FINAL REPORT

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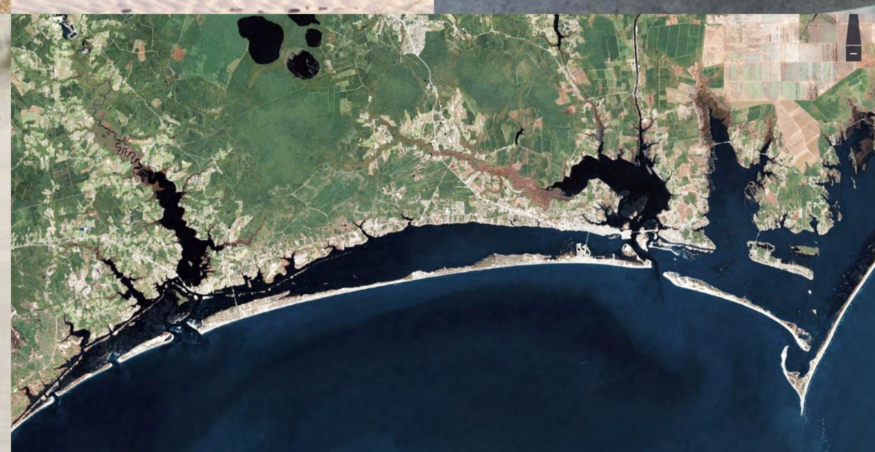

Bogue Banks Beach
and Nearshore Mapping Program

November 2015

moffatt & nichol

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Executive Summary

Comprehensive beach surveying of the Bogue Banks shoreline began in 1999 to develop the Bogue Banks Beach Restoration Project. In Spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was codified to continue assessing beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the program in October 2004 and Shackleford Banks was added in May 2005. Currently, surveys are performed annually during the spring/summer timeframe along all three islands. In addition, after large storm events surveying is performed along Bogue Banks to assess damages. The most recent annual survey was completed during spring/summer 2015 by Geodynamics. For this evaluation, the spring/summer 2015 survey was compared with the spring/summer 2014 survey to assess the changes in the beach occurring over the past year. The survey data was used to compute shoreline change at +1.1 ft NAVD88 which is designated as Mean High Water (MHW) and volume change above MHW, -5 ft NAVD88 (wading depth), -12 ft NAVD88 (outer bar), -20 ft NAVD88 (approximate closure), and -30 ft NAVD88 (offshore). This allows a detailed review of the shoreline and active profile performance since the 2014 monitoring report.

Key statistics were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2014 and 2015 survey profiles including;

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (Transects 1-112)	128,393	-9.0	-0.2	-20,768	-3.6	-465,760	2.7	341,840	-4.2	-542,511	-7.1	-908,778
Bogue Banks County Project (Transects 9-76)	88,094	-0.1	1.3	116,241	-3.2	-284,898	4.9	433,574	-2.5	-216,242	-5.9	-523,819
Bear Island (Transects 1-18)	16,500	19.2	3.5	57,316	0.8	13,323	-4.9	-81,411	-11.3	-187,109	-14.2	-234,599
Shackleford Banks (Transects 1-24)	46,001	-59.9	-2.9	-134,521	-19.7	-904,804	-34.3	-1,579,470	-44.9	-2,065,930	-51.1	-2,349,623

Key statistics for individual reaches along Bogue Banks were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-8)	7,432	-30.9	-1.7	-12,553	-4.0	-29,375	-3.6	-27,015	-10.1	-74,774	-12.8	-94,884
Emerald Isle-West (Transects 9-25)	22,344	-11.1	-2.4	-53,943	-0.5	-11,189	5.3	118,263	-1.8	-40,559	-7.5	-167,683
Emerald Isle-Central (Transects 26-36)	15,802	18.1	2.5	39,018	-2.6	-40,989	6.5	102,953	-2.4	-38,704	-7.5	-118,855
Emerald Isle-East (Transects 37-48)	13,220	-27.6	-2.0	-25,885	-5.0	-66,699	1.1	15,048	-4.5	-59,716	-7.2	-95,622
Indian Beach/Salter Path (Transects 49-58)	12,850	-4.5	3.5	44,355	-4.9	-62,813	9.0	115,676	0.3	4,482	-1.3	-16,491
Pine Knoll Shores-West (Transects 59-65)	9,063	21.3	5.0	45,634	-4.5	-41,178	6.7	60,500	-2.4	-22,060	-5.2	-47,476
Pine Knoll Shores-East (Transects 66-76)	14,815	12.1	4.5	67,063	-4.2	-62,030	1.4	21,133	-4.0	-59,685	-5.2	-77,691
Atlantic Beach (Transects 77-102)	26,176	-24.3	-3.6	-94,165	-3.6	-94,604	-2.5	-64,358	-8.2	-215,186	-9.0	-235,065
Fort Macon State Park (Transects 103-112)	6,691	-41.0	-4.5	-30,291	-8.5	-56,882	-0.1	-361	-5.4	-36,309	-8.2	-55,011
Beaufort Inlet (Transects 112B-116)	2,000	-22.4	-1.6	-3,239	-1.6	-3,223	9.9	19,800	2.8	5,651	-3.1	-6,149
Bogue Inlet-Channel (Transects 117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (Transects 9-76)	88,094	-0.1	1.3	116,241	-3.2	-284,898	4.9	433,574	-2.5	-216,242	-5.9	-523,819
Oceanfront (Transects 1-112)	128,393	-9.0	-0.2	-20,768	-3.6	-465,760	2.7	341,840	-4.2	-542,511	-7.1	-908,778

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

The Bogue Banks oceanfront shoreline experienced an overall average recession at MHW of -9.0 ft over the past year. However, this is heavily influenced by the equilibration of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and Atlantic Beach in 2014. Measurements along the County Project indicate very little overall movement in the MHW position in the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). In addition, volumetric measurements along the non-nourished reaches indicate a material gain of approximately 433,574 cy above -12 ft NAVD88. Volumetric measurements for the complete shoreline (Transects 1-112) show a gain of approximately 341,840 cy above -12 ft NAVD88. Looking at the table above, it would appear that there has been some movement of material towards the onshore from the lower depths (-20 ft NAVD88 and -30 ft NAVD88). Beyond the gains in material above -12 ft NAVD88, many reaches also experienced gains in material above MHW. Although there was a volumetric loss trend above -5 ft NAVD88, the intermediate elevation between MHW and -12 ft NAVD88, profile plots show many instances where material from the surfzone (between MHW and -5 ft NAVD88) migrated onshore, creating a new berm feature. In addition, many of these profiles show a gain in volume and landward shift of the offshore bar.

The Post-Irene Renourishment Project (February/March 2013) performance was also analyzed by comparing the 2015 survey data with post-fill surveys taken at the time of the project. Although all three reaches have experienced a loss in material from the berm out to -5 ft NAVD88, they all currently contain more material above -12 ft NAVD88 than was measured when the project was completed. The material captured landward of the offshore bar between -5 ft NAVD88 and -12 ft NAVD88 plays a vital role in absorbing wave energy and lessening the impact to material onshore.

Bear Island appears to have experienced a moderate amount of seaward advancement of the shoreline over the past year. Volumetric calculations indicate a gain in material above MHW and above -5 ft NAVD88 but a loss in material at lower elevations. Profile plots show relatively small changes in the profile shape and volume with the exception of Transect 2 near Bogue Inlet, which experienced a large amount of erosion. The significant erosion measured along Transect 2 accounts for an overwhelming majority of the volume loss calculated for the lower profile elevations along all of Bear Island. Review of the subsequent profiles show the remainder of the island was relatively stable and even showed volumetric gains at many transects.

Calculations indicate there was significant recession of the shoreline position at MHW and losses in material above all elevations analyzed on Shackleford Banks. However, profile plots indicate that Transects 1-20 experienced small to moderate recession of the shoreline at MHW and volume losses. The remaining transects located at the westernmost end of Shackleford Banks (21-23) experienced significant erosion of the dune and beachface. These remaining profiles account for a majority of the erosion experienced across the entire island. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. Calculations indicate that while Transects 1 – 20 lost approximately 200,320 cy of material above -12 ft NAVD88, Transects 21-23 lost approximately 1.36 Mcy of material above -12 ft NAVD88.

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, performed using shore parallel survey lines collected in 2014 and 2015. The difference in position at each transect was calculated and plotted to determine any trends in dune base movement along the oceanfront shoreline. An average landward movement of approximately 1.1 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position survey is highly subject to surveyor interpretation and other methods for tracking this feature are being investigated.

It is expected that next year's annual monitoring report will be performed under the new Bogue Banks Master Beach Nourishment Plan. The transition will bring with it slightly new management reaches and nourishment triggers. However, the types of analysis performed will remain consistent with previous monitoring reports. In fact, a preliminary assessment of current conditions compared to the new triggers was completed as part of this report. The new overall weighted trigger for the island is 233 cy/ft above -12 ft NAVD88, with varying triggers in each management reach. Using historical erosion rates (background and storm), it would appear that the next nourishment action may be needed within 3-6 years if there is a period of above normal storm activity. Otherwise, the next nourishment action is not expected for 7-12 years.

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1.0 Objective

The Bogue Banks Beach and Nearshore Mapping Program (BBBNMP) is sponsored by Carteret County and formally began in June 2004 as a continuation of the 1999 monitoring program initiated for assessing beach conditions. The program's primary purpose centered on forming strategies for the Bogue Banks Beach Restoration Project or County Project (Phases I, II, and III). The monitoring program was initiated along Bogue Banks and expanded to include Bear Island in October 2004. The inclusion of Shackleford Banks occurred later in May 2005. Since May 2005, surveys along Bogue Banks, Bear Island, and Shackleford Banks have been performed annually during the spring/summer timeframe. In addition, surveys occur for Bogue Banks after large storm events to quantify shoreline and volume changes and to augment the municipalities' FEMA reimbursement request for beach nourishment. The most recent annual survey occurred during the spring and summer of 2015 and was performed by Geodynamics LLC (Geodynamics). This report documents the data sources, methods, and results of a survey evaluation performed to compare the spring/summer 2015 survey with a previous survey performed in spring/summer 2014. The evaluation also includes an analysis of a post-fill survey taken in February/March 2013 as part of the Post-Irene Renourishment Project to quantify the projects performance through two years post construction.

2.0 Summary of Previous Work

Previous beach monitoring studies performed by Coastal Science & Engineering (CSE) between 2004 and 2007 were reviewed to gain an understanding of previous survey methods, associated coastal analysis, and observed trends (Note: University of North Carolina Institute of Marine Sciences completed the 2003 work). Each year, comparisons along Bogue Banks were made to an initial survey performed in 1999, providing for some long-term analysis. Bear Island and Shackleford Banks were added to the monitoring effort in 2004 and 2005, respectively. Each year, surveys for these regions were compared to the initial surveys in 2004 and 2005 to provide other long-term analysis results. In addition, at Bogue Banks, Bear Island, and Shackleford Banks, comparisons were made each year to the previous year's survey, providing insight into sand movement within a single year. **Table 1** and **Table 2** show the long-term and short-term volume changes over the various reaches of shoreline included in the BBBNMP.

Table 1. Long-term Volume Change (Previous Studies)

	Dune to -4' NGVD				Dune to -11' NGVD				Dune to -15' NGVD			
	June 1999-June 2004	June 1999-May 2005	June 1999-May 2006	June 1999-May 2007	June 1999-June 2004	June 1999-May 2005	June 1999-May 2006	June 1999-May 2007	June 1999-June 2004	June 1999-May 2005	June 2004-May 2006	June 2004-May 2007
Reach	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy
Bogue Inlet-Channel	-	-	-	-	-	-	-	-	-	-	115,528	-
Bogue Inlet-Ocean	185,872	250,657	-25,335	33,023	-268,237	395,676	99,426	147,797	-	-	-	-
Emerald Isle-West	420,971	963,253	739,518	899,412	723,052	1,321,780	1,072,208	1,185,131	-	-	685,012	1,783,395
Emerald Isle-Central	604,558	675,135	586,251	661,490	874,031	1,002,184	742,535	781,223	-	-	-11,291	1,194,915
Emerald Isle-East	700,213	670,766	640,656	685,168	965,114	963,911	803,382	946,483	-	-	-20,827	1,335,655
Indian Beach/Salter Path	856,179	829,318	681,474	783,473	1,361,192	1,290,983	1,035,738	1,155,522	-	-	-178,053	1,744,153
Pine Knoll Shores-West	329,308	305,689	226,660	403,726	398,891	526,330	357,306	680,649	-	-	87,624	1,135,995
Pine Knoll Shores-East	500,958	392,759	315,186	781,720	650,158	576,150	399,946	1,072,778	-	-	-190,587	1,796,876
Atlantic Beach	-10,721	931,032	661,520	558,278	136,193	1,902,206	1,305,619	1,194,947	-	-	1,661,386	2,358,100
Fort Macon	-196,301	15,679	23,930	36,932	-184,943	287,847	179,302	221,169	-	-	695,424	558,157
Beaufort Inlet	-	-	-	-	-	-	-	-	-	-	-	-
County Project	3,412,182	3,836,920	3,189,745	4,214,989	4,972,437	5,681,337	4,411,116	5,821,785	-	-	371,879	8,990,990
Entire Oceanfront	3,390,495	5,034,288	3,849,860	4,843,223	4,655,450	8,267,067	5,995,463	7,385,699	-	-	2,728,689	11,907,247
Bear Island	-	-	-	-	-	-	-	-	-	-	-	-
Shackleford Banks	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Short-term Volume Change (Previous Studies)

	Dune to -4' NGVD				Dune to -11' NGVD				Dune to -15' NGVD			
	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007	Dec 2003-June 2004	June 2004-May 2005	May 2005-May 2006	May 2006-May 2007
Reach	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy	cy
Bogue Inlet-Channel	-9,809	10,792	42,160	-26,182	-24,465	20,639	131,171	-7,147	-17,943	18,389	-	103,996
Bogue Inlet-Ocean	46,594	13,918	-204,216	58,358	-8,041	626,020	-299,980	48,372	-	-	-235,915	-52,942
Emerald Isle-West	54,586	542,282	-223,735	159,894	153,489	598,728	-249,571	112,922	147,494	807,600	-122,588	82,591
Emerald Isle-Central	11,253	70,577	-88,885	75,240	80,919	128,154	-259,649	38,688	70,888	238,146	-249,437	50,782
Emerald Isle-East	35,498	-29,447	-41,418	44,512	60,434	-1,204	-177,539	143,100	37,466	86,866	-127,967	130,604
Indian Beach/Salter Path	350,295	-43,495	-128,931	101,999	651,819	-85,523	-234,853	119,783	649,217	6,703	-184,756	103,996
Pine Knoll Shores-West	45,812	-8,333	-66,901	177,066	39,306	146,225	-149,924	323,343	26,129	233,908	-146,284	400,836
Pine Knoll Shores-East	45,904	-83,525	-97,553	466,534	67,286	-59,354	-197,027	672,831	11,741	-44,338	-146,248	563,500
Atlantic Beach	123,250	942,289	-269,512	-103,242	65,826	1,766,014	-596,587	-110,672	-63,325	2,189,434	-528,048	-274,554
Fort Macon	8,783	255,147	-13,739	17,087	-42,921	473,780	-84,893	33,818	-94,922	792,583	-14,647	151,211
Beaufort Inlet	41,514	85,619	-22,410	-11,428	85,574	448,098	-56,020	-4,905	103,219	1,035,861	-	-
County Project	543,349	448,059	-647,422	1,025,245	1,053,253	727,025	-1,268,564	1,410,668	942,935	1,328,884	-977,280	1,332,309
Entire Oceanfront	721,977	1,659,414	-1,134,889	997,448	1,068,117	3,592,840	-2,250,025	1,382,186	784,689	4,310,901	-1,755,890	1,156,024
Bear Island	-	-29,705	-162,365	-105,930	-	-135,310	-139,170	-343,295	-	11,980	-64,820	-471,975
Shackleford Banks	-	-	-450,401	-74,356	-	-	-686,685	55,122	-	-	-665,033	270,338

3.0 Survey Methods and Data Sources

Most recently, Geodynamics conducted a survey of Shackleford Banks, Bear Island, and Bogue Banks in March through June 2015. The profile lines and origins used in previous studies were also used for the most recent survey for ease of comparison. **Figure 3-1** and **Figure 3-2** show the location of the profile lines and origins applied by Geodynamics for the surveying. Two transects were added near Beaufort Inlet (112B) and Bogue Inlet (117B) in 2008 to better track sand movement near the inlets. As shown, lines were stationed from west to east along Bogue Banks and east to west along Bear Island and Shackleford Banks. The survey data was provided in ASCII (xyz), Excel (xyz), Shapefile (GIS), and ISRP (BMAP) formats allowing for compatibility with multiple programs. The survey references the NAD 1983 State Plane North Carolina (feet) horizontal datum and the NAVD 1988 vertical datum.

Several steps were taken by Geodynamics to ensure the most accurate survey data. The spring/summer 2015 survey represents a continuation of previous surveys conducted for the Carteret County Shore Protection Office using high-density singlebeam sonar and topographic equipment. The 2015 survey meets the requirements specified in the NOS (National Ocean Service) Hydrographic Surveys Specifications and Deliverables (April, 2007), the OCS (Office of Coast Survey) Field Procedures Manual for Hydrographic Surveying (June 2008) and the criteria for Navigation and Dredging Support Hydrographic Surveys as outlined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual, EM 1110-2-1003 (EM 1110-2-1003 January 2002). The following sections discuss the singlebeam (bathymetric) and topographic data acquisition including the associated equipment, quality control procedures, and data processing requirements.

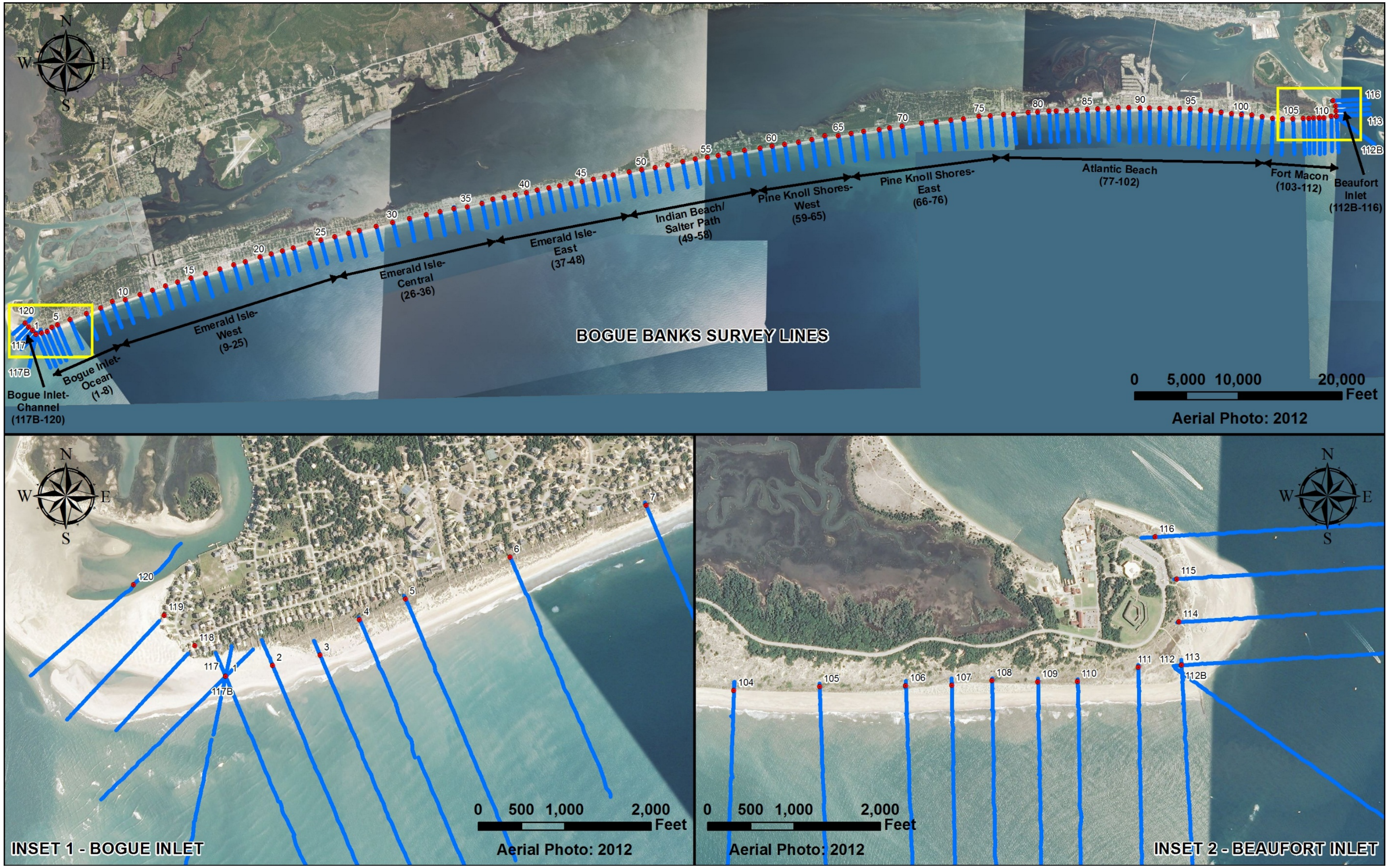


Figure 3-1. BBBNMP Profile Line Locations – Bogue Banks

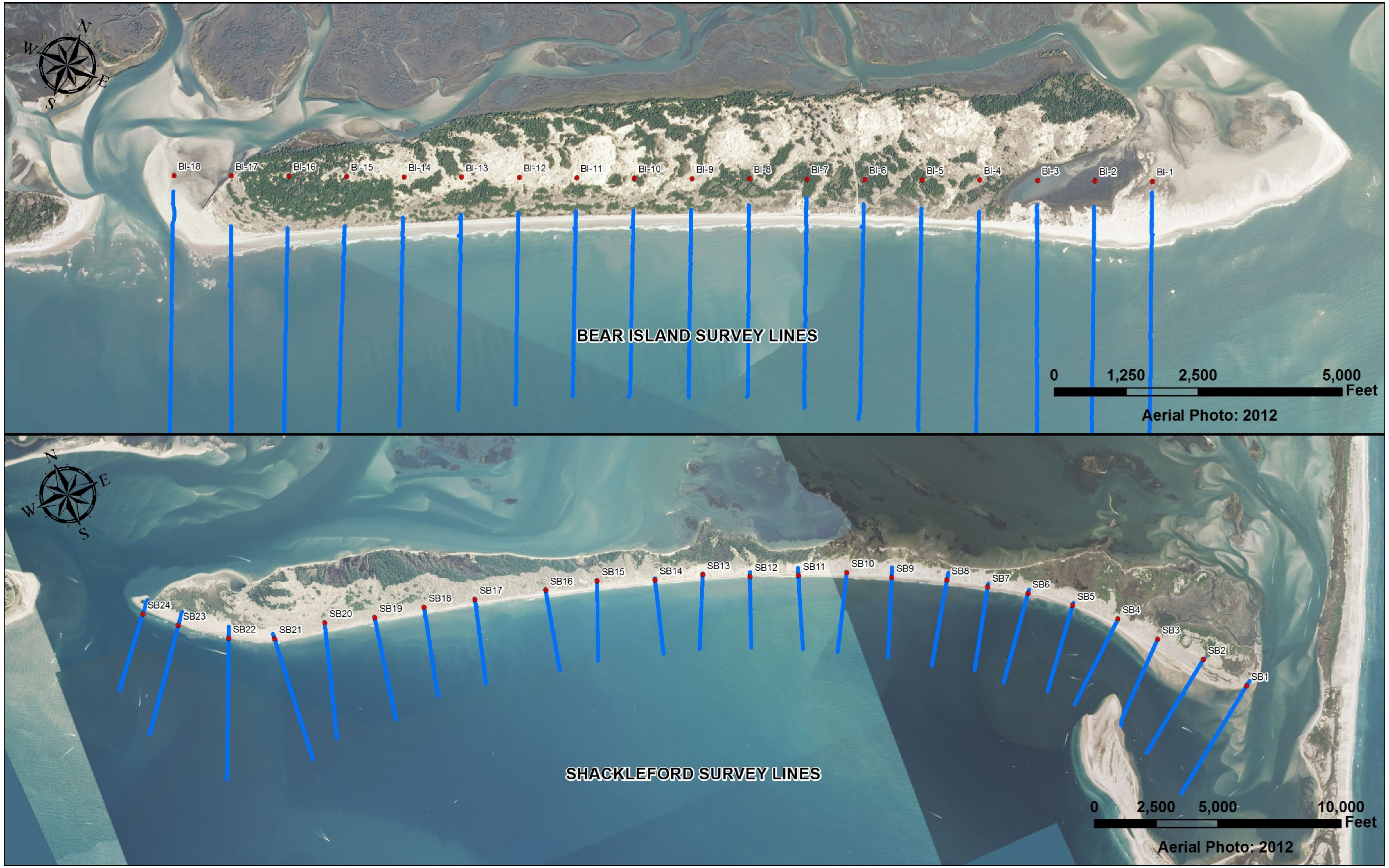


Figure 3-2. BBBNMP Profile Line Locations – Bear Island and Shackleford Banks

3.1 Singlebeam (Bathymetric) Data Acquisition and Processing

The following sections discuss the equipment, quality controls, sounding corrections, and data processing associated with the singlebeam data acquisition.

