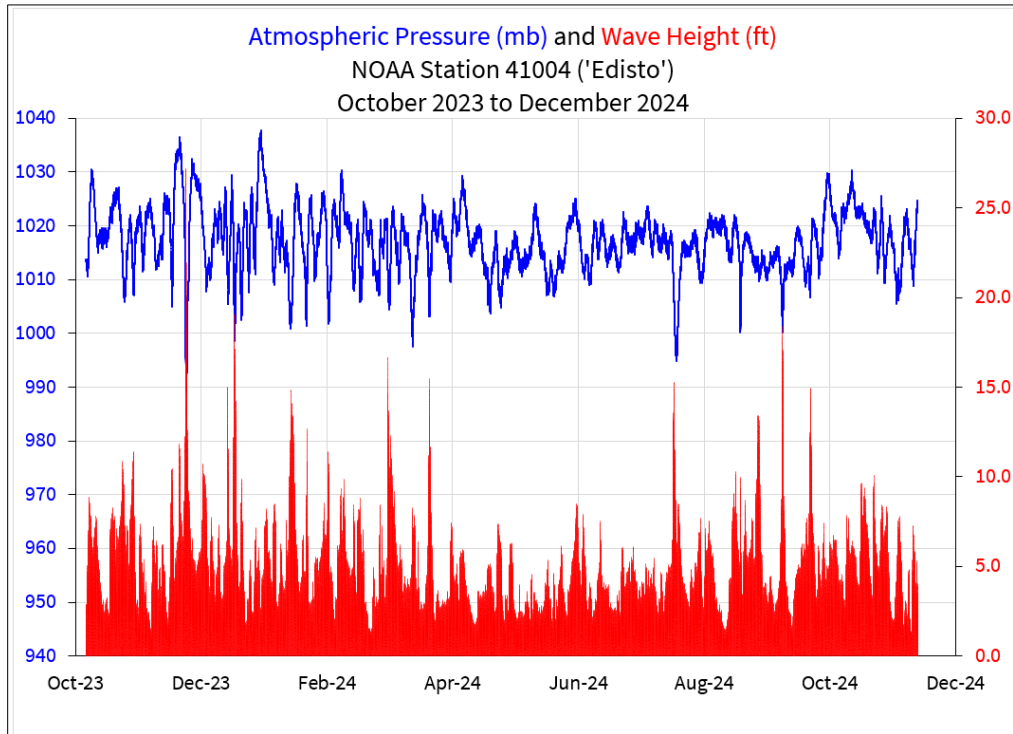
**Wind Rose, Charleston Intl Airport,  
December 1945 to December 2024**



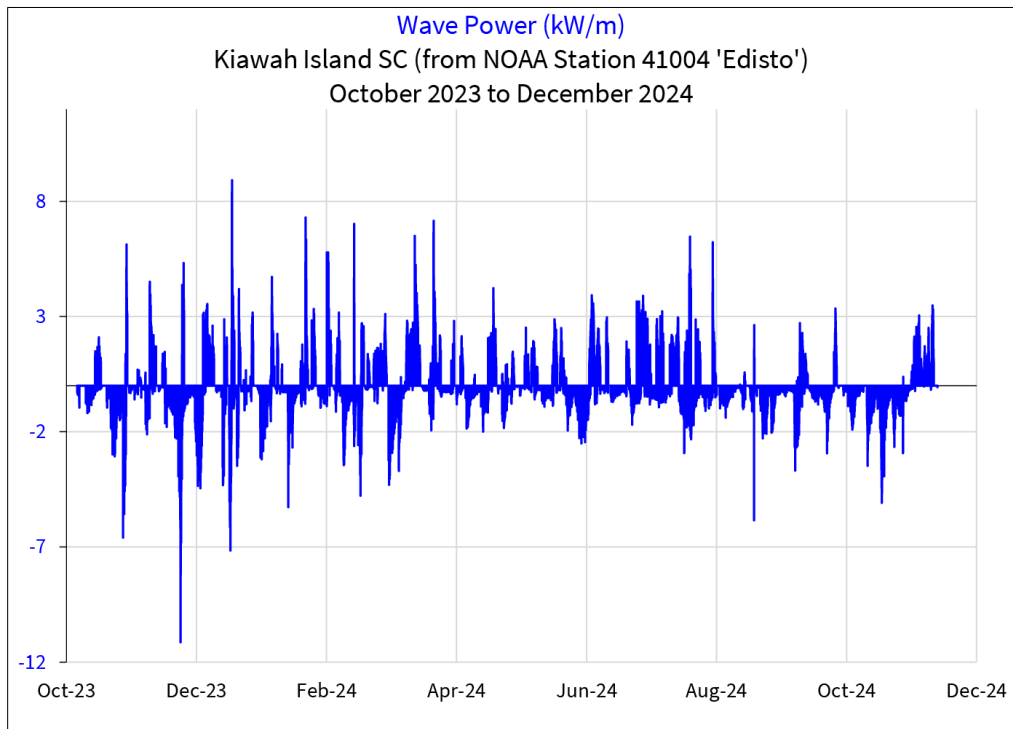
**Wind Rose, Charleston Intl Airport,  
October 2023 to December 2024**



**FIGURE 5.1.** Wind roses showing direction and magnitude of winds observed at Charleston International Airport from December 1945 to December 2024 [UPPER] and from November 2022 to December 2024 [LOWER]. The line across the wind rose indicates the average shoreline orientation along Kiawah Island (~75° N). Winds observed over the course of 2024 have featured a smaller proportion of northerly winds than reported in the long-term record.



**FIGURE 5.2.** Atmospheric pressure and wave height at NDBC 41004 from October 2023 to December 2024. Atmospheric pressure only dipped below 1000 mb during the December 17–18 nor’easter and during Tropical Storm Debby from August 7–8, 2024. Wave height also increased during the nor’easter, which is more than the normal range of values observed at the same location since 2010.



**FIGURE 5.3.** Wave power (in kW/m) and wave height (in m) for NDBC 41004 from October 2023 to December 2024. Wave power is a useful parameter for determining the relative magnitude and direction of wave energy in a longshore direction along a beach. Positive values indicate waves move from south to north (easterly transport), while negative values indicate predominance of north-to-south (westerly) transport.

The average wave height from October 2023 to December 2024 at Station 41004 was ~4.6 ft, with an average wave period of ~5.1 seconds. The maximum observed wave height was ~27.2 ft during a nor'easter on December 17<sup>th</sup>, 2023—the highest observed wave height at Station 41004 from 2010 to 2024 (Fig 5.2). The average wave direction was ~104°.

Following the relatively energetic hurricane seasons of 2015 (*Joaquin*) through 2019 (*Dorian*), the Low Country was spared from significant impacts due to tropical cyclones between 2020 and 2024. This period of relative quiet allowed beach-dune systems to replenish, a development reflected in some of the ground condition photos discussed in Section 4.3. With the addition of a shoal bypass event along the East End of Kiawah Island currently in its final stage (see Section 2.2), continued maturation of beach-dune vegetation, and improved dry beach widths are expected until the next major storm event.

Other than during the passage of a December 2023 nor'easter, atmospheric pressure never dropped below 1000 millibars (mb) for more than an hour from October 2023 to December 2024. This metric is used because 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 distinguishing 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 produce beach erosion (eg – a more energetic surf zone with longshore transport in a particular direction, occurring in phase with a high tide).

The fundamental driver of beach erosion is variation in sediment transport. An increase in erosion indicates more sand is being transported away from a location than towards it. Over time, this reduces beach volumes. Sand transport increases exponentially with shear stresses generated by currents and wave action, such that a doubling of current velocity or wave height will increase sediment transport rates several times over. This helps explain why even minor storms can produce significant erosional losses along the coast. Engineers and scientists use measurements of wave properties like height, length, and speed to estimate the magnitude of energy exerted by a single wave crest. The estimate is expressed as 'wave power' in kilowatts per meter of crest length (kW/m). Because sand can migrate either way along a beach, wave power must be adjusted so that waves generating southerly transport (north to south) and northerly transport (south to north) can be differentiated.<sup>1</sup>

To accomplish this, wave power can be calculated so that northerly – south-to-north – transport is measured above zero (positive) while southerly transport – north-to-south – is measured below zero

---

<sup>1</sup> Notwithstanding this common convention for wave analyses, the mean shoreline azimuth along Kiawah Island is ENE to WSW. Therefore, "north to south" wave energy actually moves sand from Stono Inlet to Captain Sams Inlet in a WSW direction.

(negative). The estimated wave power at Kiawah from October 2023 to December 2024 is shown in Figure 5.3. The larger-magnitude and positive wave power values in the winter months represent the passage of low-pressure tropical cyclones and nor'easters. In contrast, lower-magnitude and negative values during the summer, spring, and winter months indicate calmer seas.

The most powerful wave from October 2023 to December 2024 occurred on 10 January 2024, with an estimated 8.9 kW/m of wave power directed in a south-west direction during the passage of a strong low-pressure frontal boundary. If individual wave observations are counted as discrete events, southerly-directed wave energy was even more dominant from October 2023 to December 2024 (eg ~10,890 observations from north to south versus ~3,730 observations from south to north). This suggests the *prevailing* direction of sediment-transporting waves along Kiawah from October 2023 to December 2024 was from north to south. The total sum wave power of northerly-directed energy from October 2023 to December 2024 was ~5,740 kW/m, while southerly-directed wave power was ~-6,990 kW/m. This suggests net wave energy and therefore sediment export was in a southerly direction.

Comparing these values to longer-term trends puts recent observations in perspective. From October 2023 to December 2024 and from January 2010 to December 2024, there was generally more southerly than northerly wave energy at Kiawah. A strong seasonal signal persists such that northerly-directed wave power dominates the spring and summer, while southerly-directed wave power dominates the fall.

Offshore at the Station 41004 buoy, northerly waves tend to dominate the spectrum over the long-term, but the strongest waves are southerly-directed. From 2010 to 2024, ~80 percent of wave observations were northerly, but the average power of a southerly wave was ~56 percent greater. In many locations along the South Atlantic Bight, this observation matches beach volume changes wherein seasonality in wind and wave directions can trigger alongshore shifts in beach volumes; however, long-term averages show longshore transport from north to south in most locations.

The difference between offshore and nearshore measurements is a crucial point to consider in interpreting these data. Sediment transport is primarily influenced by wave height, which is modified by the refraction of wave energy around ebb-tidal deltas and tidal currents near inlets. Moreover, wave height varies alongshore within a single reach due to these factors as well as others – and Station 41004 is located ~40 miles from Kiawah. All this is to say, offshore buoy data are an imperfect representation but remain valuable for comparing long-term records.

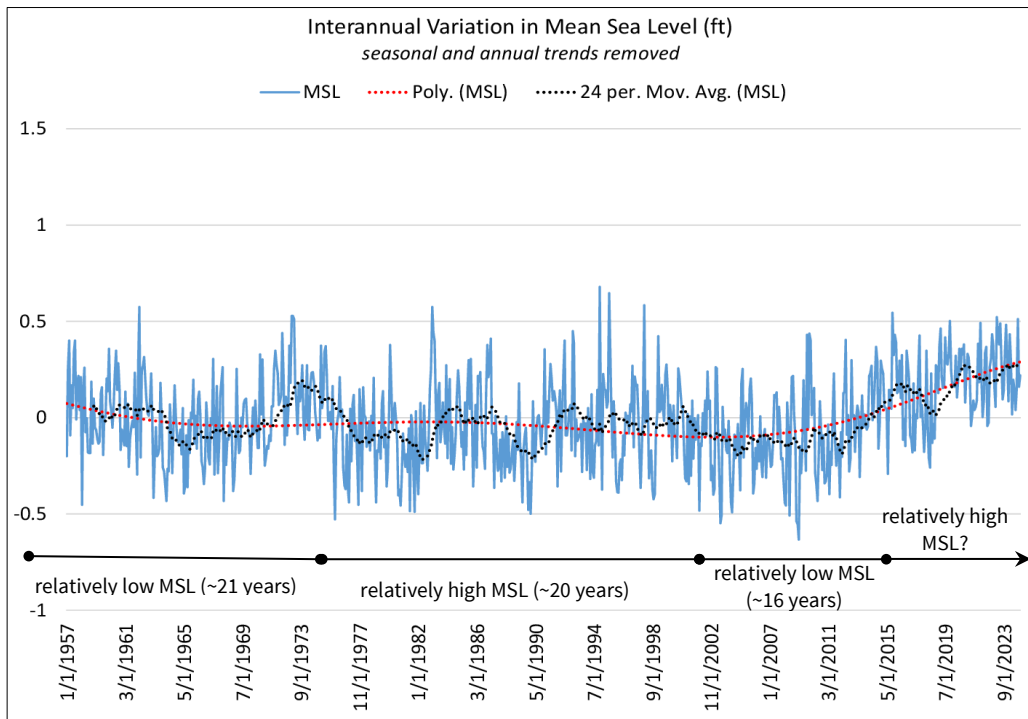
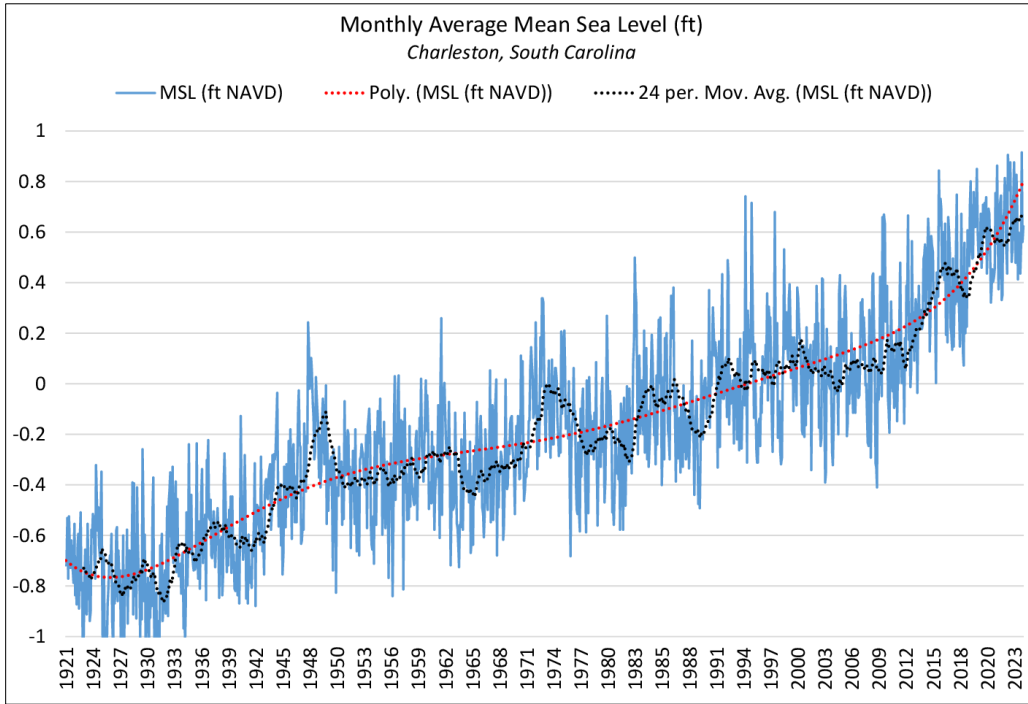
## 5.2 Sea Level Conditions and Trends

Sea level rise (SLR) is a concern in coastal communities due to the potential for increased flooding and beach erosion. While global trends of sea level show widespread increases in water levels over the past few decades, regional- and local-scale observations indicate a significant amount of variability. For instance, yearly sea level rise rates vary by  $\sim 0.1$  in/yr between the VA/NC Outer Banks and the SC/GA Lowcountry (NOAA 2020). This quantity represents  $\sim 2/3$  of the average SLR rate measured at Charleston since 1947 ( $\sim 0.17$  in/yr; NOAA 2024).

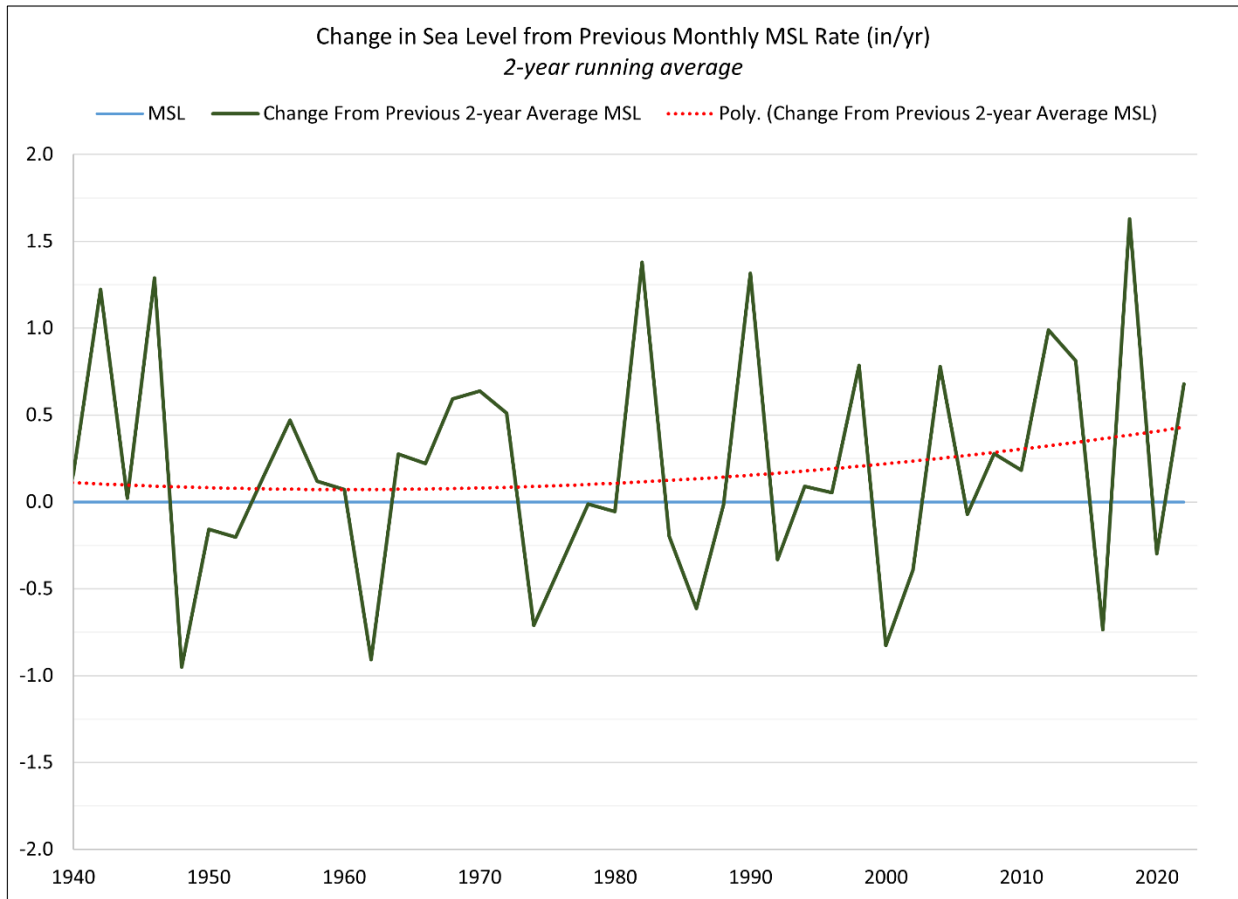
The closest SLR observation station to Kiawah Island is a tide gauge located at the Cooper River entrance channel in Charleston,  $\sim 10$  miles northeast of Stono Inlet. This station (NOAA 8665530) is part of a nationwide network of observation stations. Water level data have been collected almost continuously at Charleston since 1921. De-trending the SLR data allows us to observe fluctuations in the rate of SLR around that average long-term rate. Some years will experience a more rapid increase in water levels, while others will experience a slower increase or even decrease. Polynomial trend lines plotted over de-trended mean sea level observations from 1921 to 2024 suggest there is a  $\sim 20$ - to 30-year cycle where water levels are  $\sim 1$  to 2 inches higher or lower than the long-term mean (Fig 5.4). This pattern has been observed at other locations along the US East Coast as well (see CSE 2020) and seems to agree with modeled estimates of SLR variability at regional and sub-regional scales (see Piecuch et al, 2018).

Calculating SLR rates based on running averages of mean sea level (MSL) helps smooth the long-term curves and reveals a shorter-term,  $\sim 5$  to 10-year cycle wherein SLR rates vary by as much as  $\sim 2$ – $3$  in between given years ('moving average,' Fig 5.4; 'Change from 2-year Average MSL', Fig 5.5). Because these cycles are shorter relative to the overall data observation period, they are more easily verified against the long-term record than the 20-year sea-level cycle. As of December 2023, the long-term polynomial trend line and 2-year running averages suggest year-to-year SLR rates around Charleston will likely continue to increase (see green curve, Fig 5.5). However, because Kiawah is adjacent to a large tidal inlet (Stono Inlet) background change in SLR will have a subdued effect on beach erosion compared to a 'strand-type' shoreline with no inlets or shoals.

Sea level rise by itself does not cause erosion, but it results in beach narrowing as the mean tide level moves up the shoreface slope. Sea level controls the elevation at which waves move sand, which is of primary concern looking into the future. If sand volume is neither gained nor lost at a particular locality along Kiawah Island, 4 inches of SLR (the approximate increase since 1980) will produce an apparent shoreline recession of 8–10 ft. As this happens, the dry-sand beach elevation will also gain height due to storms overtopping the berm and washing sand toward the toe of the dune. So, even with no volume lost, the narrower beach provides less protection to oceanfront development.



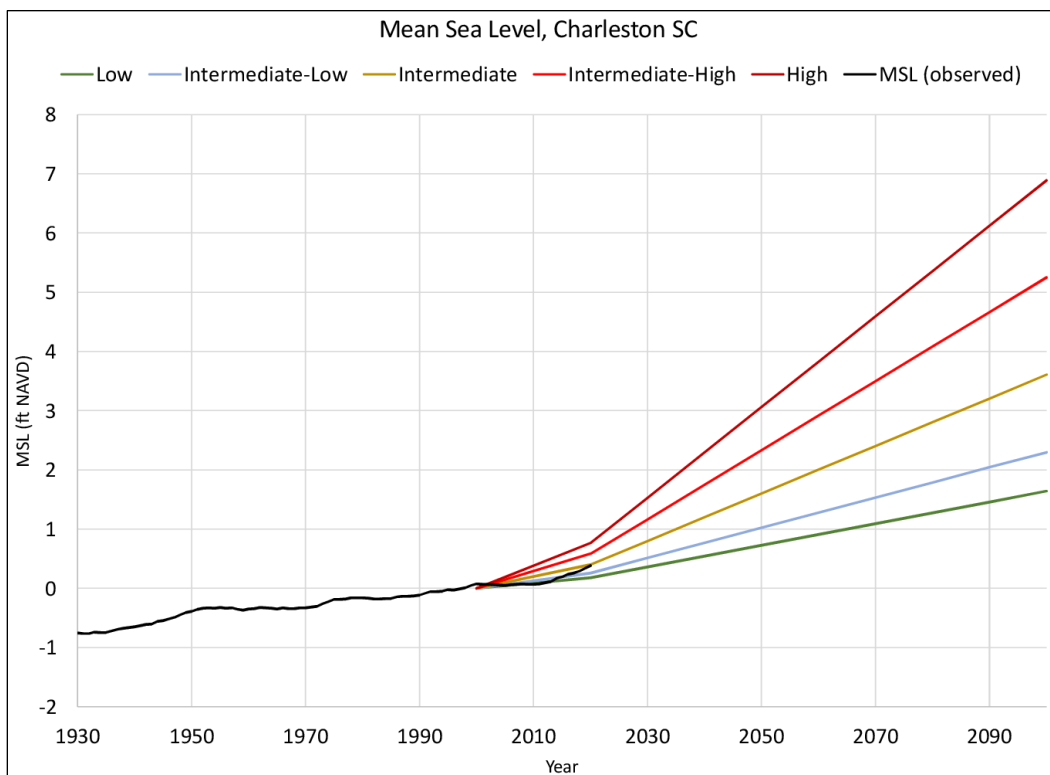
**FIGURE 5.4. [UPPER]** Interannual variations in MSL, with long-term linear and seasonal trends **not** removed. This curve indicates MSL has risen from  $\sim -0.7$  ft NAVD to  $\sim +0.8$  ft NAVD from 1957 to 2024 **[LOWER]** Changes in MSL with the linear trend removed from the data. This curve shows us how SLR rates vary around the long-term mean. A polynomial trend line (sixth order) plotted over the curve helps to visualize oscillations in MSL observed since 1957 at Charleston. The maximum difference between observed and average MSL over these 20-year periods is on the order of  $\sim 3$ – $4$  inches. Shorter-term ( $\sim 5$ – $10$ -year periods) oscillations move about that longer-term trend, as well.



**FIGURE 5.5.** Differences in MSL calculated for 2-year periods. The light blue line ('MSL') represents the average MSL observed each month (the blue curve shown in Fig 5.4 Upper). The red dotted polynomial trend line represents the difference in MSL between those 2-year periods—similar to a moving average of the blue curve in Fig 5.4. This de-trended moving average curve helps identify oscillations in SLR rates around the long-term mean SLR rate.

### 5.3 Flood Vulnerability

While analyzing past sea level trends helps predict changes in the short-term (eg – years to decades), longer-term future sea level trend projections are more useful for strategic planning within coastal communities. To that end, NOAA and several national and international organizations regularly update future sea level projections. Recent observations in global SLR trends and research into the effects of various physical phenomena on sea levels enable more confident projections of future sea levels. The latest regional projections of average SLR by 2100 within the Southeast US range from ~1.5 ft to ~7 ft (Sweet et al 2022). These projections are based on modeled values of future emissions, shifts in ocean circulation, vertical movements in the Earth’s crust, and changes to Earth’s gravitational field and rotation. For reference, the highest astronomical tide (aka ‘King Tide’) brings water levels ~3 ft above MSL at Kiawah Island. So, the water levels observed during those King Tide events represent the higher range of projected MSL by ~2060 and the lower to intermediate projected MSL by ~2100 (Fig 5.6).



**FIGURE 5.6.** Projected MSL values at Charleston average ~2 ft by 2060, and ~4 ft by 2100 according to Sweet et al 2022. Although lower and higher values are possible, these averages are statistically more likely based upon the latest future SLR model projections. The IPCC (2021) advised that SLR will continue through the end of this century regardless of any extra mitigation measures to reduce global warming. They concluded that a rise of at least 2 ft by 2100 has a high probability. Variations between that global estimate and regional estimates provided by NOAA are due to fluctuations in MSL related to vertical movement in the Earth’s crust and shifts in ocean circulation.

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, including causeways over the marsh or backyards fronting sheltered estuaries. Just a small super-elevation of the tide can quickly overtop a road that is barely above normal spring tide levels. On the other hand, locations on the open ocean generally don’t experience nuisance floods the same way. This is because dry beach elevations are typically driven by the uprush limit of waves at high tide. This creates the beach width that allows wind-blown sand to build dunes vertically just landward of that elevation. Thus, higher wave action along the oceanfront leads to relatively high elevations compared to the lagoon side of barrier islands, where there is less wave energy to build elevation above marsh and creek habitats.

Figure 5.7 shows a series of satellite images of Kiawah Island with potentially flooded areas under a range of SLR scenarios between 1 ft and 4 ft. It becomes apparent with increasing SLR that flooding will

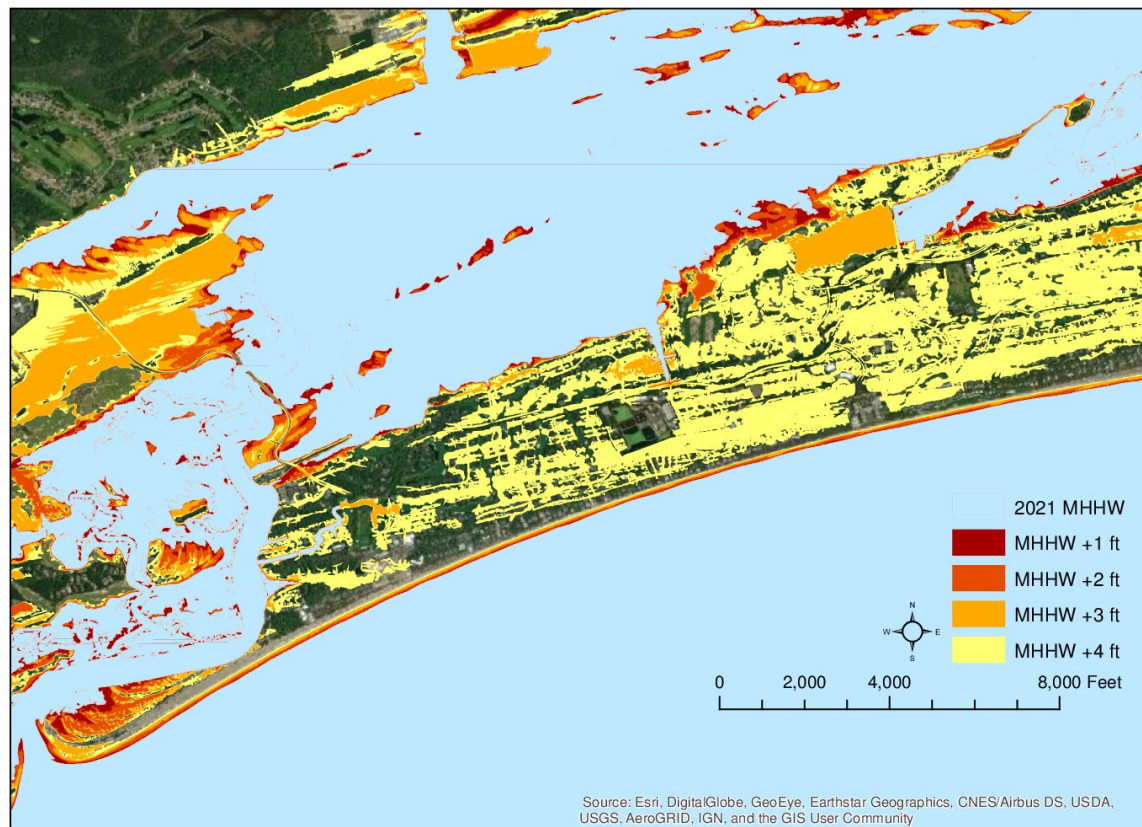
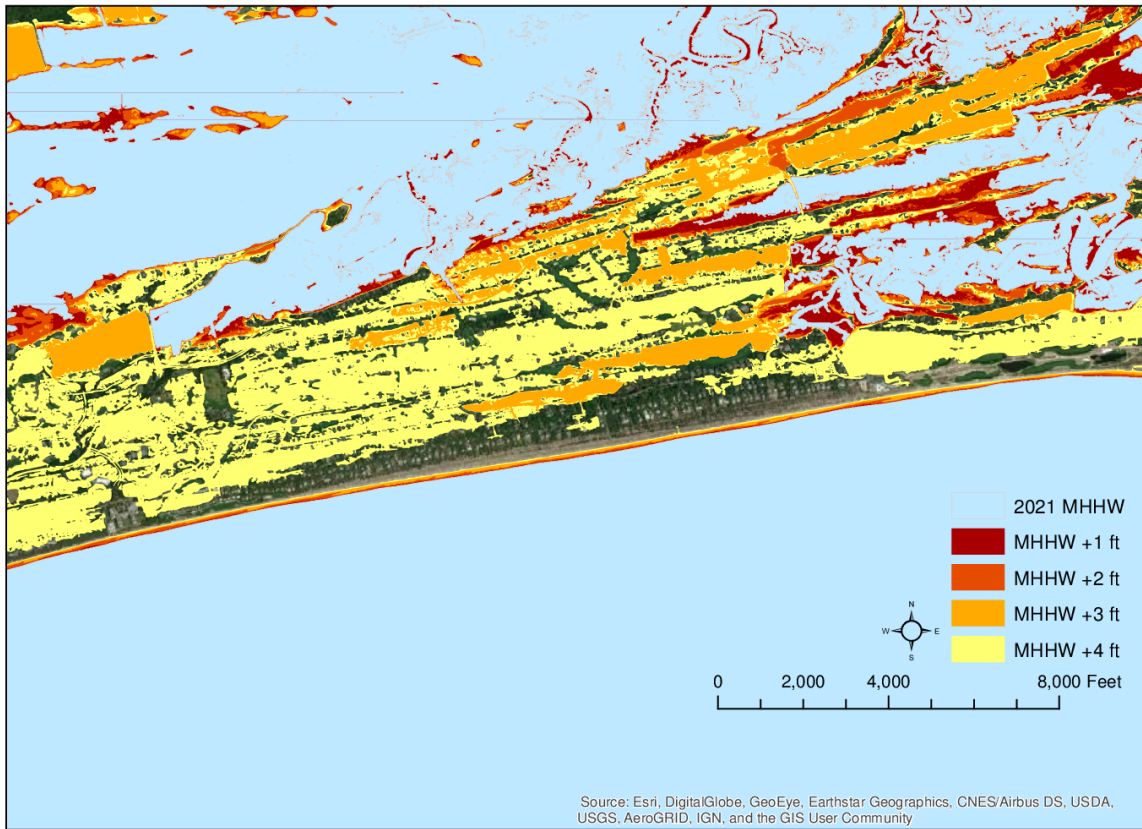
propagate inland from estuarine habitats and be more impactful along the mainland-facing shorelines of Kiawah Island than the ocean-facing beaches. NOAA provides an easy-to-use ‘Sea Level Rise Viewer’ (SLRV; see <https://coast.noaa.gov/digitalcoast/tools/slr.html>) to help people identify local variations in flood impacts under different SLR scenarios. This tool allows users to specify water levels and then generate inundation maps showing MSL as well as depth in previously dry areas. Shapefiles are available for download through this user interface; these shapefiles were used by CSE to generate Figure 5.7, which shows future MHHW elevations plus 1 ft, 2 ft, 3 ft, and 4 ft for Kiawah Island. These types of data-viewing applications are useful for determining when certain SLR scenarios start to impact a particular property.

At present, all properties on Kiawah Island remain above MHHW, except for a few stormwater ponds and the East End marsh. Thoughtful site planning around the island by the original developers, and a continuation of that ethos into the present day, has resulted in Kiawah Island not exhibiting the same degree of vulnerability to SLR as seen in some other communities around South Carolina. As a result, SLR of 1 to 2 ft is not likely to threaten many properties along the central and western portions of the island. Low-lying properties on peninsulas extending into the marsh along the island’s eastern third may experience more significant flooding. At least 1 ft of SLR is all but guaranteed by 2050 (Sweet et al, 2022).

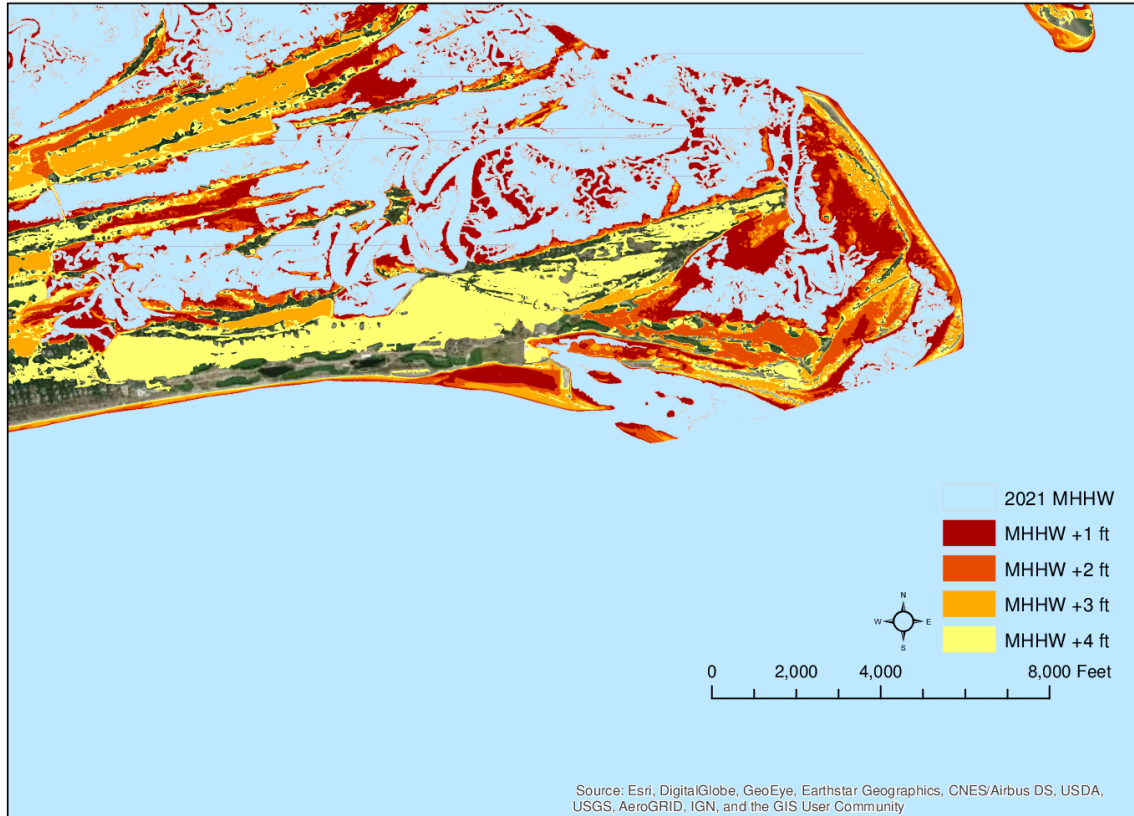
When MHHW increases from 2 ft to >3 ft above present, particularly along the eastern third of the island, low-lying properties and infrastructure bordering Bass Creek or much of Governor’s Drive would see an increase in nuisance flooding and greater storm tide elevations. The most significant impacts will be felt when MHHW increases to 4 ft above present, at which point much of the island will be threatened with inundation at each high tide.

On the oceanfront, SLR of 3 ft and 4 ft could trigger a mixture of impacts. The first 2 to 3 rows of beachfront homes would likely remain high and dry, despite a 4-ft rise in MSL. However, infrastructure connecting those homes to the mainland may be compromised if MHHW reaches elevations greater than 4 ft above its present level. The most significant expansion in flooding on the island will occur under these scenarios, so monitoring the measured rate of SLR in the coming decades will be critical for adequate advance notice for planning and mitigation purposes. A 3 ft increase in MSL is possible under the ‘Intermediate’ scenario by ~2090 (see Fig 5.6), whereas a 4 ft SLR under the same scenario is not expected until after 2100.

It is important to remember that with a significant rise in MSL, the various flood elevations will also increase. If present V-zone flood levels along Kiawah’s oceanfront are around 15 ft NAVD, they are expected to increase to at least 17 ft NAVD by 2100. Alternatively, today’s 100-year flood elevation will become 10- or 25-year flood elevation some decades from now. The impact will be much more frequent damaging storm surges.



**FIGURE 5.7.** Inundated areas under MHHW +1, 2, 3, and 4 ft around western (UPPER) and central (LOWER) Kiawah Island. Dark green areas are the highest ground.



**FIGURE 5.7(cont).** Inundated areas under MHHW +1, 2, 3, and 4 ft around eastern Kiawah Island. Dark green areas are the highest ground.

## 6.0 FINDINGS AND RECOMMENDATIONS

---

Kiawah Island lost a total of ~598,700 cy (-9.3 cy/ft/yr) of sand between October 2023 and December 2024. This compares to a loss of ~2.6 million cy (9.1 cy/ft/yr) of sand between October 2014 and November 2019, when the beach was impacted by several named storms in relatively quick succession with major losses at the Lagoon Reach. From November 2019 to October 2023, relatively quiet hurricane seasons and a large shoal bypassing event at the East End added ~1.5 million cubic yards of sand along the Lagoon Reach that has begun to spread laterally towards the Beach Club and downcoast reaches as of December 2024.

In 2024, the final phase of the shoal bypass cycle began along the East End. This resulted in erosion within both the Lagoon and Stono Inlet reaches, while the Ocean Course Reach experienced accretion. As the shoal continues to bypass sand, the Lagoon and Stono Inlet reaches are expected to erode. The ongoing shoal attachment will supply sand to the Ocean Course, Turtle Point, and (to a lesser degree) Stono Inlet reaches, with gradually decreasing rates of change as the shoal spreads along shore.

*CSE expects that along the central and western portions of Kiawah's beach, erosion rates will reduce and switch to accretion in some areas as the shoal continues spreading and migrating downcoast. It is less likely shoal sand will have much of an impact on the Kiawah Spit Reach, which is adjacent to Captain Sams Inlet. Erosion and accretion along the spit are more related to underwater shifts in the bars and channels of Captain Sams Inlet than bypassing shoals from the other end of Kiawah Island.*

The Town should continue monitoring the 2015 East End project area with attention given to the attachment and spreading of the recent shoal bypass event. Natural flushing channels are now present on either side of the containment dike and are actively migrating as the attached shoal spreads alongshore in either direction from the Lagoon Reach. The eastern channel is a safe distance from the Ocean Course and associated infrastructure, but the western channel is much closer and could threaten these areas quickly during storm conditions. CSE is currently preparing a permit application for manipulating these channels to reduce the risk of damage to the Ocean Course. That permit is expected sometime in 2025 with construction tentatively scheduled for Fall 2025 or Winter 2026. This project will be the third East End channel relocation project.

The lack of structural damage during recent hurricanes is a testament to the building setbacks and accretional nature of Kiawah Island. While many communities along South Carolina's coast experience significant property damage, overwash, and require emergency sand scraping after each storm, Kiawah regularly withstands dune recession with limited damage to upland habitats or properties.

CSE's next monitoring event will be in the fall/winter of 2025–2026.

— THIS PAGE INTENTIONALLY LEFT BLANK —

## 7.0 ACKNOWLEDGEMENTS

---

Sponsored by the Town of Kiawah Island, this report is the 18<sup>th</sup> in a series of annual beach monitoring reports following the 2006 East End beach restoration project.

We thank Mayor Craig Weaver and Jim Jordan (town wildlife biologist) for coordinating CSE's work and providing access to the project site and related information on natural changes at the eastern end.

Drew Giles and Jake Rotureau directed CSE's field surveys with assistance from Steven Traynum, Trey Hair, and Patrick Barrineau. Data reduction and analysis were accomplished by Drew Giles and Jyothirmayi Palaparathi with assistance from Patrick Barrineau. Patrick Barrineau and Jyothirmayi Palaparathi wrote the report with production assistance from Carrie Marks and Trey Hair.

