

2006 EAST END BEACH RESTORATION PROJECT
KIAWAH ISLAND SOUTH CAROLINA

Survey Report No 9
February 2016



Prepared for:
Town of Kiawah Island
South Carolina



2006 EAST END BEACH RESTORATION PROJECT
Kiawah Island – South Carolina

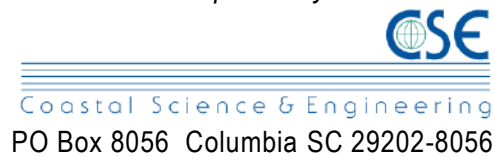
SURVEY REPORT NO 9
Annual Beach and Inshore Surveys

Prepared for:



21 Beachwalker Drive Kiawah Island SC 29455

Prepared by:



[CSE 2446 YR1]
February 2016

COVER PHOTO: Aerial (February 2016)

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

Synopsis

This report is the ninth in a series of annual monitoring reports initiated following the 2006 east end beach restoration project. It presents results of detailed surveys encompassing the oceanfront of Kiawah Island with particular focus on the area around the Ocean Course and Stono Inlet, where shoals from the Stono Inlet add sand to the beach but create episodic erosional issues as sand and channels migrate (Fig A).

The Town of Kiawah Island sponsored the 2006 east end project at a cost of \$3,575,000 for purposes of mitigating encroachment of a flushing channel on the Ocean Course and restoring the sand flow to downcoast beaches. The project moved about 550,000 cubic yards (cy) of sand and restored a wide, dry-sand beach in front of the Ocean Course. By 2014, the flushing channel was again beginning to migrate toward the Ocean Course, and another channel relocation event was completed in the late spring of 2015 (Fig A). This project was smaller in scale, moving a total of 100,000 cy with the new channel relocated ~3,000 feet (ft) east of the pre-project location. Each of these projects occurred in designated critical habitat for piping plovers and incorporated methods to reduce impacts and prolong habitat formation suitable for these birds.

Monitoring shows that Kiawah Island lost ~901,000 cy (15.7 cubic yards per foot–cy/ft) of sand between October 2014 and November 2015 (Table A). Gains along the central portion of the island were offset by losses along Captain Sams spit and the lagoon area at the eastern end. Losses along the spit were largely a result of the Captain Sams Inlet relocation project, which was completed by the Seabrook Island Property Owners Association. The 2015 Captain Sams Inlet relocation project was completed concurrently with the Kiawah east end project and shifted the channel of Captain Sams Inlet ~2,800 ft to the east (Fig B). This was the third time that Captain Sams Inlet has been relocated (1983, 1996, 2015). Since monitoring of the entire island began in 2007, the island has gained ~1.6 million cubic yards of sand, all via natural additions of sand originating in Stono Inlet (excluding losses associated with the 2015 Captain Sams Inlet project).

Kiawah Island remains one of the healthiest beaches in South Carolina. The results of shoreline monitoring and the tracking of sand supply have provided new insight into the formation of barrier islands and rates of evolution of important habitats. Based on the results herein, the prognosis for the future is favorable for Kiawah's beach.



FIGURE A. View west from the lagoon on the eastern end of Kiawah Island in January 2016.



FIGURE B. July 2015 view of the west end of Kiawah Island following the third relocation of Captain Sams Inlet, which was completed in June 2015 by the Seabrook Island Property Owners Association.

TABLE A. Beach volumes and unit volumes for each reach and the entire island between 1999 and 2015. Volumes are to -10 ft NAVD.

			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
1	Kiawah Spit	8,820	2,328,514		3,097,296	3,094,685	3,181,691	3,276,726	3,221,628	3,263,752	3,261,529	3,229,981	2,486,384
2	West Beach	11,798	2,903,774		2,994,556	2,949,260	2,978,605	2,991,545	3,000,541	3,108,310	3,170,302	3,213,238	3,205,892
3	Turtle Point	13,614	3,097,370		3,736,350	3,679,389	3,734,117	3,724,681	3,726,666	3,921,035	4,049,840	4,189,161	4,269,193
4	Ocean Course	9,000		2,832,947	2,964,385	2,903,690	3,005,533	3,026,626	3,135,711	3,278,923	3,380,461	3,503,344	3,625,872
5	Lagoon	8,000		6,559,380	6,499,468	6,763,197	7,090,470	7,385,476	7,175,787	7,156,897	7,056,459	7,089,847	6,819,651
6	Stono Inlet	6,000		1,219,056	1,213,419	1,198,757	1,155,841	1,173,275	1,176,151	1,195,114	1,156,125	1,081,375	998,921
1-6	All	57,232			20,505,475	20,588,979	21,146,257	21,578,329	21,436,484	21,924,031	22,074,717	22,306,946	21,405,913
			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
1	Kiawah Spit	8,820	264.0		351.2	350.9	360.7	371.5	365.3	370.0	369.8	366.2	281.9
2	West Beach	11,798	246.1		253.8	250.0	252.5	253.6	254.3	263.5	268.7	272.4	271.7
3	Turtle Point	13,614	227.5		274.4	270.3	274.3	273.6	273.7	288.0	297.5	307.7	313.6
4	Ocean Course	9,000		314.8	329.4	322.6	333.9	336.3	348.4	364.3	375.6	389.3	402.9
5	Lagoon	8,000		819.9	812.4	845.4	886.3	923.2	897.0	894.6	882.1	886.2	852.5
6	Stono Inlet	6,000		203.2	202.2	199.8	192.6	195.5	196.0	199.2	192.7	180.2	166.5
1-6	All	57,232			358.3	359.7	369.5	377.0	374.6	383.1	385.7	389.8	374.0
			Reach Volume Change Since Previous (cy)										
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15
1	Kiawah Spit	8,820				-2,611	87,006	95,035	-55,098	42,124	-2,223	-31,548	-743,597
2	West Beach	11,798				-45,296	29,345	12,940	8,996	107,769	61,992	42,936	-7,346
3	Turtle Point	13,614				-56,961	54,728	-9,437	1,986	194,369	128,805	139,320	80,032
4	Ocean Course	9,000			131,439	-60,695	101,843	21,093	109,085	143,212	101,538	122,883	122,528
5	Lagoon	8,000			-59,912	263,729	327,273	295,006	-209,689	-18,890	-100,438	33,388	-270,196
6	Stono Inlet	6,000			-5,637	-14,662	-42,916	17,434	2,875	18,963	-38,989	-74,750	-82,454
1-6	All	57,232				83,504	557,279	432,072	-141,844	487,547	150,685	232,229	-901,033
			Reach Unit Volume Change Since Previous (cy/ft)										
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15
1	Kiawah Spit	8,820				-0.3	9.9	10.8	-6.2	4.8	-0.3	-3.6	-84.3
2	West Beach	11,798				-3.8	2.5	1.1	0.8	9.1	5.3	3.6	-0.6
3	Turtle Point	13,614				-4.2	4.0	-0.7	0.1	14.3	9.5	10.2	5.9
4	Ocean Course	9,000			14.6	-6.7	11.3	2.3	12.1	15.9	11.3	13.7	13.6
5	Lagoon	8,000			-7.5	33.0	40.9	36.9	-26.2	-2.4	-12.6	4.2	-33.8
6	Stono Inlet	6,000			-0.9	-2.4	-7.2	2.9	0.5	3.2	-6.5	-12.5	-13.7
1-6	All	57,232				1.5	9.7	7.5	-2.5	8.5	2.6	4.1	-15.7

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

TABLE OF CONTENTS

SYNOPSIS	i
TABLE OF CONTENTS.....	v
1.0 Introduction	1
2.0 Setting and History	3
2.1 Geologic History of Kiawah Island	4
2.2 Previous Shoreline Studies	4
2.2.1 Stono Inlet	7
2.3 2006 East End Beach Restoration Project	11
2.4 2015 East End Channel Realignment Project	12
3.0 Methodology	15
3.1 Survey	15
3.2 Volume Calculations	17
4.0 Results	23
4.1 2015 Inlet Realignment Projects.....	23
4.1.1 Kiawah Island East End Channel Realignment Project	23
4.1.2 2015 Captain Sams Inlet Relocation	32
4.2 Beach Volume Changes 2014–2015	34
4.2.1 Reach 6 – Stono Inlet	34
4.2.2 Lagoon Reach.....	40
4.2.3 Reach 4 – Ocean Course	46
4.3 Downcoast Reaches	50
4.3.1 Turtle Point Reach.....	52
4.3.2 West Beach Reach	56
4.3.3 Kiawah Spit Reach.....	58
5.0 Summary of Findings	63
6.0 References and Bibliography	65
7.0 Acknowledgments	67

Appendix A) 2015 Profiles

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

1.0 Introduction

This report is prepared as part of a series of annual beach monitoring reports initiated following the 2006 east end restoration project (CSE 2005, 2007). The Town of Kiawah Island (SC) is sponsoring annual surveys of the sandy shoreline for purposes of determining the rates of sand movement, accretion, and erosion within the project area and along the remainder of the beach. This ninth 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 2015.

The purpose of this report is to describe the current health of Kiawah Island as compared to past conditions. This involves documenting sand volume changes along the entire island (Captain Sams Inlet to Penny's Creek) to identify areas where the beach and dunes may be eroding or accreting. Annual monitoring provides a quantitative account of sand volume changes, which can then be used to infer sediment transport rates along the shoreline and predict future areas of concern before critical situations arise. It also identifies areas of concern and provides recommendations for any remedial action which may be warranted.

The scope of work for the annual monitoring effort includes:

- 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 presents a brief description of Kiawah Island and its historical shoreline changes. A summary of the methods used during surveying and data analyses follows in Section 3. Section 4 includes the results of the survey. Section 5 presents a discussion of CSE's present findings and recommendations.

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

2.0 Setting and History

Kiawah Island is one of the healthiest barrier islands in South Carolina. The addition of sand generated from Stono Inlet has led to stable dunes spanning the beachfront with only minor localized erosion in specific hotspots as sand migrates downcoast from Stono Inlet. The addition of sand through the process of inlet bypassing and the foresight of the island's developers to properly study the processes controlling the morphology of the island (Hayes et al 1975, Hayes 1977) make Kiawah Island an excellent example of beachfront development and a premier community along the South Carolina coast (Fig 2.1).



FIGURE 2.1. Kiawah Island in March 2015. Sand from Stono Inlet attaches to the island at the east end, then migrates west, nourishing the beach.

2.1 Geologic History of Kiawah Island

Kiawah Island has been studied in detail since 1974, when Professor Miles O. Hayes and colleagues at the University of South Carolina initiated field measurements and review of the geologic history of the island. Using Kiawah Island as a model, Hayes coined the term “drumstick” barrier island, which today commonly describes barrier islands of the South Carolina coast and other “mixed-energy settings” (Fig 2.2) (Hayes 1977, 1994; Hayes & Michel 2008). The oldest part of the island, adjacent to the Kiawah River, was found to be about 4,000 years old. The island’s eastern end has prograded several thousand feet seaward since the mid 1800s, leading to the creation of parallel dune ridges, each representing the shoreline at the time it was created.

The island is roughly 10 miles long, bounded by Stono Inlet to the east and Captain Sams Inlet to the west (Fig 2.3). The eastern end episodically gains sand by way of shoal-bypassing events (Williams & Kana 1986, Gaudio 1998), and the sand eventually spreads to downcoast parts of the island until reaching Captain Sams Inlet, where it accumulates and forms Kiawah spit. These shoal-bypassing cycles are responsible for the continued growth of Kiawah Island, but can also cause temporary erosion, which will be discussed later. The geologic history of Kiawah and the processes controlling sand movement along the island are discussed in more detail in CSE (1999).

2.2 Previous Shoreline Studies

The first shoreline assessment of Kiawah Island was performed by Hayes and his students in the early 1970s (Hayes et al 1975). Based on the geomorphology of the island, Hayes identified five zones along the beach and recommended two middle zones (West Beach and Turtle Point) as being suitable for development landward of the second dune ridge (Fig 2.4). The early development of 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 Research Planning Institute Inc (RPI) and CSE (cf – Sexton et al 1981, Williams & Kana 1987). In July 1988, the Beach Management Act (BMA) of South Carolina was enacted, and by 1989, management of the State’s beach monitoring programs was taken over by the State, ending CSE’s involvement. In 1994, CSE was again contracted by the Town of Kiawah Island and conducted monitoring through 1999.

From 1981 through 1999, Kiawah Island either gained sand or remained stable. Specific areas showed sporadic erosion; however, the magnitude of sand loss was generally small. 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 reaches showed gains in sand volume between 1983 and 1999. Details of volume changes from 1983 to 1999 are given in CSE (1999).



FIGURE 2.2. Barrier island drumstick model (after Hayes 1977) using Isle of Palms as an example. The upcoast end is wider due to additions of sand from shoal-bypass events in the inlet. Net transport to the south builds a spit at the downcoast end of the island.

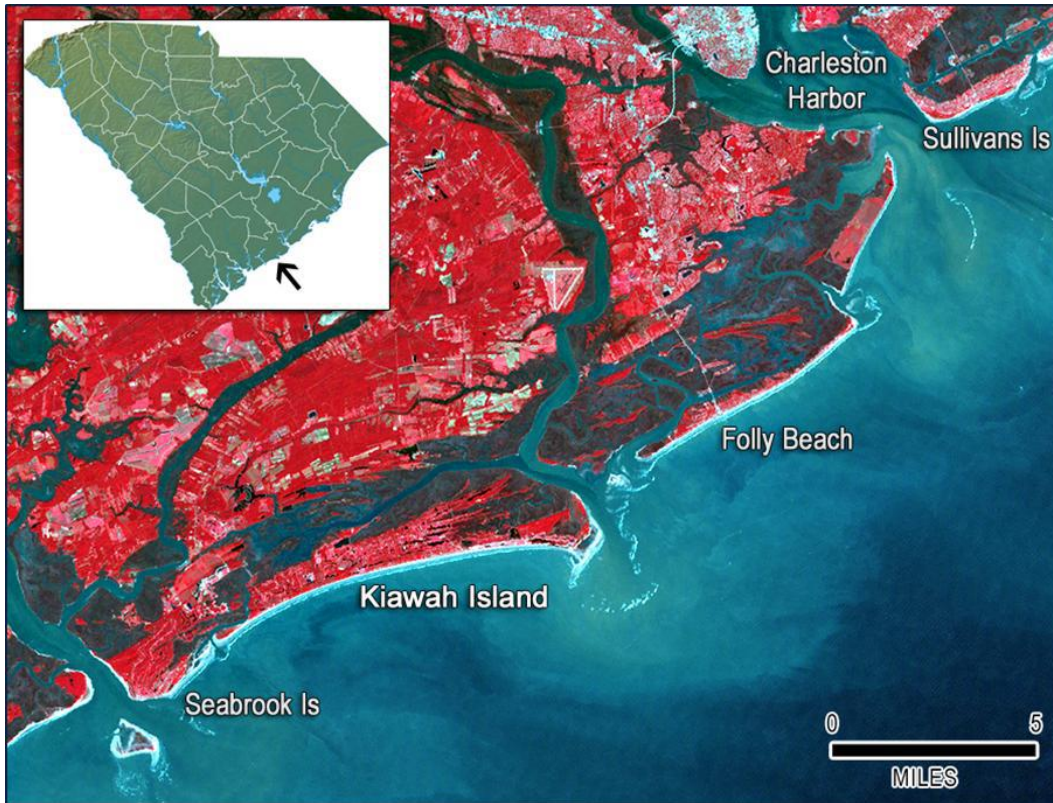


FIGURE 2.3. South Carolina coastline from Seabrook Island to Charleston Harbor. [Image courtesy Research Planning Inc and SCDNR].

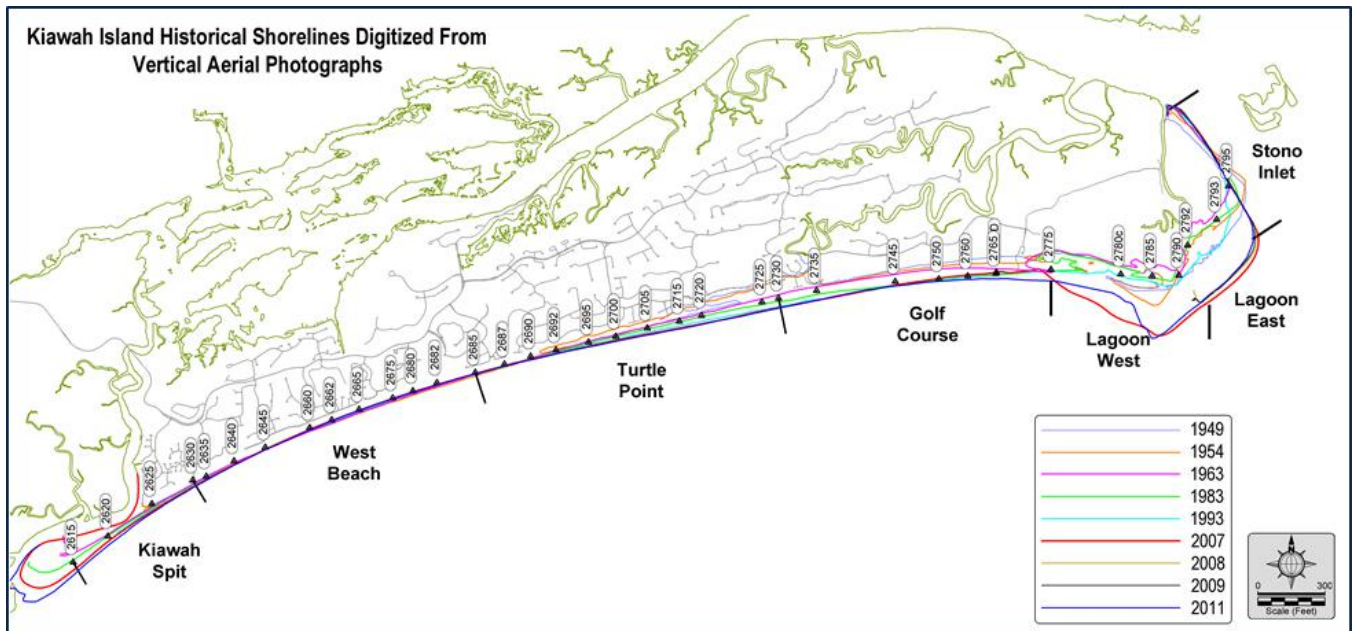


FIGURE 2.4. Historical shorelines (seaward vegetation lines). West Beach has been slightly erosional whereas all other reaches have been accretional since 1949. [Updated from CSE 1995]

2.2.1 Stono Inlet

Sand from Stono Inlet is the major littoral source 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 southern two-thirds of the South Carolina coast (Sexton & Hayes 1996). In this mixed-energy environment (Hayes 1994), waves and tidal currents both have a significant impact on shaping the morphology of the inshore zone (Fig 2.5). Sand is moved seaward by strong ebb-tidal currents at the inlets. Waves then push deposited sand landward in the form of shoals. This produces characteristic features common to much of the central and southern South Carolina coast—such as lobate deltas extending miles offshore, marginal flood channels (small channels near the beach flanking the main channel and dominated by flood currents), and migrating shoals (cf – Fig 2.2 and Fig 2.3).

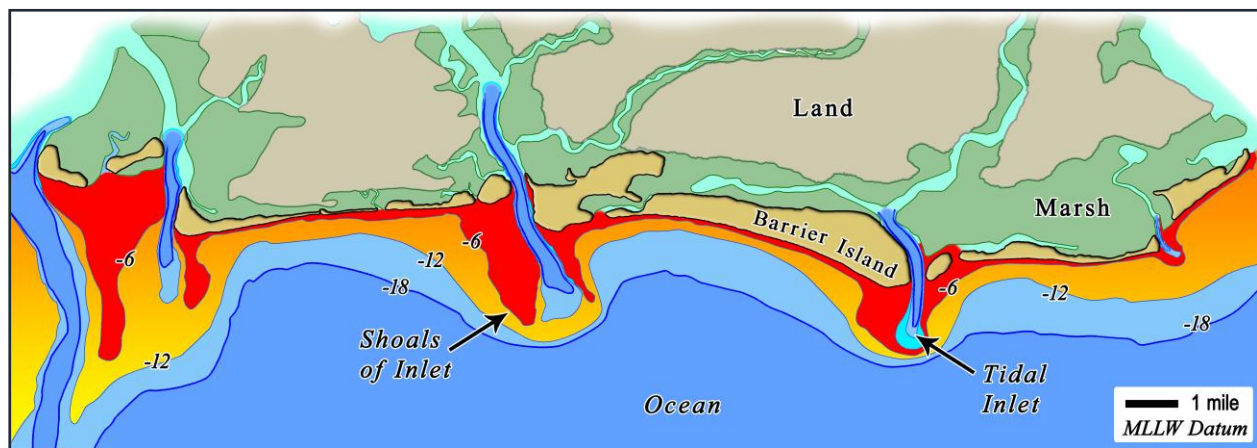


FIGURE 2.5. Nearshore bathymetry for a typical section of the central and southern South Carolina coast. Ebb-tidal deltas contain large amounts of sand, which alter the local bathymetry. This in turn directs wave energy and sediment transport patterns along the adjacent beaches. [From *Coastal Erosion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

Periodically, sand stored in the ebb-tidal delta of Stono Inlet is released when the inlet 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 because of decreased wave energy (Fig 2.6). Adjacent to the areas of accretion, erosional arcs are formed by changes in the wave patterns due to refraction around the offshore shoal. This process continues until waves have pushed the shoal to the point of attachment along the beach.

Once attached, the shoal is considered to be in Stage 3 of the shoal-bypass cycle (Kana et al 1985, Williams & Kana 1986). Waves continue to push the shoal landward and upward while spreading sand laterally along the beach. Shoal spreading (Stage 3) provides natural nourishment with sand moving downcoast via longshore currents.

THE THREE STAGES OF SHOAL BYPASSING

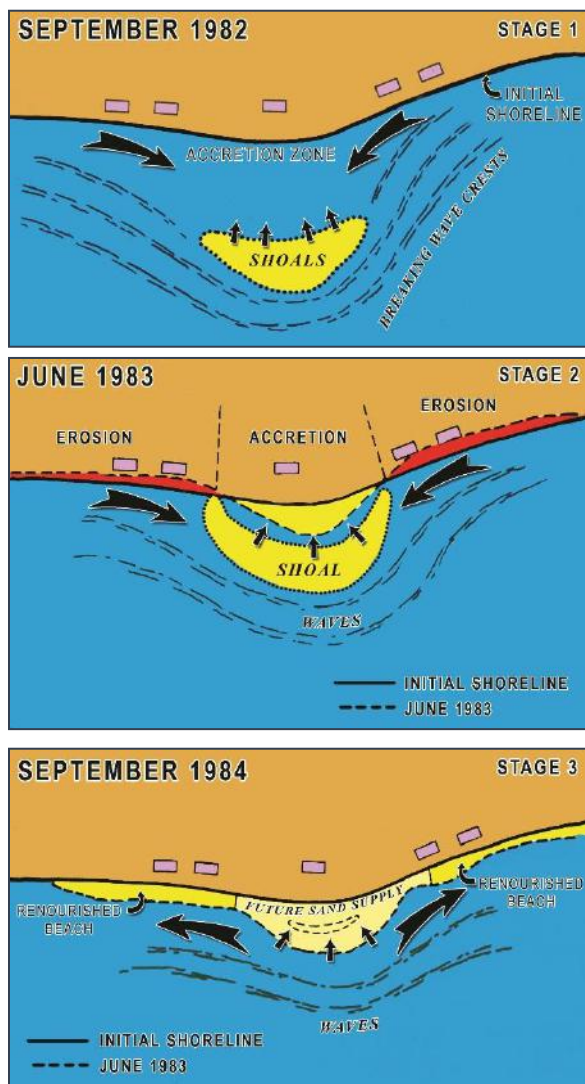


FIGURE 2.6.

[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 east 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]



The time between release of the shoal by the inlet, and attachment and spreading depends on the size of the inlet and its ebb tidal delta. Large inlets, such as Stono Inlet, tend to initiate shoal-bypassing events every 7–8 years with individual shoal volumes often exceeding 0.5 million cubic yards (Gaudio & Kana 2001).

Kiawah Island has recently experienced two impressively large shoal-bypassing events. The first formed offshore in 1994 and had completely attached to the eastern end of Kiawah by 1997. The second began attaching to Kiawah along its eastern flank in 1998. The western flank of the second shoal overlapped the eastern Kiawah shoreline as it built and migrated west and north between 1998 and 2004 (Fig 2.7). These two events were the largest ever documented on the South Carolina coast (CSE 2005). They contained such a large quantity of sand that wave action was not able to completely push the shoal against the original shoreline, and a new beach line and dune system were formed more than 2,000 feet (ft) seaward of the original shoreline. This created a lagoon between the new and old shorelines, along with a roughly 2-mile-long barrier beach (Fig 2.7). The recent shoal-bypass events showed how rapidly barrier islands can form, even in the presence of sea-level rise and other erosional forcing (Kana 2002).

By 2004, the shoals had completely attached at the eastern end but remained offshore at the western end as sand migrated westward, reaching near the (old) Ocean Course Clubhouse (Fig 2.7). The shoals had not completely attached at the western end due to a natural channel maintained by tidal flushing of the lagoon. CSE (2005) estimated the two shoals added ~5 million cubic yards to Kiawah Island. Due to the overwhelming quantity of sand added at the eastern end, the shoreline near the Ocean Course jumped seaward and changed orientation. This protrusion altered the direction of approaching waves and caused focused erosion along the Ocean Course.

As longshore transport moved the shoal westward, the flushing channel migrated with the shoal, encroaching on the Ocean Course, specifically the 16th and 18th holes. The beach at the original Ocean Course Clubhouse (near OCRM monument 2775) retreated over 500 ft between 2000 and 2005. The magnitude of the bypassing event was so great, it was apparent that severe erosion would continue for several years before the cycle would be complete (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 by CSE (2005).



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 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. This project sought to artificially create Stage 3 of the shoal-bypassing cycle and avoid further erosion of the Ocean Course. The details of the project are given 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 so as 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.
- Provide protection to 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.

The project consisted of closure of the existing flushing channel, creation of a new channel to maintain the tidal environment of the lagoon, and excavation and transfer of nourishment sand from the new inlet and accreted shoal areas to eroded downcoast areas. These actions were designed to provide a smoother transition between Kiawah’s main beach and the accreted shoal. The contracted volume for the project was 550,000 cubic yards (cy), the majority of which was placed between the new clubhouse and just west of the old flushing channel. The new flushing channel was positioned at the apex of the attached shoal (Fig 2.8).



FIGURE 2.8. Before (February 2006) and after (July 2006) aerial photos of the 2006 east end beach restoration project.

2.4 2015 East End Channel Realignment Project

The 2006 beach restoration project proved effective in restoring a 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 began planning 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 expedited and quickly eroded much of the dune area fronting 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 time frame, which was granted by regulatory agencies.

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 2.9). Excess sand was placed along the seaward edge of the driving range to facilitate 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 through lower volumes and limited manipulation of the beach area (Fig 2.10).

FIGURE 2.9. Closure of the pre-project channel on 22 May 2015.



FIGURE 2.10. Aerial image of the completed 2015 channel relocation project in July 2015. The new inlet was opened ~3,000 ft east of the old channel.

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

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™ R8 GNSS system) in early November 2015. Profiles along Kiawah Island were surveyed perpendicular to the local shoreline (CSE baseline) azimuth from the control points to a minimum of -12 ft NAVD (the depth equal to the normal limit of sand movement in this setting) or at least 3,000 ft from the dune. Surveys were conducted by combining a land-based survey and a bathymetric survey (Fig 3.1). Land surveys were accomplished using an RTK-GPS between the foredune and low-tide wading depth [(~)-6 ft NAVD], whereas overwater work was accomplished via RTK-GPS combined with a precision echo-sounder mounted on CSE's shallow-draft boat, the RV Southern Echo.

*[*Real-time kinematic global positioning system]*

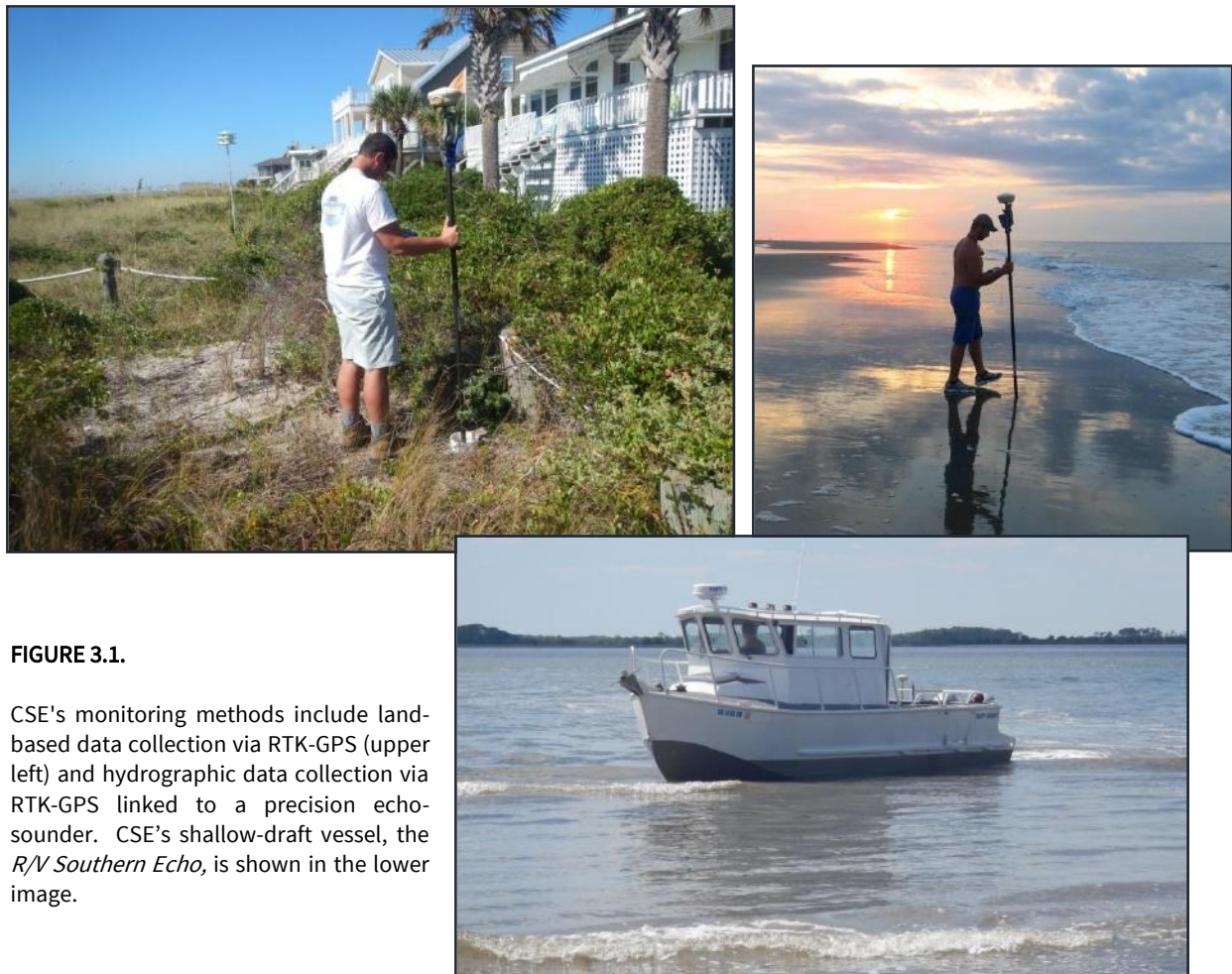


FIGURE 3.1.

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 *RV Southern Echo*, is shown in the lower image.

Working around the tidal cycle, data collected on land were extended into shallow depths in the surf zone at low tide. Then data were collected from the boat at high tide such that overlap of the two surveys occurred 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.

The 2015 survey represents the fourth survey of the Kiawah Island beach since satisfactory completion of project-required monitoring in 2011. At the request of the Town, CSE modified the scope of services for the 2012 and future monitoring to reduce overall costs while providing more detail of the beach condition west of the project area. Surveys conducted from 2007 to 2011 involved 23 stations west of the 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 total number of lines in the project area from 64 to 24 by increasing the spacing from 400 ft to 1,000–1,200 ft. The baseline was also modified at the east end to reduce the number of turns in the baseline and to simplify volume calculations.

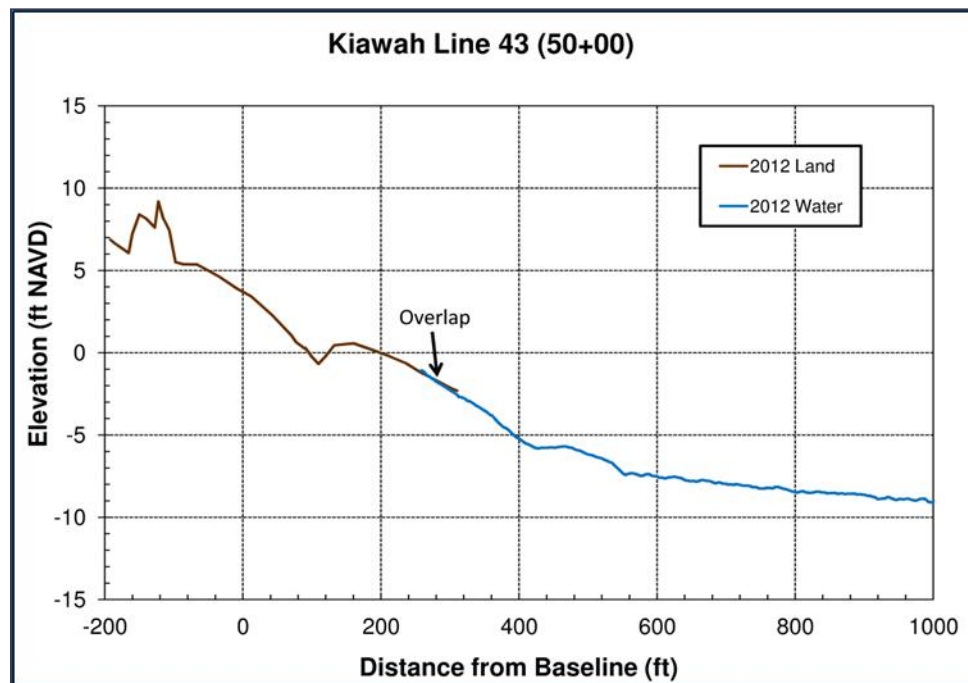


FIGURE 3.2. CSE combines land-based and hydrographic data collection to produce continuous profiles of the beach. Land-based work is accomplished at low tide, while hydrographic work is performed at high tide. This allows for overlap of the two data collection methods and ensures quality data and a complete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

The present baseline is comprised of 61 profiles with Lines 1–37 representing the shoreline west of the 2006 project area and Lines 38–61 representing the project area and east end of the island (TABLE 3.1). The baseline is shown in Figure 3.3. 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 (Fig 3.3) 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. Profiles are still used for inferring changes to the beach shape, the position of shoals and channels, and elevations of berms.

3.2 Volume Calculations

To estimate changes in the sand volume along Kiawah Island, survey data were entered into CSE’s in-house custom software, Beach Profile Analysis System (BPAS), which calculates volumes based on 2-D profile data (in x–y format) and distances between subsequent lines. The resulting volumes provide a more quantitative and objective way 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 the desired condition (Kana 1993). Volume results calculated via this method integrate all the small-scale perturbations across the beach and yield a simple measure of its condition which is less susceptible to seasonal fluctuations in the profile, a problem with shoreline change studies that are based on movement of a single contour.

Unit-volume calculations allow for distinguishing the quantity of sediment in the dunes, on the dry beach, in the intertidal zone to wading depth, and in the remaining area offshore to the approximate limit of profile change. Figure 3.4 depicts the profile volume concept. The reference boundaries are site-specific but ideally encompass the entire zone over which sand moves each year—dune to the depth of closure (DOC*), which is the depth of water where little sand movement to or from the beach occurs.

[DOC is the depth beyond which there is negligible change in bottom elevation.]*

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 from the benchmark/baseline for the start and end of beach volume calculations.

Line	Reach	Name	Offset	Cutoff	Distance to Next	Easting	Northing	Line	Reach	Name	Offset	Cutoff	Distance to Next	Easting	Northing
1	1		-200	2,500	1,000	2262721.7	271034.2	32	3	OCRM 2720	208	1,500	645	2289526.0	282752.7
2			300	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	436	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			319	1,700	752	2293263.8	283580.0
7			28	2,500	978	2267397.7	274763.4	38		0+00	320	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			92	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	4	30+00	-55	1,500	1,000	2296995.5	283911.6
11	2	OCRM 2635	41	1,500	1,232	2270247.2	276490.7	42		40+00	-120	1,500	1,000	2297993.6	283972.3
12		OCRM 2640	94	1,500	865	2271326.8	277083.3	43		50+00	-219	1,500	1,000	2298991.7	284033.0
13			67	1,400	865	2271935.3	277351.5	44		60+00	-295	1,500	1,000	2299989.8	284093.8
14		OCRM 2645	47	1,200	945	2272543.9	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	22	1,000	891	2276196.1	279099.0	49		110+00	0	2,500	1,000	2304980.4	284397.3
19			12	1,400	892	2276850.6	279320.6	50	5	120+00	350	3,200	1,000	2305978.6	284458.0
20	3	OCRM 2675	0	1,100	831	2277505.6	279542.3	51		130+00	780	3,500	1,000	2306976.7	284518.8
21		OCRM 2680	46	1,300	1,266	2278288.1	279822.4	52		140+00	615	3,500	1,000	2307974.8	284579.5
22			16	1,400	1,627	2279502.6	280179.9	53		150+00	0	2,800	1,000	2308972.9	284640.2
23		OCRM 2685	10	1,200	1,033	2280718.1	280537.6	54		160+00	0	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	93	1,300	1,145	2282876.3	281167.0	56		Inlet 0+00	540	1,300	1,200	2310628.3	285452.3
26		OCRM 2692	279	1,500	1,205	2283935.3	281602.5	57	6	Inlet 12+00	805	1,420	1,200	2309882.6	286463.7
27		OCRM 2695	119	1,400	1,080	2285131.1	281719.2	58		Inlet 24+00	920	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	2308651.3	288466.6
29		OCRM 2705	130	1,500	835	2287413.8	282268.9	60		Inlet 48+00	912	1,720	1,200	2307945.7	289498.1
30			143	1,500	843	2288034.7	282401.8	61		Inlet 60+00	640	1,520	1,200	2307300.1	290509.5
31		OCRM 2715	145	1,500	889	2288663.4	282536.4								

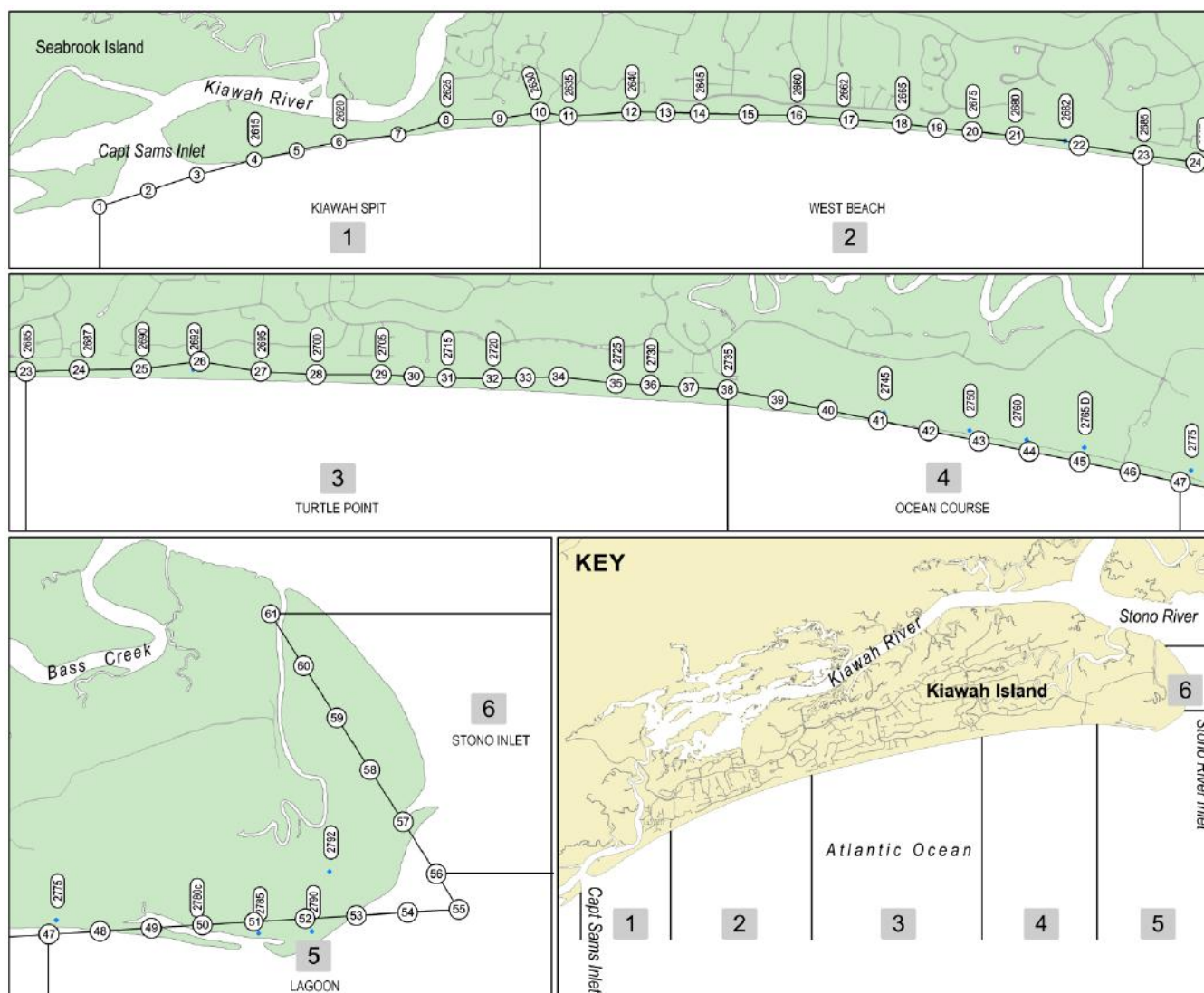


FIGURE 3.3. General location of beach stations and reaches monitored for the present report. Line numbers are shown in circles.

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	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	Ocean Course Area	38–47	9,000
Lagoon	Lagoon Area	47–55	8,000
Stono Inlet	Stono Inlet Shoreline	56–61	6,000

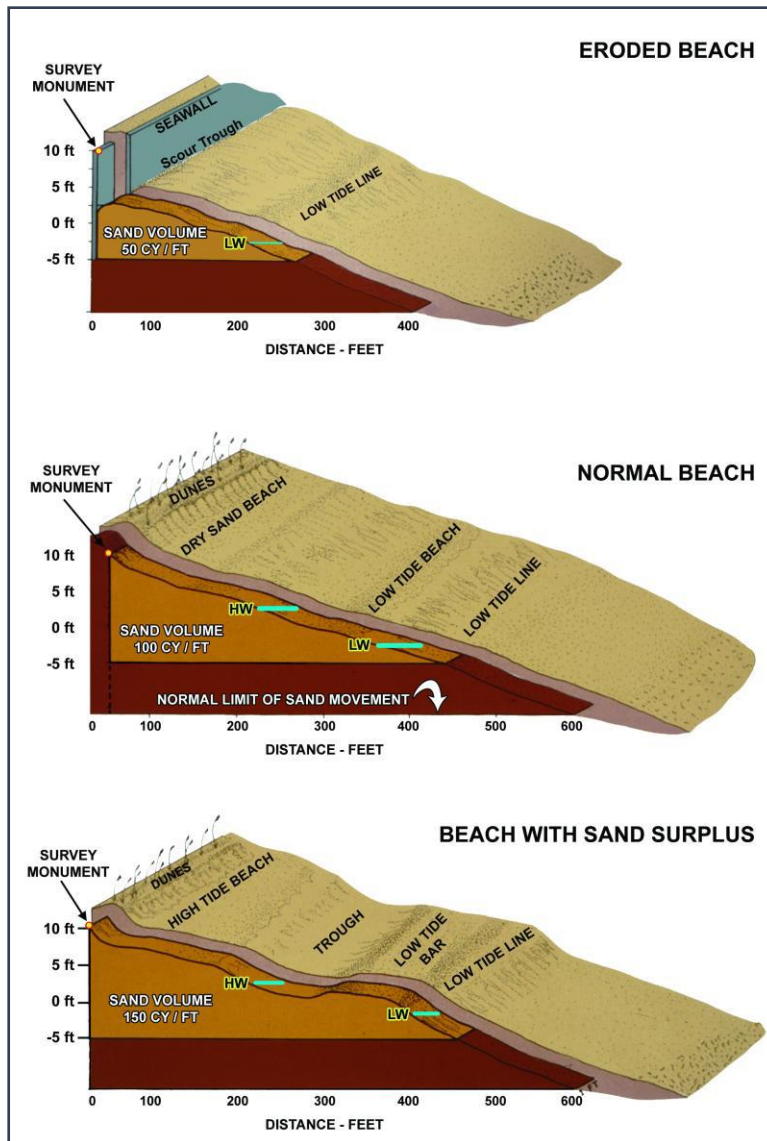


FIGURE 3.4. The concept of profile volumes - the volume of sand between defined contours over a 1-ft (unit) length of beach. [After Kana 1990]

For the present survey (2015), sand volume was calculated between the primary dune and -10 ft NAVD. The -6 ft NAVD contour has been used in past reports for consistency with earlier studies and limitations of pre-2007 data. While most sand movement 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 at the northeastern end, volume calculations were cut off at a set distance (profile specific) 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.

Figure 3.5 shows a representative profile from Kiawah Island over an approximate five-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 period encompassed by the data. This analysis confirms that nearly all measurable volume change along Kiawah's beach occurs above -10 ft NAVD and that a realistic value for DOC at decadal scales is <10 ft.

Comparative volumes and volume changes were computed using standard procedures. [CSE incorporates the average-end-area method in which the average of the area under the profiles computed at the ends of each cell is multiplied by the length of the cell to determine the cell's sand volume.] Volume results at each profile line were extrapolated to the next line. Net volumes were calculated for each profile as well as for project reaches (see Tables 3.1 and 3.2).