3.1.1 Singlebeam Survey Equipment, Hardware, and Software

The R/V Echo served as the survey platform for singlebeam data acquisition (**Figure 3-3**). The R/V Echo is designed to be a vessel of opportunity for shallow water inshore and coastal ocean mapping. The R/V Echo is a 21 ft Cape Fear Catamaran with through-hull and pole-mount singlebeam sonar capability. The vessel is powered by a 140 hp four-stroke engine mounted on a jack plate to enable ultra shallow water data collection. Data acquisition computers are housed within the water-tight console and are powered through an onboard battery bank. This vessel represents the state-of-the-art in modern hydrographic surveying. The R/V Echo specifications are presented in Table 3 and the hardware systems inventory for the R/V Echo is shown in **Table 4**.

Figure 3-3. The R/V Echo Hydrographic Survey Platform Setup

Table 3. R/V Echo Vessel Speceifications

Dimensions:	21' x 9' x 1.2'
USCG:	Designated Research Vessel
Flag	U.S.
Registry:	North Carolina
Official Number:	NC 7341 DT
Tonnage:	1
Lab Space:	1 Open Concole Operator Station
Max Speed:	30 Knots
Min. Survey Speed:	2.5 Knots
Propulsion:	1 x 140 HP Suzuki 4-Stroke Outboard Motor - 2011
Auxillary Power:	24v DC Battery Banks & 12V DC Parallel Battery Banks
Fuel Capacity:	60 Gallons
GPS:	Simrad
Sounder:	Lowrance StructureScan
Compass:	n/a
Radar:	n/a
Autopilot:	n/a
VHF:	Icom 25 watt
Cellular Phone:	iPhone 6s
Internet:	Verizon JetPack 4G LTE

Table 4. R/V Echo Hardware Systems Inventory

	Hardware	Manufacturer	Model
Horizontal & Vertical Control	RTK Radio Modem	Trimble	TDL 450H
	RTK Radio Antenna	Pacific Crest	n/a
	GPS Antenna	Trimble	Zephyr
	Cellular Internet Card	Verizon	n/a
	POS MV	Applanix	Wavemaster
Echo Sounding	StructureScan	Simrad	1.7.0
	ODOM CV100	ODOM	CV100
	Operator Station	CCS-inc	FPC-04649
Attitude Positioning	Inertial Motion Unit (IMU)	Applanix	Wavemaster
	Position Compute System (PCS)	Applanix	Wavemaster
	Primary GPS Antenna (port)	Trimble	Zephyr
	Secondary GPS Antenna	Trimble	Zephyr
Sound Velocity	Sound Profile Velocimeter	AML Oceanographic	Minos SVP-X

The vertical control for singlebeam data acquisition was provided by three basestations and a combination of VRS and RTK-GPS. They are: the North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC, "IMS Base" located at the UNC-IMS building in Morehead City, NC, and benchmark “Westport” located in Emerald Isle, NC. A repeater was also used to extend radio corrections. Station NCBE utilizes a Trimble NETR5 GNSS (Global Navigation Satellite System) receiver to collect and broadcast corrections to roving users via an internet connection.

Horizontal positioning and vessel attitude for singlebeam data was provided by the Applanix Positioning for Marine Vessels (POS/MV Wavemaster) systems and was corrected using Inertially-Aided Real-Time Kinematic (IARTK) technology. This system provides roll and pitch accuracy to 0.01°, heading to 0.02° (with a 2 m antenna baseline), heave accuracy to 5 cm or 5% (whichever is greater).

The AML Oceanographic Minos X SV&P sound velocimeter was used during the survey in order to obtain accurate sound velocity profiles throughout the survey area. Unlike traditional Conductivity, Temperature, and Depth (CTD) sensors, velocimeters measure sound speed directly using “time of flight” technology, automatically compensating for pressure, salinity, and temperature. The system comprises a sound velocity probe attached to the data collector where the survey technician logs the sound velocity profile data as the probe is deployed.

An Odom CV100 singlebeam sonar system was used to acquire singlebeam bathymetry data during the survey. The CV100 system operates at frequencies in the 200 kHz band; ideal for shallow depths (<40 m). The transducer forms a 4 degree beam. With an operational depth range from <30 cm to 600 m and a ping rate up to 20 Hz, the CV100 is ideal for shallow water surveys.

The software systems inventory for singlebeam data acquisition and processing is presented in **Table 5**.

Table 5. Singlebeam Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2014
	POSView	8.1
	Odom eChart	1.4
Data Processing	HYPACK	2015
	SeaCast	3.2.10
	ArcView	3.4
	ArcGIS	10.2
	POSPac MMS	7.1
	Matlab	2013

The HYPACK software suite was used during survey preparation in order to create profile lines plans. The initial line plan was created in accordance with the Carteret County Shore Protection Office beach profile monitoring stations established in 1999. Survey lines were extended to a length of 5000 ft from the baseline as per the official SOW. HYPACK was also used during the survey to collect singlebeam bathymetric data and topographic data.

The POSView software by Applanix was used with the POS/WM system. The software provides a tightly-coupled integration of the attitude measurements recorded by the IMU and the position measurements recorded by the GPS. POSView allowed the survey technician to monitor the attitude and positioning accuracy throughout the survey. POSView logged a POSPac True Heave file which contains the Kalman filtered heave for further post-mission attitude processing.

HYPACK was subsequently used to manipulate and process both singlebeam bathymetric data and topographic data once it was collected. The Singlebeam Editor in HYPACK was used to import, clean, and thin the data. Upon cleaning, the *Export* module was used to export the data into a specific format. The post-processed POSPac file was integrated with the singlebeam data in HYPACK single beam editor.

The POSPac MMS (mobile mapping solution) software by Applanix was used to post-process attitude and navigation data collected in POSView. By post-processing the attitude and navigation data stored in the POSPac data file with a logged GPS observable file from the basestation, common artifacts of RTK-GPS can most often be eliminated and the overall accuracy of the attitude and navigation can be increased.

ArcGIS and ArcView GIS are complete Geographic Information Systems (GIS) software packages. All survey area maps, coverage extents, and final chart products were created using ArcGIS 10.2.

3.1.2 Singlebeam Quality Control

All survey line planning was completed in HYPACK. Survey line spacing was based on previous surveys of Bogue Banks with extensions per USACE specification. Survey lines were extended to reach a 5000 ft distance offshore from the start of the profile or baseline.

At the start of each survey day, a series of pre-survey protocols were run to aide in quality control and to determine any possible errors/issues prior to surveying. A temporary benchmark located at Geodynamics headquarters in Morehead City, NC was checked daily. The GAMS parameters and POS/MV installation parameters located under the installation settings of the POS/MV were all checked each day prior to enabling Ethernet logging of POSPac data.

All singlebeam and topographic data acquisition were completed using HYPACK Survey software. Data acquisition was performed at vessel speeds of approximately 3 - 10 knots. The HYPACK data acquisition software produced a constantly-updated OTF (On-The-Fly) data matrix, which allowed for real-time monitoring of the data coverage. Data displays in HYPACK Survey were used to monitor all survey parameters and the quality of data being recorded.

Sound velocity profiles were acquired routinely and when the survey vessel moved to a different location within the survey area. Each successive sound velocity cast was assessed and used to determine the need for additional casts.

3.1.3 Corrections to Echo Soundings

The vessel offsets were measured with respect to the ship's reference point, located at the top center of the Inertial Motion Unit (IMU). The vessel offsets were then entered into POSView to ensure an accurate merging of the IMU data with the singlebeam data.

The Applanix POS/WM unit was setup to receive phase-differential RTK position offsets from the GPS base station at NCBE Pivers Island. This configuration allowed the POS Computer System (PCS) to integrate decimeter positional solutions with highly-accurate vessel attitude and positions obtained from the IMU and dual GNSS receivers. The PCS software computes velocity, roll, pitch, and true heading from the accelerometer and gyro outputs. These sensed accelerations and rates of rotation are calculated into measurements of velocity, heading, and track of the vessel through complex algorithms. For improved heading, the GPS Azimuth Measurement Subsystem (GAMS) limited the amount of noise in the vertical measurements, correcting for heading by aligning two fixed GPS antennas. Using a Kalman filter, this heading is combined with the Dynamic Heading Alignment, a method that uses data supplied by the IMU and GPS receivers to calculate heading, enabling heading accuracies between 0.05° and 0.1° RMS.

Dynamic draft is the summation of the static draft and settlement and squat corrections, and is a required corrector for the echo soundings. Dynamic draft was accounted for in the echo soundings by using RTK-GPS. The ellipsoid-based vertical corrections received from the VRS network provided the survey vessel with an accurate real-time elevation based on the vessels position in the water. This worked to factor out the static draft, settlement, and squat of the survey vessel.

Sound speed profiles were taken at the start of each survey day, and again throughout the day as warranted by the survey area and water mass properties. Sound velocity profiles were acquired routinely and when the survey vessel moved to a different location in the survey area. Each successive sound velocity cast was assessed and used to determine the need for additional casts. A total of 28 sound velocity profiles where taken during the survey which greatly exceeds the standard set forth in the USACE Hydrographic Manual. A comparison of the sound velocity profiles was conducted in order to determine sound speed variations in different parts of the survey area.

RTK-based tidal measurements were continuously recorded throughout the survey by HYPACK Survey. The GPS height determined by the POS/WM was integrated into the raw singlebeam sonar data in the HYPACK data acquisition software by integrating the post-processed POSPac Smoothed Best Estimate of Trajectory (SBET) file. After importing the raw singlebeam data in HYPACK, the GPS tide was merged with the heave such to provide accurate tidal corrections and remove any influences obtained from the wave conditions.

3.2 Topographic Data Acquisition and Processing

The following sections discuss the equipment, quality controls, sounding corrections, and data processing associated with the topographic data acquisition.

3.2.1 Topographic Survey Equipment, Hardware, and Software

A Trimble R7 RTK-GPS rover backpack system was used to acquire topographic data during the survey. The Trimble R7 RTK-GPS receiver integrates GPS observables with real-time VRS network corrections to provide a centimeter-level position and elevation. The RTK-GPS data is output from the R7 receiver at 10 Hz to the Panasonic Toughbook CF-U1 data acquisition tablet PC. A Yamaha ATV is used to transport personnel between profiles as well as collect tie-lines along morphological breaks on shore (**Figure 3-4**).

Figure 3-4. Yamaha ATV Used For Topographic Data Acquisition and Transportation

Table 6 provides the hardware systems inventory for topographic data collection.

Table 6. Topographic Hardware Systems Inventory

Hardware	Manufacturer	Model
Acquisition PC	Panasonic	Atom CF-U1
GPS Receiver	Trimble	R7
GPS Antenna	Trimble	Zephyr 2
Internet Con. (imbedded Gobi)	Qualcomm	HS-USB 250D

The vertical and horizontal control for topographic data acquisition was provided by three basestations and a combination of VRS and RTK-GPS. They are the North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC, "IMS Base" located at the UNC-IMS building in Morehead City, NC, and benchmark "Westport" located in Emerald Isle, NC. A repeater was also used to extend radio corrections. Station NCBE utilizes a Trimble NETR5 GNSS (Global Navigation Satellite System) receiver to collect and broadcast corrections to roving users via an internet connection.

Horizontal and vertical positioning for topographic data was acquired by a Trimble R7 RTK-GPS system. The topographic rover received and integrated the differential corrections from the VRS station and RTK-GPS for centimeter-level positioning.

Table 7 presents the software systems inventory for topographic data collection.

Table 7. Topographic Software Systems Inventory

	Software	Version
Data Acquisition	HYPACK	2014
	GNSS Internet Radio	1.4.11
	VZAccess Manager (Verizon/Quick link)	6.9.0
Data Processing	HYPACK	2015
	ArcView	3.4
	ArcGIS	10.2
	Microsoft Excel	2010

The HYPACK software suite was used during survey preparation in order to create profile line plans. The initial line plan was created in accordance with the Carteret County Shore Protection Office beach profile survey lines. Survey lines were extended to a length of 5000 ft offshore from the baseline to meet specific project requirements. HYPACK was also used during the survey to collect topographic data. Phase-differential RTK corrections from NCBE were received by using an imbedded Gobi card accompanied with Verizon Access Manager and GNSS Internet Radio.

HYPACK was subsequently used to manipulate and process the topographic data. The Singlebeam Editor in HYPACK was used to import, clean, and thin the data. Microsoft Excel was used to format data columns specific to the client's needs.

All survey area maps, coverage extents, and final chart products were created using ArcGIS, a complete Geographic Information Systems (GIS) software package.

3.2.2 Topographic Quality Control

All survey line planning was completed in HYPACK. The planned survey line spacing was dictated by the Carteret County Shore Protection Office Beach Profile Project. Survey lines were typically oriented parallel to the shoreline (note: lines were changed from Coastal Science and Engineering's 1999-2007 azimuths due to inconsistent data acquisition in 2008). Each topographic mapping system was tested prior to each survey day. Surveyors verified line files, data acquisition rates, masking angles, and software / hardware setup.

At the start of each survey day, a series of pre-survey protocols were run to aide in quality control and to determine any possible errors/issues prior to surveying. Benchmarks located at the Geodynamics office were checked and quality assessed prior to surveying each day. Each surveyor's rod and backpack antenna draft were checked and input in the survey software.

All topographic data acquisition was completed using the HYPACK Survey software. Data acquisition was performed by walking as upright as possible while following the planned survey line. The surveyor constantly monitored the GPS status, off-line value, distance from baseline, and overall morphology along the profile. The HYPACK data acquisition software produced a constantly updated OTF data matrix, which allowed for real-time monitoring of the data coverage as well. To ensure ample topographic data overlap with the hydrographic data, the surveyor would plot the targets acquired during the surfzone hydrographic survey. These targets indicated how far the surveyor needed to go down the profile and into the surfzone. Upon completion of a survey day, all data was thoroughly reviewed and various profiles overlaid on previous profile data for a quick in-field QA-QC check.

A series of shore parallel topographic lines were acquired between stationed topo/bathy profile transects along Bogue Banks. Approximately 4 survey lines collected from a calibrated all-terrain vehicle (ATV) were acquired and geocoded at the dune base, above/ below any noticeable berm (or open beach in absence of feature) and above/below the anticipated MHW contour. The goal of collecting these data is to calculate any deviation in the dune base over time, to improve digital elevation modeling of the beach face and to extract a more accurate MHW contour.

3.3 Vertical and Horizontal Control

The vertical datum for this survey is the North American Vertical Datum of 1988 (NAVD88). Soundings were reduced to NAVD88 from ellipsoid heights in HYPACK by integrating the local Geoid 2012a, 08 section model.

The horizontal datum for the final data product is the North Carolina State Plane Zone 3200, Feet. Horizontal control was derived using Real Time Kinematic (RTK) or VRS-RTK positioning. The North Carolina Geodetic Surveys' Virtual Reference Station "NCBE" located on Pivers Island, NC provided position and elevation as well as the multiple RTK-GPS basestations.

3.4 Merging Topographic and Bathymetric Data

Upon processing the individual hydrographic and topographic data sets in HYPACK, the datasets are merged, resulting in one edited HYPACK file per profile line. Each profile line is then thoroughly inspected for topo/bathy overlap, landward and seaward data extents, and consistency with previous profile data.

Rigorous QA-QC assessments are performed on the final topo-bathy profiles in order to ensure the highest quality data. Topographic data, in the less variable dune areas, is overlaid with the previous years' data and the horizontal and vertical alignment is evaluated. The topo-bathy profiles are examined one-by-one to review the overlap of topographic and hydrographic data to guarantee reliable surfzone data (**Figure 3-5**). The entire topo-bathy profile is then compared to the same profile from a previous years' dataset to assess the overall quality and consistency of the profile data.

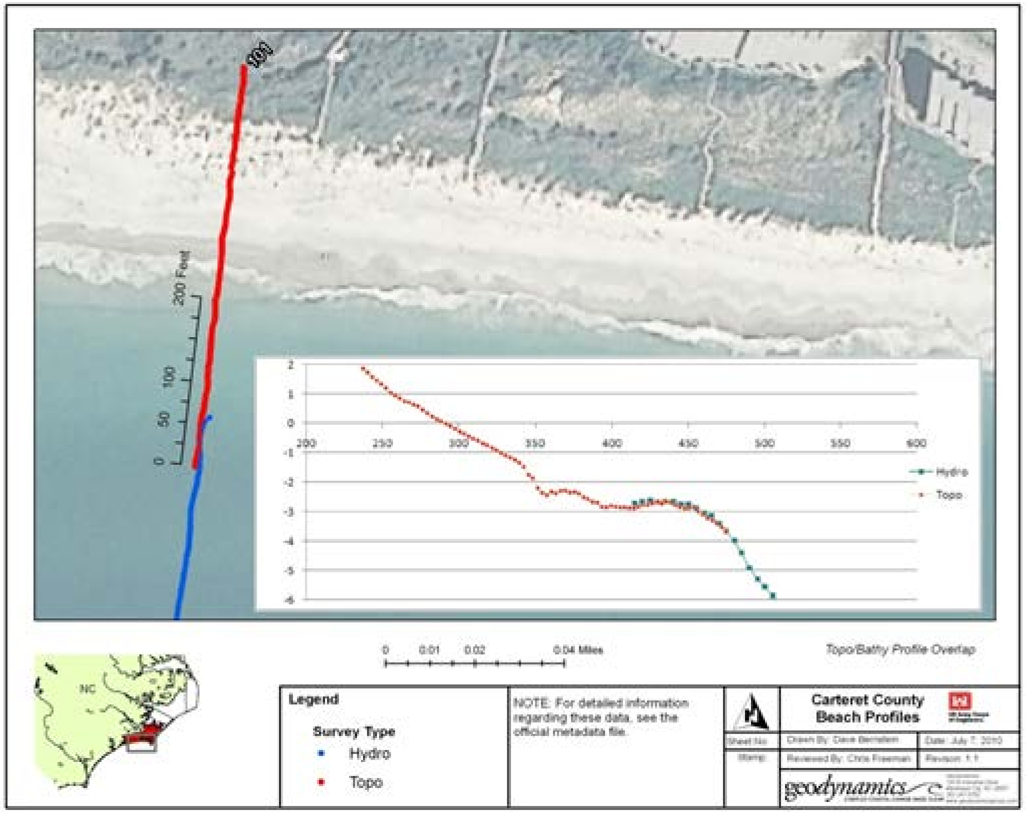


Figure 3-5. Example of Topographic and Bathymetric Data Overlap in Surfzone

3.5 Survey Data Acquisition Timeline

The most recent set of survey data was collected by Geodynamics during March through June of 2015. The Shackleford Banks survey was completed on March 9-10, 2015. Bear Island was surveyed on June 4, 2015. The Bogue Banks survey, due to weather, was performed over a longer range of dates from April 6, 2015 to June 2, 2015. The date used for the Bogue Banks profiles for this report is May 20, 2015, when a large portion of the surveying was completed.

The previous set of annual survey data, used for comparison in this report, was also collected by Geodynamics during February through June of 2014. The Shackleford Banks survey was completed on February 25, 2014. Bear Island surveys were performed on April 22-25, 2014. For this report, April 25, 2014 was used as the survey date for all profile lines on Bear Island. The Bogue Banks survey, due to weather, was performed over a longer range of dates from May 13, 2014 to June 26, 2014. The date used for the Bogue Banks profiles for this report is June 23, 2014, when a majority of the surveying was completed.

4.0 Survey Evaluation Methods

Survey comparisons and respective analysis were performed using Beach Morphology Analysis Package (BMAP). BMAP is a program developed by the USACE to analyze morphologic and dynamic properties of beach profiles.

All survey data sources were imported into ArcGIS, in xyz format, and displayed to compare the coverage of each set of data. Excel files containing the spring/summer 2014 and spring/summer

2015 beach profiles being used for the comparison were then formatted and imported into BMAP. Using BMAP, two indicators of shoreline change were calculated for each transect.

First, the change in shoreline position at mean high water (MHW), which was defined as +1.1 ft NAVD88 (based on NOAA tidal benchmark at Morehead City-equivalent to previously computed elevation of +2.1 ft NGVD29), was calculated at each transect between the spring/summer 2014 and spring/summer 2015 profiles. The resulting value represents the shoreline change (ft) over the time period between surveys. The shoreline change rate (ft/yr) was then calculated by dividing by the amount of time (years) between survey dates. This allows an equivalent comparison of shoreline migration rates occurring between different time periods.