— THIS PAGE INTENTIONALLY LEFT BLANK —

## 8.0 REFERENCES AND BIBLIOGRAPHY

---

- Barrineau, P., Janmatt, R., and Kana, TW. 2019. Comparing Empirical Depths of Closure Along the US East Coast. Coastal Sediments 2019, Proceedings of the 9th International Conference. World Scientific Publishing Co. Hackensack, NJ, pp 2103-2116.
- CSE. 1995. Shoreline assessment and recommendations for dune/beach restoration, Kiawah Island, South Carolina. Final Report for Town of Kiawah Island; Coastal Science & Engineering (CSE), Columbia, South Carolina, 42 pp. + appendices.
- CSE. 1996. Kiawah Island — 1996 beach scraping. Final survey report to Town of Kiawah Island, South Carolina. CSE, Columbia, SC, 6 pp + app.
- CSE. 1997. Kiawah Island — state of the beach — winter 1997, Kiawah Island, South Carolina. Memorandum Report to Town of Kiawah Island, South Carolina. CSE, Columbia, SC, 14 pp + app.
- CSE. 1999. Updated shoreline assessment and condition of the beach, Kiawah Island, South Carolina. Final Report for Town of Kiawah Island. CSE, Columbia, South Carolina, 81 pp + appendices.
- CSE. 2005. Kiawah Island East End erosion – opinion of probable causes and alternative strategies for management mitigation. Memorandum Report for Town of Kiawah Island, SC. CSE, Columbia, South Carolina, 31 pp.
- CSE. 2007. East end erosion and beach restoration project, Kiawah Island, Charleston County, SC. Final Report for Town of Kiawah Island, SC. CSE, Columbia, South Carolina, 54 pp + appendices.
- CSE. 2008. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 1](#). CSE. Columbia, South Carolina, 38 pp + appendices.
- CSE. 2009 (February). 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 2](#). CSE. Columbia, South Carolina, 50 pp + appendices.
- CSE. 2009 (December). 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 3](#). CSE. Columbia, South Carolina, 55 pp + appendices.
- CSE. 2011. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 4](#). CSE. Columbia, South Carolina, 69 pp + appendices.
- CSE. 2012. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 5](#). CSE. Columbia, South Carolina, 83 pp + appendices.
- CSE. 2013. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 6](#). CSE. Columbia, South Carolina, 71 pp + appendices.
- CSE. 2014. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 7](#). CSE. Columbia, South Carolina, 69 pp + appendices.
- CSE. 2015. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 8](#). CSE. Columbia, South Carolina, 71 pp + appendices.
- CSE. 2016. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 9](#). CSE. Columbia, South Carolina, 75 pp + appendices.
- CSE. 2017. 2006 East end beach restoration project, Kiawah Island, South Carolina, [Survey Report No 10](#). CSE. Columbia, South Carolina, 73 pp + appendices.
- CSE. 2020. 2020 annual beach and inshore survey, Arcadian Shores, Horry County (SC). CSE. Columbia, South Carolina. 53 pp + appendices.
- CSE. 2021. Annual beach and inshore surveys—2006 east end erosion and beach restoration project, Kiawah Island, Charleston County, SC. Monitoring Report #14 for Town of Kiawah Island, SC. CSE, Columbia, SC, 69 pp + appendix.
- CSE. 2022 (March). Annual beach and inshore surveys—2006 east end erosion and beach restoration project, Kiawah Island, Charleston County, SC. Monitoring Report #15 for Town of Kiawah Island, SC. CSE, Columbia, SC, 69 pp + appendix.

- Duc, AW, and RS Tye. 1987. Evolution and stratigraphy of a regressive barrier/back-barrier complex: Kiawah Island, South Carolina. *Sedimentology*, Vol 34, pp 237-251.
- Eiser, WC, and TW Kana. 1987. Summary of shoreline changes along Kiawah Island between September 1986 and October 1987. Report to Kiawah Island Company, Kiawah Island, SC. CSE, Columbia, SC, 12 pp + appendices.
- FitzGerald, D.M., Hein, C.J., Hughes, Z., Kulp, M., Georgiou, I., Miner, M. 2018. Runaway barrier island transgression concept: global case studies. In: Moore, L.A. and Murray, A.B (eds.) *Barrier Dynamics and Response to Changing Climate*. Springer, Cham, Switzerland, 3-56
- Gaudio, DJ. 1998. Shoal bypassing in South Carolina inlets: geomorphic variables and empirical predictions for nine inlets. Tech. Rept., Dept. Geological Sciences, Univ. South Carolina, Columbia, 182 pp.
- Gaudio, DJ, and TW Kana. 2001. Shoal bypassing in South Carolina tidal inlets: geomorphic variables and empirical predictions for nine mesotidal inlets. *Jour Coastal Research*, Vol 17, pp 280-291.
- Harris, MS, PT Gayes, JL Kindinger, JG Flocks, DE Krantz, P Donovan. 2005. Quaternary geomorphology and modern coastal development in response to an inherent geologic framework: an example from Charleston, South Carolina.
- Hayes, MO. 1977. Development of Kiawah Island, SC. In *Proc Coastal Sediments '77*, ASCE, New York, NY, pp 828-847.
- Hayes, MO. 1994. Georgia Bight. Chapter 7 in RA Davis, Jr (ed), *Geology of the Holocene Barrier Island System*, Springer-Verlag, Berlin, pp 233-304.
- Hayes, MO, SJ Wilson, DM FitzGerald, LJ Hulmes, and DK Hubbard. 1975. Coastal processes and geomorphology. In *Environmental Inventory of Kiawah Island*, Environmental Research Center Inc, Columbia, SC, 165 pp.
- Hayes, MO, and DM FitzGerald. 2013. Origin, evolution, and classification of tidal inlets. *Journal of Coastal Research*, SI 69, pp 14-33.
- Hayes, MO, and J Michel. 2008. *A Coast for All Seasons — A Naturalist's Guide to the Coast of South Carolina*. Pandion Books, a division of Research Planning, Columbia, SC, 285 pp.
- Jones, CP. 1989. Summary of proposed revisions to interim baseline and setback line at Kiawah Island. Final Report, Kiawah Resort Associates, Charleston, SC. CSE, Columbia, SC, 31 pp., appendix, attachment.
- Kana, TW. 1993. The profile volume approach to Beach Renourishment. In DK Stauble, and NC Kraus (eds.), *Beach Nourishment Engineering and Management Considerations*, Association of Civil Engineers, New York, NY, p. 176-190.
- Kana, TW. 2002. Barrier island formation via channel avulsion and shoal bypassing. In *Proc 28th Intl Conf Coastal Engineering (Cardiff)*, pp 3438-3448.
- Kana, TW. 2011. *Coastal Erosion and Solutions – A Primer*. Second Edition, Coastal Science & Engineering, Columbia, SC, 38 pp.
- Kana, TW, SP Dinnel, and WJ Sexton. 1981. Bathymetry of Kiawah River, Stono River, and historical changes in Stono Inlet, South Carolina. Tech Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 71 pp.
- Kana, TW, E.J. Hayter, and P.A. Work. 1999. Mesoscale sediment transport at southeastern U.S. tidal inlets: conceptual model applicable to mixed energy settings. *Jour. Coastal Research*, Vol 15(2), pp 303-313.
- Kana, TW, ML Williams, and SJ Siah. 1984. Shoreline changes along Kiawah Island, May 1983 — May 1984. Final Report to Kiawah Island Company, Charleston, SC. RPI, Columbia, SC, 34 pp. + app.
- Kana, TW, ML Williams, and FD Stevens. 1985. Managing shoreline changes in the presence of nearshore shoal migration and attachment. In *Proc. Coastal Zone '85*, Vol. 1, ASCE, New York, NY, pp. 1277-1294.
- Kana, TW, MJ Vogel, WJ Sexton, and MO Hayes. 1983. Shoreline changes along Kiawah Island, May 1872 through May 1983. Final Report for Kiawah Island Company, Charleston, SC. Research Planning Institute Inc, Columbia, SC, 33 pp + appendices.
- Kana, TW, SB Traynum, D Gaudio, HL Kaczowski, and T Hair. 2013. The physical condition of South Carolina beaches 1980-2010. *Jour Coastal Research*, Special Issue 69, pp 61-82.
- Katmarian, E, and TW Kana. 1996. Shoreline assessment and recommendations for dune/beach restoration, Kiawah Island, South Carolina. Final Report to Town of Kiawah Island, SC. CSE, Columbia, SC, 44 pp + appendices.

- Komar, PD. 1998. *Beach Processes and Sedimentation*. Second Edition, Prentice-Hall, Inc, Simon & Schuster, Upper Saddle River, NJ, 544 pp.
- Levisen, MV, and RF Van Dolah. 1996. Environmental evaluation of the Kiawah Island beach scraping project. Final Report to Town of Kiawah Island, SC. SCDNR Marine Resources Division, Charleston, SC, 16 pp + app.
- Moslow, TF. 1980. Stratigraphy of mesotidal barrier islands. Ph.D. Dissertation, University of South Carolina, Columbia, South Carolina. 247 pp.
- National Oceanic and Atmospheric Administration (NOAA). 2022. National Data Buoy Center Station 41004 'Edisto'. [https://www.ndbc.noaa.gov/station\\_page.php?station=41004](https://www.ndbc.noaa.gov/station_page.php?station=41004). Accessed 19 June 2022.
- National Weather Service (NWS). 2019. Hurricane Dorian Discussion Number 50. NWS National Hurricane Center Miami FL.
- Piecuch, C.G., Huybers, P., Hay, C.C. et al. Origin of spatial variation in US East Coast sea-level trends during 1900–2017. *Nature* 564, 400–404 (2018)
- SCDHEC–OCRM. 2009. Adapting to shoreline change: a foundation for improved management and planning in South Carolina. Draft Report of the Shoreline Change Advisory Committee, South Carolina Department of Health and Environmental Control, Office of Ocean and Coastal Resources Management, Charleston, SC, 151 pp.
- Sexton, WJ, and MO Hayes. 1996. Holocene deposits of reservoir quality sand along the central South Carolina coast. *American Association Petroleum Geologists, Bulletin* 80(6), pp 831-855.
- Sexton, WJ, MO Hayes, and SP Dinnel. 1981. Shoreline stability of Kiawah Island, SC, October 1975 through July 1981. Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 22 pp.
- Sexton, WJ, MO Hayes, TW Kana, MG Muthig. 1982. Shoreline stability of Kiawah Island, South Carolina (March 1981 through January 1982). Final Report to Kiawah Island Company, Charleston, SC. Research Planning Inst Inc, Columbia, SC, 30 pp.
- Sweet, VW, G Dusek, J Obeysekera, and JJ Marra. 2018. Patterns and Projections of High Tide Flooding Along the U.S. Coastline using a Common Impact Threshold. NOAA Technical Report NOS CO-OPS, Vol. 86., Silver Spring, MD: National Oceanic and Atmospheric Administration.
- Sweet, WV, G Dusek, G Carbin, JJ Marra, D Marcy, and S Simon. 2020. 2019 State of US High Tide Flooding With a 2020 Outlook. NOAA Tech. Rep. NOS CO-OPS., Vol. 92. Silver Spring, MD: National Oceanic and Atmospheric Administration, 17.
- Sweet, W., et al. 2022, Global and regional sea level rise scenarios for the United States: Updated mean projections and extreme water level probabilities along United States coastlines, NOAA Tech. Rep. NOS 01, Natl. Ocean Serv., NOAA, Silver Spring, MD, 111 pp.
- USFWS. 2006. Biological opinion: Kiawah Island beach nourishment (P/N 2005-1W-310-P). US Department of the Interior, Fish and Wildlife Service, Charleston, SC, 51 pp + app.
- Ward, LG. 1978. Physical and sedimentological processes in a salt marsh tidal channel: Kiawah Island, South Carolina. Dissertation, Department of Geology, University of South Carolina, Columbia, 180 pp.
- Williams, ML, and TW Kana. 1985. Shoreline changes along Kiawah Island, June 1984 — June 1985. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 76 pp.
- Williams, ML, and TW Kana. 1986. Shoreline changes along Kiawah Island, June 1985 to September 1986. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 48 pp. + app.
- Williams, ML, and TW Kana. 1987. Summary of shoreline changes along Kiawah Island between September 1986 and May 1987. Final Report to Kiawah Island Company, Charleston, SC. CSE, Columbia, SC, 11 pp + app.

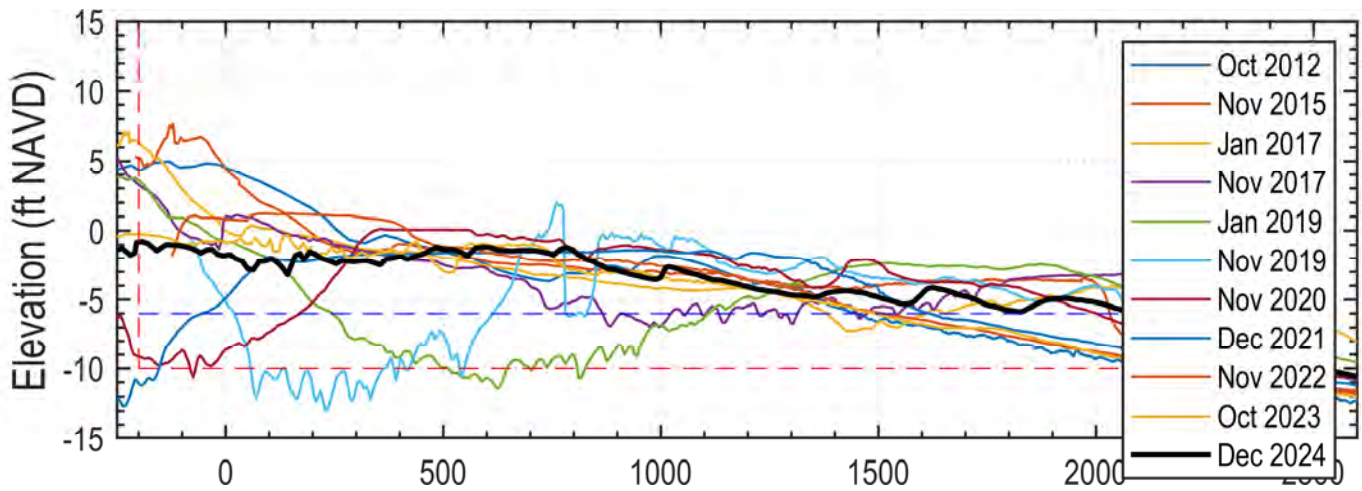
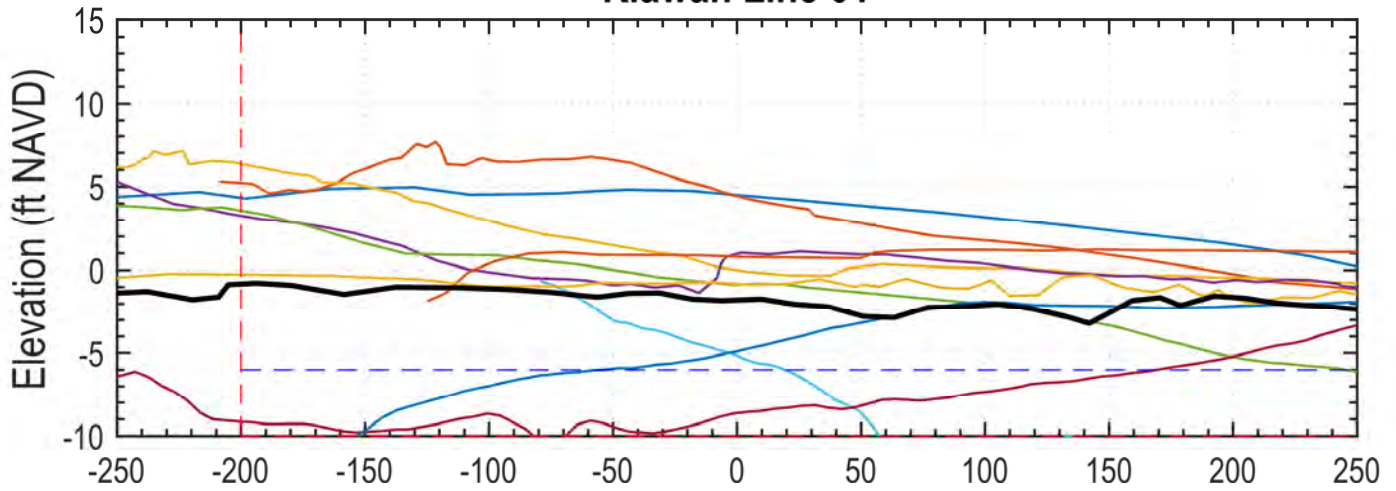
— THIS PAGE INTENTIONALLY LEFT BLANK —

# **APPENDIX A**

## **CSE Profiles**

— THIS PAGE INTENTIONALLY LEFT BLANK —

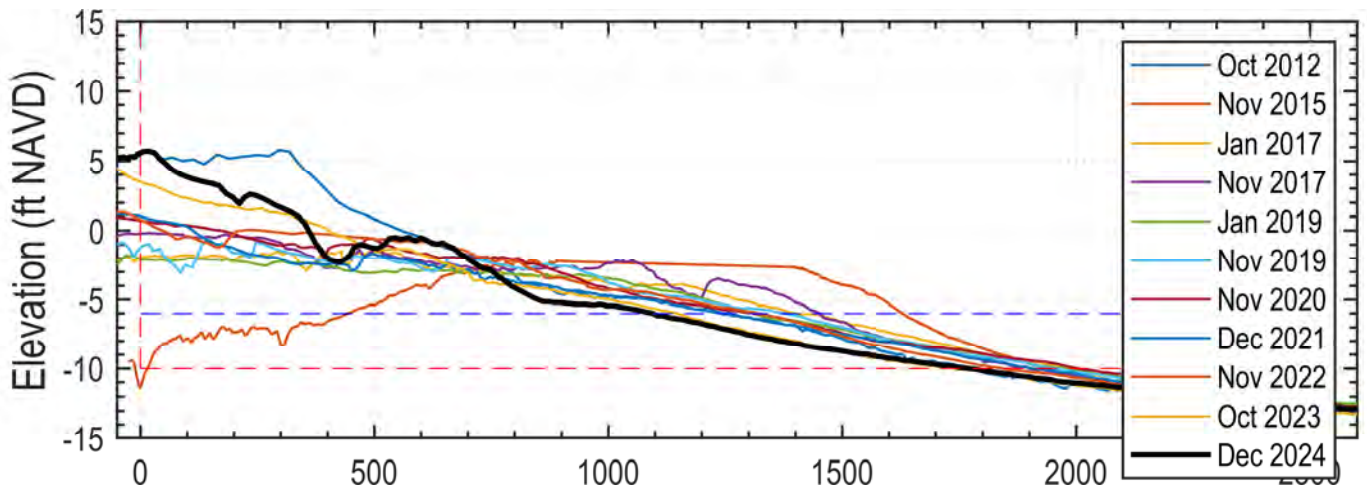
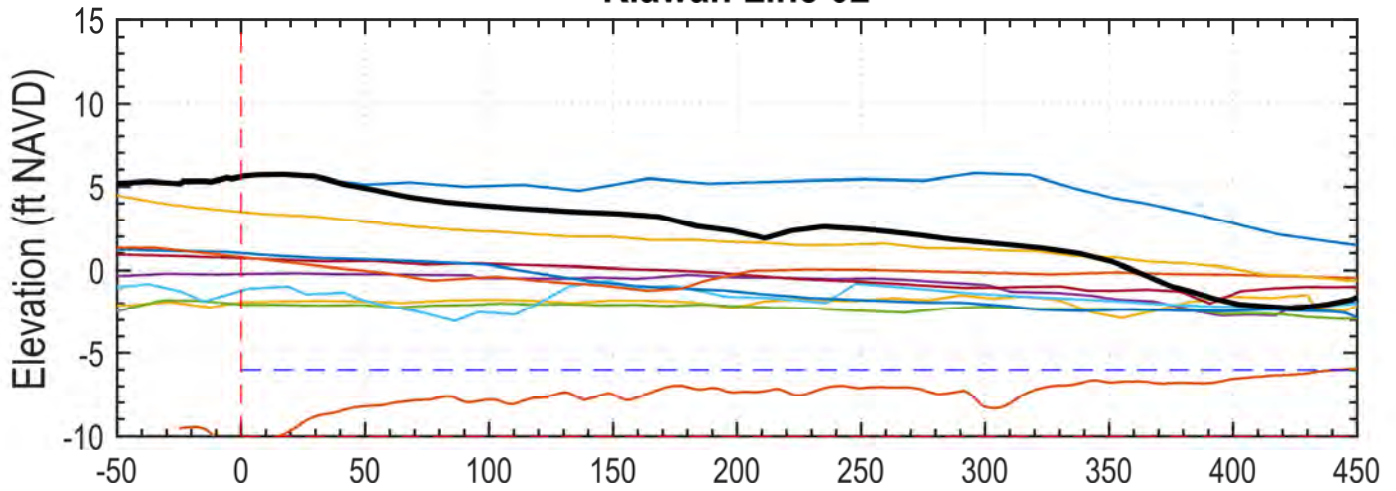
## Kiawah Line 01



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	307.6	294.3	601.9
Nov 2015	353.0	341.4	694.4
Jan 2017	274.7	393.2	667.9
Nov 2017	225.3	367.1	592.4
Jan 2019	181.6	298.0	479.6
Nov 2019	196.5	288.9	485.4
Nov 2020	247.6	326.0	573.7
Dec 2021	228.2	309.4	537.6
Nov 2022	278.5	305.8	584.3
Oct 2023	223.1	305.2	528.3
Dec 2024	237.1	367.0	604.1



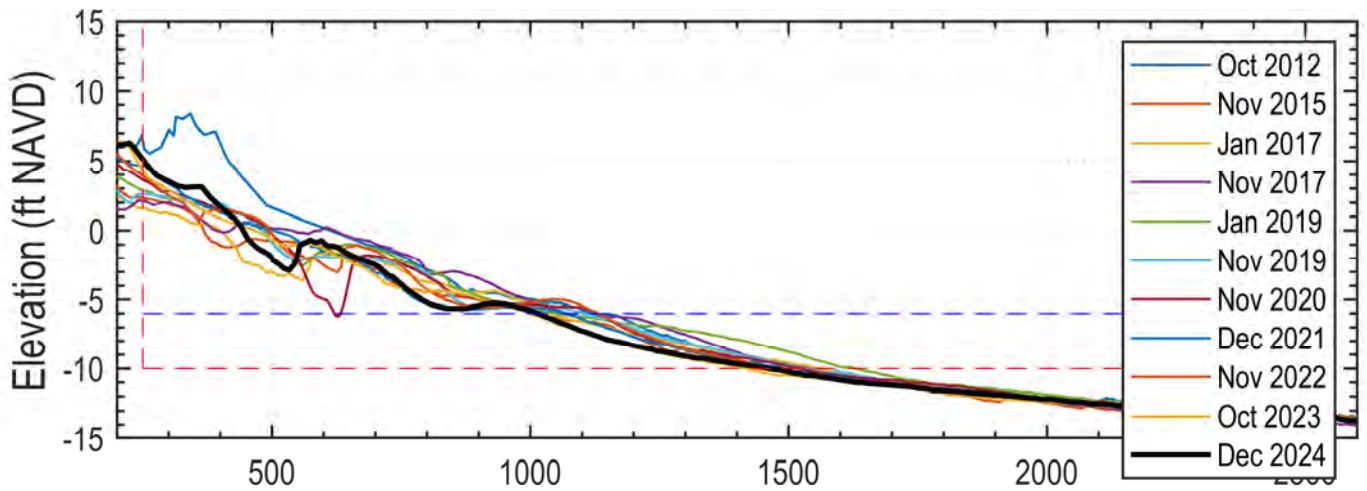
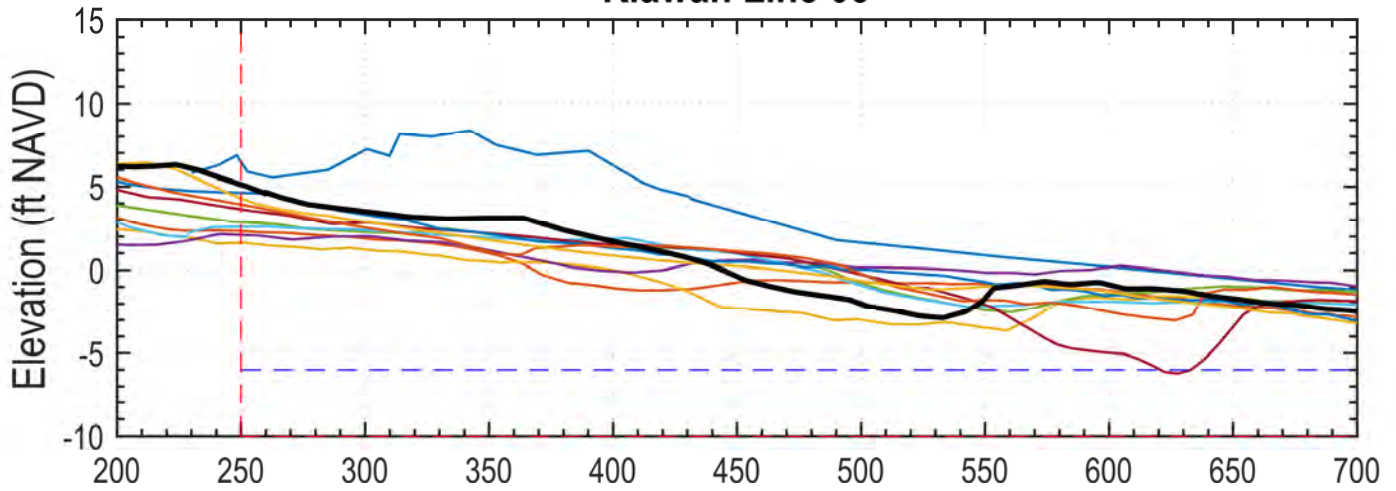
## Kiawah Line 02



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	265.2	224.1	489.3
Nov 2015	123.9	238.2	362.0
Jan 2017	155.7	250.3	406.0
Nov 2017	192.4	242.9	435.3
Jan 2019	137.1	241.9	379.0
Nov 2019	157.9	242.8	400.6
Nov 2020	181.2	241.4	422.6
Dec 2021	144.2	234.1	378.3
Nov 2022	188.7	230.7	419.4
Oct 2023	187.9	207.6	395.6
Dec 2024	200.4	206.3	406.7



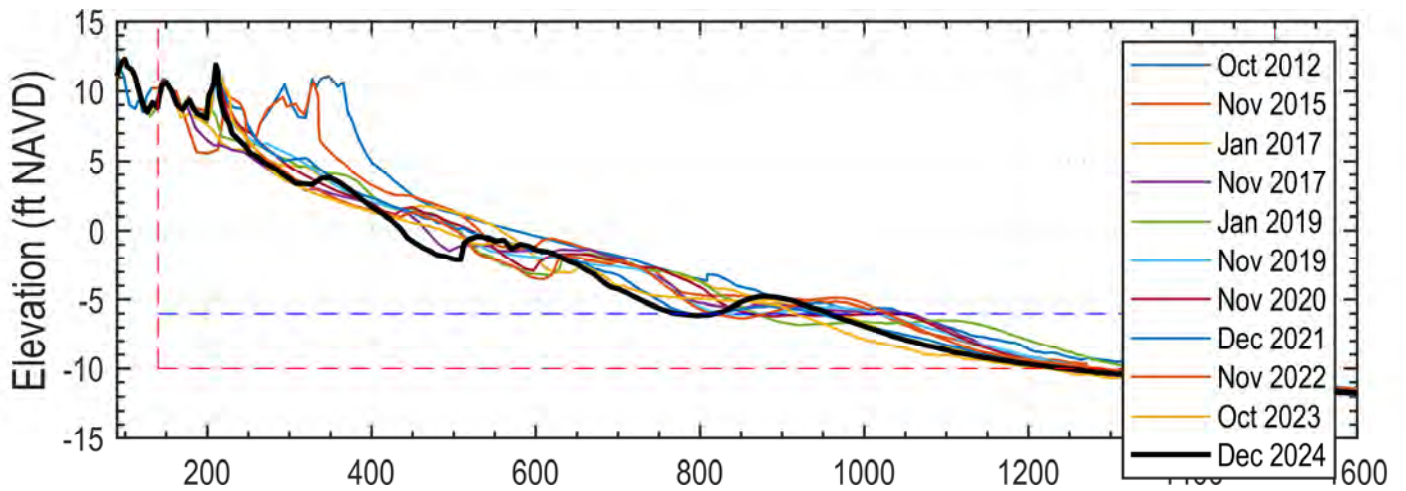
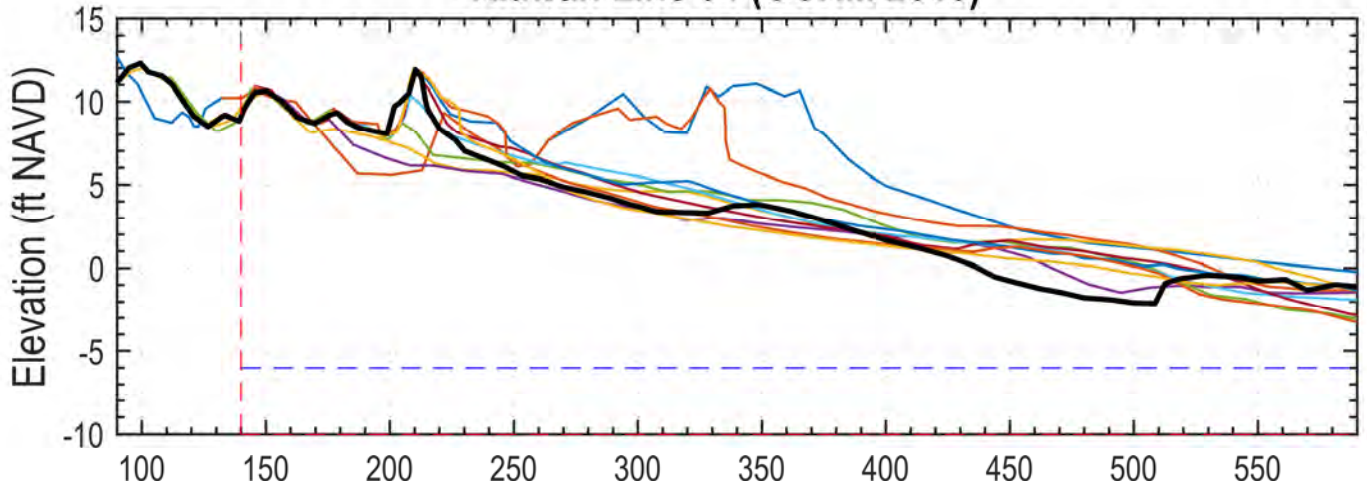
## Kiawah Line 03



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	184.6	155.1	339.7
Nov 2015	107.4	145.4	252.8
Jan 2017	104.5	152.1	256.5
Nov 2017	141.6	160.4	302.0
Jan 2019	129.2	167.7	296.9
Nov 2019	122.6	155.4	278.0
Nov 2020	118.9	152.3	271.2
Dec 2021	118.6	147.7	266.2
Nov 2022	124.0	151.1	275.2
Oct 2023	116.6	137.0	253.6
Dec 2024	116.9	139.3	256.1



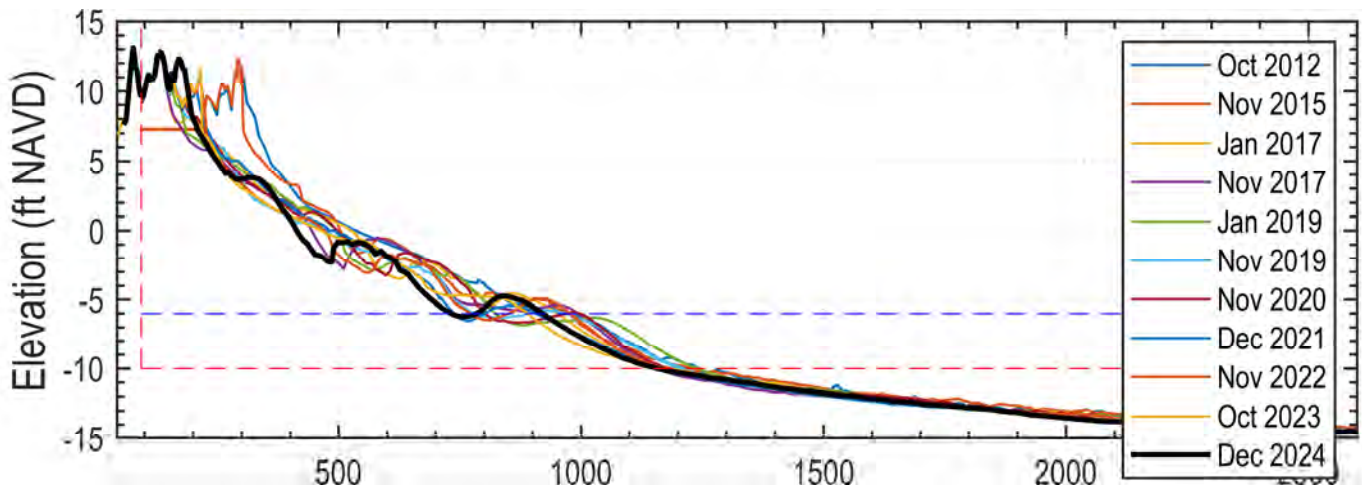
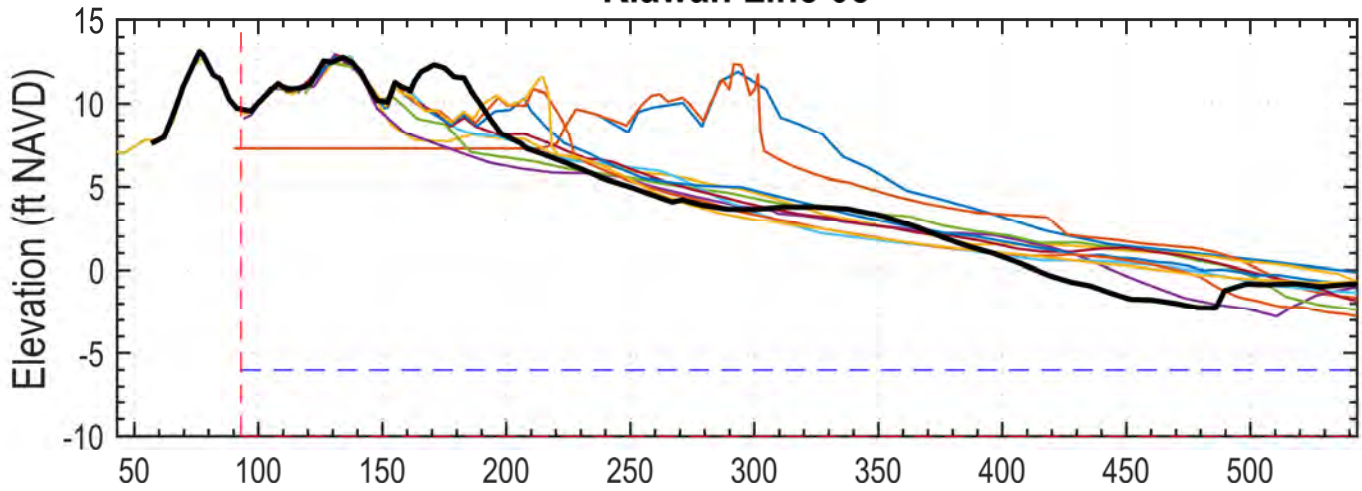
### Kiawah Line 04 (OCRM 2615)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	234.6	153.6	388.2
Nov 2015	214.7	146.2	360.9
Jan 2017	191.6	138.8	330.5
Nov 2017	177.4	148.2	325.6
Jan 2019	187.9	152.5	340.4
Nov 2019	184.7	147.3	331.9
Nov 2020	189.5	146.8	336.2
Dec 2021	187.5	139.8	327.3
Nov 2022	181.3	144.5	325.8
Oct 2023	176.7	131.8	308.5
Dec 2024	171.4	137.5	308.9



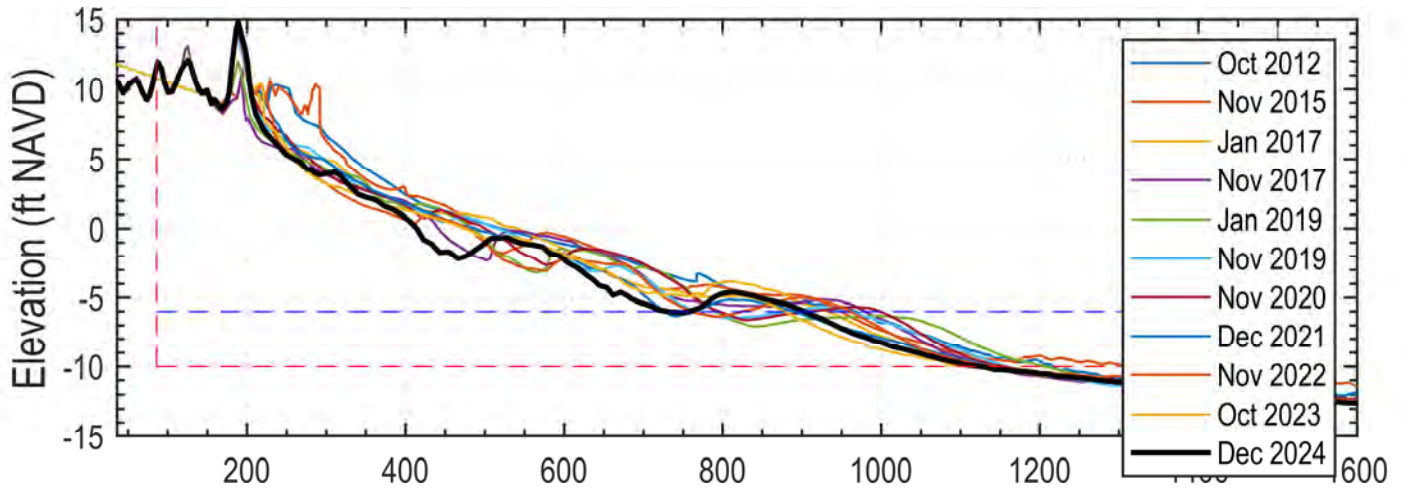
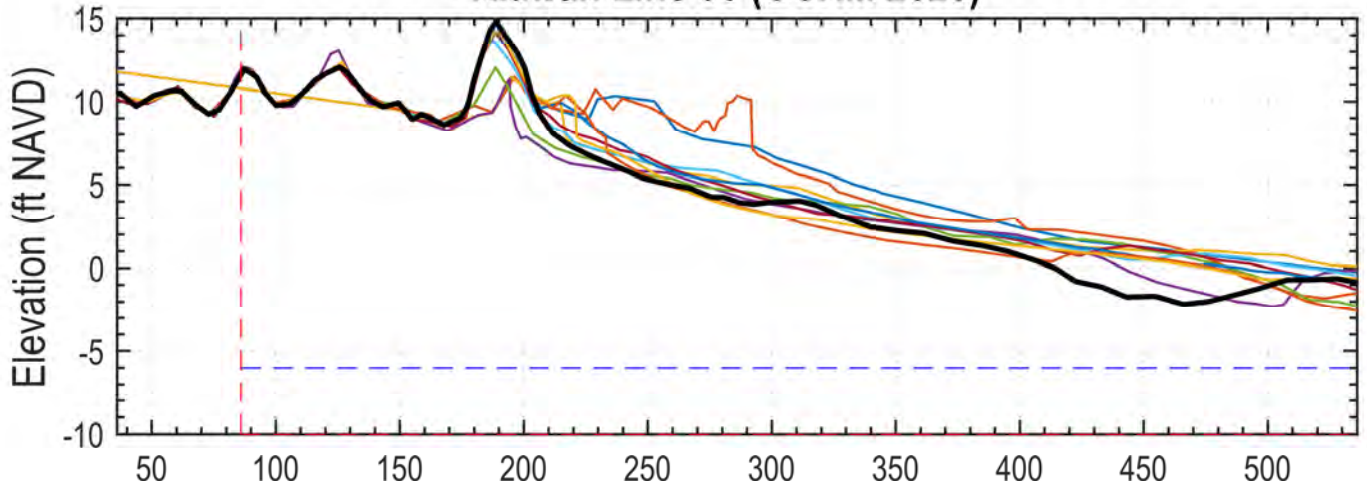
## Kiawah Line 05



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	235.1	149.3	384.3
Nov 2015	227.3	145.0	372.2
Jan 2017	209.7	141.4	351.2
Nov 2017	196.4	144.6	341.0
Jan 2019	203.4	149.5	352.9
Nov 2019	196.2	146.7	342.9
Nov 2020	205.8	143.7	349.5
Dec 2021	202.7	137.7	340.4
Nov 2022	194.8	142.1	336.9
Oct 2023	199.8	133.5	333.3
Dec 2024	191.4	137.1	328.5



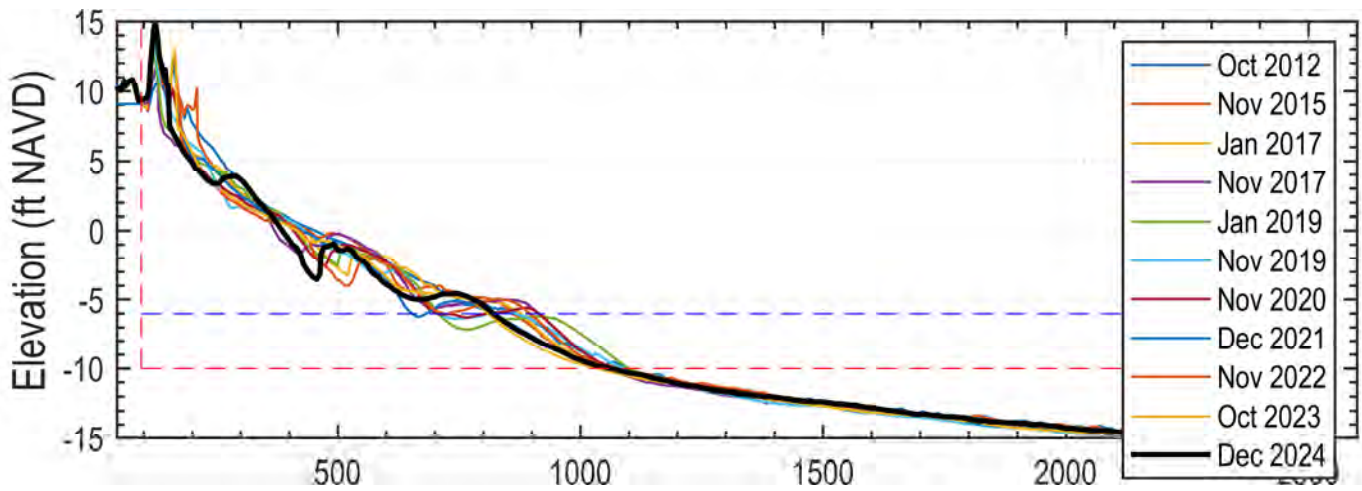
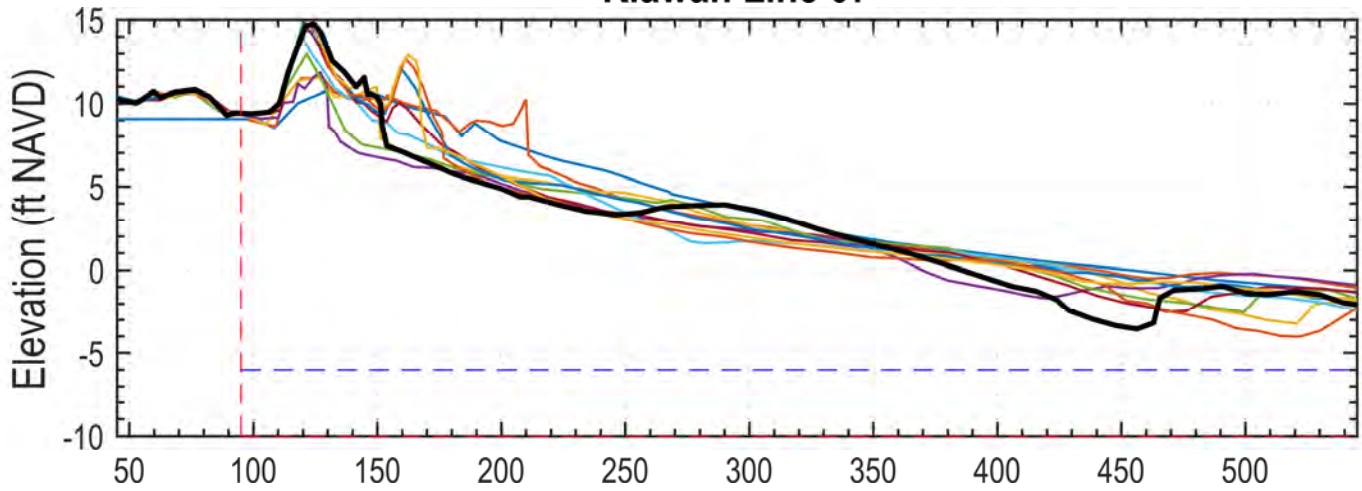
### Kiawah Line 06 (OCRM 2620)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	238.1	146.4	384.5
Nov 2015	234.1	144.1	378.2
Jan 2017	218.8	138.3	357.1
Nov 2017	206.8	142.8	349.6
Jan 2019	204.7	146.0	350.8
Nov 2019	206.9	143.4	350.3
Nov 2020	213.7	143.8	357.5
Dec 2021	209.7	136.2	345.9
Nov 2022	199.8	139.6	339.4
Oct 2023	206.4	130.8	337.2
Dec 2024	193.6	134.6	328.2