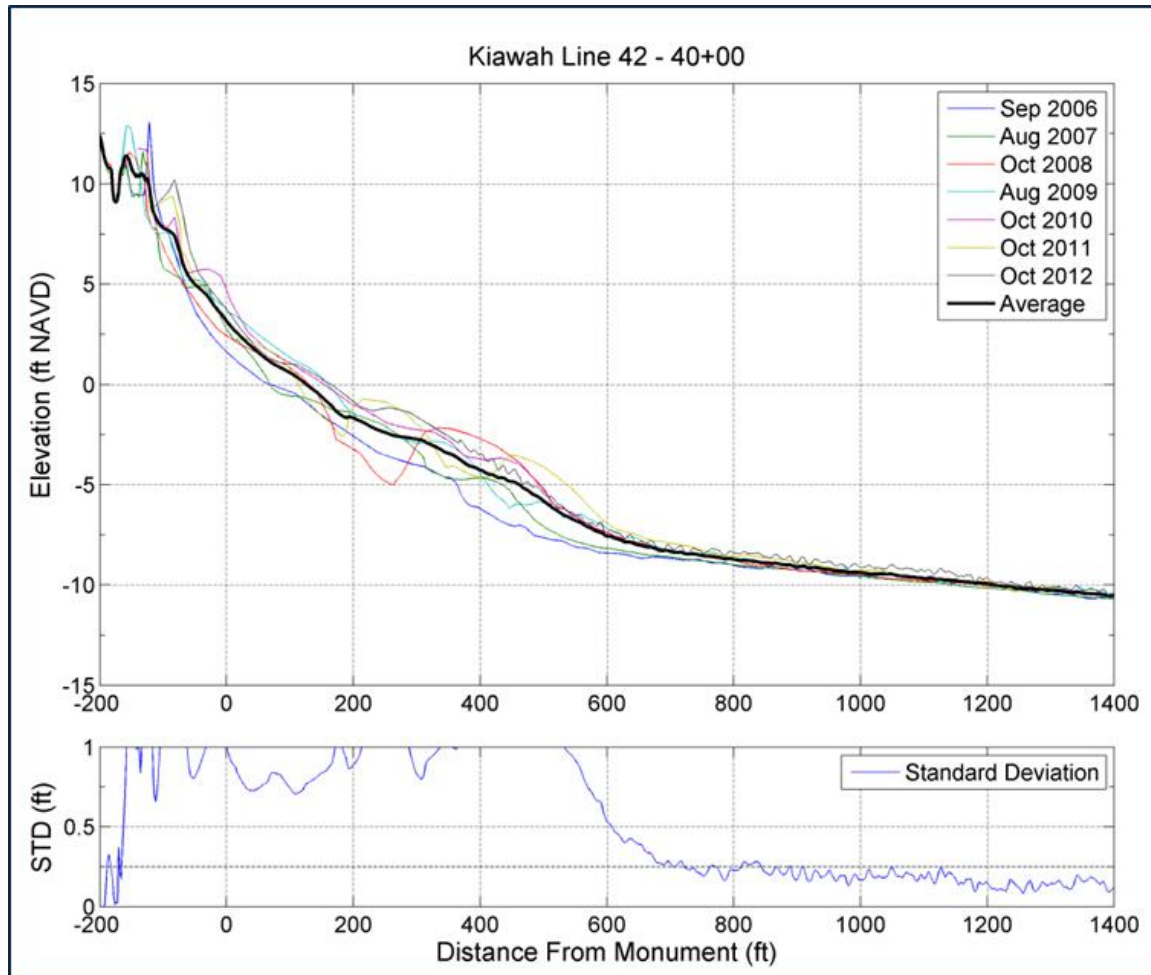


FIGURE 3.5. Comparison of repetitive profiles at a monitoring station along Kiawah Island and computation of standard deviation. Where the profiles converge, the standard deviation is low and is an indicator of little sediment exchange (approximate closure depth).

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

4.0 Results

Results of the 2015 monitoring survey are presented in the following sections. Attention is given to the areas affected by the 2015 inlet and channel relocation projects. Section 4.1 discusses each project and the impacts they had on the morphology and sediment transport pathways. Section 4.2 provides detailed sand volume changes for reaches along the east end Kiawah Island, comparing present volumes with selected conditions from previous years. Section 4.3 provides results of the downcoast reaches.

4.1 2015 Inlet Realignment Projects

4.1.1 *Kiawah Island East End Channel Realignment Project*

A general description of the 2015 Kiawah Island east end channel realignment project was provided in Section 2. This section focuses on the impacts of the project on the physical condition of the beach. As part of project planning and design, CSE completed a detailed survey of the east end between the Ocean Course Clubhouse and the location of the proposed new channel in April 2014. Another (less detailed) survey was completed in October 2014 as part of the regular annual monitoring effort. Detailed final design (pre-construction) and as-built (post-construction) surveys were performed in February and June 2015 (respectively).

By late 2014, the lagoon flushing channel had migrated into the dune area fronting the Ocean Course driving range (Fig 4.1). Sandbags were installed by the Ocean Course to prevent further migration of the channel into the upland area. At Line 46, near the eastern end of the driving range, the channel migrated ~200 ft landward between October 2013 and April 2014, and another 200 ft by February 2015 (Fig 4.2). This eliminated most of the fill placed in this area during the 2006 project. Sandbags proved effective in preventing further landward migration of the channel into the driving range, however, the seaward terminus of the channel continued to erode the dune area in front of the clubhouse. In early 2015, most of the erosion pressure was near the clubhouse and driving range tee box. Further east, the channel slowly eroded the seaward end of the 2006 closure dike, but at a much slower pace than the area further west (Fig 4.3). A significant width of the 2006 dike continued to remain, providing a "target" for the 2015 constructed dike to merge with.

The 2015 channel realignment project involved a transfer of a total of 100,000 cy via excavation of a new inlet and harvesting sand from the intertidal flats seaward of the driving range (Fig 4.4). The original intent of the project plan was to move as little material as possible (on the order of 40,000-60,000 cy); however, the rapid erosion occurring during the permitting process required more restoration of the dry sand beach than expected and the full permitted quantity was needed.

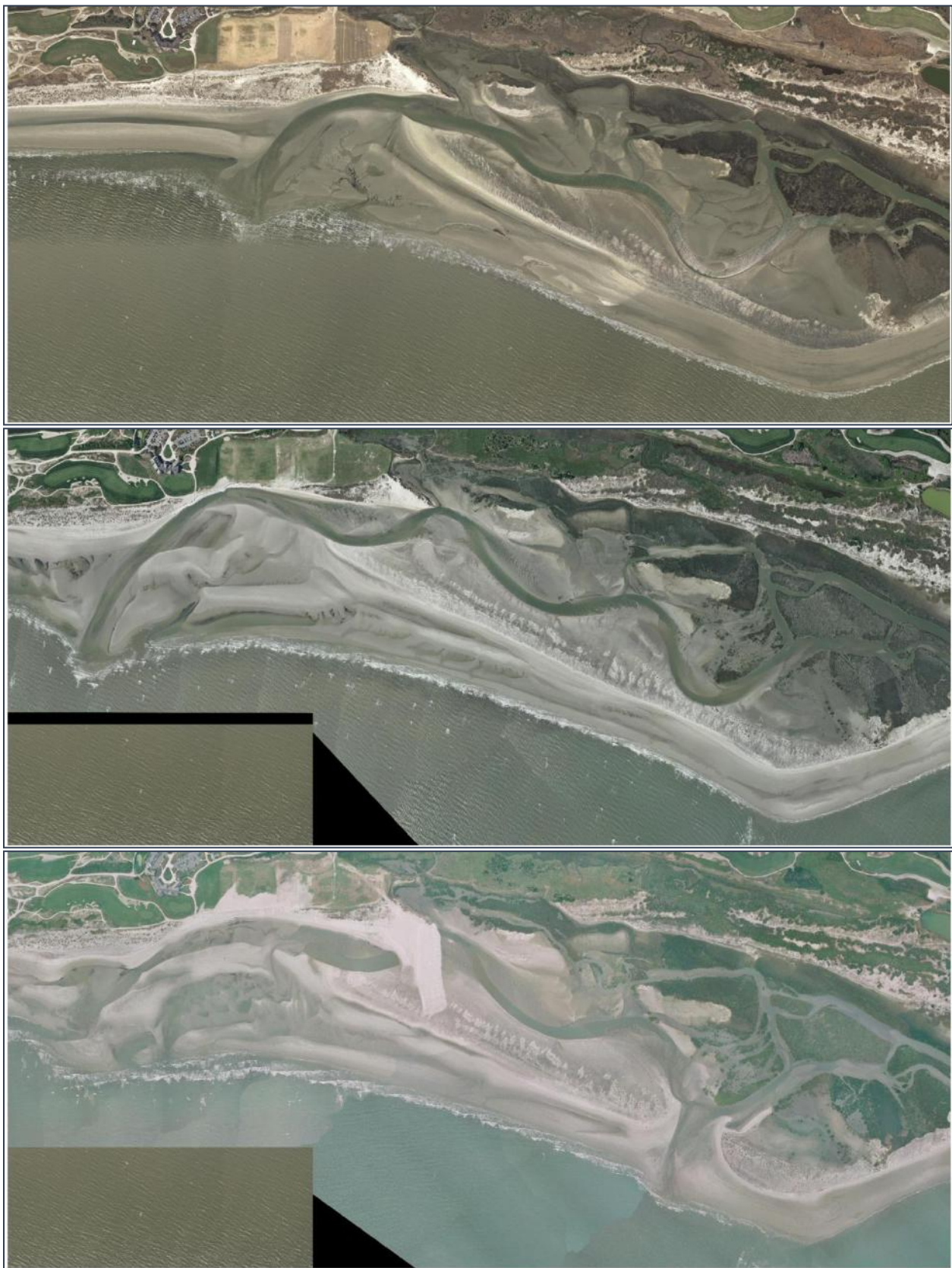


FIGURE 4.1. Aerial images of the east end project area from February 2014 (upper), April 2015 (middle), and July 2015 (lower).

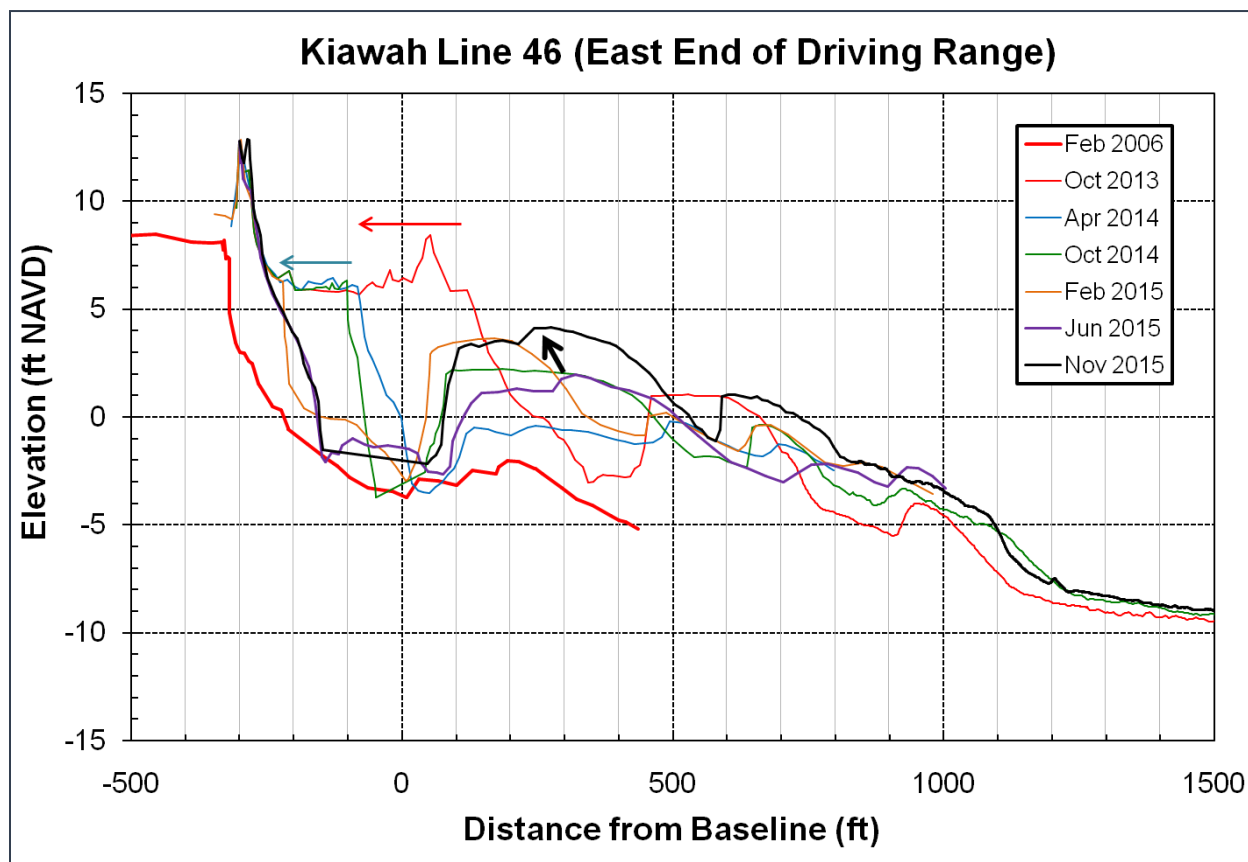


FIGURE 4.2. Profiles from station 46. The red and blue arrows show the rapid erosion due to migration of the flushing channel in 2014-2015. The black arrow shows the upward and landward migration of the abandoned shoals of the old channel since the 2015 project was completed.

FIGURE 4.3.

March 2015 aerial image of the east end of Kiawah Island.

Note the sandbag revetment at the driving range and practice green, the remnants of the 2006 closure dike, and the extensive sand flats that will migrate onshore after the channel is closed.



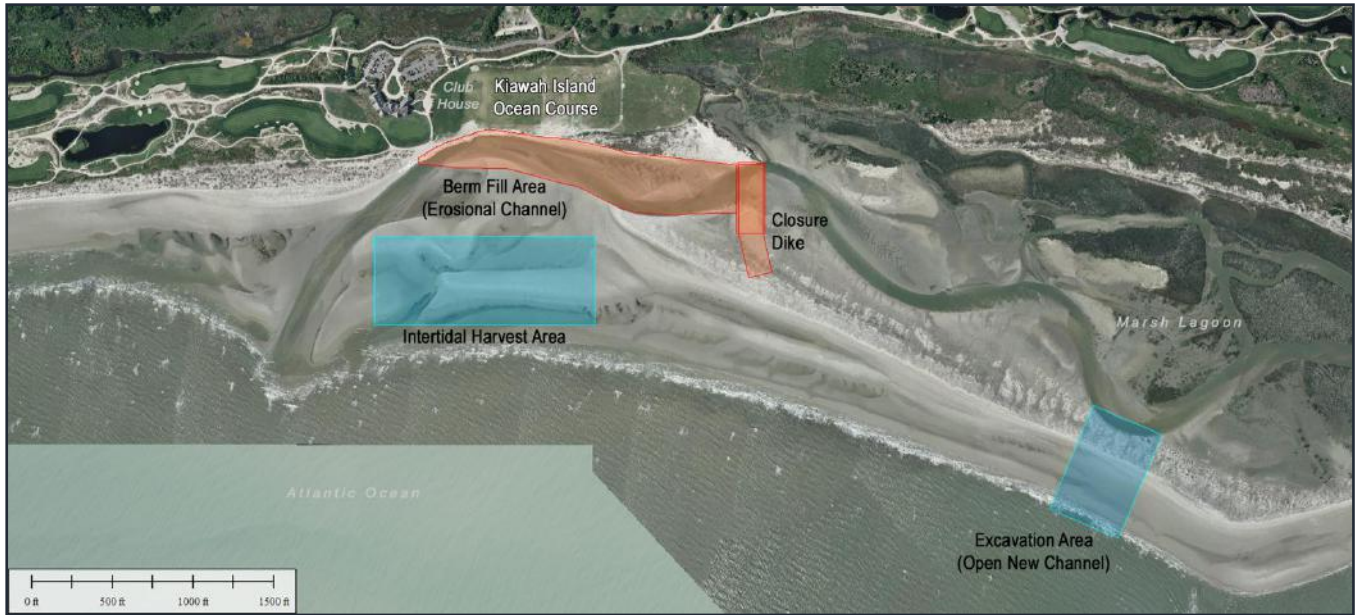


FIGURE 4.4. Generalized project plan for the 2015 east end channel realignment project.

Construction occurred between 18 May and 11 June 2015, using land-based equipment in daylight hours. A total of two excavators and up to five off-road dump trucks were used to excavate and haul sand. Once placed, bulldozers were used to shape the fill into the design template. Initial excavations were completed in the area of the new inlet with the inlet opening on its own after the first day of work. Once the new inlet was open and flushing, work continued to construct the closure dike across the old channel. Once ~20,000 cy of sand were placed and stockpiled along the dike, the old inlet was closed on 22 May. Work continued to expand the dike to the design template and then sand was placed along the erosional scarp fronting the driving range to restore the beach and fill in as much of the old channel as possible.

The 2015 project had two main goals. The most important was closure of the old channel to prevent continued tidal flushing. Currents through the channel were scouring the upland area as the channel continued to migrate to the west. The migration was due to the dominate sediment transport patterns constantly pushing sand in this area to the west. By eliminating the flow in the channel, the scour is eliminated, and sand on the seaward side of the channel is pushed landward by wave action. The extensive intertidal flats seaward of the old channel were expected to migrate up the beach and restore the eroded area naturally over the months and years following construction.

The second goal was to expedite this natural recovery by restoring as much of the eroded area as possible with the sand volume available under the project permits. During construction, an effort was

made to place as much sand along the eroded bank as possible; however, a substantial amount of sand was needed to fill in deeper parts of the old channel near the clubhouse to stabilize the bank and facilitate removal of sandbags. The available volume was insufficient to restore a wide dry beach along the entire eroded area, but was sufficient to provide at least 30 ft of dry sand along the area and fill in the critical low areas of the channel, which reduced the potential for continued erosion and expedited landward sand migration (natural recovery).

Post-construction photos are shown in Figure 4.5. Beach profiles from Line 45 (Ocean Course Clubhouse) and Line 47 (dike) are shown in Figure 4.6. At Line 45, the pre and post project profiles (green and orange lines, respectively) show a fairly similar shape along the inland channel boundary (approx -200 ft from the baseline). Note that between February and initiation of the project, this profile continued to erode, and the channel deepened significantly (to approx -8 ft NAVD), which is not reflected in the data shown. The project filled in the deep channel to a point where it was dry at low tide. Between June and November (black line), sand along the intertidal beach has migrated landward with the closest sandbar moving ~200 ft landward and essentially merging with the dry-sand beach. Another sandbar (in the form of an intertidal ridge extending from the east) has emerged further seaward in the profile (~300–500 ft from the baseline) and will migrate up the beach over the next several months.

Line 47 was the location where the channel was actively eroding into the 2006 closure dike. The pre-project profiles (red and blue lines) show that the erosion was not severe at this location; however, the channel was deepening along the dike. The 2015 dike was constructed along the axis of Line 47, so the data show a cross-section of the landward-to-seaward width of the dike. Approximately 400 ft of sand were placed at (~)+8 ft NAVD to build the main dike section. Further seaward, sand was added at +6 ft NAVD to tie into existing high ground along the lagoon outer berm. Little notable change was observed at this location between June and November 2015. CSE expects this station to gradually erode over the next few years as the shoreline adjusts to the new channel alignment and sand moves to the west.

Figure 4.7 shows aerial views (7 January 2016) of the project area. West of the dike, the old channel has filled in between the clubhouse and vehicle access path along the middle of the driving range. Between the access path and the dike, an area of standing water remains, flushed by a very small channel. A large, intertidal ridge extends to the west from the area of dry beach seaward of the dike. This sand will eventually merge with the shoreline in front of the driving range. Hurricane *Joaquin* (early October 2015) likely contributed to onshore migration of the intertidal sand, and additional winter storms will be effective at moving detached shoals and bars landward.



FIGURE 4.5. Photos from June 15 (above) and June 16 (aerials) showing the condition of the beach immediately after project construction.



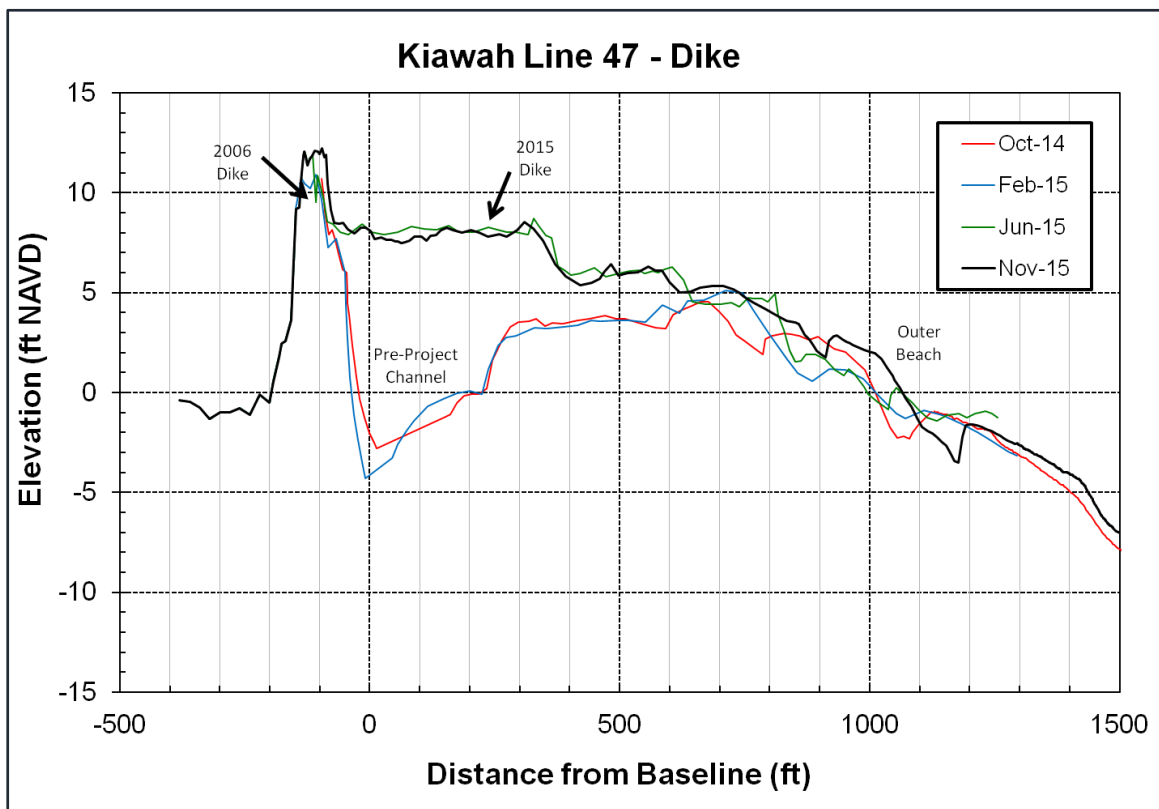
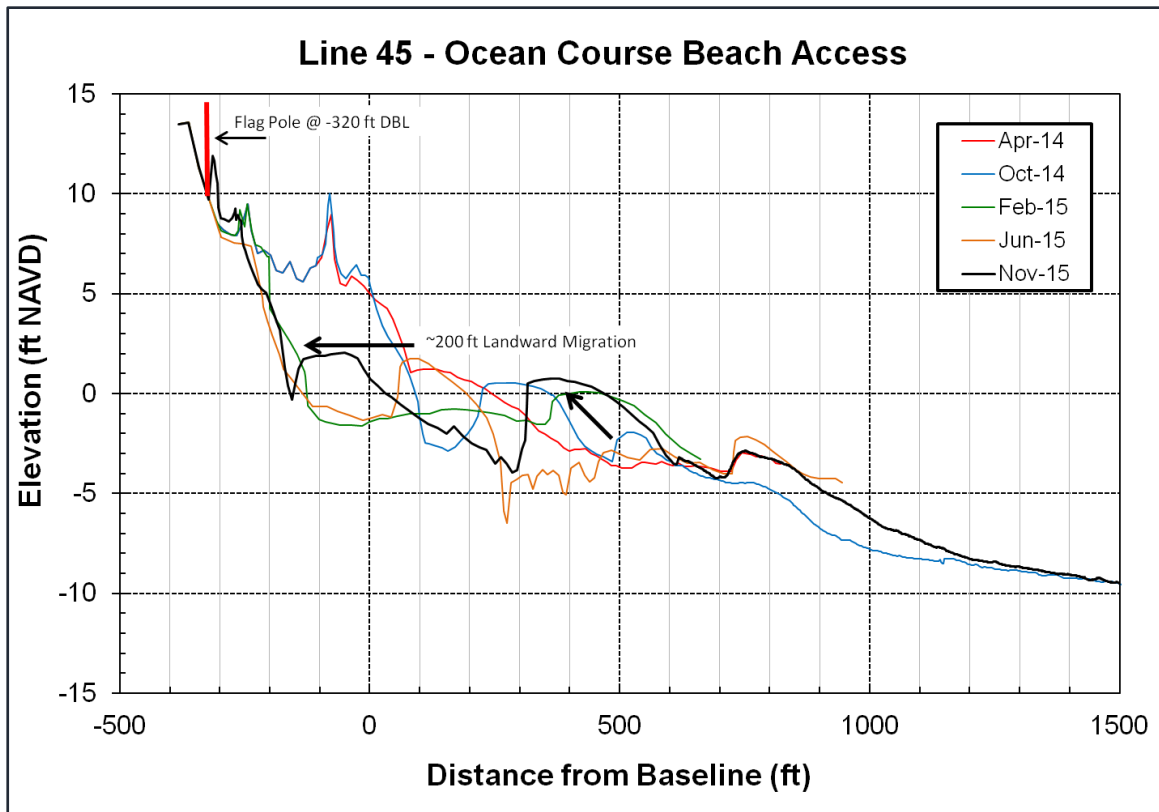


FIGURE 4.6. Profiles from Lines 45 (Ocean Course Beach Access) and Line 47 (closure dike). See text for additional information.



FIGURE 4.7. Aerial images from 7 January 2016 showing the project area ~7 months after project completion. Note the infilling of the old channel and the merging intertidal sandbars on the top image. The bottom image shows the new inlet, which has deflected to the west since the project. Hurricane *Joaquin* impacted this area in early October 2015, creating washovers of the lagoon outer berm further east (see later sections).

CSE anticipates that the dry beach fronting the driving range will continue to accrete sand along the upper profile over the next several months. Sand fencing should be used to facilitate dune development in strategic places, while the intertidal flats and washover areas east of the dike should be left to natural processes for habitat conservation.

The new inlet quickly appeared natural following initial opening in mid May. By January 2016, the inlet had rotated to a more east/west configuration and has migrated ~425 ft to the west. It is likely that much of the migration occurred during Hurricane *Joaquin*. The Town is presently monitoring the position of the channel on a quarterly basis (Fig 4.8). If data suggest that the inlet will continue to migrate to a point where it becomes a concern, another channel relocation project should be considered. The permit for the project allows for another event to occur after three years of the initial project (fall of 2018). The Town should anticipate needing to perform such a project around that date. Should migration occur so rapidly that a critical situation arises before 2018, the Town may apply to state and federal agencies for a modification to the permit conditions.

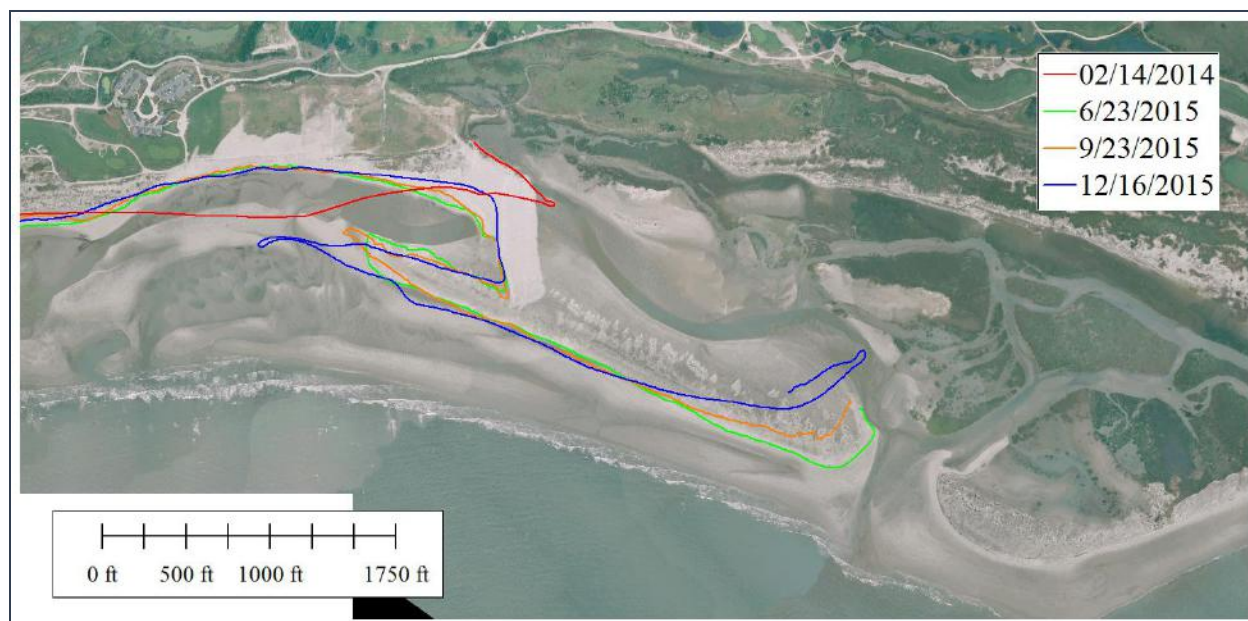


FIGURE 4.8. Map delineating the western boundary of the flushing channel based on hand-held GPS surveys and aerial photography overlaid on a July 2015 (post project) aerial image. Once the channel reaches the February 2014 position (red line), another channel realignment project may be conducted. The new channel migrated ~425 ft between June and December 2015.

4.1.2 2015 Captain Sams Inlet Relocation

The SIPOA sponsored and implemented the third relocation of Captain Sams Inlet along the western boundary of Kiawah Island in the spring of 2015. Similar projects were completed in 1983 and 1996 in an effort to maintain a sand supply to Seabrook Island. The general design of the project was to relocate the inlet using land-based equipment to the inlet's 1960 position via opening a new channel through Captain Sams spit and closing the old channel with a sand dike. The project is similar to the channel relocation project at the east end of Kiawah, only larger in scale. The inlet historically migrates towards Seabrook Island at a rate of 200-300 ft/yr. When it reaches a certain point, it begins to rapidly erode Seabrook Island's North Beach, and sediment transport is reduced to other portions of Seabrook. SIPOA has an agreement with the Town of Kiawah Island and owners of the spit property to periodically relocate the channel back to the 1960 position.

The 2015 relocation was conducted under permits obtained by SIPOA with an allowable construction window of 15 May to 15 August. Work began on 18 May by clearing the area of the new channel. A basin was excavated along the footprint of the designed new channel with the sand from the excavation being deposited along the closure dike. Surplus sand was stockpiled at the western end of the dike to use in the closure sequence. The new channel was opened on 2 June 2015. Additional sand was stockpiled on both sides of the old channel and a first closure attempt was made on 4 June. The first closure attempt was unsuccessful due to higher than predicted tides and weather, and a second, successful attempt was made on the night of 11–12 June (Fig 4.9). A total of ~140,000 cy of sand was excavated and transferred from the basin and intertidal area during the project.

The project resulted in the western 2,800 ft of Kiawah Island (a portion of Captain Sams Spit) being temporarily lost to Seabrook. Figure 4.10 shows the post-construction photo and locations of monitoring stations. Profile Line 1 is now on the Seabrook side of Captain Sams Inlet; Line 2 is essentially in the inlet channel. For volume analysis, any volume associated with these profiles is excluded from computations. As the inlet migrates over time, the lines will be reincorporated into the volume measures as applicable. CSE anticipates the spit returning to near its pre-project condition in the next 12–15 years.



FIGURE 4.9. January 2015 (top) and July 2015 (bottom) aerial images of Captain Sams Inlet, which was relocated ~3,000 ft to the east by SIPOA in May-June 2015.



FIGURE 4.10. Post-project map of the west end of Kiawah Island and TOKI beach monitoring stations. Lines 1 and 2 are now located on the Seabrook side of the new inlet.

4.2 Beach Volume Changes 2014–2015

Reach volume changes are reported from the eastern end of the island (Reach 6 – Stono Inlet) to the western end (Reach 1 – Captain Sams Spit). Methods for volume calculations are given in Section 3. Unit volumes for each station are provided in Table 4.1. Volumes for each reach are provided in Table 4.2.

4.2.1 Reach 6 – Stono Inlet

The Stono Inlet Reach spans ~6,000 ft from Line 56 to Line 61 (see Fig 3.3). Beach profiles in this reach are steeper than the front-beach reaches due to the presence of Stono Inlet and reduced wave energy along the inlet. Unit volumes from Stono Inlet are shown in Figure 4.11. The majority of the Stono Inlet reach has been relatively stable since 2006 with the exception being Line 56, which eroded from 2006 to 2010, accreted from 2010 to 2012, and continued to erode for a net loss of 140 cy/ft since 2006. The eastern end of the reach has accreted consistently, gaining 71.6 cy/ft since 2006. The remainder of the reach shows an average loss of 23.7 cy/ft since 2006 (2.6 cy/ft/yr).

TABLE 4.1. Unit volumes for monitoring profiles at Kiawah Island, SC (to -10 ft NAVD).

Kiawah Island 2015 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
1 - Kiawah Spit	1	1,000								601.9	577.7	576.6	694.2
	2	997								319.8	320.2	304.2	337.4
	3	1,153								339.7	346.1	337.0	252.8
	4	844	300.2		392.4	392.4	391.9	406.7	392.1	388.2	384.7	387.0	369.5
	5	845								384.3	384.5	386.4	382.1
	6	1,157	252.5		361.9	361.1	375.2	384.1	380.9	381.9	381.4	383.5	372.6
	7	978								364.0	362.0	359.4	357.5
	8	1,040	240.6		309.0	309.9	321.6	334.7	331.0	347.6	353.8	346.8	339.6
	9	806								334.9	335.6	334.6	329.3
2 - West Beach	10	547	268.3		300.9	299.1	303.6	318.5	317.1	335.8	339.8	339.1	332.6
	11	1,232	255.0		289.3	290.4	300.2	307.1	312.3	323.8	327.7	325.1	319.1
	12	665	232.9		261.1	257.9	273.1	273.1	275.4	284.8	293.0	294.6	288.9
	13	665								277.8	281.6	287.8	285.3
	14	945	251.9		252.3	248.5	257.7	258.2	259.3	270.7	278.3	280.9	275.4
	15	946								267.5	273.3	279.5	271.4
	16	1,025	235.6		254.5	252.8	258.3	260.3	253.0	265.4	269.6	278.3	279.4
	17	1,026								251.6	256.6	261.8	257.3
	18	691	228.6		236.9	229.7	231.1	232.6	229.9	237.9	247.9	253.2	245.7
	19	692								242.8	245.5	248.4	250.8
	20	831	273.3		243.8	239.0	239.3	237.4	239.2	247.5	252.7	260.2	261.6
	21	1,266					222.0	220.0	226.8	234.1	238.9	235.1	243.8
	22	1,627								246.0	246.4	254.5	260.4
3 - Turtle Point	23	1,033	234.3		253.9	249.0	252.2	253.0	257.3	261.3	271.2	270.5	285.4
	24	1,215					257.1	255.3	259.0	265.4	274.7	285.8	286.3
	25	1,145	219.7		250.7	244.3	248.7	245.3	248.4	262.3	270.9	282.1	289.2
	26	1,205					259.9	251.7	258.3	265.2	278.2	294.2	291.2
	27	1,080	266.2		262.7	274.3	279.7	270.2	277.2	287.6	304.5	314.5	325.2
	28	1,269	299.2		278.2	291.8	295.2	292.3	300.8	307.4	324.3	337.0	344.6
	29	635	268.3		321.9	313.4	325.8	323.1	322.1	344.5	360.4	370.5	381.0
	30	643								345.7	354.7	369.1	383.8
	31	889	265.3		322.6	325.1	326.4	331.6	326.8	347.1	353.9	374.1	385.1
	32	645	286.4		306.2	302.0	306.9	309.3	305.3	323.3	330.2	351.9	351.1
	33	646								282.4	299.6	310.3	319.1
	34	1,125					224.2	229.8	225.6	241.8	249.5	255.3	264.9
	35	666	217.0		252.1	250.3	253.3	254.5	245.4	269.3	267.0	273.8	277.3
4 - Ocean Course	36	666	252.2		257.4	204.2	259.9	263.7	257.8	275.8	275.7	276.7	279.7
	37	752								271.7	274.2	271.6	275.0
	38	1,000		241.6	247.0	247.8	251.4	256.6	251.2	266.7	266.2	269.4	259.9
	39	1,000								277.5	276.9	271.5	270.5
	40	1,000		251.1	251.6	257.3	276.6	279.3	276.4	288.9	291.4	286.3	279.0
	41	1,000								285.1	274.2	289.1	264.9
	42	1,000		216.1	232.2	248.2	259.7	271.1	272.1	281.1	282.4	276.0	247.0
	43	1,000								325.7	310.4	324.1	298.6
	44	1,000		294.9	355.1	346.9	351.5	362.9	356.3	371.2	364.1	424.1	517.4
	45	1,000								454.2	527.4	526.0	523.1
	46	1,000		505.6	500.1	453.5	465.3	441.4	486.7	537.7	572.5	551.5	580.9
	47	1,000								647.9	696.4	840.0	1028.8
5 - Lagoon	48	1,000		617.4	578.8	541.8	561.5	562.6	689.5	758.3	839.2	879.5	979.9
	49	1,000								980.9	978.9	960.1	841.8
	50	1,000								1012.4	1005.7	1025.4	1160.0
	51	1,000								929.1	838.9	799.5	1165.8
	52	1,000								967.5	881.7	821.2	796.1
	53	1,000								984.6	934.2	859.6	811.5
	54	1,000								604.7	593.3	548.7	456.4
	55	0								588.4	621.0	602.3	567.8
6 - Stono Inlet	56	1,200		322.0	312.4	269.6	219.4	187.0	220.3	237.2	229.9	208.7	182.4
	57	1,200		169.0	168.2	186.0	184.6	176.3	154.5	163.2	165.7	168.3	148.1
	58	1,200		146.2	143.4	140.7	137.1	156.6	163.7	169.4	158.5	141.5	112.2
	59	1,200		167.6	166.9	165.4	168.1	180.7	178.6	173.7	162.1	145.3	140.6
	60	1,200		150.0	156.8	154.8	157.1	173.5	173.1	161.2	147.4	131.3	137.2
	61	1,200		108.9	111.3	123.7	137.5	146.2	144.4	146.2	159.6	163.2	180.5

TABLE 4.2. Volumes and Unit Volumes for each monitoring reach. Volumes are calculated to -10 ft NAVD.

			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
1	Kiawah Spit	8,820	2,328,514		3,097,296	3,094,685	3,181,691	3,276,726	3,221,628	3,263,752	3,261,529	3,229,981	2,486,384
2	West Beach	11,798	2,903,774		2,994,556	2,949,260	2,978,605	2,991,545	3,000,541	3,108,310	3,170,302	3,213,238	3,205,892
3	Turtle Point	13,614	3,097,370		3,736,350	3,679,389	3,734,117	3,724,681	3,726,666	3,921,035	4,049,840	4,189,161	4,269,193
4	Ocean Course	9,000		2,832,947	2,964,385	2,903,690	3,005,533	3,026,626	3,135,711	3,278,923	3,380,461	3,503,344	3,625,872
5	Lagoon	8,000		6,559,380	6,499,468	6,763,197	7,090,470	7,385,476	7,175,787	7,156,897	7,056,459	7,089,847	6,819,651
6	Stono Inlet	6,000		1,219,056	1,213,419	1,198,757	1,155,841	1,173,275	1,176,151	1,195,114	1,156,125	1,081,375	998,921
1-6	All	57,232			20,505,475	20,588,979	21,146,257	21,578,329	21,436,484	21,924,031	22,074,717	22,306,946	21,405,913
			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
1	Kiawah Spit	8,820	264.0		351.2	350.9	360.7	371.5	365.3	370.0	369.8	366.2	281.9
2	West Beach	11,798	246.1		253.8	250.0	252.5	253.6	254.3	263.5	268.7	272.4	271.7
3	Turtle Point	13,614	227.5		274.4	270.3	274.3	273.6	273.7	288.0	297.5	307.7	313.6
4	Ocean Course	9,000		314.8	329.4	322.6	333.9	336.3	348.4	364.3	375.6	389.3	402.9
5	Lagoon	8,000		819.9	812.4	845.4	886.3	923.2	897.0	894.6	882.1	886.2	852.5
6	Stono Inlet	6,000		203.2	202.2	199.8	192.6	195.5	196.0	199.2	192.7	180.2	166.5
1-6	All	57,232			358.3	359.7	369.5	377.0	374.6	383.1	385.7	389.8	374.0
			Reach Volume Change Since Previous (cy)										
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15
1	Kiawah Spit	8,820				-2,611	87,006	95,035	-55,098	42,124	-2,223	-31,548	-743,597
2	West Beach	11,798				-45,296	29,345	12,940	8,996	107,769	61,992	42,936	-7,346
3	Turtle Point	13,614				-56,961	54,728	-9,437	1,986	194,369	128,805	139,320	80,032
4	Ocean Course	9,000			131,439	-60,695	101,843	21,093	109,085	143,212	101,538	122,883	122,528
5	Lagoon	8,000			-59,912	263,729	327,273	295,006	-209,689	-18,890	-100,438	33,388	-270,196
6	Stono Inlet	6,000			-5,637	-14,662	-42,916	17,434	2,875	18,963	-38,989	-74,750	-82,454
1-6	All	57,232				83,504	557,279	432,072	-141,844	487,547	150,685	232,229	-901,033
			Reach Unit Volume Change Since Previous (cy/ft)										
Reach	Name	Length			Aug-07	Oct-08	Aug-09	Oct-10	Oct-11	Oct-12	Oct-13	Oct-14	Nov-15
1	Kiawah Spit	8,820				-0.3	9.9	10.8	-6.2	4.8	-0.3	-3.6	-84.3
2	West Beach	11,798				-3.8	2.5	1.1	0.8	9.1	5.3	3.6	-0.6
3	Turtle Point	13,614				-4.2	4.0	-0.7	0.1	14.3	9.5	10.2	5.9
4	Ocean Course	9,000			14.6	-6.7	11.3	2.3	12.1	15.9	11.3	13.7	13.6
5	Lagoon	8,000			-7.5	33.0	40.9	36.9	-26.2	-2.4	-12.6	4.2	-33.8
6	Stono Inlet	6,000			-0.9	-2.4	-7.2	2.9	0.5	3.2	-6.5	-12.5	-13.7
1-6	All	57,232				1.5	9.7	7.5	-2.5	8.5	2.6	4.1	-15.7

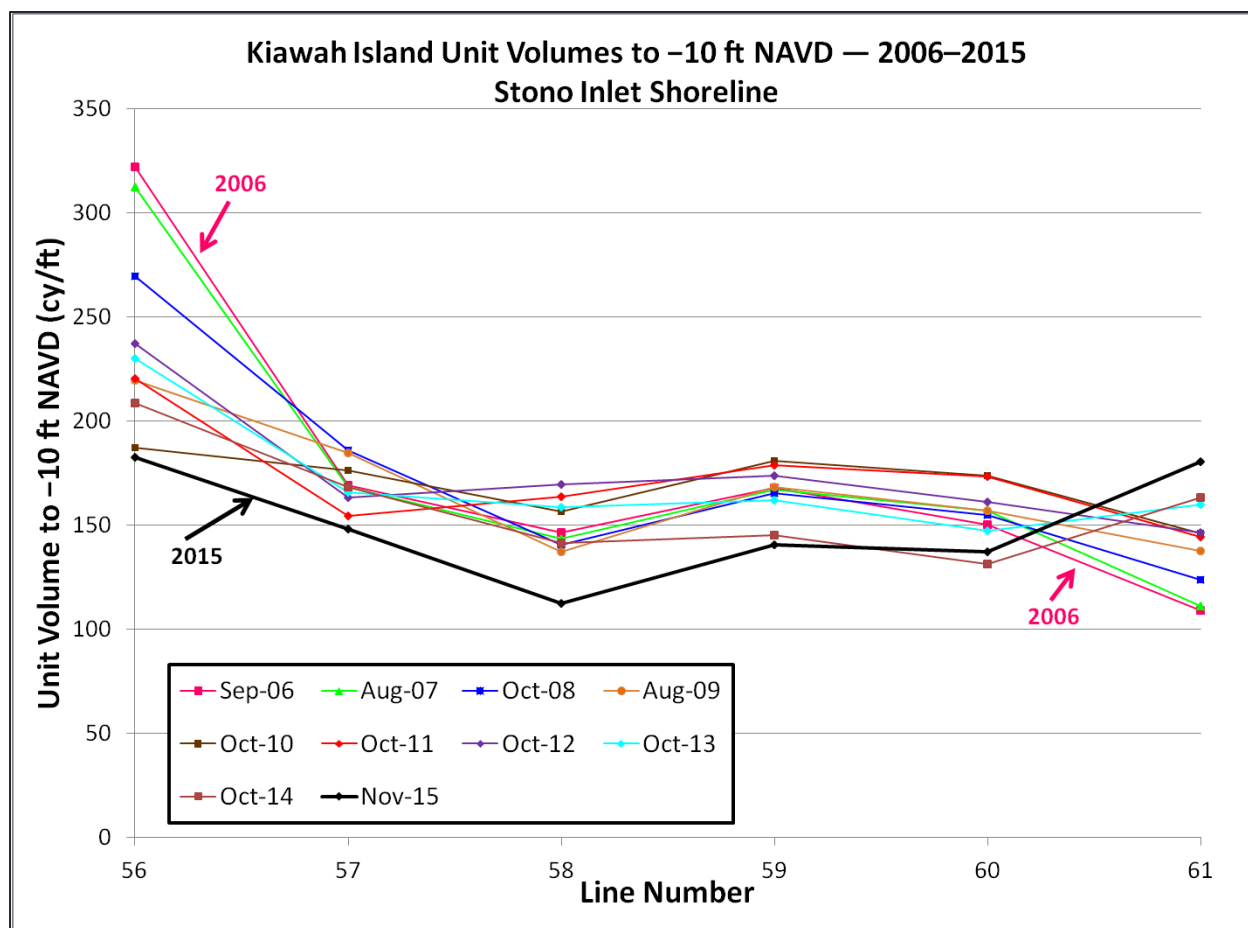


FIGURE 4.11. Unit volumes for stations along the Stono Inlet Reach.

Over the past year, the south end of the reach was the most erosional area with Lines 56-58 losing 20-29 cy/ft. Lines 59 and 60 were fairly stable, and Line 61 gained 17.3 cy/ft. This decrease in erosion from south to north indicates that sand was moving north along the beach into the inlet. This is not surprising as the only significant waves able to reach this length of beach must approach from the south or southeast, which will push sand to the north. Overall, the reach lost ~82,500 cy (13.7 cy/ft) of sand between October 2014 and November 2015. Since 2007, the reach has lost a total of 215,000 cy, which is an average annual erosion rate of 4.3 cy/ft/yr. Excluding the Kiawah Spit Reach (which artificially lost sand this past year due to the inlet relocation project), the Stono Inlet Reach is the only reach with a net loss of sand compared to the 2007 condition.

Photos (Fig 4.12 and Fig 4.13) from the November 2015 survey and January 2016 overflight show there was severe erosion along the southern end of the reach (Lines 56–57) with a large dune escarpment and signs of an overwash event (likely occurring during Hurricane *Joaquín*). A very thin strip of dune separates the ocean from the lagoon marsh between Lines 56 and 57 (foreground of Fig 4.12). Continued erosion of this area may lead to the formation of a new breach inlet at the site. Profiles show the primary dune was completely eroded at Lines 57 and 58, leaving a low dune area susceptible to overwash during storms (Fig 4.14).



FIGURE 4.12. January 2016 aerial image of the Stono Inlet Reach.