Second, representative volume changes were calculated at each transect between the spring/summer 2014 and the spring/summer 2015 surveyed conditions. Volume changes were calculated for five different extents in order to better understand the processes occurring onshore and offshore of the Bogue Banks beach area. Calculations included volume change above MHW (+1.1 ft NAVD88-equivalent to +2.1 ft NGVD29), above -5 ft NAVD88 (wading depth/recreational beach-equivalent to -4 ft NGVD29), above -12 ft NAVD88 (outer bar-equivalent to -11 ft NGVD29), above -20 ft NAVD88, and above -30 ft NAVD88.

Upon inspection of recent survey data, it appears the depth of closure occurs somewhere between -20 ft NAVD88 and -30 ft NAVD88 (likely closer to -20 ft NAVD88). For those profiles which did not extend to -30 ft NAVD88, volume calculations were performed above -30 ft out to the extent of the shortest survey. As with the shoreline change, the results represent volume change (cy/ft) over the period of time between surveys. The volume change rate (cy/ft/yr) was then calculated by dividing by the amount of time (years) between survey dates in order to better compare changes between different time periods. In addition, the volume changes were converted to cumulative changes over the entire shoreline. This was done by applying the average end area method to the unit volume changes (cy/ft) and unit volume change rates (cy/ft/yr) computed at each transect and summing the total volume changes over the entire shoreline. The resulting value indicated the total loss or gain of material between survey periods based on the applicable profile extents. It should be noted that the uncertainty in the hydrographic portion of the survey is approximately ±0.11 ft. If this uncertainty is applied along the portion of the profile between the seaward side of the outer bar (approximately 1300 ft offshore) and a depth of -30 ft NAVD88 (approximately 2850 ft offshore) along all 128,393 ft of oceanfront shoreline, this lends itself to an uncertainty of approximately ±811,000 cy.

Volume changes calculated for portions of the profiles above MHW represent changes in the amount of material in the dune system and on the subaerial beach. These areas are highly influenced by storm activity. Volume comparisons for portions of the profiles above -5 ft NAVD88, an approximate wading depth, represent changes in the recreational beach area. Volume comparisons above -12 ft NAVD88 help to track sand movement to and from the outer sand bar and are ultimately used in decision making for future beach nourishment projects. Volume comparisons above -20 ft NAVD88 allow for the tracking of sand movement offshore while reducing the amount of uncertainty associated with the survey data by eliminating changes beyond this depth related to the vertical margin of uncertainty in the hydrographic survey data. Finally, volume comparisons above -30 ft NAVD88 allow the complete tracking of sand movement offshore. However, hydrographic survey measurement accuracy may impact these calculations. This is a comprehensive way to assess the impact of storm activity on the subaerial beach and dune system as well as track the movement of sand offshore and quantify total gains and losses in the entire system. **Figure 4-1** presents a graphic showing the various calculation lenses.

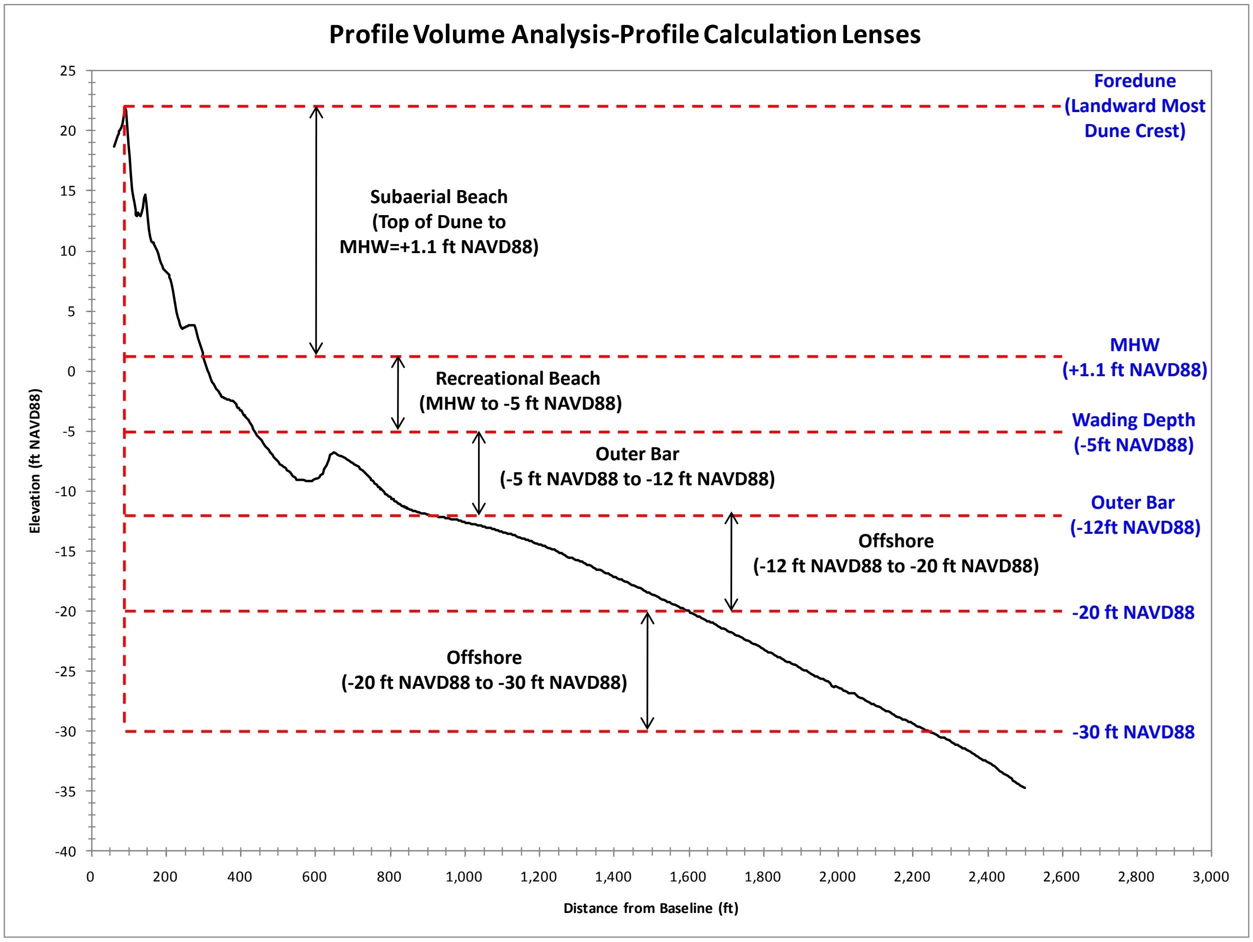


Figure 4-1. Profile Volume Calculation Lenses

In addition to the annual 2014/2015 comparison, the volumes calculated for the spring/summer 2015 survey were also compared to the post-fill surveys completed in February/March 2013 after the Post-Irene Renourishment Project. The comparison covered the regions above MHW (+1.1 ft NAVD88), -5 ft NAVD88 and -12 ft NAVD88 which roughly represents the seaward extent/depth of the nourishment template and the post-fill survey. These calculations give an idea as to how much of the nourishment material remains on the recreational/visible beach and how much is still located above -12 ft NAVD88 and thus provides protection of the beach. However, crosshore transport occurring seaward of the -12 ft NAVD88 contour is difficult to quantify due to the extents of the post-fill survey. In addition, the longshore transport of material to adjacent transects is difficult to calculate but an attempt was made to capture some of this based on visual inspection of the profile plots.

Furthermore, an assessment of the change in position of the base of the dune along Bogue Banks was performed using shore parallel survey lines collected in 2014 and 2015 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline.

Finally, in preparation for management under the upcoming Master Beach Nourishment Plan, a preliminary assessment of current conditions compared to the new nourishment triggers was completed as part of this report. The assessment utilized historical erosion rates to estimate the potential time remaining until the next nourishment action may be necessary.

For visual reference, a Digital Elevation Model (DEM) was created by Geodynamics using Surfer, a 3D surface mapping software package, for both the spring/summer 2014 and spring/summer 2015 profile data. The MHW shoreline position contour was extracted from the spring/summer 2014 and spring/summer 2015 DEMs and plotted on aerials. These figures are presented in **Appendix A**.

5.0 Discussion of Annual Surveying Evaluation

This section discusses long-term background erosion rates, recent events (i.e. nourishment projects, storms, etc.), overall shoreline trends, regional shoreline trends, the post-Irene project performance, and FEMA beach maintenance analysis. For reference, **Appendix B** contains plots of the shoreline and volume changes from the spring/summer 2014 and the spring/summer 2015 surveys at each transect, for Bogue Banks, Bear Island, and Shackleford Banks. **Appendix C** presents profile comparison plots for individual transects for the spring/summer 2014 and the spring/summer 2015 surveys. Where applicable, the Irene post-fill profiles (February/March 2013) are also plotted for comparison. Lastly, **Appendix D** provides the computed shoreline changes and volume changes measured at each individual transect in tabular format.

5.1 Determination of Background Erosion Rate for Bogue Banks

Due to the numerous nourishment projects which have taken place along Bogue Banks since the monitoring program was initiated in 1999, it is important to determine a background erosion rate without nourishment from which to compare the performance of the various projects and to develop long-term trends in volume losses/gains. Therefore, the historical volume changes above -12 ft NAVD88 and beach nourishment volumes were documented. The Bogue Banks area has undergone extensive beach nourishment throughout the duration of the monitoring effort as part of the County Project, the USACE Section 933 Project, USACE Dredge Disposal Projects, and post-storm FEMA work. **Table 8** and **Table 9** summarize the nourishment projects in the study area since initiation of the monitoring program.

Table 8. Nourishment Volumes by Project

Year	Project	Reach	In-Place Volume (cy)
2002	County Phase 1	Pine Knoll Shores - East & West	1,276,586
2002	County Phase 1	Indian Beach/Salter Path	456,994
2002	USACE Disposal	Fort Macon	209,348
2003	County Phase 2	Emerald Isle - East & Central (berm)	1,743,788
2003	County Phase 2	Emerald Isle - East & Central (dune)	123,938
2004	USACE Section 933	Indian Beach/Salter Path & Pine Knoll Shores - West	699,282
2004	FEMA Post Isabel	Emerald Isle - East & Central	156,000
2005	Brandt Island Pump Out	Atlantic Beach	2,390,000
2005	USACE Disposal	Fort Macon	530,729
2005	County Phase 3	Emerald Isle - West	690,868
2007	USACE Section 933	Pine Knoll Shores - East & West	507,939
2007	FEMA Post Ophelia	Emerald Isle, Pine Knoll Shores, & Indian Beach/Salter Path	1,229,836
2007	USACE Disposal	Fort Macon	184,828
2008	AIWW Tangent B Disposal	Pine Knoll Shores East	148,393
2011	USACE Disposal	Atlantic Beach	799,504
2011	USACE Disposal	Fort Macon	547,196
2013	FEMA Post Irene	Pine Knoll Shores & Emerald Isle	965,011
2014	USACE Disposal	Atlantic Beach	522,518
2014	USACE Disposal	Fort Macon	585,067
		Total	**13,767,825**

Table 9. Nourishment Volumes by Reach

Reach (Transects)	Nourishment Volume (cy)
Bogue Inlet - Ocean (1-8)	59,272
Emerald Isle - West (9-25)	1,133,823
Emerald Isle - Central & East (26-48)	2,819,736
Indian Beach/Salter Path (49-58)	1,358,842
Pine Knoll Shores (59-76)	2,626,962
Atlantic Beach (77-102)	3,712,022
Fort Macon (103-112)	2,057,168
Total	**13,767,825**

To calculate the background erosion rate, nourishment volumes were subtracted from total volume changes above -12 ft NAVD88 between a baseline survey taken in 1999 and the spring/summer 2015 survey. The volume changes were established by adding the annual volume changes calculated by M&N since 2008 to the volume changes from 1999-2007 calculated in the 2007 monitoring report (CSE 2007). **Table 10** shows the computed volume change (including nourishments) above -12 ft NAVD88 from 1999-2015 for the defined reaches.

Table 10. Volume Change by Reach Above -12 ft NAVD88

Reach (Transects)	Volume Change (cy) (1999-2007)	Volume Change (cy) (2007-2008)	Volume Change (cy) (2008-2009)	Volume Change (cy) (2009-2010)	Volume Change (cy) (2010-2011)	Volume Change (cy) (2011-2012)	Volume Change (cy) (2012-2013)	Volume Change (cy) (2013-2014)	Volume Change (cy) (2014-2015)	Volume Change (cy) (1999-2015)
Bogue Inlet - Ocean (Transects 1-8)	147,797	-218,444	169,134	-82,982	-28,440	-199,903	91,493	11,826	-27,015	-136,535
Emerald Isle - West (Transects 9-25)	1,185,131	-107,631	75,690	-107,529	30,257	-264,467	408,863	152,049	118,263	1,490,626
Emerald Isle - Central & East (Transects 26-48)	1,727,705	117,522	-96,085	-281,475	57,244	-293,600	684,367	24,036	118,002	2,057,715
Indian Beach/Salter Path (Transects 49-58)	1,155,522	-116,245	-118,761	-118,078	55,234	-163,958	-44,355	58,729	115,676	823,764
Pine Knoll Shores (Transects 59-76)	1,753,427	-57,453	-53,514	-162,946	-81,597	-313,077	385,385	-66,012	81,633	1,485,846
Atlantic Beach (Transects 77-102)	1,194,947	27,172	-106,720	-11,803	750,462	-530,856	59,686	573,232	-64,358	1,891,761
Fort Macon (Transects 103-112)	221,169	-137,402	-151,048	-46,357	595,792	-167,964	-79,760	436,823	-361	670,893
Total	**7,385,698**	**-492,481**	**-281,305**	**-811,170**	**1,378,951**	**-1,933,825**	**1,505,678**	**1,190,683**	**341,840**	**8,284,070**

Table 11 shows the average annual background erosion rates for each reach of the Bogue Banks oceanfront. The average background erosion rate for the entire Bogue Banks shoreline is approximately -2.67 cy/ft/yr. This result is slightly lower than last year due to some natural recovery during a quiescent year which will be discussed in the volume change analysis.

Table 11. Average Annual Background Erosion Rates (1999 - 2015)

Reach (Transects)	Length (ft)	Volume Change Above -12 ft NAVD88 (cy) (1999-2015)	Nourishment Volume (cy)	Background Erosion (cy)	Average Annual Background Erosion Rates (cy/ft/yr)
Bogue Inlet - Ocean (Transects 1-8)	7,432	-136,535	59,272	-195,807	-1.65
Emerald Isle - West (Transects 9-25)	22,344	1,490,626	1,133,823	356,803	1.00
Emerald Isle - Central & East (Transects 26-48)	29,022	2,057,715	2,819,736	-762,021	-1.64
Indian Beach/Salter Path (Transects 49-58)	12,850	823,764	1,358,842	-535,078	-2.60
Pine Knoll Shores (Transects 59-76)	23,878	1,485,846	2,626,962	-1,141,116	-2.99
Atlantic Beach (Transects 77-102)	26,176	1,891,761	3,712,022	-1,820,261	-4.35
Fort Macon (Transects 103-112)	6,691	670,893	2,057,168	-1,386,275	-12.95
Total	**128,393**	**8,284,070**	**13,767,825**	**-5,483,755**	**-2.67**

5.2 Key Events During the Reporting Period

Beach changes are greatly influenced by natural and engineered processes. This section describes key events that occurred during the reporting period that likely had an impact on shoreline change as well as profile volume gains and losses.

5.2.1 Storm Events

Wave data from the NDBC Onslow Bay Outer-Station 41036 buoy was downloaded for the period of time from the 2014 survey through December 2014 when the buoy was taken offline. Therefore, wave data from the NDBC Masonboro Inlet – Station 41110 was downloaded for January 2015 through May 2015. The wave data was then plotted in order to analyze storm activity which may have impacted the study area. **Figure 5-1** shows the location of the buoys while **Figure 5-2** and **Figure 5-3** present a plot of the wave heights during the reporting period. The 2014 Atlantic hurricane season (June 2014 – November 2014) was relatively mild with 8 named storms of which only 1 impacted the North Carolina Coast (Hurricane Arthur – July 2014). Offshore significant wave height exceeded 10 ft only four times at buoy 41036 in Onslow Bay. The winter storm season (December 2013 – May 2014) was also relatively quiet. A small winter storm occurred in January 2015 and wave heights exceeded 10 ft only once during tropical Storm Ana in May 2015.

Figure 5-1. Onslow Bay Outer-Station 41036 Buoy Location

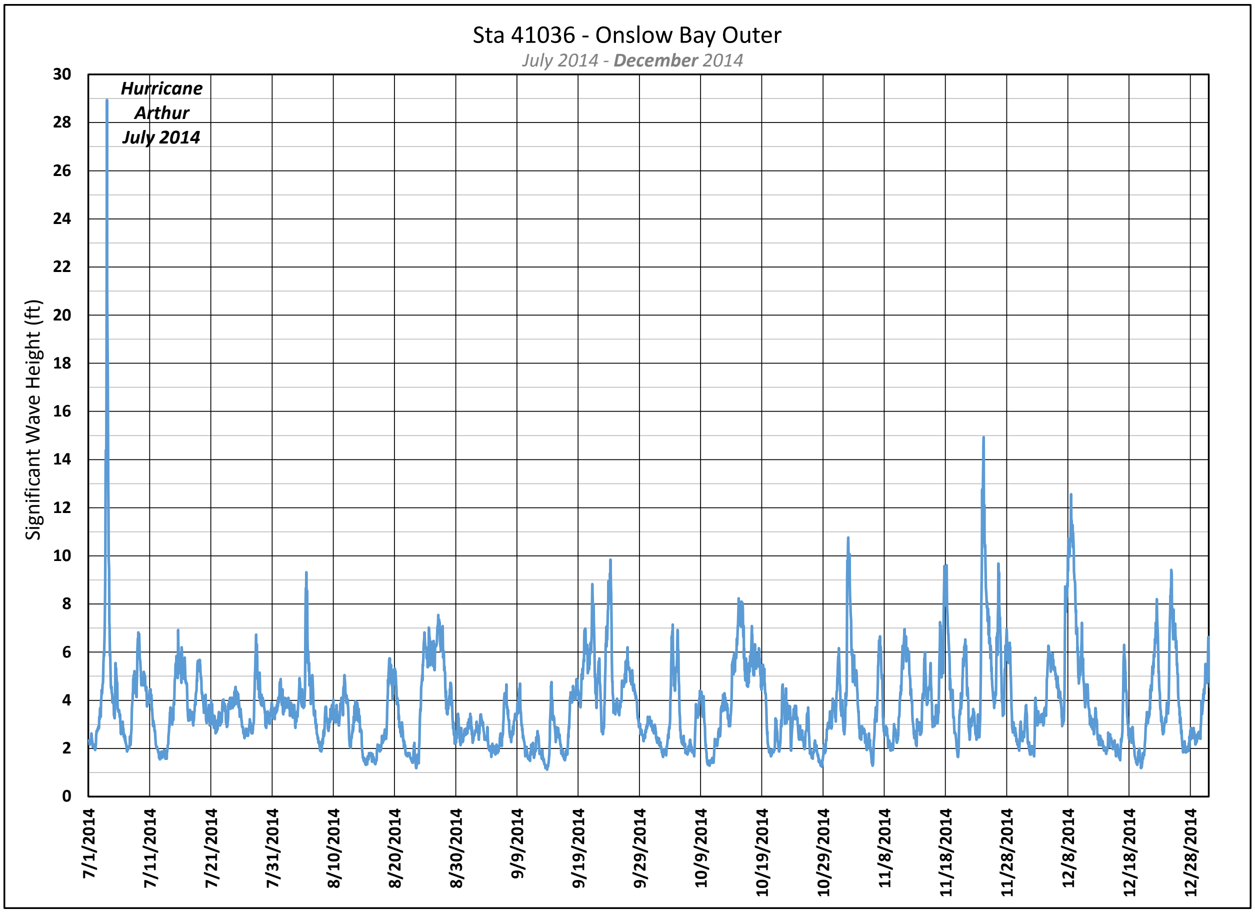


Figure 5-2. Onslow Bay Outer-Station 41036 Wave Height

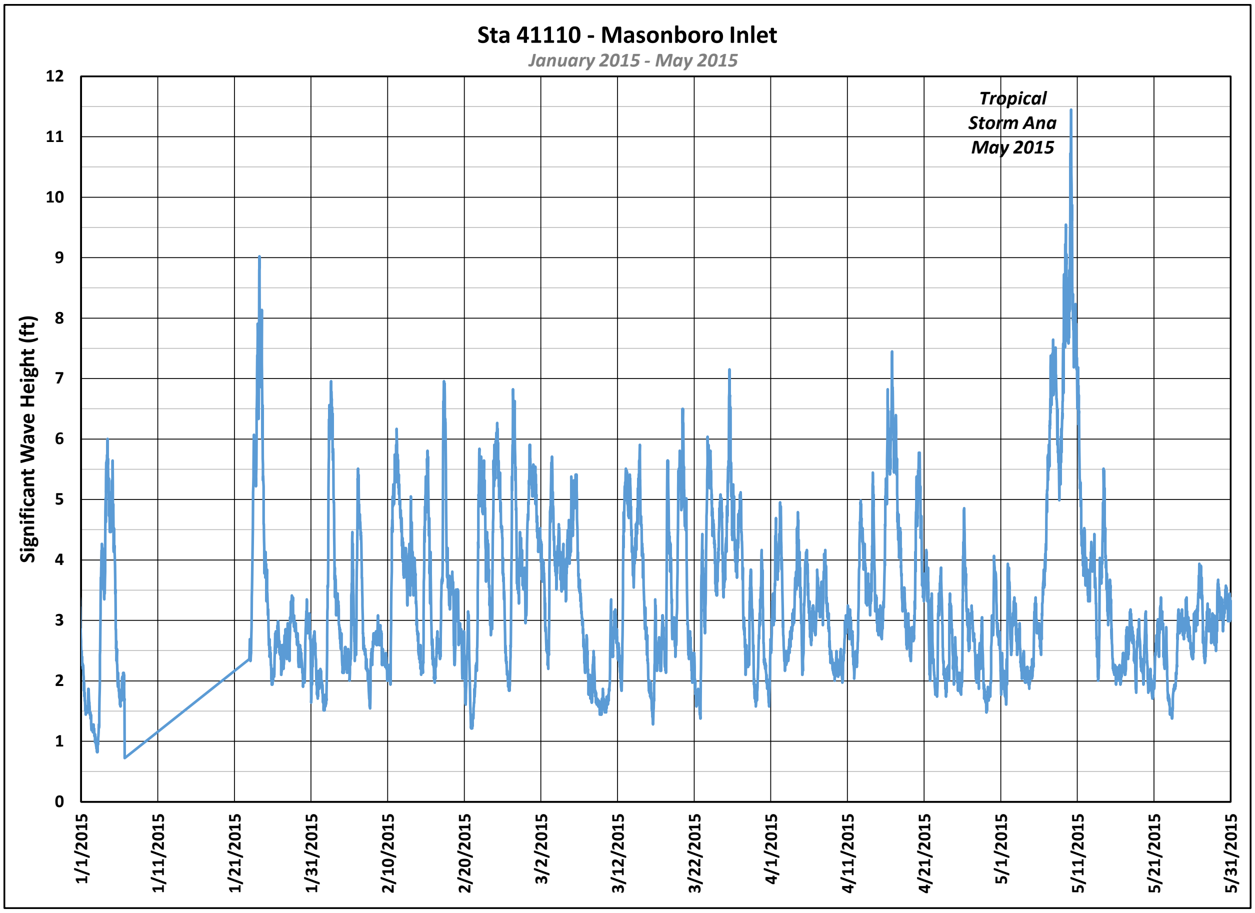


Figure 5-3. Masonboro Inlet – Station 41110 Wave Height

5.2.2 Nourishment Events

There was no nourishment activity during the time between the 2014 and 2015 surveys. As a reminder, the Morehead City Harbor Maintenance Project placed 1,107,585 cy on the beach in Fort Macon (585,067 cy) and Atlantic Beach (522,518 cy) in 2014, just prior to that years' annual survey. Also, in 2013 the Post-Irene Renourishment project placed 965,011 cy of material on the beach in Emerald Isle West (198,190 cy), Emerald Isle East (451,600 cy), and Pine Knoll Shores (315,221 cy).