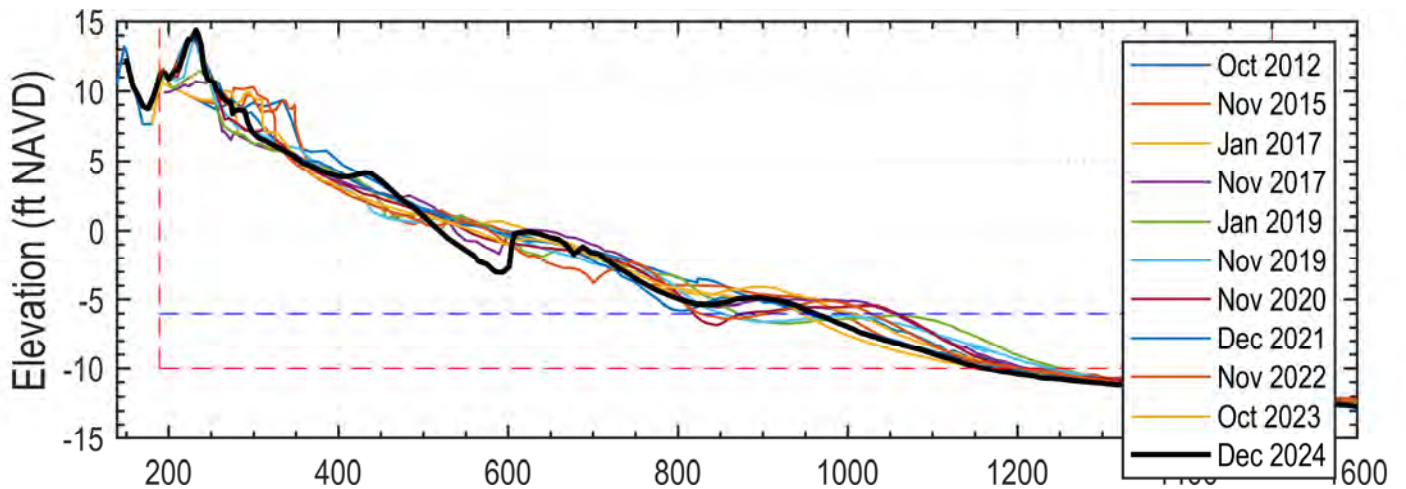
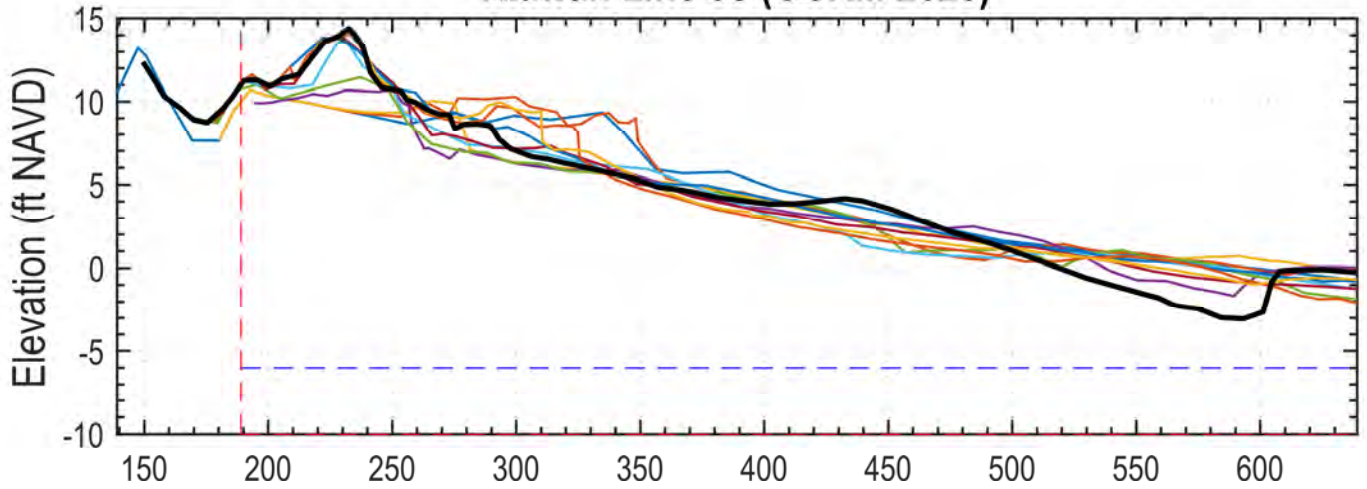
## Kiawah Line 07



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	187.4	129.3	316.7
Nov 2015	184.3	126.6	310.8
Jan 2017	173.8	126.6	300.4
Nov 2017	162.7	131.2	293.9
Jan 2019	163.9	132.0	296.0
Nov 2019	162.6	129.9	292.6
Nov 2020	165.2	130.8	296.0
Dec 2021	166.5	122.6	289.1
Nov 2022	161.6	128.8	290.4
Oct 2023	168.4	119.0	287.4
Dec 2024	161.2	122.2	283.4



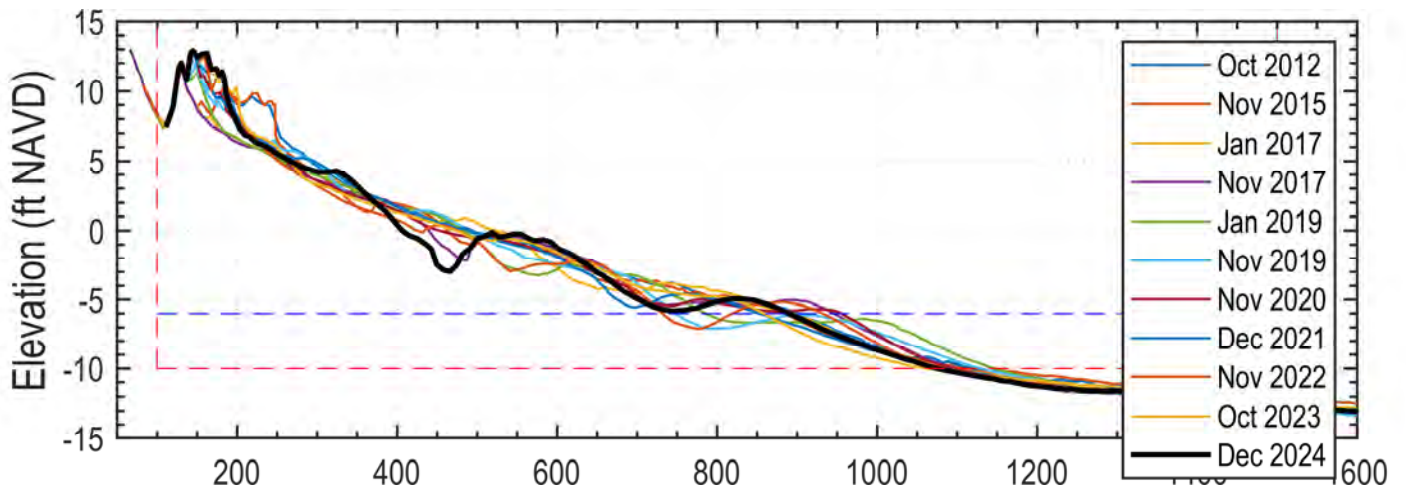
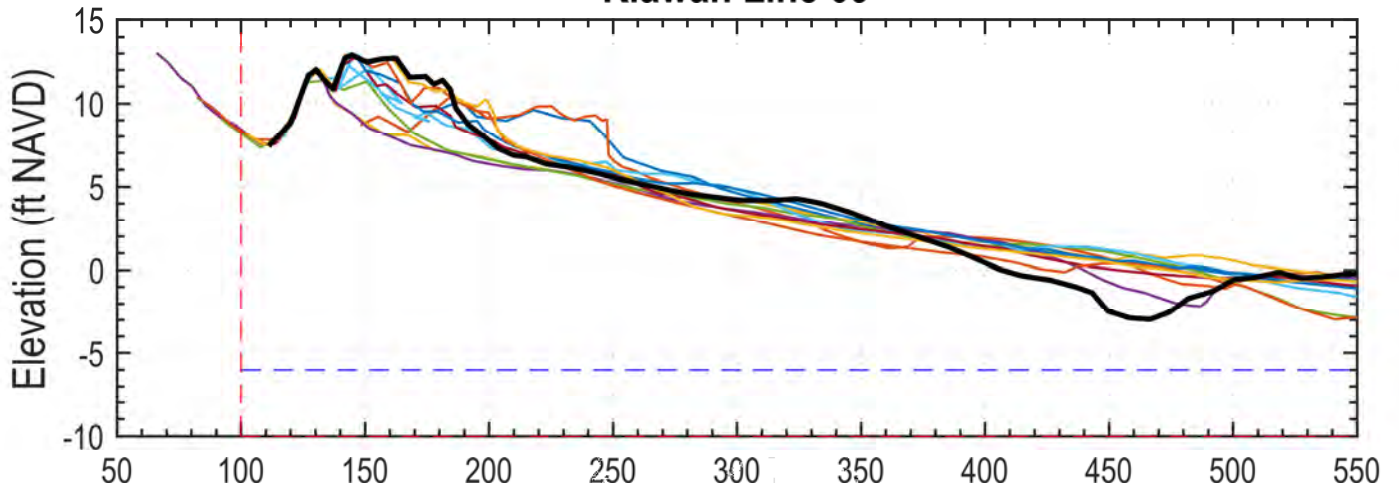
### Kiawah Line 08 (OCRM 2625)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	213.0	134.6	347.6
Nov 2015	209.6	130.5	340.1
Jan 2017	201.1	133.2	334.3
Nov 2017	198.6	138.4	337.0
Jan 2019	191.0	141.1	332.1
Nov 2019	189.9	137.0	326.9
Nov 2020	194.9	136.8	331.6
Dec 2021	199.7	129.2	328.9
Nov 2022	191.2	133.8	325.0
Oct 2023	201.1	124.6	325.7
Dec 2024	195.4	128.0	323.4



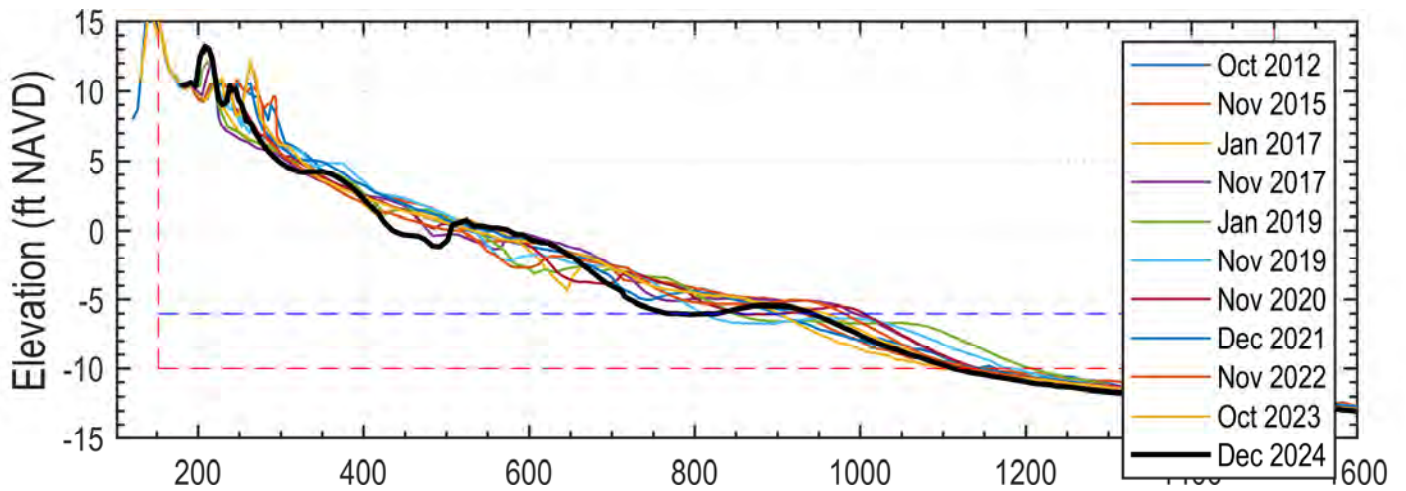
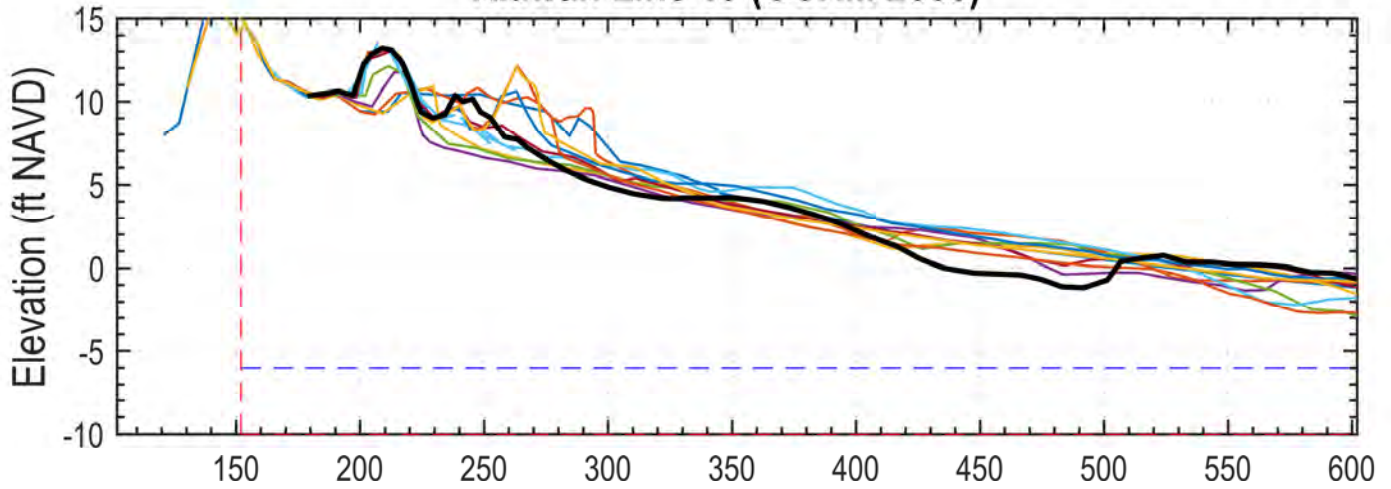
## Kiawah Line 09



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	202.8	132.2	334.9
Nov 2015	200.0	129.3	329.3
Jan 2017	190.3	130.4	320.7
Nov 2017	185.9	135.6	321.5
Jan 2019	183.3	138.4	321.7
Nov 2019	190.7	133.8	324.5
Nov 2020	190.4	135.9	326.3
Dec 2021	195.3	127.6	322.9
Nov 2022	183.5	130.9	314.5
Oct 2023	197.8	124.4	322.2
Dec 2024	190.2	129.5	319.7



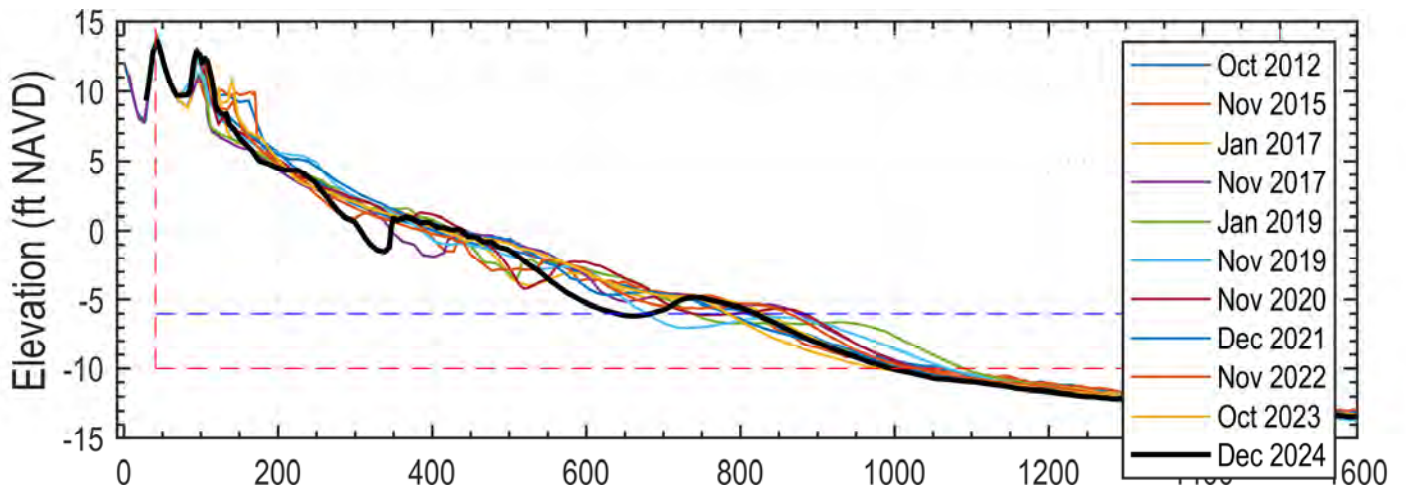
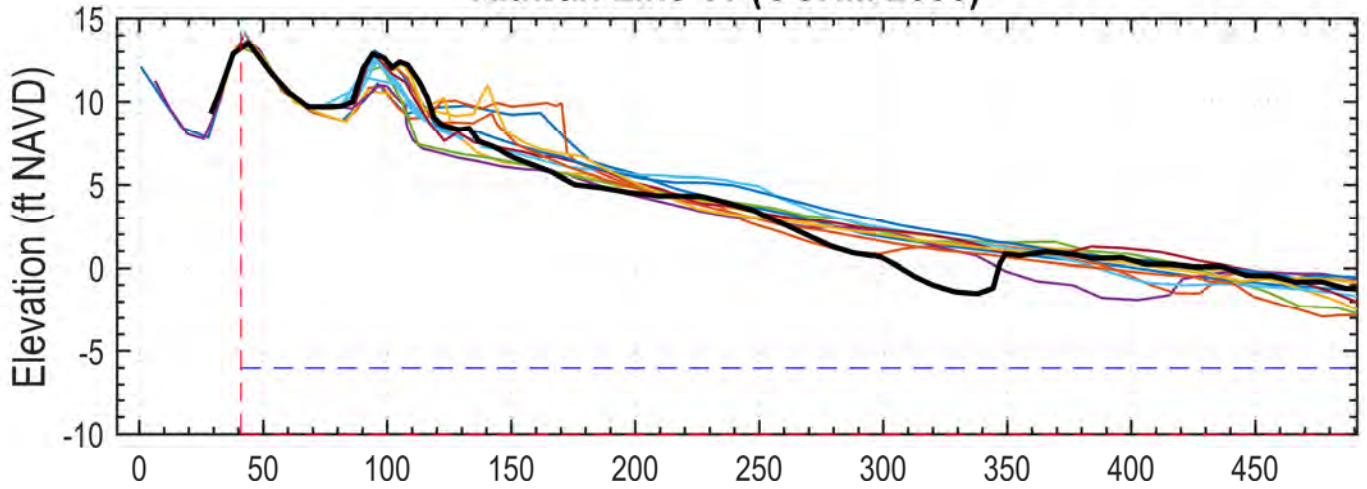
### Kiawah Line 10 (OCRM 2630)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	205.0	130.8	335.8
Nov 2015	206.5	126.9	333.3
Jan 2017	192.4	130.7	323.1
Nov 2017	193.3	135.2	328.4
Jan 2019	189.6	139.6	329.1
Nov 2019	197.1	135.4	332.5
Nov 2020	193.8	135.5	329.3
Dec 2021	202.6	126.5	329.1
Nov 2022	193.5	132.5	326.0
Oct 2023	202.8	122.8	325.6
Dec 2024	184.2	128.6	312.9



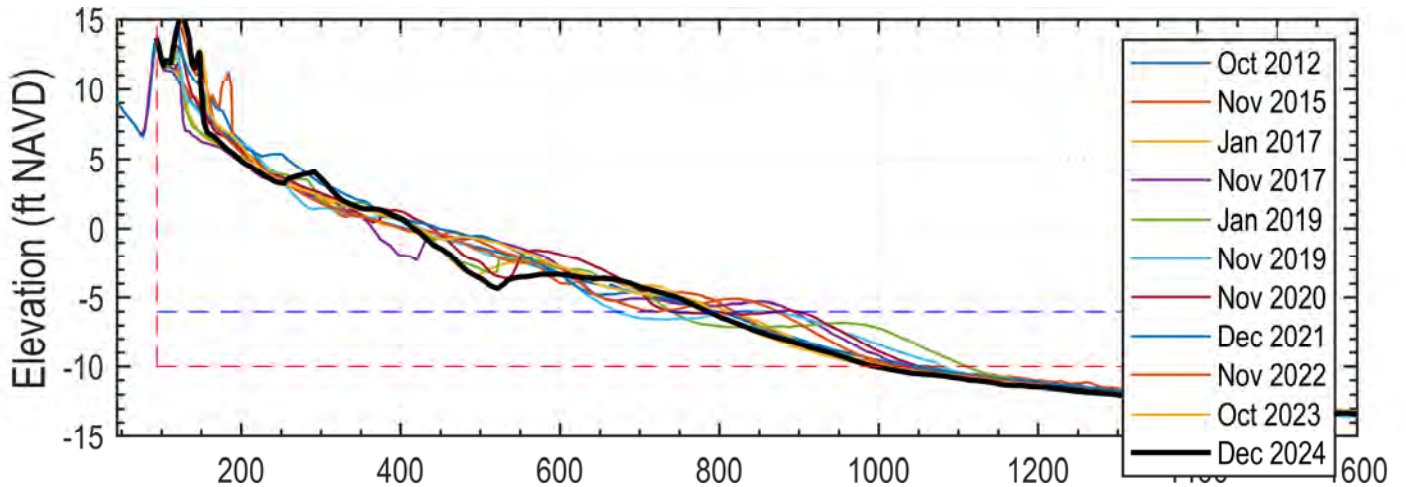
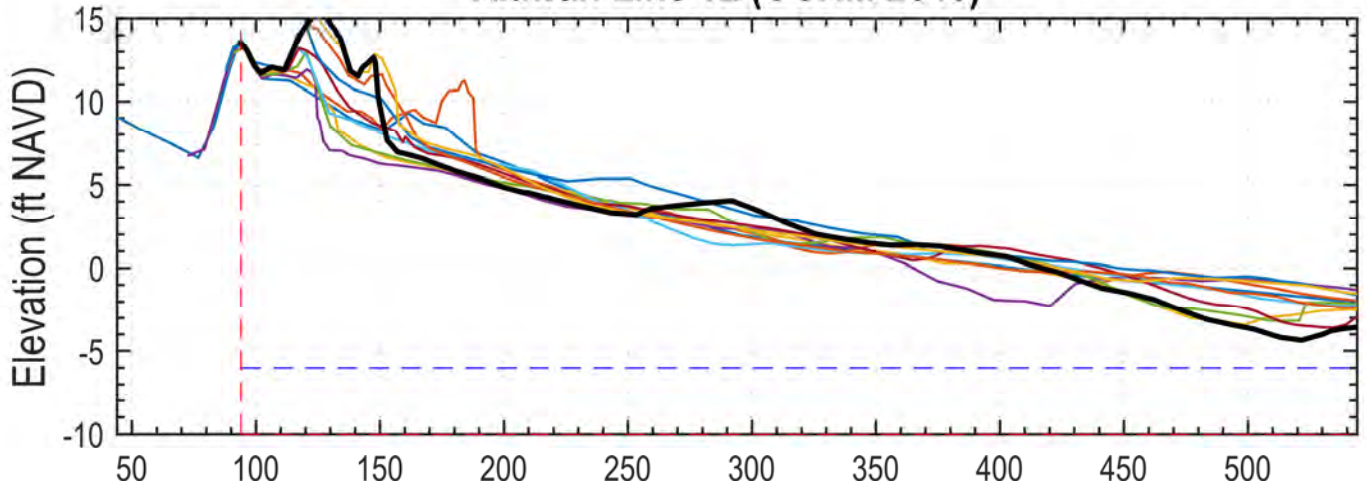
### Kiawah Line 11 (OCRM 2635)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	194.5	129.3	323.8
Nov 2015	194.0	126.1	320.0
Jan 2017	185.6	129.0	314.6
Nov 2017	183.3	134.1	317.4
Jan 2019	187.4	138.8	326.1
Nov 2019	184.9	133.3	318.2
Nov 2020	191.5	134.2	325.7
Dec 2021	198.1	126.1	324.2
Nov 2022	184.3	132.0	316.3
Oct 2023	196.3	121.7	318.0
Dec 2024	176.0	126.9	303.0



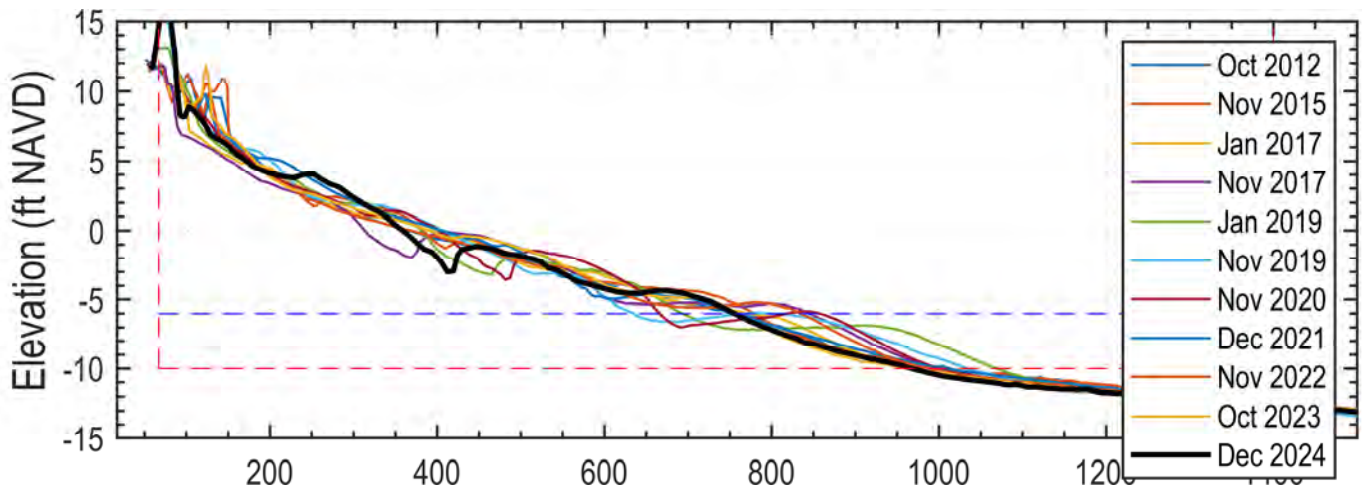
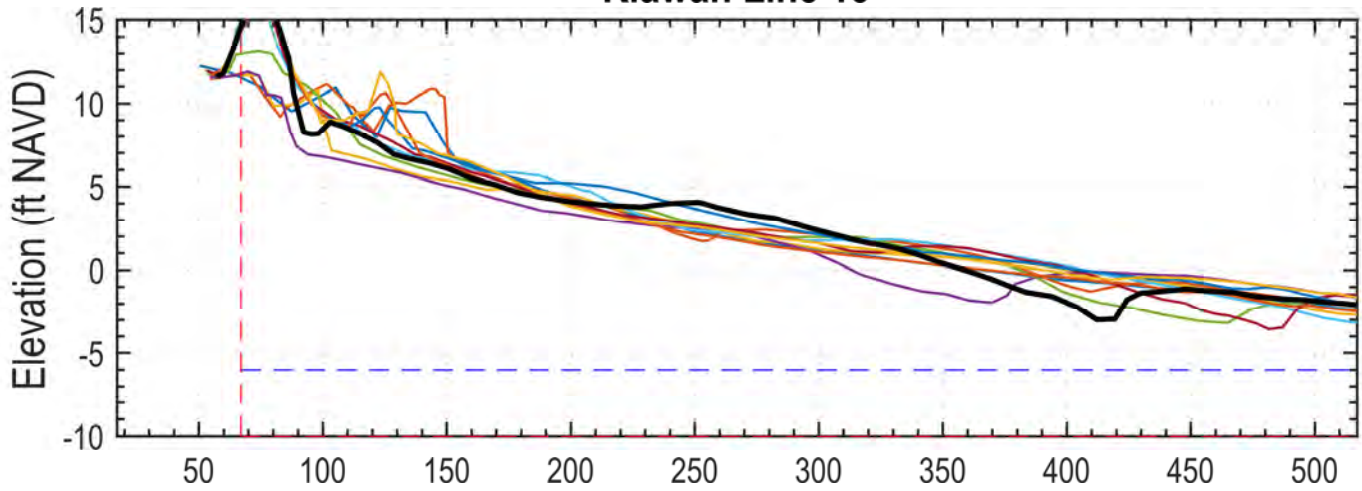
### Kiawah Line 12 (OCRM 2640)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	165.1	119.8	284.8
Nov 2015	173.4	119.1	292.5
Jan 2017	159.0	119.8	278.8
Nov 2017	157.4	128.0	285.4
Jan 2019	161.5	130.9	292.5
Nov 2019	156.5	129.3	285.8
Nov 2020	169.1	129.6	298.7
Dec 2021	177.9	119.1	297.0
Nov 2022	165.6	125.0	290.7
Oct 2023	175.5	115.8	291.3
Dec 2024	164.5	116.9	281.4



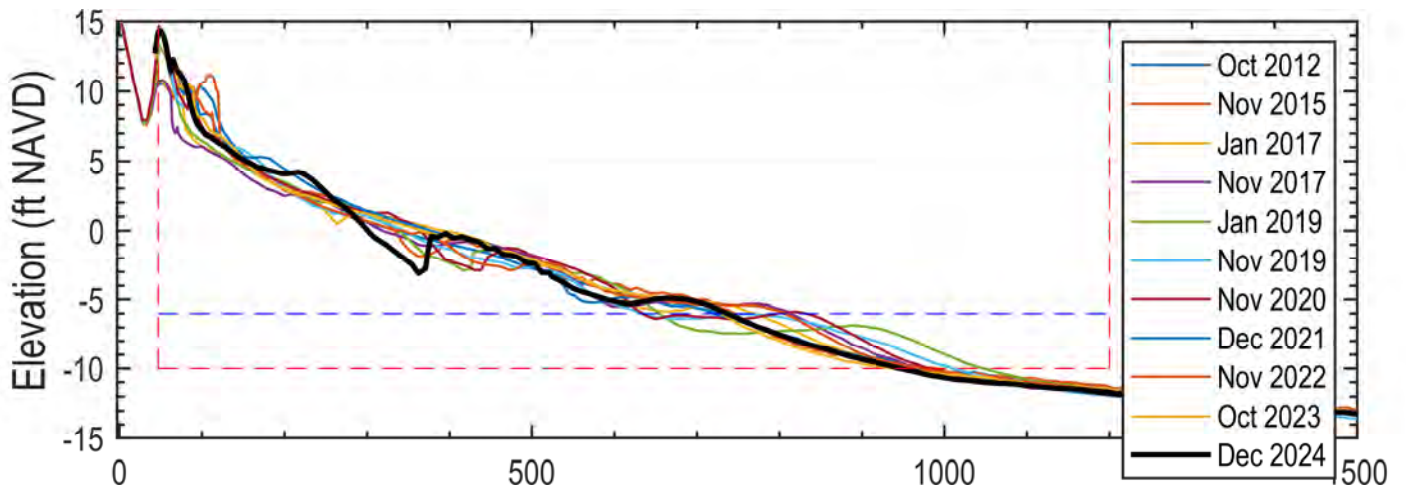
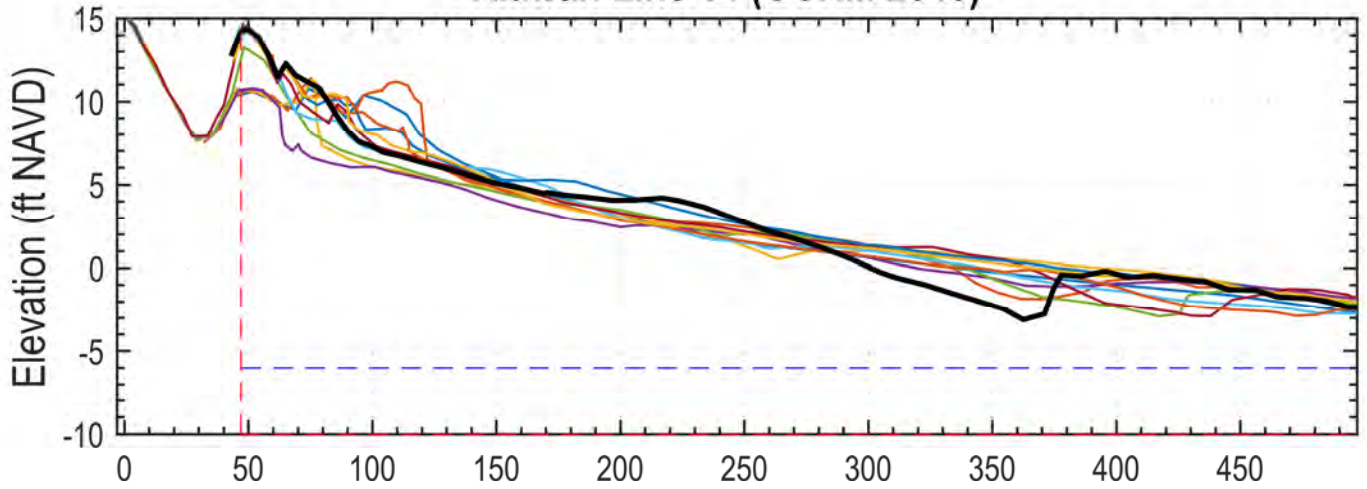
# Kiawah Line 13



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	159.5	118.2	277.8
Nov 2015	169.3	118.0	287.3
Jan 2017	157.3	119.4	276.7
Nov 2017	148.3	125.7	274.0
Jan 2019	156.9	128.3	285.3
Nov 2019	158.2	127.0	285.2
Nov 2020	163.1	124.5	287.6
Dec 2021	169.3	118.9	288.2
Nov 2022	160.1	123.6	283.7
Oct 2023	169.0	114.1	283.1
Dec 2024	161.1	115.5	276.6



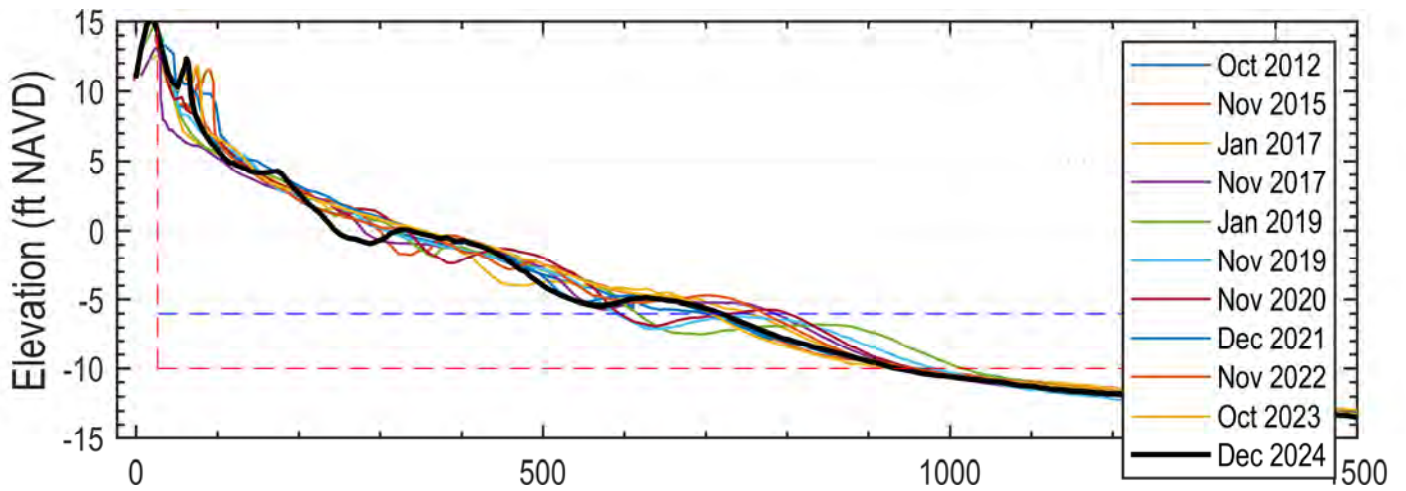
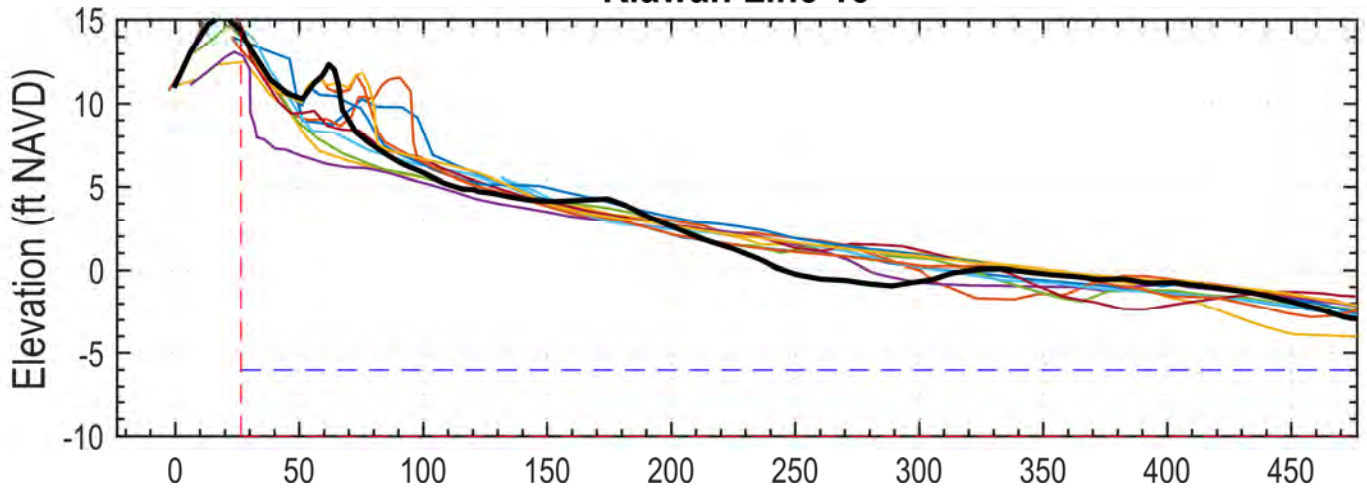
### Kiawah Line 14 (OCRM 2645)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	153.8	117.0	270.8
Nov 2015	160.4	115.7	276.1
Jan 2017	153.1	119.4	272.5
Nov 2017	145.4	124.1	269.5
Jan 2019	148.6	125.3	273.8
Nov 2019	146.7	126.4	273.0
Nov 2020	155.2	125.6	280.8
Dec 2021	162.0	116.3	278.2
Nov 2022	155.4	122.3	277.8
Oct 2023	161.4	112.8	274.2
Dec 2024	153.2	115.9	269.1



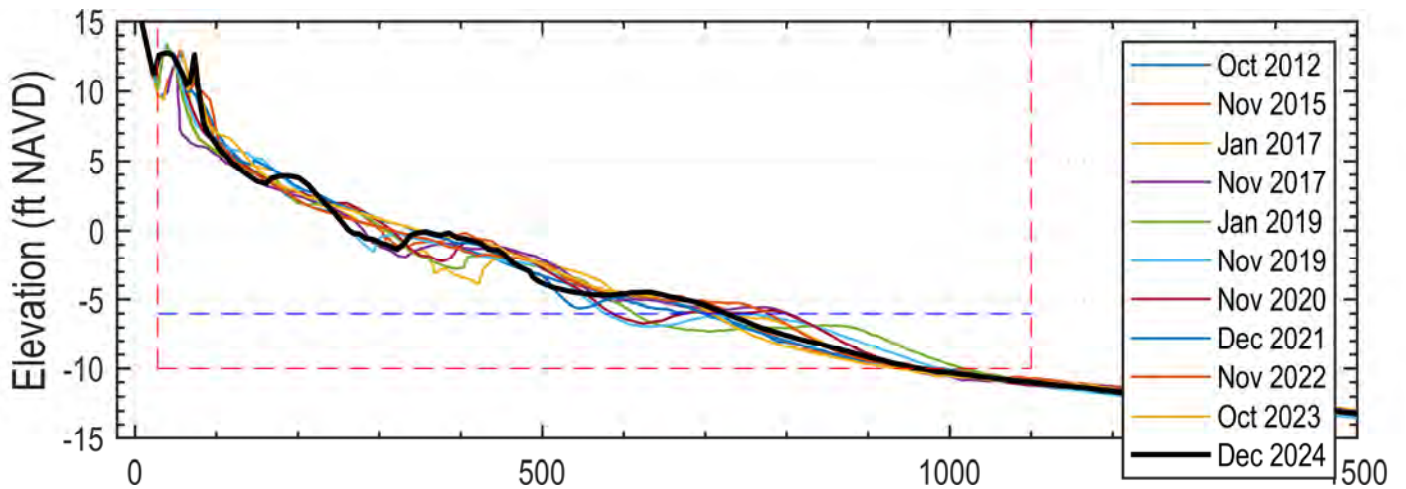
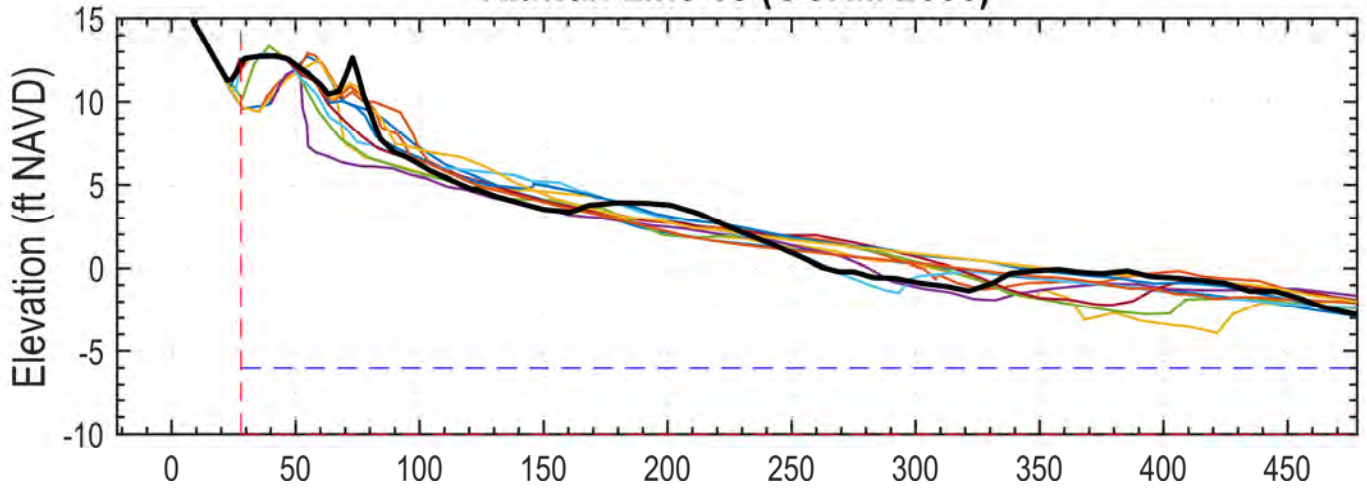
## Kiawah Line 15



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	152.7	115.4	268.1
Nov 2015	158.4	115.0	273.5
Jan 2017	149.0	120.0	269.0
Nov 2017	141.8	123.1	264.9
Jan 2019	146.6	124.4	271.1
Nov 2019	146.7	122.7	269.4
Nov 2020	151.5	122.8	274.3
Dec 2021	157.8	115.5	273.3
Nov 2022	155.6	121.3	276.9
Oct 2023	163.3	113.0	276.3
Dec 2024	146.5	116.8	263.4