FIGURE 4.13. Ground photos from Line 56 (left) and Line 58 (right). The primary dune was lost at Line 58, leaving the potential for overwash during storms.

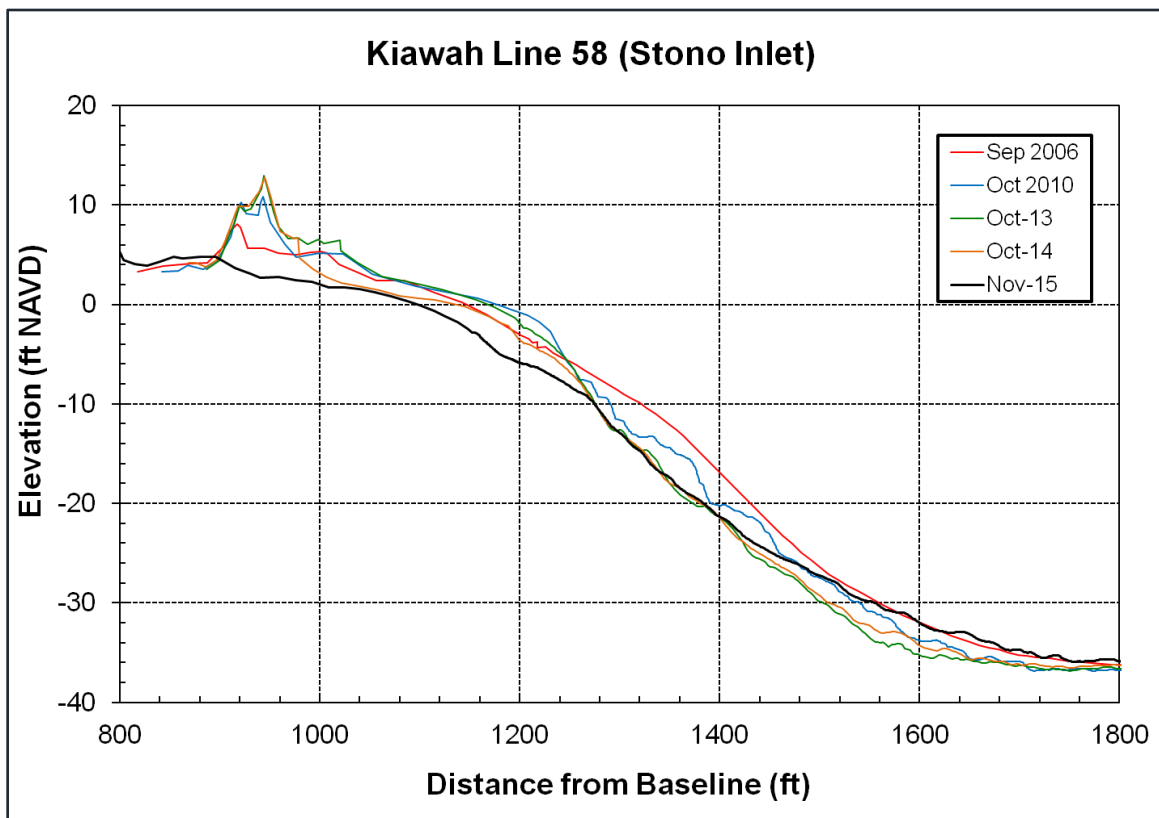


FIGURE 4.14. Profiles from Line 58 along the Stono Inlet shoreline. The primary dune eroded over the past year.

4.2.2 Lagoon Reach

The Lagoon Reach spans 8,000 ft from the 2006 closure dike (Line 47 along the 2015 closure dike) to Line 55 at the eastern point of the island (Fig 4.15). 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).

Due to the rapid shoreline fluctuations and varying shoreline directions in this reach, CSE has elected to compute beach volumes using 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, where 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 the linear shoreline change.

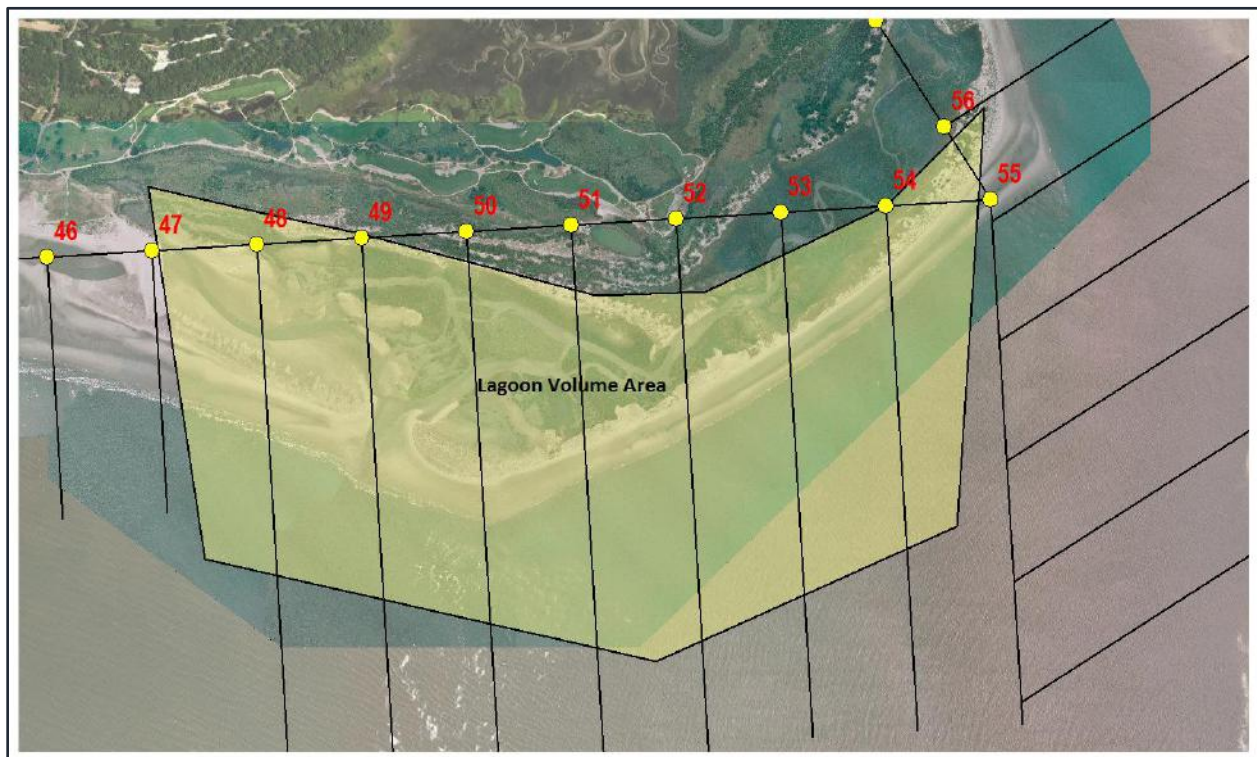


FIGURE 4.15. The Lagoon Reach extends from Line 47 to Line 55. Due to the dynamic nature of the area, the total volume for this reach is calculated from DTMs within the boundaries shown here.

A shoal-bypass event occurred in the lagoon reach between 2007 and 2009, attaching in late 2009 at the southern apex of the lagoon. During the attachment process, the beach in the lee of the shoal accreted, gaining sand from adjacent areas nearby and creating a large protrusion in the shoreline. Once attached, sand spread rapidly from the attachment site, contributing to gains along the western lagoon and Stono Inlet shoreline between 2009 and 2012. Beginning in 2012, another shoal-bypass event became visible in a similar location as the previous event.

In 2012, the incoming shoal was positioned ~1,700 ft from the beach and was still far enough offshore to only have limited impacts to the beach. Between 2012 and 2014, the shoal migrated ~1,200 ft landward (Fig 4.17). More information and photos of the evolution of these shoal events were provided in previous monitoring reports to the Town (ie CSE 2015). Between October 2015 and November 2015, the shoal continued to migrate landward, attaching to the beach at the -7 ft contour (low-tide wading depth). Interestingly, the shoal decreased in elevation, which may indicate that the sand is presently moving in a more alongshore direction rather than directly toward the beach. The photo in Figure 4.16 shows the shoal (visible by the breakers at the left of the image) attached to the beach just east of the new inlet channel.

Other than the relocation of the inlet channel, the most significant change along the lagoon area was erosion and overwash of the berm along the eastern half of the reach. Lines 51–54 all showed complete loss of the dune and significant recession of the shoreline due to overwash (Fig 4.18). Up to 300 ft of landward recession was observed between 2014 and 2015. Much of the area is now susceptible to overwash during storms or extreme tides, as the maximum elevation along the stretch is (~)-5 ft NAVD, which near the typical elevation of a unvegetated dry sand beach. Photos from November 2015 confirm that nearly the entire span of the lagoon reach was overwashed by a recent tide (Fig 4.19 and Fig 4.20).



Figure 4.16. March 2015 (top) and January 2016 (bottom) aerial images of the Lagoon Reach.

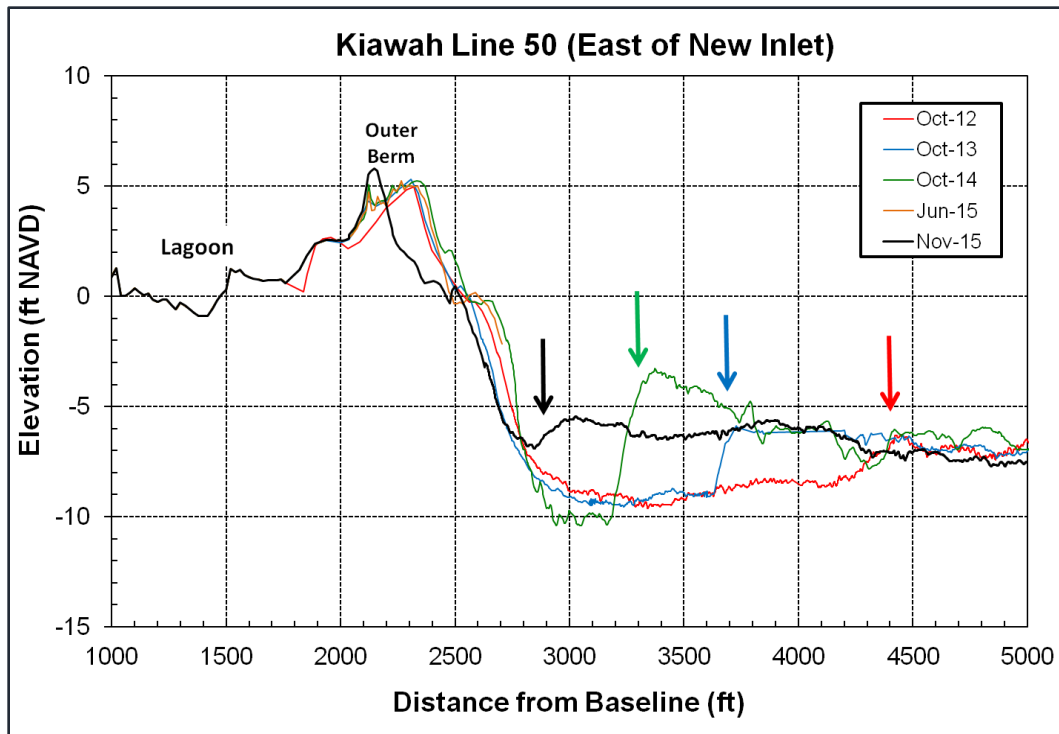


FIGURE 4.17. Profiles from Line 50 near the center of shoal attachment. Landward migration of the shoal is visualized by the colored arrows on the plot.

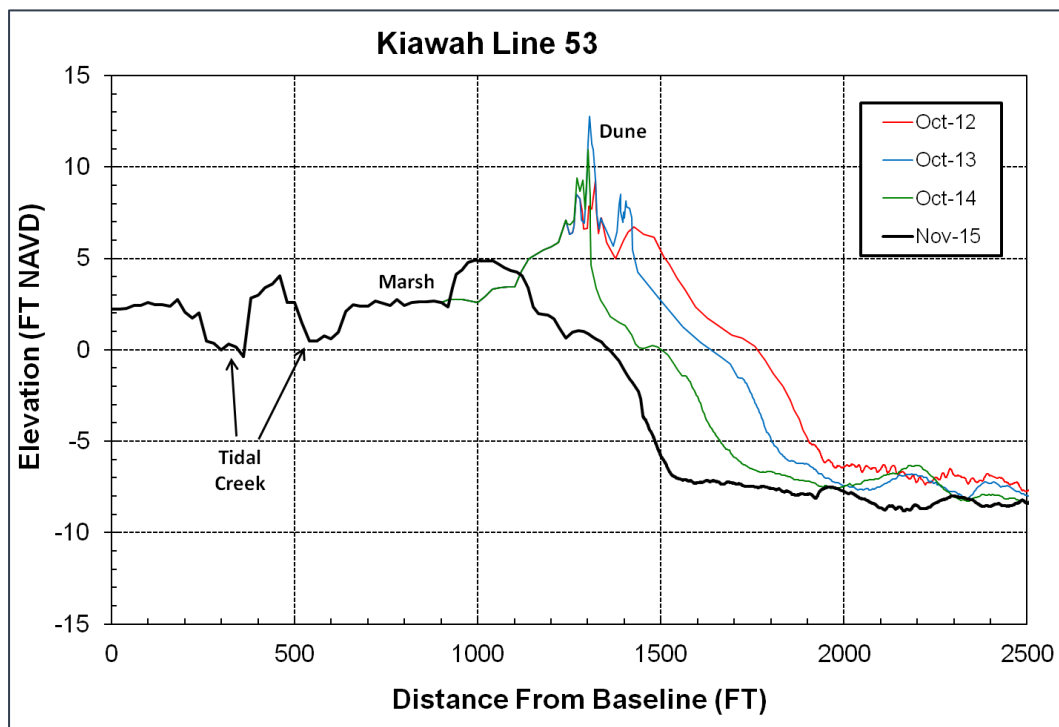


FIGURE 4.18. Profiles from Line 53 showing rapid shoreline recession and loss of dunes over the past year. Elevations of 4-5 ft are insufficient to prevent overwash during storms and extreme tides.



FIGURE 4.19. November 2015 ground photos from Line 53 (right) and 51 (left) showing overwash conditions and exposed marsh on the active beach.



FIGURE 4.20. Photo looking west from Line 48 showing evidence of a recent washover event along the outer berm of the lagoon, east of the constructed dike.

Overall, the Lagoon Reach lost 270,200 cy (33.8 cy/ft) of sand over the past year. This is the highest total loss of sand observed during any previous monitoring interval. Volume change was complicated over the past year due to the 2015 project, which removed upwards of 40,000 cy of sand from the outer berm when the new inlet was excavated. Despite the erosion over the past year, the reach holds 320,000 cy (40 cy/ft) more sand than the 2007 condition with all the gain from natural processes. CSE expects continued erosion of the eastern portion of the lagoon due to limited sand supply and overwash effects. The attaching shoal is relatively small, and does not likely contain sufficient sand to restore the stable beach. It is important to note that the entire lagoon system is an ephemeral feature, created from two large shoal bypass events beginning in the 1990s. The sand from those events continues to attempt to merge with the earlier shoreline through washovers and spreading to downcoast areas. Additional sand continues to periodically attach to the east end, which may temporarily halt the landward retreat of the outer berm and extend the life of the lagoon further into the future.

4.2.3 Reach 4 – Ocean Course

The Ocean Course Reach is the transition zone between the developed shoreline with a typical strand beach and the dynamic lagoon area (Fig 4.21). It spans ~9,000 ft between Line 38 (Kiawah Beach Club) and Line 47 (closure dike). West of the Ocean Course Clubhouse, the beach profile is much more consistent from year to year, allowing for more applicable volume measures using individual profiles and the average-end-area method. This reach was the recipient of the majority of nourishment fill in the 2006 and 2015 projects; however in the 2015 project, sand was shifted from the intertidal beach within the reach to higher in the profile, so the net volume gain was limited to only the sand quantity hauled from the new inlet area.



FIGURE 4.21. January 2016 aerial images of the Ocean Course Reach.

The Ocean Course Reach has consistently accreted since 2008, and totals 660,000 cy (73.5 cy/ft) more sand than the 2007 condition. The reach gain 122,500 cy of sand between 2014 and 2015, which is a nearly identical gain as the previous year; however, the gains are skewed by the east end of the reach, which gained a significant amount of sand during the 2015 project. Unit volumes for each profile in the reach are shown in Figure 4.22 and reveal that the western end of the reach was erosional and the eastern end accretional. Erosion along the western end was a result of sediment trapping in the delta of the inlet channel, which forced sand to be deposited in the nearshore zone near the inlet rather than continuing downcoast and feeding the beach.

Lines 38-43 showed an average of 16.1 cy/ft erosion with the maximum of 29.1 cy/ft at Line 42 (16th fairway, Fig 4.23). At Line 44 (18th fairway), the beach grew substantially due to the buildup of the inlet delta at this location (Fig 4.23). A characteristic feature of migrating inlets is an accretional bulge just downcoast of the inlet with an erosional arc further downcoast.

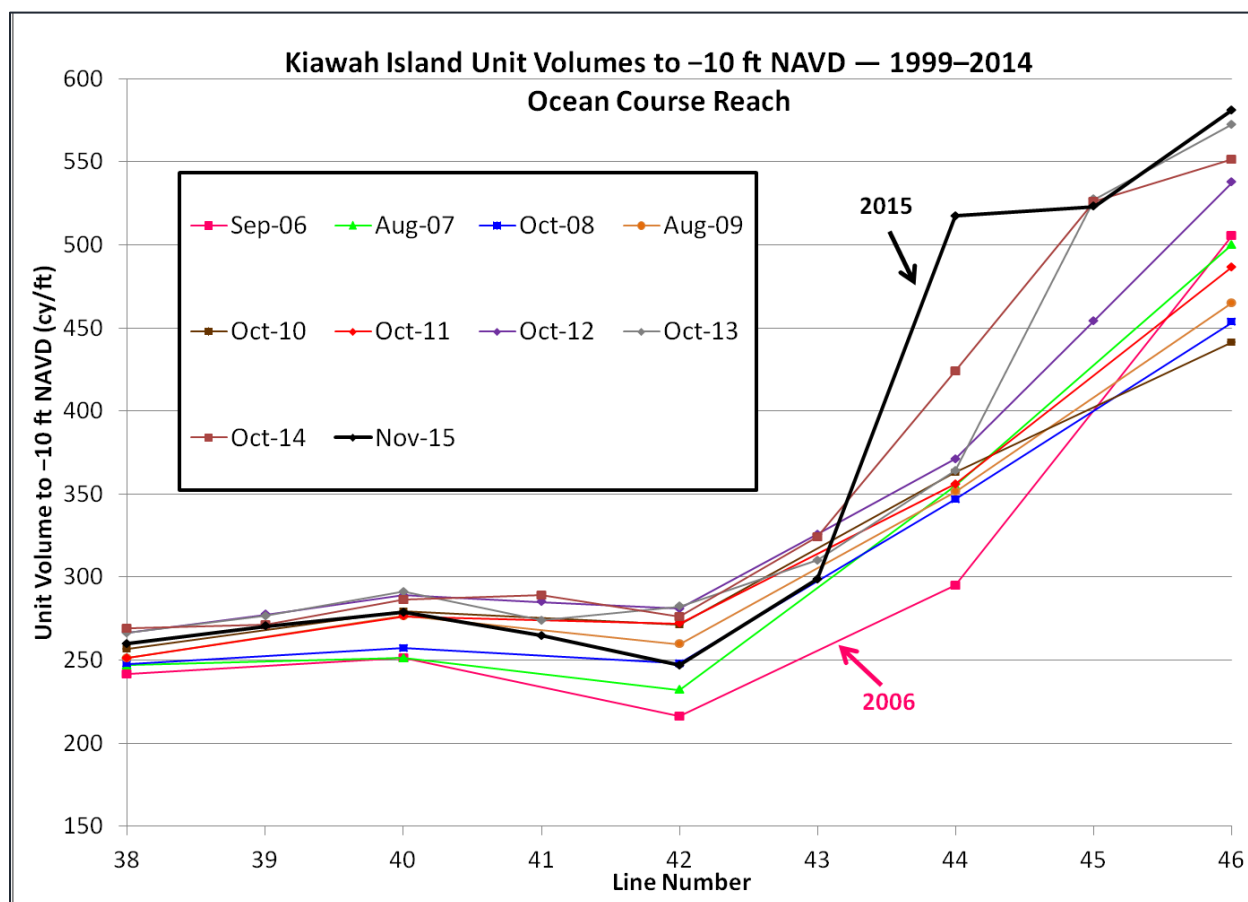


FIGURE 4.22. Unit volumes for the profiles of the Ocean Course Reach.

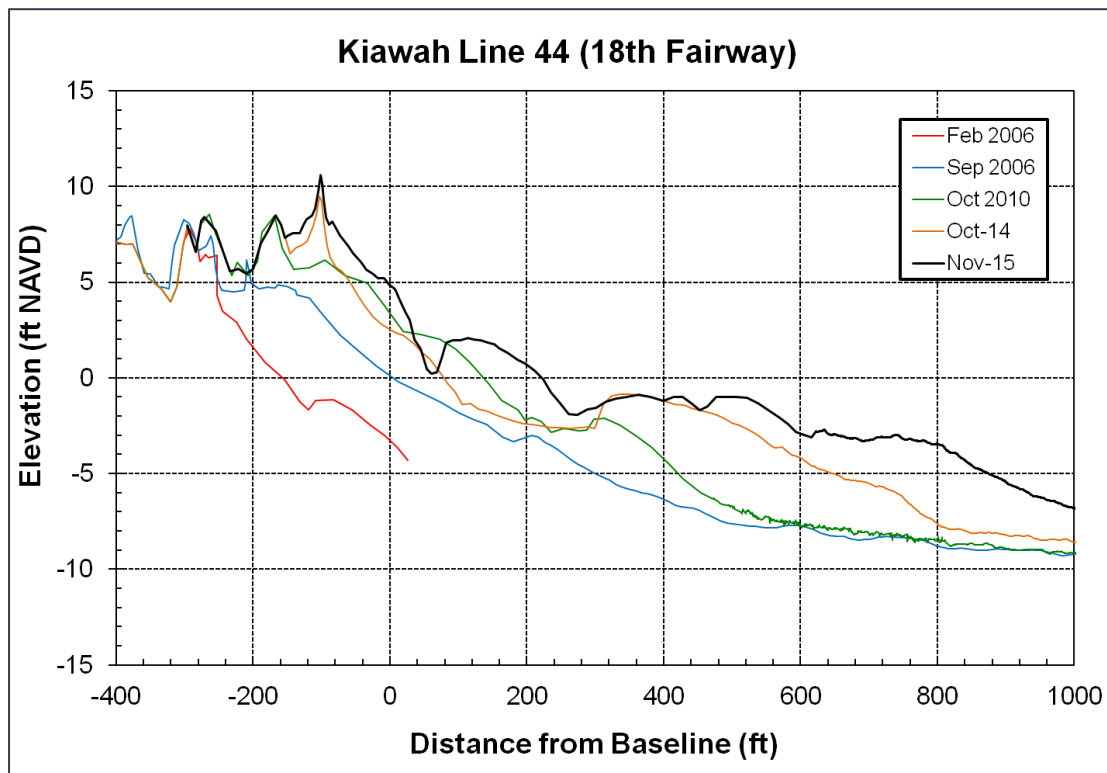
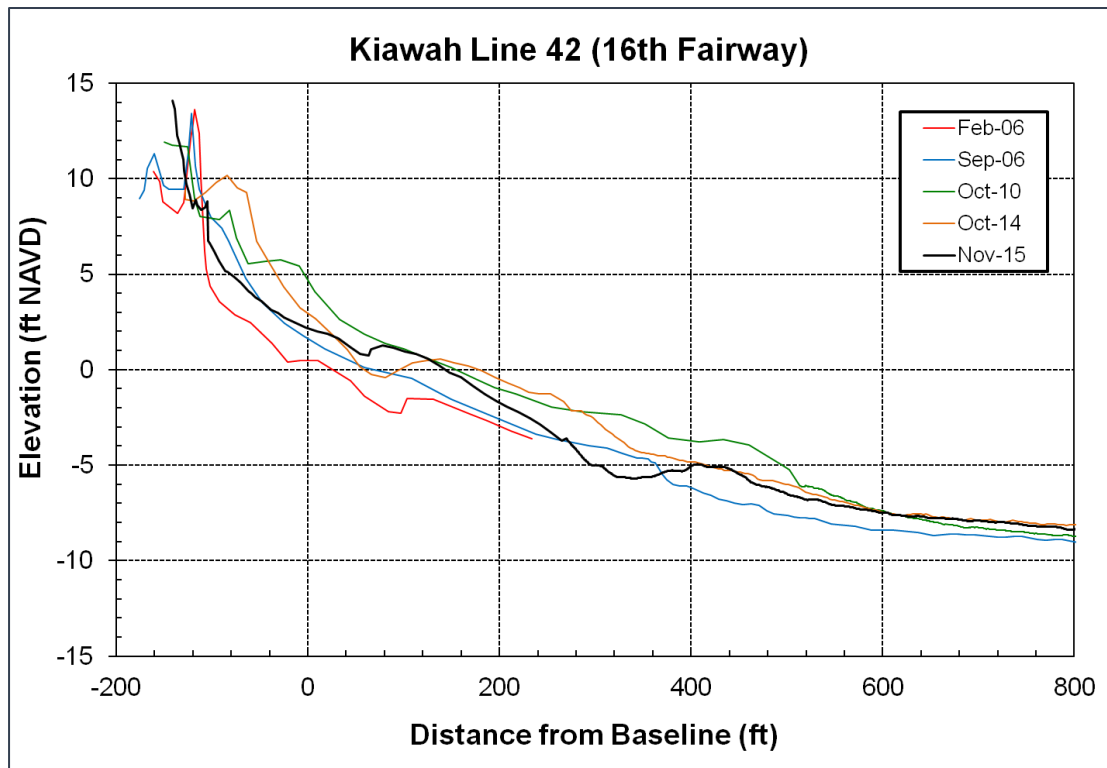


FIGURE 4.23. Profiles from Lines 42 (upper) and 44 (lower) highlighting the influence of the channel delta. At Line 42, the beach eroded over the past year due to sand trapping at the inlet further east. At Line 44, the beach grew as this area is directly adjacent to the inlet, and the delta extends from the beach. Profiles for Line 46 are presented in FIGURE 4.2.

Ground photos (Fig 4.24) show the downcoast erosion (Line 39) and adjacent accretion (Line 43). Line 44 gained nearly 90 cy/ft of sand between 2014 and 2015. This excess sand will migrate onshore and downcoast now that the inlet has been relocated, as the channel currents are no longer capable of maintaining the delta. Much like the sediment transport patterns observed following the previous relocations of Captain Sams Inlet (CSE 1996–2004), CSE expects the old channel delta to collapse and migrate onshore as a series of sandbars over the next several months up to three years. This sand will restore the eroded portions of the reach before continuing downcoast and feeding the remainder of the island. A similar process is expected to take place along the eastern portion of the reach with sand moving landward by wind and wave action eventually filling the remnant channel and restoring the dry sand beach. Presently, the remnant of the old channel remains intact, creating a low area ~300 ft wide separating the upland shoreline from the outer berm (see Fig 4.2).



FIGURE 4.24. Clockwise from top left. (1) Line 39 looking east. An erosion escarpment was present in November 2015 between Lines 38 and 43. (2) View east from Line 43 towards the accretional area downdrift of the old inlet channel. (3) View east from Line 45 at the Ocean Course clubhouse. This beach was restored during the 2015 project and remained stable as of November 2015. (4) View west from Line 47 at the closure dike. The wet area in the background is the designed berm for the 2015 project, which was intentionally left at a low elevation to allow periodic washovers.

4.3 Downcoast Reaches

The 2015 monitoring data for reaches downcoast of the east end project area were compared to 1999 and 2006–2013 data. Profiles in these areas use OCRM monuments and newly (2012) created profiles 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, West Beach Reach has been stable, while the Turtle Point Reach and Kiawah Spit Reach have been accretional. Profiles are given in Appendix A.

At several of the downcoast stations, the 1999 profile lines terminate before reaching –10 ft NAVD. At these stations, volumes were computed to –6 ft NAVD and then adjusted by a factor of 1.95 to produce a representative volume to –10 ft. This scale factor was computed from volume analysis of the 1999 profiles which did extend to –10 ft NAVD. The importance of collecting and analyzing data to the depth of closure is evident in the volume changes between 2010 and 2011.

In 2011, a significant underwater bar was present at most of the profiles in the downcoast reaches. Most of the sand volume associated with the bar was positioned vertically between –6 ft and –10 ft NAVD. Thus, volume change calculations to –6 ft NAVD miss the volume in the bar and do not provide a full accounting of beach condition. For example, at station 2695, the unit volume change to –6 ft NAVD (low-tide wading depth) was –4.7 cy/ft from 2010 to 2011. However, the volume change between –6 ft and –10 ft NAVD was +11.7 cy/ft, yielding a more realistic total volume change of +7.0 cy/ft. While the underwater volumes in bars may not provide immediate benefit to the visible beach, they indicate the likelihood of future beach buildup.

Future monitoring should strive for a full accounting of sand volumes into deeper water because the resulting data provide the most objective measure of beach condition.

Figure 4.25 shows unit volumes for each station in the downcoast reaches. It is apparent that the present condition along the majority of the beach is much healthier than it was in 1999. Only at Line 20 (OCR 2675 near Sea Forest Drive) does the current condition have less volume than in 1999. Overall, the downcoast reaches have gained 1.6 million cubic yards of sand since 1999 (despite the loss of ~743,600 cy at Captain Sams spit this past year), which is equivalent to an average annual accretion rate of 2.9 cy/ft/yr over the ~6-mile beach length.

Over the past year, the downcoast beach was accretional along Turtle Point (+80,000 cy) and erosional at West Beach (–7,346 cy) and Kiawah spit (–743,600 cy). Cumulatively, the area west of the Kiawah Beach Club lost 670,900 cy (–19.6 cy/ft) over the past year. This compares to a gain of

~150,700 cy over the previous year. Over the past year, 18 of the 35 profiles east of new Captain Sams Inlet in downcoast reaches gained sand.

[A gain of 4.3 cy/ft/yr (1999-2014 accretion rate) is roughly equivalent to a beach widening of 6-7 ft/yr in settings like Kiawah Island, where DOC is relatively shallow (Kana et al 2013). Over the 15-year period (1999-2014), this rate of sand accumulation has widened Kiawah's beach by an average of roughly 100 ft. Relocation of Captain Sams Inlet in 2015 has skewed erosion values in the downcoast reaches.]*

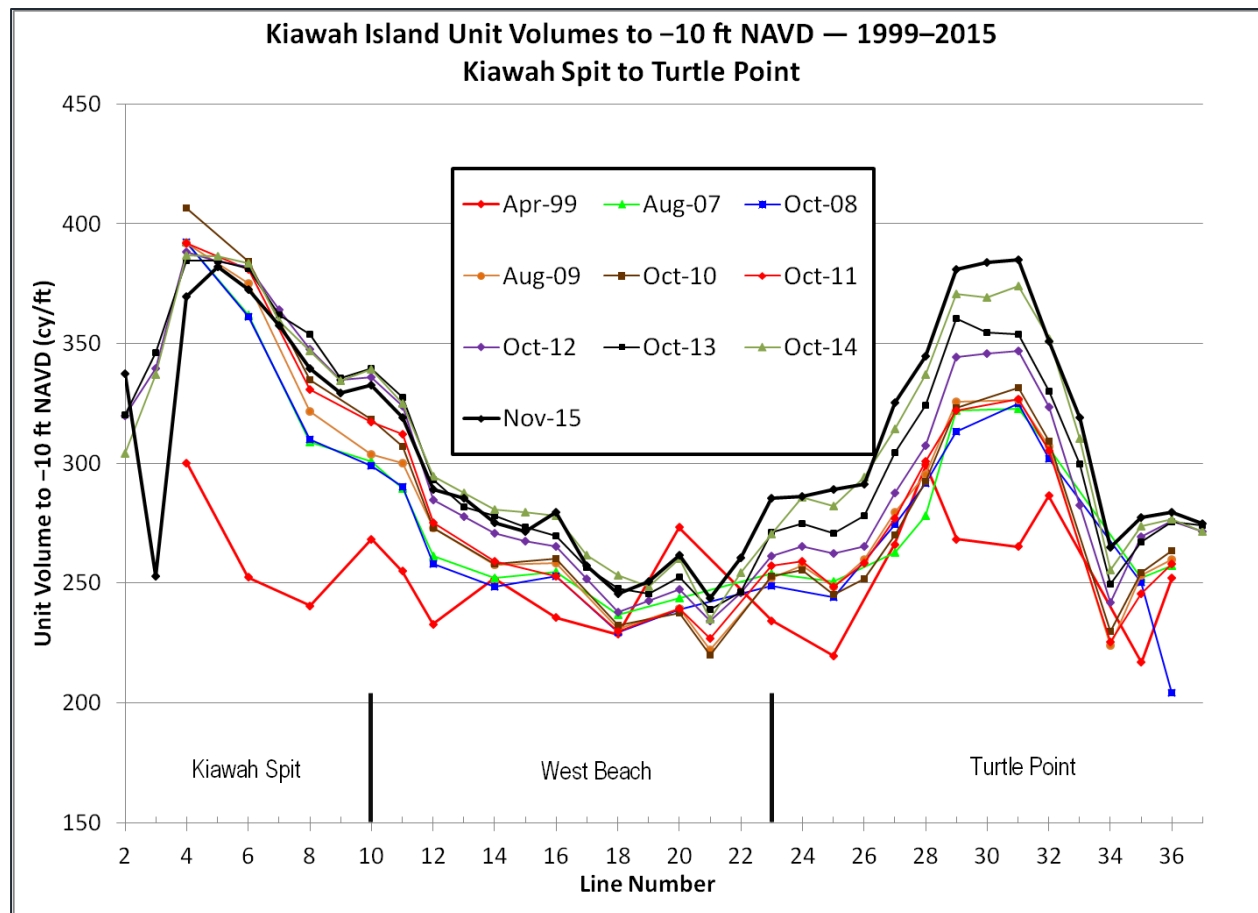


FIGURE 4.25. Unit volumes in the downcoast reaches between 1999 and 2015. Only Line 20 shows a volume presently lower than the 1999 condition. (Lines 1 and 2 are on the Seabrook side of Captain Sams Inlet following the 2015 relocation project.)

4.3.1 Turtle Point Reach

The Turtle Point Reach extends 13,614 ft from Line 23 (16th hole of Turtle Point Golf Course) to Line 38 (Kiawah Beach Club). The reach was fairly stable from 2007 to 2011, showing yearly unit volume changes ranging from -4.2 cy/ft to +4.0 cy/ft. The reach was much more accretional from 2011 to 2014, gaining an average of 11.3 cy/ft. The reach gained 80,000 cy (5.9 cy/ft) over the past year. Since 2007, the reach has gained 532,800 cy (39.1 cy/ft), which is a volume nearly as large as several beach nourishment projects conducted in SC. The reach has averaged 4.7 cy/ft/yr accretion, which has contributed to growing dune fields and expanding vegetation.

All stations except two within the reach gained sand over the past year up to 15.0 cy/ft. Lines 26 and 32 lost 2.9 and 0.8 cy/ft, respectively. Profiles from the Turtle Point Reach (Fig 4.26) show that at the time of the survey, sand was eroded from the high beach (+5 ft NAVD) and deposited lower in the profile (-3 ft to -5 ft NAVD). This is typical of a "winter" or "storm" beach profile that has experienced larger wave action. Despite the erosion of the high beach and escarpment along the toe of the dune, there was no complete loss of the primary dune.

Ground photos (Fig 4.27) show an escarpment 2-3 ft high along the eastern and western ends of the reach, and a smaller scarp along the central portion of the reach. The Town reported a small breach in the primary dune line between boardwalks 38 and 39 that occurred during Hurricane *Joaquin* in early October 2015 (Fig 4.27). CSE advised the Town that the area will infill naturally over time, though sand from an upland source could be placed along the dune line to facilitate faster recovery should the Town elect to do so.

Beach profiles show dune heights range between +10 ft NAVD and +15 ft NAVD (note data may not extend to the highest dune due to vegetative cover or difficulty accessing densely vegetated areas). In the central portion of the reach, the dune line has moved over 100 ft seaward since 1999. At the east and west ends of the reach, the dune line has grown ~50 ft seaward since 1999. A wide and relatively-low-elevation dune field exists throughout the reach (Fig 4.28).

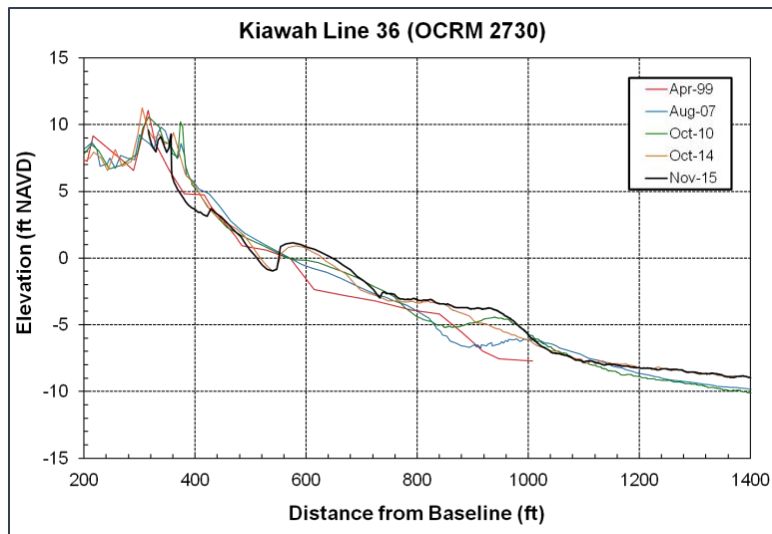
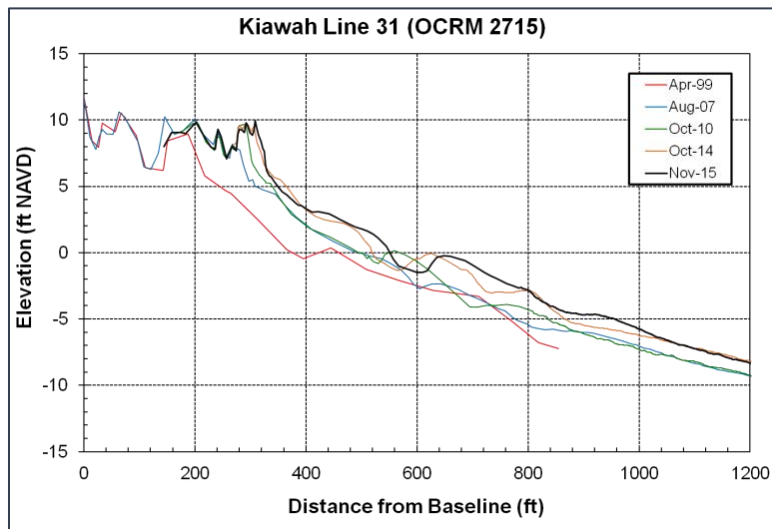
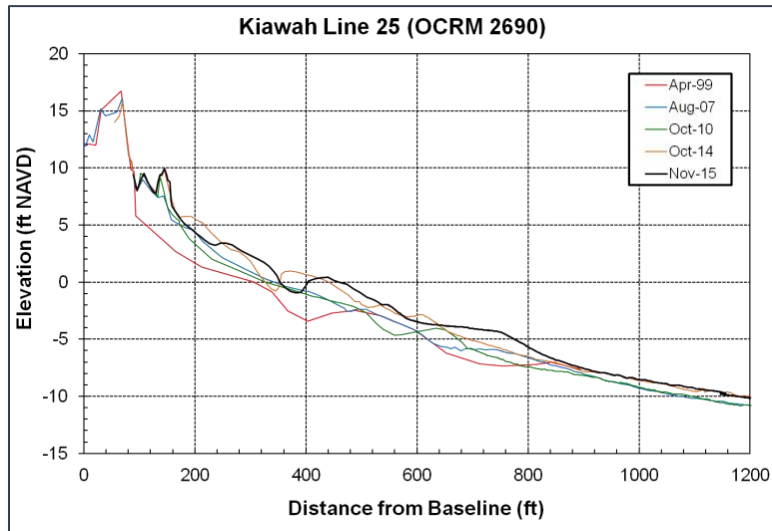


FIGURE 4.26. Profiles from the Turtle Point Reach. Over the past year, most of the profiles lost sand along the upper beach, but gained sand in the lower profile. This is typical of winter or storm profiles.



FIGURE 4.27. Ground photos from November 2015 of the Turtle Point Reach. Line 24 looking east (upper left). Line 30 looking east (center right). Line 35 looking east (center left). The dune breach between Lines 33 and 34 (lower).



FIGURE 4.28. January 2016 aerial images of the Turtle Point Reach. **[UPPER]** The west end of the reach, just north of the Turtle Point golf course. **[CENTER]** The central area of the reach with the arrow showing the location of the Hurricane *Joaquin* dune breach, which has filled in with dead marsh grass and sand. **[LOWER]** The area just west of the Kiawah Beach Club.

4.3.2 West Beach Reach

West Beach Reach encompasses the beach between Lines 10 and 23 (Sand Alley to the 16th tee of Turtle Point Golf Club). Historically, this reach has been fairly stable compared to remaining reaches. Although the reach 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 3.8 cy/ft of sand from 2007 to 2008, but accreted during every monitoring interval between 2008 and 2014. Over the past year, the reach was fairly stable, but had a net loss of 7,350 cy (0.6 cy/ft). Volume change within the reach ranged between -8.1 cy/ft and +8.7 cy/ft. Generally, the western half of the reach was erosional while the eastern half accreted. Lines 10 through 15 lost an average of 5.7 cy/ft while Lines 16 through 23 gained an average of 2.8 cy/ft. Overall, the reach has gained 211,300 cy (17.9 cy/ft) of sand since 2007, and 302,100 cy (25.6 cy/ft) since 1999.

Profiles from the reach (Fig 4.29) show similar changes as the Turtle Point Reach with erosion of the high-tide beach, escarpment of the toe of the dune, and buildup of the subtidal bar at -5 ft NAVD. The escarpment reached up to 5 ft tall in certain areas of the reach (Fig 4.30). While structures in this area have the least setback of any area on the island, there remains a substantial dune and buffer fronting each property. Based on the historical accretion trend measured along the reach and the measured accretion upcoast, CSE expects the beach to recover during calmer weather. The dune escarpment will heal under lower wave conditions typical of spring and summer months.

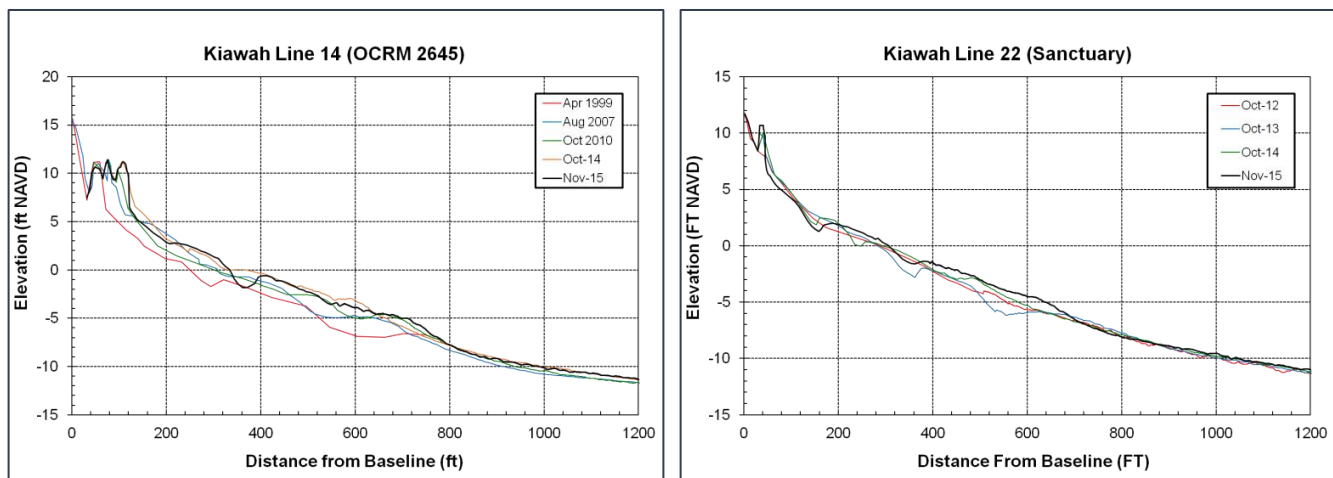


FIGURE 4.29. Profiles from Line 14 and Line 22 in the West Beach Reach. Line 14 lost 5.5 cy/ft while Line 22 gained 5.9 cy/ft over the past year.

FIGURE 4.30.

November 2015 ground photos and January 2016 aerial photos of the West Beach Reach.

Clockwise from top right – (1) Line 11 looking east. (2) Line 22 near the Sanctuary looking west. (3) Aerial of the eastern end of the reach. (4) Aerial of the western end of the reach. (5) Line 18 looking east.



4.3.3 *Kiawah Spit Reach*

The Kiawah Spit Reach encompasses the downdrift end of the island. It acts as a collection site for sand transported by longshore currents from upcoast areas. 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.

Previous shoreline monitoring reports by CSE referenced three OCRM monuments in this reach. CSE has added six additional lines to better account for beach changes along the spit with the most westward line located near the 2012 position of Captain Sams Inlet. To compare equivalent shoreline segments, CSE extrapolated volume to the western end of the spit for the lines without 1999–2011 data. This was accomplished by applying the percent of volume change at the most westward line with data (Line 4) to the lines without data, beginning at the 2011–2012 change and working back in time.

For example, the 2011–2012 volume change at Line 4 was –390 cy, which is –0.03 percent of the 2011 volume. This percentage was applied to the 2012 volume at Lines 1–3 to obtain 2011 volumes for each of those lines. The 2010–2011 volume change at Line 4 was then applied to these new 2011 volumes for Lines 1–3 to provide new 2010 volumes, and so on. While the method is obviously limited in accuracy, it does provide a rough volume estimate of the lines west of Line 4 to compare with more recent results.

As mentioned in Section 4.1.2, in June 2015, Captain Sams Inlet was relocated ~3,000 ft to the east by heavy equipment. This placed the eastern margin of the inlet ~450 ft west of Line 3. Any sand volume previously associated with Kiawah Island between Lines 1 and this point is now considered to be part of Seabrook Island. This resulted in a dramatic loss in sand volume in the reach over the past year.

Between October 2014 and November 2015, the reach lost a total of 743,600 cy (84.3 cy/ft) of sand (Fig 4.31). The majority of the loss was due to the inlet recut; however, all lines on the Kiawah side of the channel lost sand, averaging 7.6 cy/ft from Line 4 to Line 10. The erosion observed over the past year continues an erosional trend along the reach which began in 2013. Overall, the reach gained 166,500 cy between 2007 and 2012, then lost 33,700 from 2012 to 2014. Despite the erosion associated with the inlet recut, the reach holds 158,000 cy (17.9 cy/ft) more sand than the 1999 condition, which was three years after the last inlet relocation in 1996.