5.3 Regional Shoreline and Volume Trends

Key statistics were calculated to quantify average shoreline and volume changes for each individual shoreline reach as well as the entire oceanfront shoreline. The computed statistics include average shoreline change, average volume change, and cumulative volume change (e.g. total volume of material lost or gained along a section of shoreline). **Table 12** through **Table 14** provides a summary of the resulting statistics for Bogue Banks, Bear Island, and Shackleford Banks. Evaluation of the computed statistics will take into account volume changes computed for portions of the profile above MHW (+1.1 ft NAVD88), above -5 ft NAVD 88, above -12 ft NAVD88, above -20 ft NAVD88, and above -30 ft NAVD88 in order to better understand onshore and offshore processes. For Bogue Banks, since each reach consists of a different length of shoreline, the calculations provide a weighted average for unit shoreline change (ft) and unit volume change (cy/ft) along the Bogue Banks Oceanfront and County Project. The weighted average also accounts for differences in the shoreline length between each transect.

Table 12. Bogue Banks Regional Shoreline and Volume Change Statistics (Spring/Summer 2014 – Spring/Summer 2015 Comparison)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-8)	7,432	-30.9	-1.7	-12,553	-4.0	-29,375	-3.6	-27,015	-10.1	-74,774	-12.8	-94,884
Emerald Isle-West (Transects 9-25)	22,344	-11.1	-2.4	-53,943	-0.5	-11,189	5.3	118,263	-1.8	-40,559	-7.5	-167,683
Emerald Isle-Central (Transects 26-36)	15,802	18.1	2.5	39,018	-2.6	-40,989	6.5	102,953	-2.4	-38,704	-7.5	-118,855
Emerald Isle-East (Transects 37-48)	13,220	-27.6	-2.0	-25,885	-5.0	-66,699	1.1	15,048	-4.5	-59,716	-7.2	-95,622
Indian Beach/Salter Path (Transects 49-58)	12,850	-4.5	3.5	44,355	-4.9	-62,813	9.0	115,676	0.3	4,482	-1.3	-16,491
Pine Knoll Shores-West (Transects 59-65)	9,063	21.3	5.0	45,634	-4.5	-41,178	6.7	60,500	-2.4	-22,060	-5.2	-47,476
Pine Knoll Shores-East (Transects 66-76)	14,815	12.1	4.5	67,063	-4.2	-62,030	1.4	21,133	-4.0	-59,685	-5.2	-77,691
Atlantic Beach (Transects 77-102)	26,176	-24.3	-3.6	-94,165	-3.6	-94,604	-2.5	-64,358	-8.2	-215,186	-9.0	-235,065
Fort Macon State Park (Transects 103-112)	6,691	-41.0	-4.5	-30,291	-8.5	-56,882	-0.1	-361	-5.4	-36,309	-8.2	-55,011
Beaufort Inlet (Transects 112B-116)	2,000	-22.4	-1.6	-3,239	-1.6	-3,223	9.9	19,800	2.8	5,651	-3.1	-6,149
Bogue Inlet-Channel (Transects 117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Reach Length	Weighted Avg	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total	Weighted Avg	Total
County Project (Transects 9-76)	88,094	-0.1	1.3	116,241	-3.2	-284,898	4.9	433,574	-2.5	-216,242	-5.9	-523,819
Oceanfront (Transects 1-112)	128,393	-9.0	-0.2	-20,768	-3.6	-465,760	2.7	341,840	-4.2	-542,511	-7.1	-908,778

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

Table 13. Bear Island Shoreline and Volume Change Statistics (Spring/Summer 2014 – Spring/Summer 2015 Comparison)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (Transects 1-18)	16,500	19.2	3.5	57,316	0.8	13,323	-4.9	-81,411	-11.3	-187,109	-14.2	-234,599

Table 14. Shackleford Banks Shoreline and Volume Change Statistics (Spring/Summer 2014 – Spring/Summer 2015 Comparison)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (Transects 1-24)	46,001	-59.9	-2.9	-134,521	-19.7	-904,804	-34.3	-1,579,470	-44.9	-2,065,930	-51.1	-2,349,623

Table 12 indicates that the Bogue Banks oceanfront shoreline experienced an overall average recession at MHW of -9.0 ft over the past year. However, this is heavily influenced by the equilibration of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and Atlantic Beach. Measurements along the County Project indicate very little overall

movement in the MHW position in the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). In addition, volumetric measurements along the non-nourished reaches indicate a material gain of approximately 433,574 cy above -12 ft NAVD88. Volumetric measurements for the complete shoreline (Transects 1-112) show a gain of approximately 341,840 cy above -12 ft NAVD88. Looking at **Table 12**, it would appear that there has been some movement of material towards the onshore from the lower depths (-20 ft NAVD88 and -30 ft NAVD88). Beyond the gains in material above -12 ft NAVD88, many reaches also experienced gains in material above MHW. However, there was a volumetric loss trend above -5 ft NAVD88, the intermediate elevation between MHW and -12 ft NAVD88. Profile plots in **Appendix C** show many instances where material from the surfzone (between MHW and -5 ft NAVD88) migrated onshore, creating a new berm feature. In addition, many of these profiles show a gain in volume and landward shift of the offshore bar.

Bear Island appears to have experienced a moderate amount of seaward advancement of the shoreline over the past year, as shown in **Table 13**. Volumetric calculations indicate a gain in material above MHW and above -5 ft NAVD88 but a loss in material at lower elevations. Profile plots included in **Appendix C** show relatively small changes in profile shape and volume with the exception of Transect 2 near Bogue Inlet which experienced a large amount of erosion. The significant erosion measured along Transect 2 accounts for an overwhelming majority of the volume loss shown in **Table 13** for the lower profile elevations along all of Bear Island. Review of the subsequent profiles show the remainder of the island was relatively stable and even showed volumetric gains at many transects.

Table 14 indicates there was significant recession of the shoreline position at MHW and losses in material above all elevations analyzed on Shackleford Banks. However, profile plots in **Appendix C** indicate that Transects 1-20 experienced small to moderate recession of the shoreline at MHW and volume losses. The remaining transects located at the westernmost end of Shackleford Banks (21-23) experienced significant erosion of the dune and beachface. These remaining profiles account for a majority of the erosion experienced across the entire island. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. Calculations indicate that while Transects 1 – 20 lost approximately 200,320 cy of material above -12 ft NAVD88, Transects 21-23 lost approximately 1.36 Mcy of material above -12 ft NAVD88.

Figure 5-4 and **Figure 5-5** display the trends seen in **Table 12** through **Table 14** with bar plots of the average unit volume changes and cumulative volume changes at each reach for Bogue Banks, Bear Island, and Shackleford Banks. Apparent from these figures is the gain in material above -12 ft NAVD88 for all reaches along Bogue Banks except Bogue Inlet – Ocean, Atlantic Beach, and Fort Macon. Also apparent are several reaches that experienced gains in material above MHW. As mentioned previously, there were many instances where material from the surfzone (between MHW and -5 ft NAVD88) has been pushed onshore, creating a berm that had previously been eroded. Also noticeable is the significant losses experienced on Shackleford Banks.

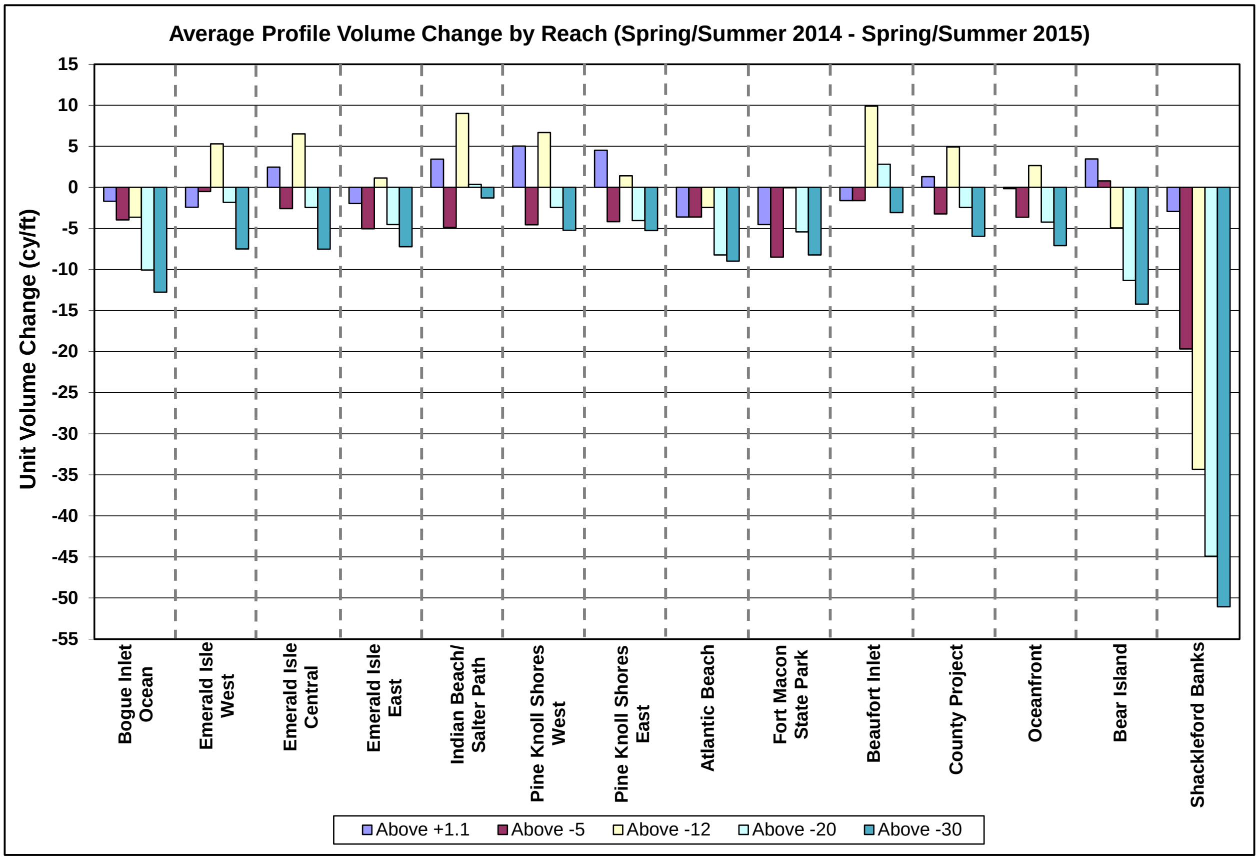


Figure 5-4. Average Unit Volume Change by Reach

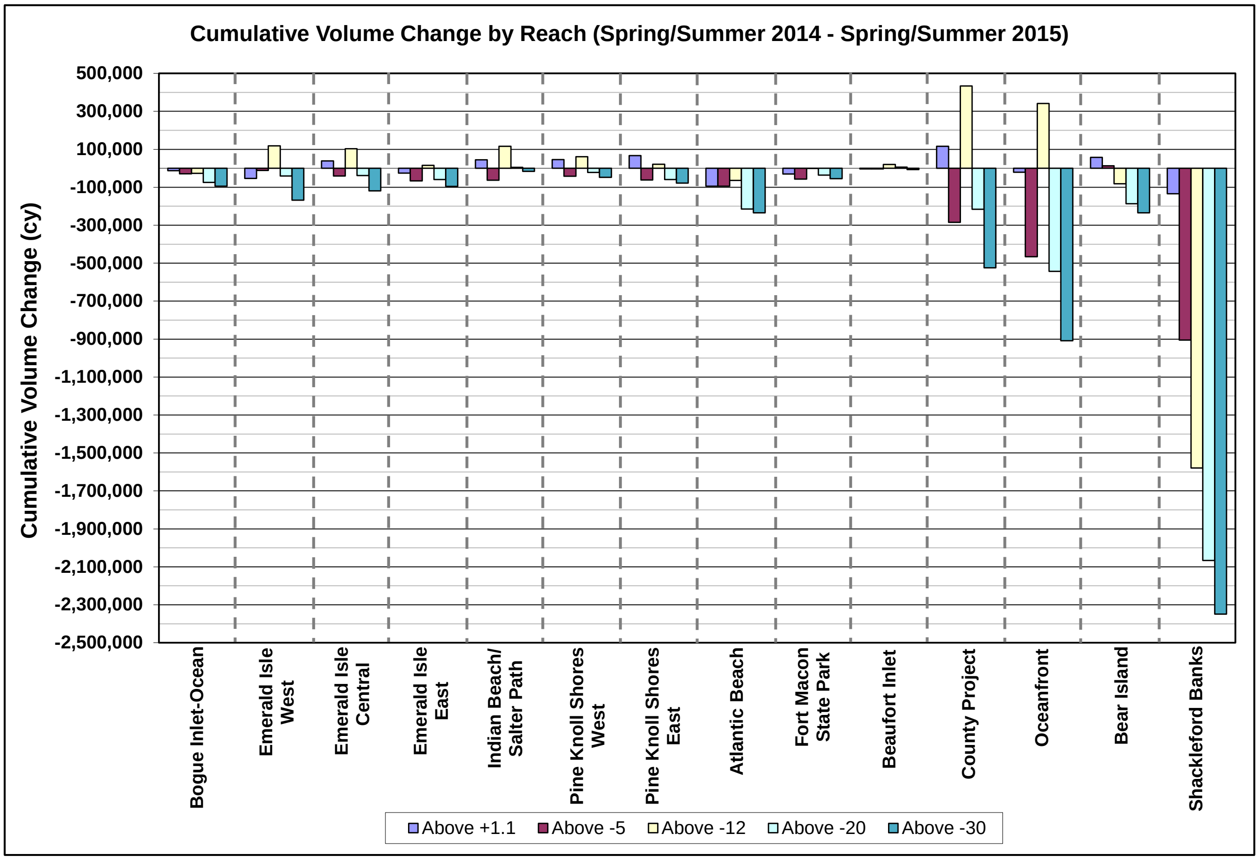


Figure 5-5. Cumulative Volume Change by Reach

A target minimum volume for each profile from the foredune (landward most crest of the primary dune) to the outer bar (above -12 ft NAVD88) was established at 225 cy/ft during the formulation of the original County Project. **Figure 5-6** displays the average profile volume to the outer bar per transect within each reach of shoreline for 2008 - 2015. Values displayed in the graph are tabulated in **Table 15**. As shown in **Figure 5-6**, there are currently no reaches along Bogue Banks that are close to the historical minimum target of 225 cy/ft. Furthermore, many of the reaches gained material above -12 ft NAVD88 over the past year.

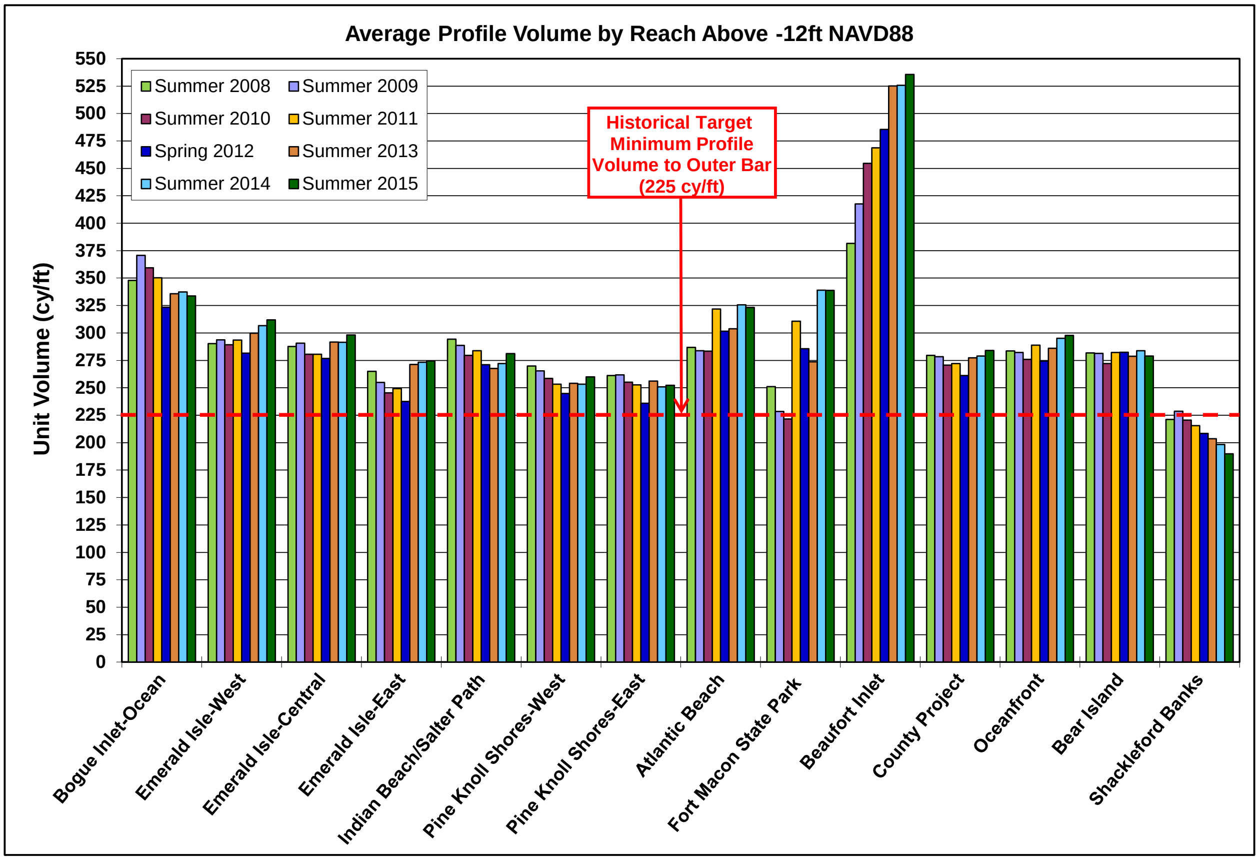


Figure 5-6. Average Profile Volume From Foredune to Outer Bar by Reach

Table 15. Average Profile Volume From Foredune to Outer Bar by Reach (cy/ft)

Reach	Transects	July 2008	June 2009	June 2010	June 2011	April 2012	July 2013	June 2014	May 2015
Bogue Inlet-Channel	117-120	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bogue Inlet-Ocean	1-8	348	371	359	350	323	336	337	334
Emerald Isle-West	9-25	290	294	289	293	282	300	307	312
Emerald Isle-Central	26-36	288	291	280	281	277	292	292	298
Emerald Isle-East	37-48	265	255	245	249	238	271	273	274
Indian Beach/Salter Path	49-58	294	289	280	284	271	268	272	281
Pine Knoll Shores-West	59-65	270	265	258	253	245	254	253	260
Pine Knoll Shores-East	66-76	261	262	255	253	236	256	251	252
Atlantic Beach	77-102	287	284	283	322	302	304	326	323
Fort Macon State Park	103-112	251	229	222	311	286	274	339	339
Beaufort Inlet	112B-116	382	418	455	469	485	525	526	536
County Project	9-76	280	278	271	272	261	277	279	284
Oceanfront	1-112	284	282	276	289	274	286	295	298
Bear Island	1-18	282	281	272	282	282	279	284	279
Shackleford Banks	1-24	221	229	221	216	208	204	198	190

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, which was performed using shore parallel survey lines collected in 2014 and 2015 by driving the survey ATV along the base of the dune. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline. **Figure 5-7** presents the results of this analysis. An average landward movement of approximately 1.1 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position surveyed is highly subject to surveyor interpretation. Other methods for tracking this feature are being investigated.

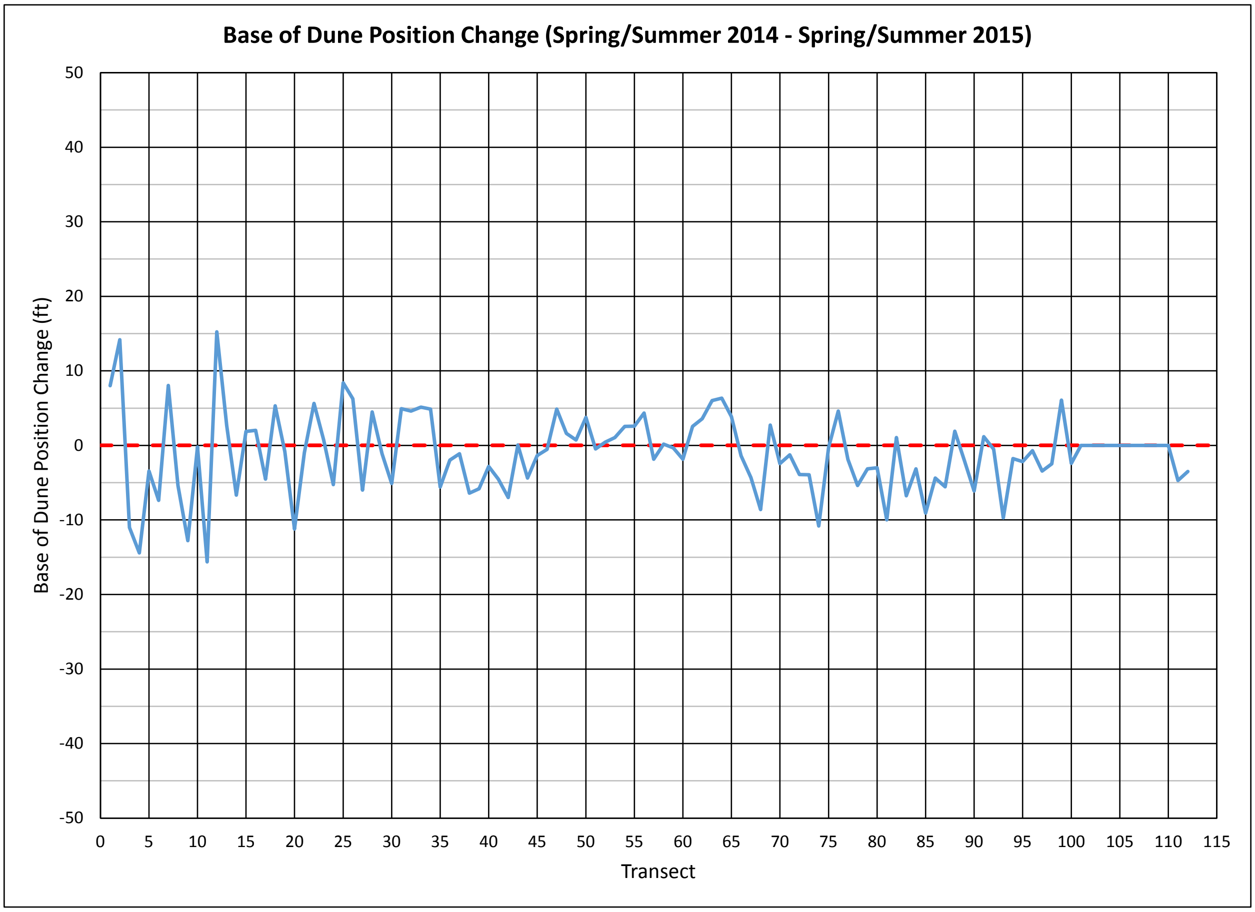


Figure 5-7. Base of Dune Position Change

5.4 Local Shoreline and Volume Trends

Local shoreline trends are discussed below for the defined regions of Bogue Banks (**Figure 3-1**) as well as Bear Island and Shackleford Banks. A summary of the information provided previously in **Table 12** through **Table 14** and volume change plots in **Appendix B** has been created for each region of study.