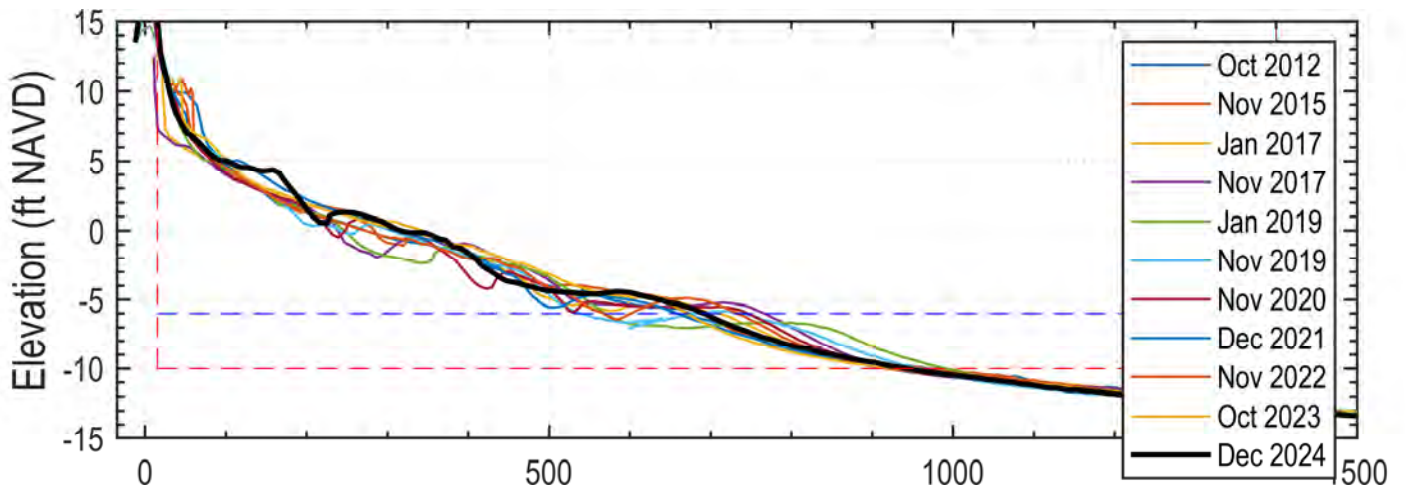
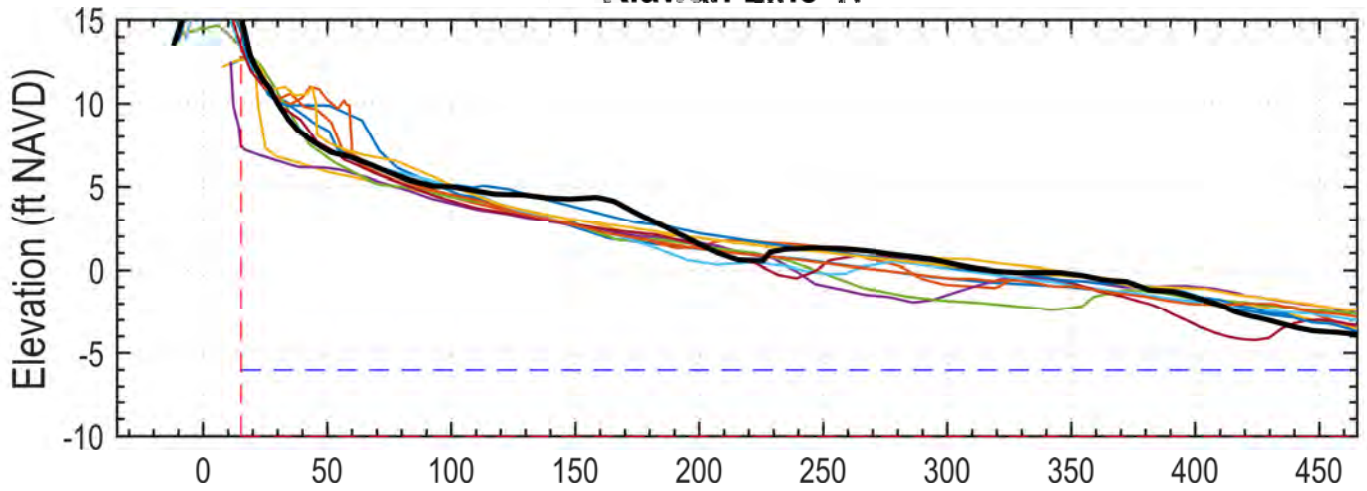
### Kiawah Line 16 (OCRM 2660)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	149.3	116.1	265.4
Nov 2015	161.1	116.4	277.4
Jan 2017	148.0	120.6	268.6
Nov 2017	145.5	124.7	270.2
Jan 2019	143.7	124.1	267.8
Nov 2019	146.7	123.8	270.5
Nov 2020	149.8	123.6	273.4
Dec 2021	156.4	115.2	271.6
Nov 2022	156.9	120.8	277.8
Oct 2023	164.7	113.3	278.0
Dec 2024	154.4	118.9	273.3



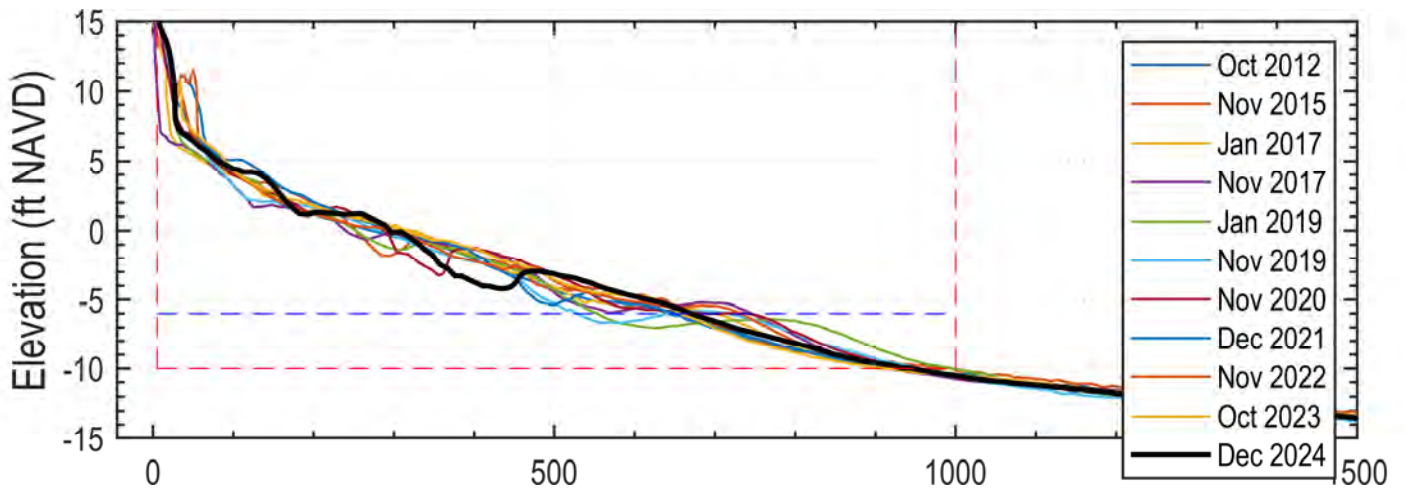
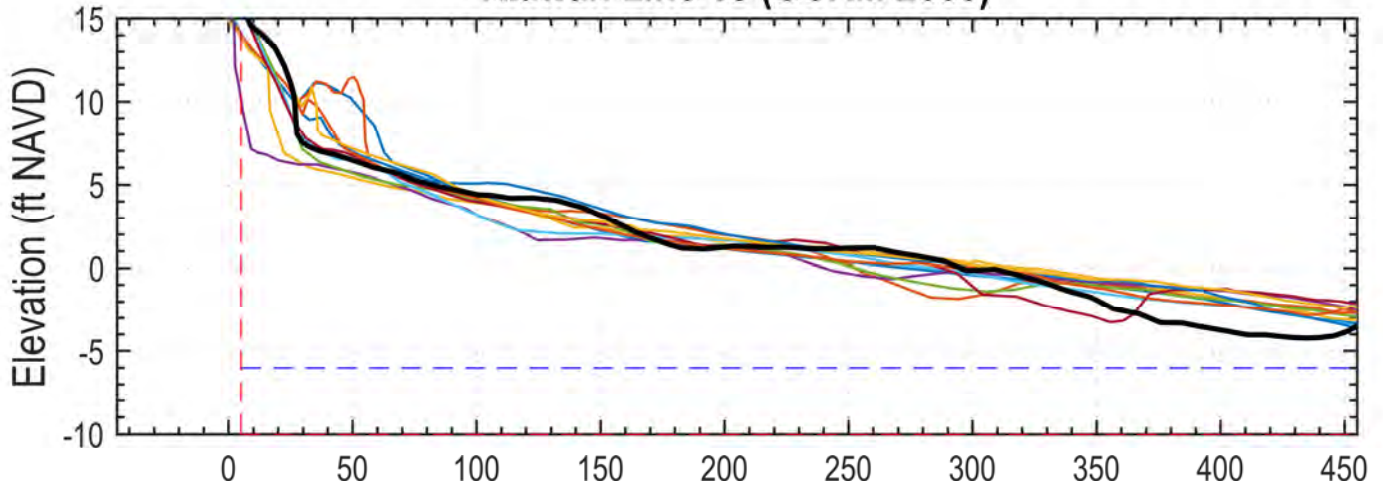
## Kiawah Line 17



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	137.0	114.7	251.7
Nov 2015	143.8	113.6	257.4
Jan 2017	136.1	115.9	252.0
Nov 2017	129.7	121.6	251.3
Jan 2019	127.7	122.1	249.8
Nov 2019	129.3	121.3	250.6
Nov 2020	130.7	119.4	250.1
Dec 2021	141.0	111.9	252.9
Nov 2022	136.5	117.2	253.7
Oct 2023	149.1	110.9	260.0
Dec 2024	143.8	115.3	259.1



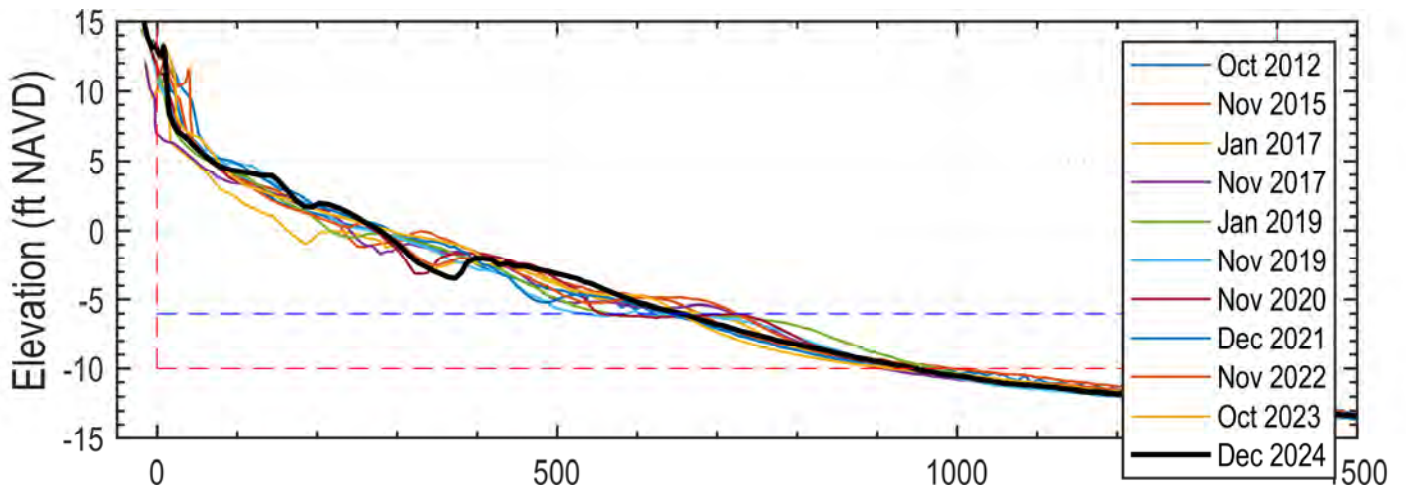
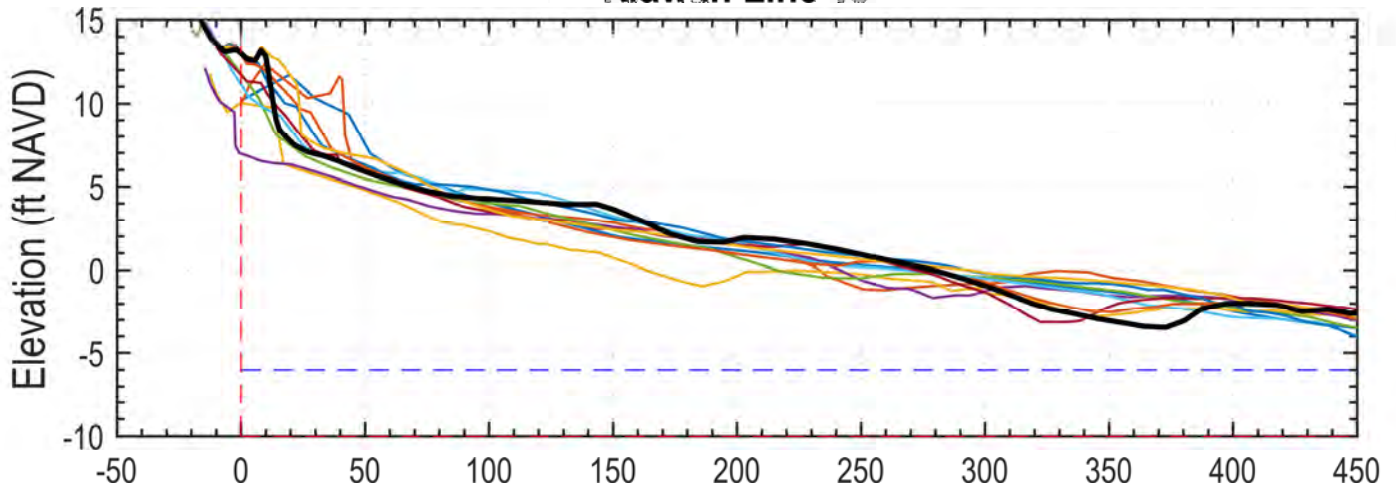
### Kiawah Line 18 (OCRM 2665)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	139.1	112.9	252.0
Nov 2015	144.8	115.1	259.9
Jan 2017	136.8	116.0	252.8
Nov 2017	129.2	120.5	249.7
Jan 2019	130.5	123.8	254.3
Nov 2019	127.7	120.5	248.2
Nov 2020	139.3	122.4	261.7
Dec 2021	144.7	113.0	257.8
Nov 2022	143.0	119.1	262.1
Oct 2023	150.1	111.5	261.6
Dec 2024	140.3	116.5	256.8



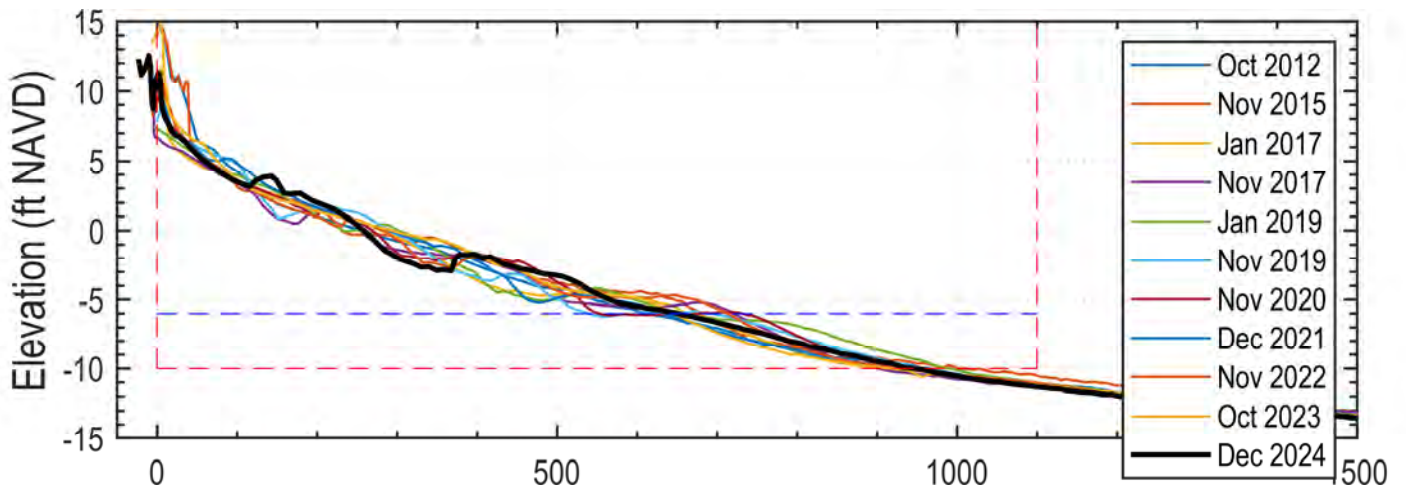
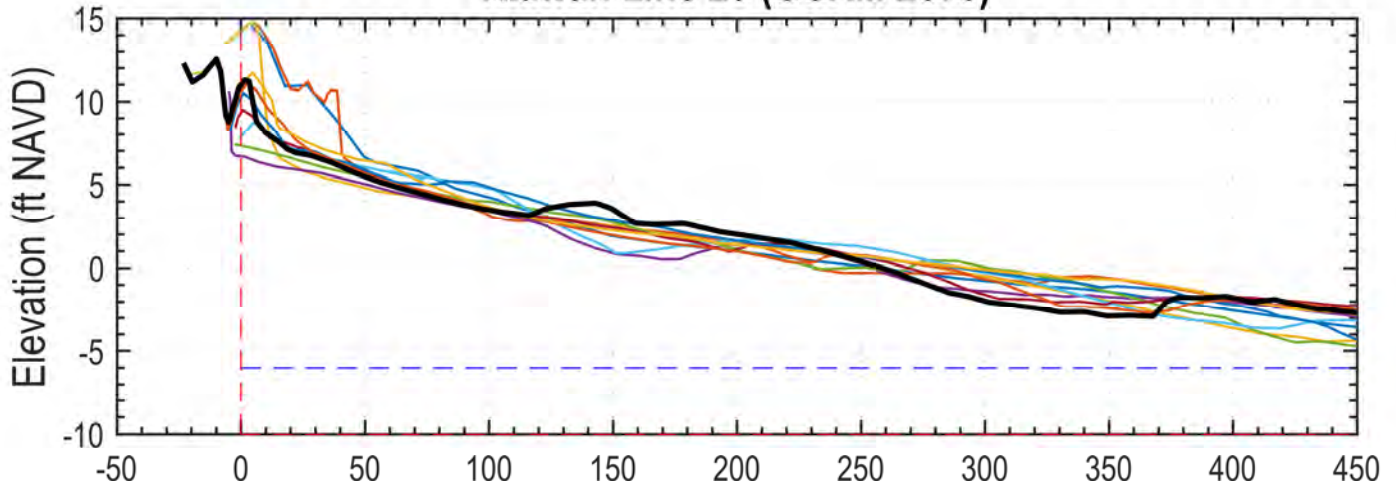
## Kiawah Line 19



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	136.4	115.6	252.1
Nov 2015	145.1	116.6	261.7
Jan 2017	117.2	116.0	233.2
Nov 2017	125.9	119.1	245.0
Jan 2019	125.7	125.7	251.3
Nov 2019	128.9	120.2	249.1
Nov 2020	132.7	119.7	252.4
Dec 2021	139.7	112.9	252.5
Nov 2022	135.9	119.4	255.3
Oct 2023	144.5	110.8	255.3
Dec 2024	139.9	116.7	256.6



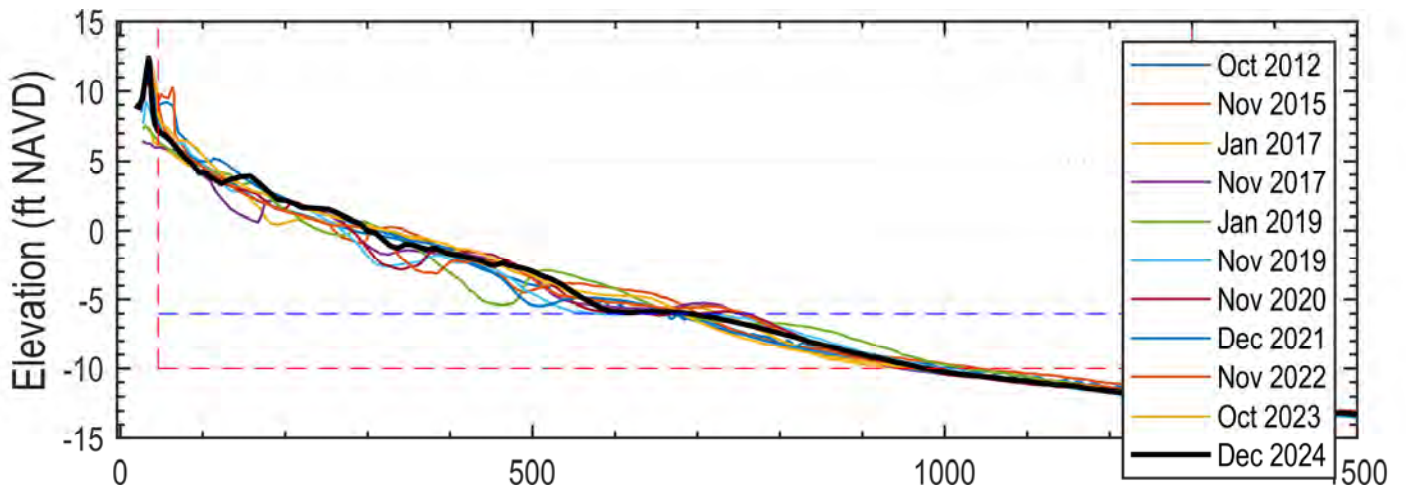
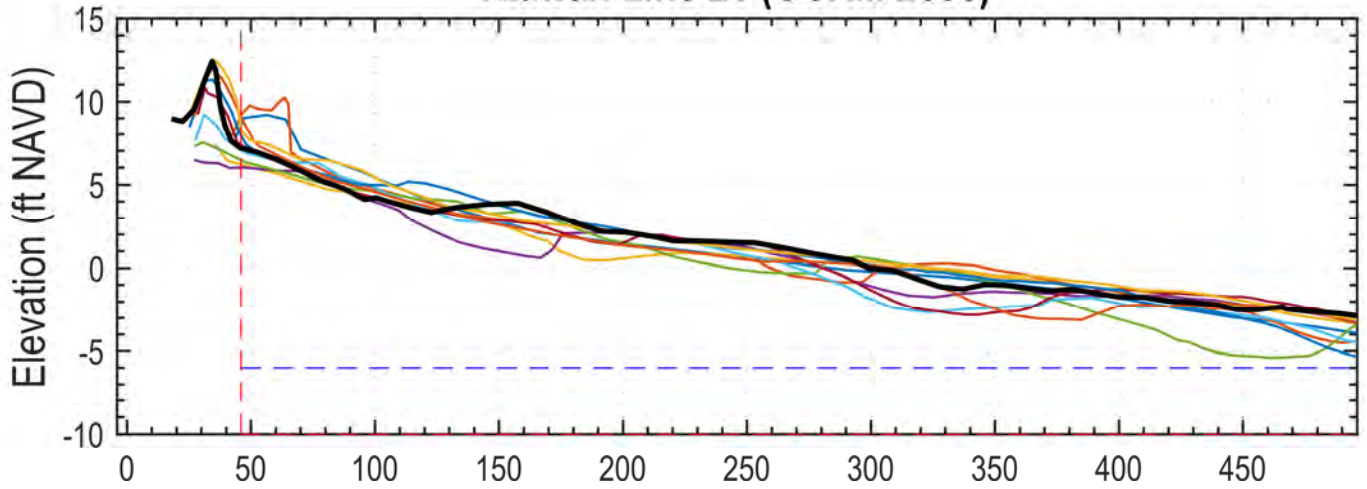
### Kiawah Line 20 (OCRM 2675)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	134.9	113.3	248.2
Nov 2015	144.6	117.2	261.7
Jan 2017	127.0	113.6	240.6
Nov 2017	122.4	118.0	240.5
Jan 2019	126.2	126.8	252.9
Nov 2019	125.8	121.6	247.4
Nov 2020	129.5	121.5	250.9
Dec 2021	133.9	111.9	245.9
Nov 2022	133.7	117.4	251.2
Oct 2023	139.7	110.4	250.1
Dec 2024	132.8	117.7	250.5



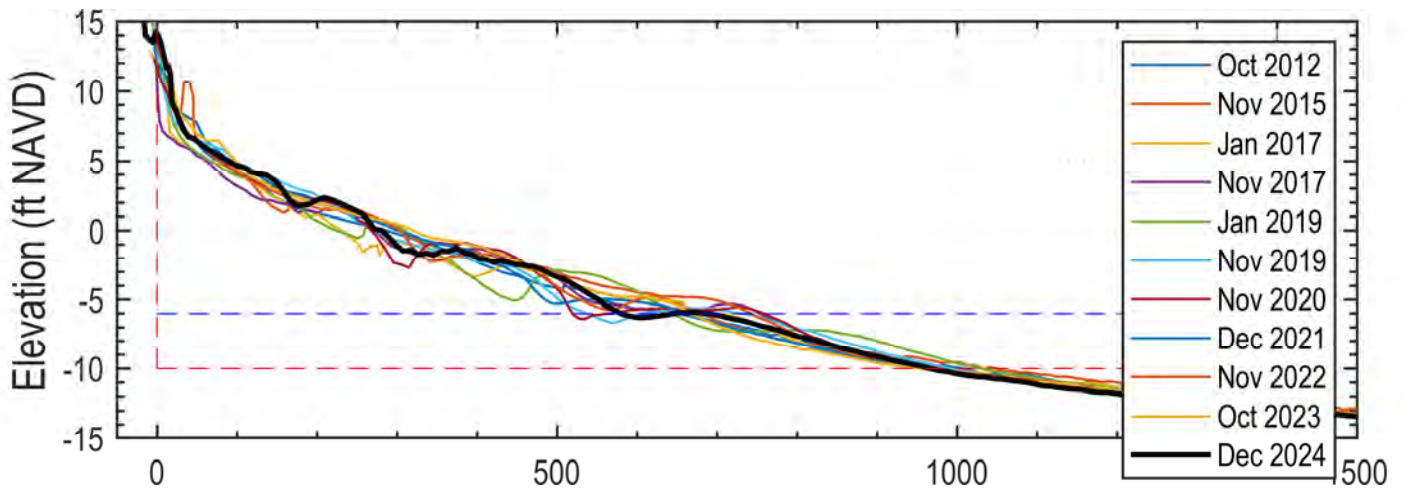
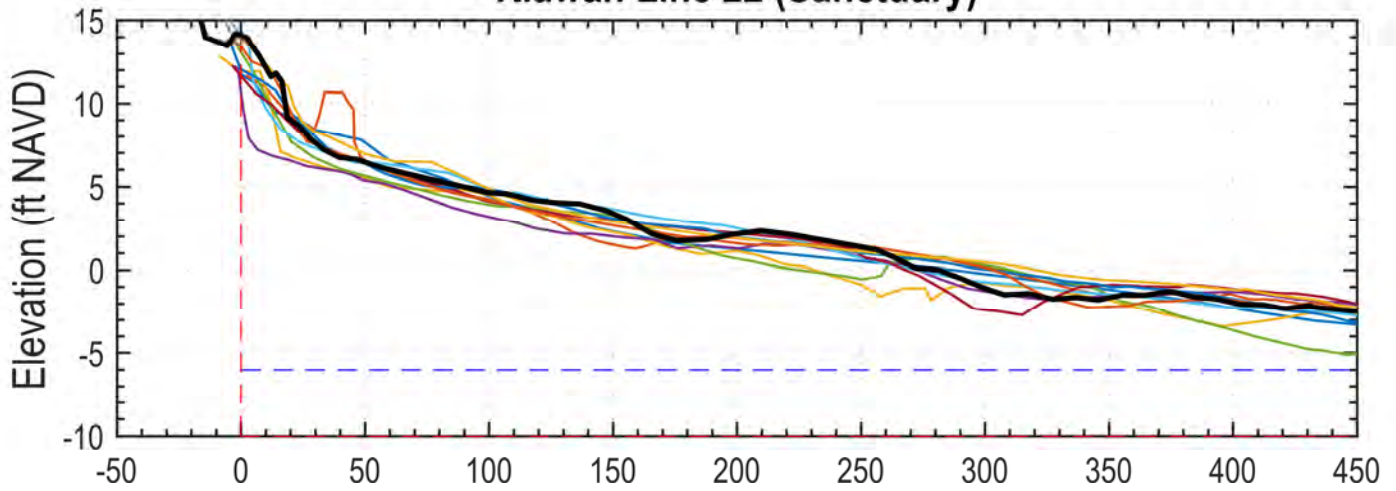
### Kiawah Line 21 (OCRM 2680)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	120.5	113.6	234.0
Nov 2015	128.7	115.1	243.8
Jan 2017	118.5	113.3	231.8
Nov 2017	114.6	116.8	231.4
Jan 2019	116.6	123.6	240.2
Nov 2019	108.4	120.1	228.5
Nov 2020	115.9	118.2	234.1
Dec 2021	122.1	111.0	233.0
Nov 2022	117.0	117.2	234.1
Oct 2023	131.6	109.7	241.3
Dec 2024	123.3	117.0	240.3



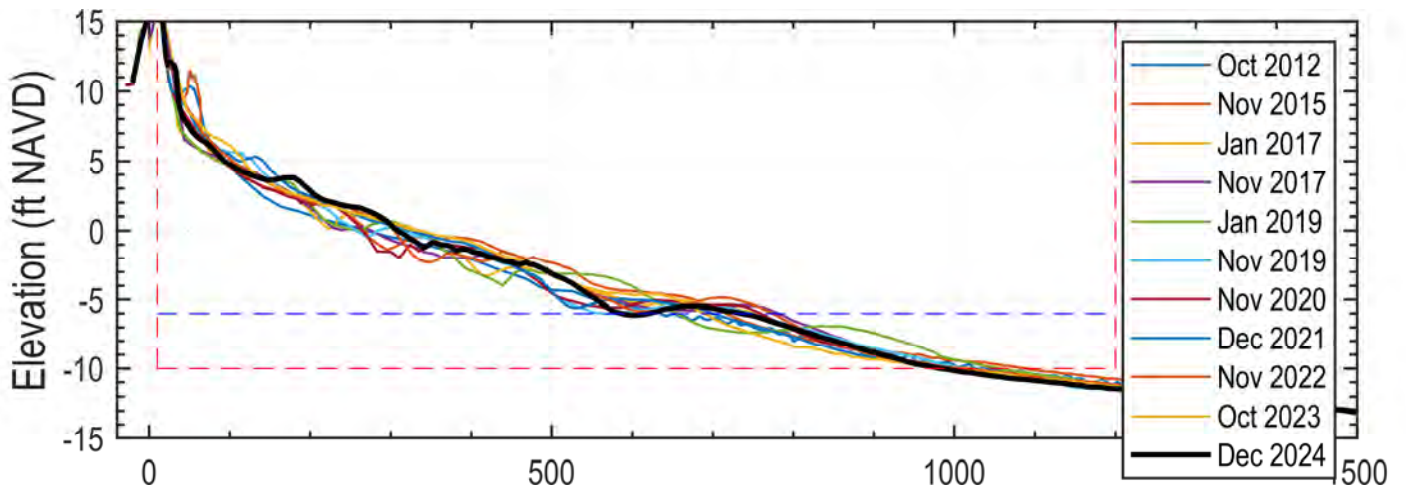
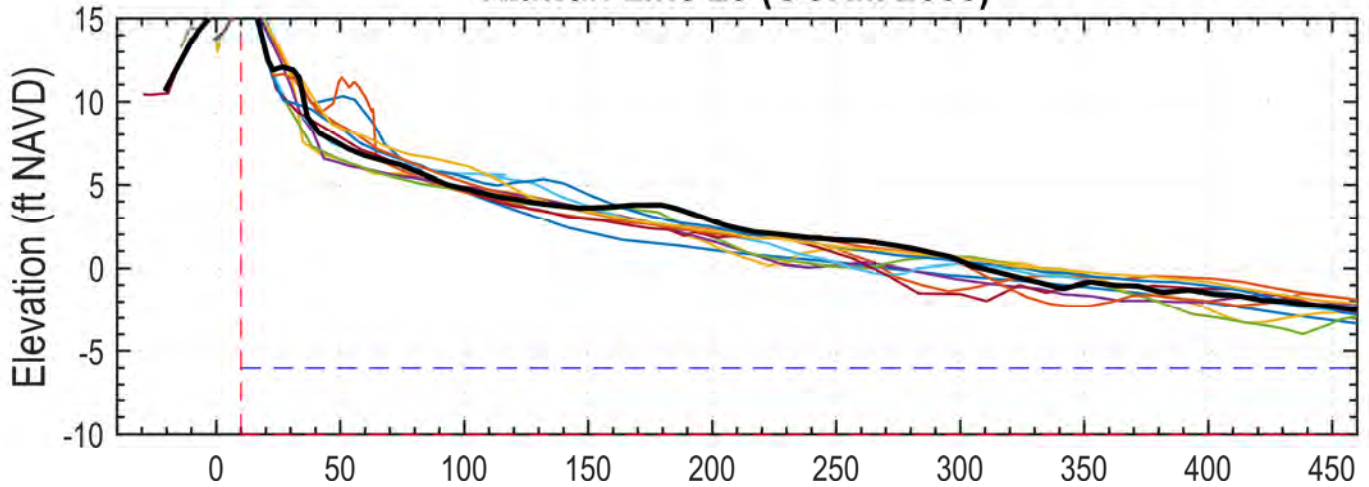
### Kiawah Line 22 (Sanctuary)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	138.3	120.0	258.2
Nov 2015	150.2	121.6	271.9
Jan 2017	131.8	120.2	252.0
Nov 2017	132.7	124.6	257.4
Jan 2019	135.8	126.3	262.2
Nov 2019	138.9	126.2	265.1
Nov 2020	139.2	124.6	263.8
Dec 2021	142.6	117.5	260.1
Nov 2022	144.6	123.1	267.7
Oct 2023	154.6	115.3	269.8
Dec 2024	143.4	122.0	265.4



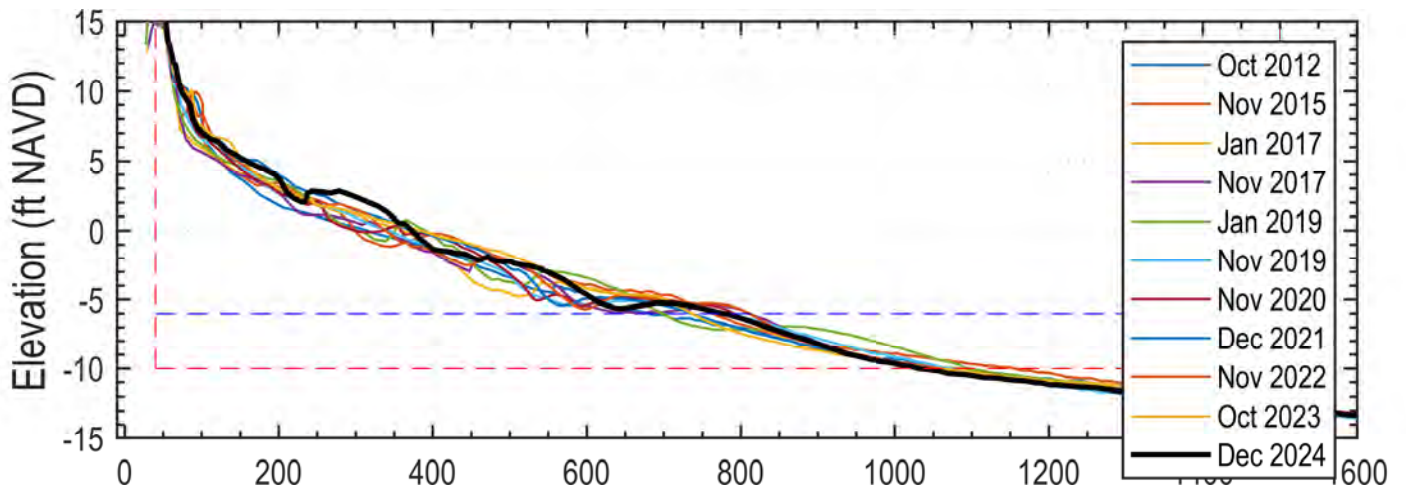
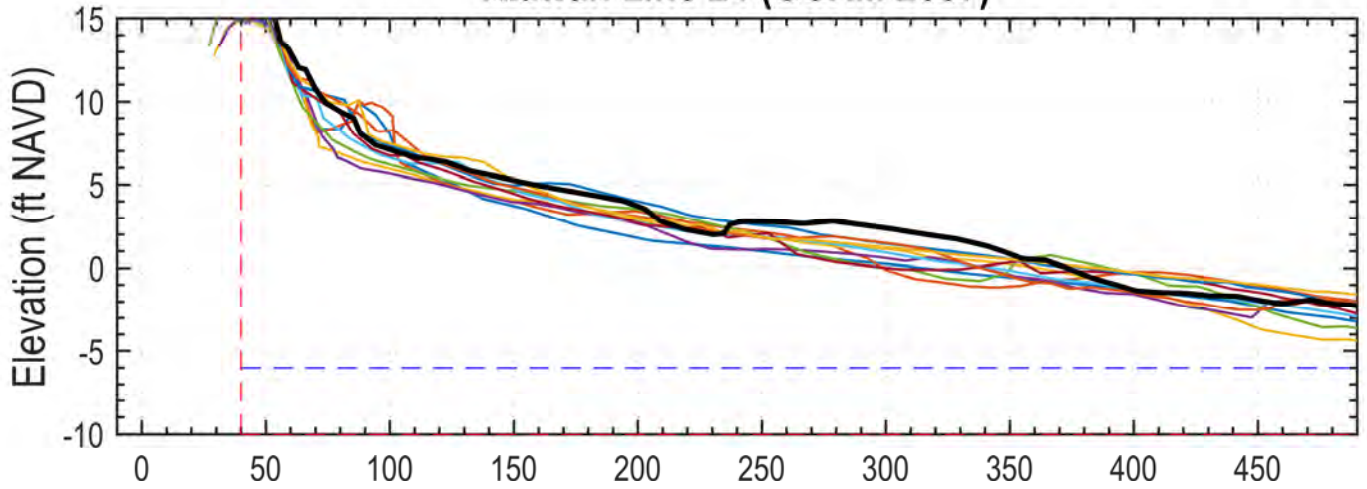
### Kiawah Line 23 (OCRM 2685)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	139.2	122.1	261.3
Nov 2015	160.0	125.5	285.4
Jan 2017	148.1	124.5	272.7
Nov 2017	144.0	127.5	271.5
Jan 2019	146.1	128.9	275.0
Nov 2019	144.8	127.6	272.4
Nov 2020	142.7	124.5	267.2
Dec 2021	153.0	120.5	273.5
Nov 2022	152.6	125.4	278.0
Oct 2023	161.1	117.0	278.1
Dec 2024	152.1	124.9	277.0



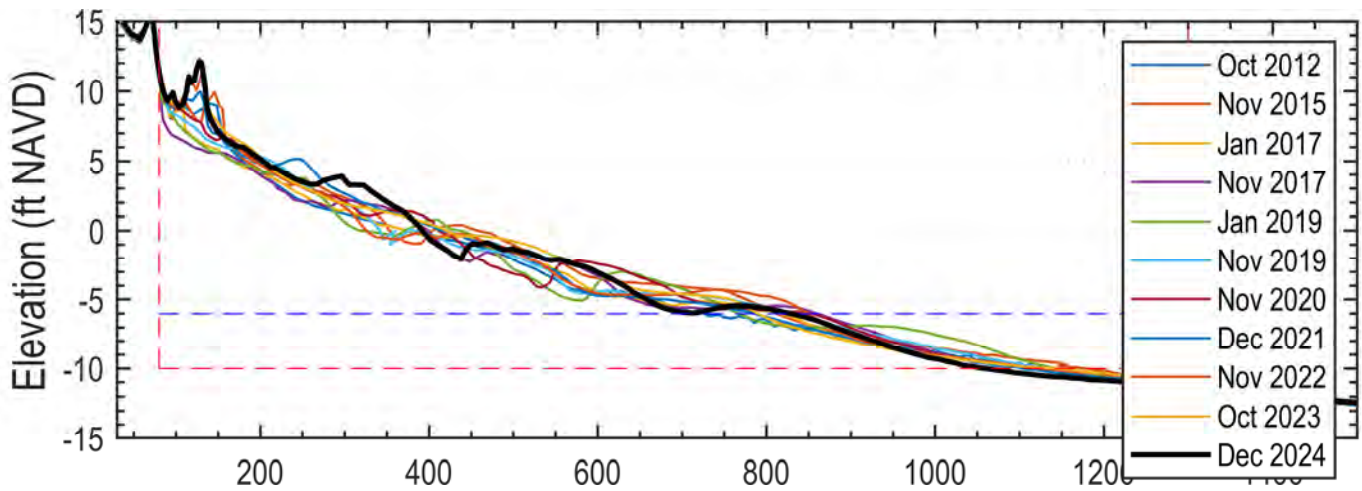
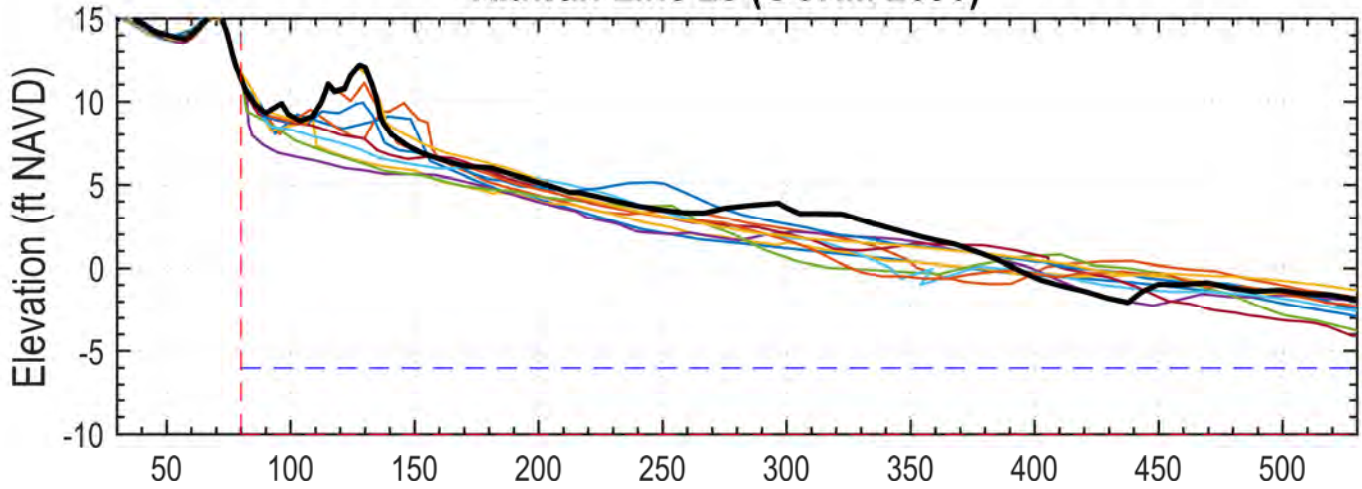
### Kiawah Line 24 (OCRM 2687)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	142.2	123.4	265.6
Nov 2015	162.4	129.2	291.6
Jan 2017	148.2	125.4	273.7
Nov 2017	144.9	128.5	273.4
Jan 2019	155.2	131.6	286.8
Nov 2019	151.9	130.2	282.1
Nov 2020	154.9	126.4	281.3
Dec 2021	165.1	123.0	288.1
Nov 2022	161.1	127.4	288.5
Oct 2023	171.2	121.1	292.3
Dec 2024	168.4	126.3	294.7