At Line 3, ~200 ft of dune recession has occurred due to expansion of the inlet mouth following construction (Fig 4.32). This has resulted in encroachment of the water into the upland myrtle area,

and dead myrtle bushes are visible. Once the inlet returns to a natural cross-section, CSE expects sand to accumulate on the Kiawah side of the channel and begin to rebuild the spit. Line 4 also lost a measurable width of dune, but by Line 5, erosion was more associated with supply from upcoast rather than the inlet. The dune east of Line 5 was scarped much like the rest of the front beach; however, little loss was observed to the crest of the dune (Fig 4.32).



FIGURE 4.31. January 2016 aerial images of the Kiawah Spit Reach. Captain Sams Inlet was relocated ~3,000 ft east in June 2015.

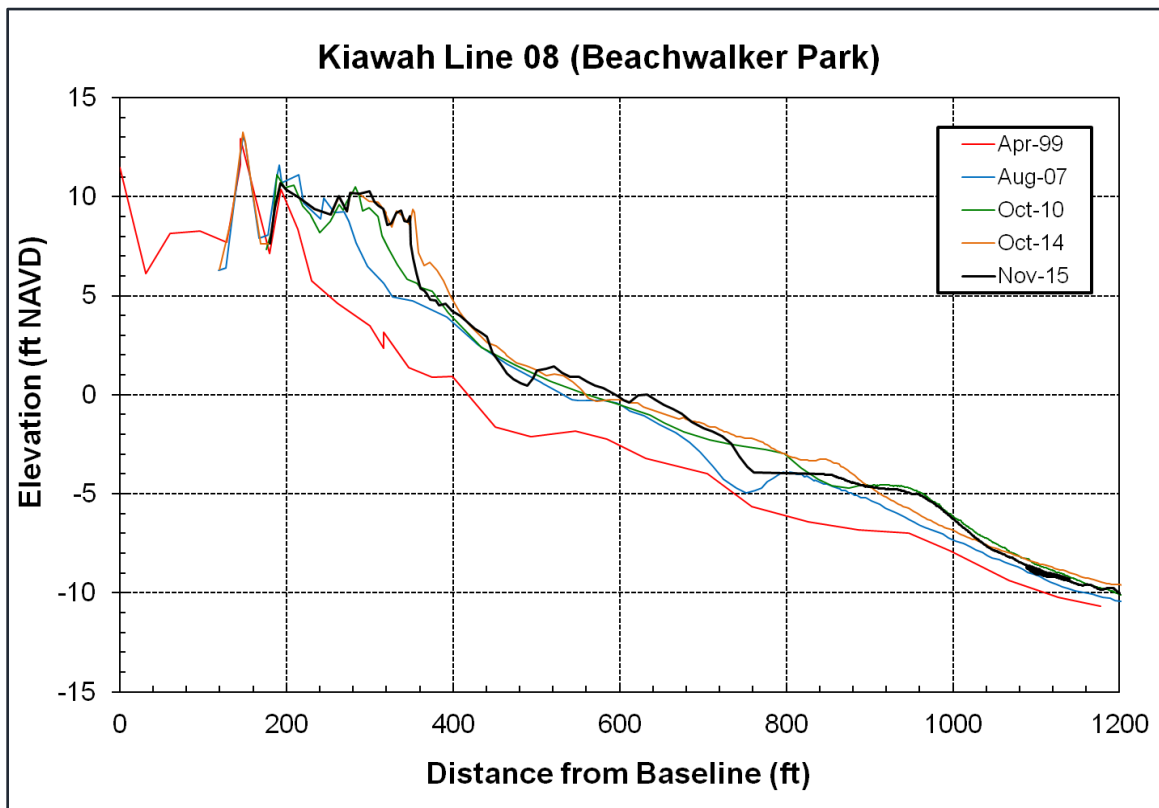
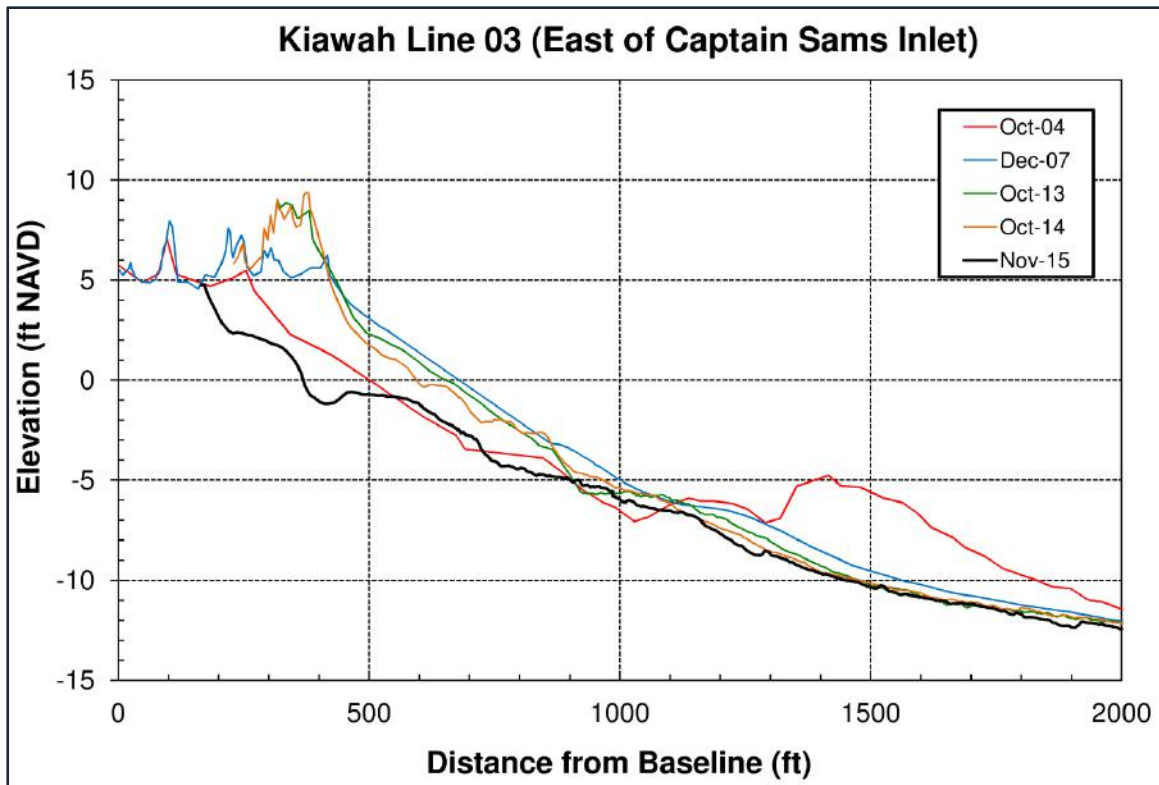


FIGURE 4.32. Profiles from the Kiawah Spit Reach.



FIGURE 4.33. Ground photos from November 2015 of the Kiawah Spit Reach. **[UPPER]** Adjustment of the new inlet channel has resulted in erosion of the beach into the myrtle thicket at Line 3. **[CENTER]** Line 6 looking east. **[LOWER]** View east from Line 8 near Beachwalker Park.

5.0 Summary of Findings

The 2015 monitoring survey, conducted in early November, is the ninth annual monitoring event since completion of the 2006 beach restoration project and the first following the 2015 channel realignment project. It is also the first survey since Captain Sams Inlet was relocated by the SIPOA in June 2015. Data suggest that the two projects are continuing to adjust by increasing channel width, collapse of delta shoals, and onshore migration of those shoals.

In addition to these projects, Hurricane *Joaquin* impacted the beach in early October 2015, creating severe erosion and overwash along the lagoon, escarpments along the entire beachfront, and a small dune breach along the center of the island. The Town-sponsored project at the eastern end held up well during Hurricane *Joaquin* and is progressing as anticipated with intertidal sand moving up the beach. CSE expects this process to continue over the next few years, which will restore much of the eroded area in front of the Ocean Course driving range. The new channel needs to be monitored regularly to anticipate future problems or the need for another relocation effort.

Cumulatively, the island was erosional over the past year, losing a total of 901,000 cy (15.7 cy/ft). The majority of the erosion was due to the "shortening" of the island by the Captain Sams Inlet relocation. Historically the spit has grown at a rate of 200–300 ft/yr, and CSE anticipates this growth to begin over the next year. The migration rate will likely be lower in the first few years due to the presence of the marsh on the landward side of the channel. The Lagoon Reach also eroded significantly along the eastern shoreline of the lagoon, which lost up to 300 ft in certain areas. The Lagoon Reach continues to harbor extensive washover and intertidal flat habitats thought to be suitable for endangered species. The Town has contracted with SCDNR to conduct piping plover and benthic invertebrate surveys in the lagoon area.

Most of the island's beach-fronting structures had an erosional escarpment in November 2015 due to higher than normal tides and storm events. Despite this, Turtle Point Reach gained sand, and West Beach Reach showed only minimal erosion. Ocean Course Reach was erosional along most of the beach-fronting holes 14 through 18, but gained sand where the old channel delta remains just west of the clubhouse.

The 2014–2015 timeframe included several significant events as mentioned above. Despite the dramatic changes, the island continues to be one of the healthiest beaches along South Carolina's coast. Efforts made to study the coastal processes and the erosional history of the island prior to development have proven effective in protecting the developed areas of the island. Monitoring the beach changes along the entire beachfront is critical in understanding the temporary shifts in sediment transport and planning for future needs. While monitoring of any sort entails some cost, its value lies in prediction of localized problems such as the events that led to the 2015 project. CSE is scheduled to repeat annual monitoring efforts in fall of 2016.

— *THIS PAGE INTENTIONALLY LEFT BLANK* —

6.0 References and Bibliography

- 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.
- 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.
- 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.
- 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 Cntr Inc, Columbia, SC, 165 pp.
- 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.

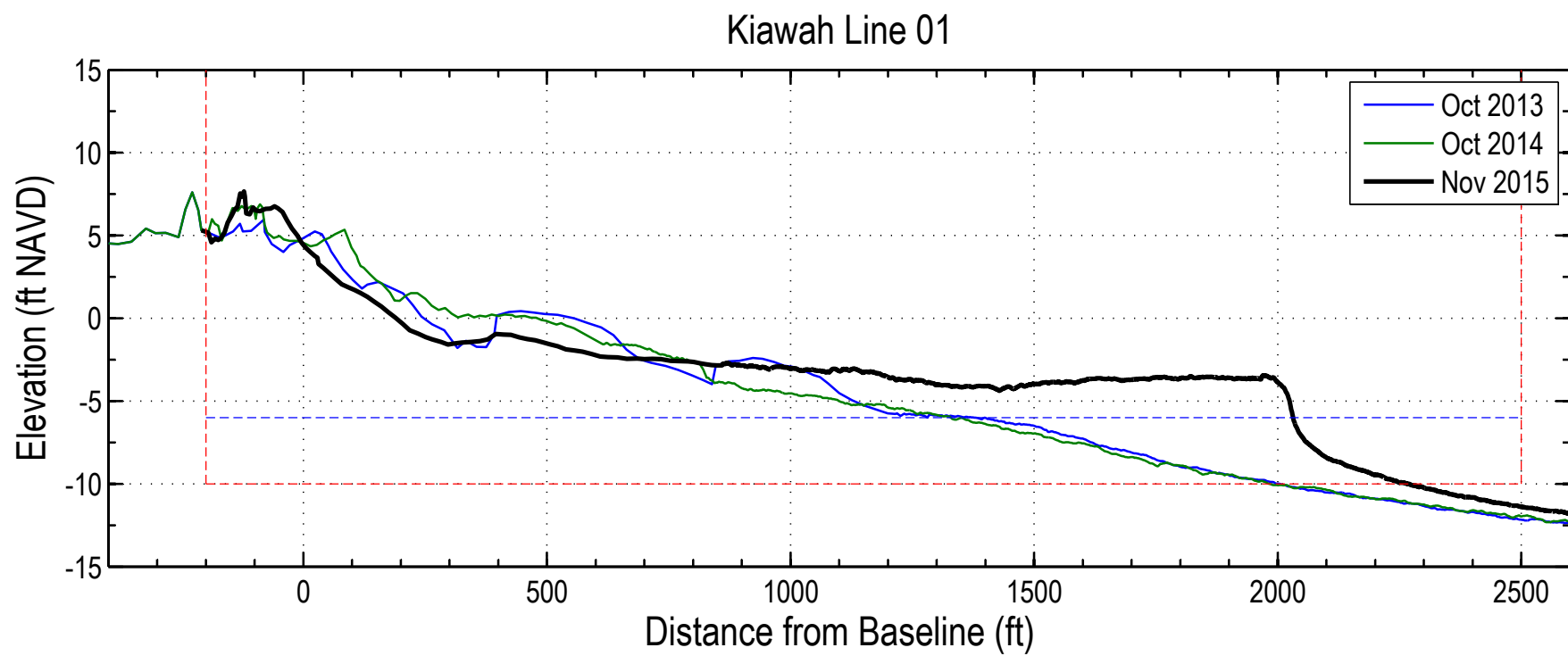
- Jones, CP. 1989. Summary of proposed revisions to interim baseline and setback line at Kiawah Island. Final Report, Kiawah Resort Associates, Charleston, SC. CSE, Columbia, SC, 31 pp., appendix, attachment.
- Kana, TW. 1993. The profile volume approach to Beach Renourishment. In DK Stauble, and NC 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 Gaudiano, HL Kaczowski, and T Hair. 2013. The physical condition of South Carolina beaches 1980–2010. Jour Coastal Research, Special Issue 69, pp 61-82.
- Katmariam, 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.
- 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.
- 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.
- 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, GW. 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.

7.0 Acknowledgments

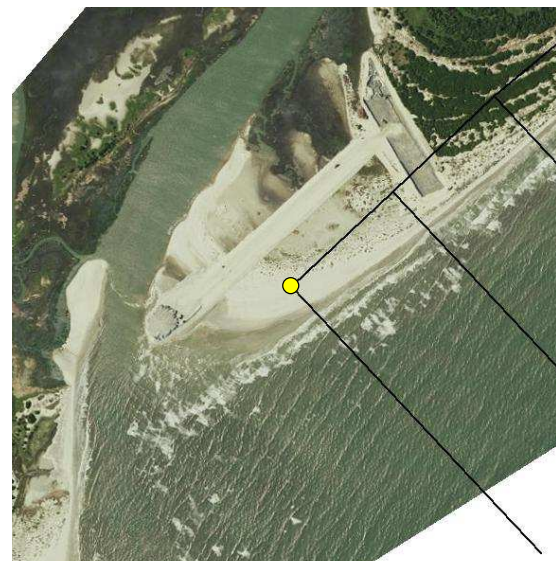
This report is the ninth in a series of annual beach monitoring reports following the 2006 east end beach restoration project, and first following the 2015 channel relocation project, which were sponsored by the Town of Kiawah Island.

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

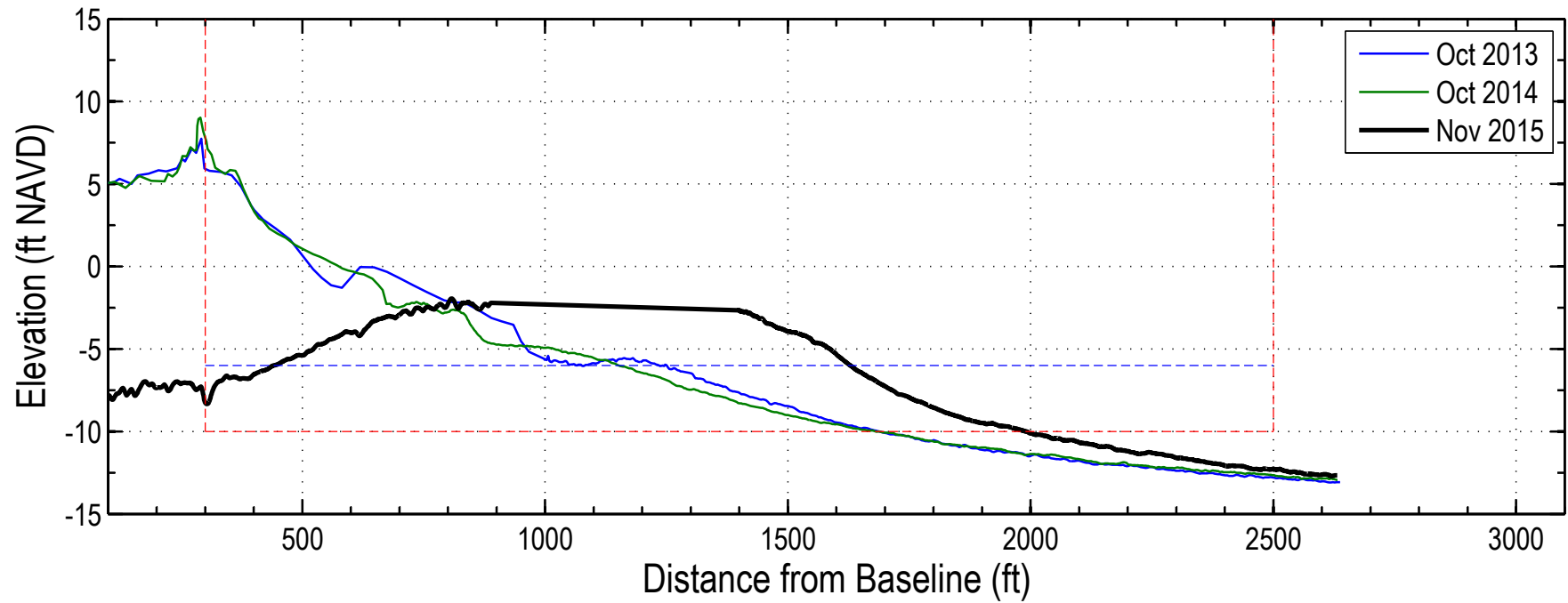
CSE's field surveys were directed by Drew Giles with assistance by Luke Fleniken, Steven Traynum, and Trey Hair. Data reduction and analysis were accomplished by Steven Traynum and Drew Giles with assistance by Trey Hair and Dr. Tim Kana. The report was written by Steven Traynum with production assistance by Diana Sangster and Trey Hair.



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	307.6	294.3	601.9
Oct 2013	297.8	279.9	577.7
Oct 2014	302.3	274.3	576.6
Nov 2015	353.0	341.4	694.4



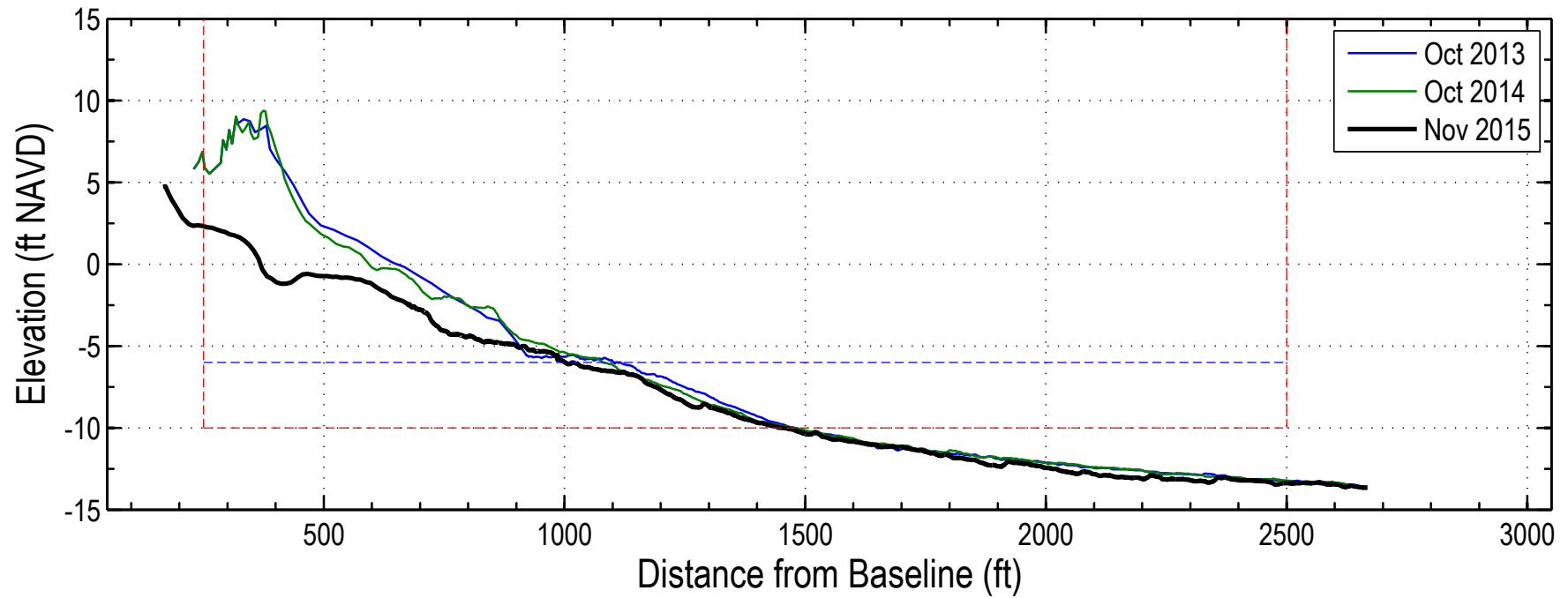
Kiawah Line 02



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	140.1	179.7	319.8
Oct 2013	150.3	169.9	320.2
Oct 2014	143.7	160.5	304.2
Nov 2015	123.9	213.5	337.4



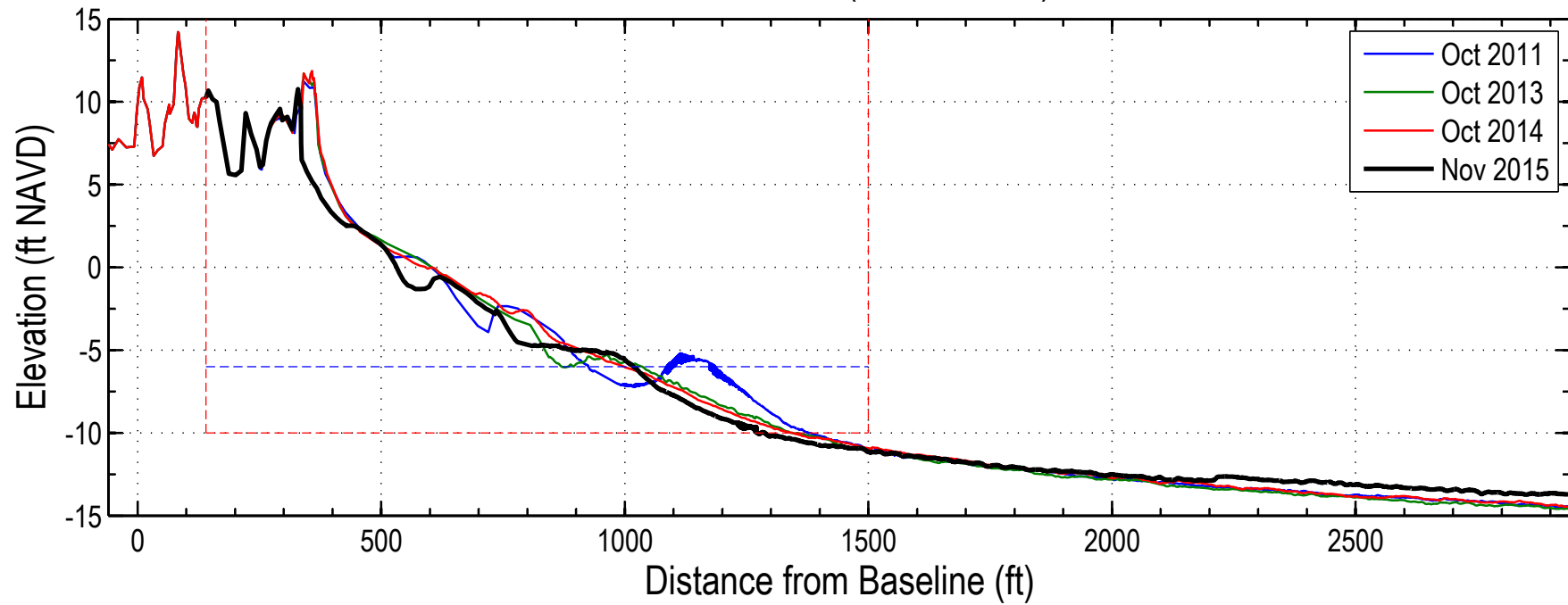
Kiawah Line 03



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	184.6	155.1	339.7
Oct 2013	191.8	154.3	346.1
Oct 2014	187.5	149.5	337.0
Nov 2015	107.4	145.4	252.8



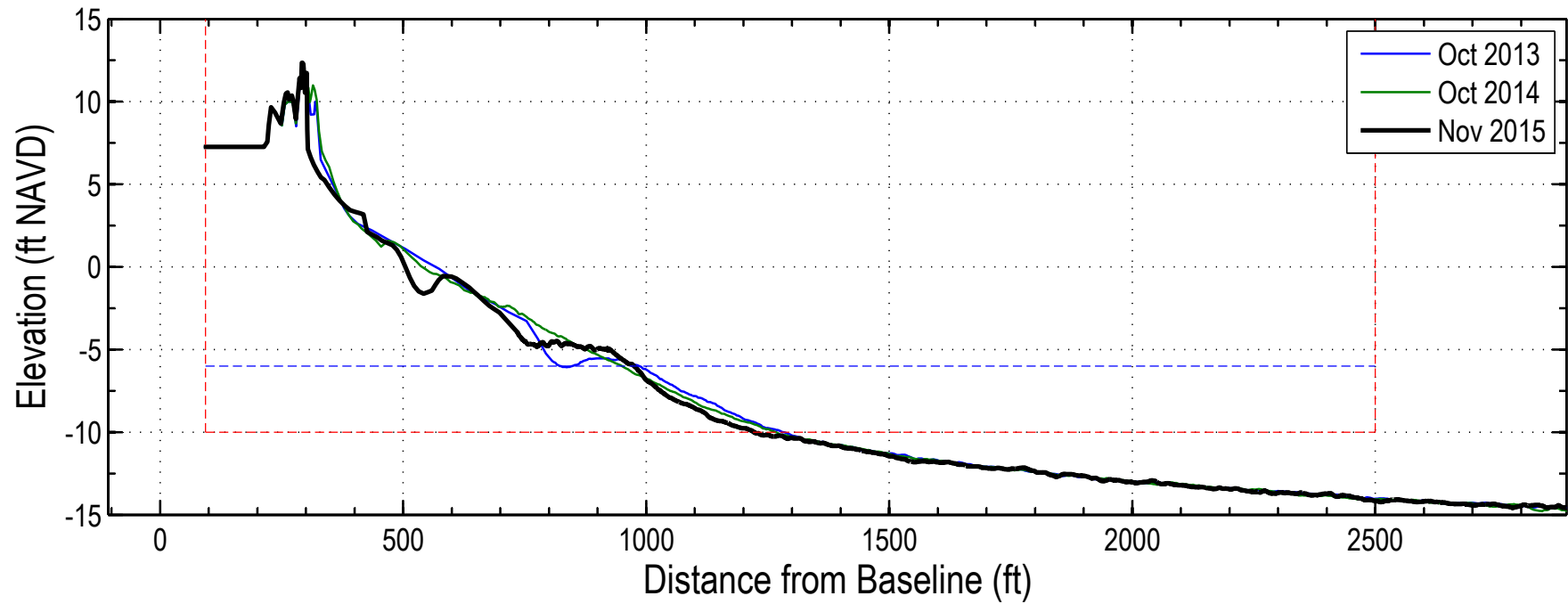
Kiawah Line 04 (OCRM 2615)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	236.0	156.4	392.4
Aug 2009	233.0	158.8	391.9
Oct 2010	249.6	157.1	406.7
Oct 2011	230.0	162.1	392.1
Oct 2012	234.6	153.6	388.2
Oct 2013	230.7	154.0	384.7
Oct 2014	235.9	151.1	387.0
Nov 2015	214.7	146.2	360.9



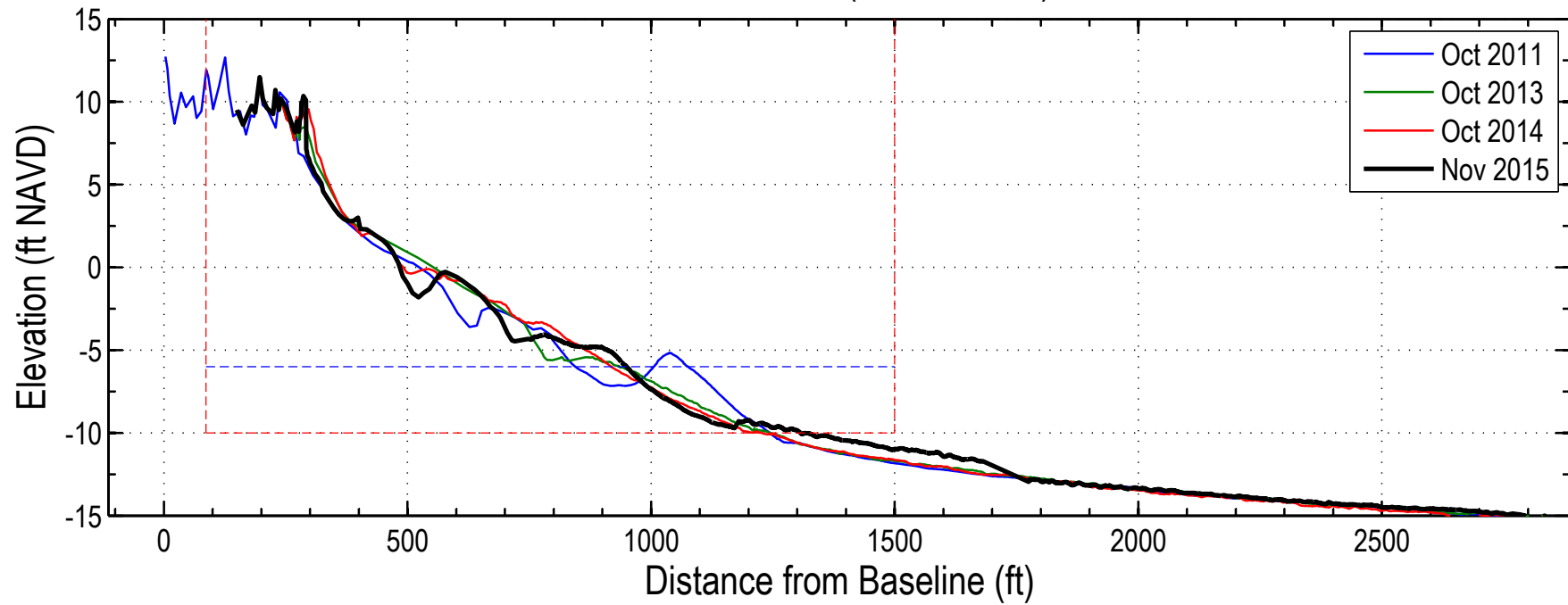
Kiawah Line 05



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	235.1	149.3	384.3
Oct 2013	232.7	151.9	384.5
Oct 2014	238.1	148.3	386.4
Nov 2015	227.3	145.0	372.2

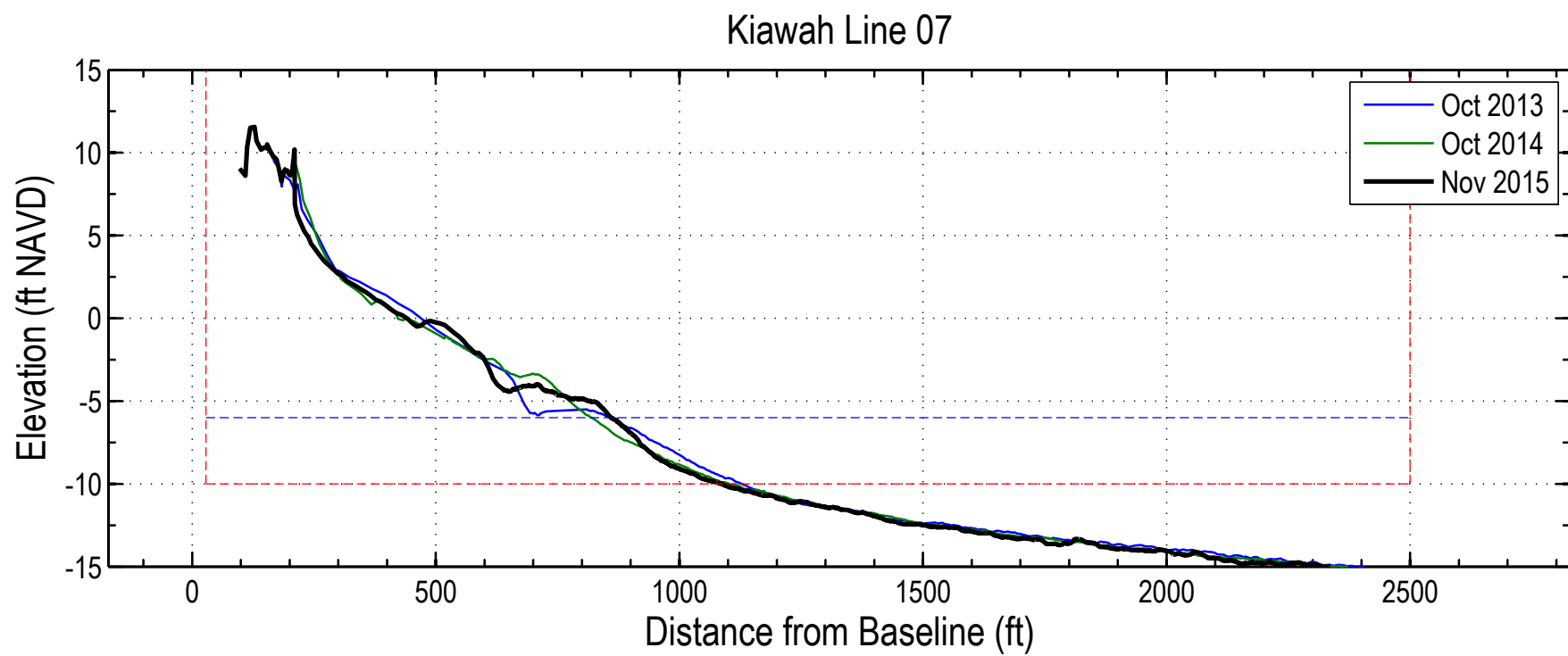


Kiawah Line 06 (OCRM 2620)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	217.9	143.9	361.9
Oct 2008	217.1	144.0	361.1
Aug 2009	229.8	145.3	375.2
Oct 2010	239.3	144.9	384.1
Oct 2011	227.2	153.7	380.9
Oct 2012	235.6	146.4	381.9
Oct 2013	234.4	147.0	381.4
Oct 2014	240.3	143.1	383.5
Nov 2015	231.5	144.1	375.6

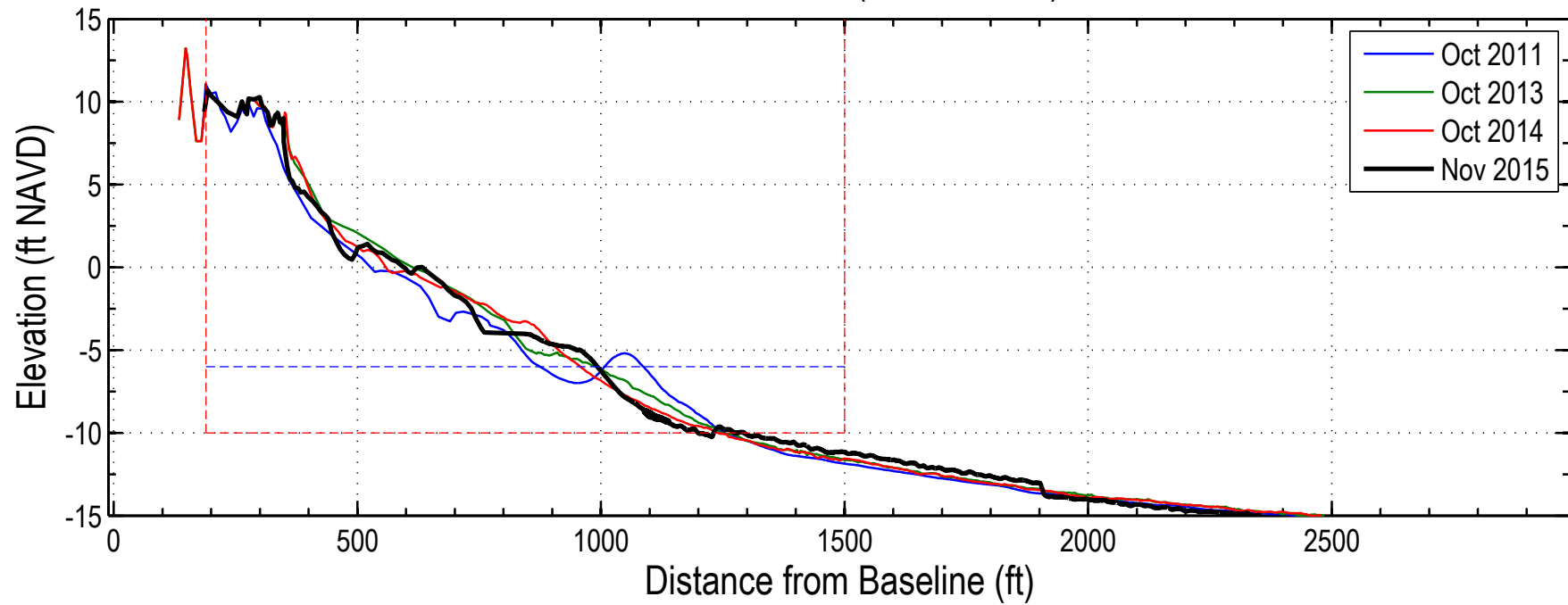




Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	224.8	139.2	364.0
Oct 2013	220.2	141.9	362.0
Oct 2014	223.9	135.5	359.4
Nov 2015	221.0	136.5	357.5



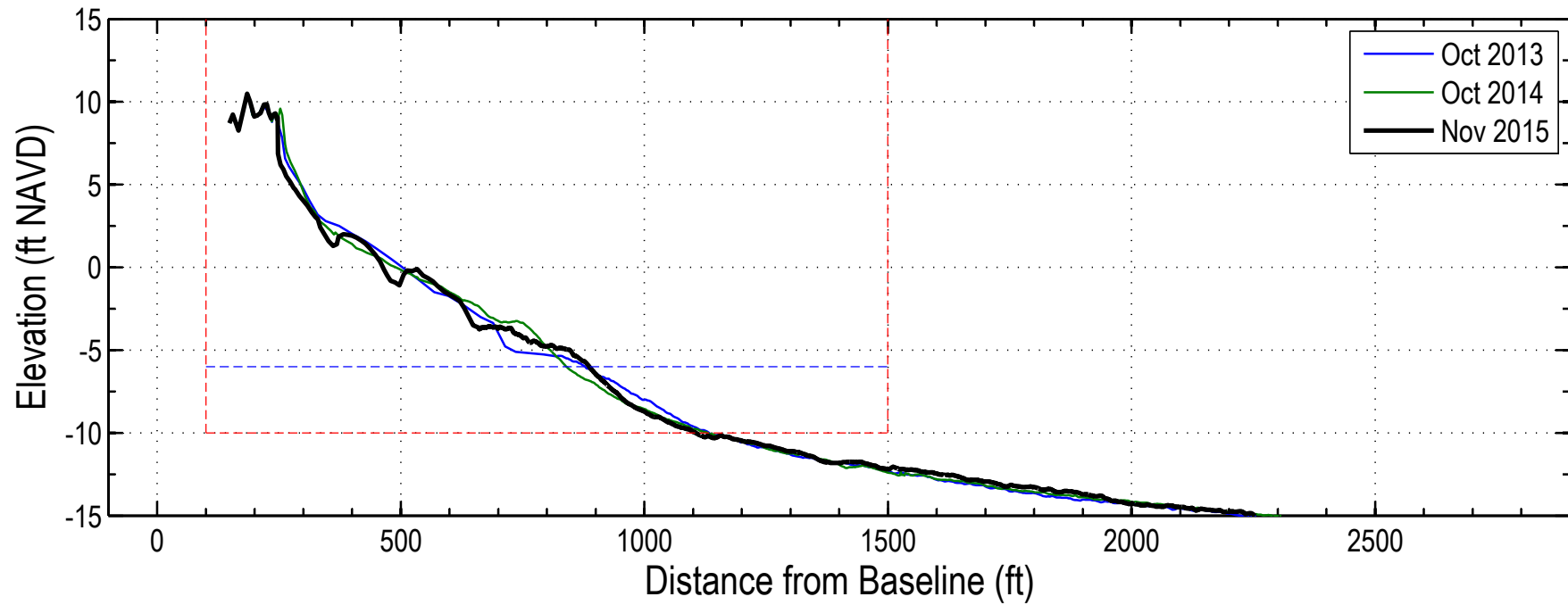
Kiawah Line 08 (OCRM 2625)



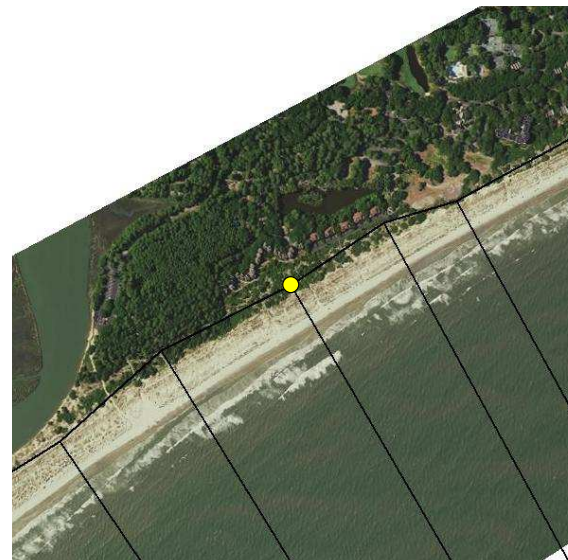
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	183.1	125.9	309.0
Oct 2008	182.2	127.7	309.9
Aug 2009	192.2	129.4	321.6
Oct 2010	202.6	132.1	334.7
Oct 2011	190.1	140.9	331.0
Oct 2012	213.0	134.6	347.6
Oct 2013	216.4	137.5	353.8
Oct 2014	215.1	131.7	346.8
Nov 2015	209.6	130.8	340.5



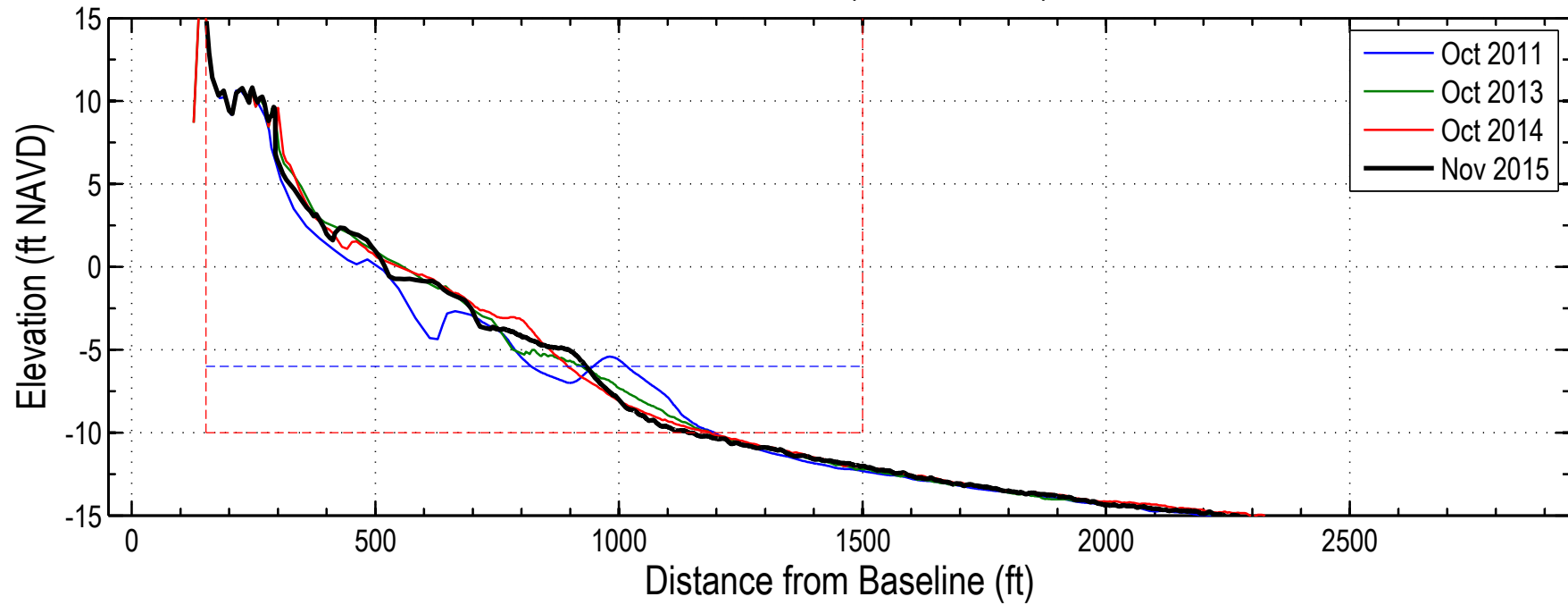
Kiawah Line 09



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	202.8	132.2	334.9
Oct 2013	202.1	133.5	335.6
Oct 2014	206.5	128.0	334.6
Nov 2015	200.0	129.3	329.3



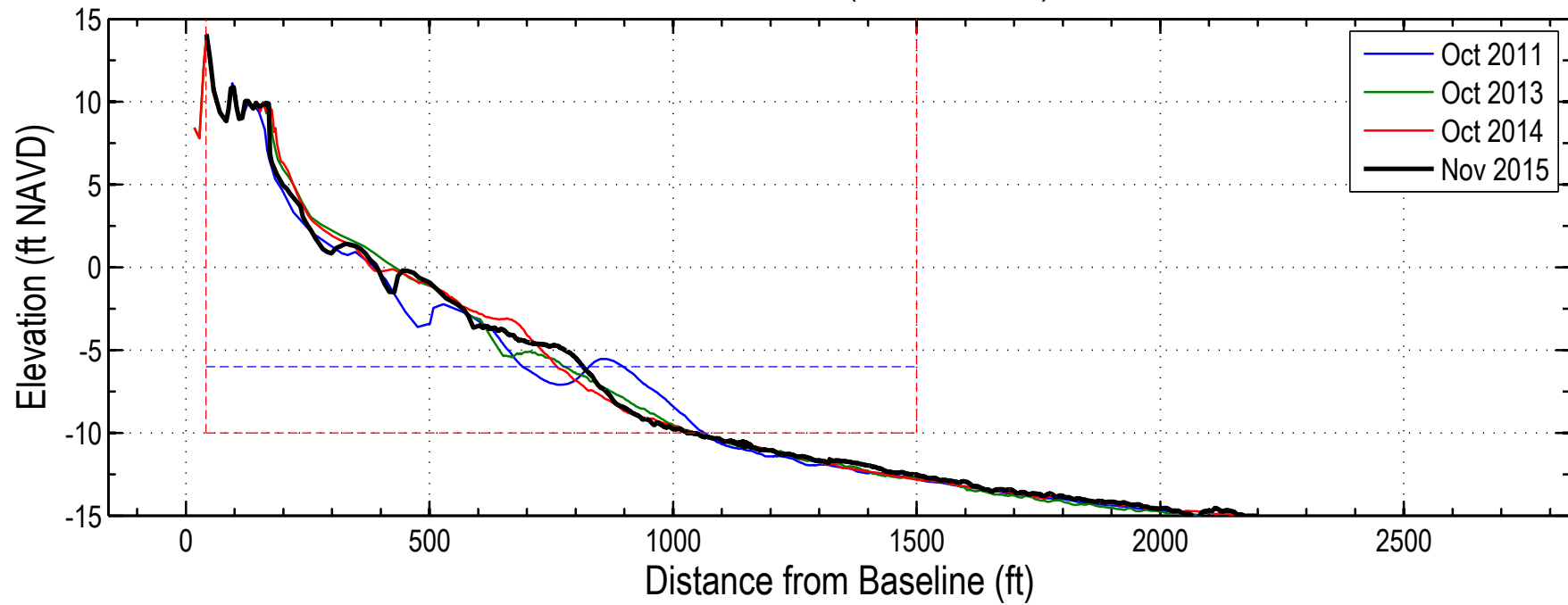
Kiawah Line 10 (OCRM 2630)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	179.6	121.2	300.9
Oct 2008	176.3	122.8	299.1
Aug 2009	181.4	122.2	303.6
Oct 2010	191.6	126.9	318.5
Oct 2011	179.5	137.6	317.1
Oct 2012	205.0	130.8	335.8
Oct 2013	207.3	132.5	339.8
Oct 2014	212.0	127.1	339.1
Nov 2015	206.4	126.9	333.3