5.4.1 Emerald Isle

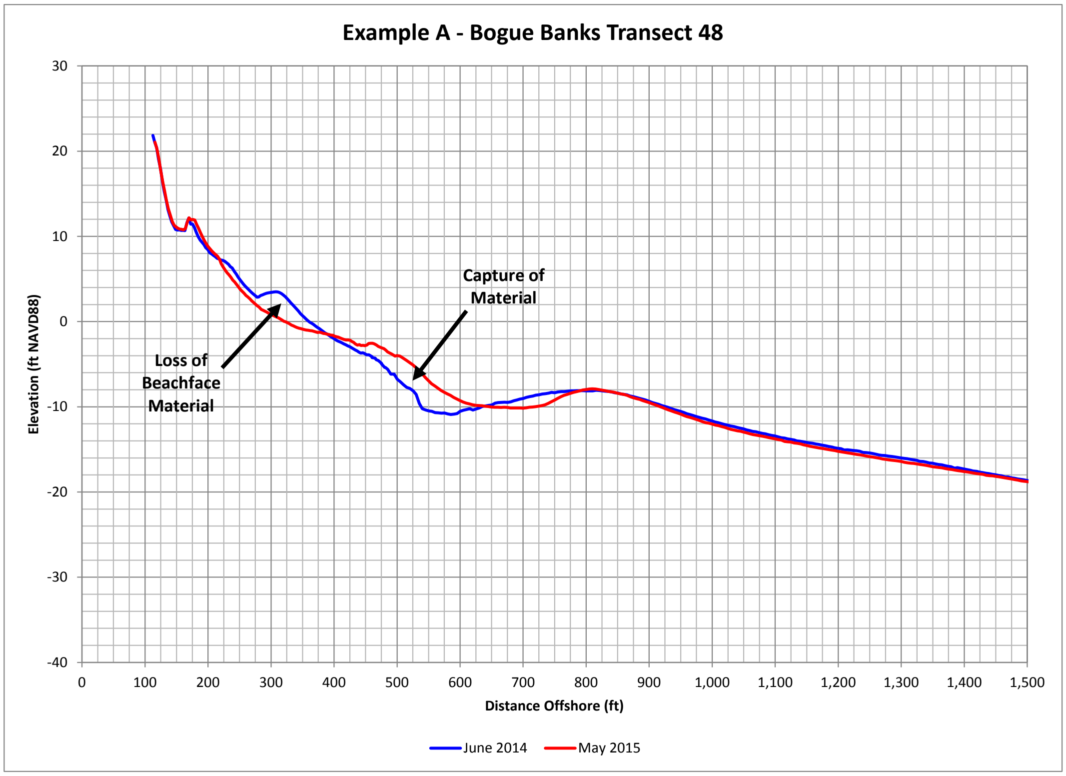
The Emerald Isle region covers Transects 9 through 48. Since monitoring began in 1999, Emerald Isle has received a total of 3.95 million cy of nourishment material as a result of the County Project and FEMA post-storm work (Isabel, Ophelia, and Irene). Most recently, Emerald Isle West received 198,190 cy of material and Emerald Isle East received 451,600 cy of material during the 2013 post-Irene Renourishment Project. **Table 16** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Emerald Isle region.

Table 16. Average Shoreline and Volume Change for Emerald Isle (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Emerald Isle-West (Transects 9-25)	22,344	-11.1	-2.4	-53,943	-0.5	-11,189	5.3	118,263	-1.8	-40,559	-7.5	-167,683
Emerald Isle-Central (Transects 26-36)	15,802	18.1	2.5	39,018	-2.6	-40,989	6.5	102,953	-2.4	-38,704	-7.5	-118,855
Emerald Isle-East (Transects 37-48)	13,220	-27.6	-2.0	-25,885	-5.0	-66,699	1.1	15,048	-4.5	-59,716	-7.2	-95,622

Shoreline change at MHW showed a mixed response throughout the reaches of Emerald Isle with shoreline recession in Emerald Isle West and East and shoreline accretion in Emerald Isle Central. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show pockets of shoreline recession and accretion throughout Emerald Isle that span several transects at a time.

Volumetrically, **Table 16** indicates that Emerald Isle West and Emerald Isle East experienced losses in material above MHW and above -5 ft NAVD88, as well as offshore, but a gain in material above -12 ft NAVD88. The profile plots in **Appendix C** show that in cases where beachface and surf zone material has been lost, it has been captured landward of the offshore bar, above -12 ft NAVD88, and is therefore still within the system and providing protection (see **Figure 5-8**, Example A). The Emerald Isle Central reach actually gained material above MHW, but then lost material above -5 ft NAVD88, and gained material above -12 ft NAVD88 as with the other reaches. Profile plots in **Appendix C** show that in this reach, surfzone material appears to have been pushed onshore and there has been some volume growth in the offshore bar (see **Figure 5-8**, Example B). Overall, the Emerald Isle region gained a total of 236,265 cy of material above -12 ft NAVD88, an important factor in oceanfront protection, with the largest gains occurring in Emerald Isle West and Emerald Isle Central. **Figure 5-9** displays the unit volume change at each transect above the five elevations analyzed.



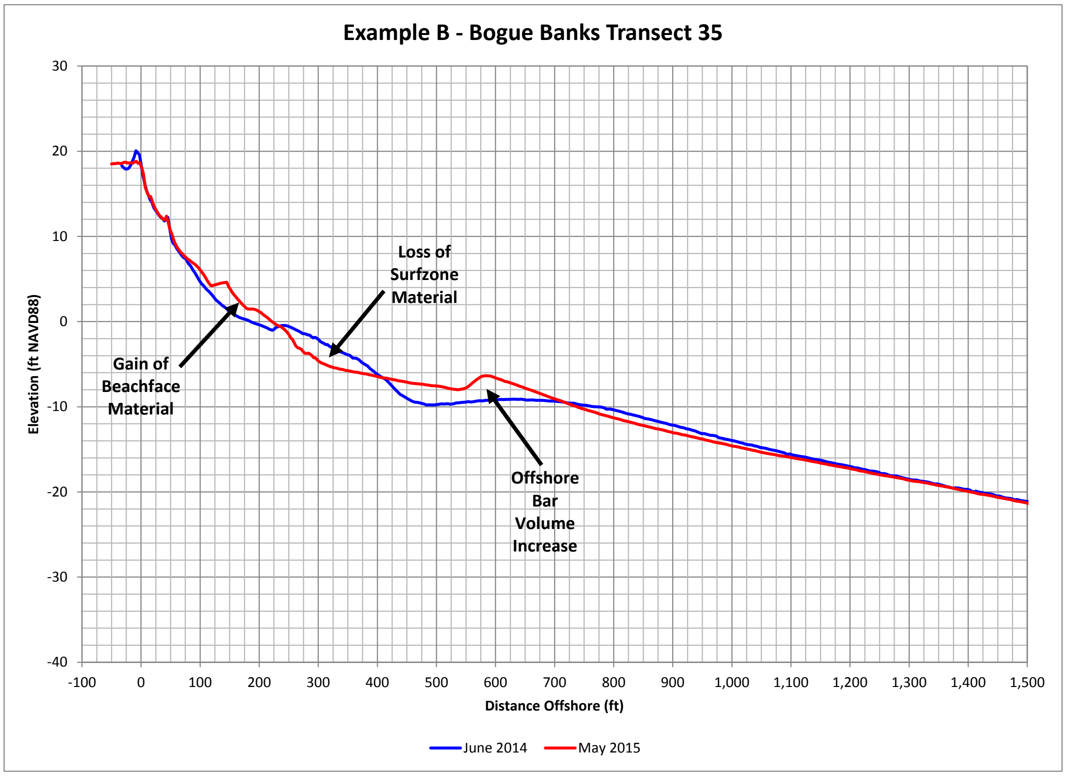


Figure 5-8. Example Profiles – Emerald Isle

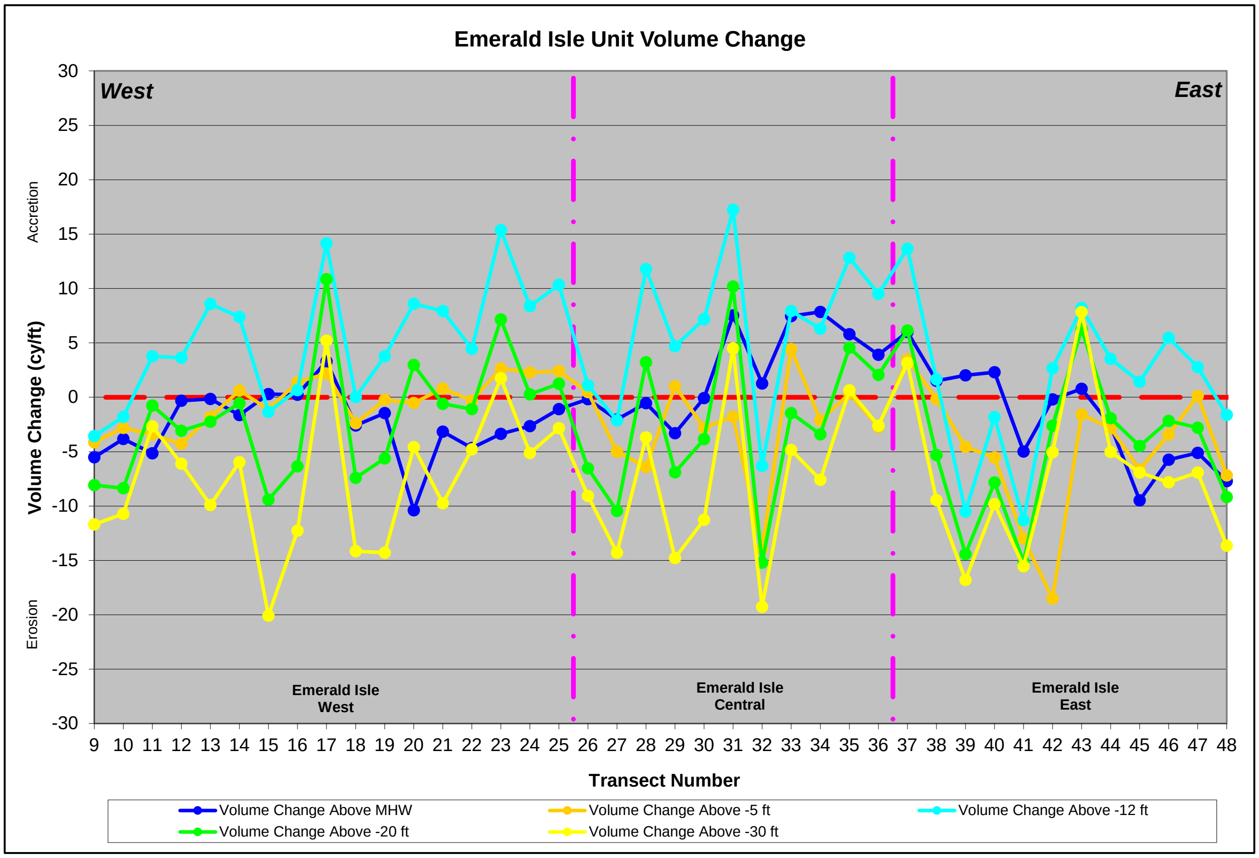


Figure 5-9. Emerald Isle Unit Volume Change (2014 - 2015)

5.4.2 Indian Beach/Salter Path

The Indian Beach region covers Transects 49 through 58. Since monitoring efforts began in 1999, this region has received 1.36 million cy of nourishment material from the County Project, USACE Section 933, and FEMA post-storm work (Ophelia). **Table 17** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Indian Beach/Salter Path region.

Table 17. Average Shoreline and Volume Change for Indian Beach/Salter Path (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Indian Beach/Salter Path (Transects 49-58)	12,850	-4.5	3.5	44,355	-4.9	-62,813	9.0	115,676	0.3	4,482	-1.3	-16,491

Shoreline change at MHW in the Indian Beach/Salter Path area showed a slight recession of approximately -4.5 ft between the last two surveys. However, the shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that there was a mix of shoreline recession and accretion throughout the reach.

Volumetrically, **Table 17** indicates that the Indian Beach/Salter Path area gained material above MHW, but then lost material above -5 ft NAVD88 and gained material above -12 ft NAVD88. The profile plots in **Appendix C** show that material appears to have been pushed onshore from the surf zone, resulting in the gains above MHW and losses above -5 ft NAVD88. There also appears to be a landward movement and volume gain around the offshore bar, accounting for the gains experienced above -12 ft NAVD88 (see **Figure 5-10**). Overall, the reach experienced a gain of 115,676 cy above -12 ft NAVD88, an important factor in oceanfront protection. **Figure 5-11** displays the unit volume change at each transect for the Indian Beach/Salter path region. The above mentioned pattern of gains above MHW, losses above -5 ft NAVD88, and gains above -12 ft NAVD88 is fairly consistent throughout the reach.

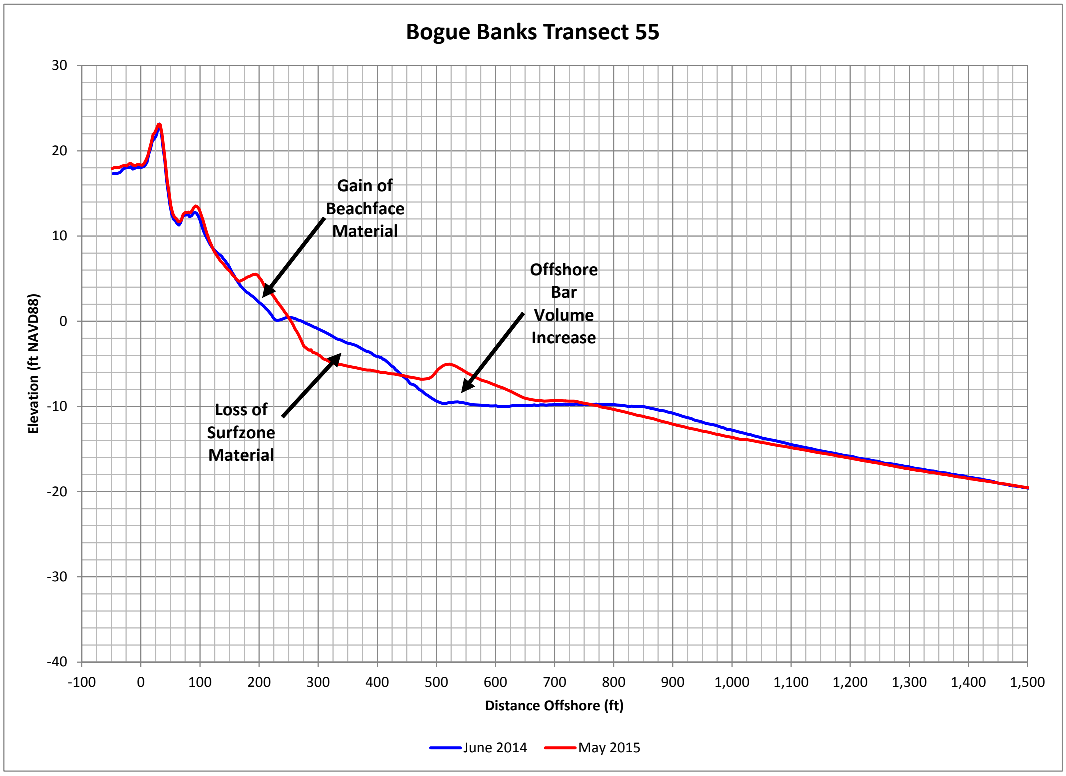


Figure 5-10. Example Profile – Indian Beach/Salter Path

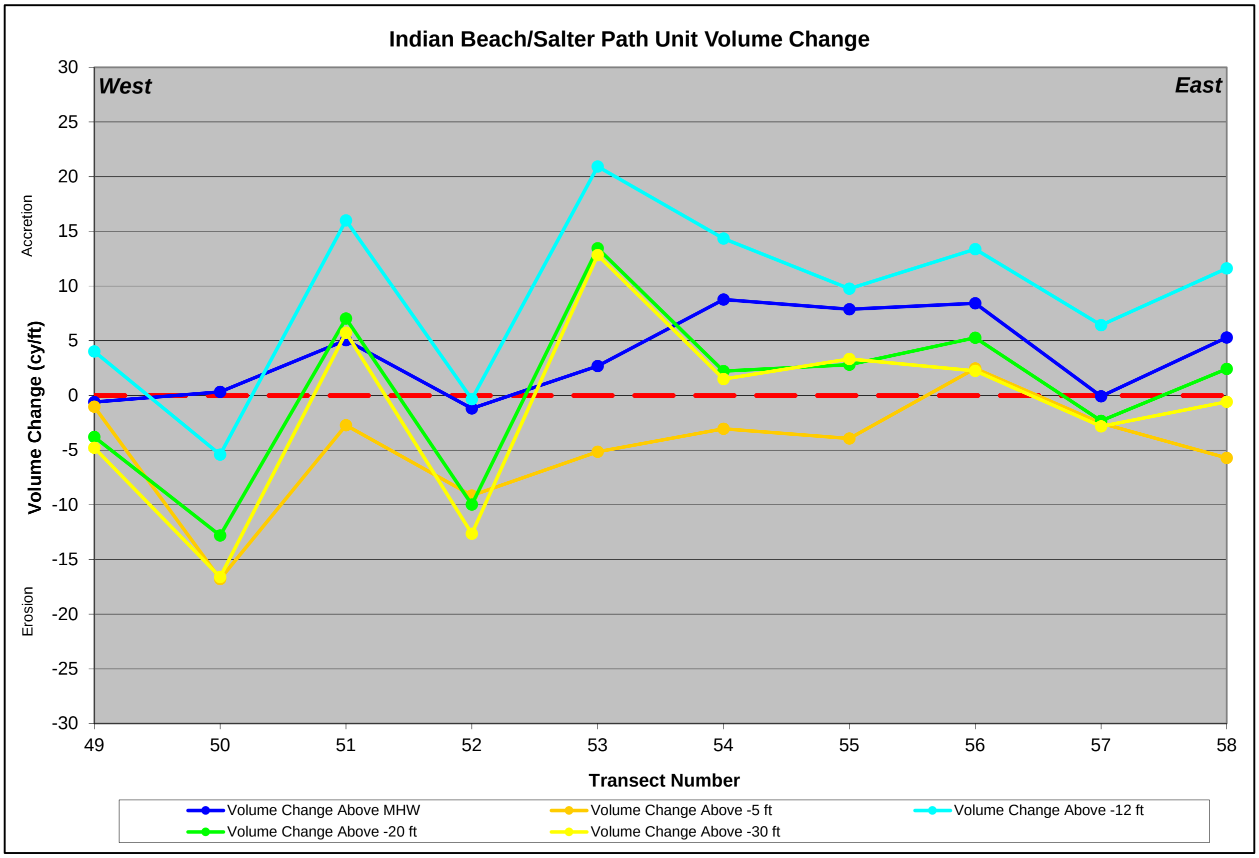


Figure 5-11. Indian Beach/Salter Path Unit Volume Change (2014 - 2015)

5.4.3 Pine Knoll Shores

The Pine Knoll Shores region covers Transects 59 through 76. Since monitoring efforts began in 1999, the Pine Knoll Shores region has received 2.63 million cy of nourishment material as a result of the County Project, USACE Section 933, and FEMA post-storm work (Ophelia and Irene). Most recently, Pine Knoll Shores received 315,221 cy of material as part of the 2013 post-Irene Renourishment Project. **Table 18** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Pine Knoll Shores region.

Table 18. Average Shoreline and Volume Change for Pine Knoll Shores (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Pine Knoll Shores-West (Transects 59-65)	9,063	21.3	5.0	45,634	-4.5	-41,178	6.7	60,500	-2.4	-22,060	-5.2	-47,476
Pine Knoll Shores-East (Transects 66-76)	14,815	12.1	4.5	67,063	-4.2	-62,030	1.4	21,133	-4.0	-59,685	-5.2	-77,691

Shoreline change at MHW showed overall seaward advancement in both reaches of Pine Knoll Shores. The shoreline change plot in **Appendix B** and the profile plots in **Appendix C** indicate this behavior was fairly consistent throughout each reach.

Volumetrically, **Table 18** indicates that both reaches experienced a gain in material above MHW, a loss in material above -5 ft NAVD88, and a gain in material above -12 ft NAVD88. This volume change pattern is similar to what was experienced in Indian Beach/Salter Path, and Emerald Isle Central. The profile plots in **Appendix C** show that material appears to have been pushed onshore from the surf zone, resulting in the gains above MHW and losses above -5 ft NAVD88. There also appears to be a landward movement and volume gain around the offshore bar, accounting for the gains experienced above -12 ft NAVD88 (see **Figure 5-12**). Overall, the reach experienced a gain of 81,633 cy above -12 ft NAVD88, an important factor in oceanfront protection. **Figure 5-13** displays the unit volume change at each transect for the Pine Knoll Shores region. The above mentioned pattern of volume gains above MHW, volume losses above -5 ft NAVD88, and volume gains above -12 ft NAVD88 is fairly consistent throughout the reach.