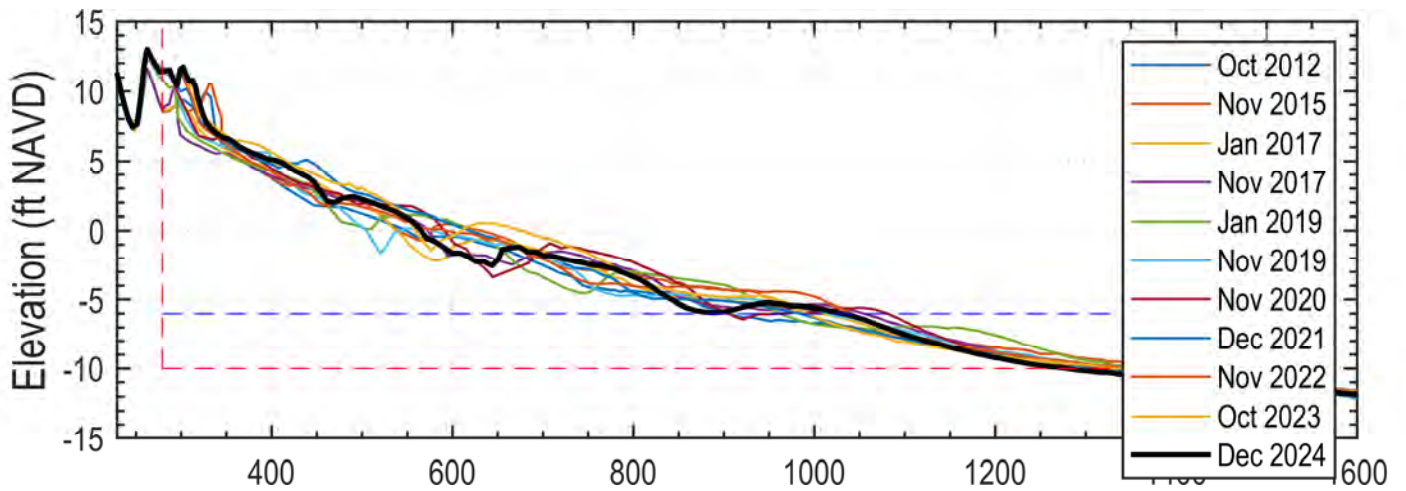
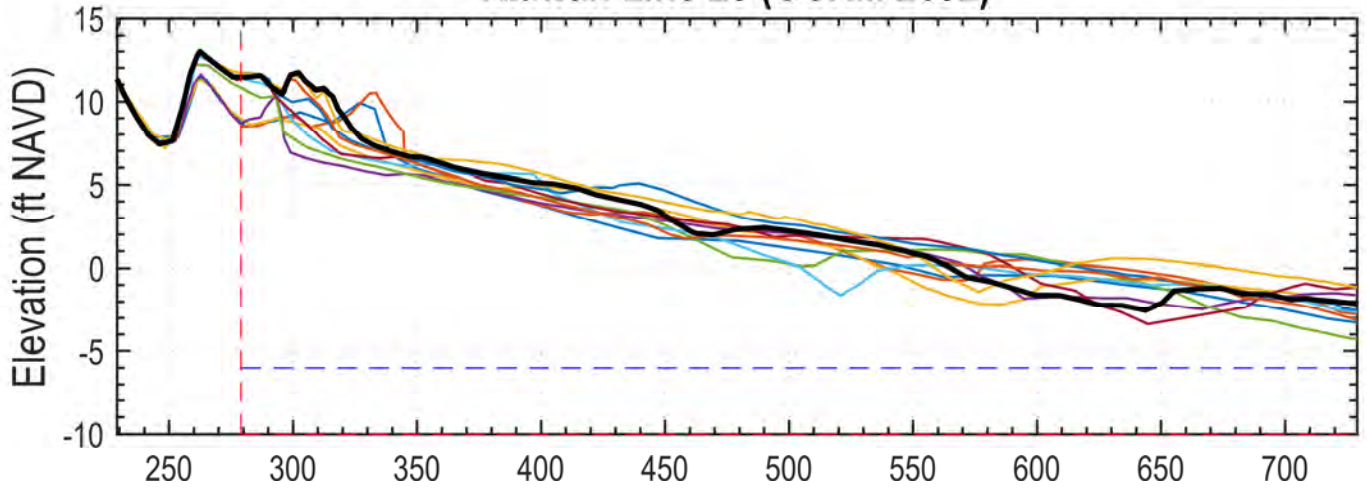
### Kiawah Line 25 (OCRM 2690)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	146.2	125.7	271.9
Nov 2015	168.1	130.9	299.0
Jan 2017	148.2	125.9	274.0
Nov 2017	147.8	130.8	278.7
Jan 2019	148.9	135.0	283.9
Nov 2019	153.2	131.3	284.5
Nov 2020	160.3	129.9	290.1
Dec 2021	162.5	124.9	287.4
Nov 2022	160.4	127.7	288.1
Oct 2023	172.2	123.7	295.9
Dec 2024	167.8	126.3	294.1



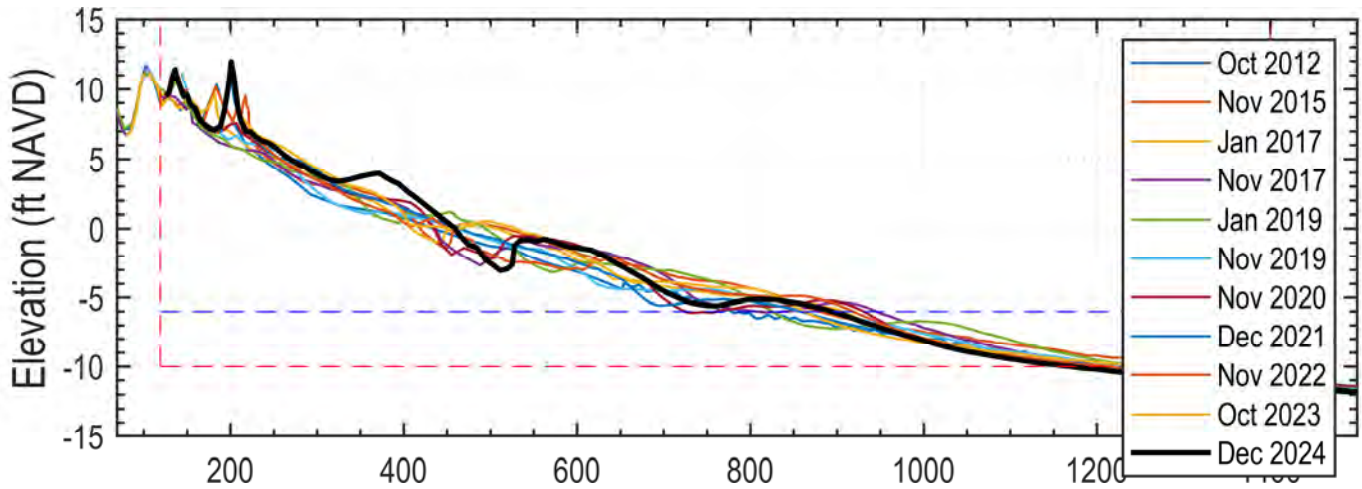
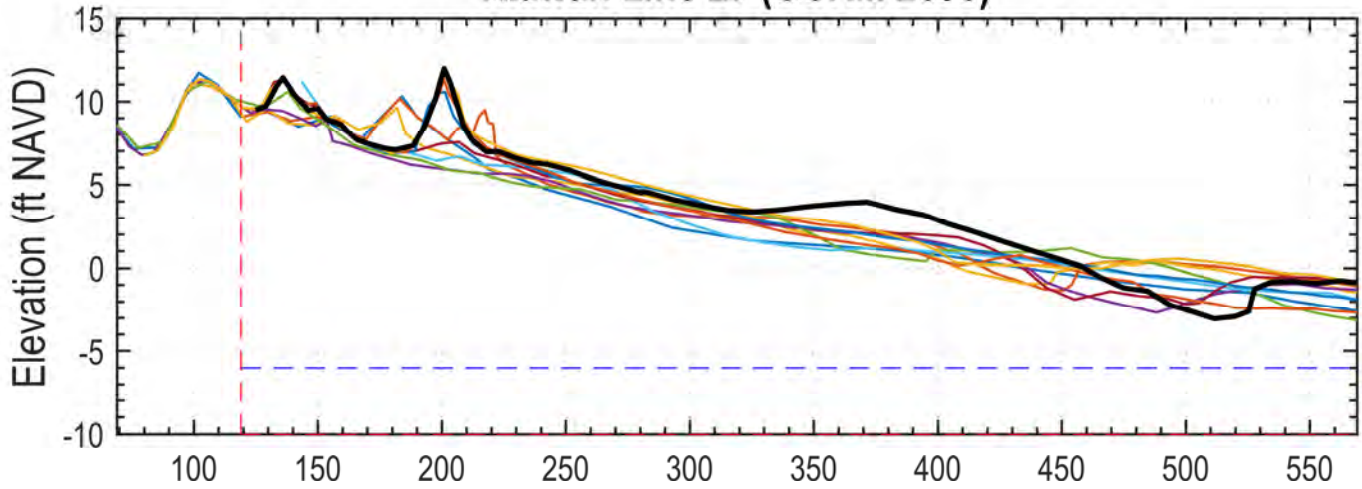
### Kiawah Line 26 (OCRM 2692)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	140.7	124.5	265.2
Nov 2015	160.4	130.6	291.0
Jan 2017	149.7	126.4	276.1
Nov 2017	148.8	131.2	279.9
Jan 2019	148.9	134.1	283.0
Nov 2019	146.6	130.1	276.7
Nov 2020	158.6	131.6	290.2
Dec 2021	162.5	125.3	287.8
Nov 2022	159.0	129.2	288.2
Oct 2023	173.7	124.3	298.0
Dec 2024	156.2	126.7	282.9



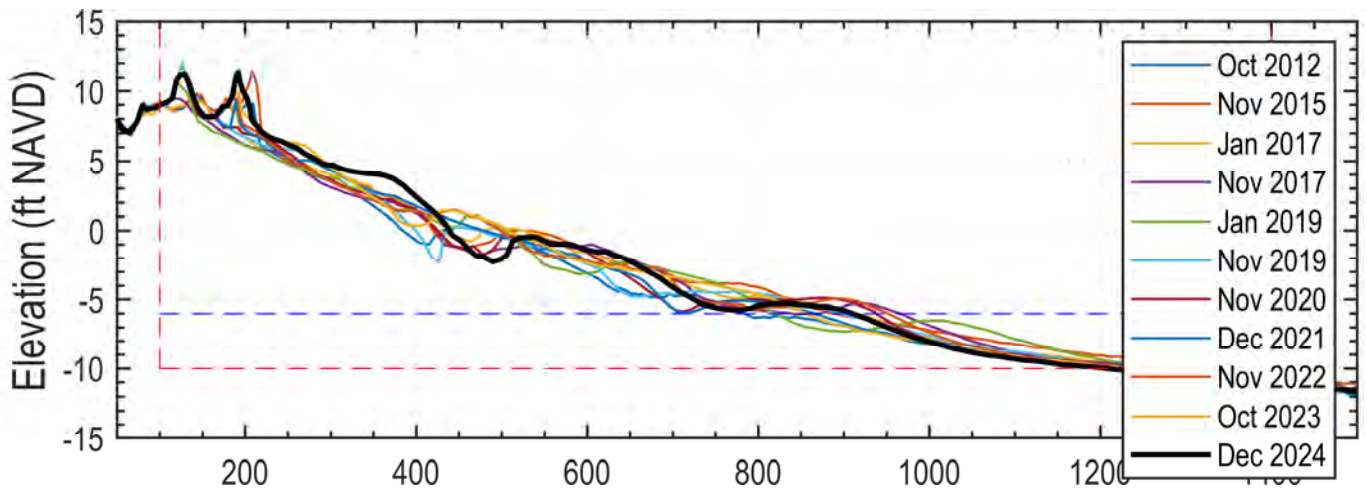
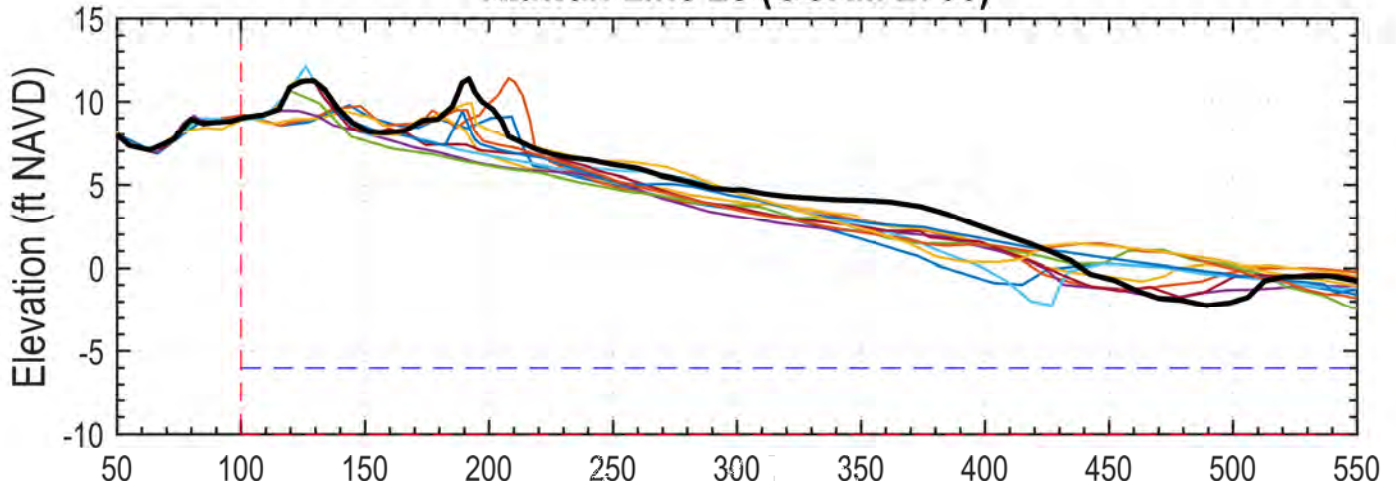
### Kiawah Line 27 (OCRM 2695)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	156.3	131.3	287.6
Nov 2015	183.9	140.5	324.5
Jan 2017	173.2	134.6	307.8
Nov 2017	167.6	138.9	306.5
Jan 2019	172.0	139.6	311.6
Nov 2019	166.1	136.2	302.3
Nov 2020	171.6	133.1	304.8
Dec 2021	171.3	130.9	302.2
Nov 2022	173.9	133.9	307.8
Oct 2023	186.6	131.0	317.6
Dec 2024	182.0	131.1	313.1



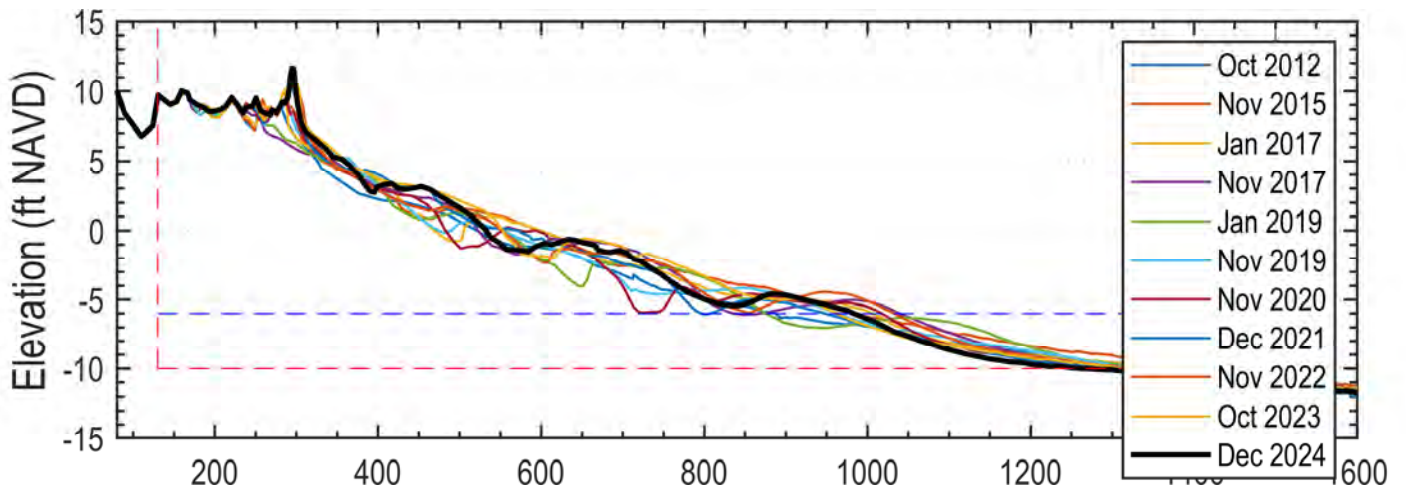
### Kiawah Line 28 (OCRM 2700)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	172.1	135.4	307.4
Nov 2015	197.5	146.4	343.9
Jan 2017	192.6	140.6	333.2
Nov 2017	180.0	143.5	323.5
Jan 2019	183.3	144.2	327.5
Nov 2019	182.2	139.5	321.7
Nov 2020	184.1	138.5	322.6
Dec 2021	185.9	133.9	319.8
Nov 2022	191.3	140.5	331.8
Oct 2023	197.9	133.6	331.5
Dec 2024	197.2	135.6	332.7



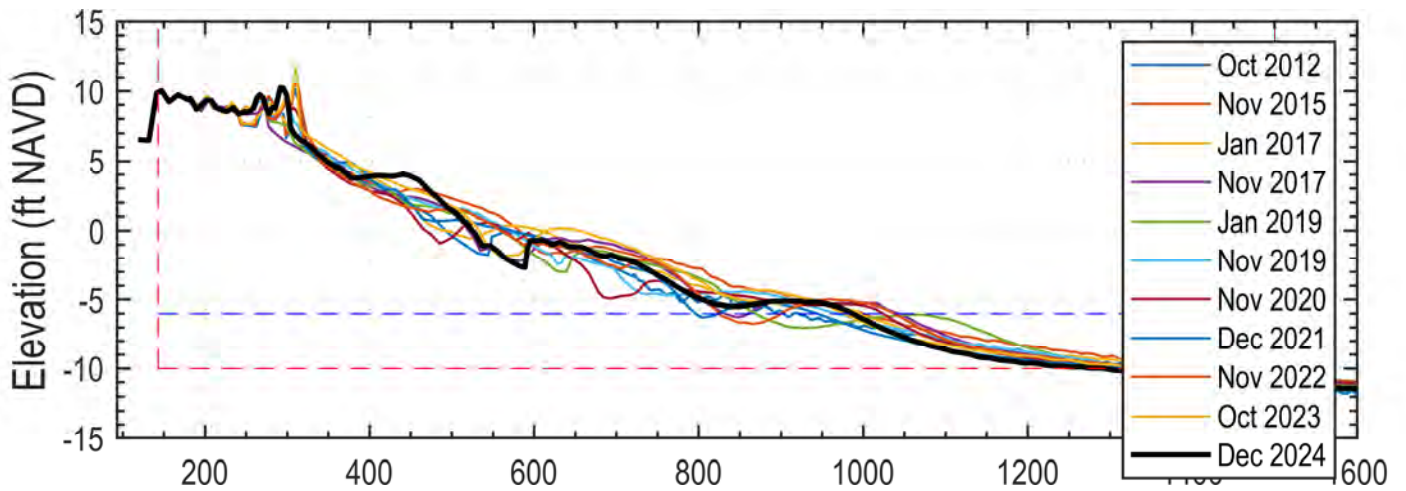
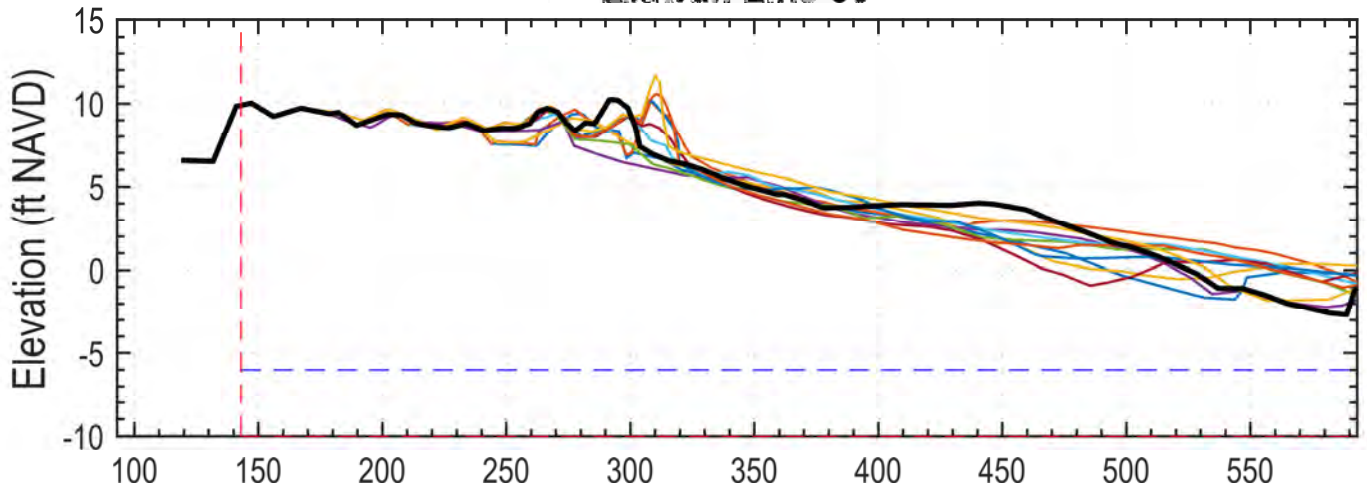
### Kiawah Line 29 (OCRM 2705)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	200.7	143.8	344.5
Nov 2015	225.9	155.8	381.7
Jan 2017	220.5	147.7	368.2
Nov 2017	215.5	150.1	365.6
Jan 2019	207.6	151.2	358.8
Nov 2019	211.9	147.7	359.6
Nov 2020	209.2	145.1	354.2
Dec 2021	218.8	141.8	360.6
Nov 2022	222.4	148.6	371.1
Oct 2023	234.0	142.8	376.8
Dec 2024	224.0	140.7	364.7



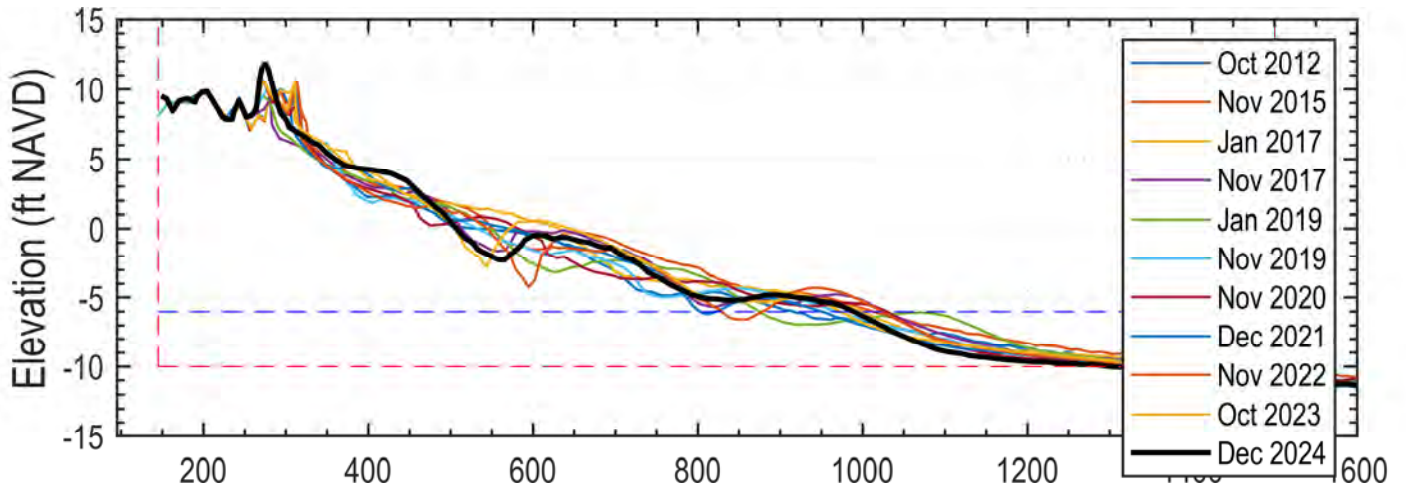
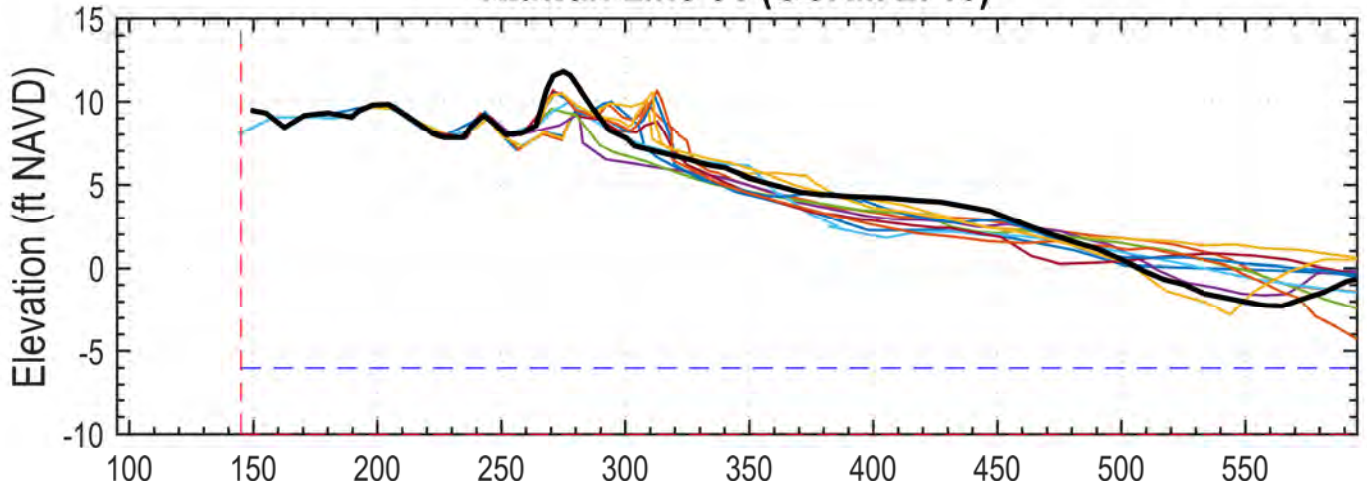
### Kiawah Line 30



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	201.8	143.9	345.7
Nov 2015	230.7	153.3	384.0
Jan 2017	217.0	147.5	364.4
Nov 2017	211.9	148.8	360.7
Jan 2019	210.8	150.5	361.3
Nov 2019	212.4	146.3	358.7
Nov 2020	203.9	145.1	348.9
Dec 2021	211.6	138.0	349.5
Nov 2022	213.9	146.0	359.8
Oct 2023	229.0	142.3	371.3
Dec 2024	215.3	139.0	354.3



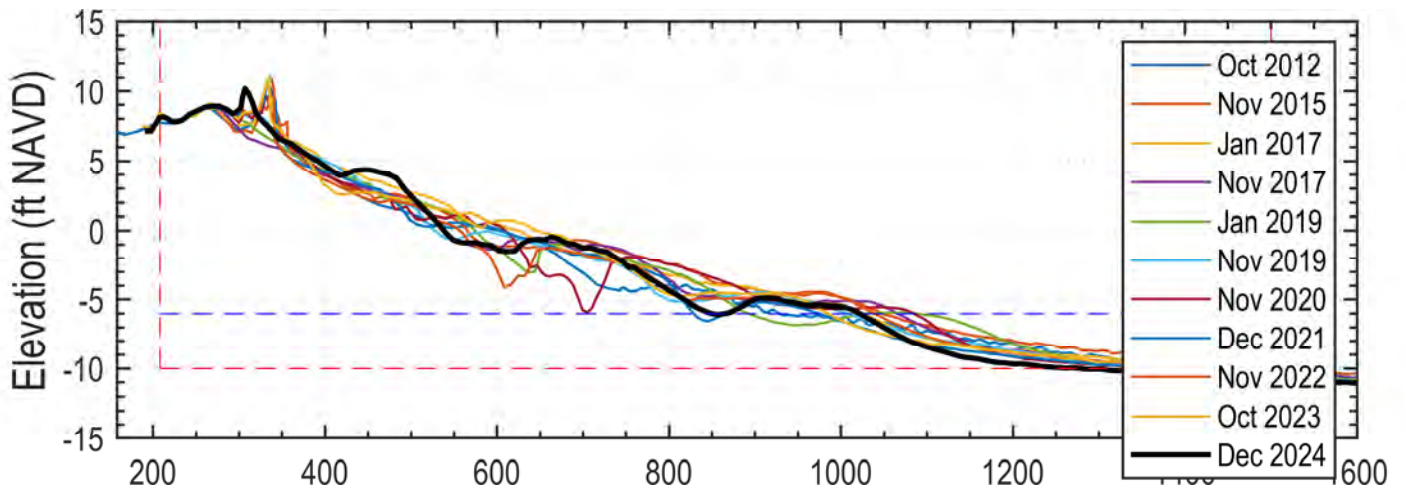
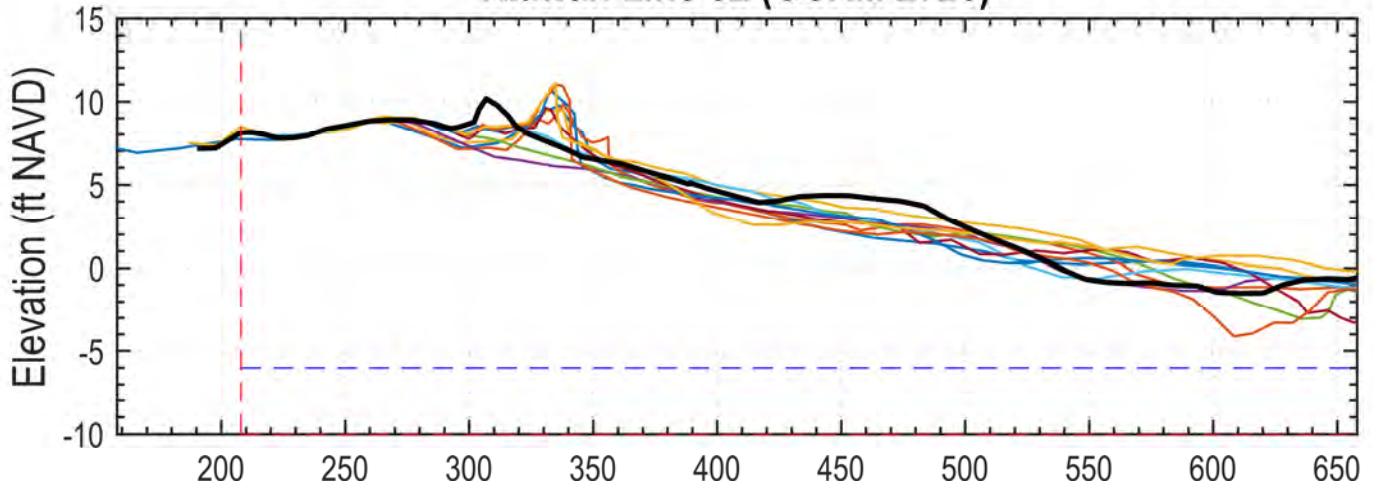
### Kiawah Line 31 (OCRM 2715)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	200.9	146.0	346.8
Nov 2015	227.6	155.2	382.8
Jan 2017	225.3	146.9	372.2
Nov 2017	212.0	148.8	360.9
Jan 2019	204.4	151.0	355.5
Nov 2019	204.3	144.0	348.3
Nov 2020	208.5	144.2	352.7
Dec 2021	212.5	140.4	352.9
Nov 2022	208.1	144.9	352.9
Oct 2023	218.7	143.0	361.7
Dec 2024	214.7	138.2	352.9



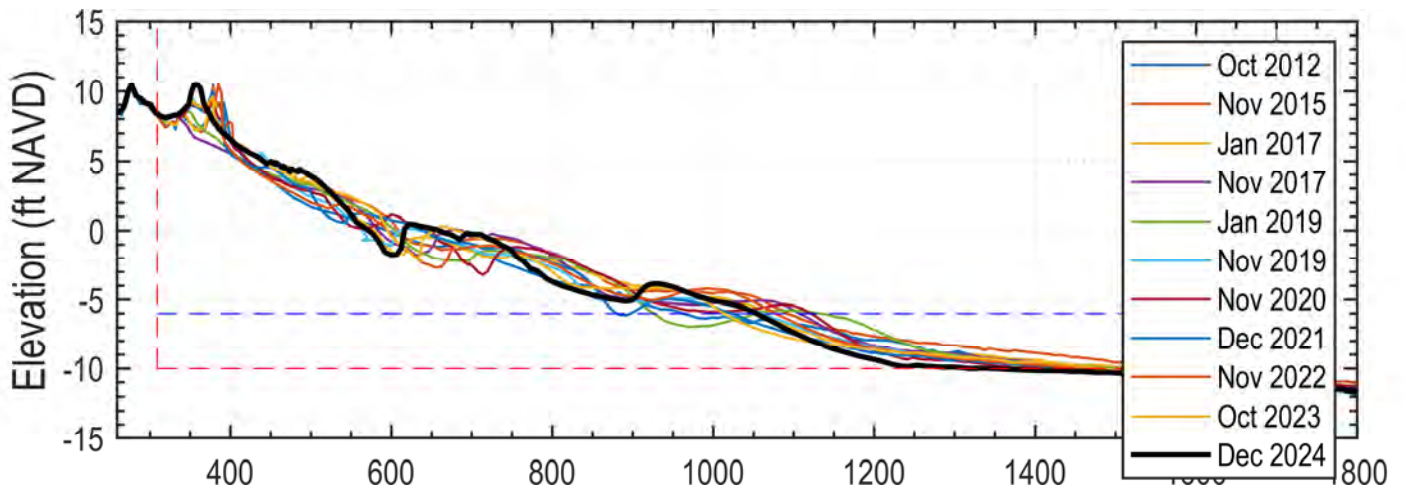
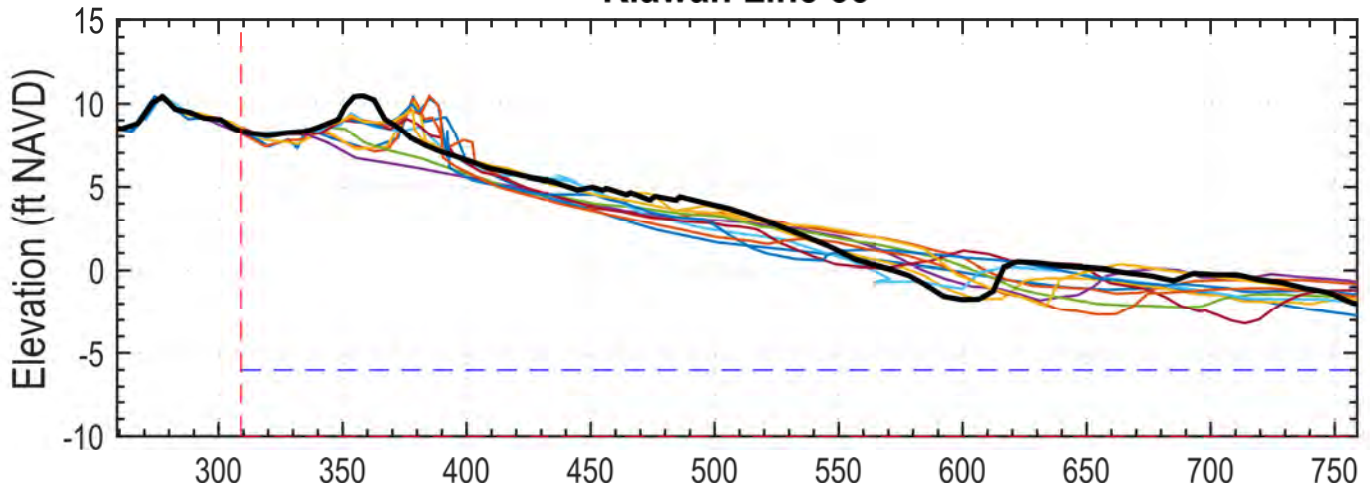
### Kiawah Line 32 (OCRM 2720)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	180.3	143.0	323.3
Nov 2015	202.7	151.8	354.5
Jan 2017	207.0	142.2	349.2
Nov 2017	190.4	144.7	335.1
Jan 2019	188.7	145.9	334.6
Nov 2019	190.0	139.5	329.6
Nov 2020	191.2	141.0	332.3
Dec 2021	188.2	133.1	321.3
Nov 2022	185.4	140.2	325.7
Oct 2023	198.0	136.5	334.5
Dec 2024	192.9	131.7	324.6



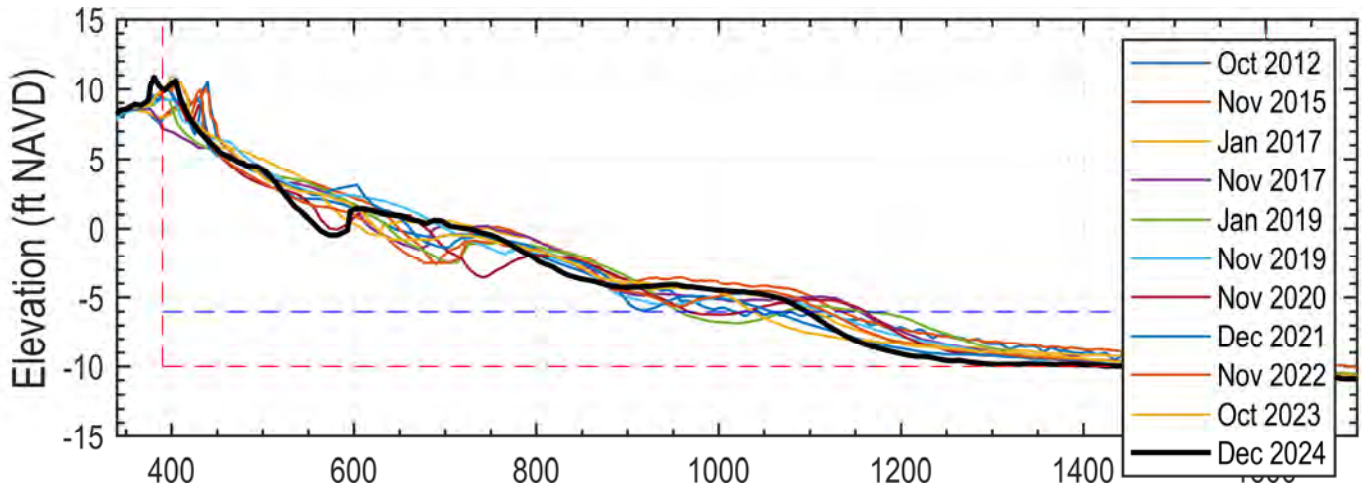
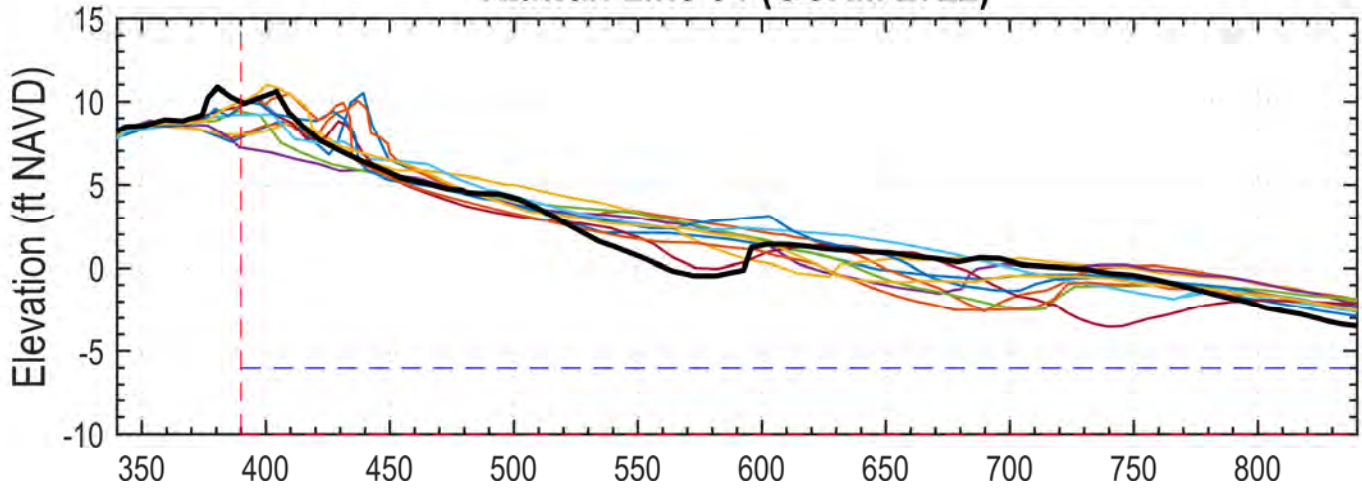
## Kiawah Line 33



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	148.4	134.0	282.4
Nov 2015	174.2	144.4	318.6
Jan 2017	166.5	132.6	299.1
Nov 2017	162.1	135.2	297.4
Jan 2019	157.0	137.2	294.2
Nov 2019	158.3	131.1	289.4
Nov 2020	163.4	131.7	295.1
Dec 2021	161.1	126.2	287.3
Nov 2022	161.2	131.3	292.5
Oct 2023	168.6	127.2	295.8
Dec 2024	165.7	122.4	288.1



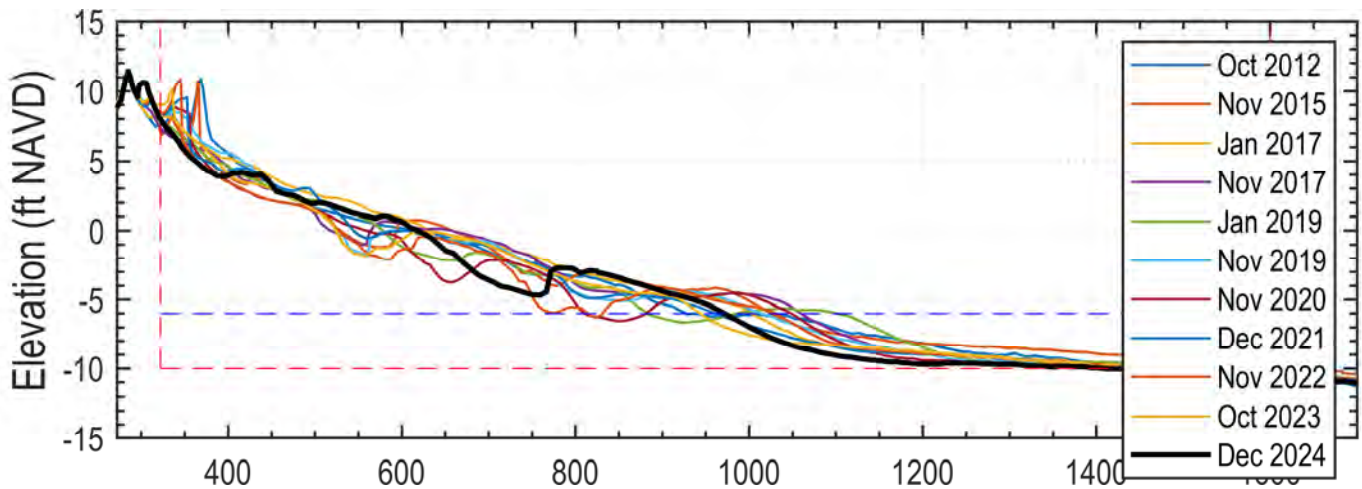
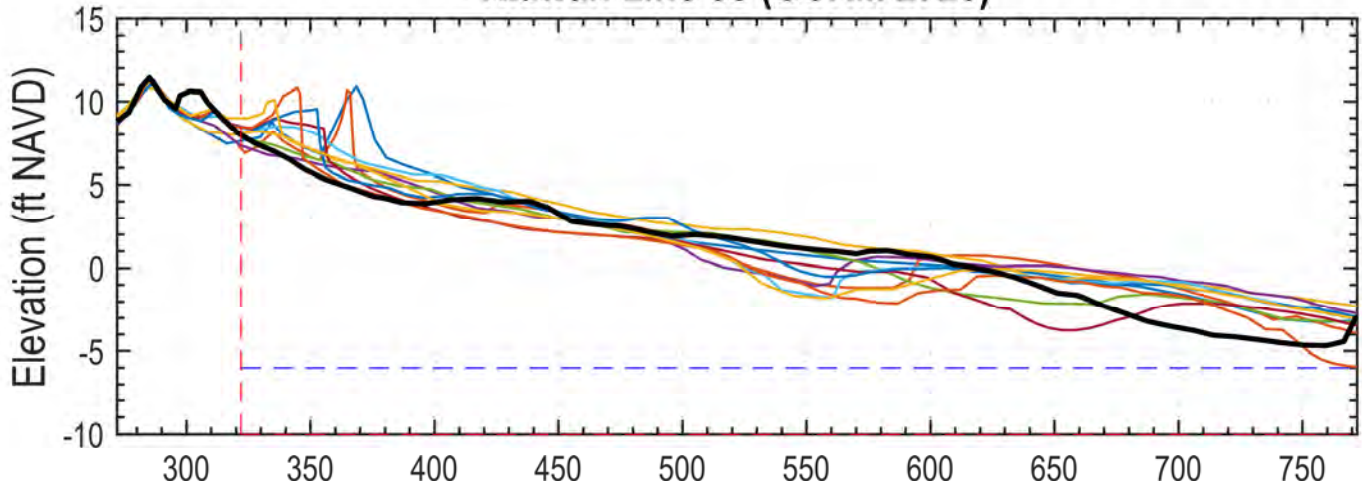
### Kiawah Line 34 (OCRM 2722)