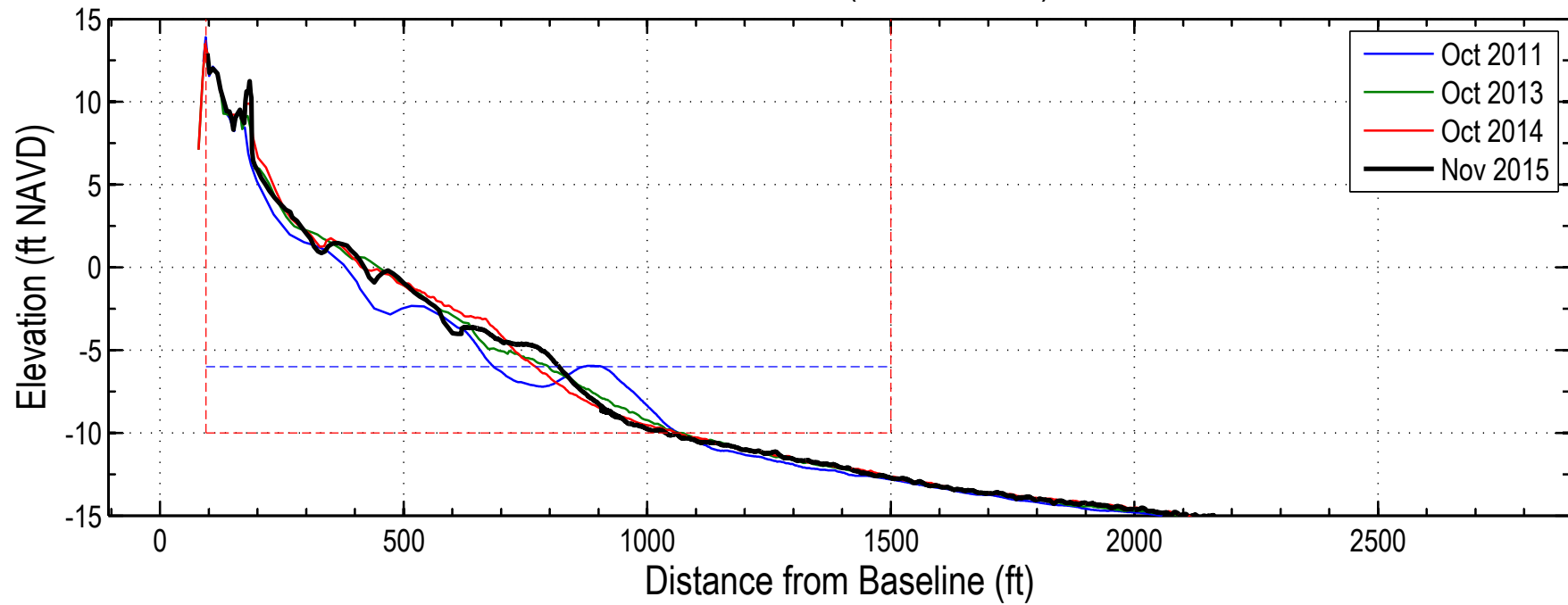
Kiawah Line 11 (OCRM 2635)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	170.2	119.1	289.3
Oct 2008	169.5	120.9	290.4
Aug 2009	176.6	123.6	300.2
Oct 2010	182.4	124.7	307.1
Oct 2011	176.3	135.9	312.3
Oct 2012	194.5	129.3	323.8
Oct 2013	196.3	127.9	324.3
Oct 2014	201.3	123.7	325.1
Nov 2015	193.9	126.1	320.0

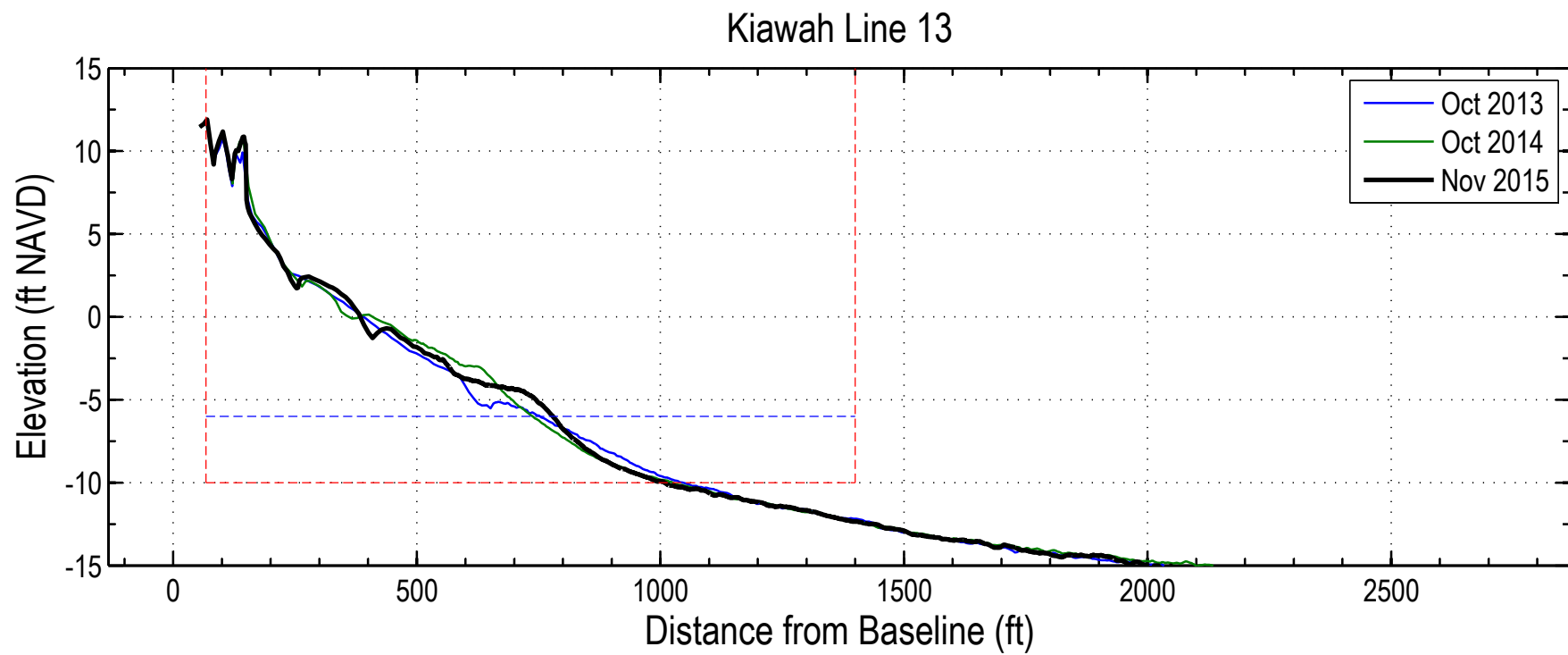


Kiawah Line 12 (OCRM 2640)

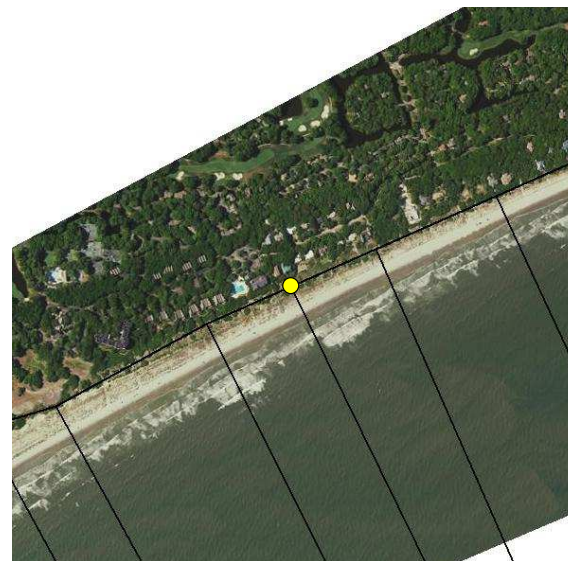


Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	147.2	113.9	261.1
Oct 2008	144.7	113.2	257.9
Aug 2009	155.8	117.3	273.1
Oct 2010	156.1	117.1	273.1
Oct 2011	148.2	127.2	275.4
Oct 2012	165.1	119.8	284.8
Oct 2013	170.7	122.4	293.0
Oct 2014	177.5	117.1	294.6
Nov 2015	173.3	119.1	292.4

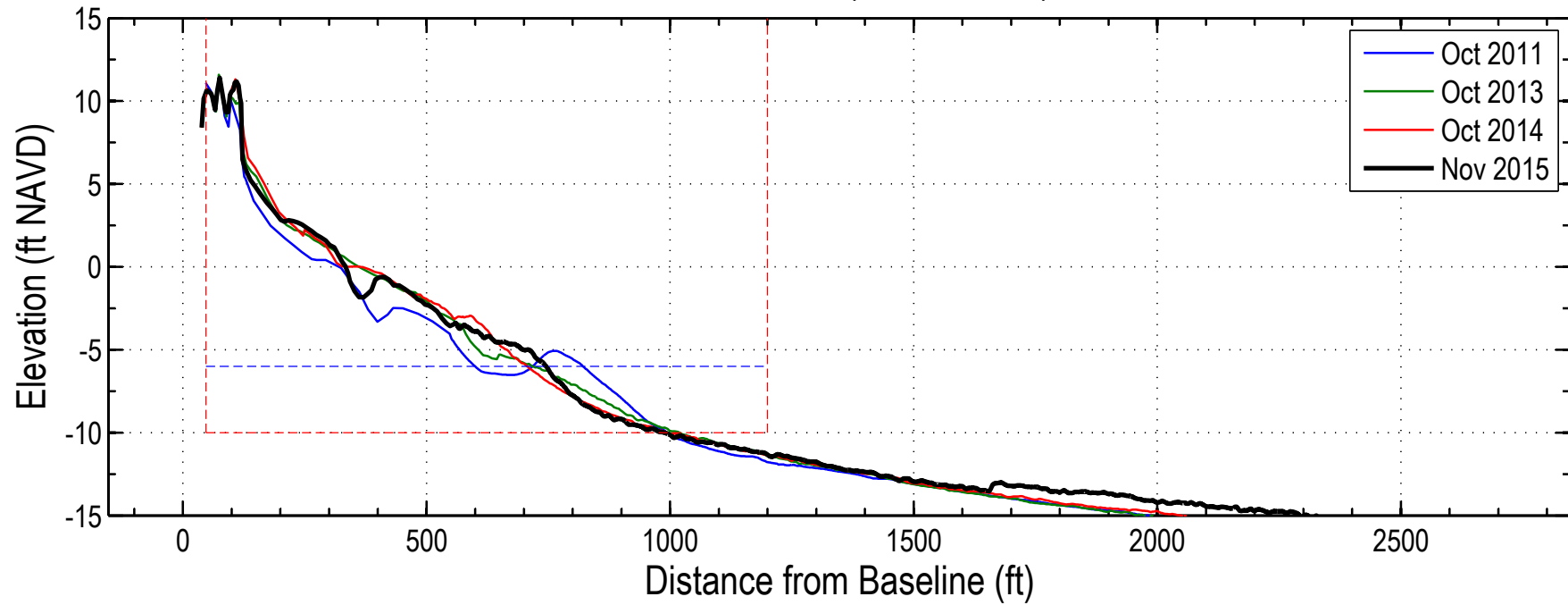




Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	159.5	118.2	277.8
Oct 2013	160.0	121.7	281.6
Oct 2014	171.4	116.4	287.8
Nov 2015	169.3	118.0	287.3

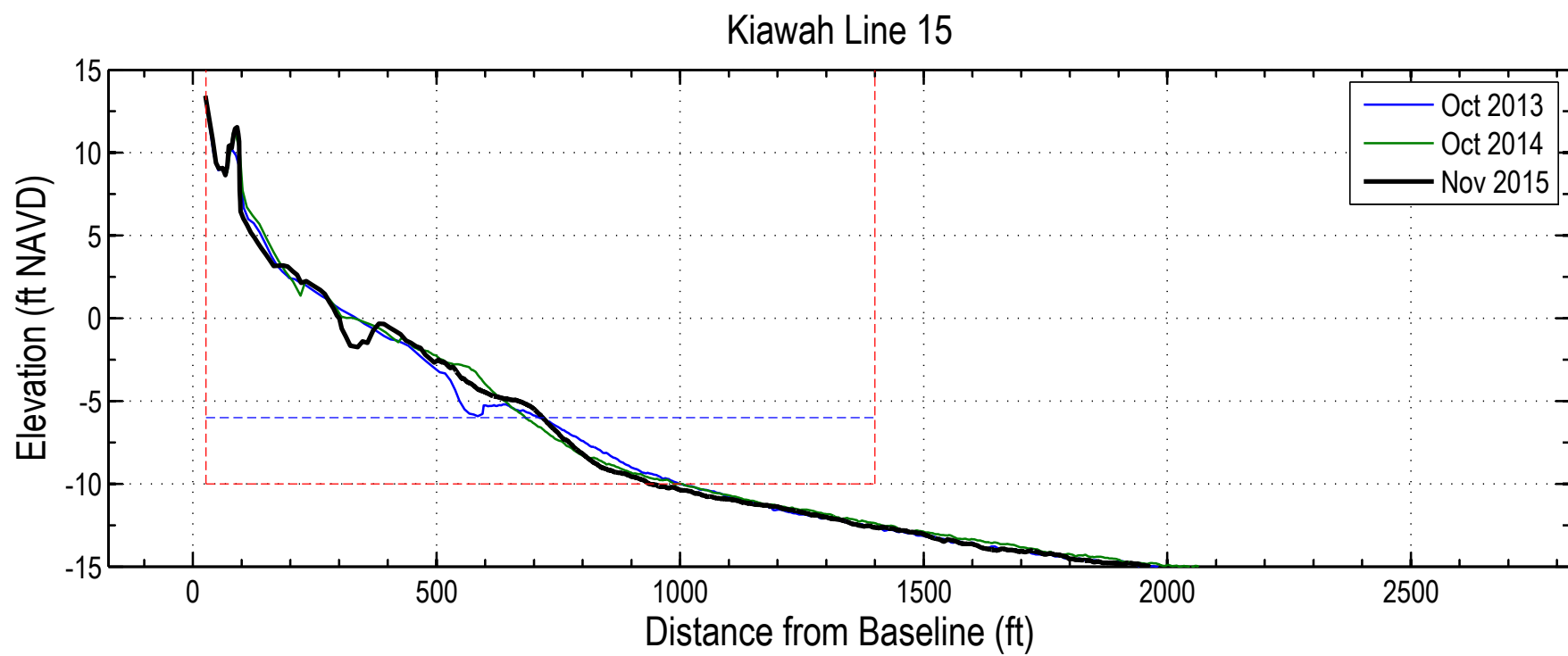


Kiawah Line 14 (OCRM 2645)



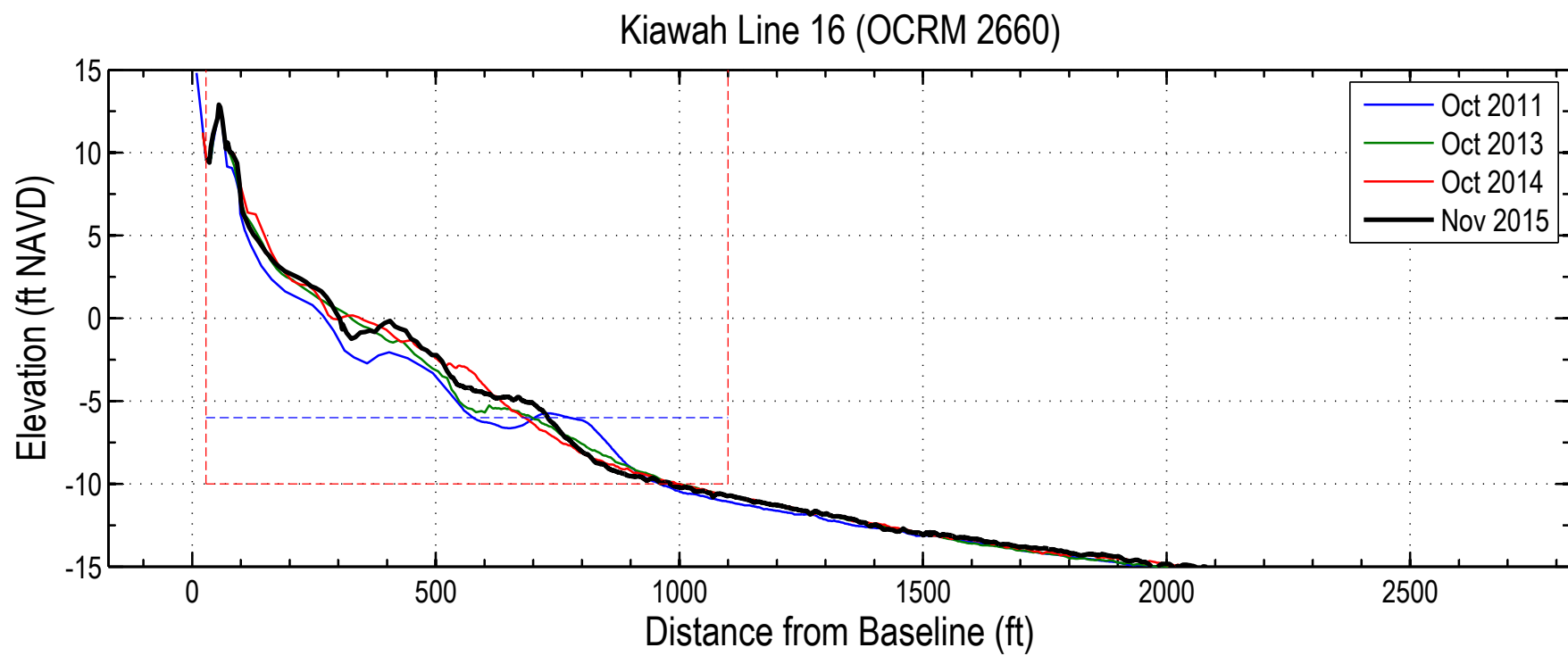
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	142.2	110.1	252.3
Oct 2008	138.4	110.0	248.5
Aug 2009	143.7	114.1	257.7
Oct 2010	144.0	114.2	258.2
Oct 2011	134.2	125.0	259.3
Oct 2012	153.8	117.0	270.7
Oct 2013	157.9	120.3	278.3
Oct 2014	165.7	115.2	280.9
Nov 2015	160.4	115.7	276.1





Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	152.0	115.4	267.5
Oct 2013	152.5	120.8	273.3
Oct 2014	164.3	115.2	279.5
Nov 2015	158.4	115.0	273.5

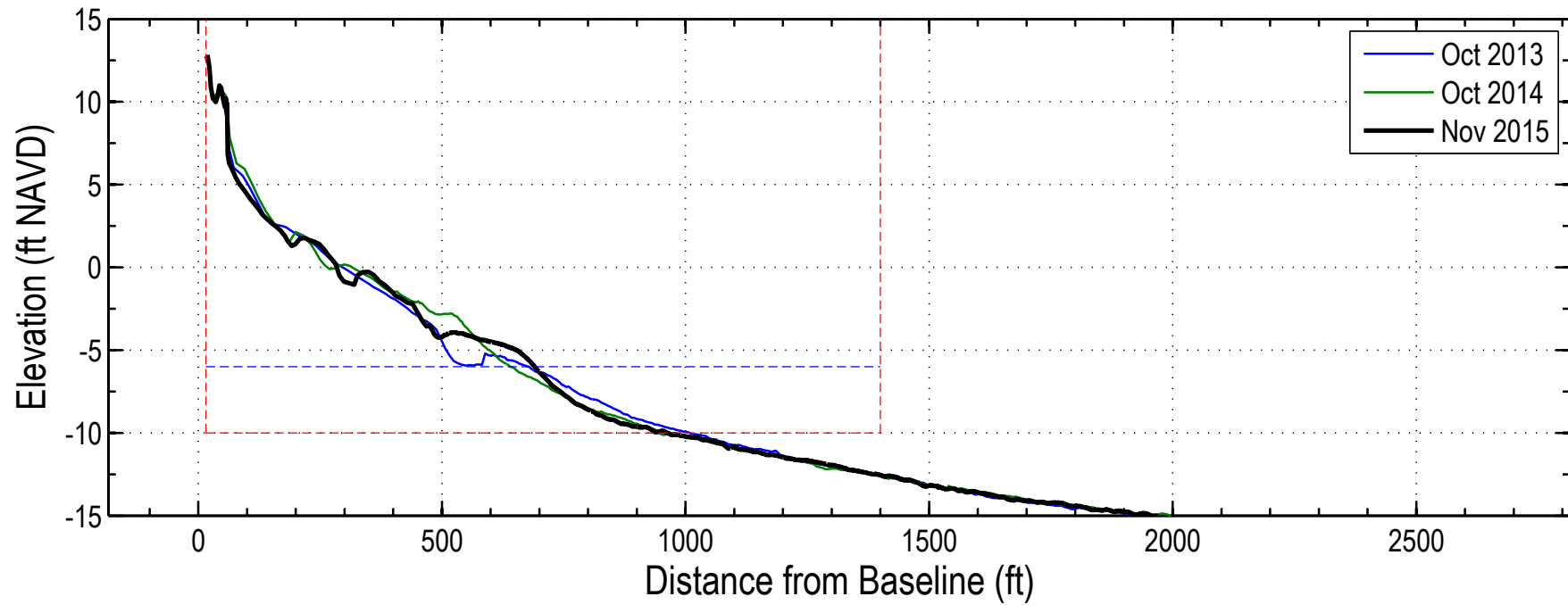




Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	142.5	112.0	254.5
Oct 2008	140.0	112.8	252.8
Aug 2009	143.8	114.5	258.3
Oct 2010	146.4	113.9	260.3
Oct 2011	130.3	122.7	253.0
Oct 2012	149.3	116.1	265.4
Oct 2013	150.5	119.1	269.6
Oct 2014	162.8	115.5	278.3
Nov 2015	161.1	116.4	277.4

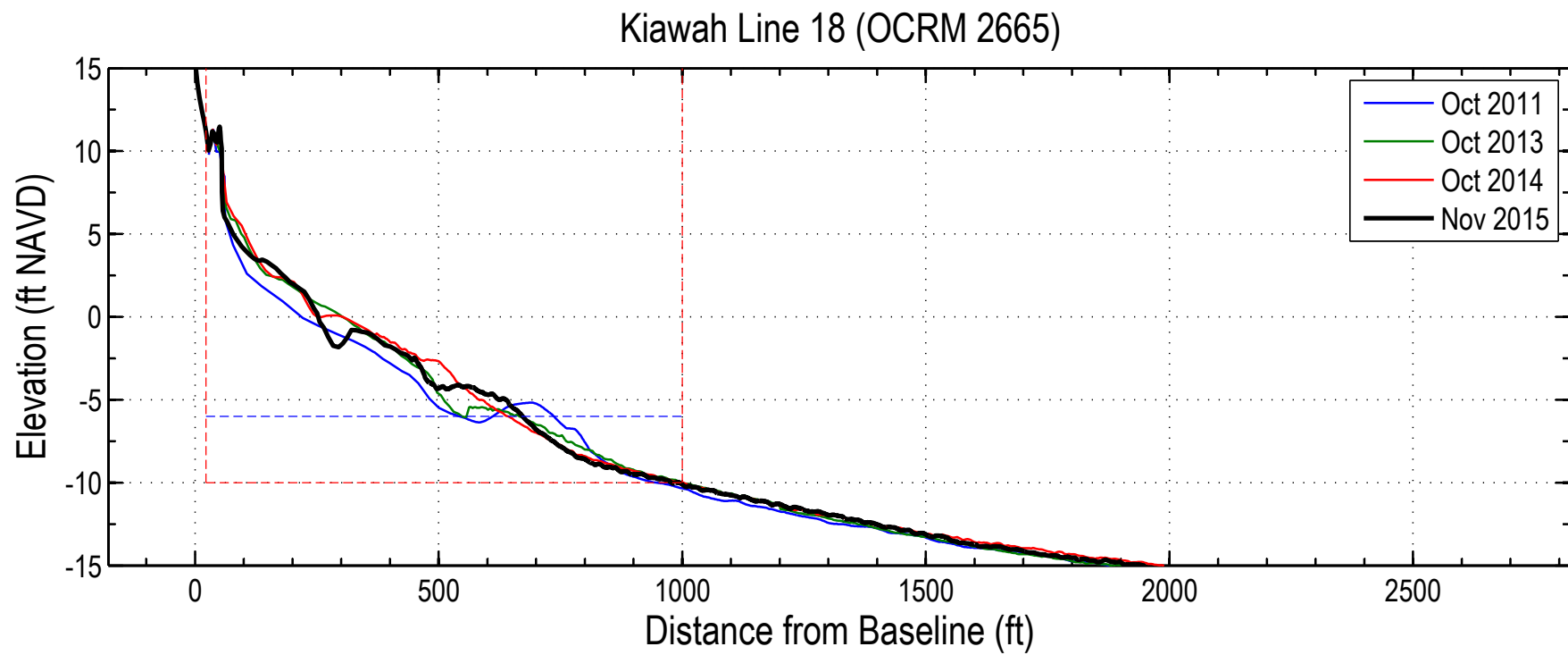


Kiawah Line 17



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	136.9	114.7	251.6
Oct 2013	137.4	119.2	256.6
Oct 2014	148.9	113.0	261.8
Nov 2015	143.7	113.6	257.3

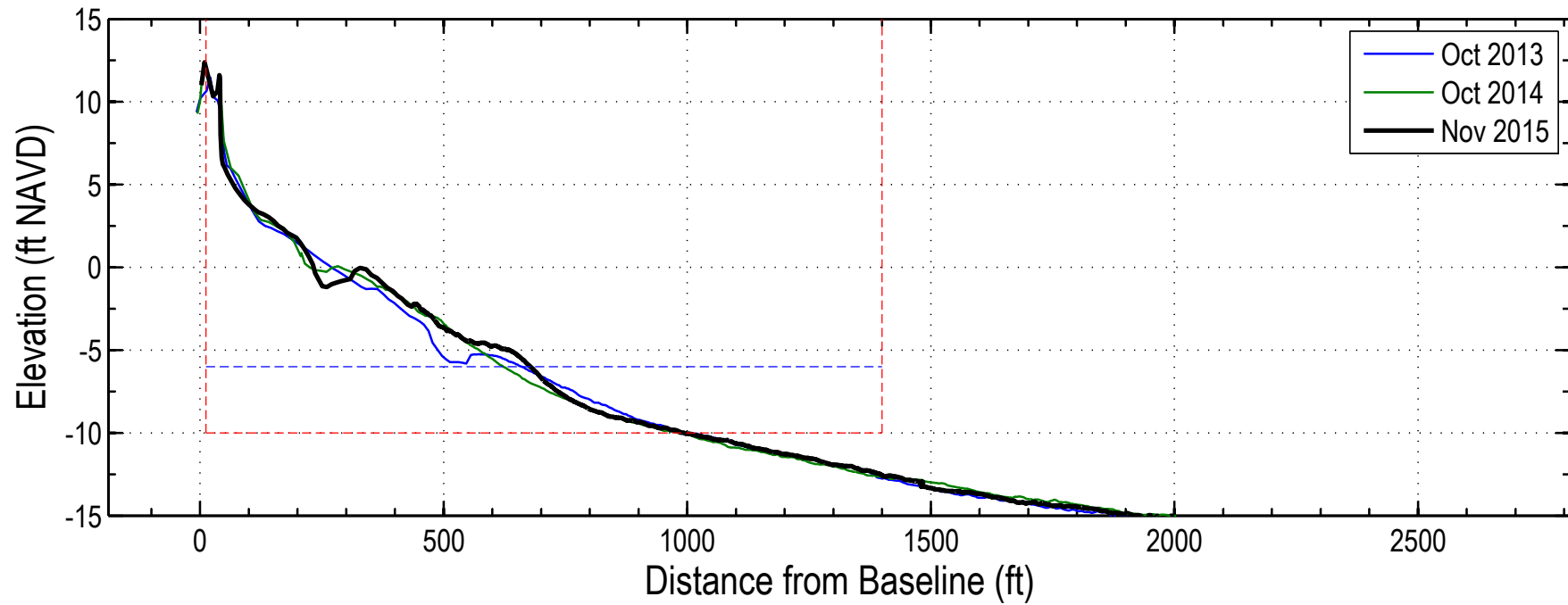




Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	125.7	111.2	236.9
Oct 2008	120.1	109.6	229.7
Aug 2009	121.3	109.8	231.1
Oct 2010	124.9	107.7	232.6
Oct 2011	112.4	117.6	229.9
Oct 2012	127.5	110.4	237.9
Oct 2013	131.1	116.8	247.9
Oct 2014	140.1	113.1	253.2
Nov 2015	133.1	112.5	245.7

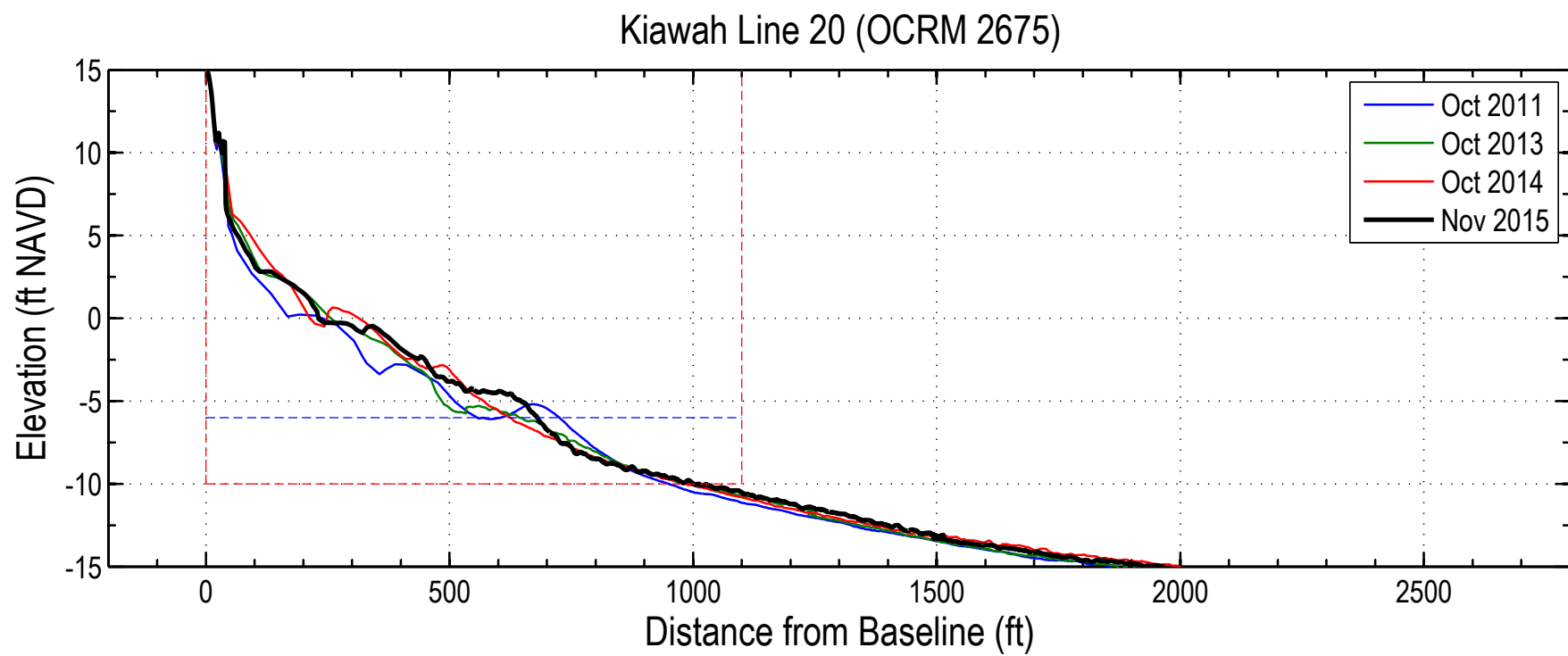


Kiawah Line 19



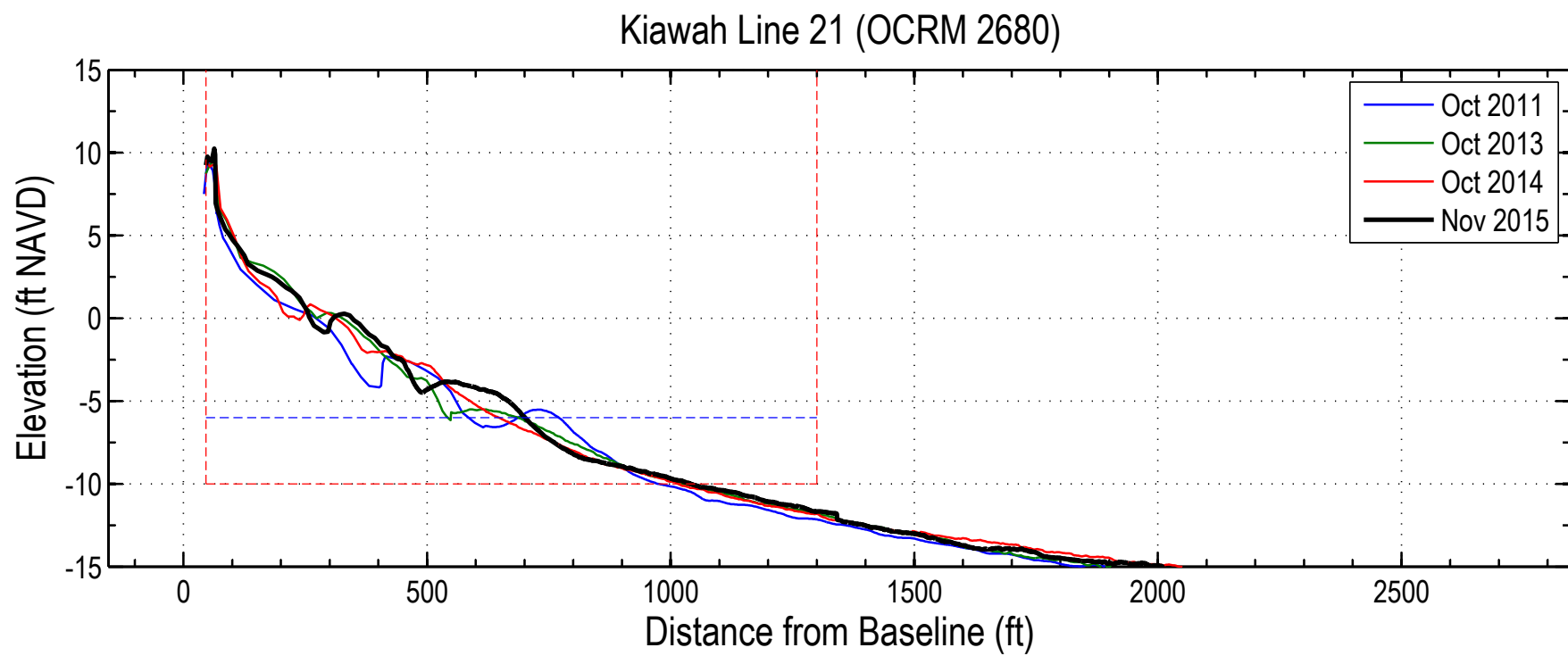
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	128.9	113.8	242.8
Oct 2013	127.4	118.1	245.5
Oct 2014	136.2	112.1	248.4
Nov 2015	137.3	114.8	252.1





Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	130.3	113.5	243.8
Oct 2008	127.8	111.2	239.0
Aug 2009	127.8	111.5	239.3
Oct 2010	128.0	109.4	237.4
Oct 2011	118.5	120.7	239.2
Oct 2012	134.2	113.3	247.5
Oct 2013	134.0	118.7	252.7
Oct 2014	144.9	115.4	260.2
Nov 2015	144.6	117.2	261.8

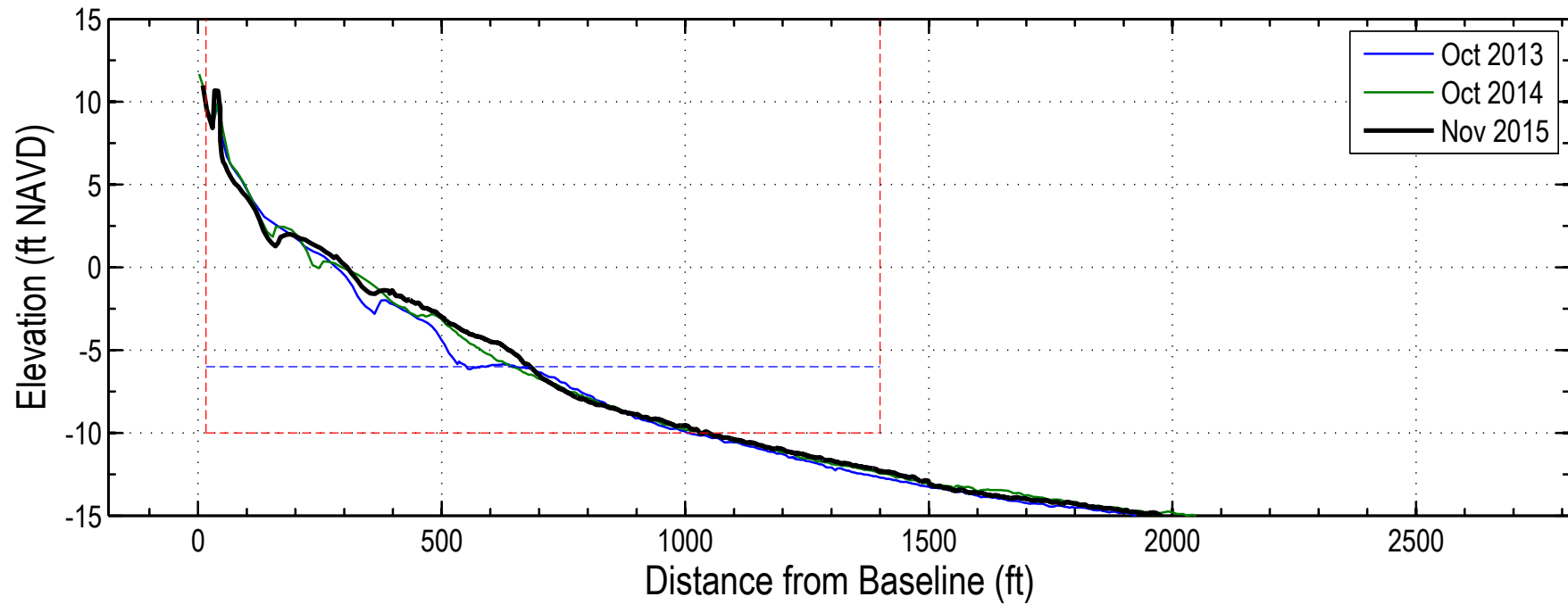




Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2009	113.5	108.5	222.0
Oct 2010	113.2	106.8	220.0
Oct 2011	108.3	118.6	226.8
Oct 2012	120.5	113.6	234.1
Oct 2013	121.5	117.4	238.9
Oct 2014	121.8	113.3	235.1
Nov 2015	128.7	115.1	243.8



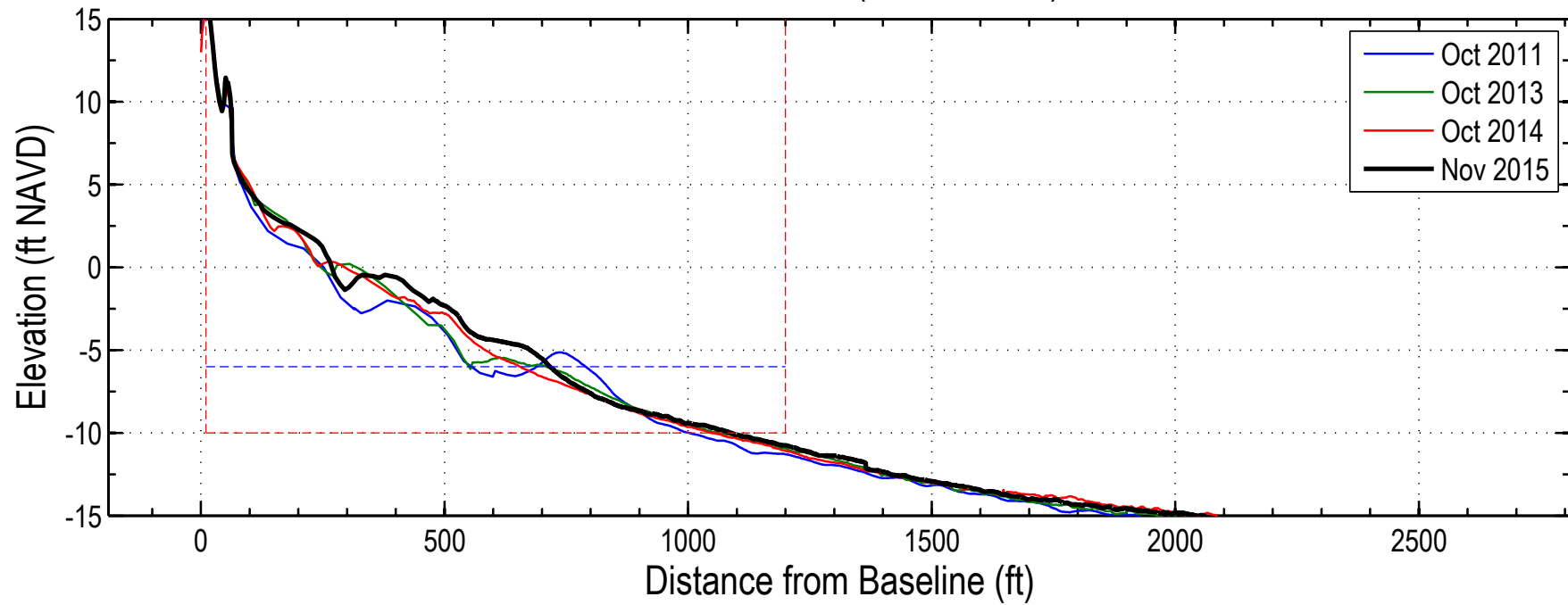
Kiawah Line 22



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	128.4	117.6	246.0
Oct 2013	126.8	119.6	246.4
Oct 2014	135.6	118.9	254.5
Nov 2015	140.2	119.3	259.4



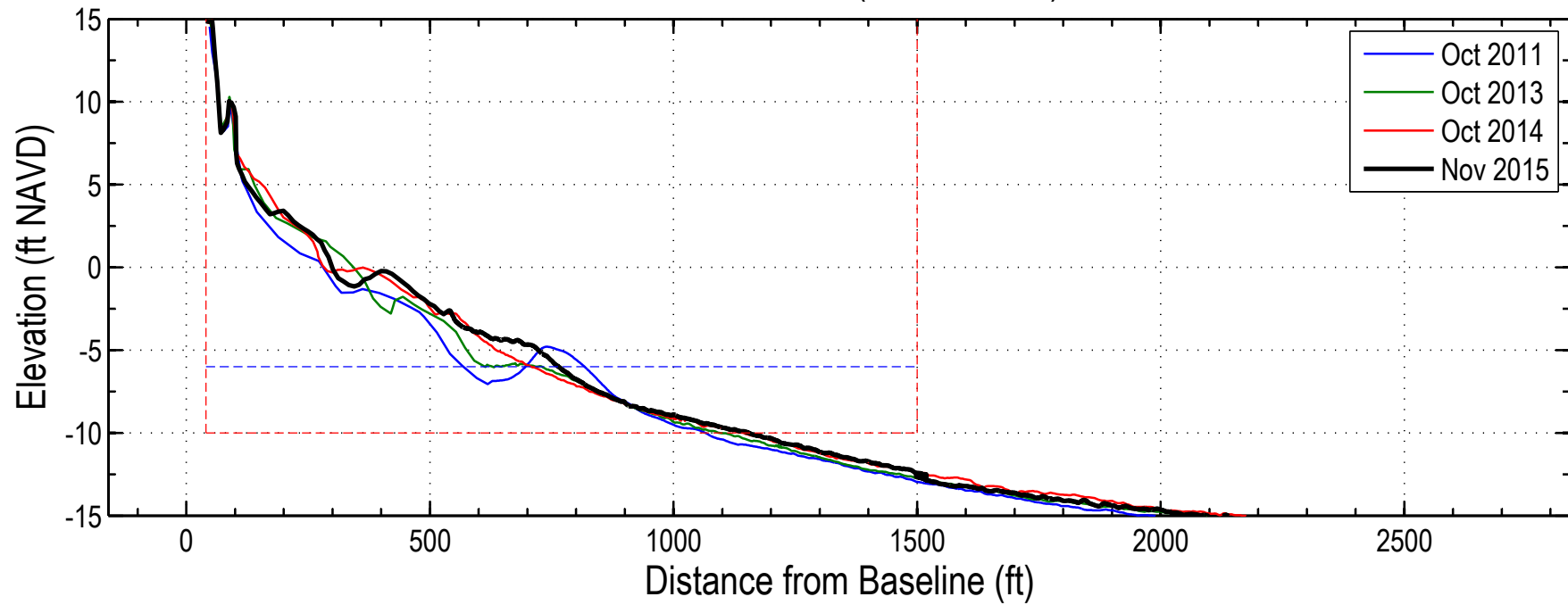
Kiawah Line 23 (OCRM 2685)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	138.8	115.0	253.9
Oct 2008	133.1	115.9	249.0
Aug 2009	133.6	118.6	252.2
Oct 2010	137.9	115.0	253.0
Oct 2011	131.3	126.0	257.3
Oct 2012	139.2	122.1	261.3
Oct 2013	144.5	126.8	271.2
Oct 2014	148.6	121.9	270.5
Nov 2015	160.0	125.5	285.4