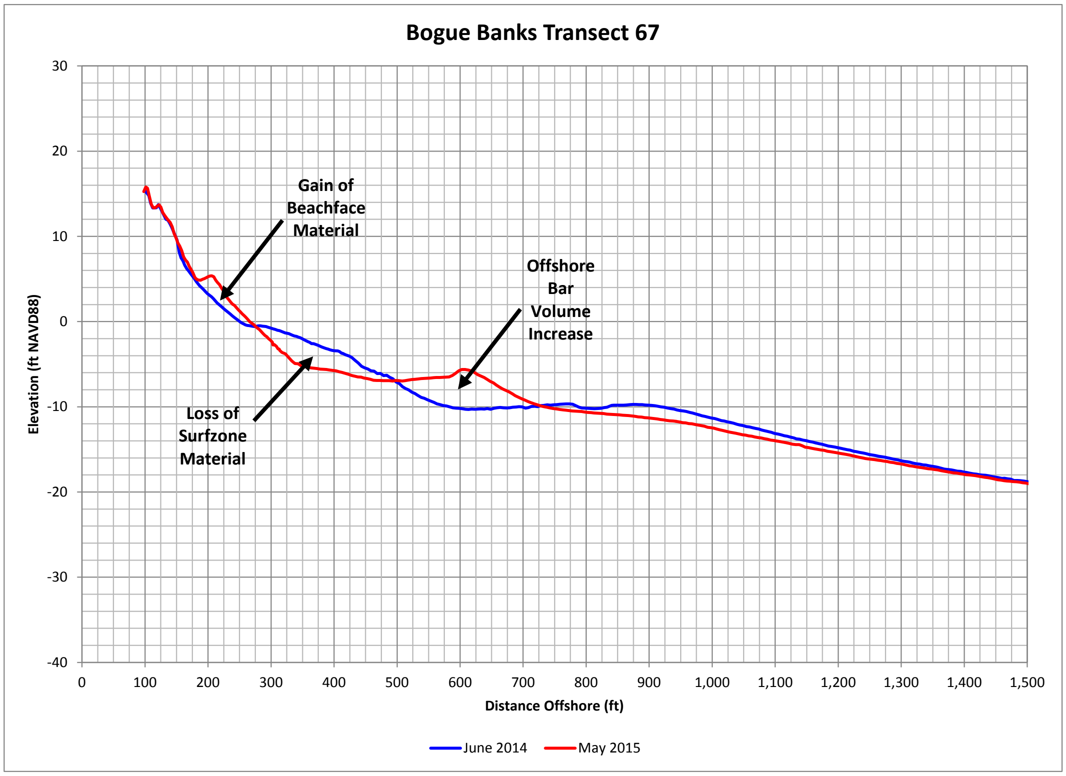


Figure 5-12. Example Profile – Pine Knoll Shores

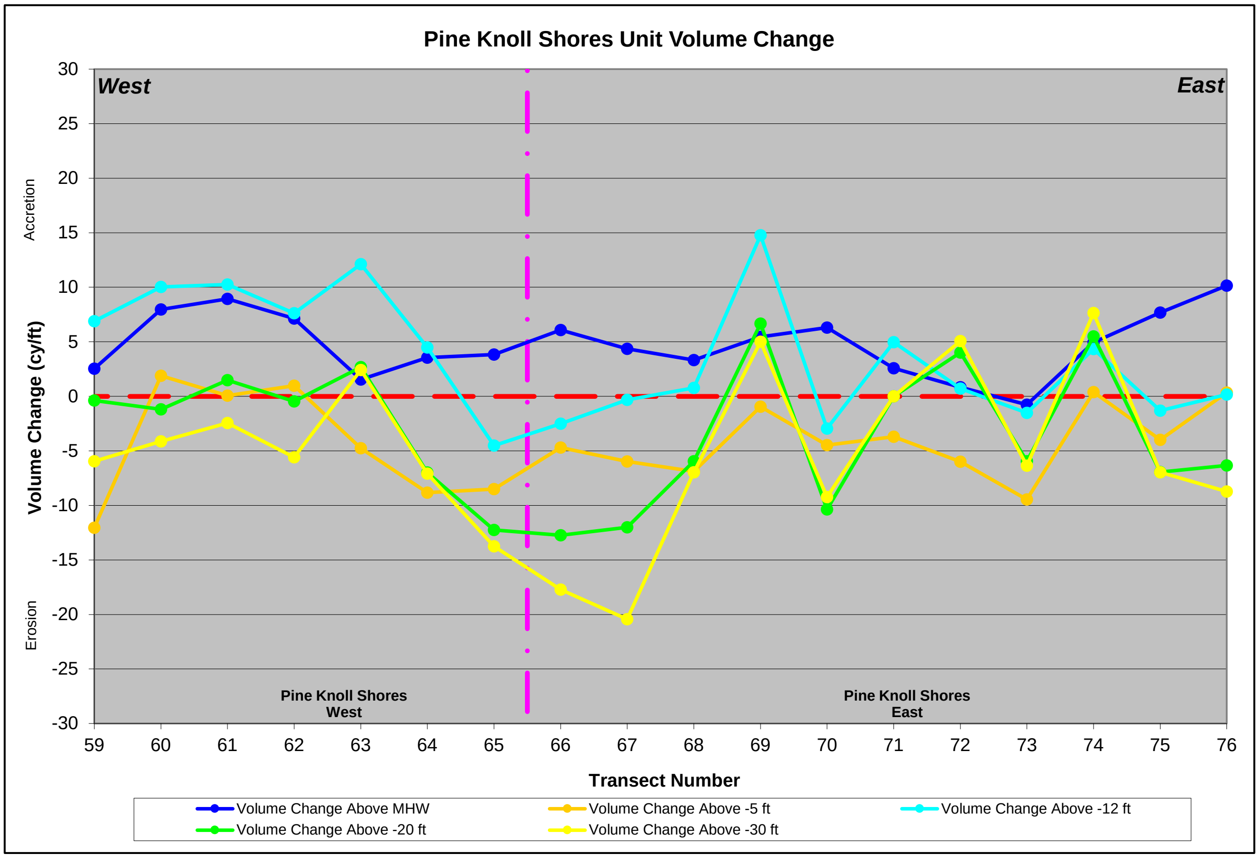


Figure 5-13. Pine Knoll Shores Unit Volume Change (2014 - 2015)

5.4.4 Atlantic Beach

The Atlantic Beach region covers Transects 77 through 102. Since monitoring began in 1999, the region has received 3.71 million cy of nourishment material from the Brandt Island Pump Out and USACE dredge disposal. Most recently, approximately 522,518 cy of material was placed on Atlantic Beach in spring 2014 as part of the Morehead City Harbor Maintenance Dredging Project. **Table 19** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Atlantic Beach region.

Table 19. Average Shoreline and Volume Change for Atlantic Beach (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Atlantic Beach (Transects 77-102)	26,176	-24.3	-3.6	-94,165	-3.6	-94,604	-2.5	-64,358	-8.2	-215,186	-9.0	-235,065

Atlantic Beach experienced an overall shoreline recession at MHW of approximately -24.3 ft over the past year. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that the shoreline experienced the largest recession in areas where the nourishment was placed (Transects 97 – 102), however, there were large pockets of shoreline recession along the entire reach.

Volumetrically, the reach experienced losses in material above each elevation between 2014 and 2015 which is to be expected due to initial losses and profile equilibration associated with nourishment projects. **Table 19** shows that overall, Atlantic Beach lost approximately 64,360 cy above -12 ft NAVD 88. However, in the area where nourishment was placed (Transects 97-102), approximately 149,140 cy of material was lost. **Figure 5-14** displays the unit volume change for each transect in the Atlantic Beach region. As can be seen, the westernmost portion of the reach experienced some gains in material above -12 ft NAVD88. Within the middle portion of the reach this trend reversed with some small losses occurring above -12 ft NAVD88. Losses within the easternmost portion of the reach grew in magnitude compared to the middle beach portion. The larger losses along the easternmost beach most likely occurred due to equilibration of the recent harbor maintenance project.

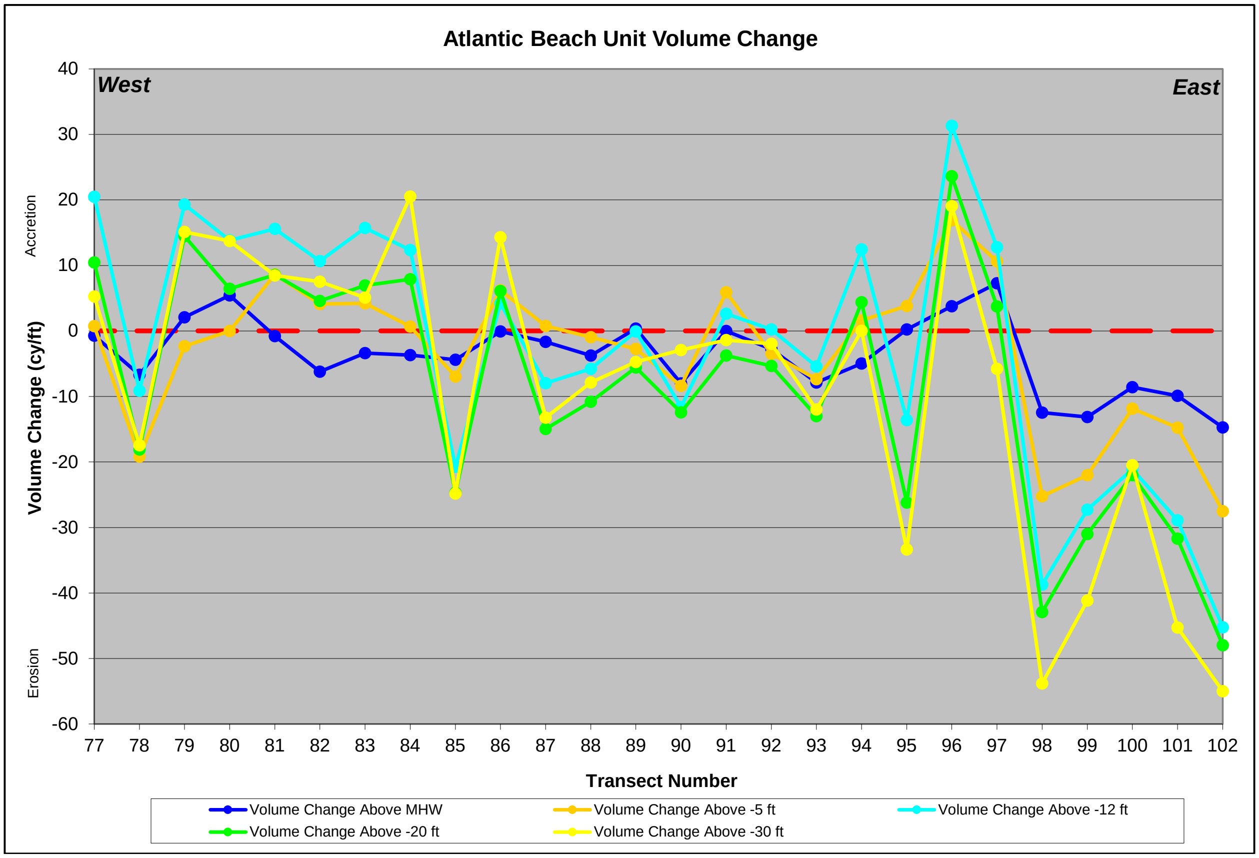


Figure 5-14. Atlantic Beach Unit Volume Change (2014 - 2015)

5.4.5 Fort Macon State Park

The Fort Macon State Park region covers Transects 103 through 112. Since monitoring began in 1999, this region has received 2.06 million cy of nourishment material from USACE Inner Harbor Dredging Disposal. Most recently, 585,067 cy of material was placed on Fort Macon in Spring 2014 as part of the Morehead City Harbor Maintenance Dredging Project. **Table 20** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Fort Macon State Park region.

Table 20. Average Shoreline and Volume Change for Fort Macon State Park (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Fort Macon State Park (Transects 103-112)	6,691	-41.0	-4.5	-30,291	-8.5	-56,882	-0.1	-361	-5.4	-36,309	-8.2	-55,011

Fort Macon experienced an overall shoreline recession at MHW of approximately -41.0 ft over the past year. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** show that the shoreline experienced the largest recession in areas where the nourishment was placed (Transects 103 – 107). However, there was some seaward advancement of the shoreline adjacent to the terminal groin, as expected due to littoral transport of nourishment material toward Beaufort Inlet.

Volumetrically, the reach experienced losses in material above each elevation between 2014 and 2015 due to the equilibration of the nourishment project. Overall, there doesn't appear to be much loss above -12 ft NAVD88. However, there was a loss of approximately 44,600 cy of material above -12 ft NAVD88 from Transects 103 – 107 where the nourishment was placed. Due to littoral transport toward Beaufort Inlet, the reach experienced an almost equal gain in volume of approximately 44,300 cy from Transects 108 – 112. **Figure 5-15** displays the unit volume change for each transect in the Fort Macon region. As can be seen, the western portion of the reach, in general, experienced mostly losses while the eastern portion of the reach experienced some gain in material.

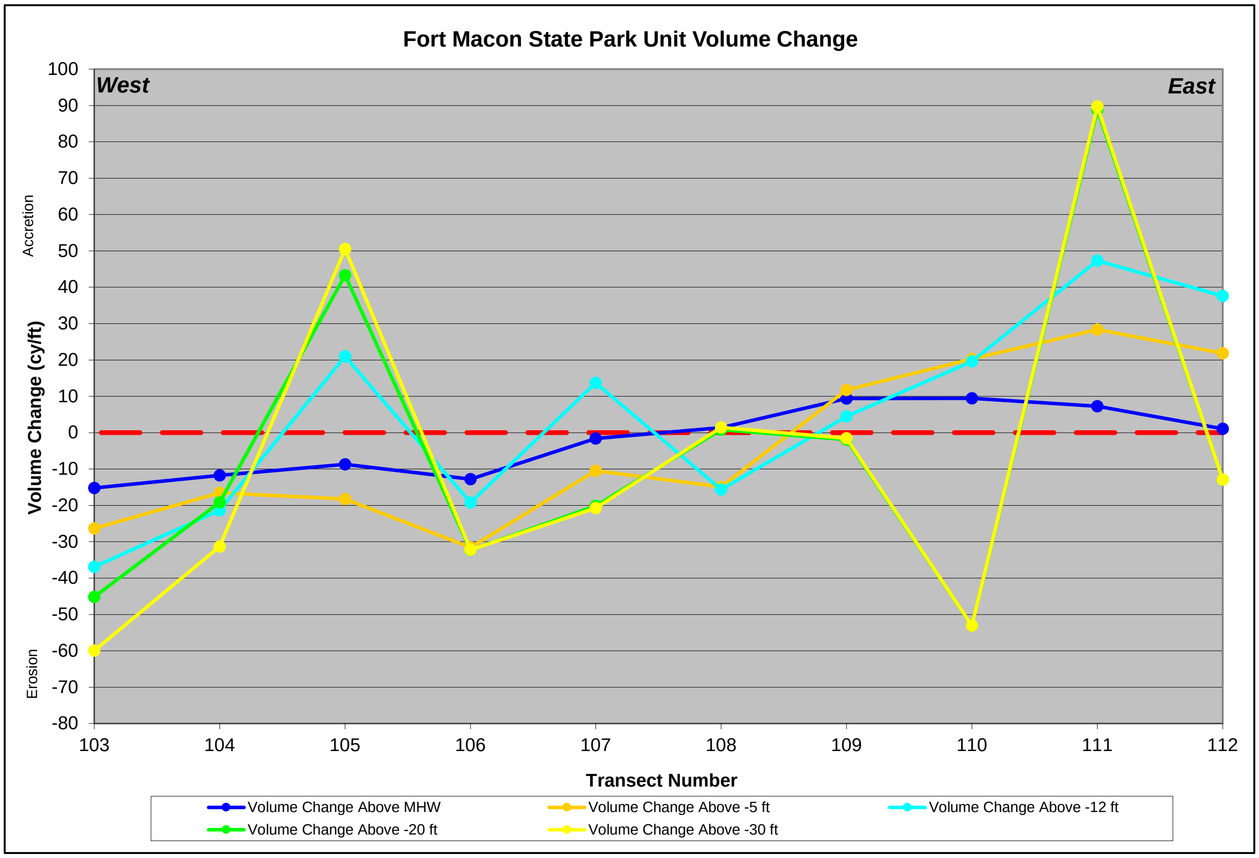


Figure 5-15. Fort Macon State Park Unit Volume Change (2014 - 2015)

5.4.6 Bogue Inlet

The Bogue Inlet region is comprised of an area along the western terminus of Bogue Banks which covers Transects 1 through 8 and an area along the eastern side of Bogue Inlet covering Transects 117 through 120. **Table 21** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Bogue Inlet region.

Table 21. Average Shoreline and Volume Change for Bogue Inlet (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-8)	7,432	-30.9	-1.7	-12,553	-4.0	-29,375	-3.6	-27,015	-10.1	-74,774	-12.8	-94,884
Bogue Inlet-Channel (Transects 117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

As shown in **Table 21**, the Bogue Inlet-Ocean region shoreline experienced recession at MHW and volumetric losses above all elevations. **Figure 5-16** displays the unit volume change at each transect for the Bogue Inlet-Ocean region. It can be seen that the majority of the losses occurred at Transect 1 and 2, adjacent to Bogue Inlet. The remainder of the reach was fairly stable.

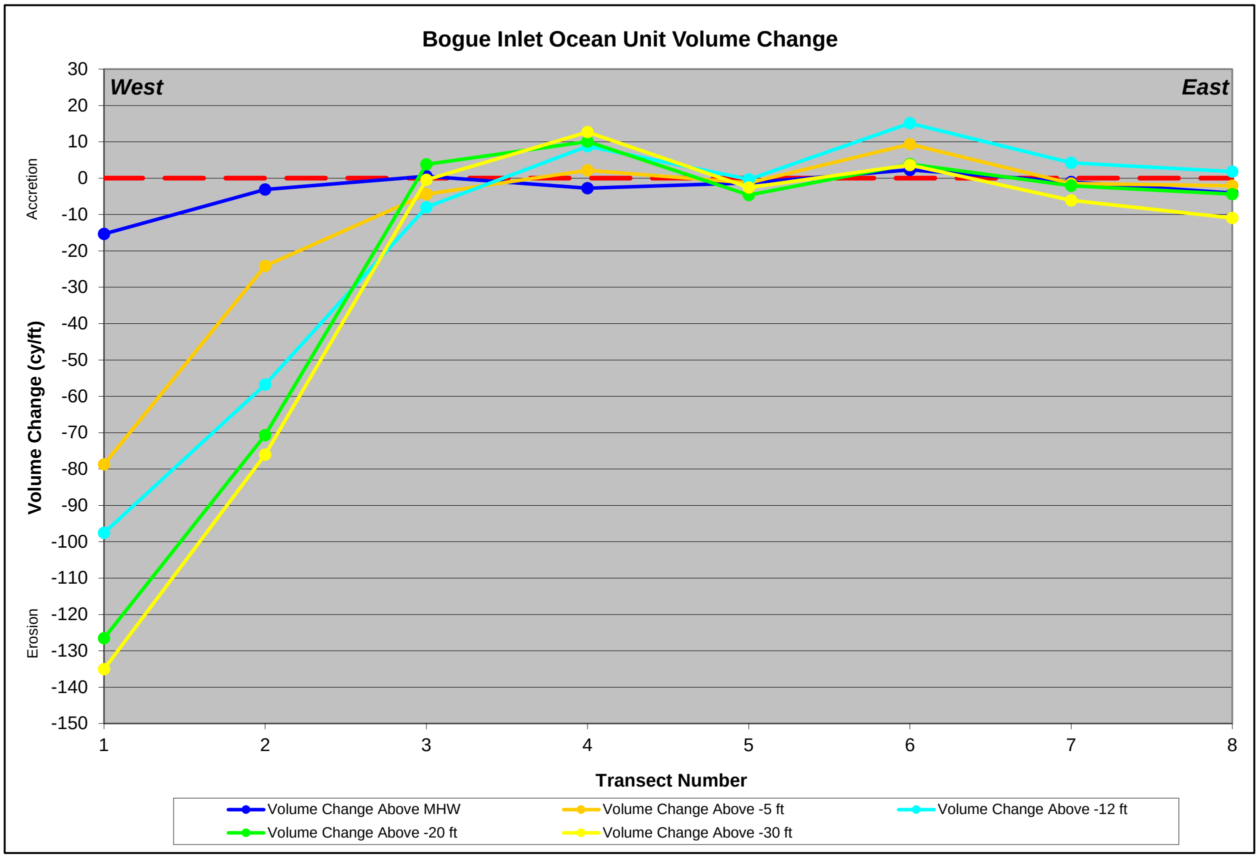


Figure 5-16. Bogue Inlet Ocean Unit Volume Change (2014 - 2015)

The Bogue Inlet-Channel region is highly dynamic due to the inlet. The location of dry land changes so frequently that profiles along Bogue Inlet often do not line up properly from year to year. Therefore, analytical calculations were not performed at Transect 117 through 120. However, upon investigation of the profile plots in **Appendix C**, it appears that that there has been some erosion at the mouth of the inlet at Transects 117B and 117 which was captured in the spit at Transect 118. Transects 119 and 120 show some eastward migration of Bogue Inlet channel.

In June 2015, Geodynamics conducted a topographic and hydrographic survey to assess conditions at the Point. Based on this survey, it appears that approximately 420 ft exist between the edge of the current channel location and the boundary of the “safe box” which was determined as part of the Master Beach Nourishment Plan (see **Figure 5-17**). When compared with a similar survey taken in April 2014, the channel appears to have moved approximately 30 ft to the east between April 2014 and June 2015.