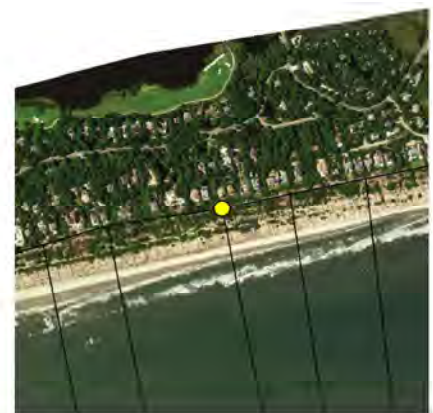
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	139.8	133.0	272.8
Nov 2015	158.6	138.0	296.6
Jan 2017	153.3	128.0	281.3
Nov 2017	143.6	129.3	272.9
Jan 2019	137.6	130.7	268.3
Nov 2019	147.9	124.8	272.7
Nov 2020	133.8	125.7	259.4
Dec 2021	143.6	118.9	262.5
Nov 2022	135.4	124.7	260.1
Oct 2023	144.4	119.3	263.7
Dec 2024	143.1	115.3	258.4



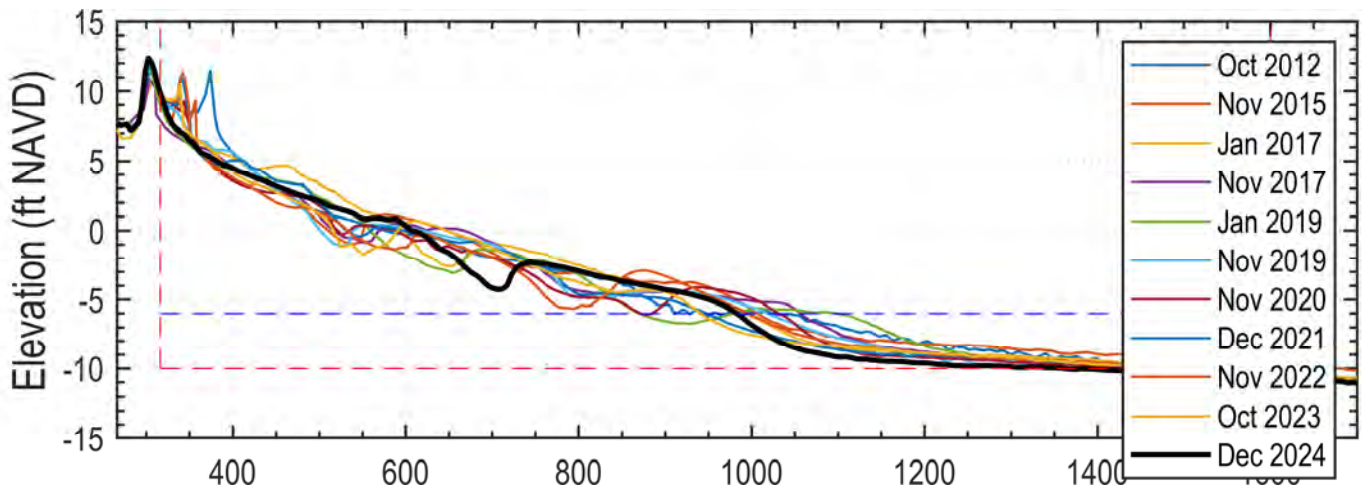
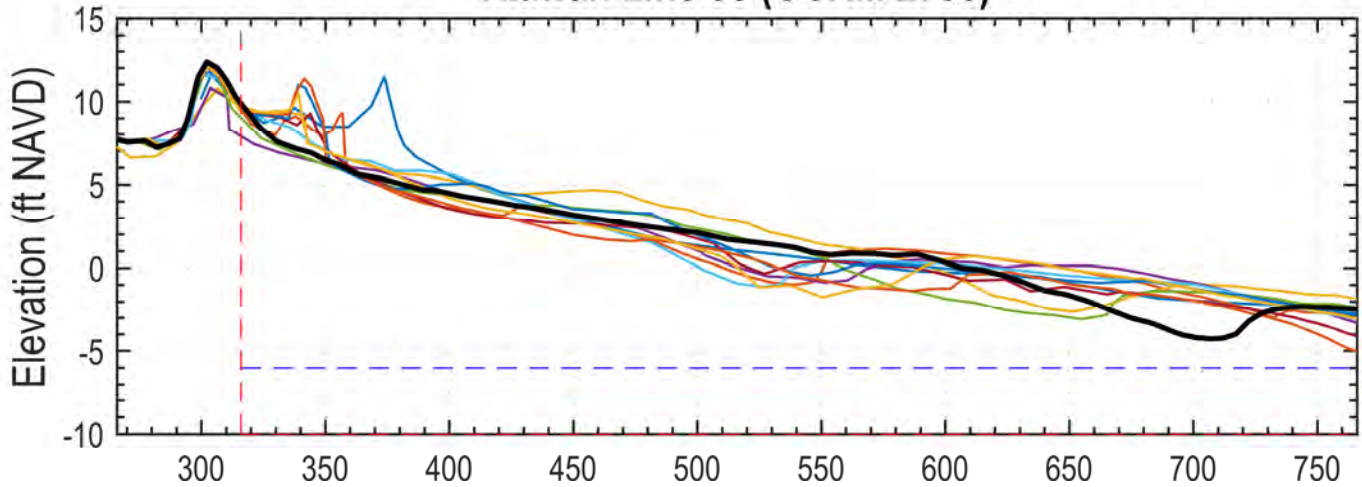
### Kiawah Line 35 (OCRM 2725)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	139.1	130.2	269.3
Nov 2015	140.6	136.6	277.2
Jan 2017	151.3	122.0	273.3
Nov 2017	139.2	125.0	264.2
Jan 2019	126.8	129.3	256.2
Nov 2019	136.7	121.8	258.5
Nov 2020	119.8	119.7	239.5
Dec 2021	134.9	118.4	253.3
Nov 2022	118.3	122.6	240.9
Oct 2023	131.0	116.8	247.8
Dec 2024	130.8	110.5	241.3



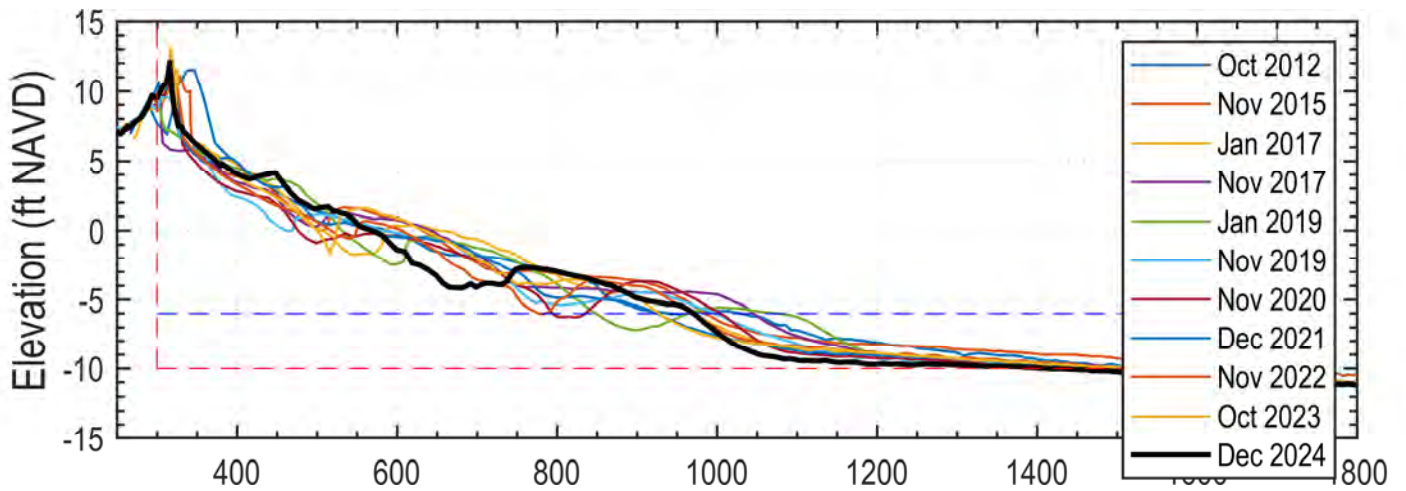
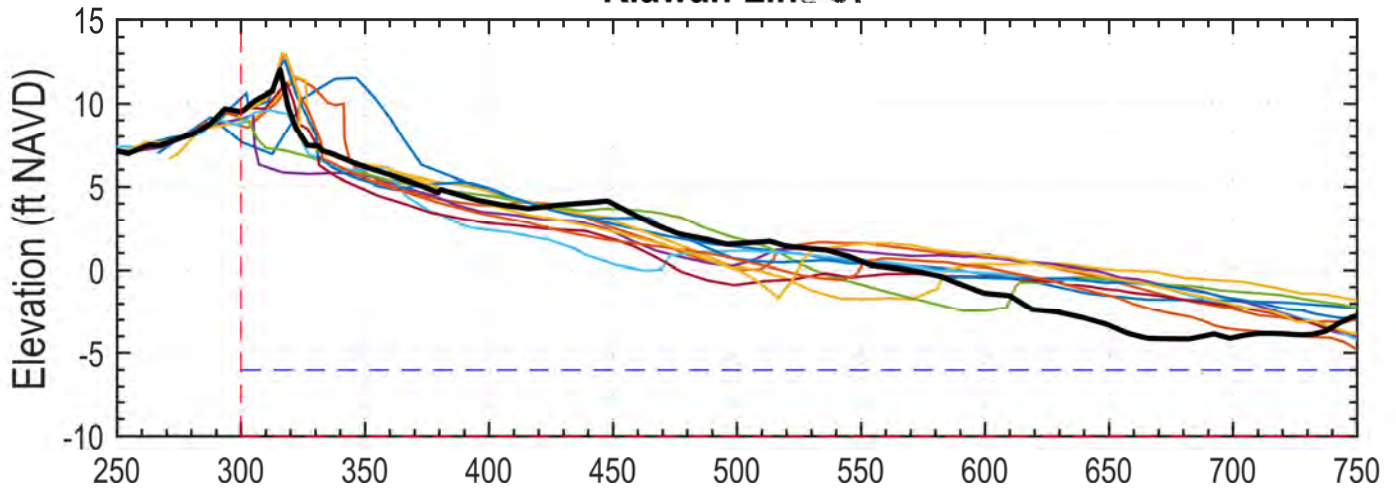
### Kiawah Line 36 (OCRM 2730)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	142.4	133.4	275.8
Nov 2015	143.7	136.1	279.8
Jan 2017	152.4	122.6	275.0
Nov 2017	139.1	126.1	265.2
Jan 2019	129.0	130.1	259.1
Nov 2019	138.4	123.0	261.3
Nov 2020	131.0	120.0	251.0
Dec 2021	138.2	117.1	255.3
Nov 2022	130.0	122.8	252.8
Oct 2023	134.9	117.5	252.4
Dec 2024	138.1	110.5	248.5



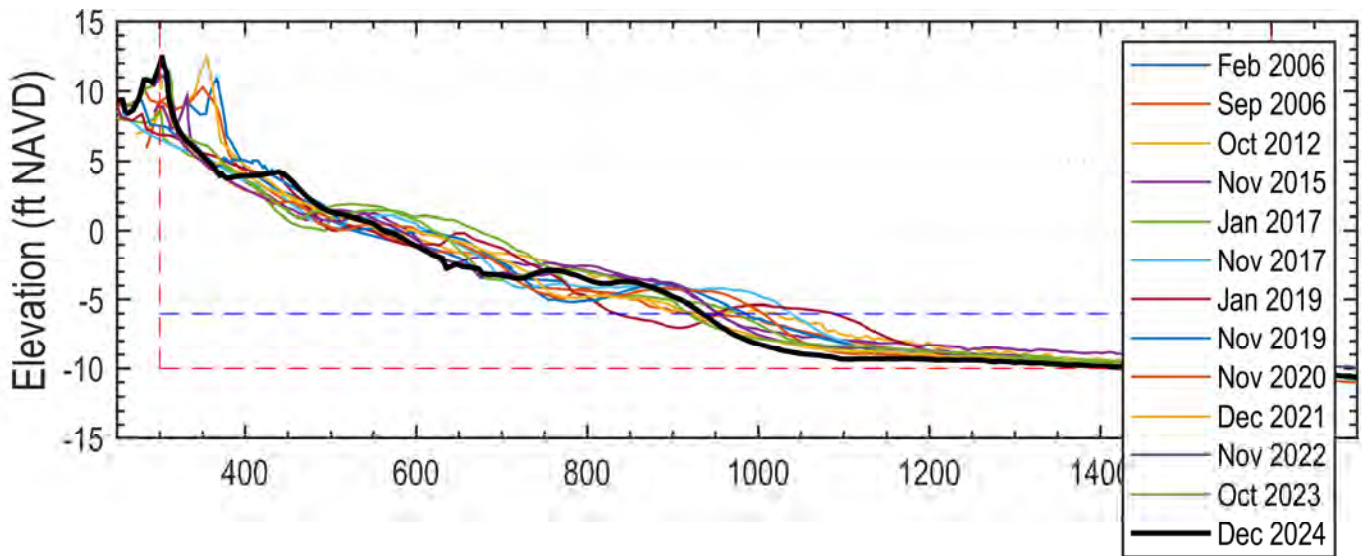
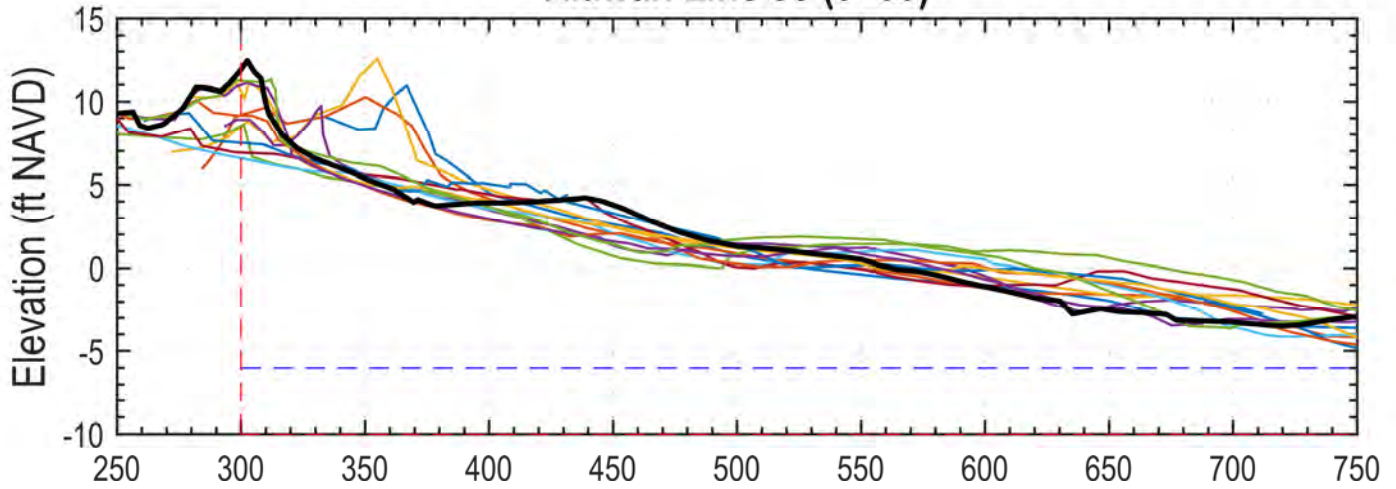
## Kiawah Line 37



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	148.0	136.0	283.9
Nov 2015	151.3	137.5	288.7
Jan 2017	145.7	121.9	267.7
Nov 2017	141.3	128.1	269.4
Jan 2019	134.5	128.1	262.6
Nov 2019	128.3	122.1	250.4
Nov 2020	126.7	118.4	245.1
Dec 2021	137.5	117.0	254.5
Nov 2022	129.8	122.4	252.2
Oct 2023	142.1	118.5	260.6
Dec 2024	136.4	111.1	247.5



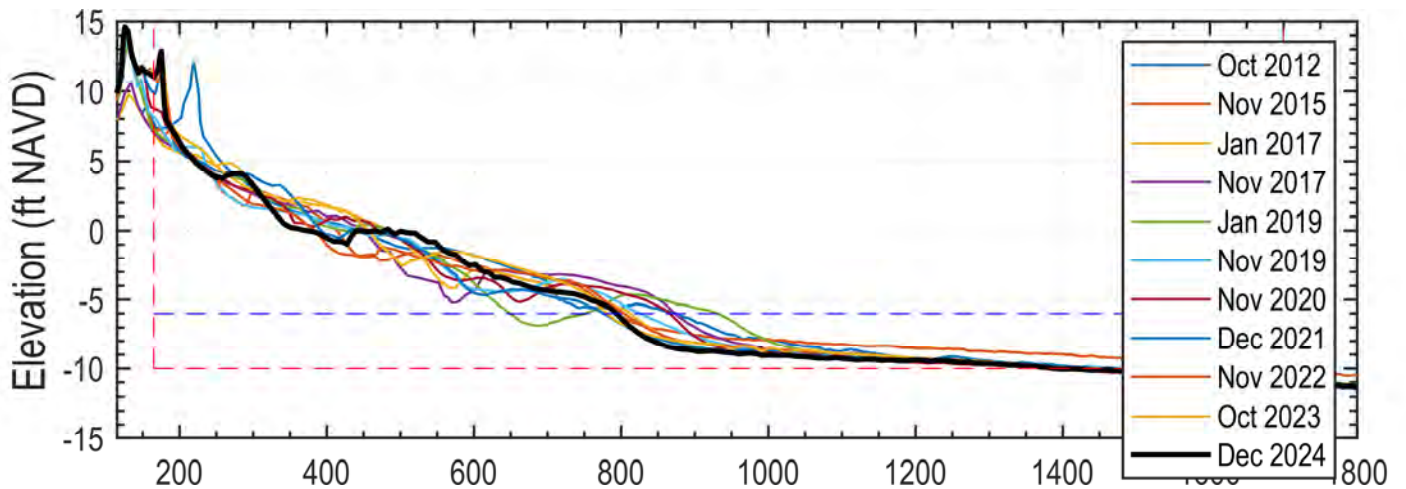
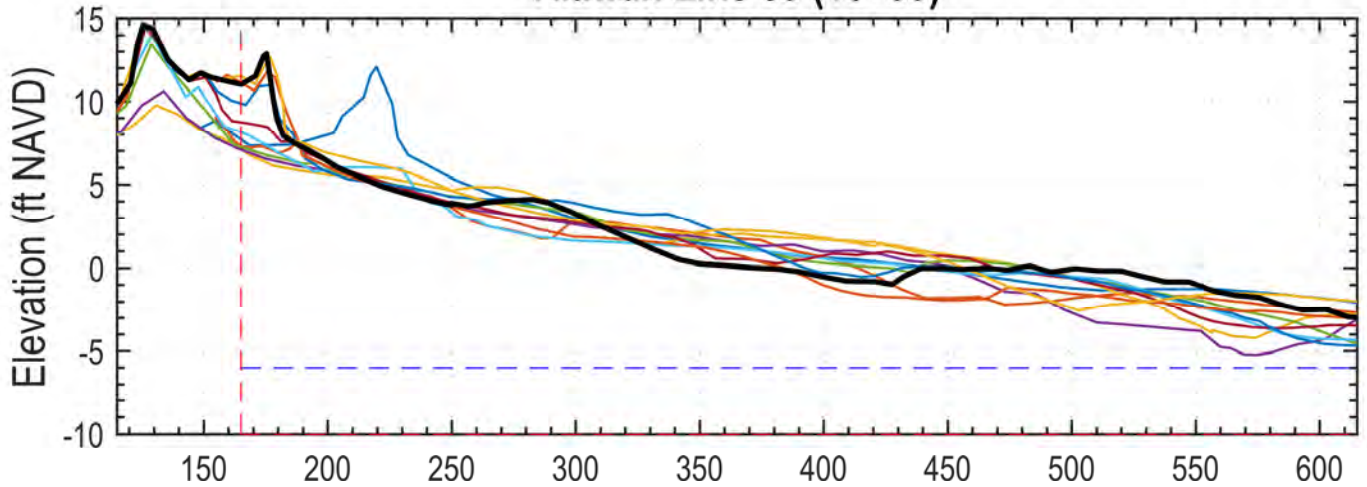
### Kiawah Line 38 (0+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	149.2	184.1	333.3
Sep 2006	132.8	123.1	255.8
Oct 2012	146.4	133.7	280.1
Nov 2015	138.9	134.4	273.3
Jan 2017	137.2	123.2	260.4
Nov 2017	135.9	124.8	260.7
Jan 2019	130.4	130.5	260.8
Nov 2019	136.3	123.3	259.7
Nov 2020	129.7	119.7	249.4
Dec 2021	130.7	117.3	248.0
Nov 2022	133.1	121.3	254.4
Oct 2023	139.7	119.4	259.1
Dec 2024	134.0	110.8	244.8



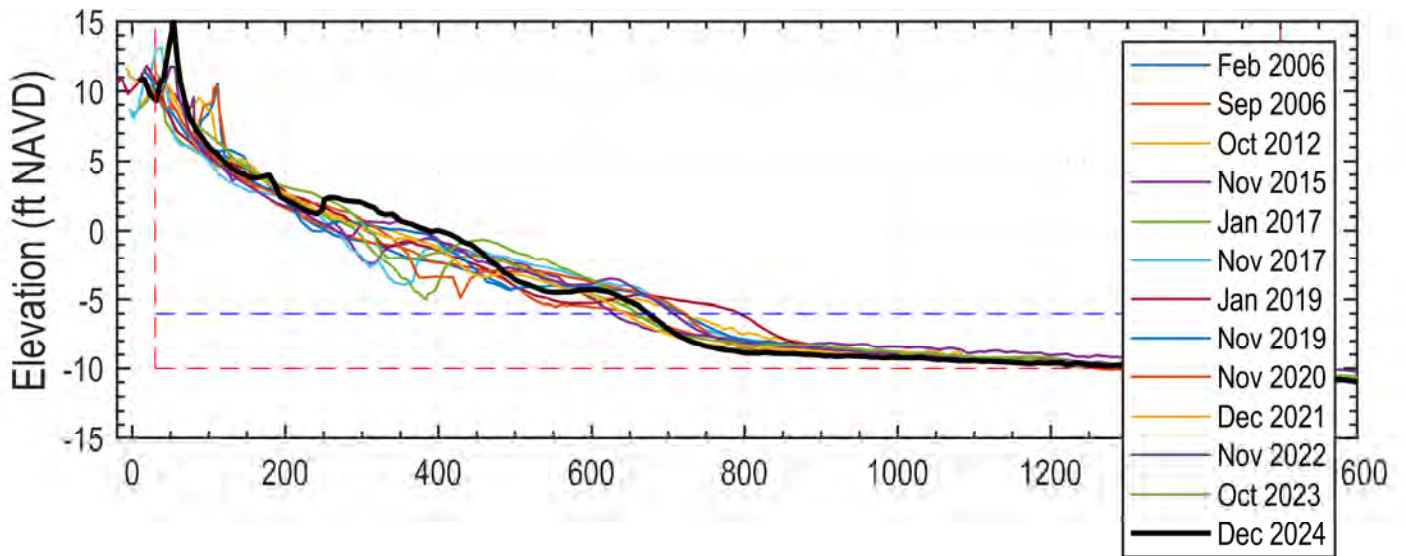
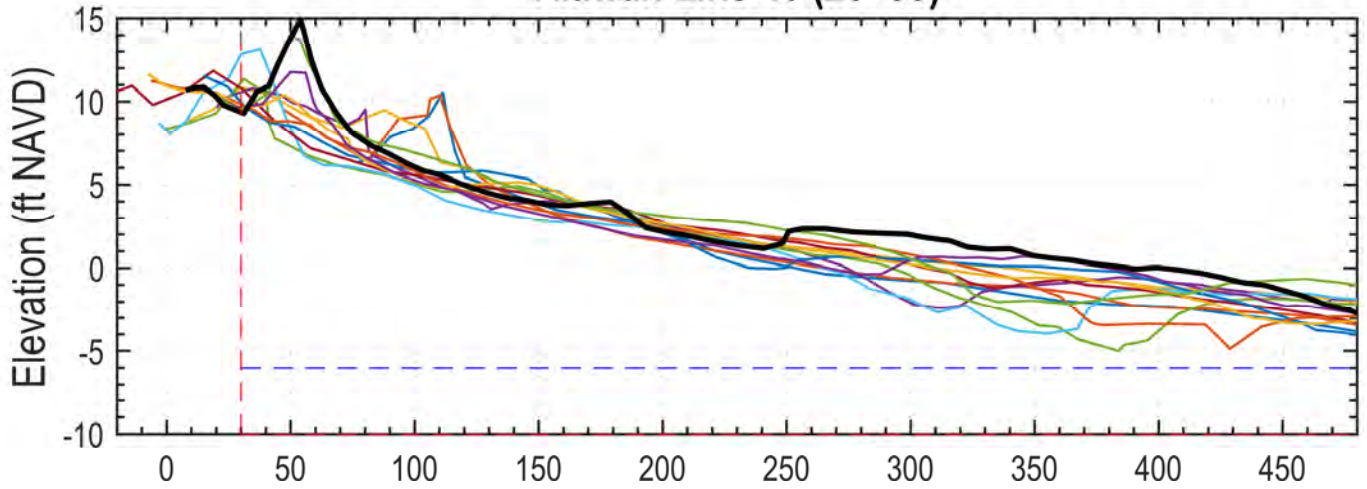
### Kiawah Line 39 (10+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	145.5	132.1	277.5
Nov 2015	130.1	140.4	270.5
Jan 2017	136.9	119.6	256.5
Nov 2017	133.9	124.6	258.4
Jan 2019	127.9	129.3	257.2
Nov 2019	128.9	121.8	250.7
Nov 2020	134.7	120.5	255.2
Dec 2021	131.5	117.9	249.3
Nov 2022	129.1	120.7	249.8
Oct 2023	146.5	119.4	265.9
Dec 2024	134.9	113.7	248.6



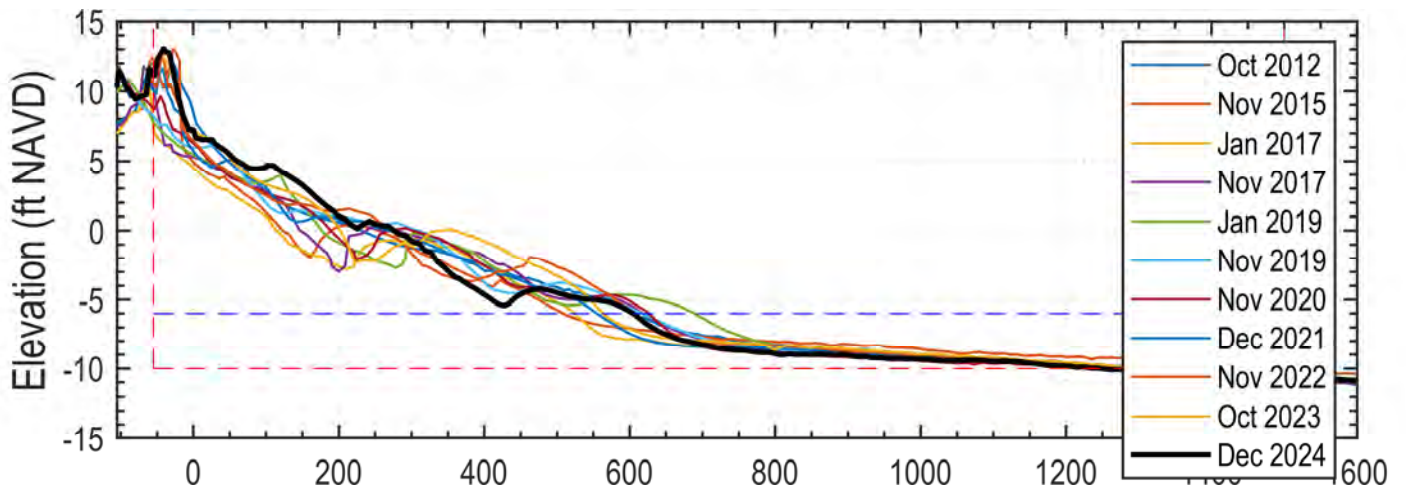
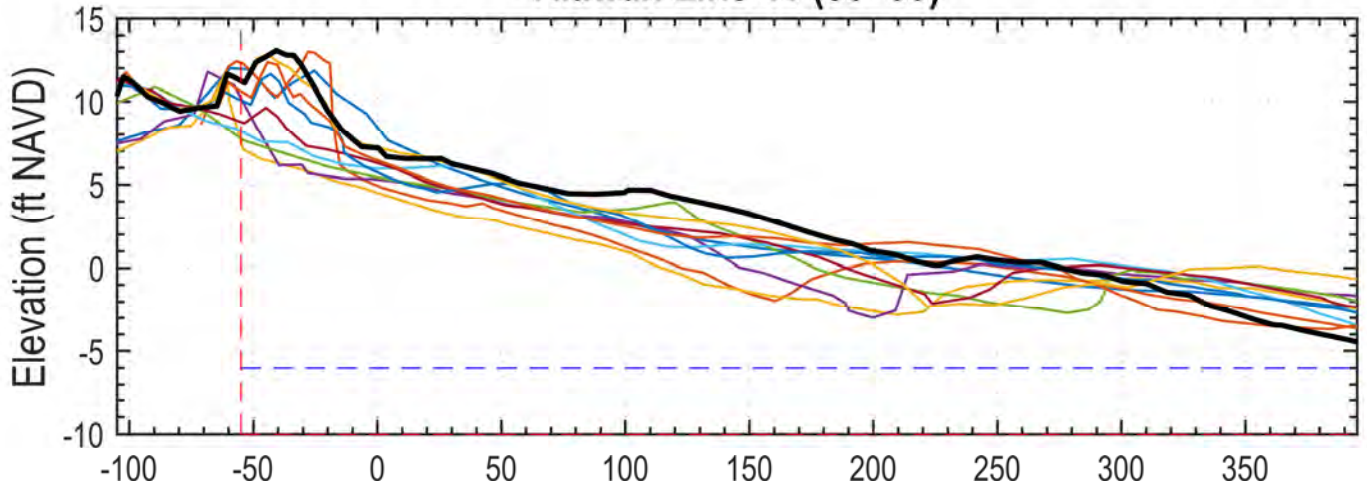
### Kiawah Line 40 (20+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	123.3	82.6	205.9
Sep 2006	131.3	121.9	253.1
Oct 2012	156.3	132.7	288.9
Nov 2015	144.3	135.2	279.5
Jan 2017	133.1	122.6	255.7
Nov 2017	140.3	125.8	266.1
Jan 2019	142.8	133.6	276.5
Nov 2019	145.4	128.4	273.9
Nov 2020	143.7	122.4	266.0
Dec 2021	142.9	121.1	264.0
Nov 2022	150.8	127.4	278.1
Oct 2023	161.8	125.4	287.2
Dec 2024	159.0	117.6	276.6



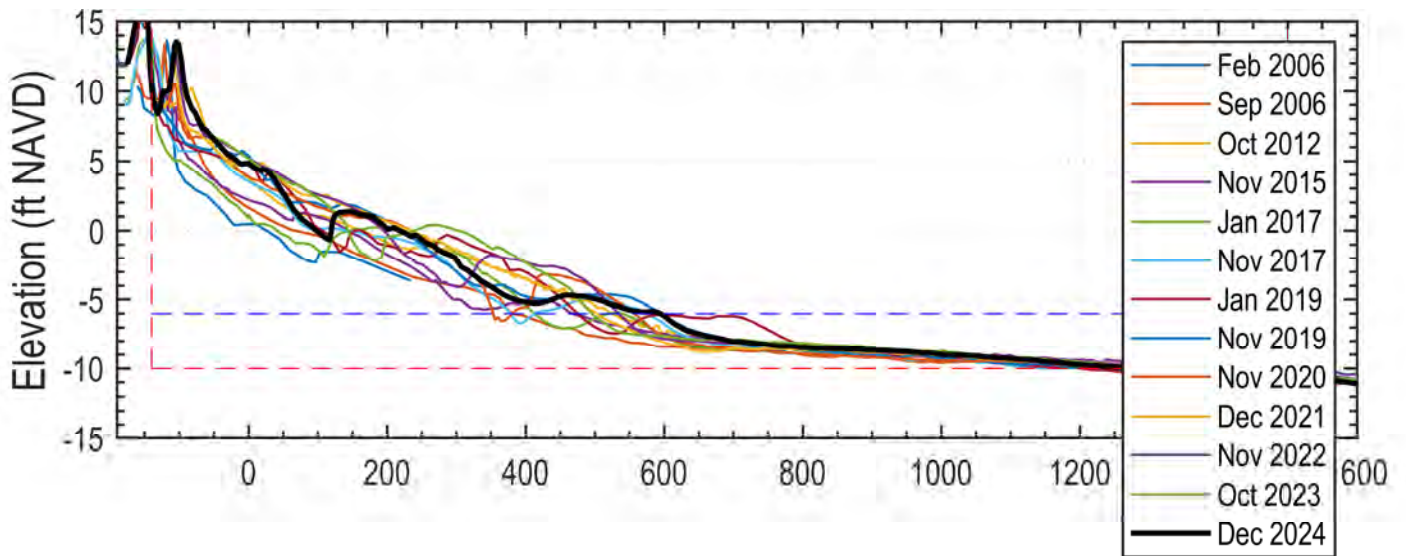
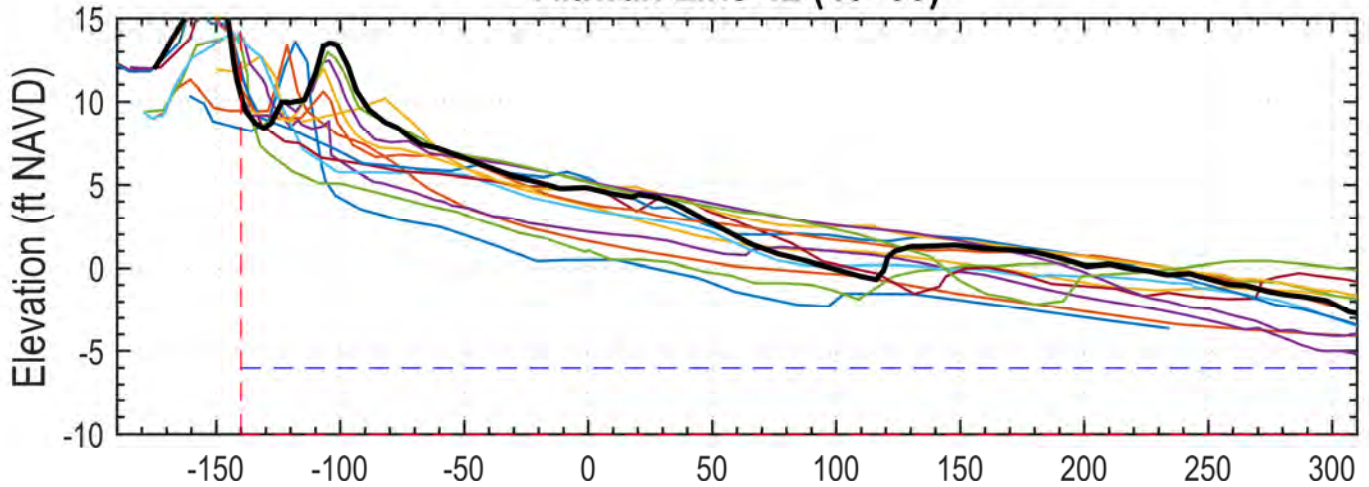
### Kiawah Line 41 (30+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	153.2	131.9	285.1
Nov 2015	127.5	137.5	264.9
Jan 2017	116.6	118.9	235.5
Nov 2017	138.0	125.1	263.2
Jan 2019	140.1	133.5	273.5
Nov 2019	146.9	127.9	274.8
Nov 2020	144.3	121.0	265.4
Dec 2021	145.9	122.1	268.0
Nov 2022	153.1	129.0	282.1
Oct 2023	161.2	128.4	289.6
Dec 2024	153.5	122.2	275.7



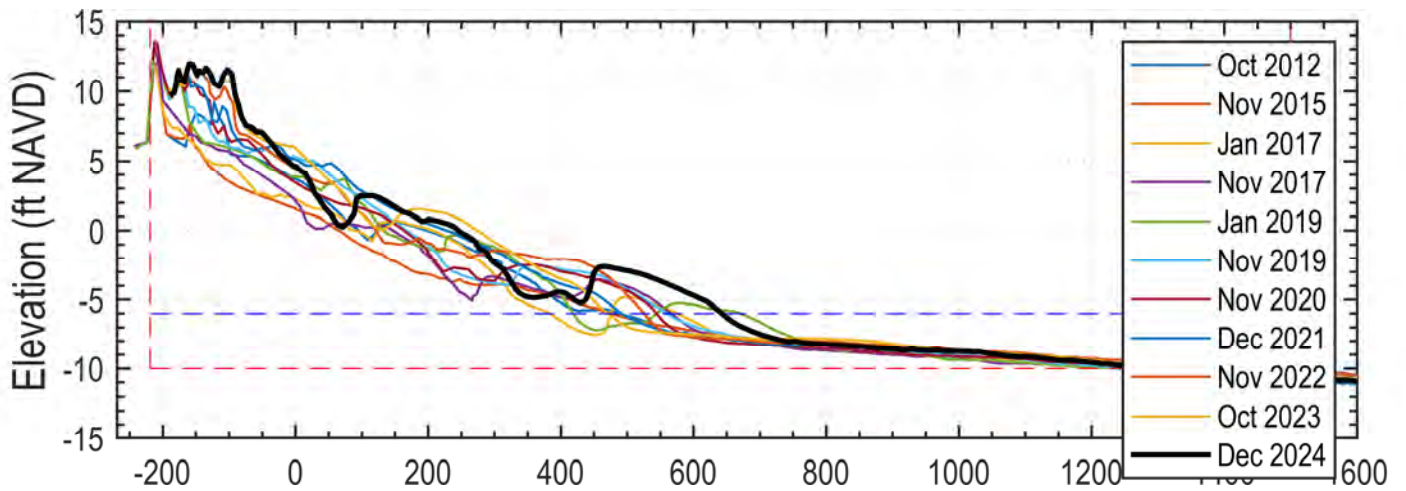
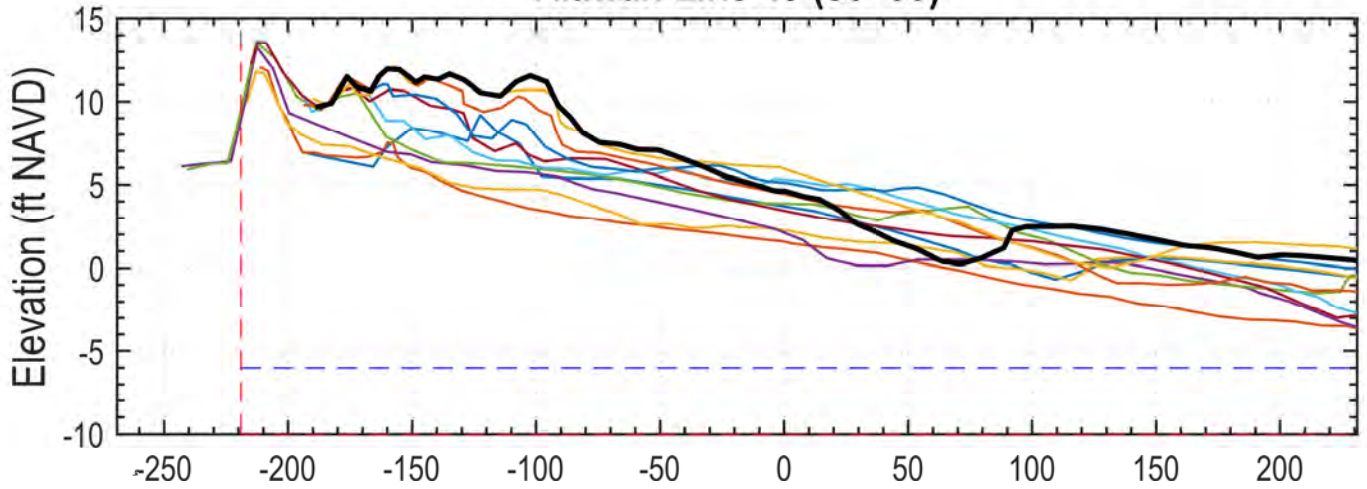
### Kiawah Line 42 (40+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	94.2	88.7	182.9
Sep 2006	115.4	115.8	231.3
Oct 2012	159.9	137.1	297.0
Nov 2015	122.2	140.2	262.4
Jan 2017	125.5	129.6	255.0
Nov 2017	139.8	129.8	269.6
Jan 2019	154.0	141.4	295.4
Nov 2019	160.3	135.8	296.1
Nov 2020	161.6	128.6	290.1
Dec 2021	171.7	130.4	302.1
Nov 2022	174.2	136.9	311.1
Oct 2023	178.9	138.4	317.3
Dec 2024	161.5	141.1	302.6