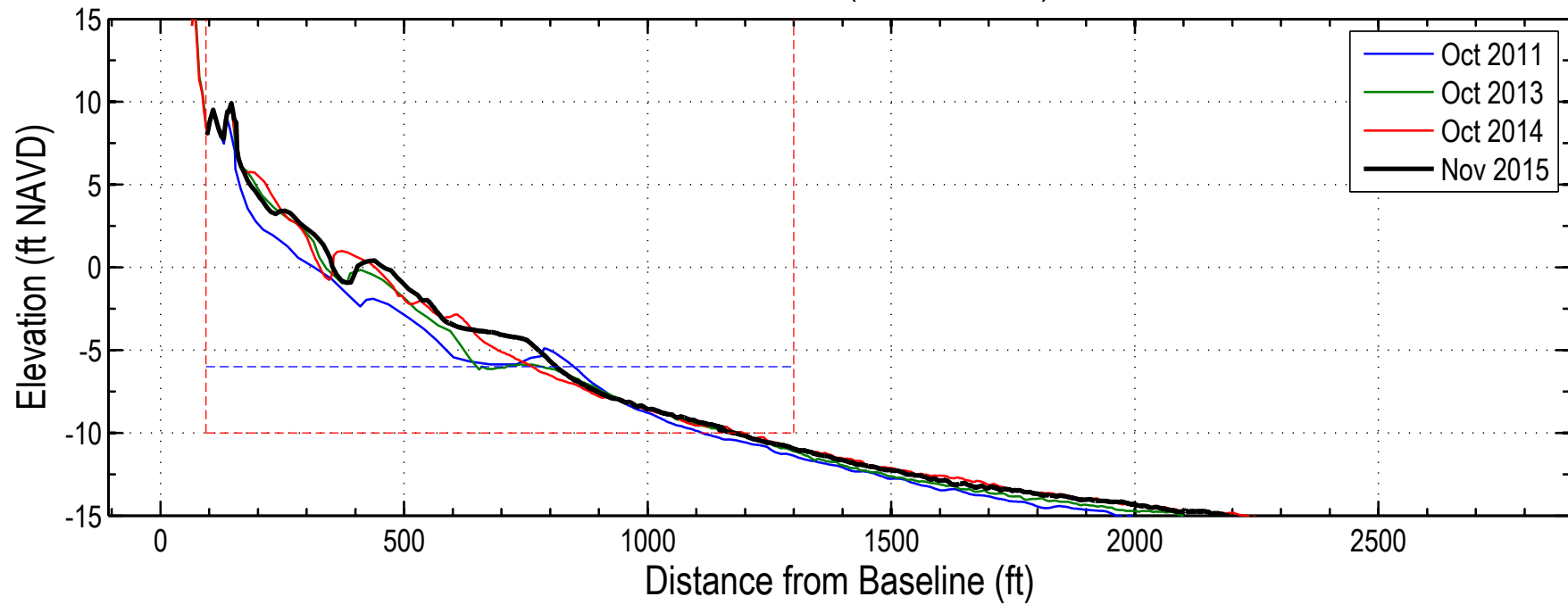
Kiawah Line 24 (OCRM 2687)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2009	136.2	120.9	257.1
Oct 2010	138.8	116.6	255.3
Oct 2011	133.4	125.6	259.0
Oct 2012	142.0	123.4	265.4
Oct 2013	148.4	126.3	274.7
Oct 2014	159.5	126.3	285.8
Nov 2015	162.4	129.2	291.6



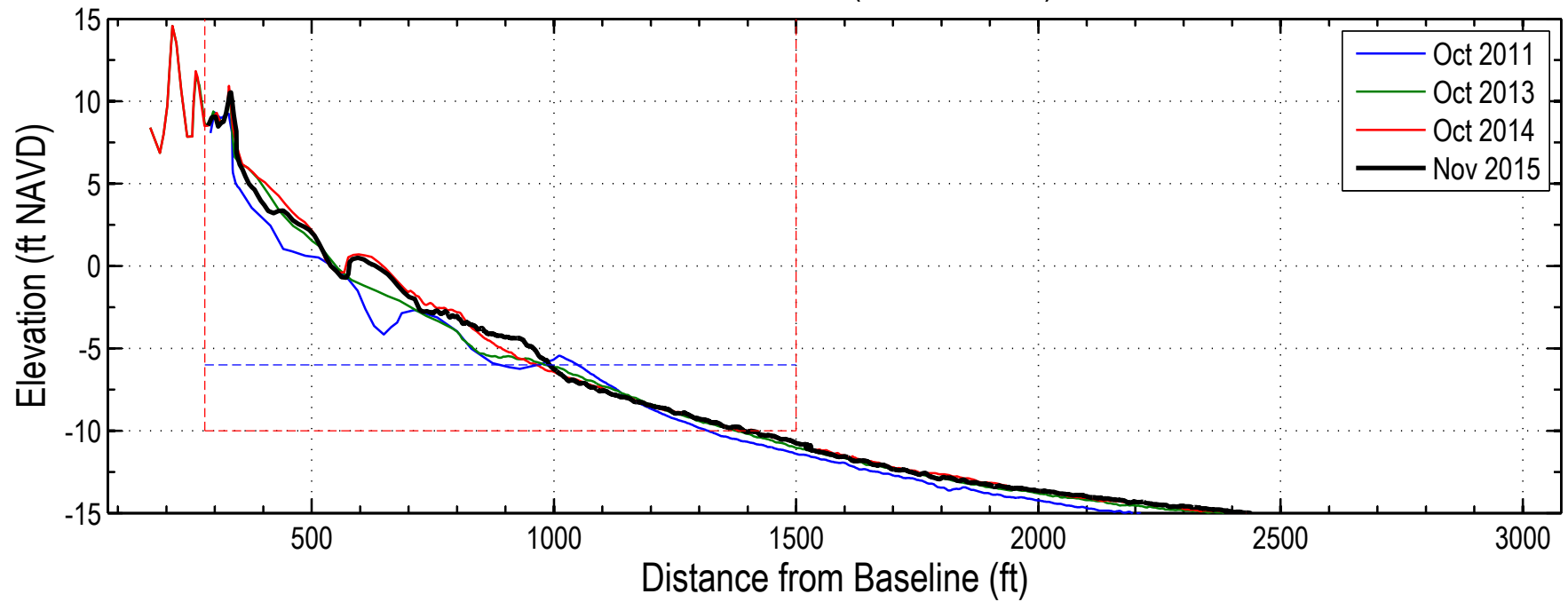
Kiawah Line 25 (OCRM 2690)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	130.8	119.9	250.7
Oct 2008	126.2	118.1	244.3
Aug 2009	129.5	119.2	248.7
Oct 2010	128.9	116.4	245.3
Oct 2011	120.9	127.5	248.4
Oct 2012	138.5	123.8	262.3
Oct 2013	142.6	128.3	270.9
Oct 2014	155.5	126.5	282.1
Nov 2015	161.0	128.9	289.9



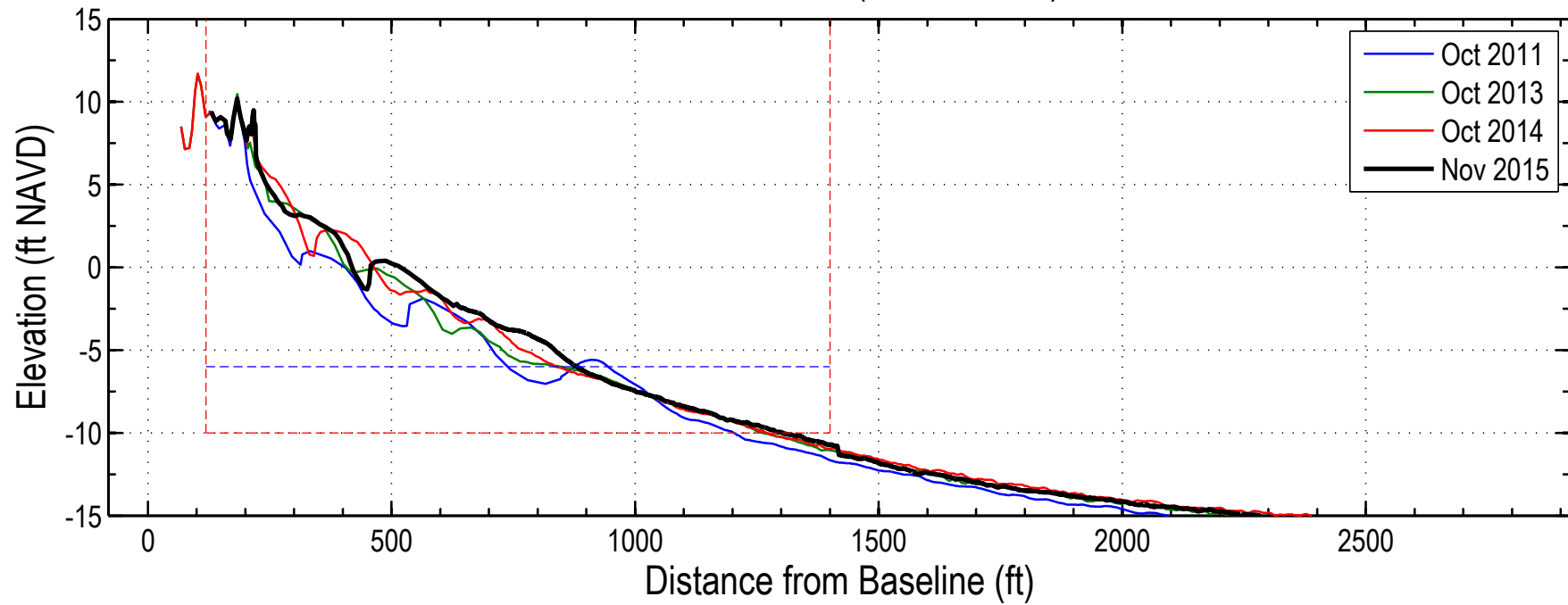
Kiawah Line 26 (OCRM 2692)



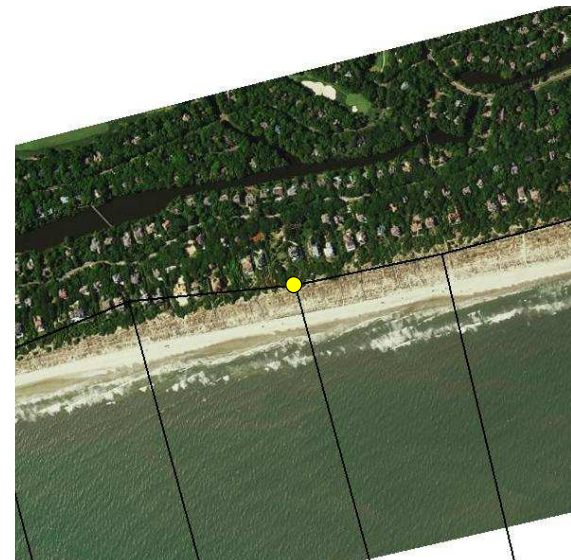
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2009	137.1	122.8	259.9
Oct 2010	133.0	118.7	251.7
Oct 2011	127.3	131.0	258.3
Oct 2012	140.7	124.5	265.2
Oct 2013	146.2	132.0	278.2
Oct 2014	163.7	130.5	294.2
Nov 2015	160.5	130.6	291.1



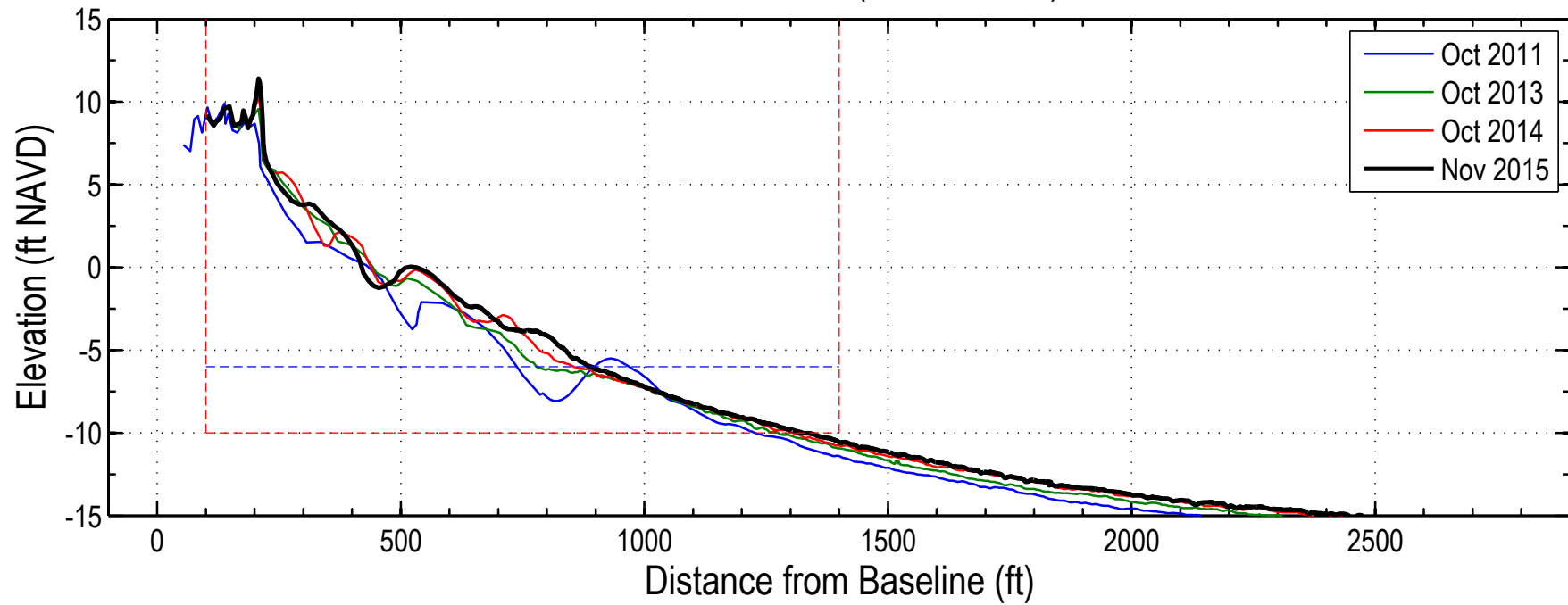
Kiawah Line 27 (OCRM 2695)



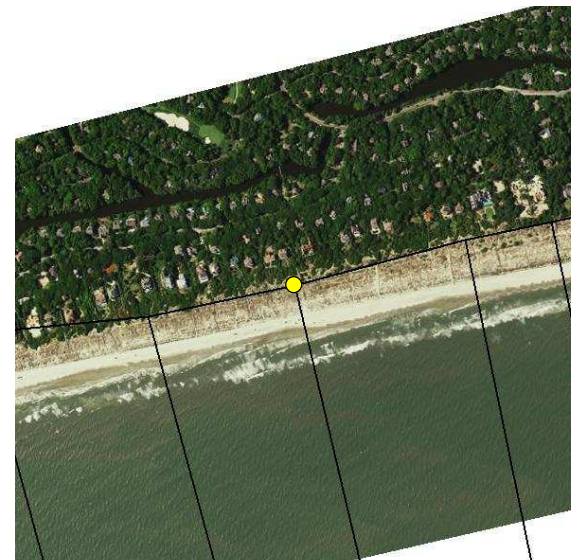
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	138.8	123.9	262.7
Oct 2008	150.3	124.0	274.3
Aug 2009	150.8	128.9	279.7
Oct 2010	146.9	123.3	270.2
Oct 2011	142.2	135.0	277.2
Oct 2012	156.3	131.3	287.6
Oct 2013	164.8	139.7	304.5
Oct 2014	176.0	138.5	314.5
Nov 2015	183.9	140.5	324.4



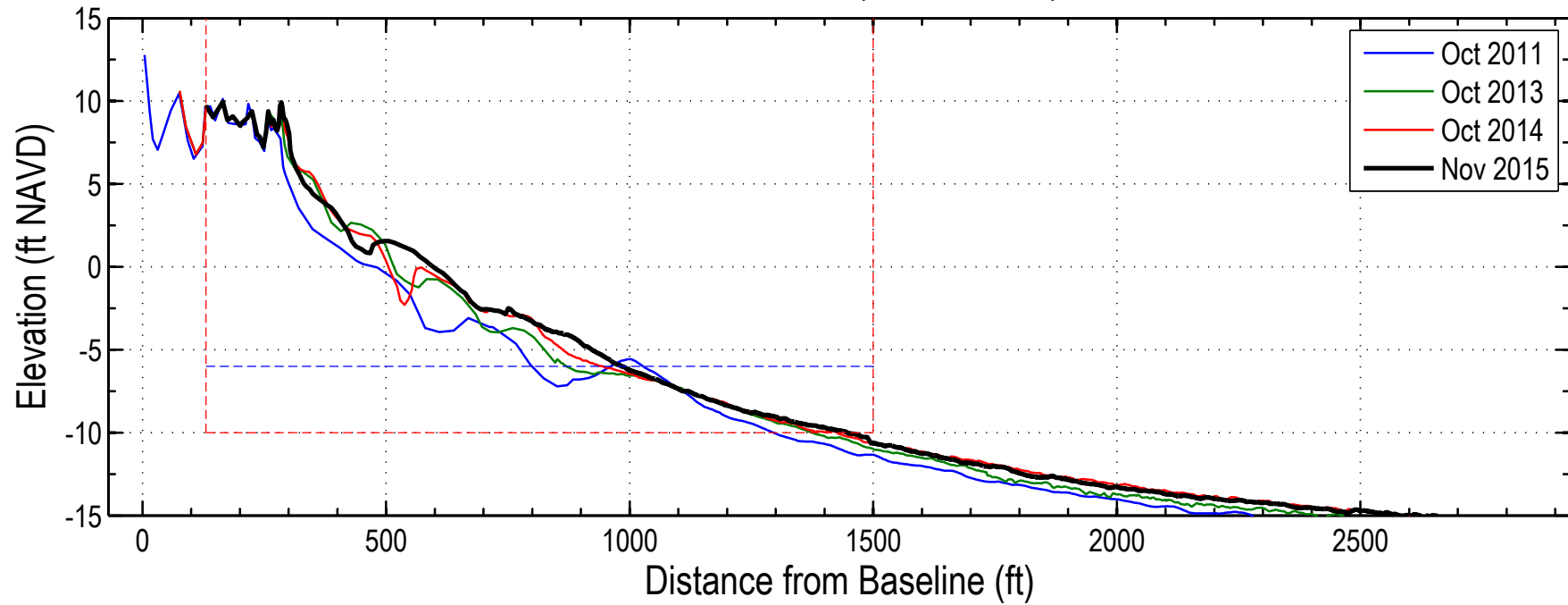
Kiawah Line 28 (OCRM 2700)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	150.5	127.7	278.2
Oct 2008	160.5	131.3	291.8
Aug 2009	161.5	133.7	295.2
Oct 2010	163.2	129.0	292.3
Oct 2011	163.9	136.9	300.8
Oct 2012	172.1	135.4	307.4
Oct 2013	182.7	141.6	324.3
Oct 2014	192.6	144.4	337.0
Nov 2015	197.5	146.4	343.9



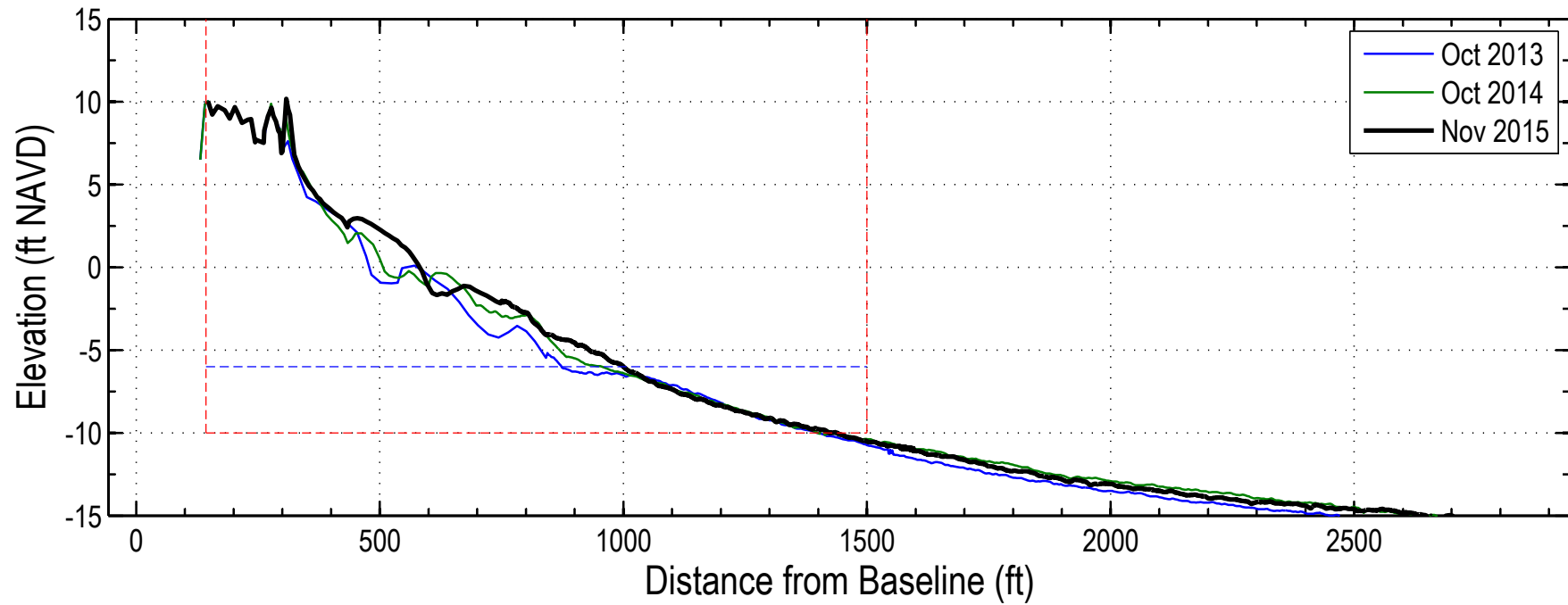
Kiawah Line 29 (OCRM 2705)



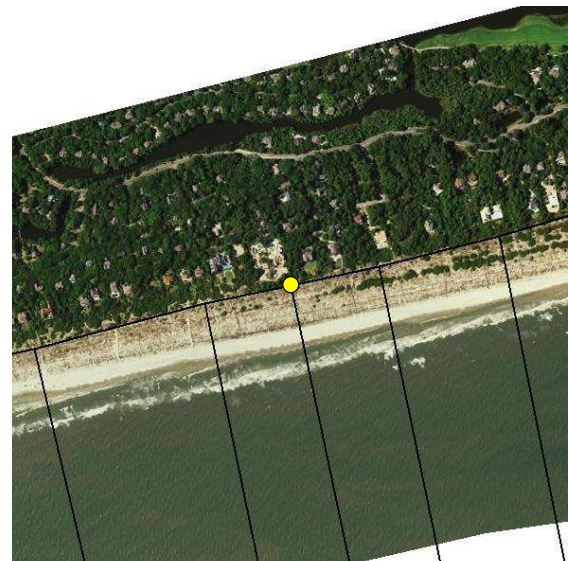
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	184.9	137.1	321.9
Oct 2008	175.8	137.6	313.4
Aug 2009	185.3	140.5	325.8
Oct 2010	186.8	136.4	323.1
Oct 2011	176.1	146.0	322.1
Oct 2012	200.7	143.8	344.5
Oct 2013	208.6	151.8	360.4
Oct 2014	216.6	153.9	370.5
Nov 2015	225.9	155.8	381.7



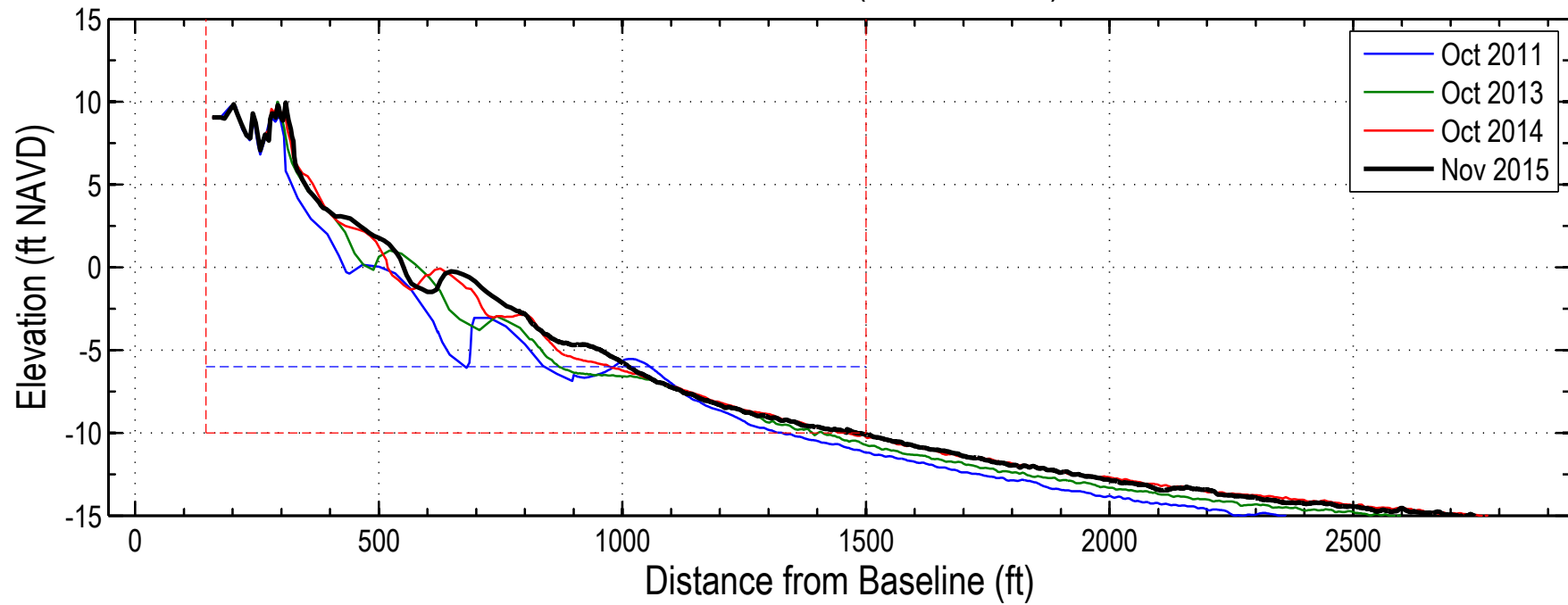
Kiawah Line 30



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	201.8	143.9	345.7
Oct 2013	202.6	152.2	354.7
Oct 2014	216.0	153.1	369.1
Nov 2015	230.7	153.3	383.9



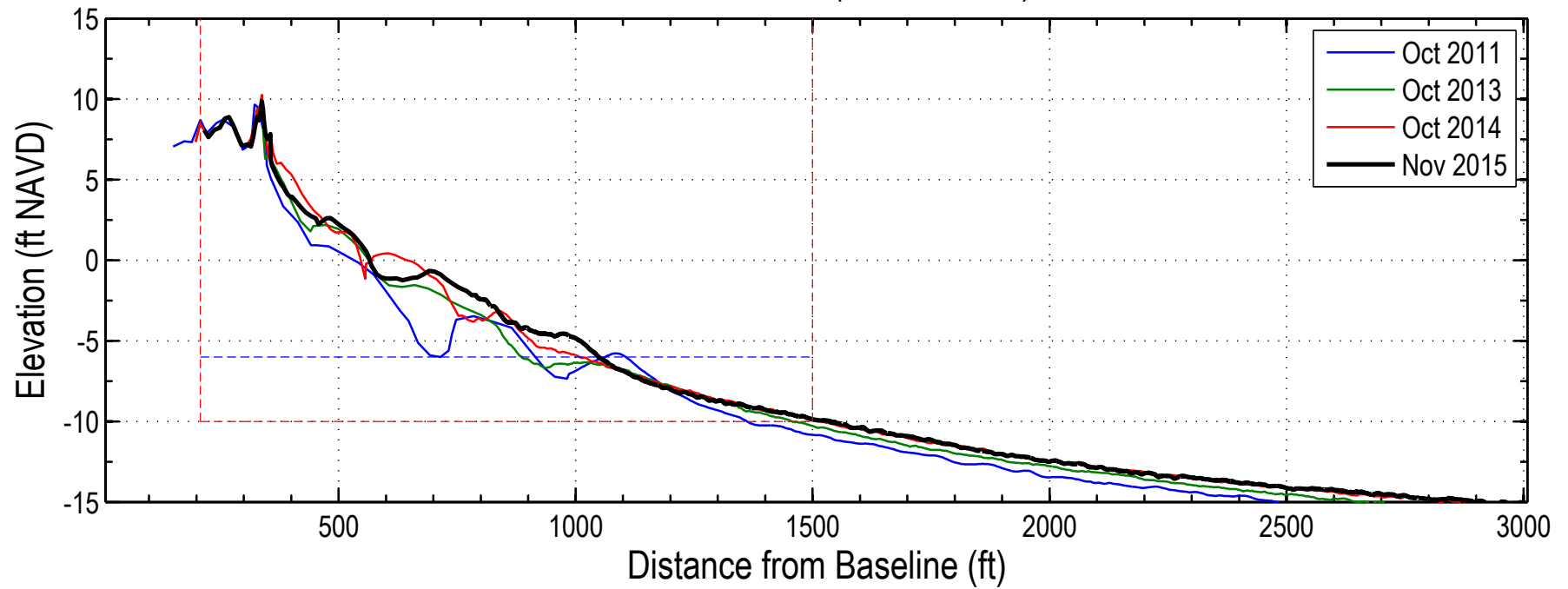
Kiawah Line 31 (OCRM 2715)



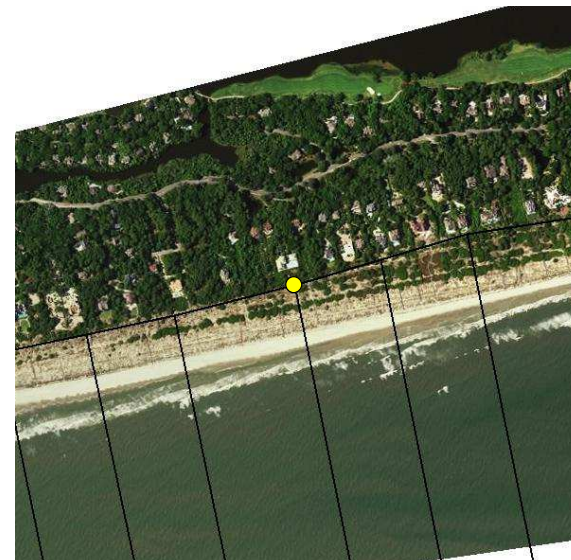
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	183.4	139.2	322.6
Oct 2008	186.6	138.5	325.1
Aug 2009	184.0	142.4	326.4
Oct 2010	193.4	138.2	331.6
Oct 2011	178.3	148.5	326.8
Oct 2012	201.1	146.0	347.1
Oct 2013	203.3	150.6	353.9
Oct 2014	218.2	155.8	374.1
Nov 2015	227.8	155.2	383.0



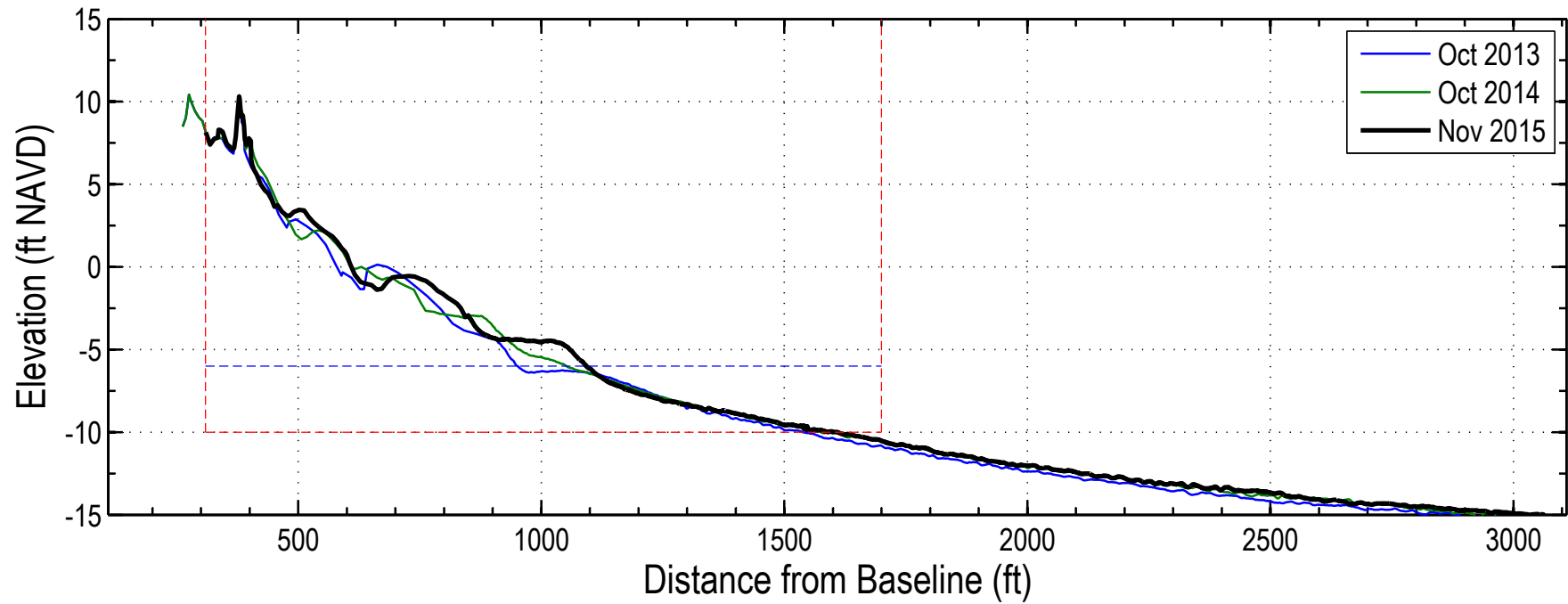
Kiawah Line 32 (OCRM 2720)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	169.9	136.3	306.2
Oct 2008	166.7	135.4	302.0
Aug 2009	169.1	137.9	306.9
Oct 2010	176.4	132.9	309.3
Oct 2011	160.5	144.8	305.3
Oct 2012	180.3	143.0	323.3
Oct 2013	181.9	148.3	330.2
Oct 2014	199.4	152.5	351.9
Nov 2015	202.5	151.8	354.4



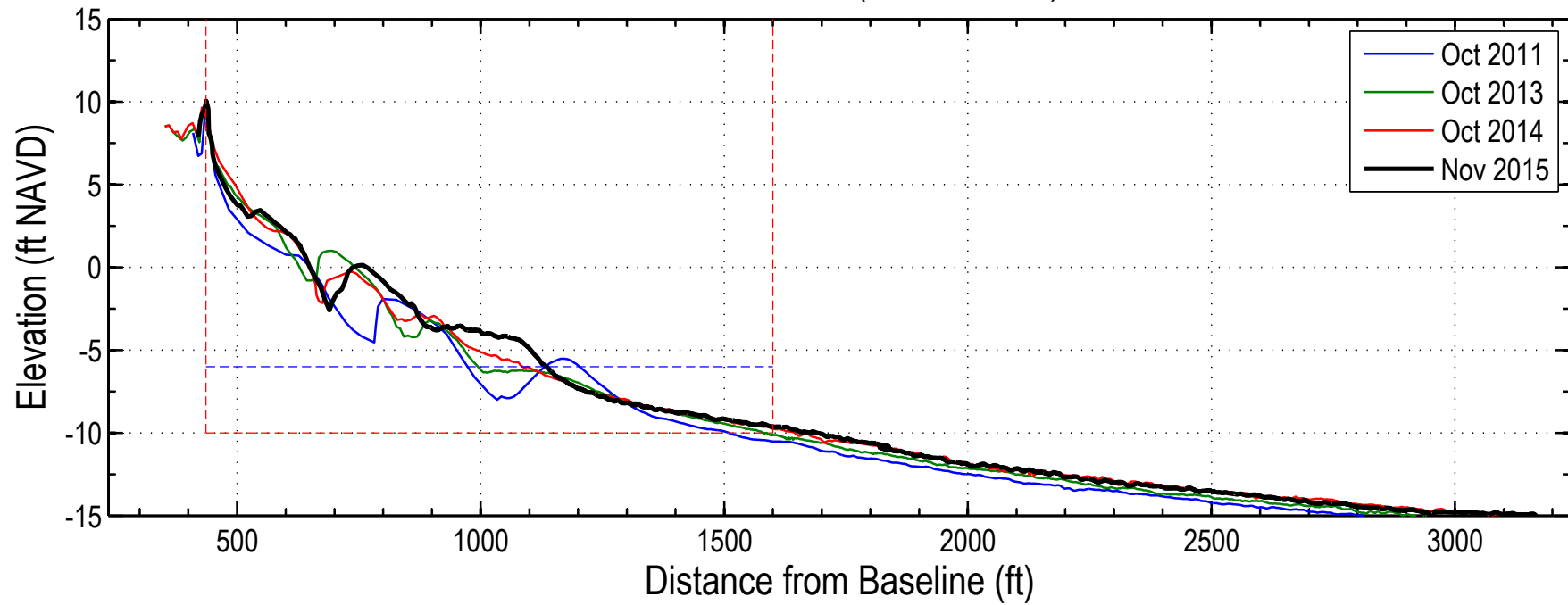
Kiawah Line 33



Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	148.4	134.0	282.4
Oct 2013	158.1	141.5	299.6
Oct 2014	165.9	144.4	310.3
Nov 2015	174.2	144.4	318.6



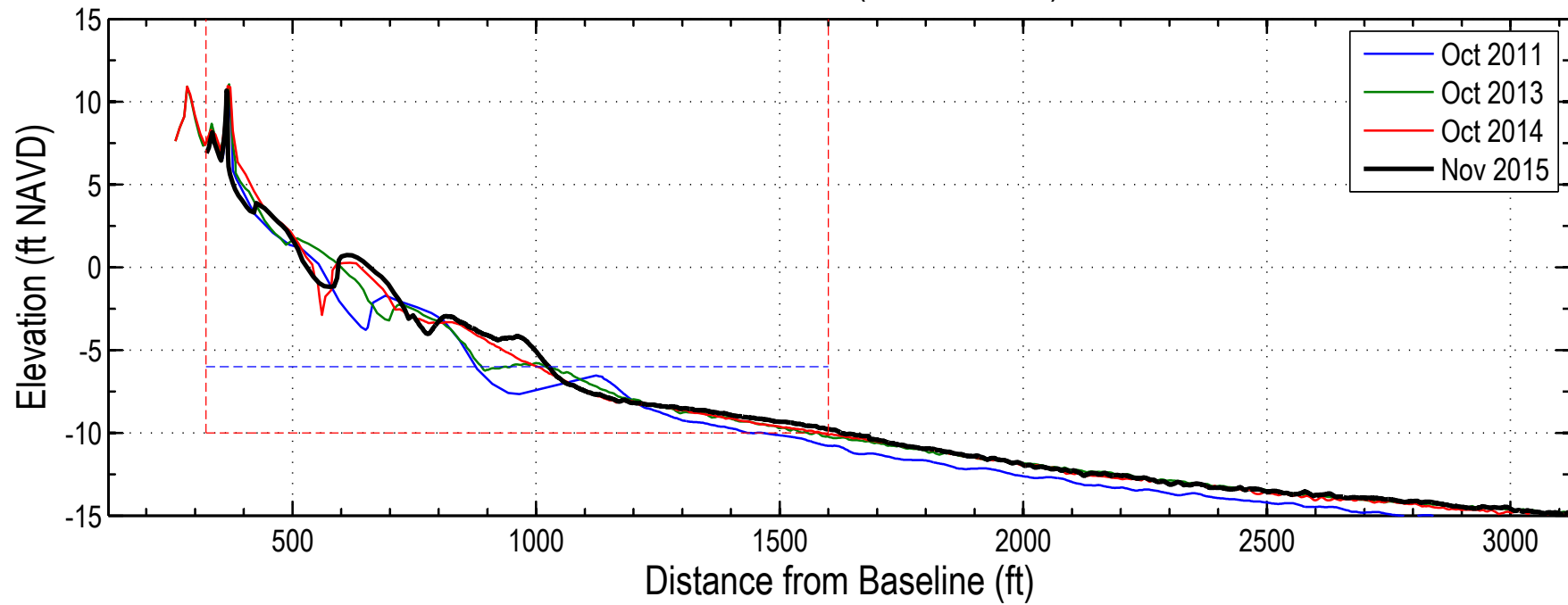
Kiawah Line 34 (OCRM 2722)



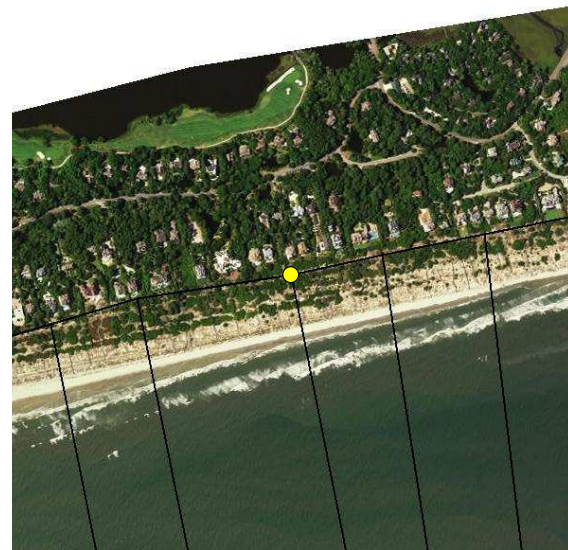
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2009	105.5	118.6	224.2
Oct 2010	113.6	116.2	229.8
Oct 2011	103.5	122.1	225.6
Oct 2012	115.6	126.2	241.8
Oct 2013	120.7	128.7	249.5
Oct 2014	124.4	130.9	255.3
Nov 2015	133.7	131.2	264.9



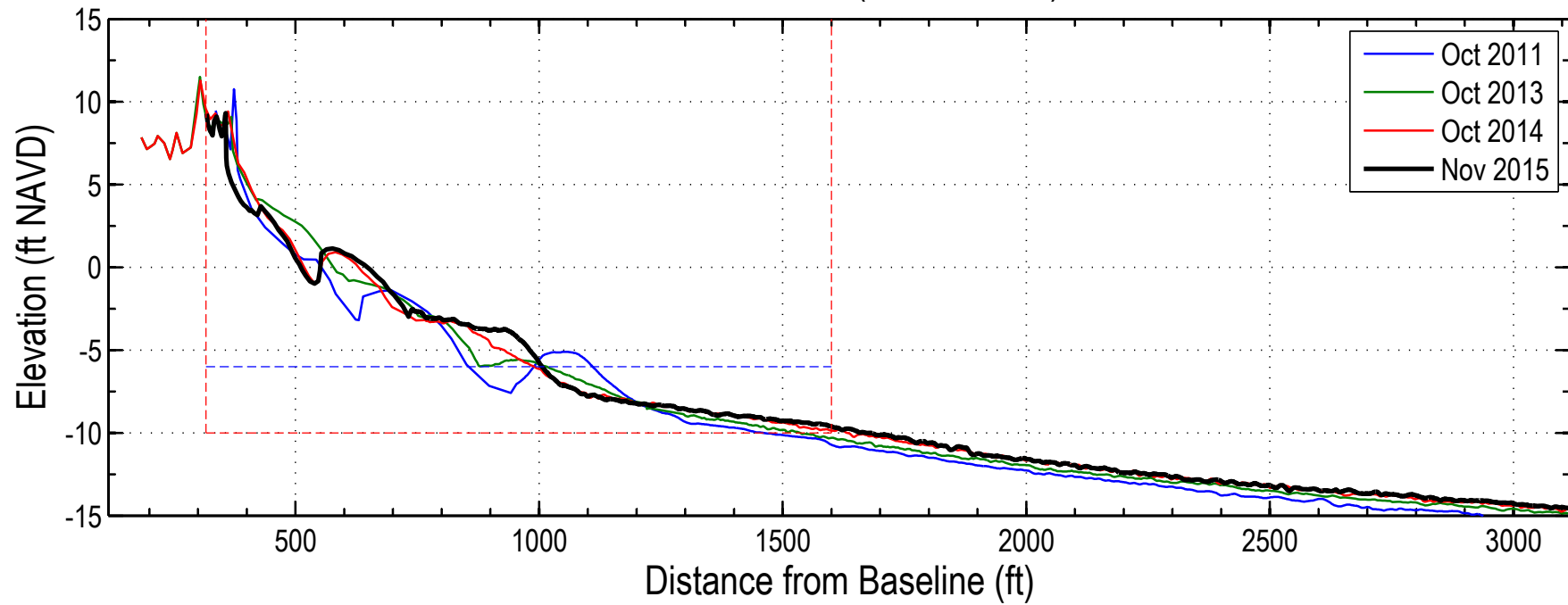
Kiawah Line 35 (OCRM 2725)



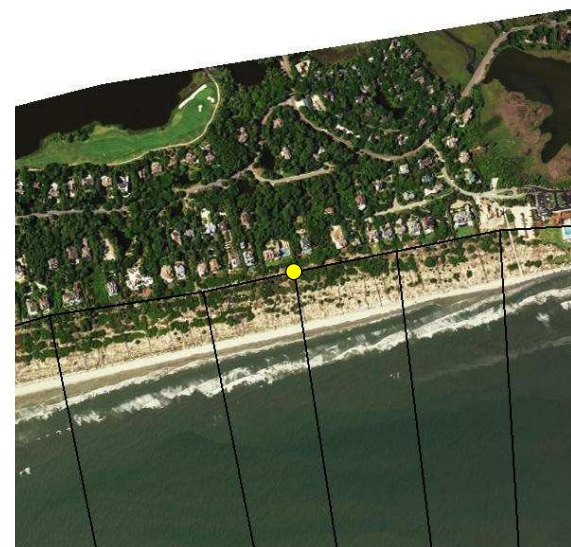
Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	128.0	124.1	252.1
Oct 2008	126.3	124.0	250.3
Aug 2009	126.9	126.4	253.3
Oct 2010	132.4	122.1	254.5
Oct 2011	122.0	123.4	245.4
Oct 2012	139.1	130.2	269.3
Oct 2013	131.5	135.5	267.0
Oct 2014	140.5	133.3	273.8
Nov 2015	140.6	136.6	277.2