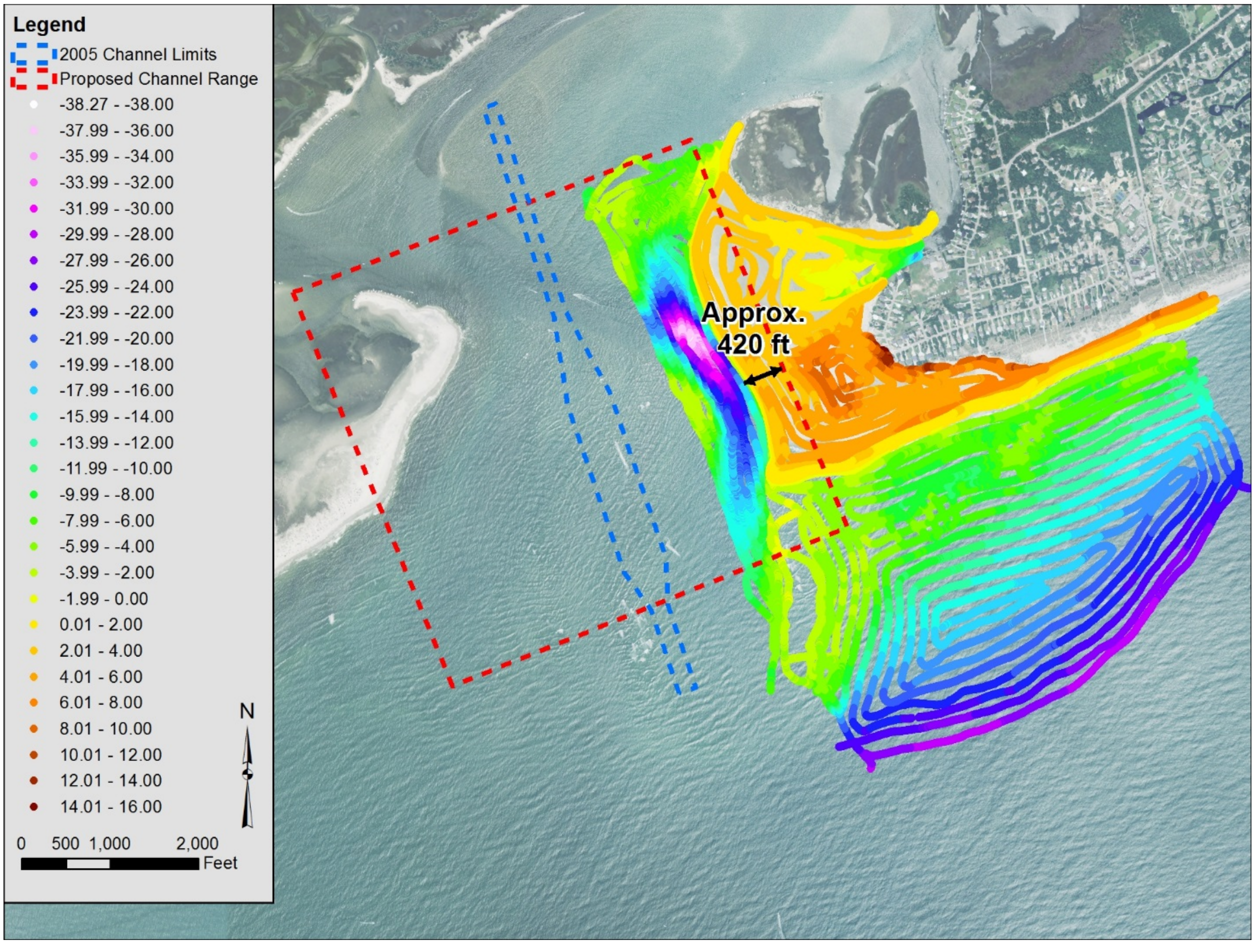


Figure 5-17. Bogue Inlet Channel Survey

5.4.7 Beaufort Inlet

The Beaufort Inlet region is comprised of an area along the western side of Beaufort Inlet which covers Transects 112B through 116. **Table 22** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Beaufort Inlet region.

Table 22. Average Shoreline and Volume Change for Beaufort Inlet (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Beaufort Inlet (Transects 112B-116)	2,000	-22.4	-1.6	-3,239	-1.6	-3,223	9.9	19,800	2.8	5,651	-3.1	-6,149

The calculation for shoreline recession across Beaufort Inlet indicates the region experienced significant recession at MHW. However, upon inspection of the profile plots in **Appendix C**, it appears that there was a large amount of shoreline recession at Transect 114 while the remainder of the transects showed very little change at this elevation.

Volume changes at Beaufort Inlet fluctuate between minor gains and losses above the different elevations. Transect 112B deviates from this trend as it experienced some large offshore changes, however the rest of the reach remained fairly stable. **Figure 5-18** displays the unit volume change at each transect in the Beaufort Inlet region.

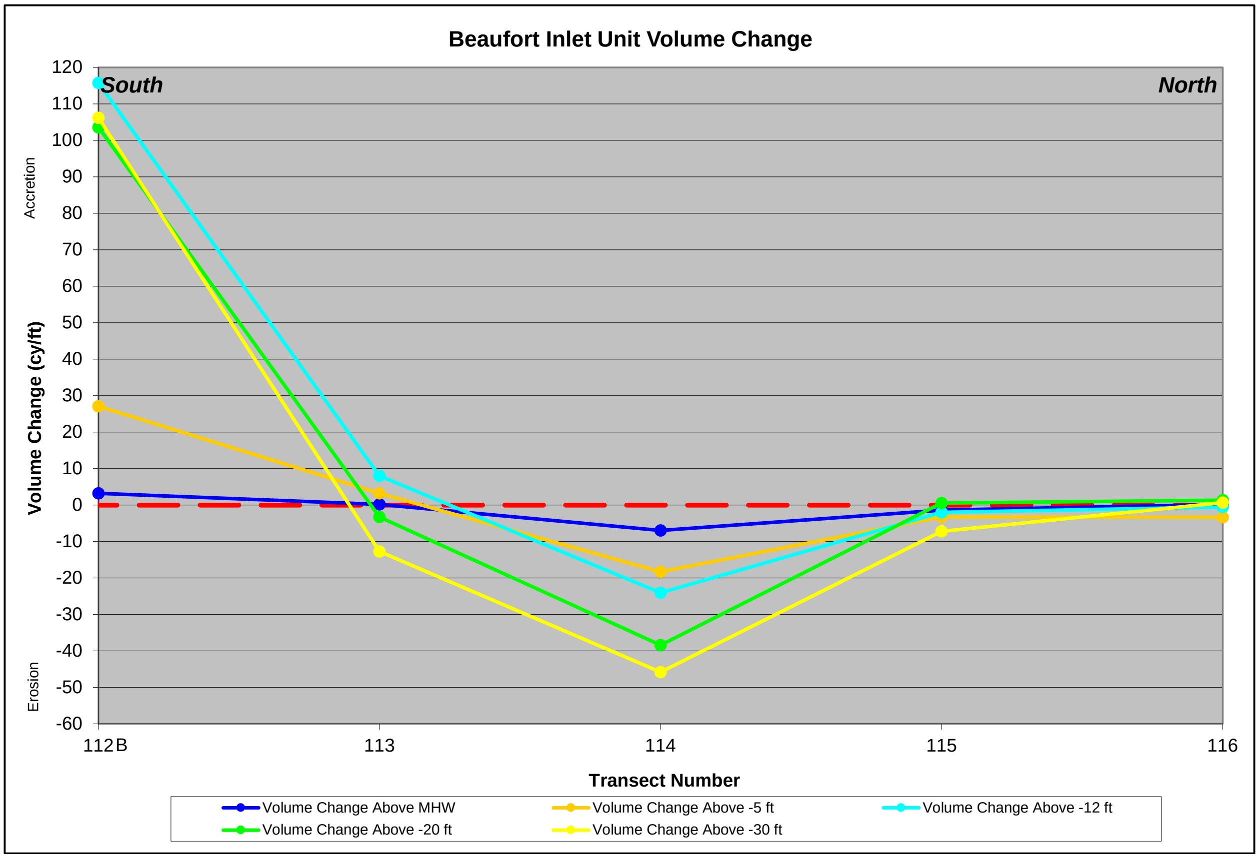


Figure 5-18. Beaufort Inlet Unit Volume Change (2014 - 2015)

In May 2015, the USACE performed a condition survey of the Morehead City Harbor navigation channel. **Figure 5-19** presents the results of the survey. Apparent from this figure is the submerged "toe" of Shackleford Banks along the eastern side of the channel. Also of importance is a more shallow feature cutting through the middle of the stretches of deep water. This feature was also detected in the profile plot of Transect 112B (at approximately 3,000 ft offshore) along with another shallow feature approximately 1,300 ft offshore as shown in **Figure 5-20**.

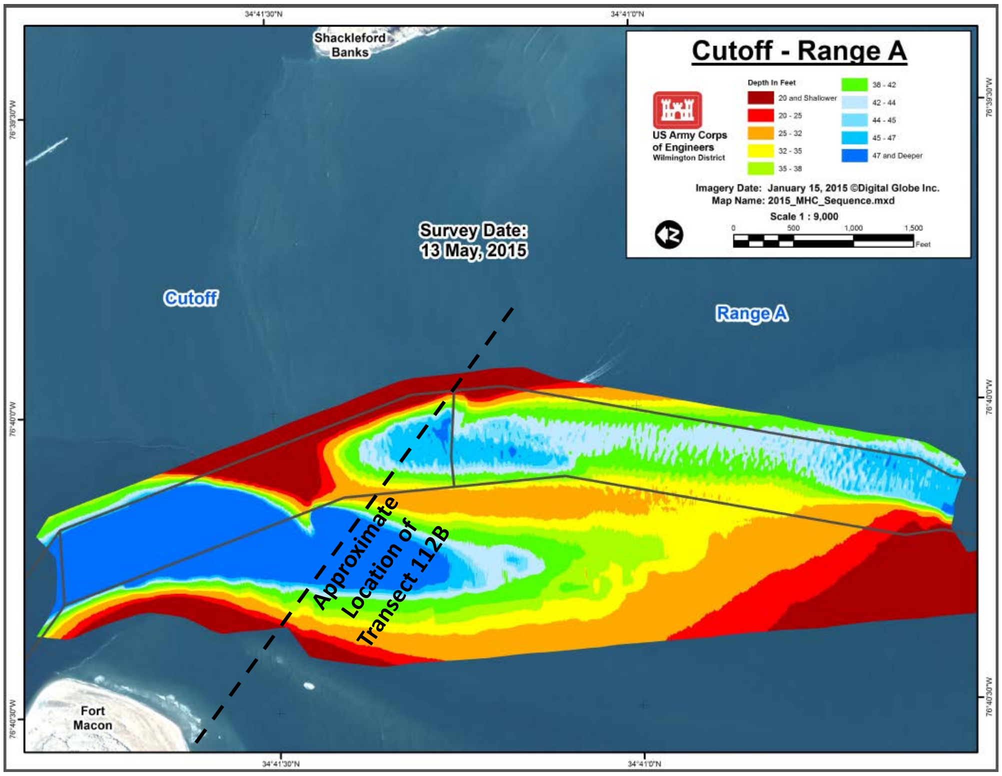


Figure 5-19. USACE Morehead City Harbor Navigation Channel Survey - May 2015 (USACE)

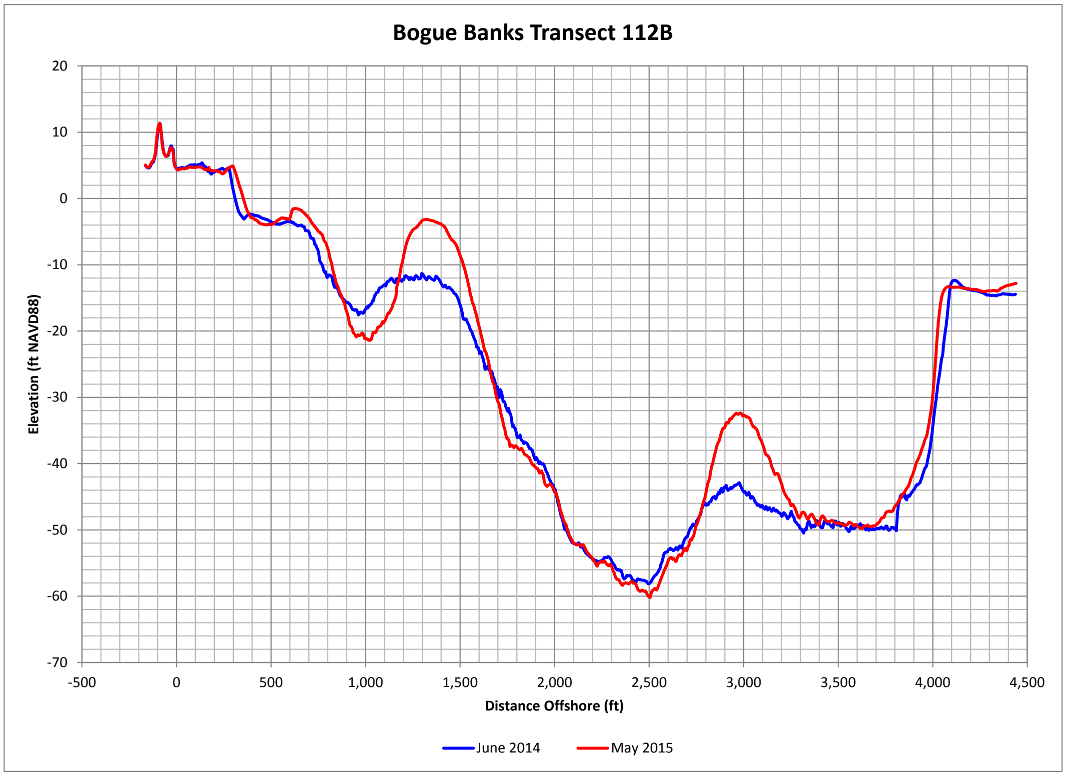


Figure 5-20. Beaufort Inlet Transect 112B

5.4.8 Bear Island

Bear Island contains 18 transects spaced 1000 ft apart. **Table 23** presents a summary of average shoreline and volume changes occuring between 2014 and 2015 for the Bear Island region.

Table 23. Average Shoreline and Volume Change for Bear Island (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bear Island (Transects 1-18)	16,500	19.2	3.5	57,316	0.8	13,323	-4.9	-81,411	-11.3	-187,109	-14.2	-234,599

Bear Island experienced a moderate amount of seaward shoreline advancement over the past year, as shown in **Table 23**. Volumetric calculations indicate a gain in material above MHW and above -5 ft NAVD88 but a loss in material at lower elevations. After examining the volume change plots in **Appendix B** and profile plots in **Appendix C**, it is apparent that most of the profiles showed relatively small changes in volume and profile shape with the exception of Transect 2 near Bogue Inlet. **Figure 5-21** displays the unit volume change at each transect on Bear Island. As can be seen, with the exception of Transect 2, the island was fairly stable with some erosion on the western half of the island and some accretion on the eastern half. Profiles from Transect 18 were not included in the analysis due to the absence of dry land at this transect.

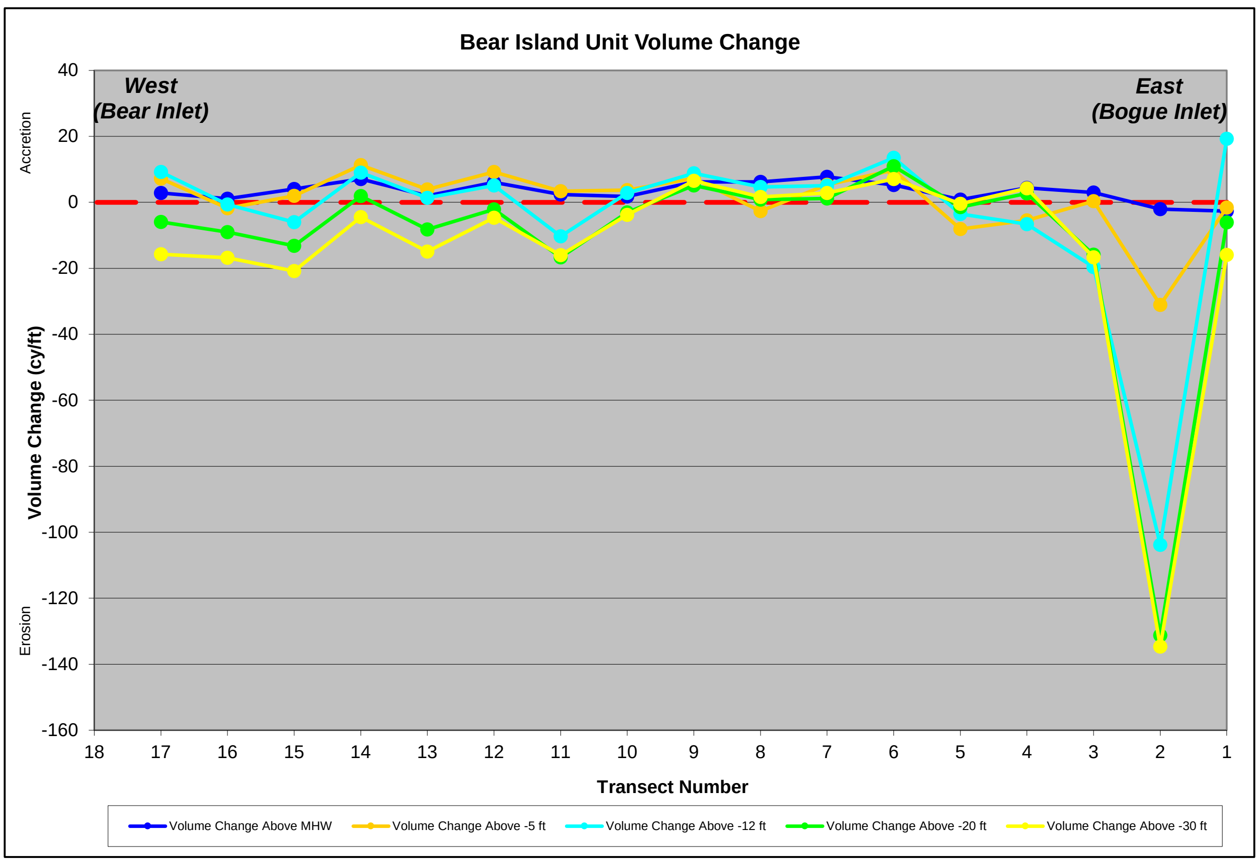


Figure 5-21. Bear Island Unit Volume Change (2014 - 2015)

5.4.9 Shackleford Banks

Shackleford Banks is comprised of 24 transects and is a natural shoreline, receiving no nourishment. As a result, varying accretion and erosion occurs along the island. **Table 24** presents a summary of average shoreline and volume changes occurring between 2014 and 2015 for the Shackleford Banks region. Due to the erosional behavior of the western end of the island which began in 2010, statistics for the island have been divided between Transects 1-20 and 21 – 23. It should be noted that Transect 24 no longer contains any dry land and was therefore not included in the statistical analysis.

Table 24. Average Shoreline and Volume Change for Shackleford Banks (2014 - 2015)

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Shackleford Banks (Transects 1-20)	39,459	12.8	0.5	21,304	-0.7	-29,537	-5.6	-220,320	-10.4	-411,491	-17.0	-671,540
Shackleford Banks (Transects 21-23)	6,542	-498.7	-23.8	-155,825	-133.8	-875,267	-207.8	-1,359,150	-252.9	-1,654,440	-256.5	-1,678,083
Shackleford Banks (Transects 1-24)	46,001	-59.9	-2.9	-134,521	-19.7	-904,804	-34.3	-1,579,470	-44.9	-2,065,930	-51.1	-2,349,623

Table 24 indicates Transects 1 – 20, which comprise most of the island, experienced a moderate seaward shoreline advancement. The shoreline change plot in **Appendix B** and profile plots in **Appendix C** indicate that the shoreline position was relatively stable for a majority of the transects with just a few spots of localized seaward advancement. The remaining transects along Shackleford Banks (21-23) experienced significant landward recession of the shoreline at MHW. Profile plots in **Appendix C** show significant erosion of the dunes and beachface.

Volumetrically, Transects 1-20 experienced a moderate amount of erosion above -12 ft NAVD88 (approximately 200,320 cy). The remaining transects along Shackleford Banks (21-23) experienced significant losses in volume of approximately 1.36 Mcy. As mentioned previously, significant erosion of the dunes and beachface is apparent in the profile plots in **Appendix C**. **Figure 5-22** displays the unit volume change at each transect on Shackleford Banks. It is evident from this figure that the majority of the loss on Shackleford Banks was located at Transects 21 through 23, adjacent to Beaufort Inlet, while the remainder of the island experienced minor losses in comparison. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area.

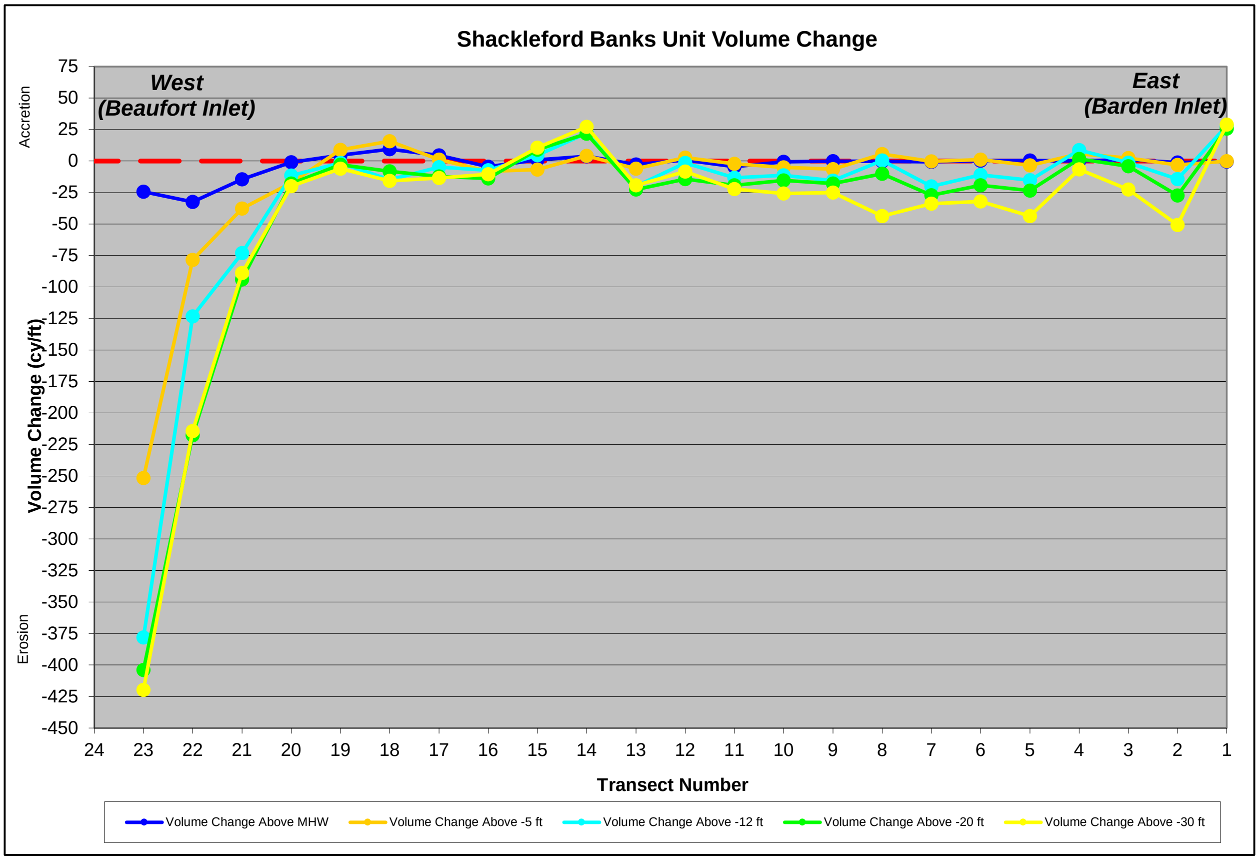


Figure 5-22. Shackleford Banks Unit Volume Change (2014 – 2015)

5.5 Transition to Bogue Banks Master Beach Nourishment Plan

Carteret County is currently in the process of developing a programmatic Environmental Impact Statement (EIS) which would essentially outline the nourishment needs (quantity, location, and timeframe) and sediment resources for Bogue Banks for the next 50 years. One environmental permit, obtained from review of the EIS, would be available to cover all nourishment actions for the next 50 years, eliminating the time-consuming process of permitting each individual project and allowing for placement of sand as needed. The engineering portion of the EIS, which provides detailed analysis of the estimation of nourishment needs and sediment source quantities, has been completed by Moffatt & Nichol. The document is currently being reviewed for incorporation into the remainder of the EIS which is being drafted by Dial Cordy & Associates. Copies of the updated engineering plan were submitted to the Federal Emergency Management Agency (FEMA) and the North Carolina Division of Emergency Management (NCDEM) in July 2015. It is expected that by the next annual survey (spring/summer 2016), Carteret County will be operating under the new Master Plan. Incorporation of the Master Plan into ongoing annual monitoring efforts will require some changes to the current analysis which will be explained in the following section.