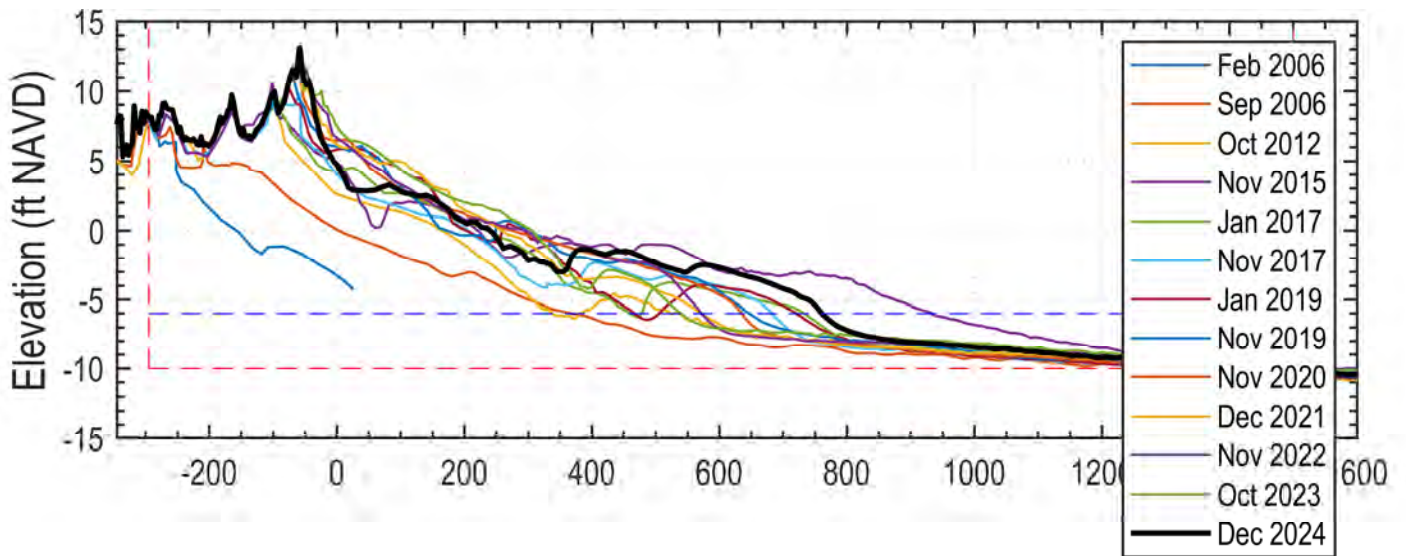
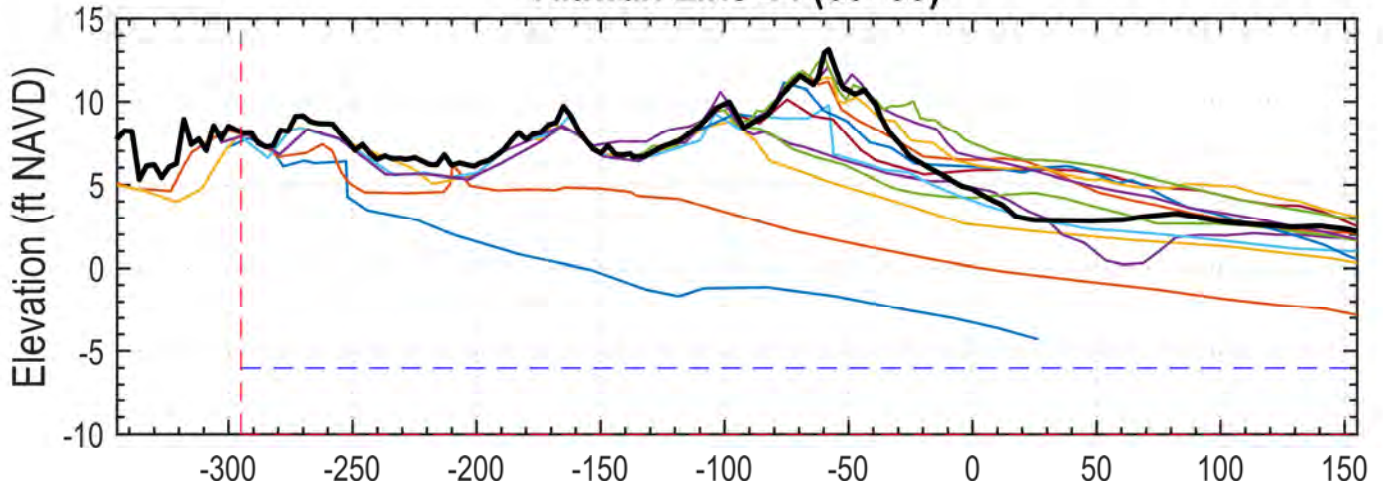
### Kiawah Line 43 (50+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	179.0	147.2	326.2
Nov 2015	141.0	158.5	299.5
Jan 2017	163.4	146.6	310.0
Nov 2017	167.9	144.9	312.8
Jan 2019	193.7	151.9	345.6
Nov 2019	203.7	149.9	353.5
Nov 2020	200.6	146.1	346.7
Dec 2021	217.3	151.0	368.3
Nov 2022	216.0	154.6	370.5
Oct 2023	225.5	155.5	381.0
Dec 2024	226.2	159.8	386.0



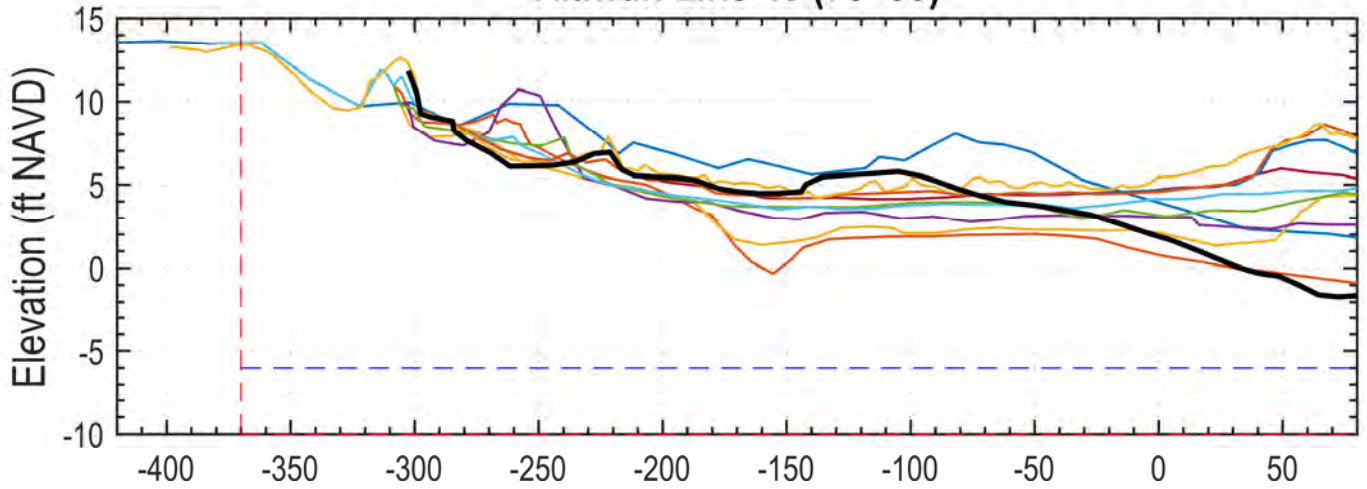
### Kiawah Line 44 (60+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	76.8	60.6	137.5
Sep 2006	148.6	146.3	294.9
Oct 2012	205.0	166.2	371.2
Nov 2015	298.5	215.7	514.2
Jan 2017	249.9	179.6	429.6
Nov 2017	249.1	170.0	419.1
Jan 2019	267.1	173.9	441.0
Nov 2019	278.8	175.1	454.0
Nov 2020	303.3	169.7	473.0
Dec 2021	278.2	169.7	447.9
Nov 2022	284.7	176.6	461.2
Oct 2023	286.7	182.9	469.6
Dec 2024	291.5	188.6	480.1



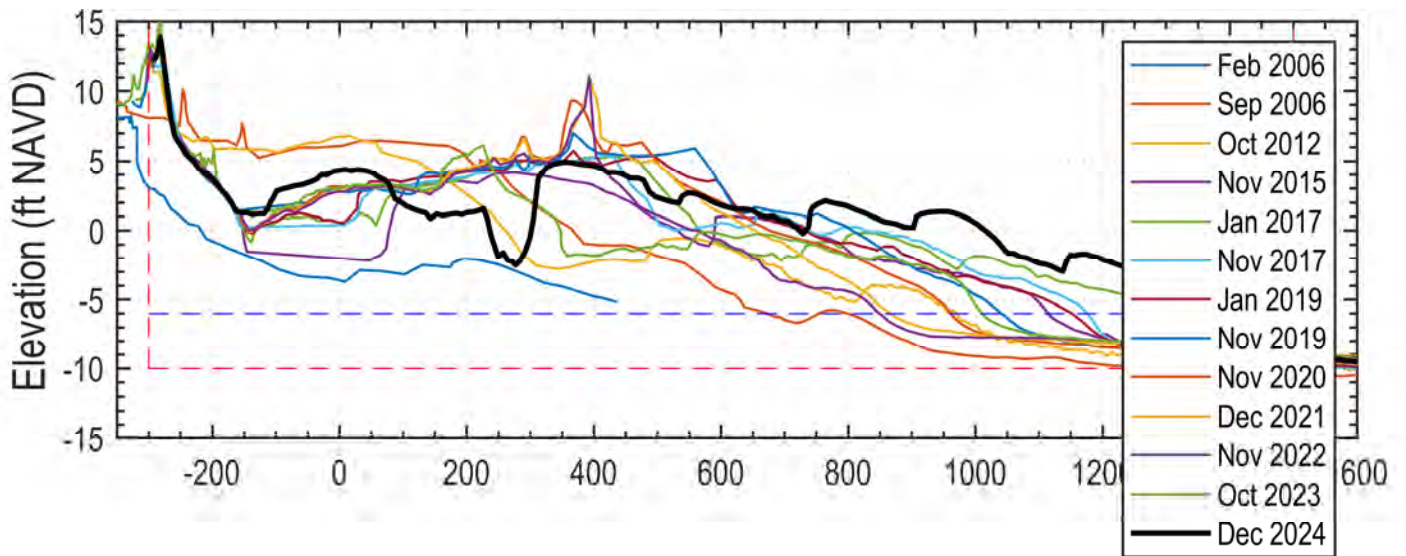
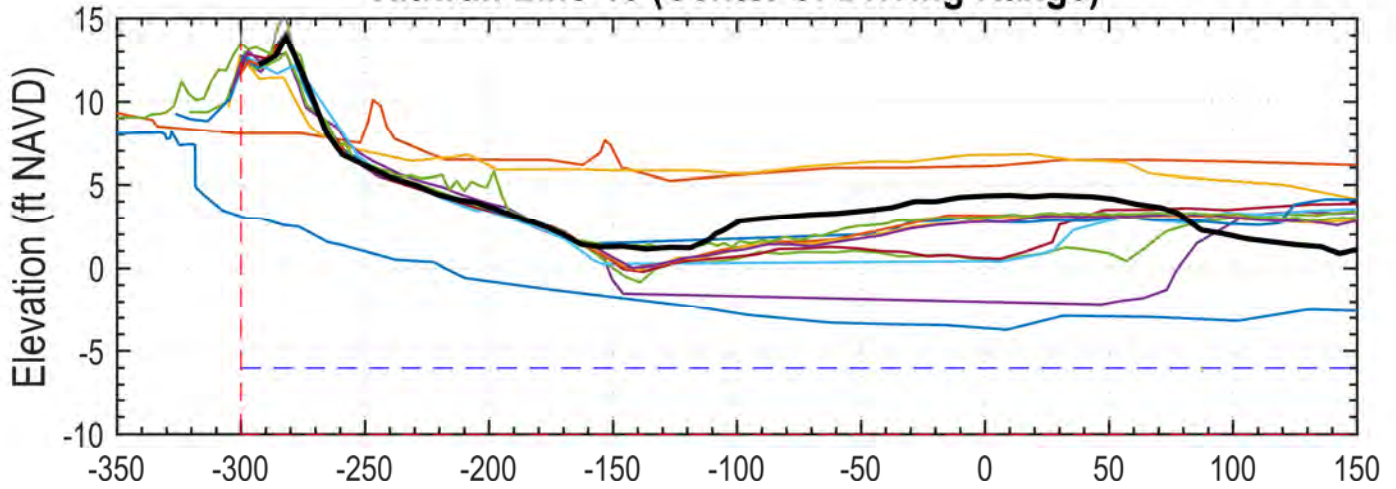
### Kiawah Line 45 (70+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	267.0	187.2	454.2
Nov 2015	289.1	234.9	524.0
Jan 2017	330.4	216.8	547.2
Nov 2017	340.5	207.3	547.7
Jan 2019	360.7	212.2	573.0
Nov 2019	386.1	207.8	593.8
Nov 2020	381.5	203.0	584.5
Dec 2021	367.4	205.2	572.6
Nov 2022	364.1	208.1	572.2
Oct 2023	317.8	212.3	530.1
Dec 2024	349.0	228.4	577.4



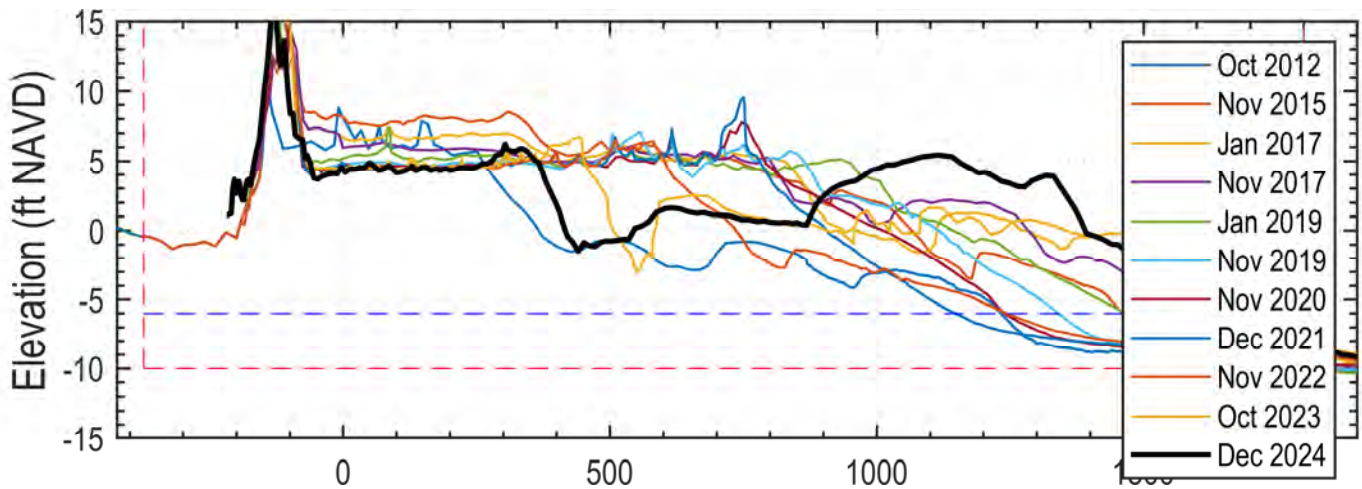
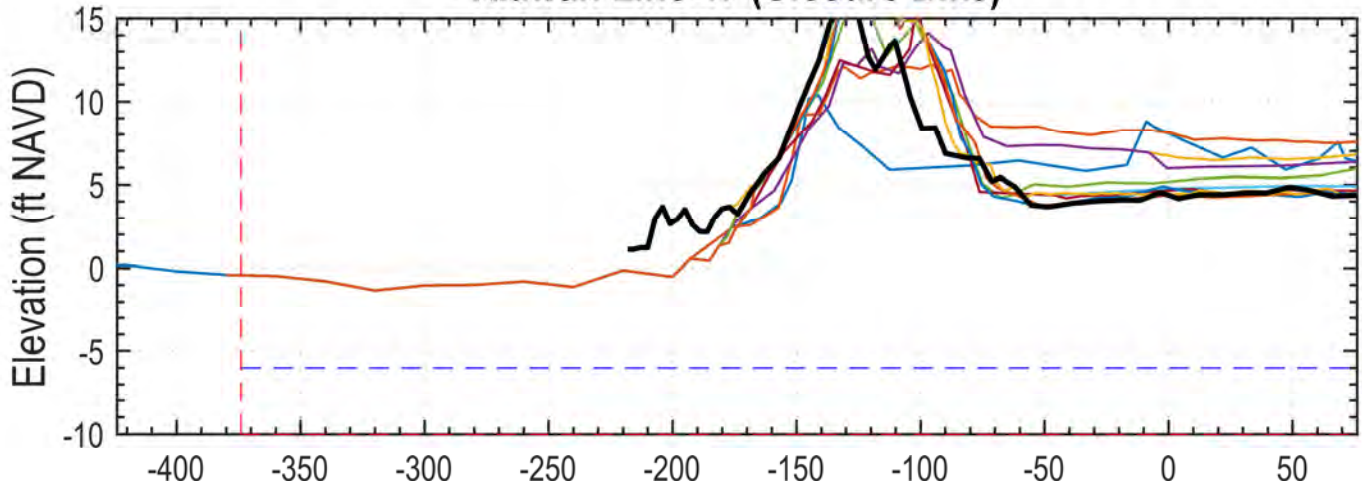
### Kiawah Line 46 (Center of Driving Range)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	98.1	140.4	238.6
Sep 2006	322.4	183.2	505.6
Oct 2012	324.7	213.0	537.7
Nov 2015	345.2	235.8	581.0
Jan 2017	404.2	247.7	651.8
Nov 2017	401.4	232.0	633.4
Jan 2019	415.6	231.4	646.9
Nov 2019	427.0	224.5	651.6
Nov 2020	402.7	218.8	621.5
Dec 2021	380.3	220.8	601.1
Nov 2022	340.9	219.8	560.7
Oct 2023	342.1	230.8	572.9
Dec 2024	454.7	254.8	709.5



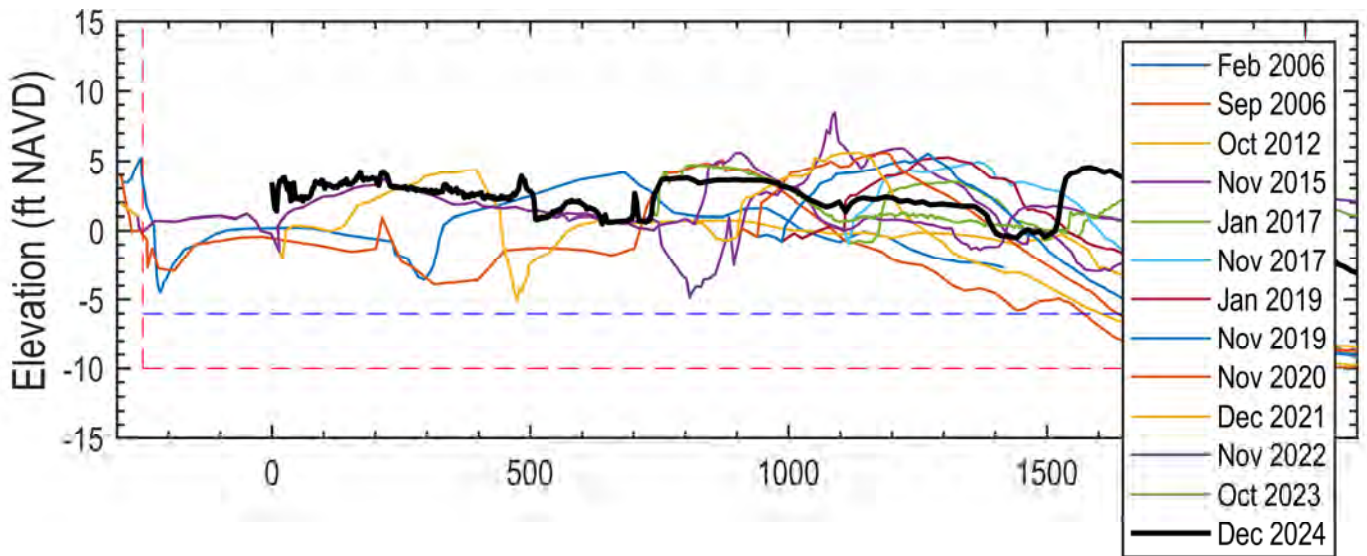
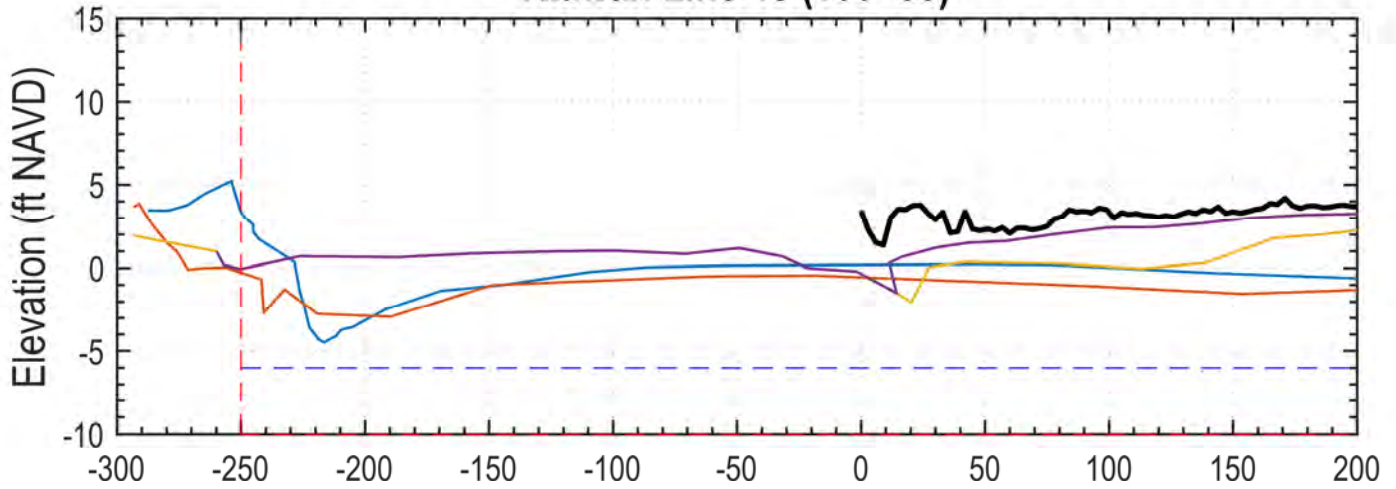
### Kiawah Line 47 (Closure Dike)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	388.4	259.5	647.9
Nov 2015	638.9	295.3	934.2
Jan 2017	669.8	312.5	982.2
Nov 2017	652.3	300.8	953.1
Jan 2019	617.9	283.8	901.7
Nov 2019	580.8	277.2	858.0
Nov 2020	545.7	270.6	816.2
Dec 2021	515.1	273.0	788.1
Nov 2022	470.2	280.9	751.1
Oct 2023	632.1	322.0	954.0
Dec 2024	655.6	321.4	977.0



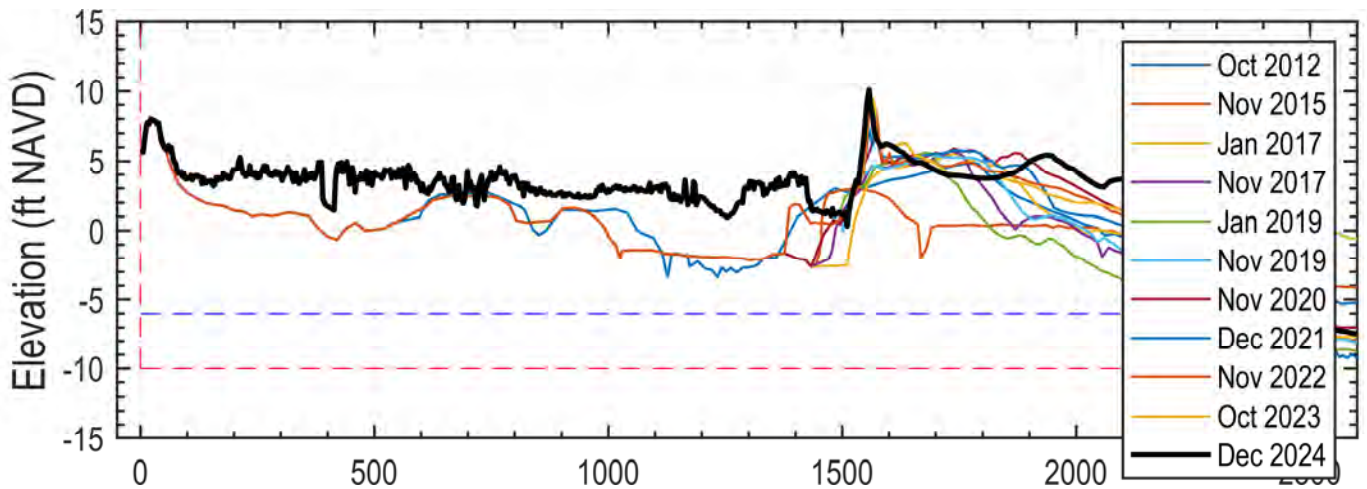
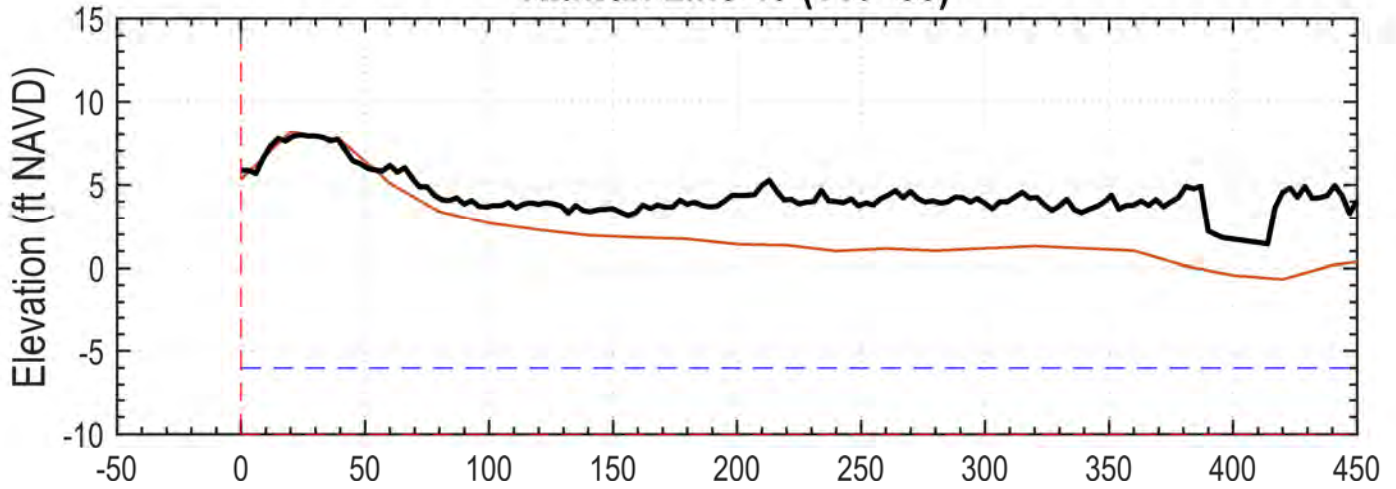
### Kiawah Line 48 (100+00)



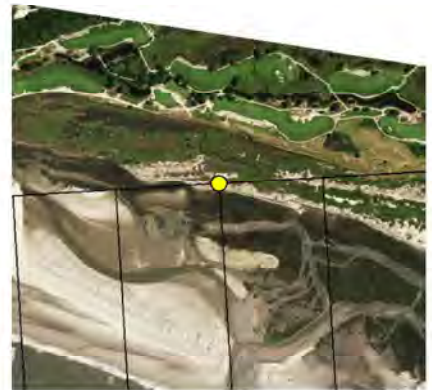
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	409.2	319.1	728.2
Sep 2006	329.2	288.2	617.4
Oct 2012	452.0	306.4	758.3
Nov 2015	570.8	332.8	903.6
Jan 2017	565.1	333.3	898.4
Nov 2017	573.3	331.0	904.3
Jan 2019	542.4	320.6	862.9
Nov 2019	518.8	312.0	830.8
Nov 2020	510.6	309.2	819.7
Dec 2021	476.9	310.0	786.8
Nov 2022	622.3	333.3	955.6
Oct 2023	1155.8	333.3	1489.2
Dec 2024	1141.8	333.3	1475.1



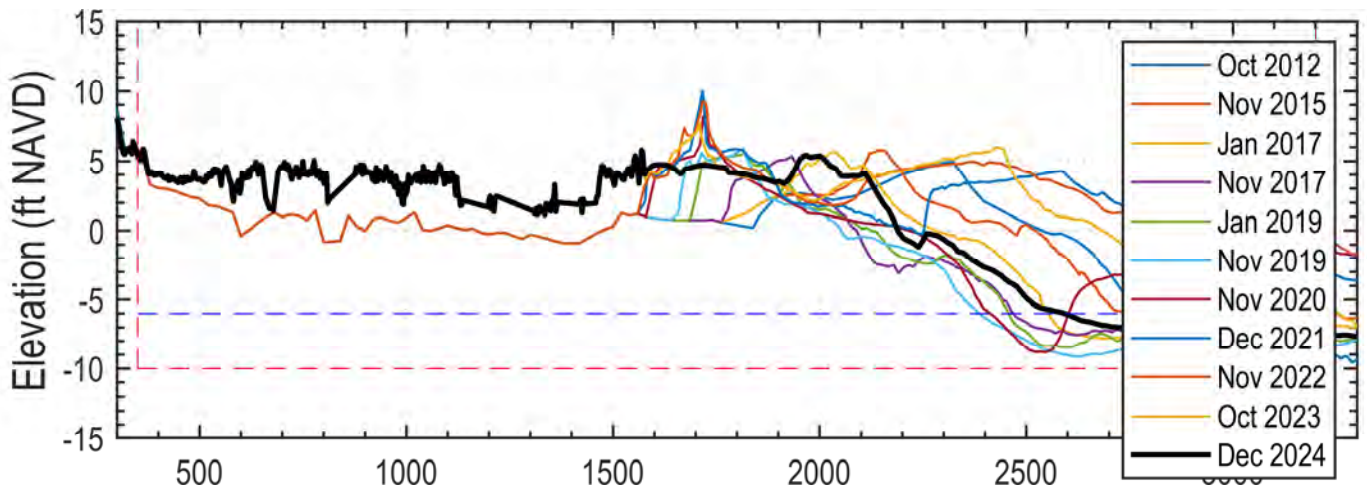
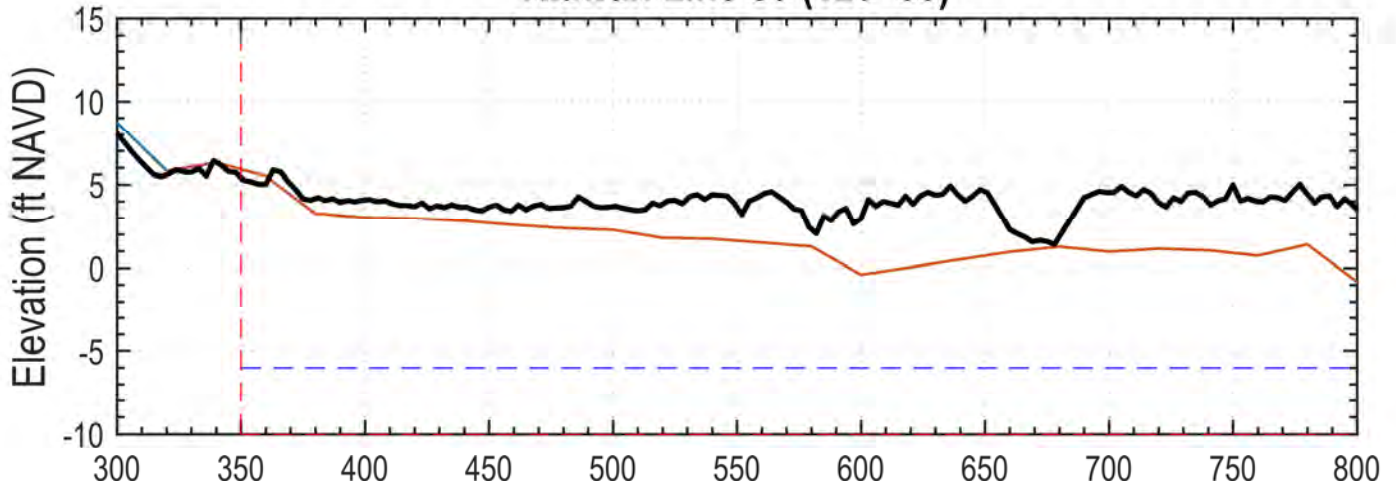
### Kiawah Line 49 (110+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	619.1	361.0	980.1
Nov 2015	554.0	367.1	921.1
Jan 2017	594.2	365.5	959.7
Nov 2017	568.2	364.4	932.6
Jan 2019	534.6	353.0	887.6
Nov 2019	575.3	362.8	938.1
Nov 2020	634.4	369.1	1003.5
Dec 2021	664.0	370.4	1034.3
Nov 2022	673.8	370.4	1044.1
Oct 2023	859.8	370.4	1230.1
Dec 2024	817.1	369.8	1186.9



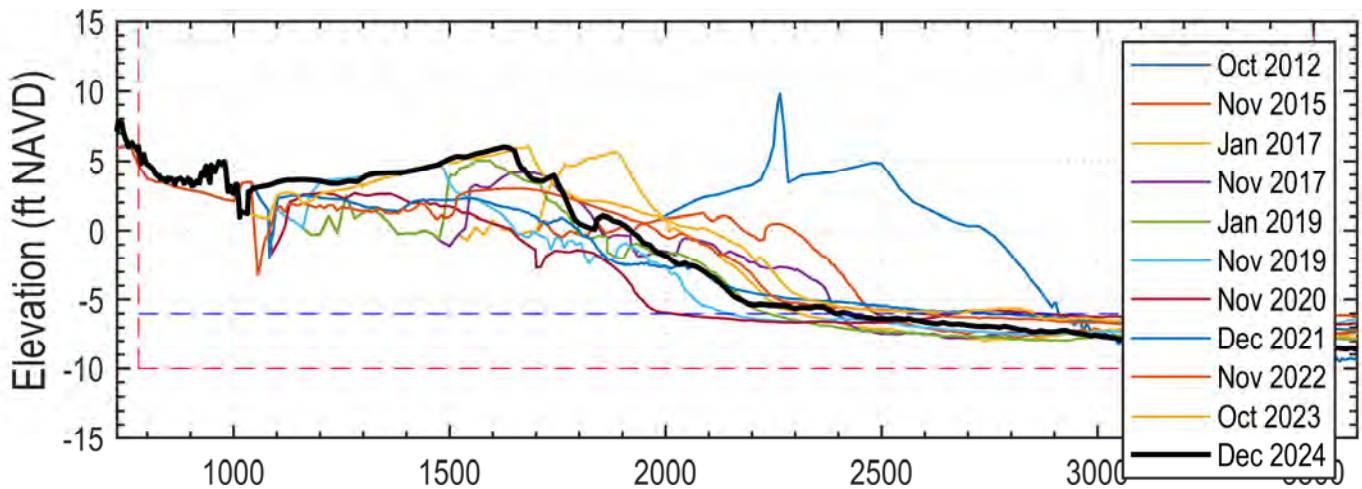
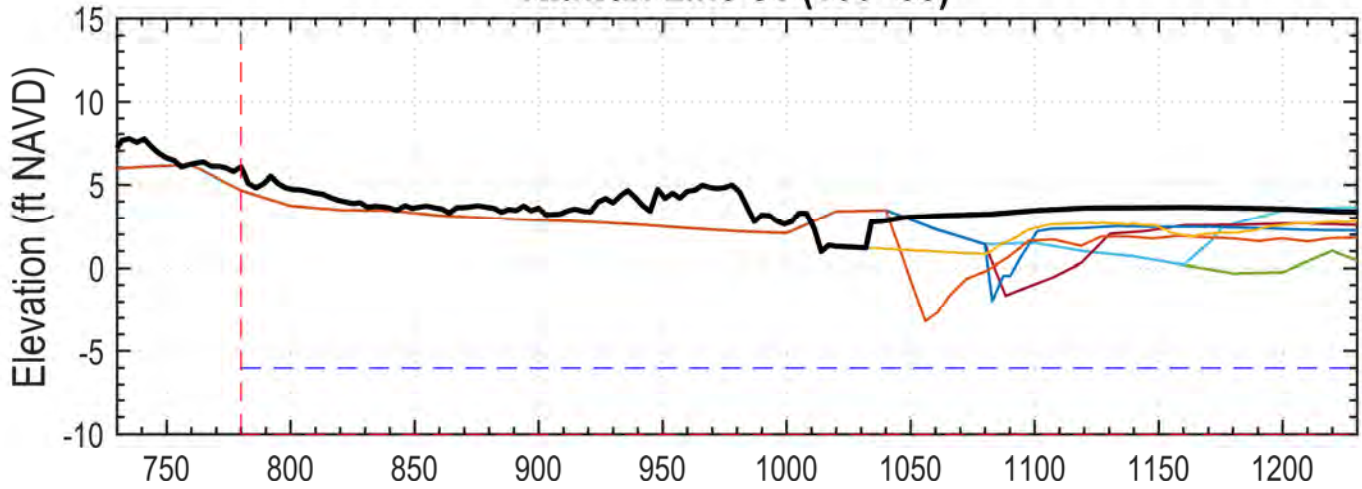
### Kiawah Line 50 (120+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	626.8	385.6	1012.4
Nov 2015	607.0	418.8	1025.9
Jan 2017	559.7	397.4	957.2
Nov 2017	505.6	390.9	896.5
Jan 2019	520.5	370.7	891.2
Nov 2019	507.9	352.0	859.9
Nov 2020	601.1	410.0	1011.1
Dec 2021	785.7	422.2	1207.9
Nov 2022	845.6	422.2	1267.9
Oct 2023	860.2	421.7	1282.0
Dec 2024	699.8	396.3	1096.0



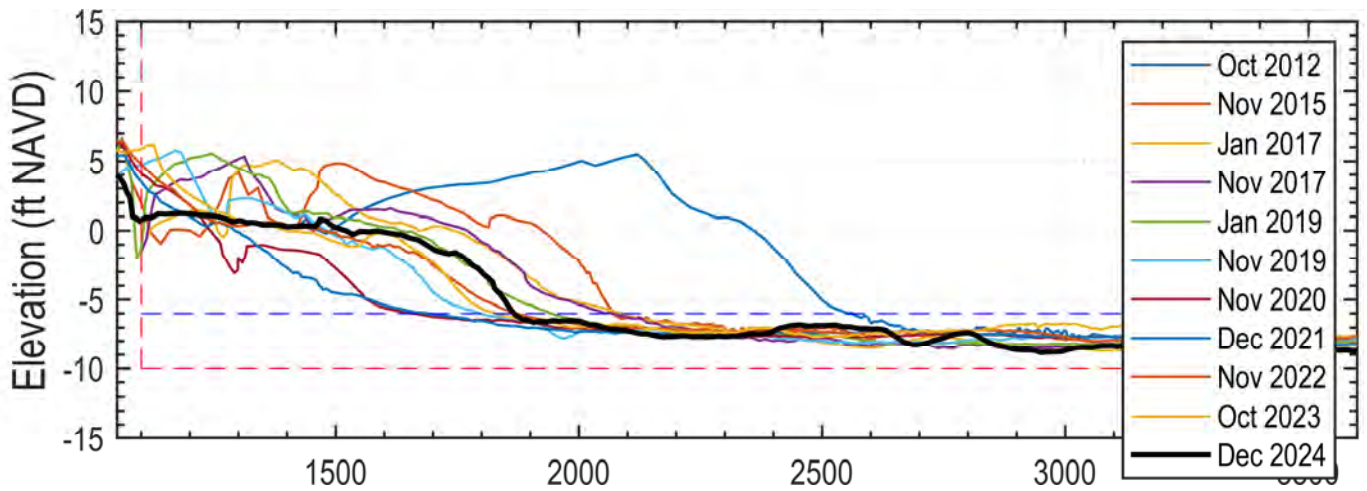
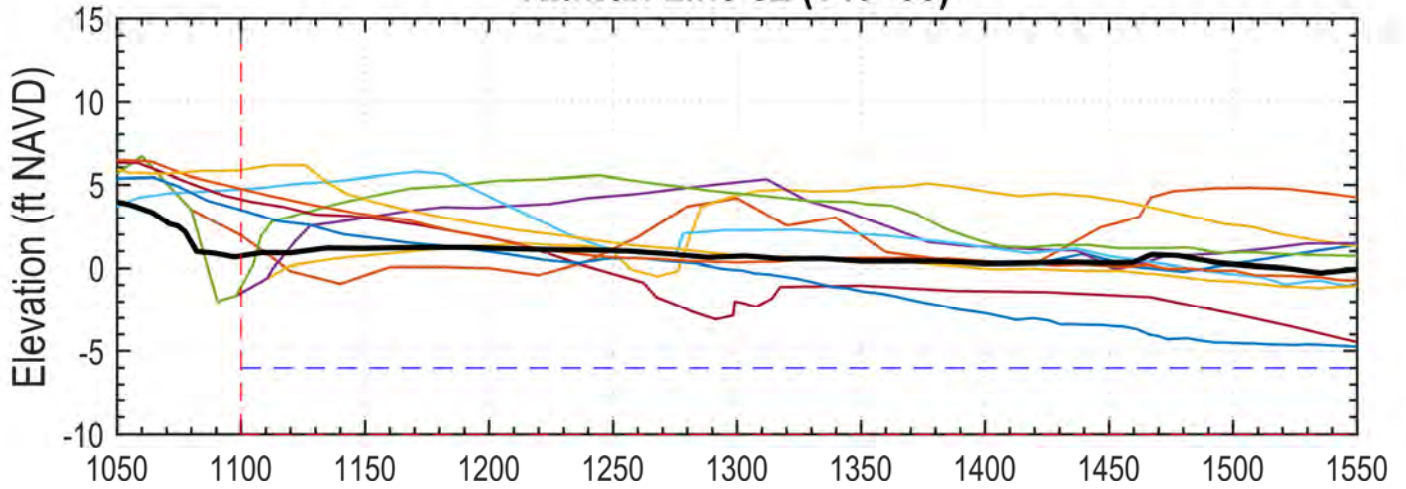
### Kiawah Line 51 (130+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	580.6	348.5	929.1
Nov 2015	407.7	371.7	779.4
Jan 2017	390.1	343.8	733.9
Nov 2017	395.0	339.8	734.8
Jan 2019	365.2	333.5	698.8
Nov 2019	356.2	347.4	703.6
Nov 2020	307.2	382.4	689.6
Dec 2021	367.5	384.9	752.4
Nov 2022	402.7	381.6	784.3
Oct 2023	484.7	380.3	865.0
Dec 2024	443.3	345.7	789.0