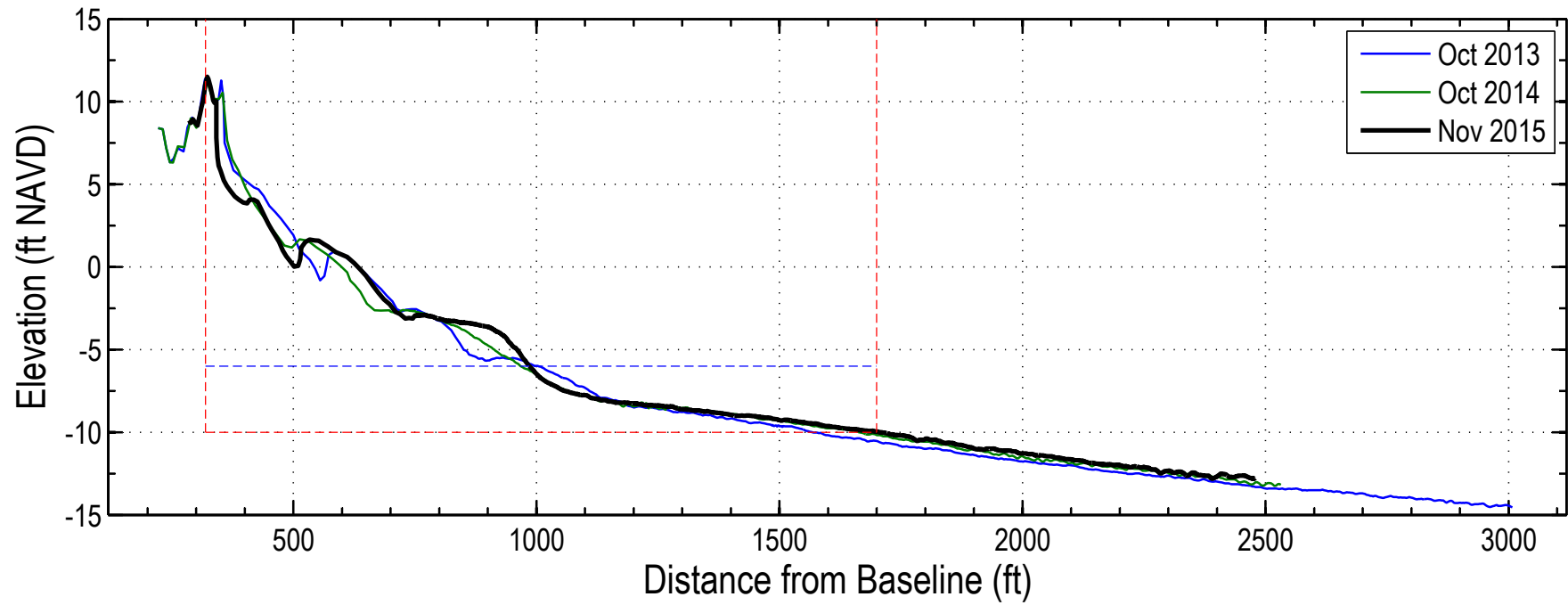
Kiawah Line 36 (OCRM 2730)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Aug 2007	133.2	124.3	257.4
Oct 2008	79.7	124.5	204.2
Aug 2009	133.3	126.6	259.9
Oct 2010	141.2	122.5	263.7
Oct 2011	128.5	129.3	257.8
Oct 2012	142.4	133.4	275.8
Oct 2013	142.2	133.5	275.7
Oct 2014	141.6	135.1	276.7
Nov 2015	143.7	136.1	279.8

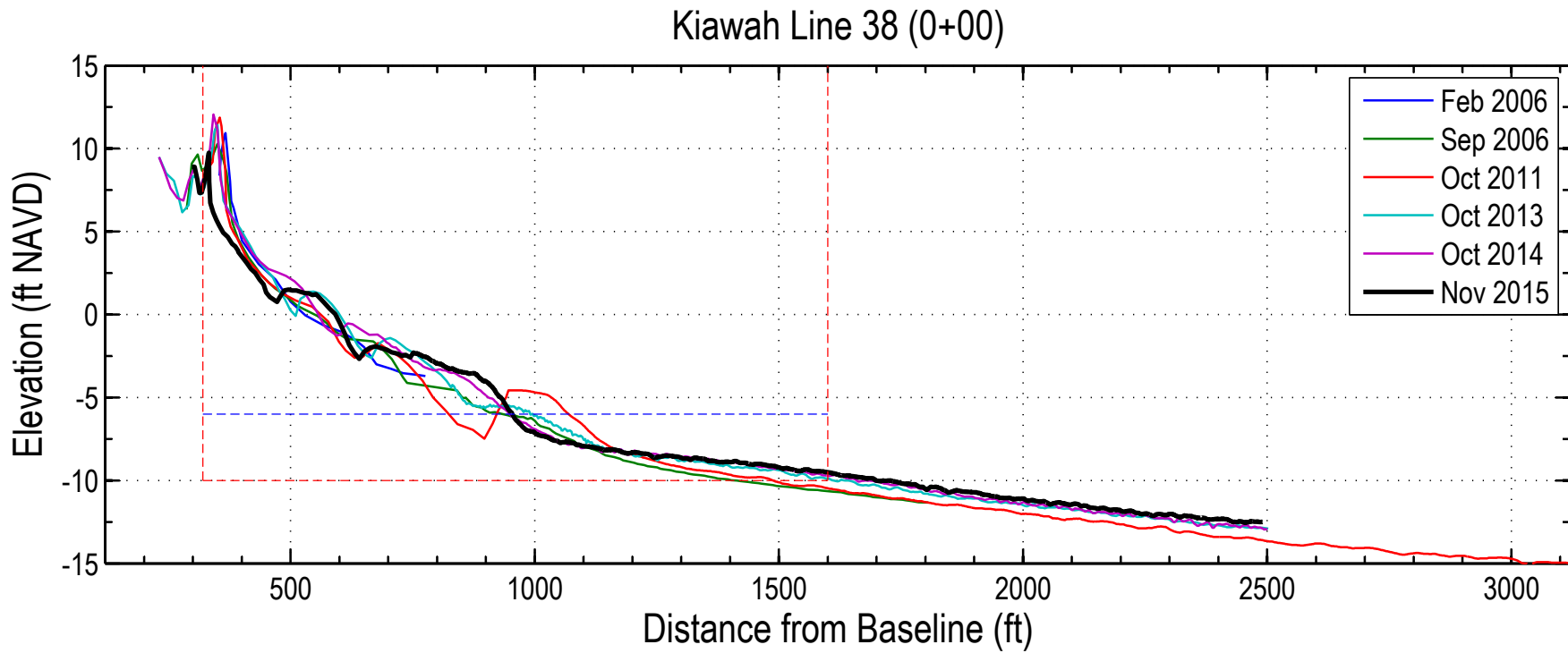


Kiawah Line 37

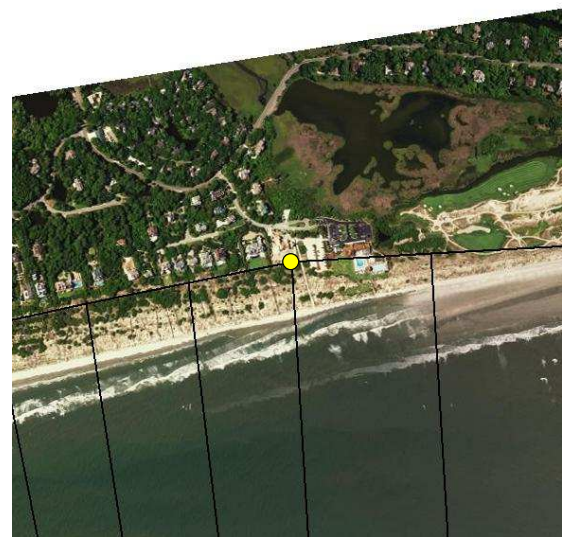


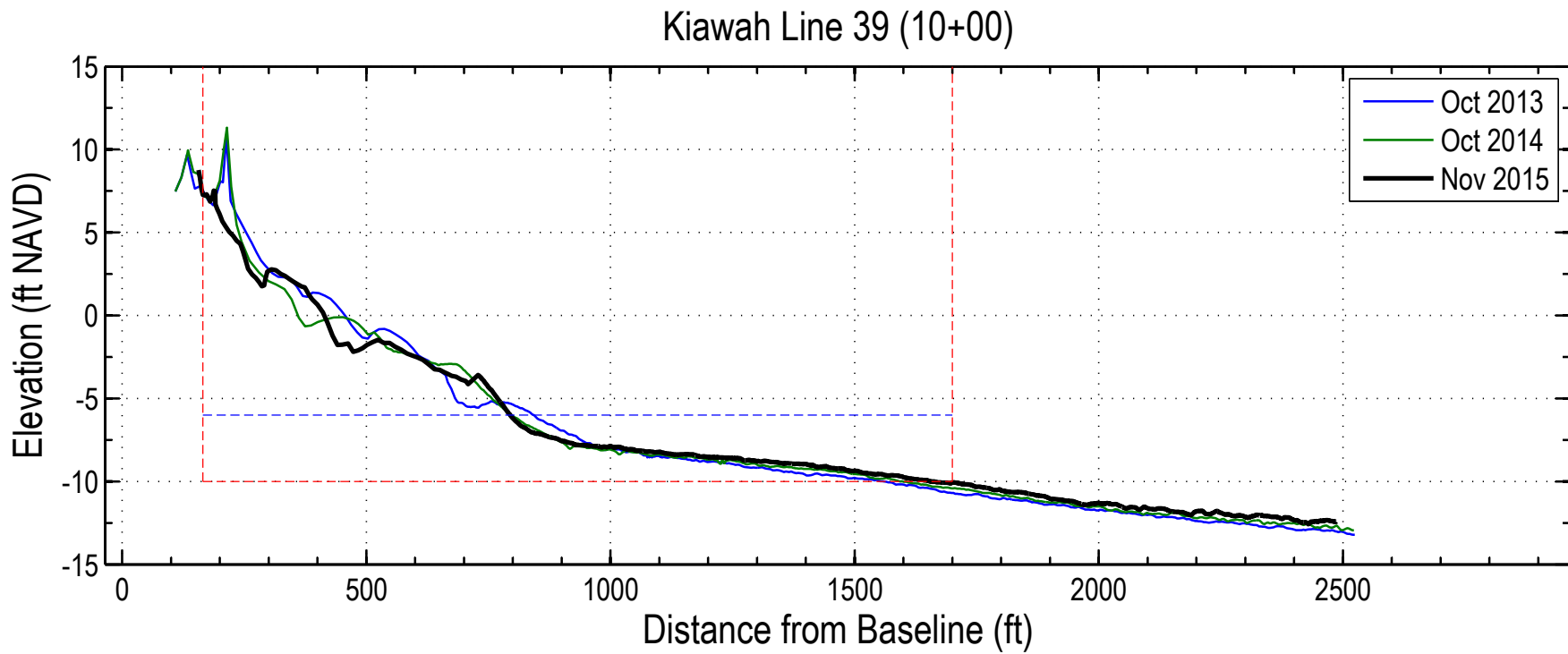
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	138.5	133.2	271.7
Oct 2013	141.6	132.6	274.2
Oct 2014	138.1	133.5	271.6
Nov 2015	140.3	134.7	275.0



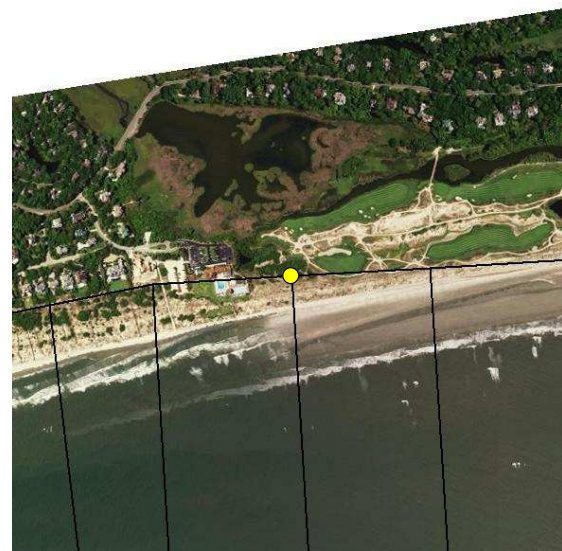


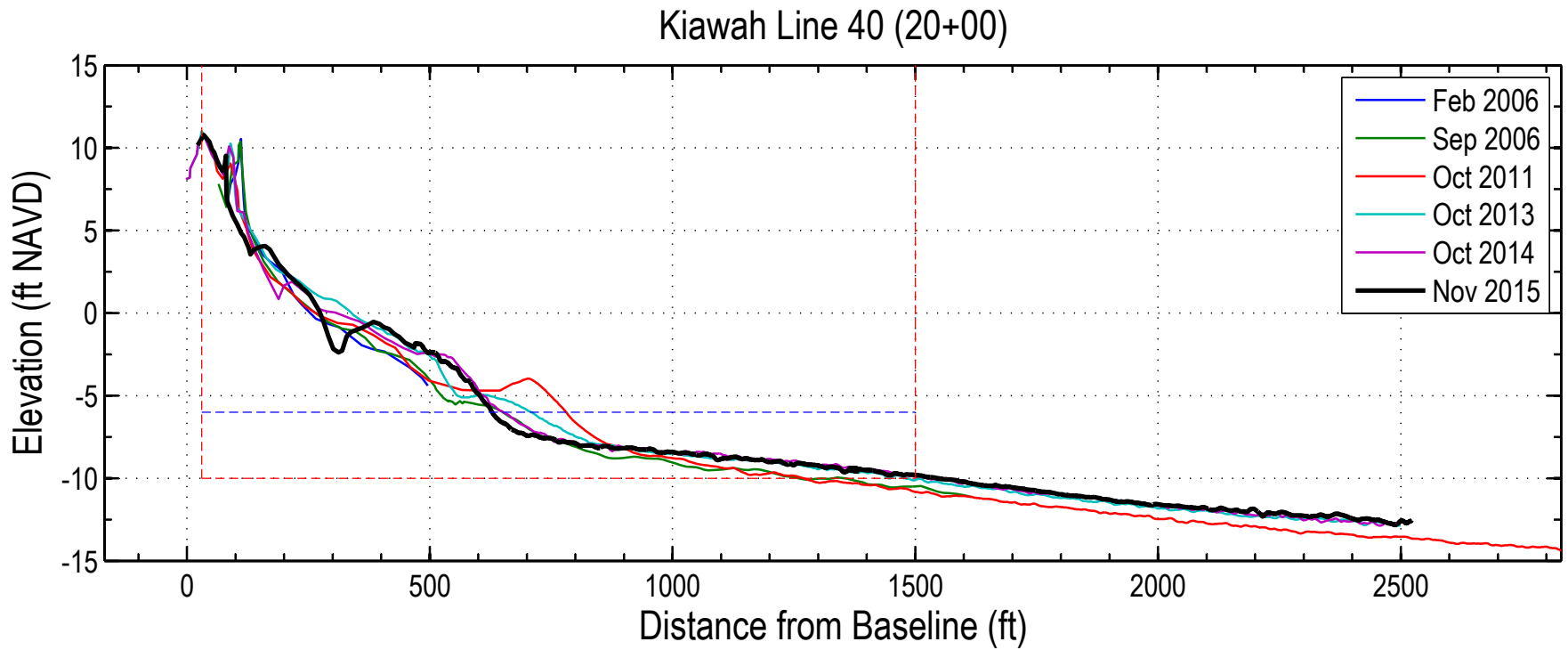
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	138.2	181.1	319.3
Sep 2006	121.5	120.1	241.6
Aug 2007	126.9	120.1	247.0
Oct 2008	126.0	121.8	247.8
Aug 2009	128.0	123.4	251.4
Oct 2010	133.9	122.7	256.6
Oct 2011	123.7	127.5	251.2
Oct 2012	136.0	130.7	266.7
Oct 2013	133.4	132.8	266.2
Oct 2014	138.0	131.4	269.4
Nov 2015	128.5	131.4	259.9



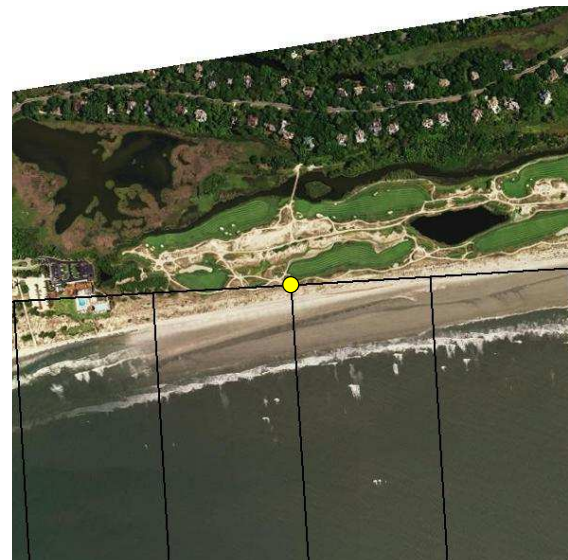


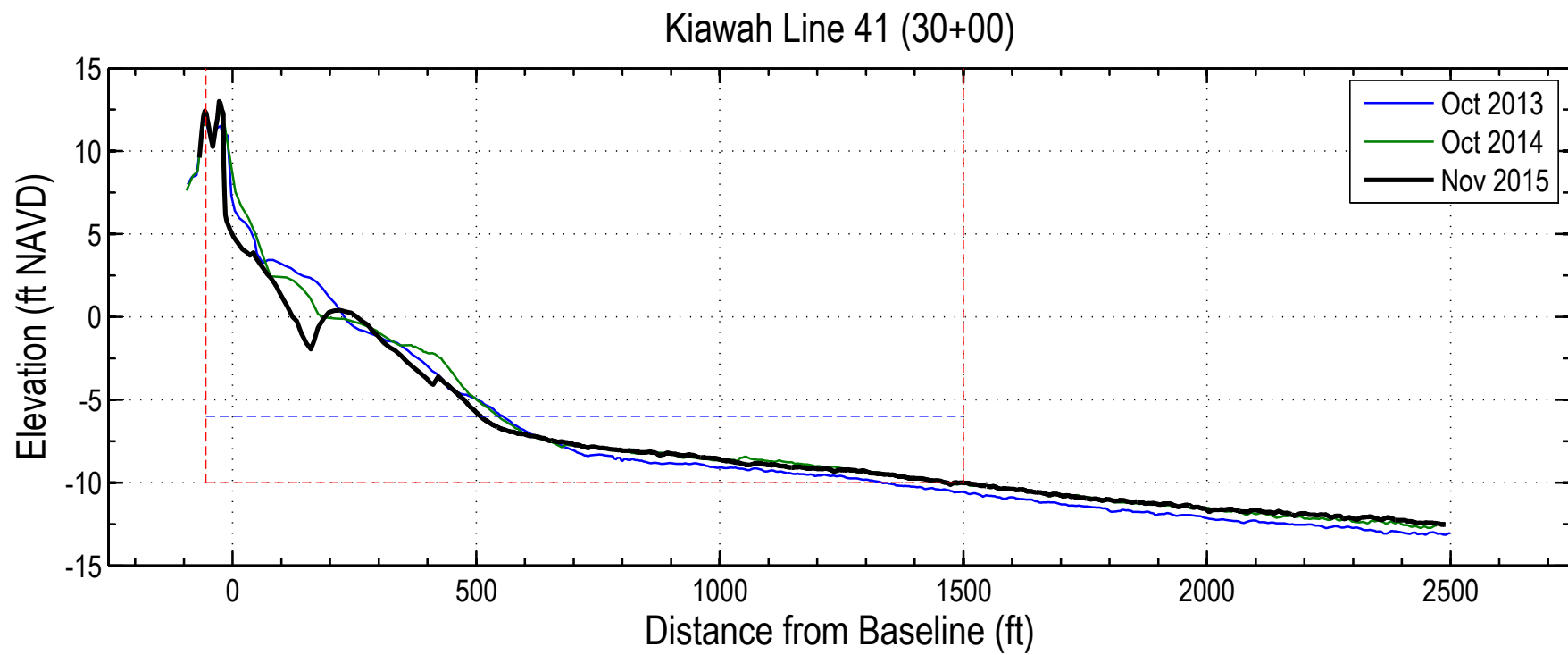
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	145.5	132.1	277.5
Oct 2013	141.1	135.8	276.9
Oct 2014	135.9	135.6	271.5
Nov 2015	130.1	140.4	270.5





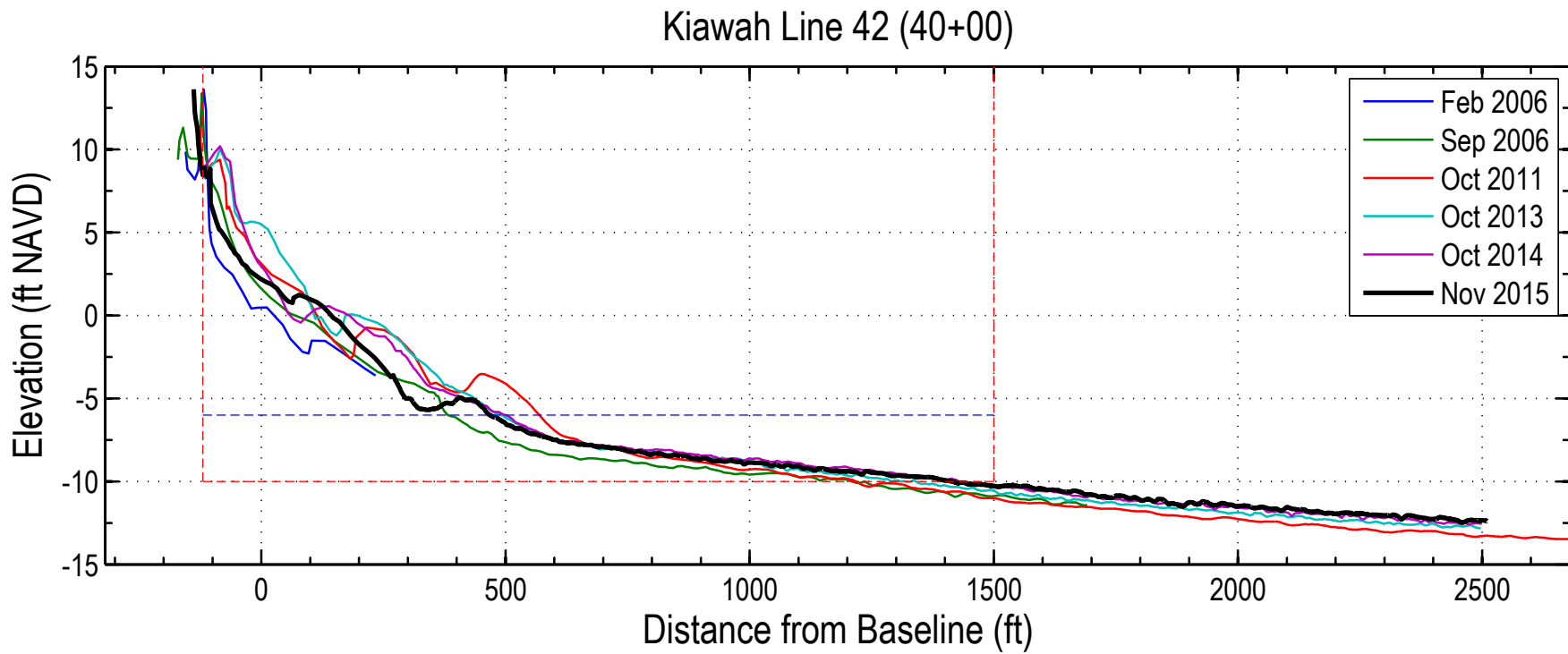
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	124.8	82.6	207.3
Sep 2006	129.2	121.9	251.1
Aug 2007	129.7	121.9	251.6
Oct 2008	131.8	125.5	257.3
Aug 2009	146.6	130.0	276.6
Oct 2010	150.7	128.6	279.3
Oct 2011	143.0	133.4	276.4
Oct 2012	156.3	132.7	288.9
Oct 2013	151.8	139.5	291.4
Oct 2014	147.3	139.0	286.3
Nov 2015	144.3	135.2	279.5





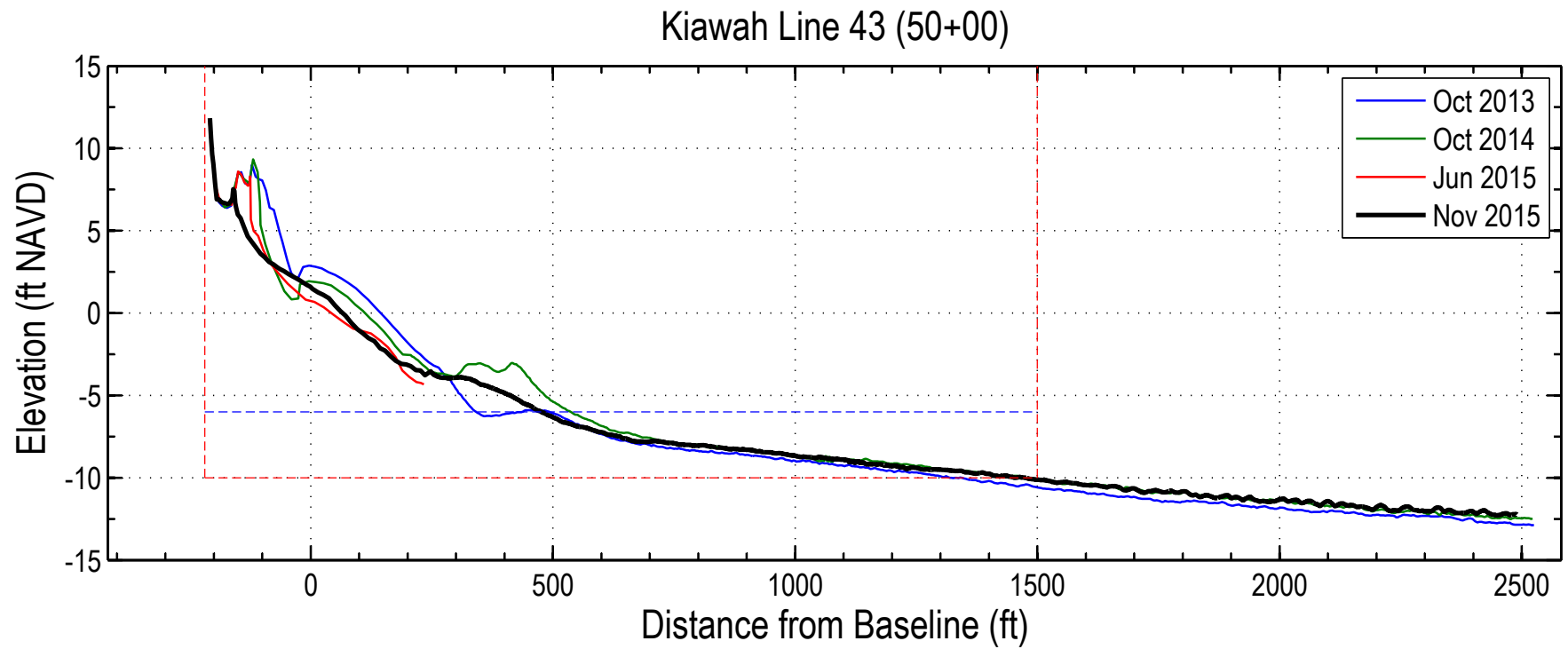
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	153.2	131.9	285.1
Oct 2013	147.4	126.8	274.2
Oct 2014	149.1	140.0	289.1
Nov 2015	127.5	137.5	264.9





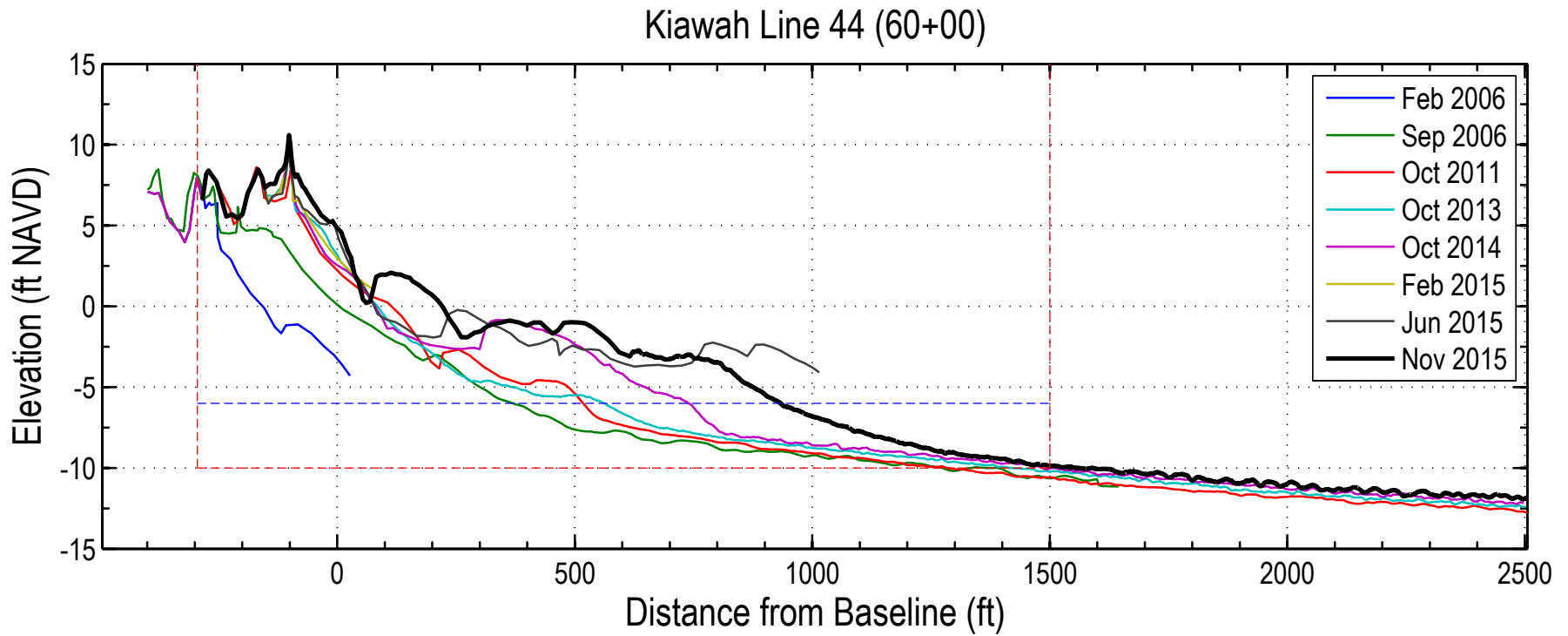
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	82.7	85.8	168.4
Sep 2006	103.3	112.9	216.1
Aug 2007	115.9	116.3	232.2
Oct 2008	123.0	125.2	248.2
Aug 2009	131.1	128.5	259.6
Oct 2010	143.7	127.4	271.1
Oct 2011	139.0	133.1	272.1
Oct 2012	147.0	134.1	281.1
Oct 2013	146.7	135.7	282.4
Oct 2014	133.2	142.9	276.0
Nov 2015	109.7	137.2	247.0





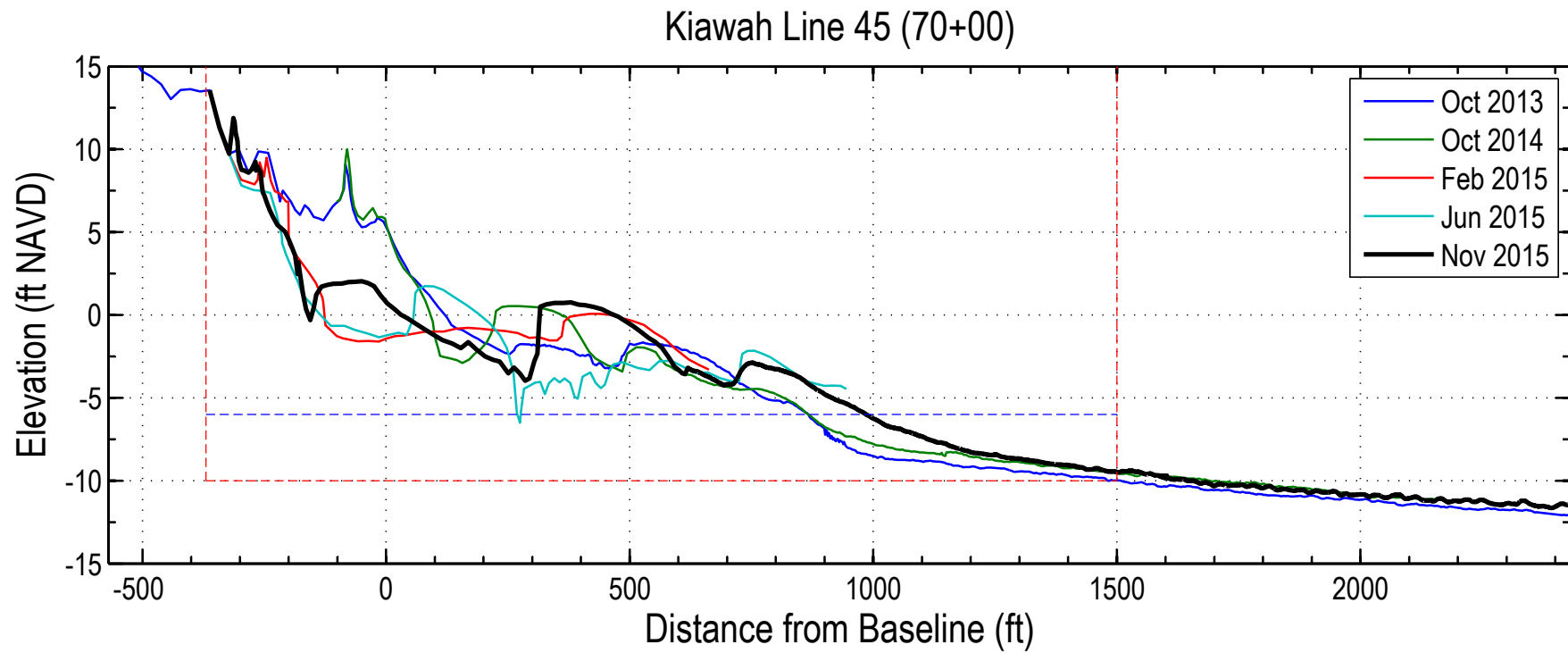
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	178.5	147.2	325.7
Oct 2013	160.7	149.7	310.4
Oct 2014	161.4	162.7	324.1
Jun 2015	131.8	114.1	245.8
Nov 2015	140.7	158.5	299.2





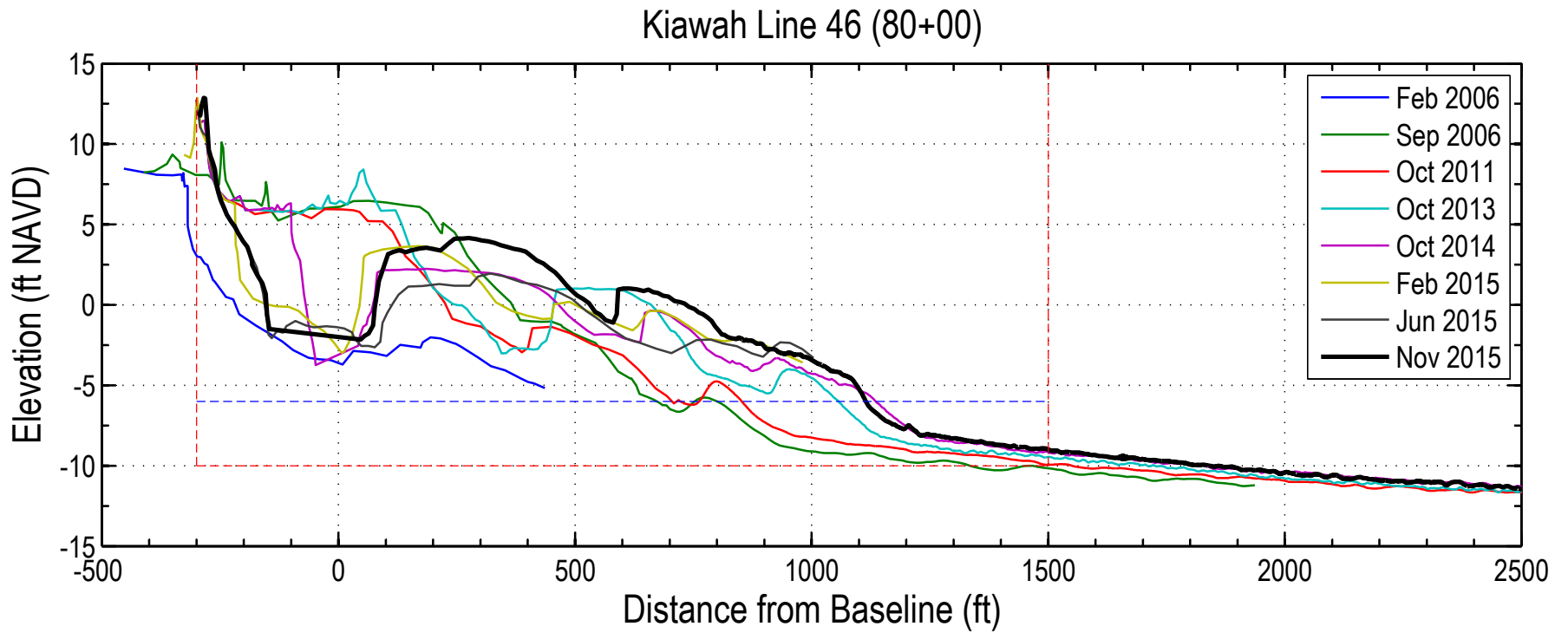
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	76.8	60.6	137.4
Sep 2006	148.6	146.3	294.9
Aug 2007	203.6	151.5	355.1
Oct 2008	205.3	141.6	346.9
Aug 2009	200.8	150.6	351.5
Oct 2010	209.1	153.8	362.9
Oct 2011	197.1	159.2	356.3
Oct 2012	205.0	166.2	371.2
Oct 2013	192.1	172.0	364.1
Oct 2014	236.6	187.6	424.1
Feb 2015	208.1	128.1	336.2
Jun 2015	290.4	220.9	511.3
Nov 2015	298.6	215.7	514.3





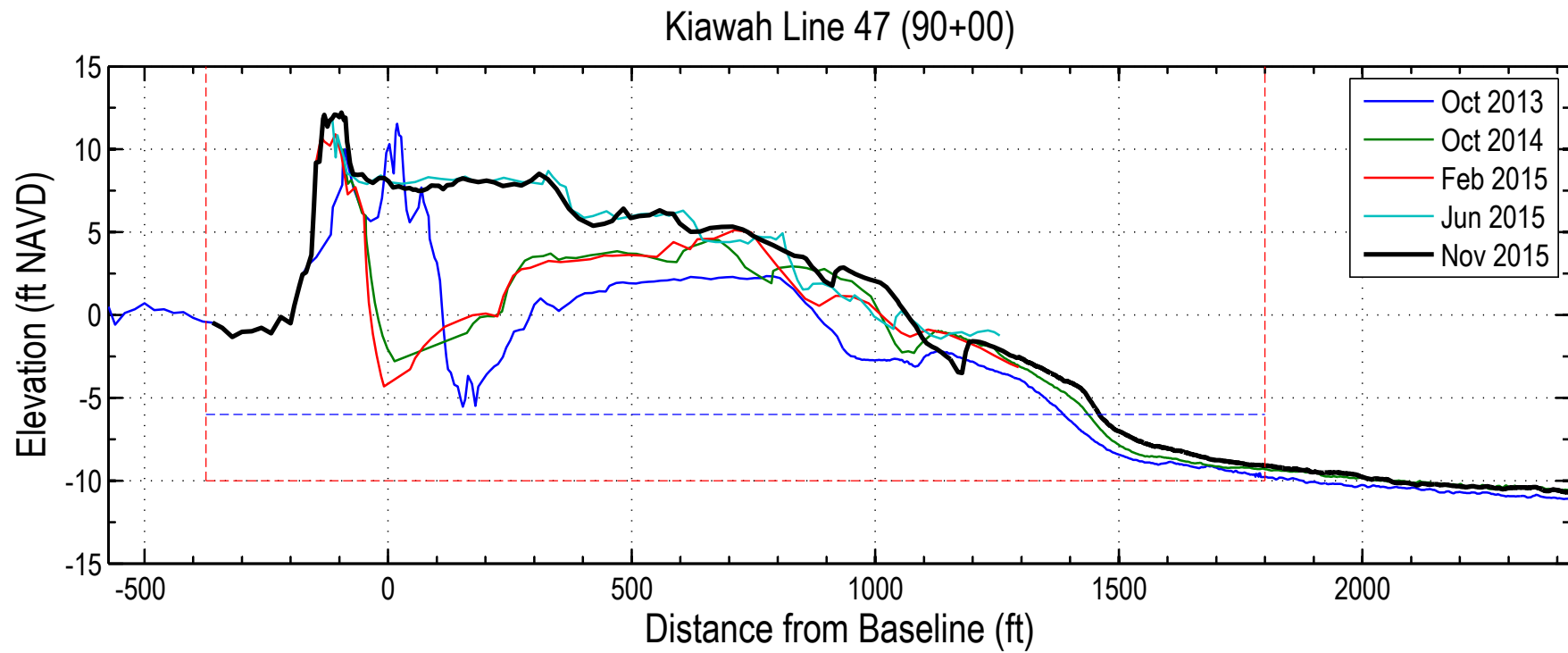
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	267.0	187.2	454.2
Oct 2013	318.7	208.8	527.4
Oct 2014	304.7	221.3	526.0
Feb 2015	271.9	203.6	475.5
Jun 2015	256.1	225.3	481.4
Nov 2015	288.7	234.9	523.6





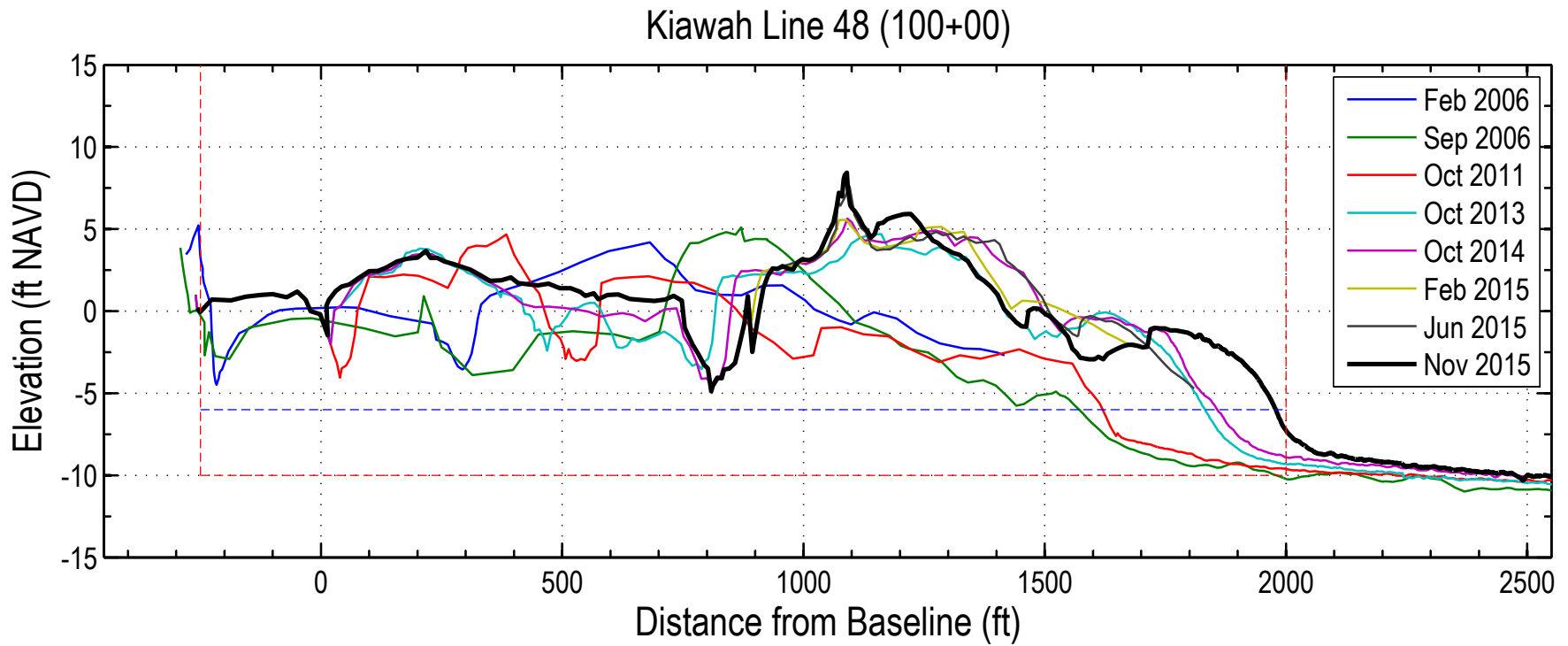
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	98.1	140.4	238.6
Sep 2006	322.4	183.2	505.6
Aug 2007	312.3	187.8	500.1
Oct 2008	280.7	172.7	453.5
Aug 2009	286.7	178.6	465.3
Oct 2010	261.9	179.5	441.4
Oct 2011	286.1	200.6	486.7
Oct 2012	324.7	213.0	537.7
Oct 2013	348.9	223.6	572.5
Oct 2014	316.1	235.3	551.5
Feb 2015	311.6	238.9	550.5
Jun 2015	286.3	223.2	509.4
Nov 2015	345.1	235.8	580.9





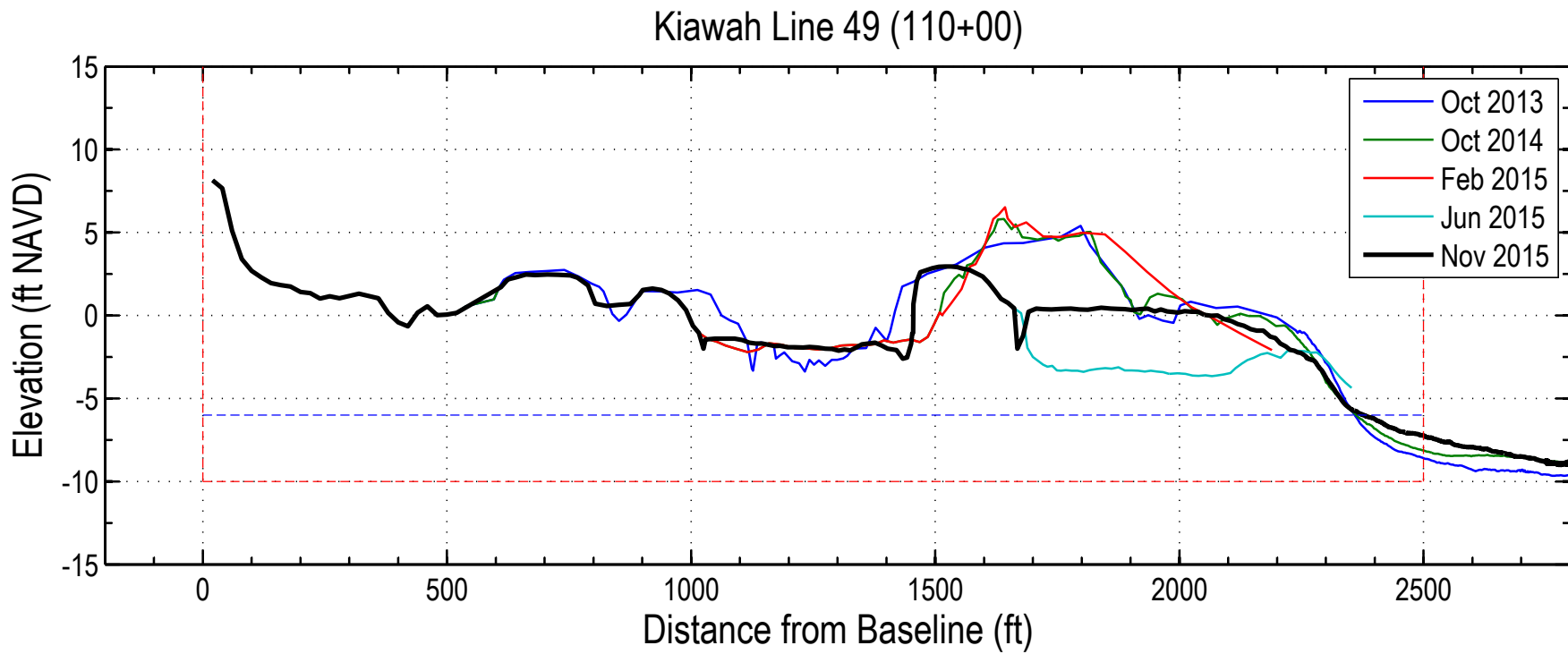
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	388.4	259.5	647.9
Oct 2013	414.9	281.5	696.4
Oct 2014	551.8	288.2	840.0
Feb 2015	472.2	305.3	777.5
Jun 2015	637.0	292.5	929.5
Nov 2015	638.8	295.3	934.1