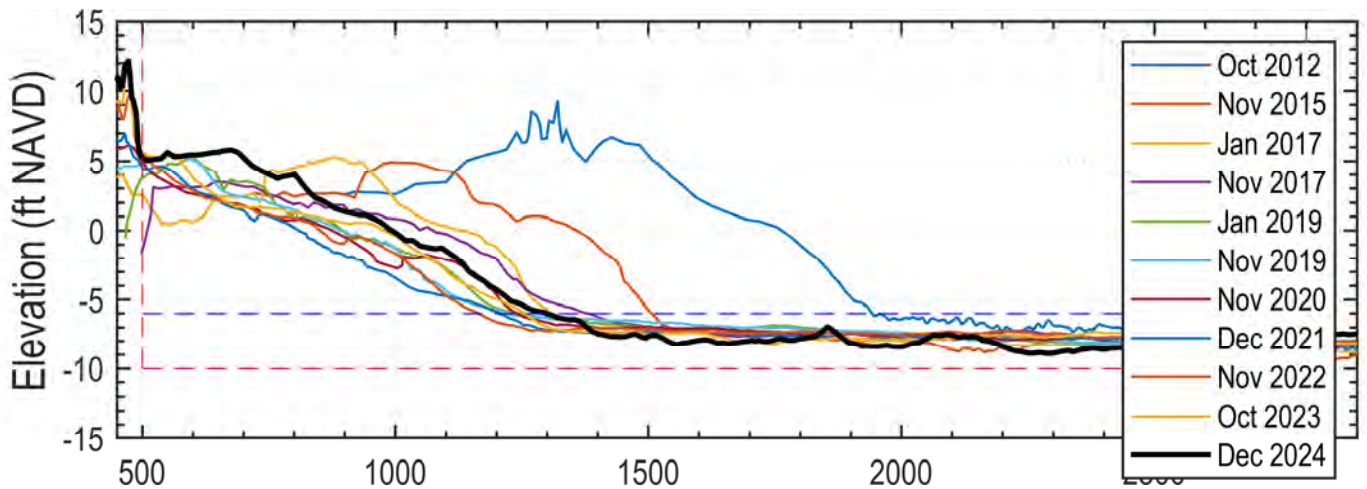
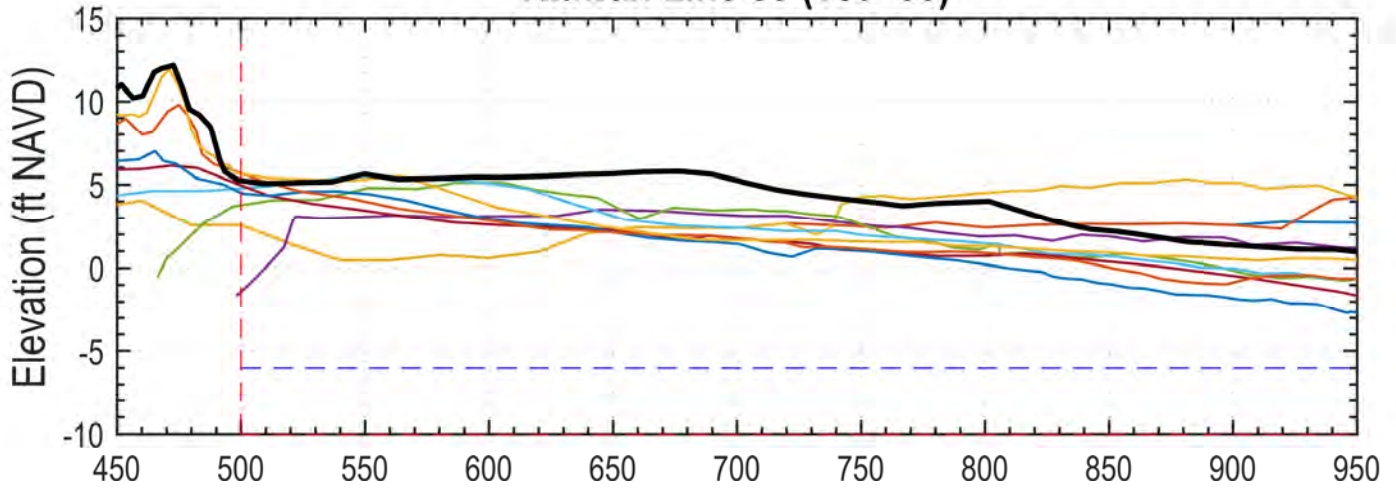
### Kiawah Line 52 (140+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	411.2	296.9	708.2
Nov 2015	258.7	282.6	541.3
Jan 2017	222.0	258.5	480.5
Nov 2017	225.2	247.5	472.6
Jan 2019	206.9	258.6	465.6
Nov 2019	158.4	256.2	414.7
Nov 2020	92.9	256.8	349.6
Dec 2021	84.6	260.0	344.6
Nov 2022	151.8	274.8	426.6
Oct 2023	156.5	277.7	434.2
Dec 2024	161.2	248.0	409.1



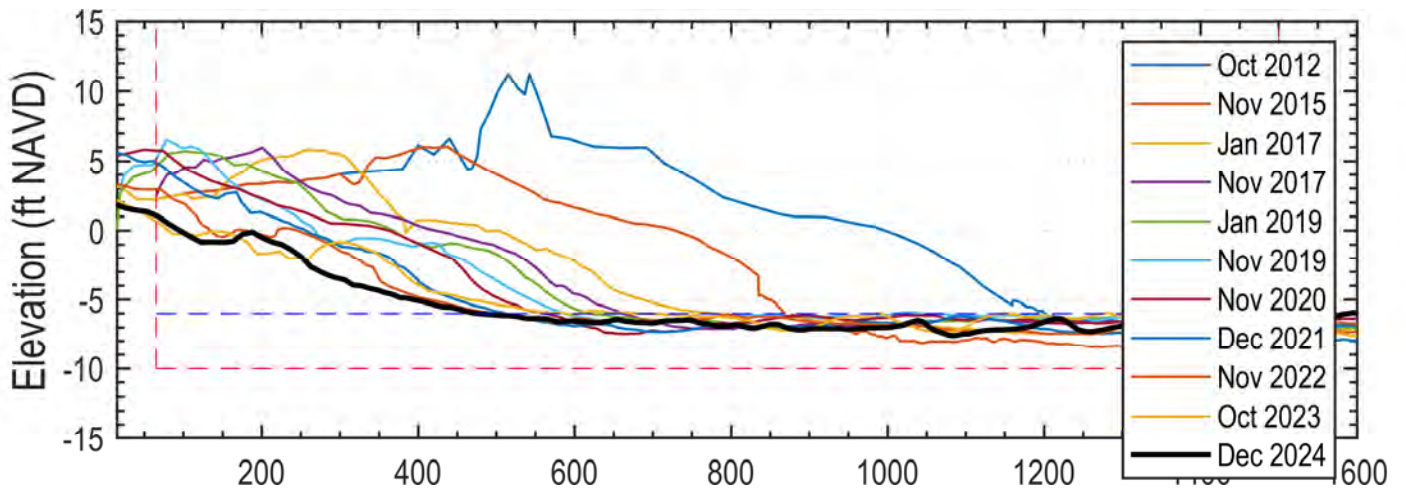
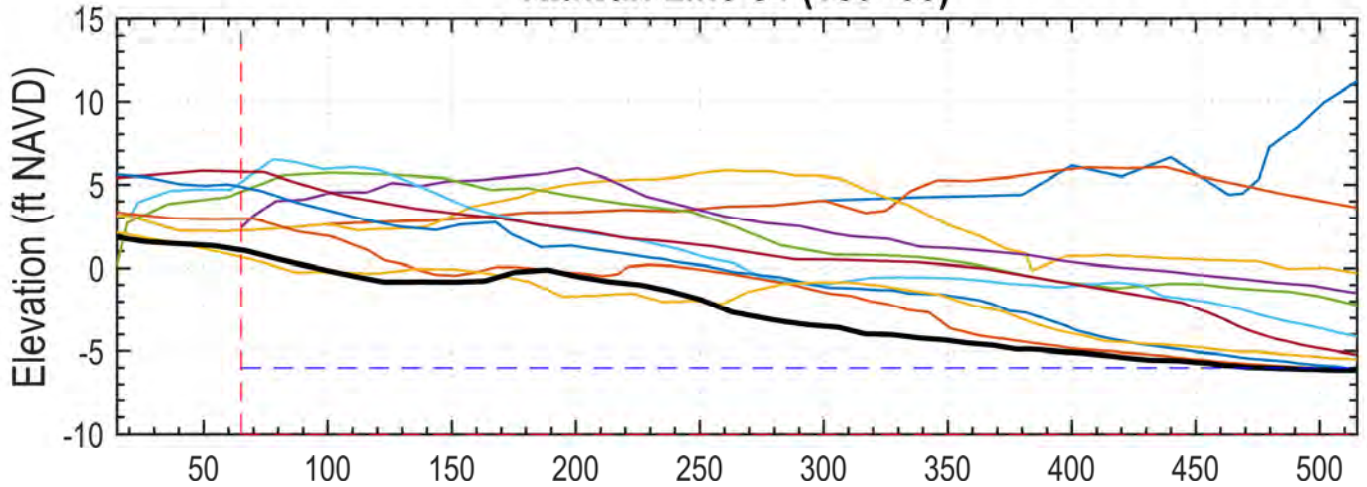
### Kiawah Line 53 (150+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	463.5	298.4	761.9
Nov 2015	286.4	242.8	529.2
Jan 2017	224.1	248.8	472.9
Nov 2017	203.8	252.0	455.8
Jan 2019	173.5	255.6	429.1
Nov 2019	164.7	261.9	426.6
Nov 2020	157.8	256.4	414.2
Dec 2021	133.9	245.6	379.5
Nov 2022	147.4	254.4	401.8
Oct 2023	174.2	237.6	411.7
Dec 2024	211.5	229.5	441.0



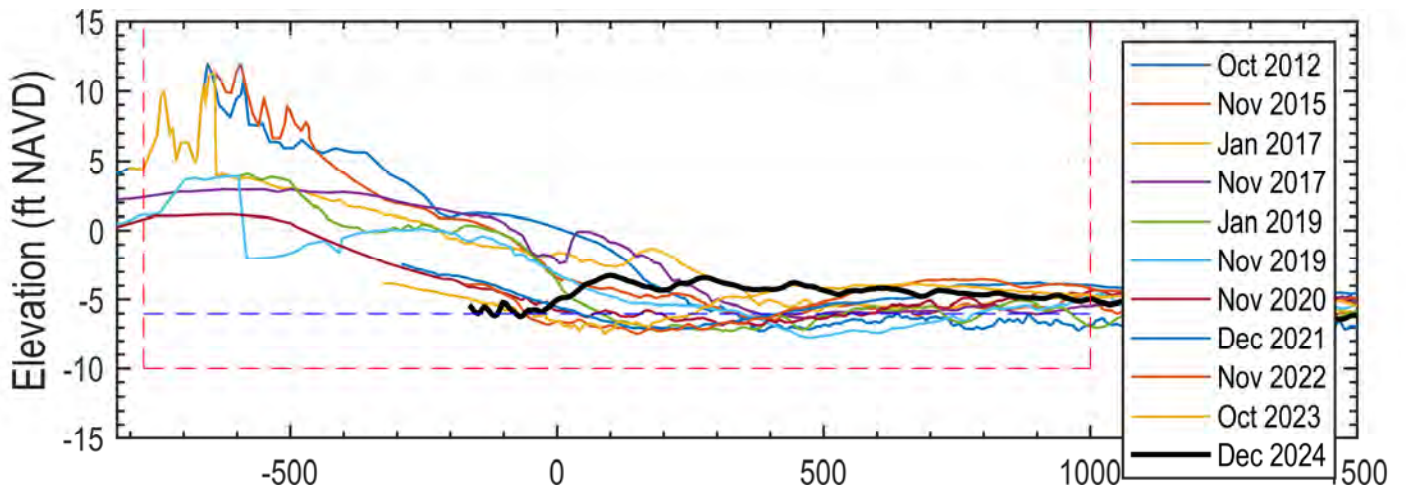
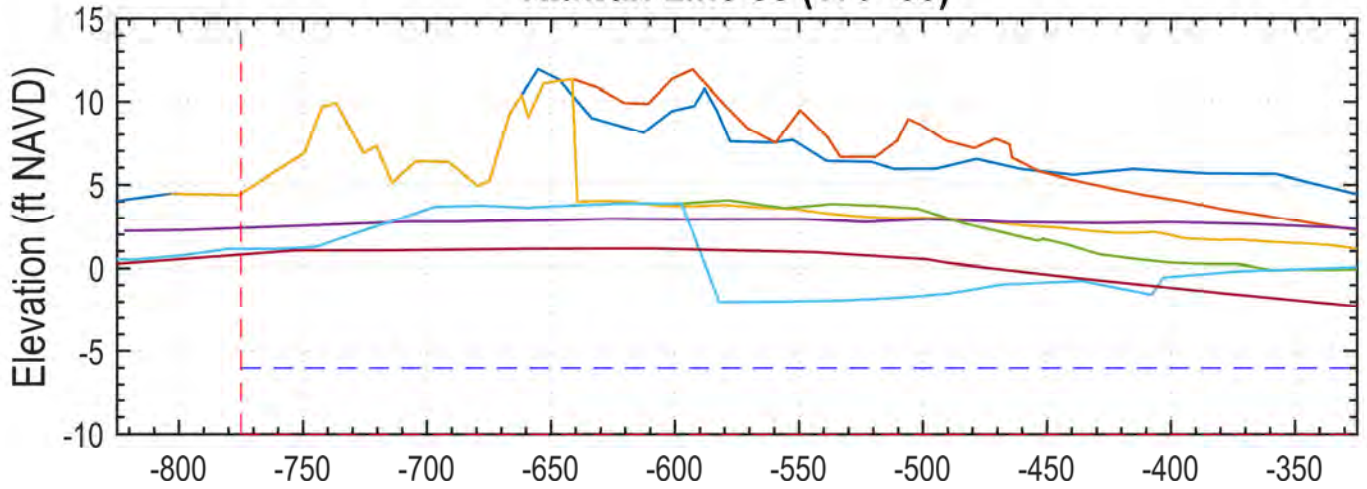
### Kiawah Line 54 (160+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	373.4	201.2	574.6
Nov 2015	245.4	169.3	414.7
Jan 2017	170.8	186.3	357.1
Nov 2017	151.3	191.2	342.5
Jan 2019	138.1	192.5	330.6
Nov 2019	115.8	203.6	319.4
Nov 2020	112.2	193.8	306.0
Dec 2021	85.9	181.0	266.9
Nov 2022	67.0	185.3	252.3
Oct 2023	65.4	197.9	263.2
Dec 2024	50.8	183.9	234.6



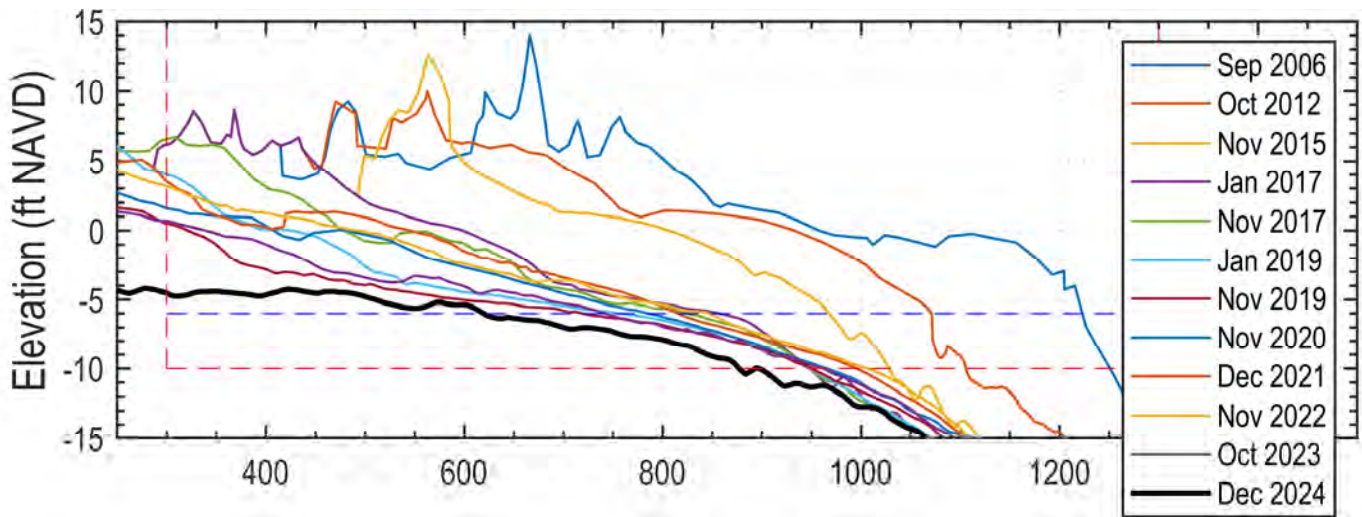
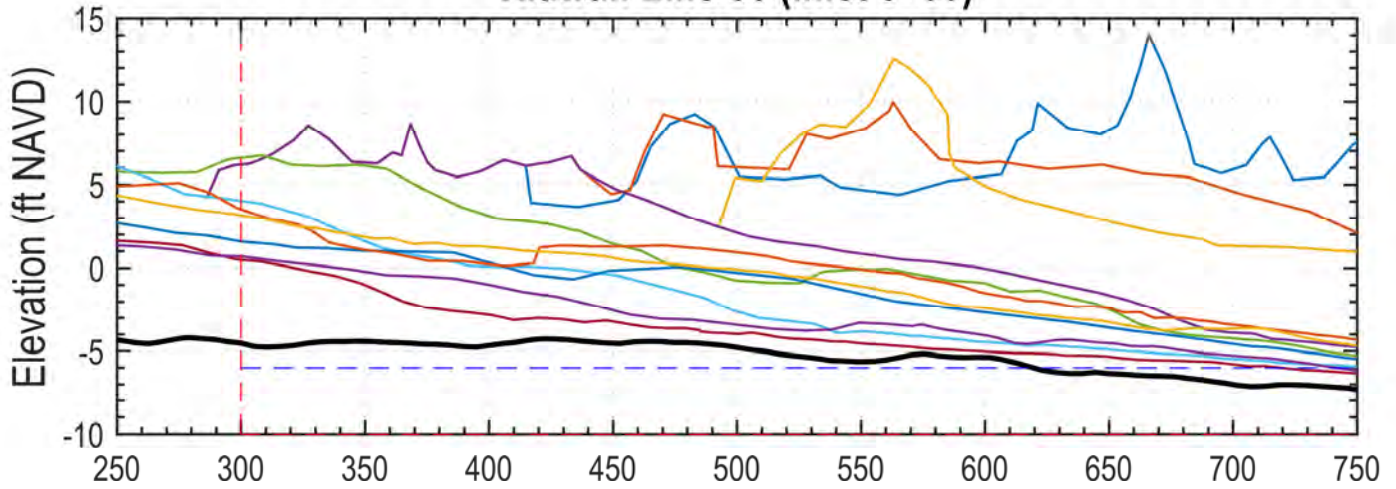
### Kiawah Line 55 (170+00)



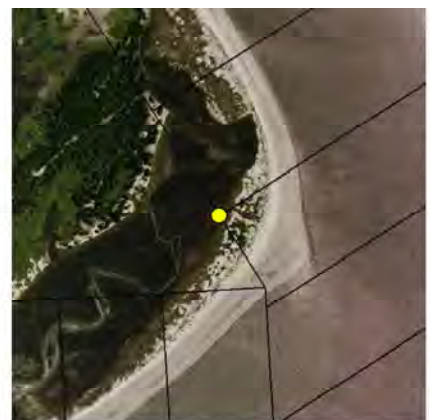
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	341.9	246.6	588.4
Nov 2015	317.0	262.0	579.0
Jan 2017	297.6	263.0	560.6
Nov 2017	275.0	262.2	537.3
Jan 2019	215.3	248.2	463.4
Nov 2019	189.1	247.5	436.5
Nov 2020	143.1	256.5	399.6
Dec 2021	117.3	253.8	371.1
Nov 2022	91.5	248.8	340.4
Oct 2023	92.9	256.0	348.9
Dec 2024	76.2	262.9	339.0



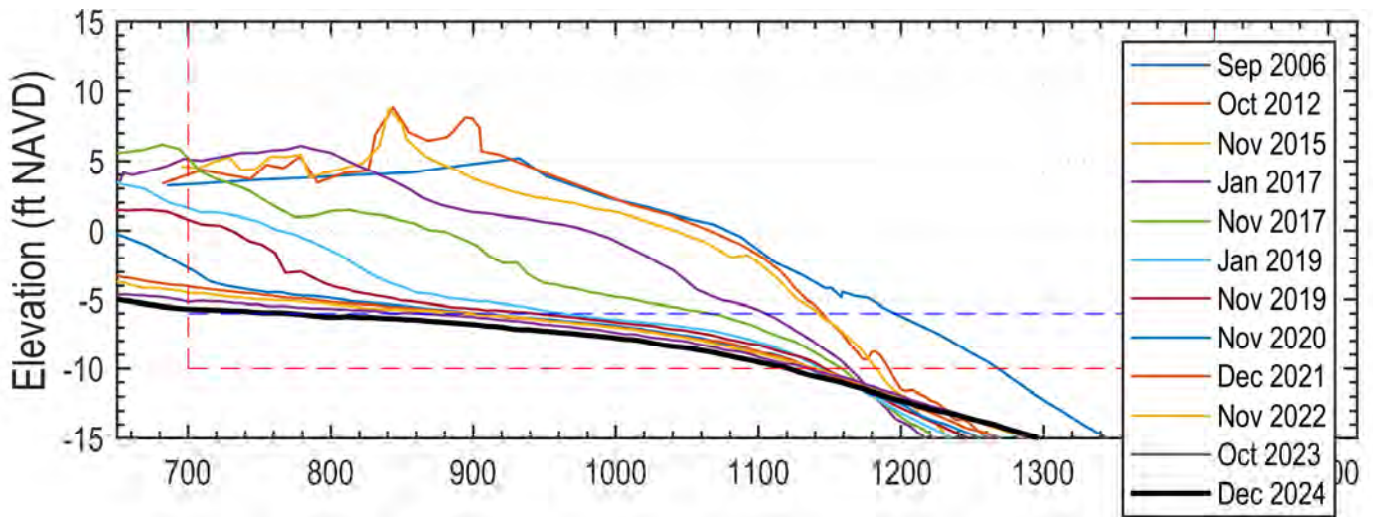
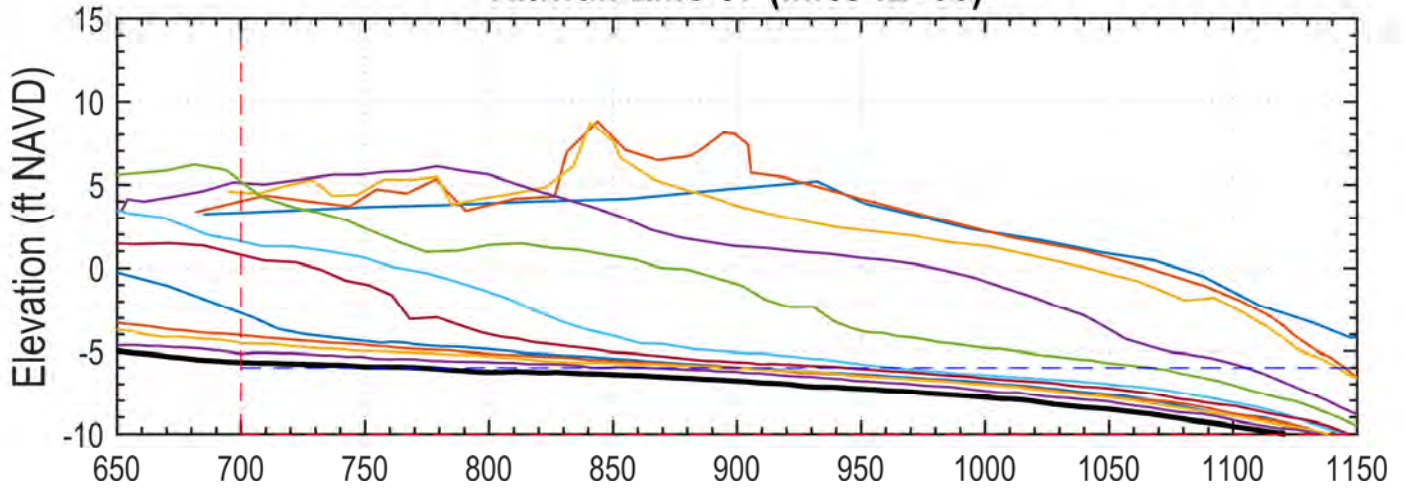
### Kiawah Line 56 (Inlet 0+00)



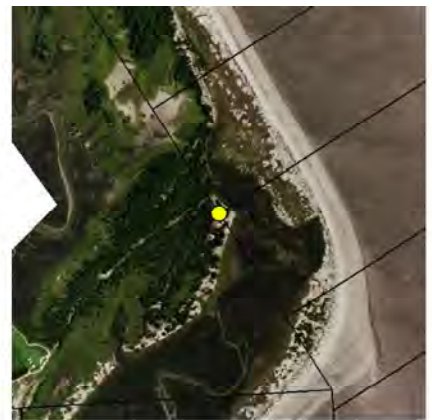
Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	327.2	138.6	465.8
Oct 2012	269.9	115.7	385.7
Nov 2015	220.9	103.8	324.7
Jan 2017	133.7	90.6	224.3
Nov 2017	106.4	88.9	195.3
Jan 2019	61.7	85.1	146.7
Nov 2019	35.7	82.8	118.5
Nov 2020	75.7	86.1	161.8
Dec 2021	94.6	90.1	184.7
Nov 2022	88.1	92.2	180.3
Oct 2023	49.7	83.3	132.9
Dec 2024	13.7	71.1	84.7



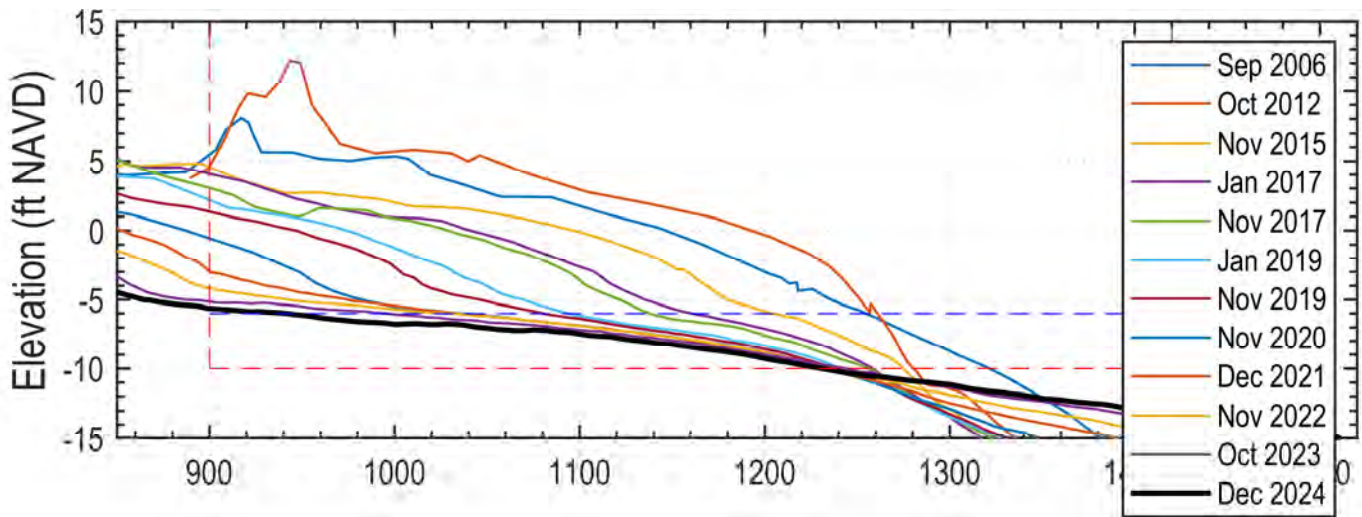
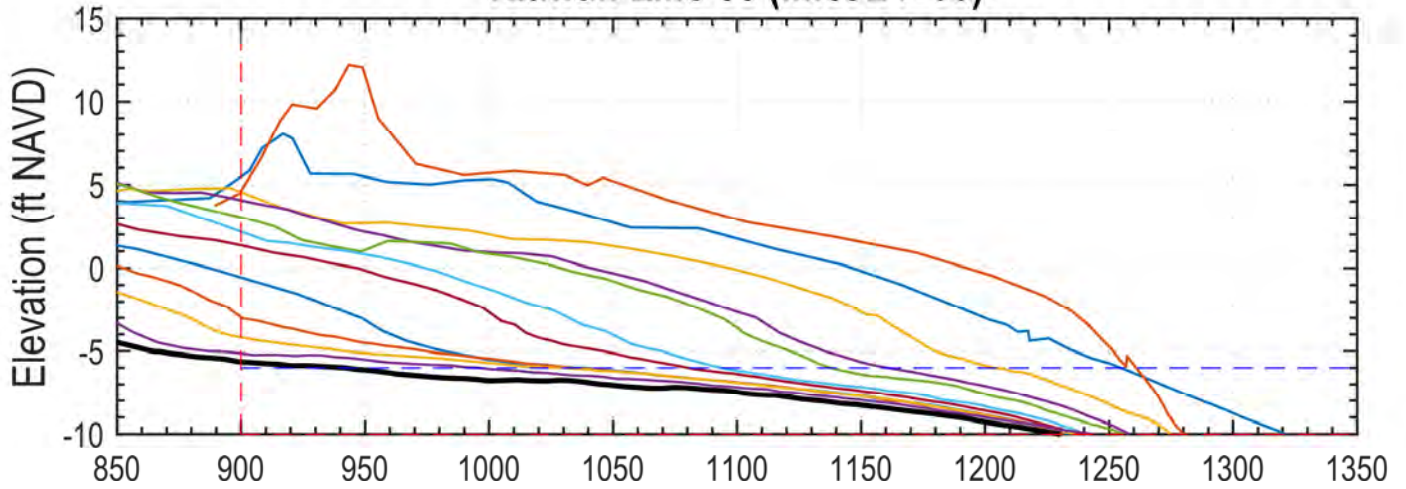
### Kiawah Line 57 (Inlet 12+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	143.0	79.1	222.1
Oct 2012	149.6	69.0	218.6
Nov 2015	136.6	68.8	205.4
Jan 2017	110.6	64.8	175.3
Nov 2017	67.1	62.2	129.3
Jan 2019	33.1	56.6	89.7
Nov 2019	21.3	55.2	76.6
Nov 2020	8.6	52.2	60.9
Dec 2021	6.7	51.9	58.6
Nov 2022	5.0	51.3	56.3
Oct 2023	2.7	48.7	51.4
Dec 2024	0.4	43.3	43.8



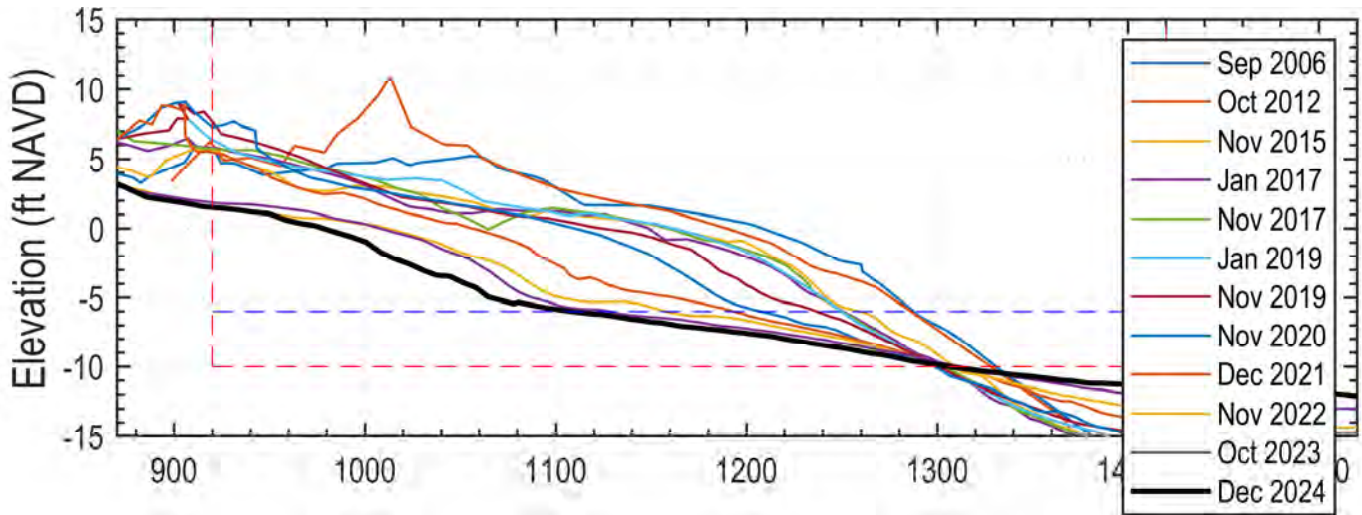
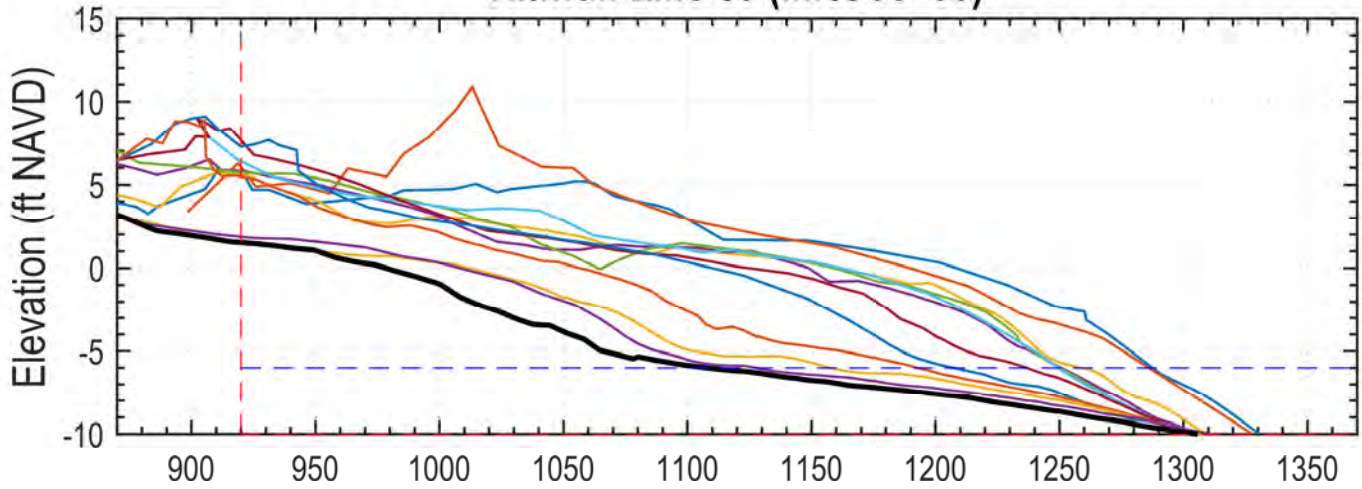
### Kiawah Line 58 (Inlet 24+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	101.4	57.4	158.9
Oct 2012	127.2	54.9	182.1
Nov 2015	71.4	51.2	122.6
Jan 2017	54.7	47.2	101.9
Nov 2017	48.6	45.4	94.0
Jan 2019	32.3	41.3	73.7
Nov 2019	24.9	40.0	64.9
Nov 2020	10.8	37.8	48.5
Dec 2021	6.3	37.6	43.9
Nov 2022	3.7	37.6	41.3
Oct 2023	1.7	35.6	37.3
Dec 2024	0.3	31.6	31.9



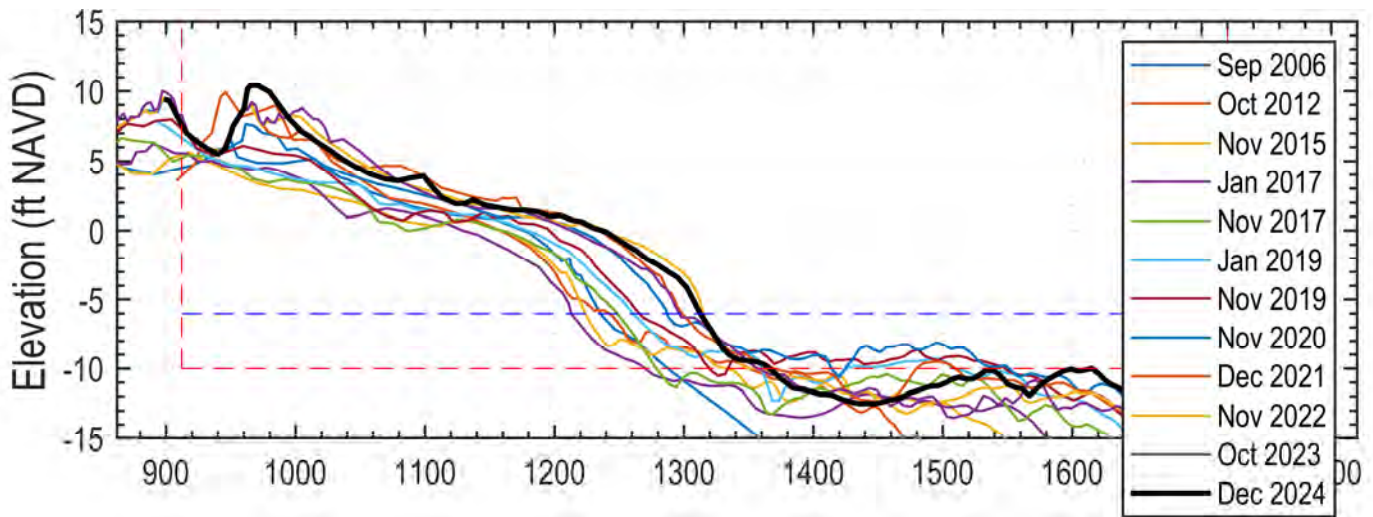
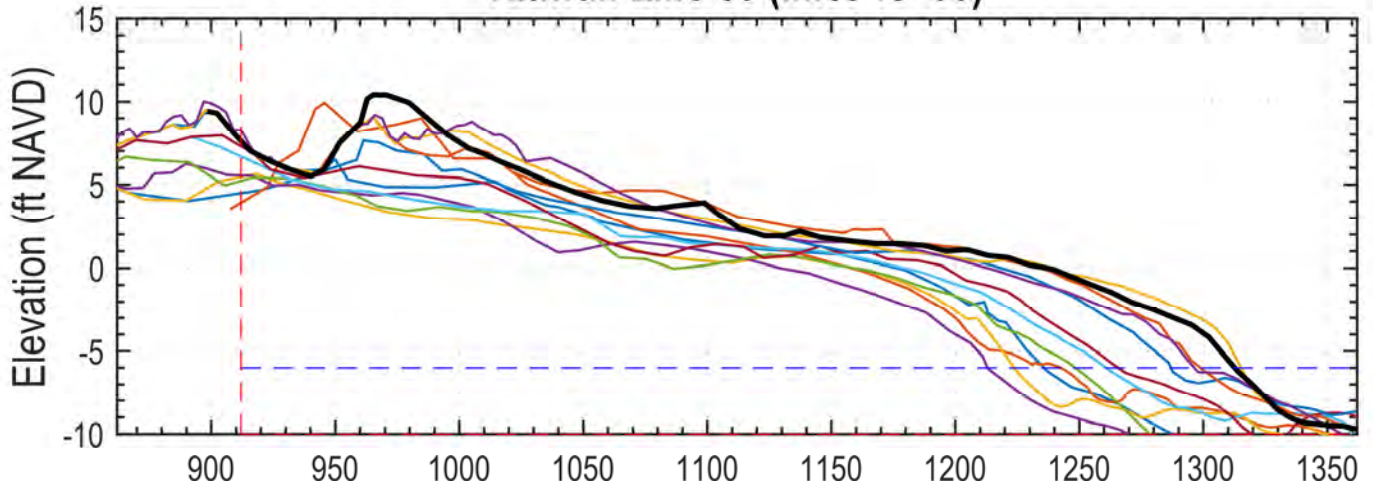
### Kiawah Line 59 (Inlet 36+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	109.8	57.8	167.6
Oct 2012	116.4	57.3	173.7
Nov 2015	86.5	54.1	140.6
Jan 2017	84.8	52.8	137.7
Nov 2017	88.1	52.5	140.6
Jan 2019	90.5	52.4	142.9
Nov 2019	81.4	52.0	133.3
Nov 2020	74.4	49.9	124.3
Dec 2021	55.6	49.3	104.9
Nov 2022	37.3	48.1	85.4
Oct 2023	35.4	46.0	81.4
Dec 2024	27.3	43.6	70.9



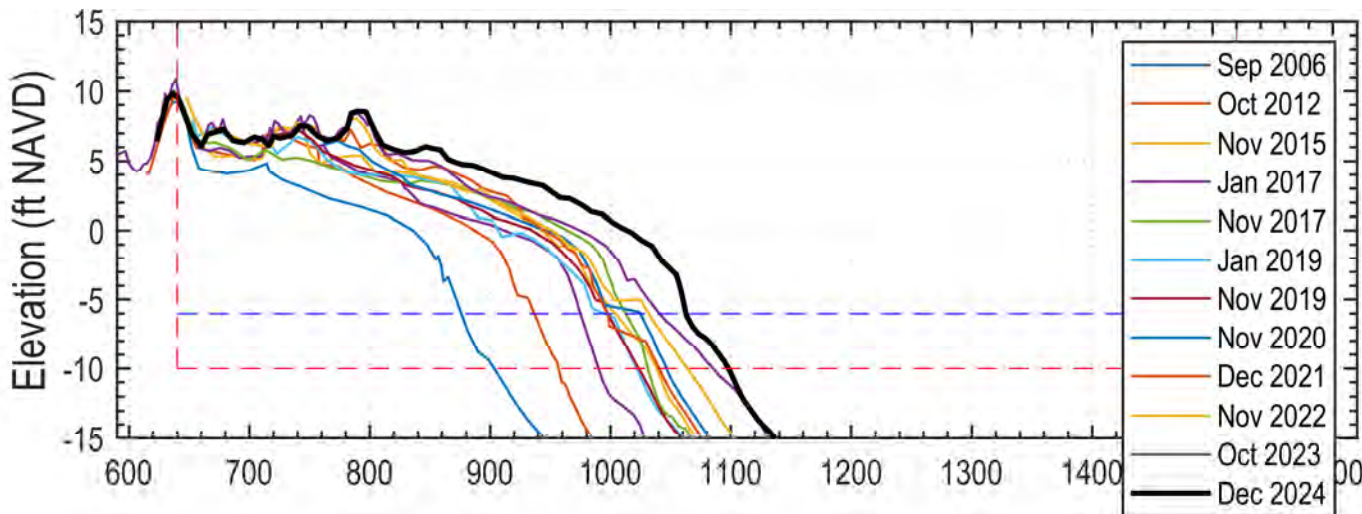
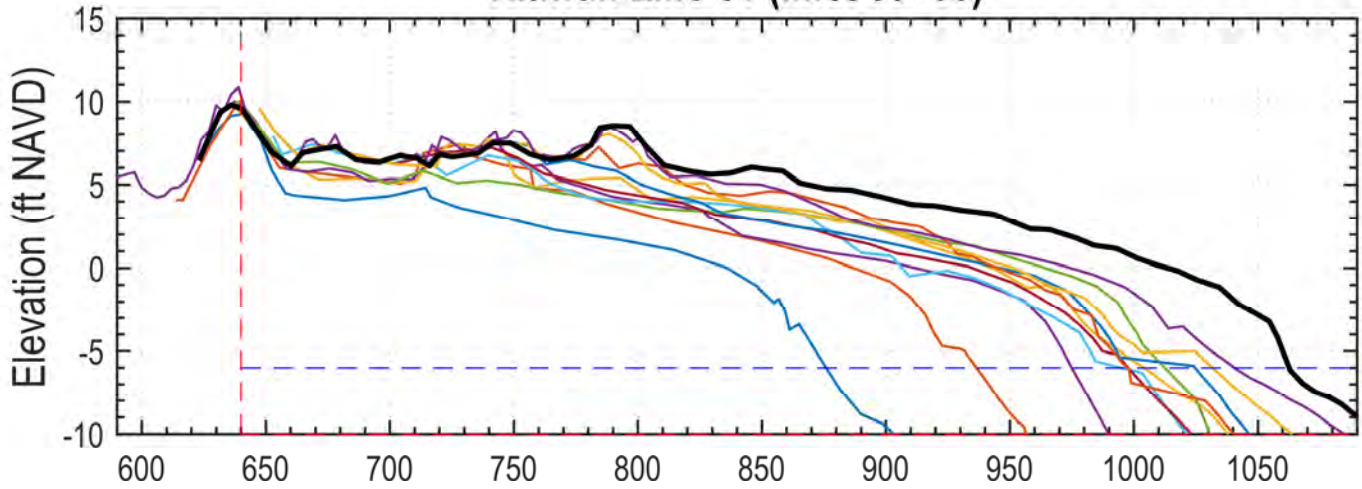
### Kiawah Line 60 (Inlet 48+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	98.2	51.7	150.0
Oct 2012	105.5	55.3	160.8
Nov 2015	85.1	52.2	137.2
Jan 2017	82.9	47.9	130.8
Nov 2017	89.0	52.2	141.2
Jan 2019	98.4	58.5	156.9
Nov 2019	103.6	62.9	166.5
Nov 2020	118.4	69.2	187.6
Dec 2021	131.4	61.9	193.3
Nov 2022	134.0	61.6	195.6
Oct 2023	129.5	61.9	191.3
Dec 2024	133.9	61.9	195.8



### Kiawah Line 61 (Inlet 60+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	72.3	36.6	108.9
Oct 2012	100.8	45.4	146.2
Nov 2015	125.6	56.7	182.3
Jan 2017	114.4	50.7	165.1
Nov 2017	126.7	56.8	183.5
Jan 2019	119.5	55.0	174.5
Nov 2019	123.7	54.9	178.6
Nov 2020	129.3	58.6	188.0
Dec 2021	135.7	56.4	192.1
Nov 2022	136.9	60.4	197.3
Oct 2023	146.0	62.7	208.8
Dec 2024	163.1	65.2	228.3