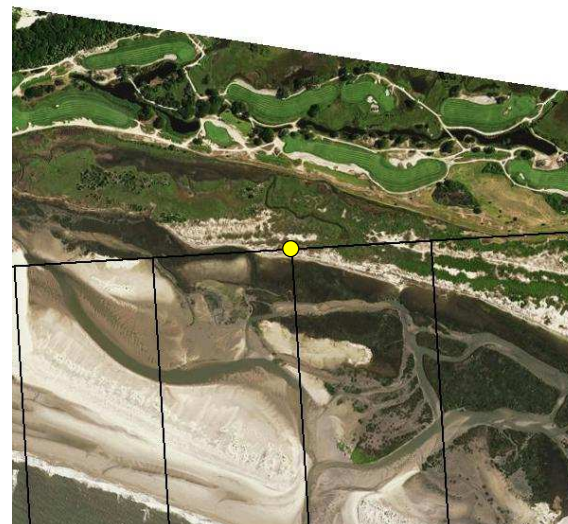


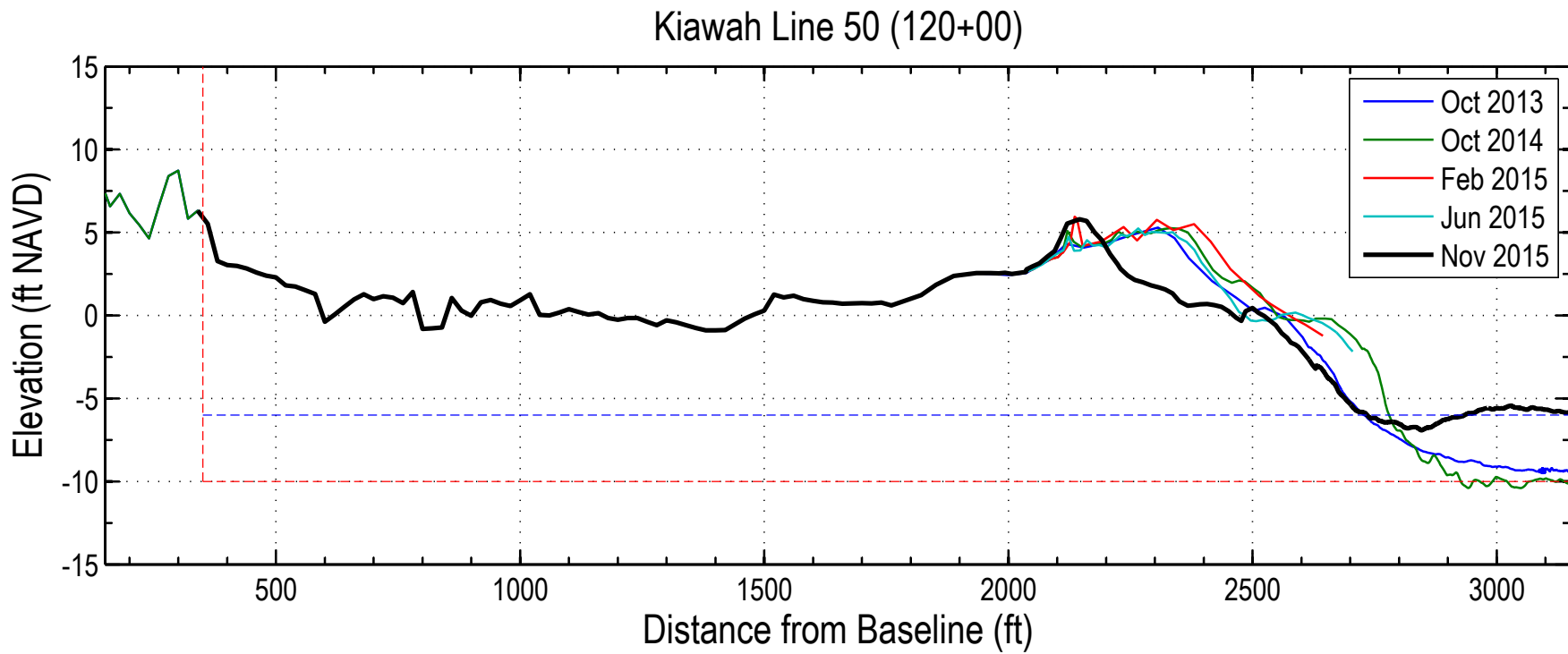
Date	Vol to -6	Vol -6 to -10	Vol to -10
Feb 2006	409.2	319.1	728.2
Sep 2006	329.2	288.2	617.4
Aug 2007	303.7	275.2	578.8
Oct 2008	290.3	251.4	541.8
Aug 2009	307.6	253.9	561.4
Oct 2010	310.6	252.1	562.6
Oct 2011	393.7	295.8	689.5
Oct 2012	452.0	306.4	758.3
Oct 2013	520.3	318.9	839.2
Oct 2014	556.3	323.2	879.5
Feb 2015	566.7	333.3	900.0
Jun 2015	564.0	324.1	888.1
Nov 2015	570.8	332.8	903.6





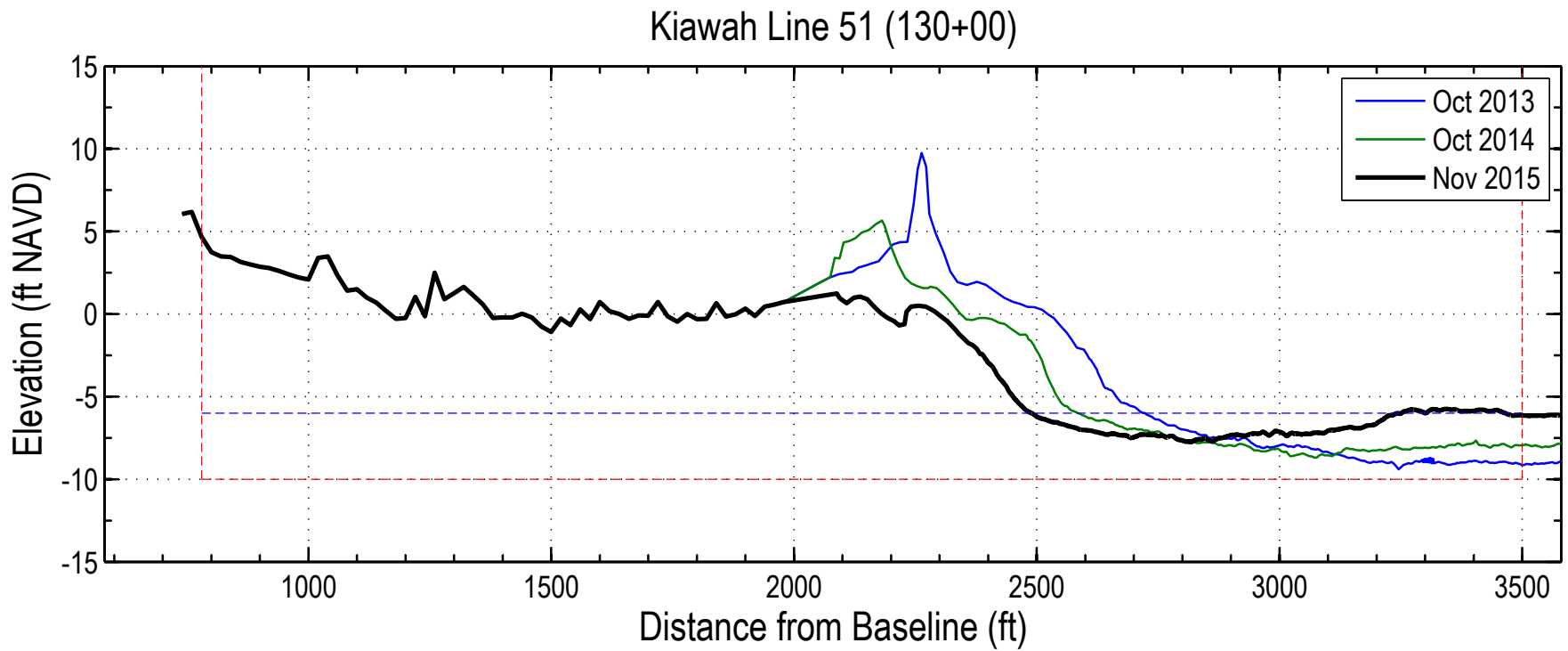
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	620.0	361.0	980.9
Oct 2013	617.4	361.5	978.9
Oct 2014	596.2	363.9	960.1
Feb 2015	600.9	369.0	969.9
Jun 2015	498.6	366.9	865.6
Nov 2015	554.9	367.1	922.0





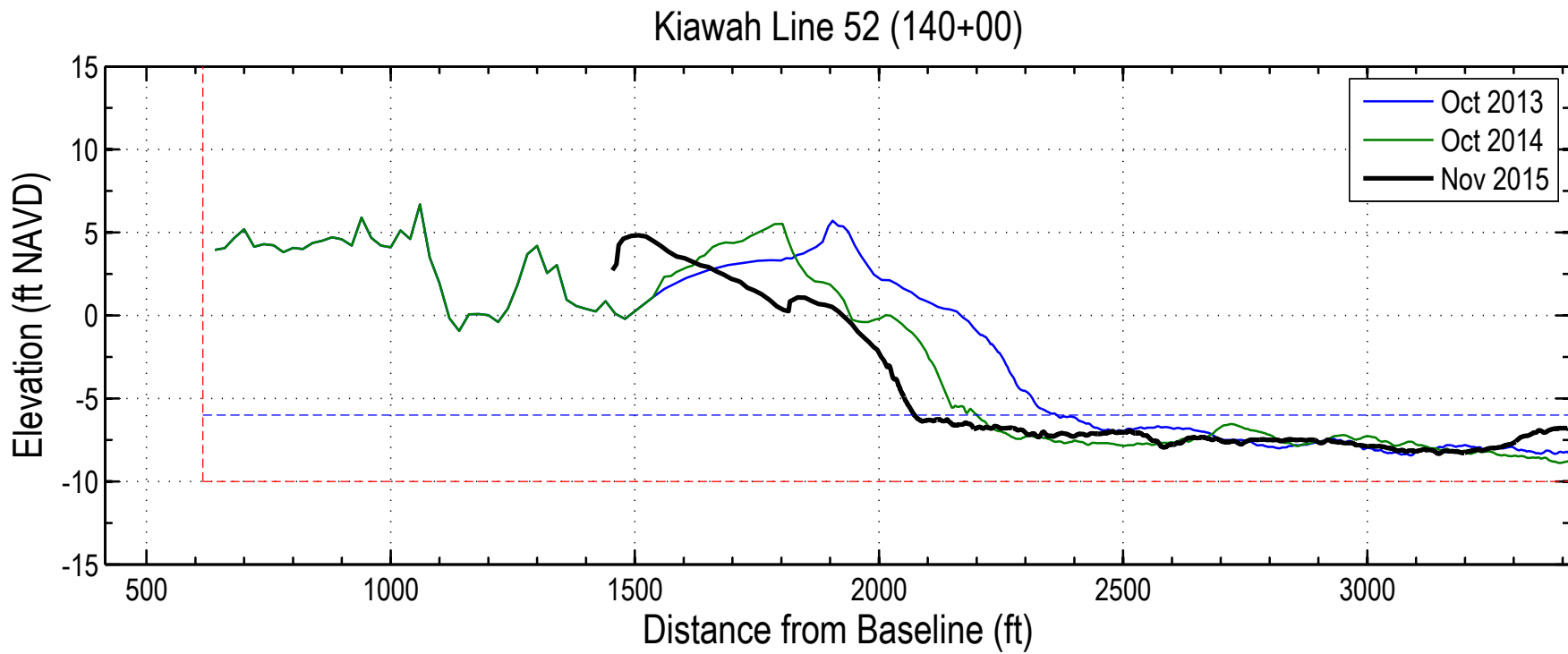
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	626.8	385.6	1012.4
Oct 2013	628.5	377.3	1005.7
Oct 2014	655.7	369.7	1025.4
Feb 2015	663.5	394.5	1058.0
Jun 2015	646.8	376.9	1023.6
Nov 2015	607.0	418.8	1025.9





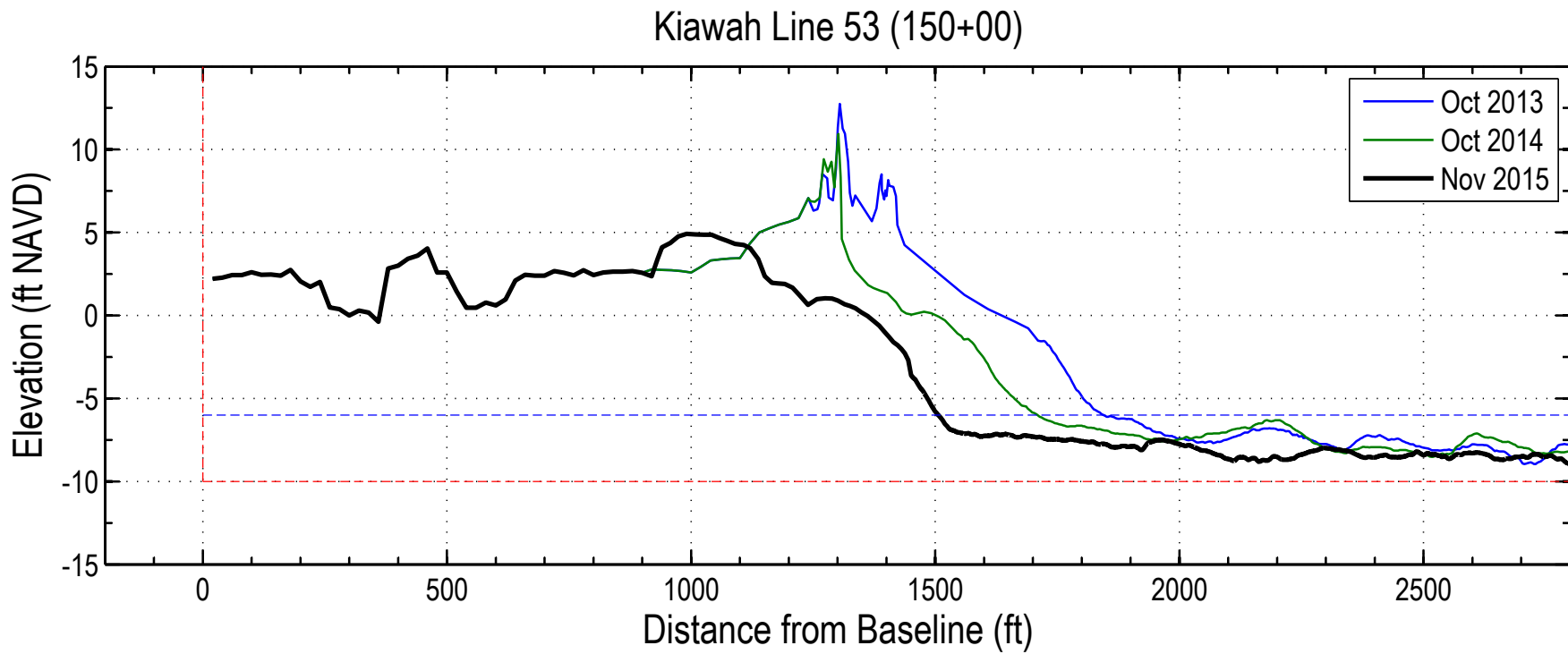
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	580.6	348.5	929.1
Oct 2013	500.5	338.5	838.9
Oct 2014	458.4	341.2	799.5
Nov 2015	407.7	371.7	779.4





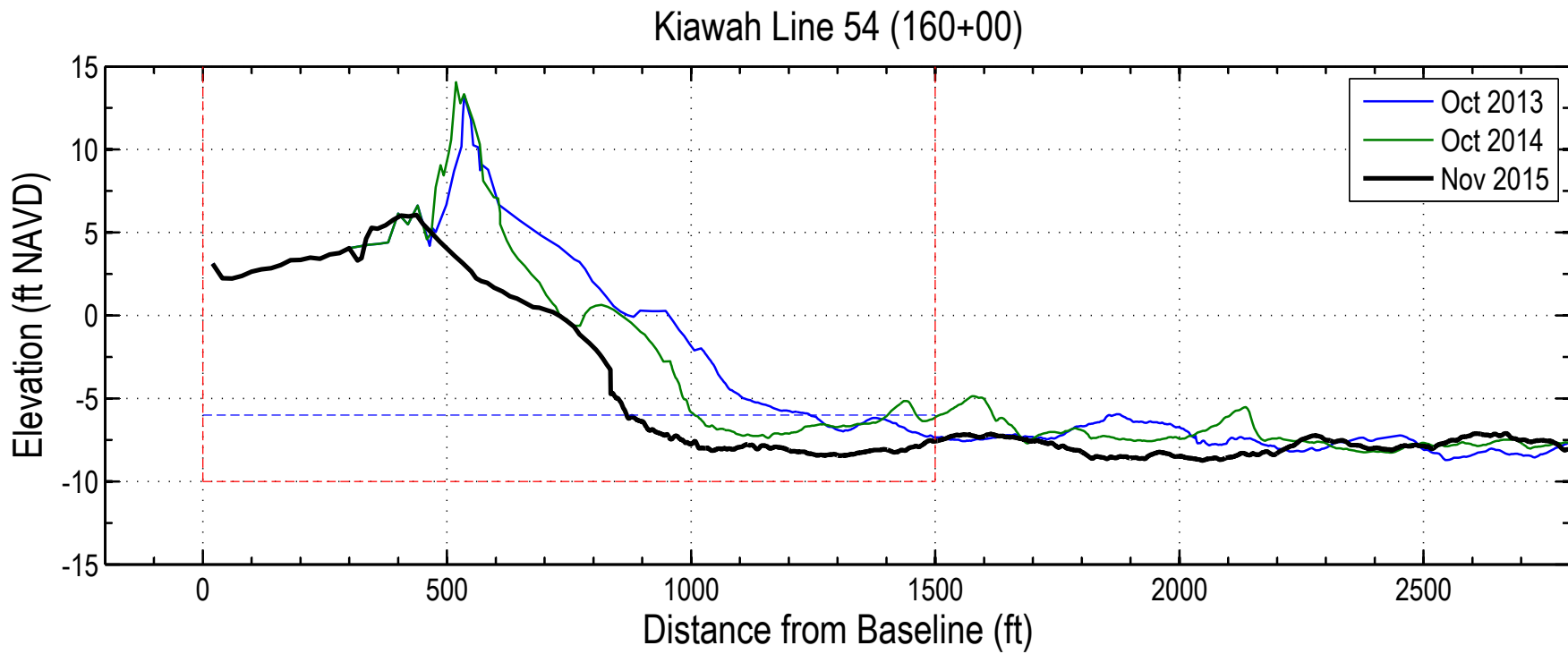
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	598.7	368.8	967.5
Oct 2013	522.7	359.0	881.7
Oct 2014	475.4	345.8	821.2
Nov 2015	441.6	354.5	796.1



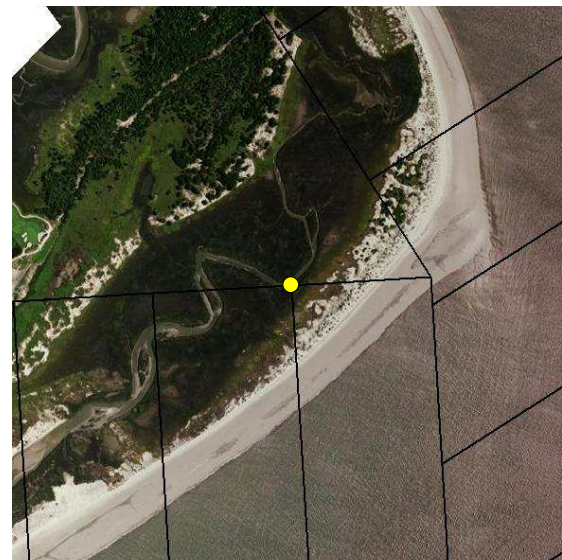


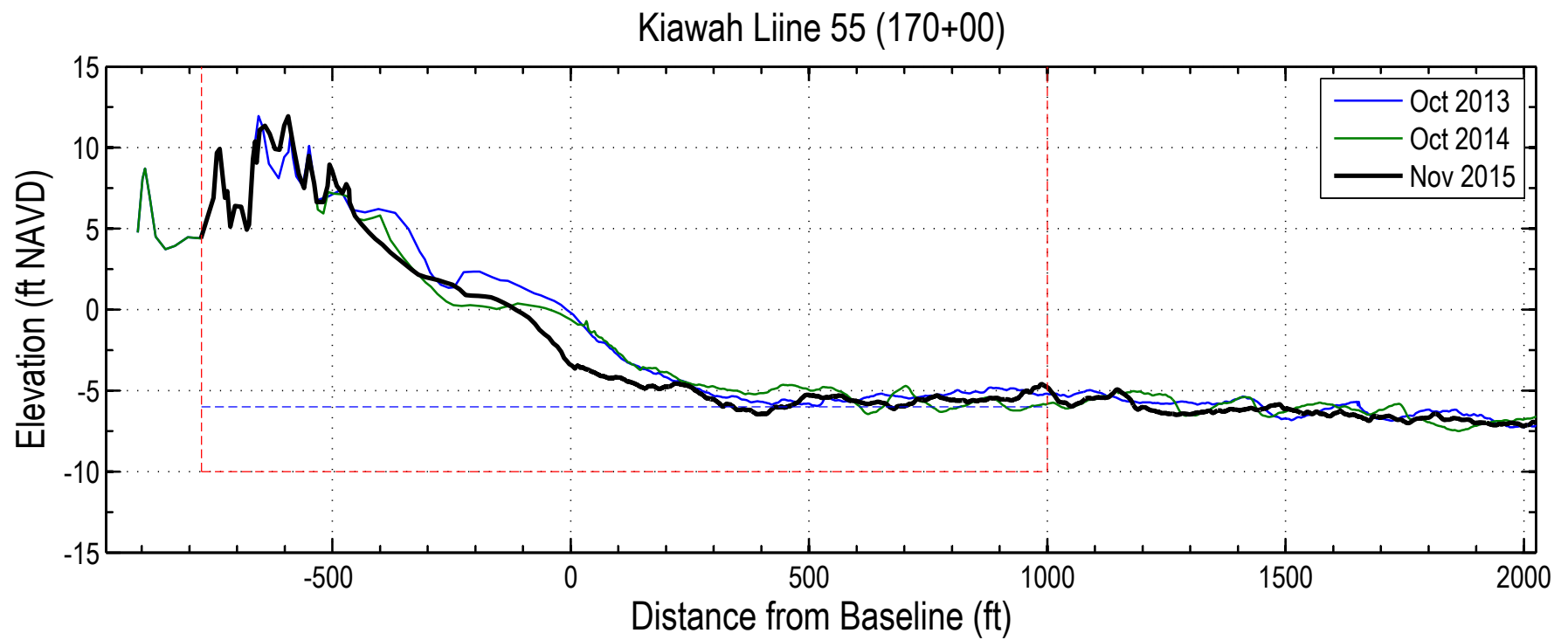
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	612.1	372.5	984.6
Oct 2013	574.1	360.1	934.2
Oct 2014	503.4	356.2	859.6
Nov 2015	435.0	316.9	751.9





Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	393.9	210.8	604.7
Oct 2013	377.4	215.9	593.3
Oct 2014	338.5	210.2	548.7
Nov 2015	265.9	178.9	444.8

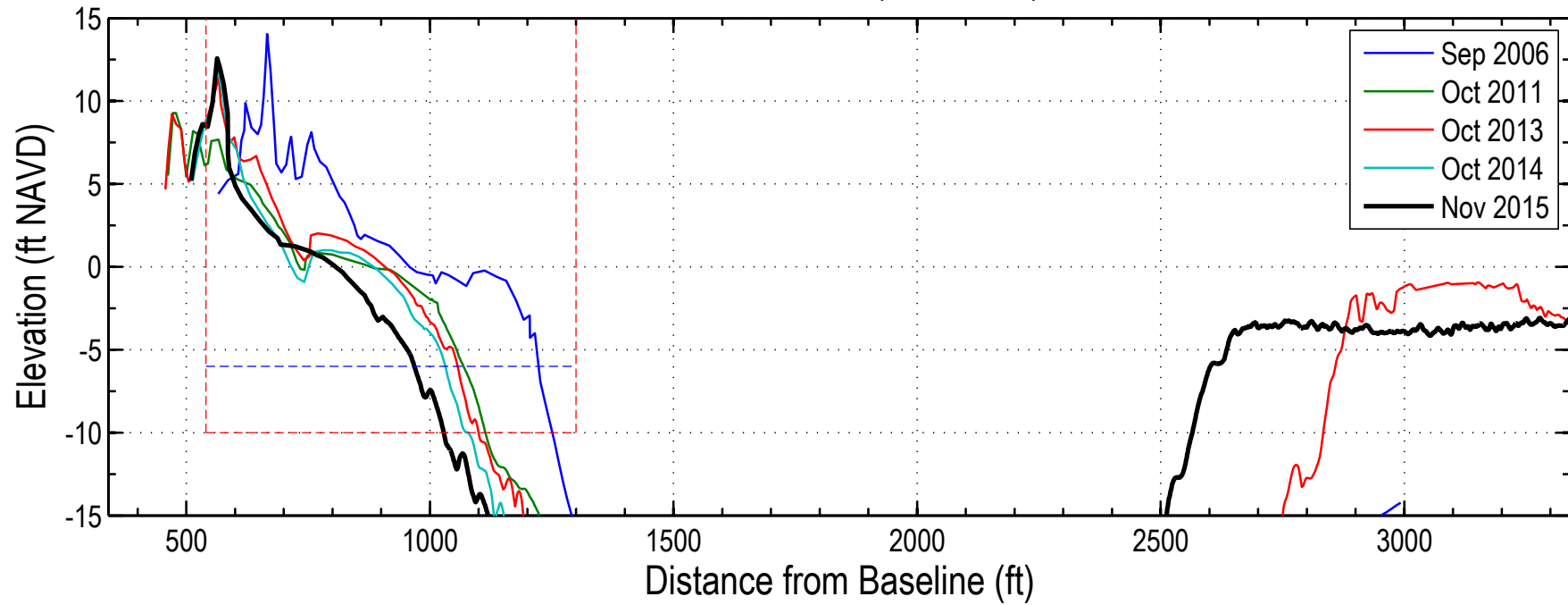




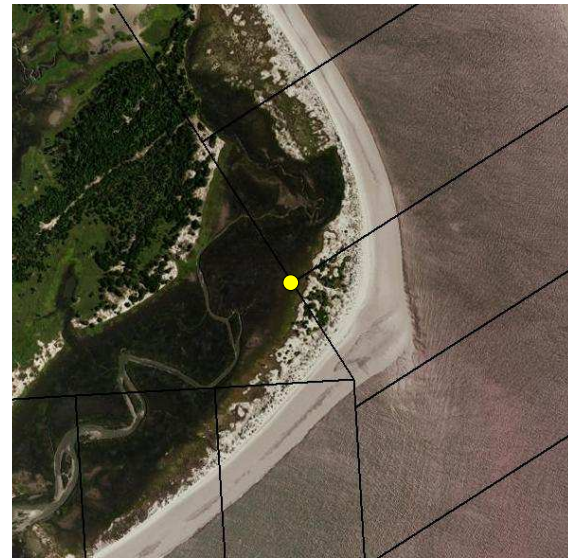
Date	Vol to -6	Vol -6 to -10	Vol to -10
Oct 2012	341.9	246.6	588.4
Oct 2013	358.1	263.0	621.0
Oct 2014	340.5	261.8	602.3
Nov 2015	317.0	262.0	579.0



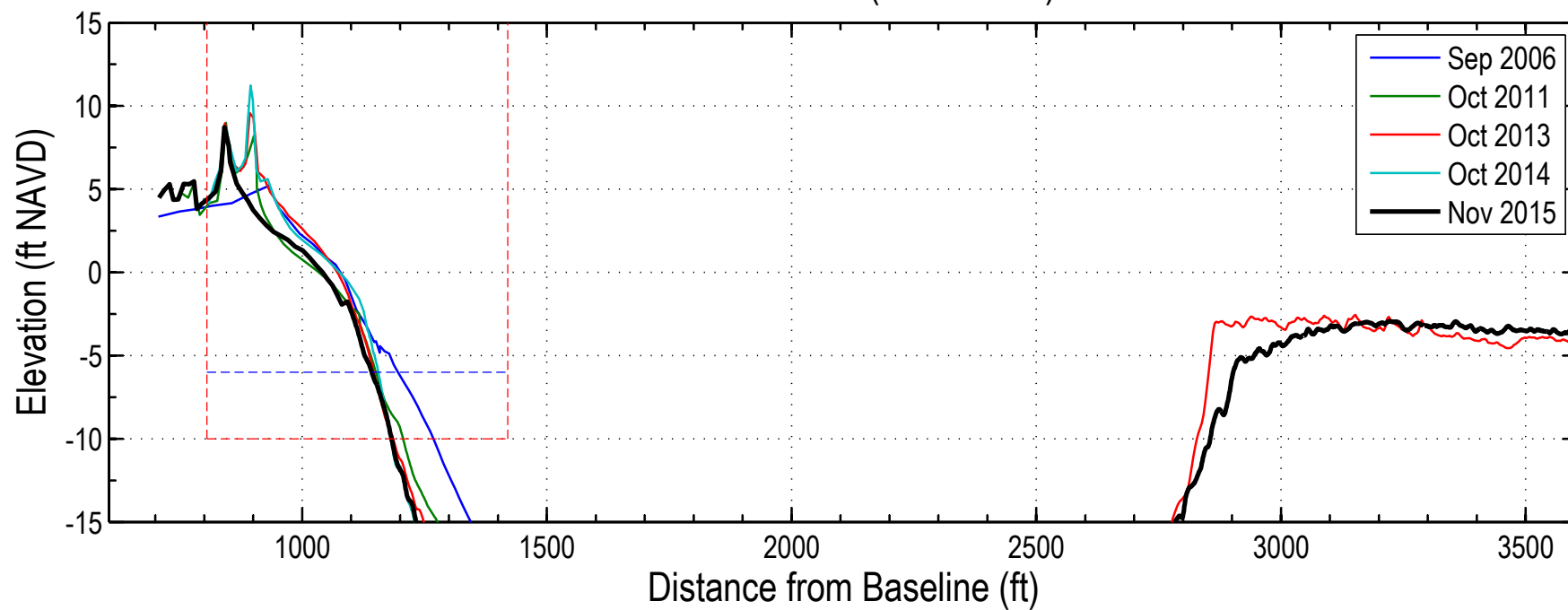
Kiawah Line 56 (Inlet 0+00)



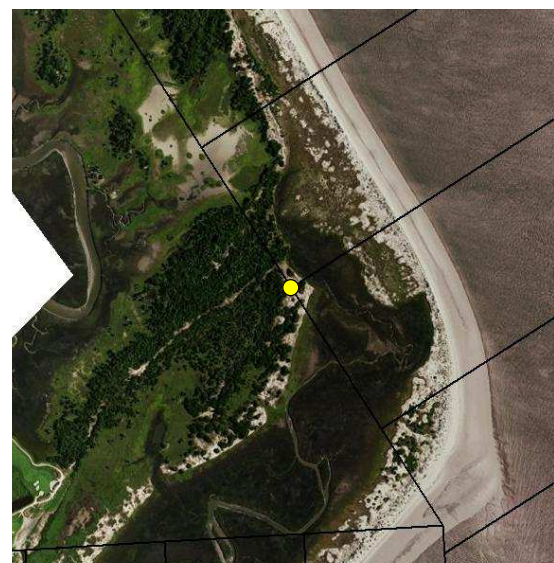
Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	219.0	103.0	322.0
Aug 2007	215.7	96.7	312.4
Oct 2008	177.4	92.2	269.6
Aug 2009	133.3	86.2	219.4
Oct 2010	109.5	77.6	187.0
Oct 2011	138.2	82.1	220.3
Oct 2012	157.0	80.2	237.2
Oct 2013	150.7	79.2	229.9
Oct 2014	133.0	75.7	208.7
Nov 2015	114.1	68.3	182.4



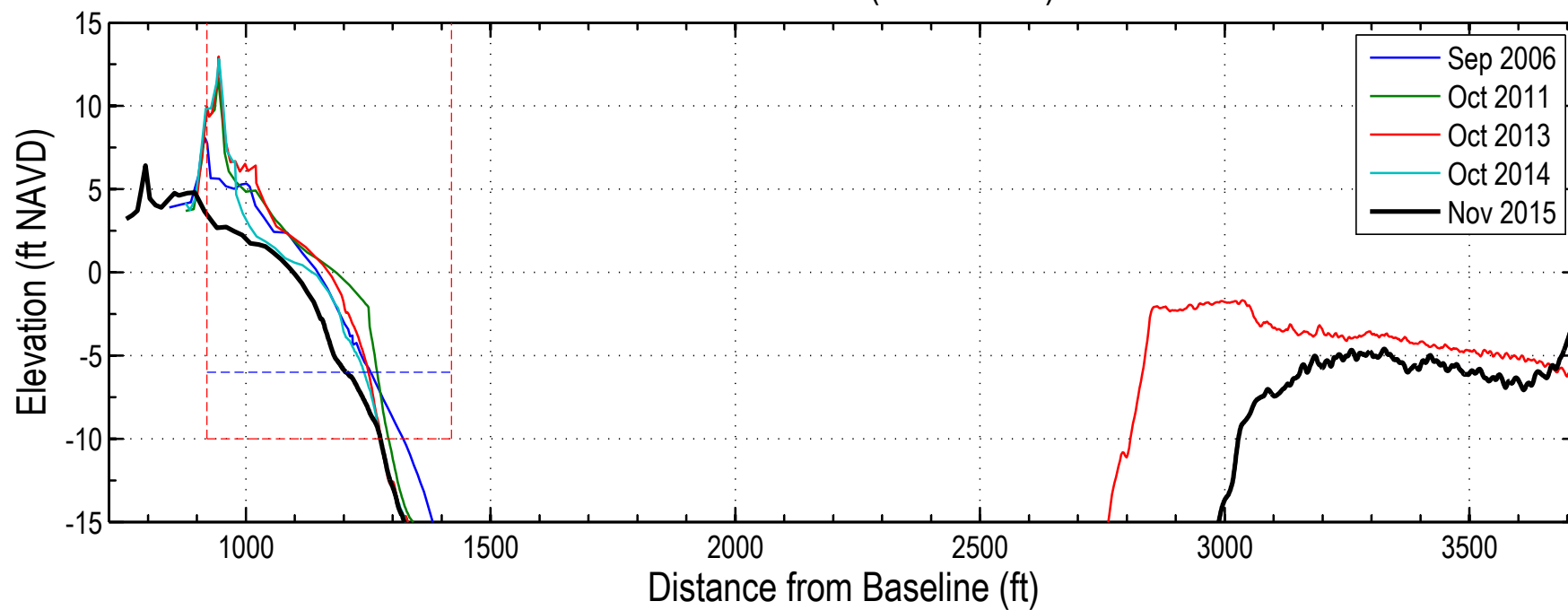
Kiawah Line 57 (Inlet 12+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	105.5	63.5	169.0
Aug 2007	106.7	61.6	168.2
Oct 2008	125.0	60.9	186.0
Aug 2009	122.5	62.2	184.6
Oct 2010	116.7	59.6	176.3
Oct 2011	99.5	55.0	154.5
Oct 2012	109.8	53.4	163.2
Oct 2013	112.5	53.2	165.7
Oct 2014	114.5	53.8	168.3
Nov 2015	94.8	53.3	148.1



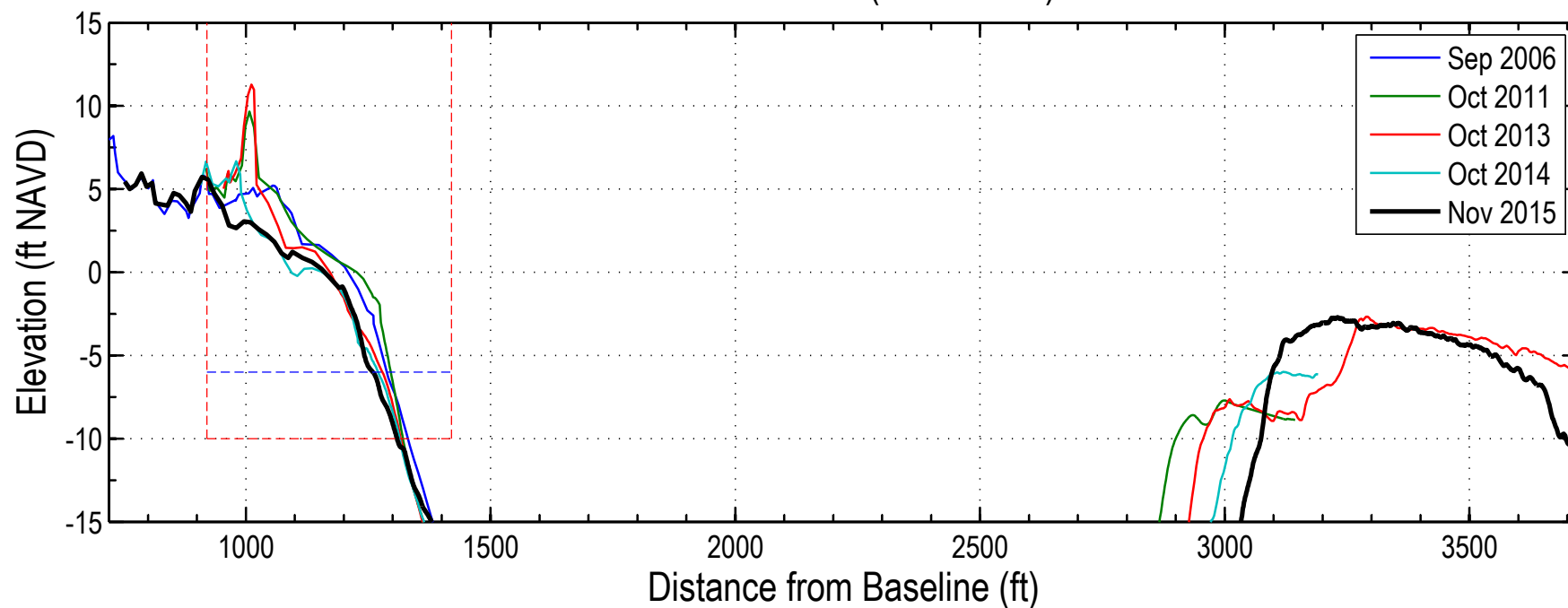
Kiawah Line 58 (Inlet 24+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	91.8	54.5	146.2
Aug 2007	89.2	54.2	143.4
Oct 2008	89.7	50.9	140.7
Aug 2009	85.6	51.5	137.1
Oct 2010	104.9	51.7	156.6
Oct 2011	110.5	53.2	163.7
Oct 2012	117.5	51.9	169.4
Oct 2013	107.6	50.9	158.5
Oct 2014	91.2	50.4	141.5
Nov 2015	64.0	48.2	112.2



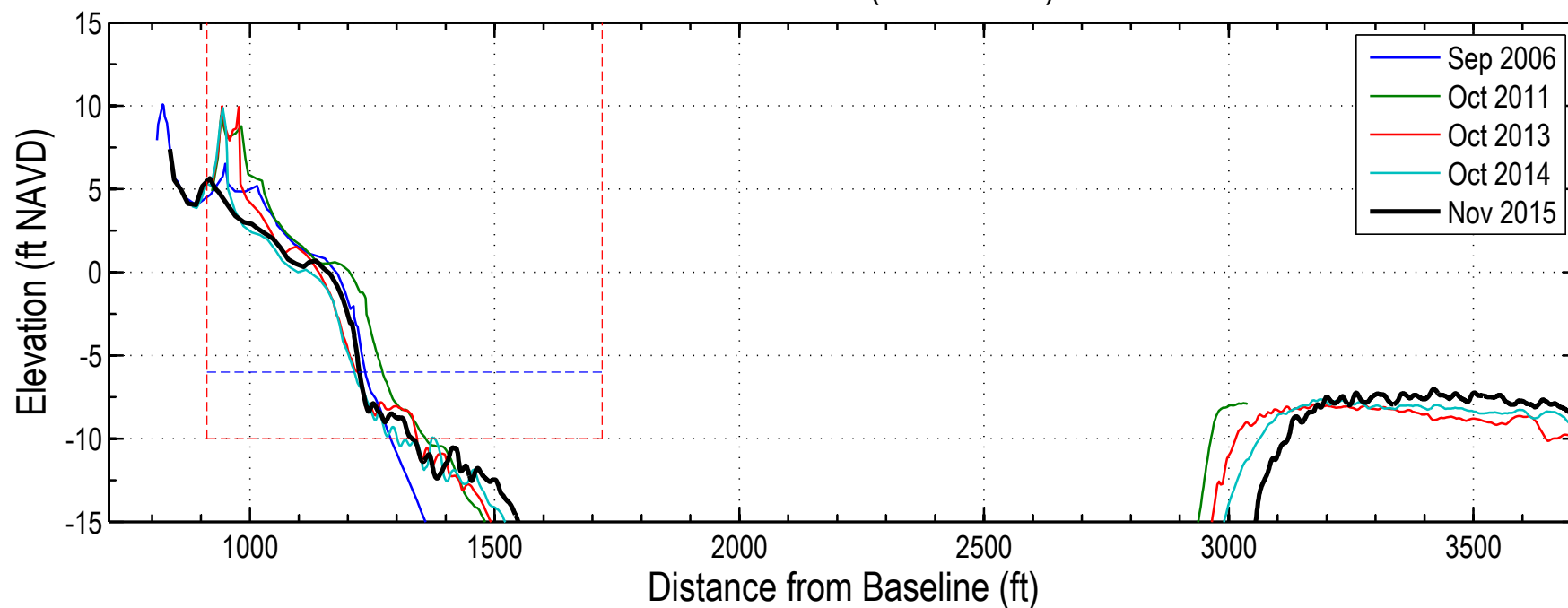
Kiawah Line 59 (Inlet 36+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	109.8	57.8	167.6
Aug 2007	109.2	57.7	166.9
Oct 2008	108.0	57.4	165.4
Aug 2009	110.4	57.7	168.1
Oct 2010	122.4	58.3	180.7
Oct 2011	121.0	57.6	178.6
Oct 2012	116.4	57.3	173.7
Oct 2013	105.8	56.2	162.1
Oct 2014	89.8	55.5	145.3
Nov 2015	86.5	54.1	140.6

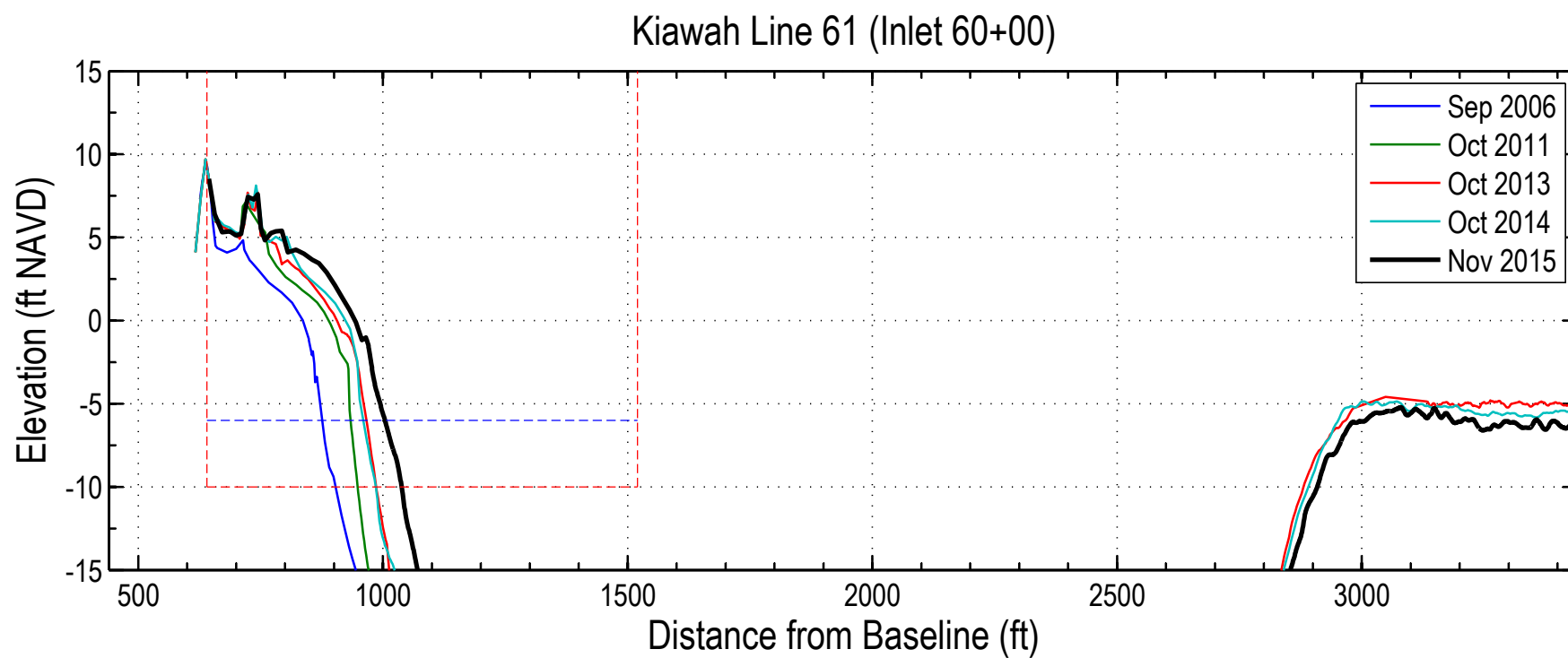


Kiawah Line 60 (Inlet 48+00)



Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	98.2	51.7	150.0
Aug 2007	103.0	53.8	156.8
Oct 2008	101.8	52.9	154.8
Aug 2009	101.1	56.0	157.1
Oct 2010	110.6	62.9	173.5
Oct 2011	114.1	58.9	173.1
Oct 2012	105.9	55.3	161.2
Oct 2013	93.2	54.2	147.4
Oct 2014	81.4	49.9	131.3
Nov 2015	85.1	52.2	137.2





Date	Vol to -6	Vol -6 to -10	Vol to -10
Sep 2006	72.3	36.6	108.9
Aug 2007	74.0	37.3	111.3
Oct 2008	84.4	39.3	123.7
Aug 2009	91.8	45.7	137.5
Oct 2010	102.1	44.1	146.2
Oct 2011	99.8	44.6	144.4
Oct 2012	100.8	45.4	146.2
Oct 2013	109.8	49.8	159.6
Oct 2014	114.0	49.2	163.2
Nov 2015	125.4	56.7	182.1