5.5.1 New Management Reaches and Nourishment Triggers

Currently, one of the triggers for nourishment action is if the average profile volume from the foredune (landward most crest of the primary dune) to the outer bar (above -12 ft NAVD88) in any of the established reaches (see Figure 3-1) falls below 225 cy/ft. This method provides for an equal amount of sand for everyone but not necessarily and equal amount of protection. Based on the engineering analysis and historical and expected future funding levels, it was determined that Carteret County would be able to maintain protection from a 25-yr storm event. The engineering analysis included detailed SBEACH modeling which was used to determine the amount of material that is needed to provide a 25-yr event level of protection in each reach. This is different for each reach depending on existing dune height, berm width, offshore slope, etc. In addition, some changes were made to the reaches including slightly increasing the size of the Bogue Inlet-Ocean reach and consequently slightly decreasing the size of the Emerald Isle West reach. Pine Knoll Shores West and East were also combined into one reach based on beach profile morphology as well as detailed Crystal Ball analytical analysis of historical erosion rates. **Table 25** presents the current and future management reaches and nourishment triggers. Each reach will have a slightly different volume trigger, with an island wide weighted average of 233 cy/ft. **Figure 5-23** presents the new triggers with respect to the historical profile volume above -12 ft NAVD88.

Table 25. Current and Future Management Reaches and Nourishment Triggers

CURRENT REACHES:				NEW MANAGEMENT REACHES:			
Reach (Profiles)	Length (ft)	2015 Volume Above -12 ft (cy/ft)	-12 ft Trigger (cy)	Reach (Profiles)	Length (ft)	2014 Volume Above -12 ft (cy/ft)	-12 ft Trigger (cy)
Bogue Inlet-Ocean (1-8)	7,432	334	225	Bogue Inlet (1-11)	11,488	319	235
Emerald Isle-West (9-25)	22,344	312	225	Emerald Isle West (12-25)	18,288	316	266
Emerald Isle-Central (26-36)	15,802	298	225	Emerald Isle Central (26-36)	15,802	298	211
Emerald Isle-East (37-48)	13,220	274	225	Emerald Isle East (37-48)	13,220	274	221
Indian Beach-Salter Path (49-58)	12,850	281	225	Indian Beach/Salter Path (49-58)	12,850	281	224
Pine Knoll Shores-West (59-65)	9,063	260	225	Pine Knoll Shores (59-76)	23,878	255	211
Pine Knoll Shores-East (66-76)	14,815	252	225				
Atlantic Beach (77-102)	26,176	323	225	Atlantic Beach (77-102)	26,176	323	254

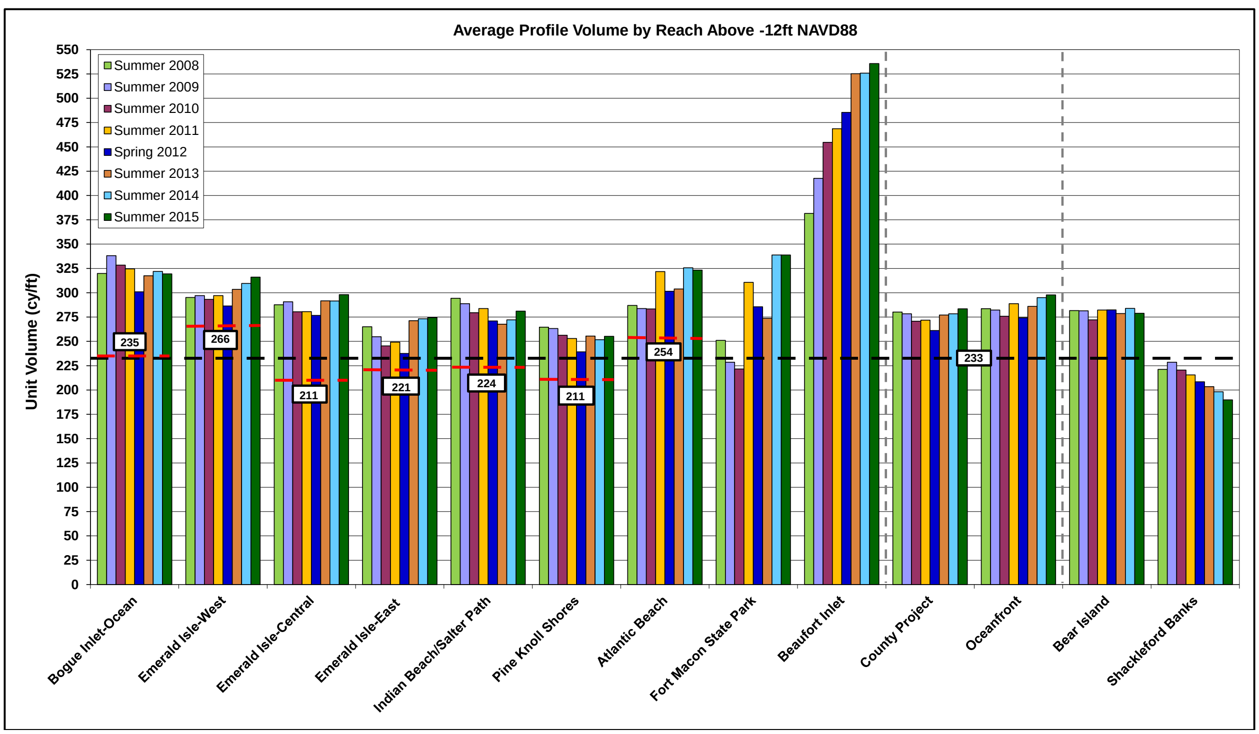


Figure 5-23. Future Management Reaches and Nourishment Triggers

5.5.2 Estimation of Years Remaining Until Next Nourishment

One component of the detailed Crystal Ball analytical analysis is the ability to assign confidence intervals to the future nourishment projections. This was used to determine the number of years until the next nourishment might be required based on the most recent 2015 survey data and historical erosion rates. **Table 26** presents the estimates of the remaining time until the new nourishment triggers are realized within each reach based on various confidence intervals. It appears the first nourishments will be required in a 7-12 year range under average conditions (see 50%, 55%, and 60% confidence intervals). However, if a period of above normal storm activity were to impact the area, these estimates could go down to 3-6 years (see 70%, 75% and 85% confidence intervals).

Table 26. Years Remaining Until Nourishment

Reach (Profiles)	Management Reach Length (ft)	-12 ft 2015 Volume (cy)	Preliminary -12 ft Trigger (cy)	Volume Remaining (cy)	Years to 25 yr Trigger 50%	Years to 25 yr Trigger 55%	Years to 25 yr Trigger 60%	Years to 25 yr Trigger 65%	Years to 25 yr Trigger 70%	Years to 25 yr Trigger 75%	Years to 25 yr Trigger 85%
Bogue Inlet (1-11)	11,488	319	235	84	22	13	10	7	6	5	4
Emerald Isle West (12-25)	18,288	316	266	50	145	145	145	78	30	18	9
Emerald Isle Central (26-36)	15,802	298	211	87	55	44	27	19	15	12	8
Emerald Isle East (37-48)	13,220	274	221	53	11	9	7	6	5	5	3
Indian Beach/Salter Path (49-58)	12,850	281	224	57	12	9	7	6	5	5	4
Pine Knoll Shores (59-76)	23,878	255	211	44	12	9	8	6	5	5	3
Atlantic Beach (77-102)	26,176	323	254	69	11	10	8	7	6	6	4
TOTAL	**121,702**										
AVERAGE		**295**	**233**	**63**	**38**	**34**	**30**	**19**	**10**	**8**	**5**
		weighted	weighted								

5.6 Post-Irene Project Analysis

During the 2011-2012 monitoring cycle, Hurricane Irene impacted Carteret County, in particular Bogue Banks. Based on pre- and post-storm monitoring efforts, Moffatt & Nichol determined that Bogue Banks lost approximately 1.4 million cubic yards (cy) of material as a result of the storm. The Post-Irene Renourishment Project, funded by FEMA, the County's Beach Commission/Shore Protection Office, and local communities, took place in February and March of 2013. The project took just under seven weeks to construct, placing approximately 965,011 cy of material along three reaches of Bogue Banks. Pine Knoll Shores (Reach 1) received a total of 315,221 cy of material over 12,905 ft of beach for an average of 24.4 cy/ft. Emerald Isle East (Reach 2) received approximately 451,600 cy of material over 12,504 ft of beach for an average of 36.1 cy/ft. Emerald Isle West (Reach 3) received approximately 198,190 cy of material over 9,485 ft of beach for an average of 20.9 cy/ft.

This section provides an overall analysis of the performance of the 2013 Post-Irene Renourishment Project at each of the three reaches along Bogue Banks where nourishment material was placed. Volume change between the post-project annual surveys (2013, 2014, and 2015) and the post-fill (AD) survey above elevations +1.1 ft NAVD88 (MHW), -5 ft NAVD88, and -12 ft NAVD88 was calculated to determine the amount of nourishment material remaining at various elevations. It is important to note some of the nourishment material has been transported alongshore outside the nourishment reach and cross-shore beyond a depth of -12 ft NAVD88 and may not be captured in these calculations.

The nourishment extents within Emerald Isle West (Reach 3) include Transects 10 through 16. **Table 27** presents the amount of material placed above each elevation based on the before dredge

(BD) and after dredge/post-fill (AD) surveys. **Table 27** also shows the change in volume between the AD survey and the spring/summer 2015 survey, and the percent difference between the surveys. The percent difference indicates what percentage of material has been lost (negative values) or gained (positive values) at each elevation with respect to the volume of material placed. In Emerald Isle West, approximately 47% of the material placed above MHW has been lost. However, a much smaller loss above -5 ft NAVD88 and a volume gain above -12 ft NAVD88 indicates this volume has been captured and is still providing protection to the system.

Table 27. Emerald Isle – West Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2013 (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Difference in Cumulative Volume Change AD - 2015 (cy)	Percent Difference AD - 2015
1.1	111,365	-31,377	-40,292	-52,479	-47.1%
-5	152,899	-43,807	6,099	-8,435	-5.5%
-12	198,190	-22,577	97,627	125,185	63.2%

The nourishment extents within Emerald Isle East (Reach 2) include Transects 35 through 45. **Table 28** presents the amount of material placed above each elevation based on the before dredge (BD) and after dredge/post-fill (AD) surveys. **Table 28** also shows the change in volume between the AD survey and the spring/summer 2015 survey, and the percent difference between the surveys. The percent difference indicates what percentage of material has been lost (negative values) or gained (positive values) at each elevation with respect to the volume of material placed. In Emerald Isle East, approximately 36.6% of the material placed above MHW has been lost while approximately 33.1 % of the material placed above -5 ft NAVD88 has been lost. However, the volume gain above -12 ft NAVD88 (16.1 %) indicates this volume and additional sand has been captured and is still providing protection to the system.

Table 28. Emerald Isle - East Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2013 (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Difference in Cumulative Volume Change AD - 2015 (cy)	Percent Difference AD - 2015
1.1	169,748	-40,266	-71,539	-62,202	-36.6%
-5	330,050	-70,220	-55,257	-109,166	-33.1%
-12	451,600	21,032	150,923	72,902	16.1%

The nourishment extents within Pine Knoll Shores (Reach 1) include Transects 62 through 71. **Table 29** presents the amount of material placed above each elevation based on the before dredge (BD) and after dredge/post-fill (AD) surveys. **Table 29** also shows the change in volume between the AD survey and the spring/summer 2015 survey, and the percent difference between the surveys. The percent difference indicates what percentage of material has been lost (negative values) or gained (positive values) at each elevation with respect to the volume of material placed. In Pine Knoll Shores, approximately 9.5% of the material placed above MHW and approximately 66.7% of the material placed above -5 ft NAVD88 has been lost. However, the volume gain (58.7%) in material above -12 ft NAVD88 indicates this volume and additional sand has been captured and is still providing protection to the system.

Table 29. Pine Knoll Shores Project Performance

Elevation (ft NAVD88)	Cumulative Volume Change BD - AD (cy)	Difference in Cumulative Volume Change AD - 2013 (cy)	Difference in Cumulative Volume Change AD - 2014 (cy)	Difference in Cumulative Volume Change AD - 2015 (cy)	Percent Difference AD - 2015
1.1	152,123	-57,390	-66,788	-14,465	-9.5%
-5	258,562	-66,987	-110,275	-172,447	-66.7%
-12	315,221	3,176	84,236	185,002	58.7%

Although all three reaches have experienced a loss in material from the berm out to -5 ft NAVD88, they all currently contain more material above -12 ft NAVD88 than originally in place after the project was completed. The process of profile equilibration most likely created the material shift to the lower profile regions. The placed material most likely equilibrated or shifted from the constructed profile to a more natural shape in response to wave and tide actions. The material that has been captured landward of the offshore bar between -5 ft NAVD88 and -12 ft NAVD88 is very important in absorbing wave energy and lessening the impact to material onshore.

5.7 Statistical Analysis of Recent Volume Change Trends

Using the eight most recent high quality survey datasets (2008-2015), statistical analyses were performed to determine if any long-term trends in ocean front behavior are visible for Bogue Banks, Bear Island, and Shackleford Banks. The average volume change per year and standard deviation was calculated for each transect using the volume changes from the current monitoring report along with the five previous reports (M&N 2009, 2010, 2011, 2012, 2013, and 2014). In areas where nourishment occurred, the amount of nourishment material was subtracted out in order to determine trends in beach change without the effects of the nourishment. **Appendix E** tabulates these statistics for each transect along Bogue Banks, Bear Island, and Shackleford Banks.

5.7.1 Bogue Banks

To determine the longterm trends along Bogue Banks, nourishments within the time period from 2008 -2015 (Post-Irene - February/March 2013 and MCH Maintenance Dredging in 2011, 2014) were subtracted out of the total volume change at each transect based on an average cubic yard per foot placed along each reach of beach in order to determine the background erosion rate. Therefore, these numbers are subject to some uncertainty since the same amount of nourishment was likely not placed at each transect. **Figure 5-24** shows the mean volume change with nourishment and **Figure 5-25** shows the mean volume change with the nourishment subtracted out from 2008-2015. In comparison of the two figures, the hotspots along Emerald Isle and Pine Knoll Shores are very visible as well as the increased erosion rates in Atlantic Beach and Fort Macon when nourishment effects are subtracted out.

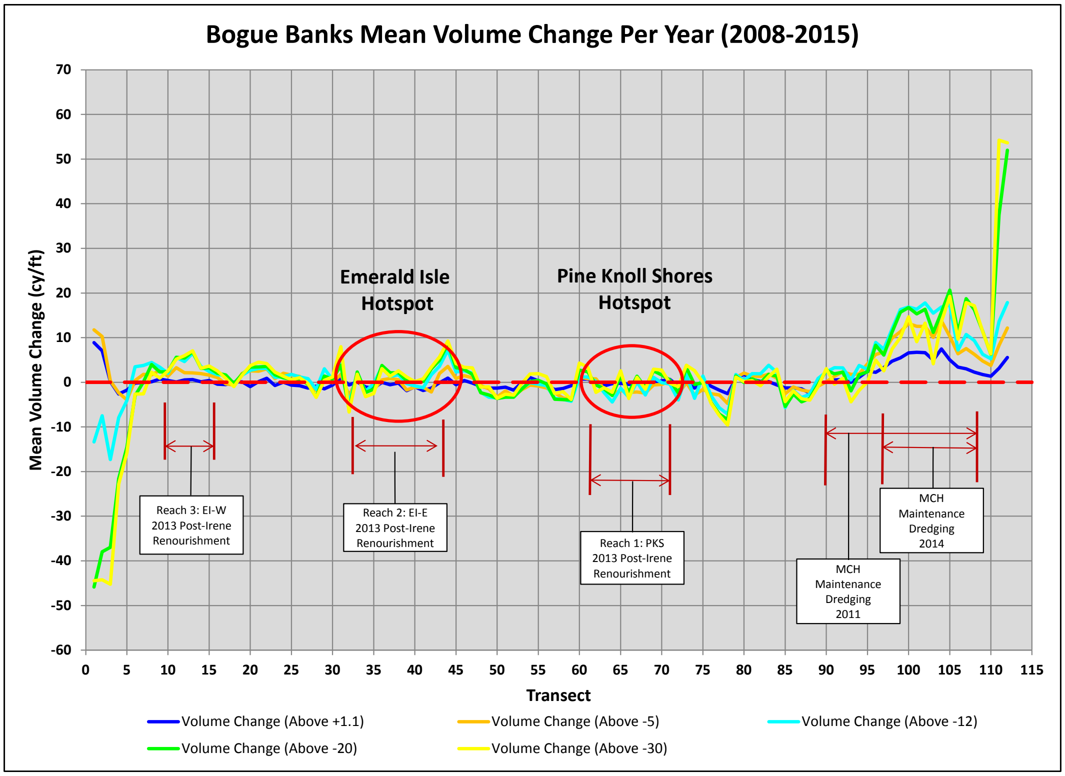


Figure 5-24. Bogue Banks Mean Volume Change (With Nourishment)

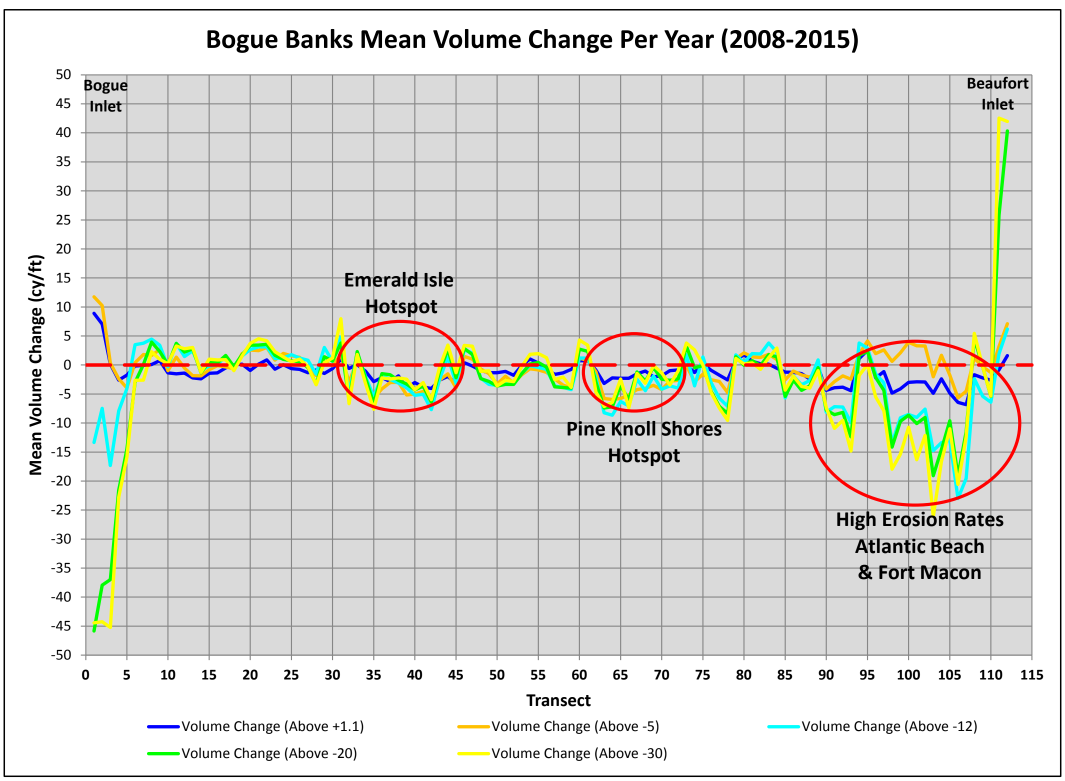


Figure 5-25. Bogue Banks Mean Volume Change (Without Nourishment)

The standard deviations of the average annual volume change (without nourishment) were also calculated for each referenced elevation included in the analysis. **Figure 5-26** through **Figure 5-30** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

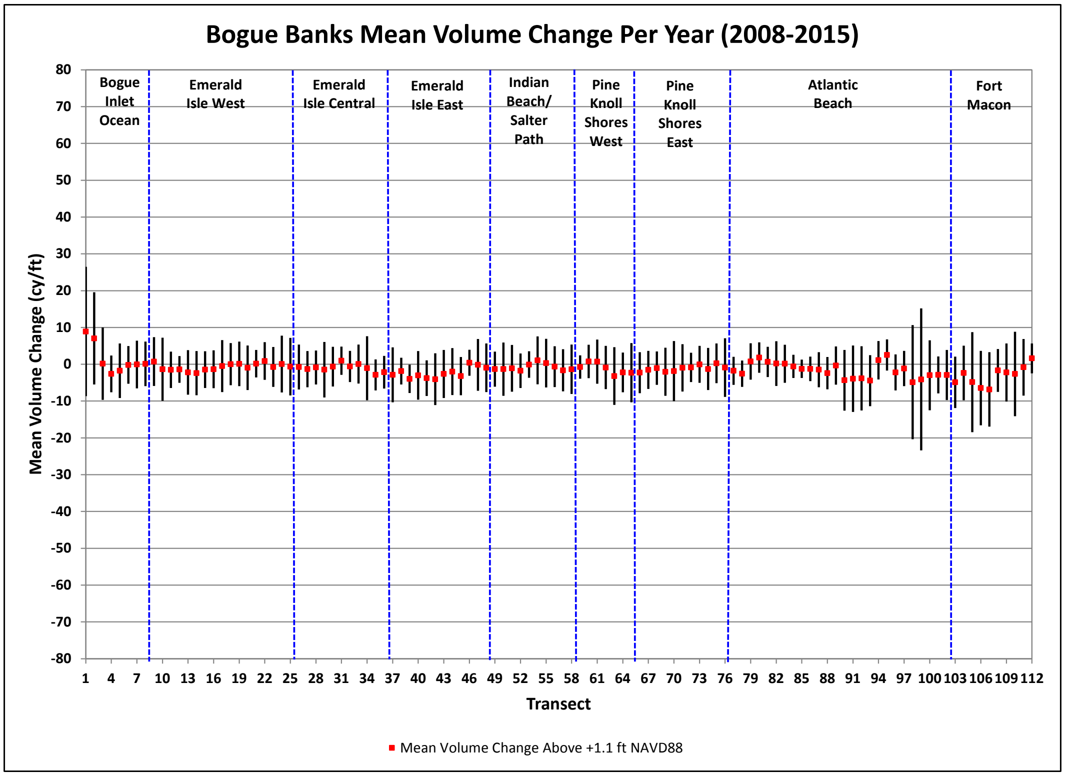


Figure 5-26. Bogue Banks Statistical Analysis of Volume Change Above +1.1 ft NAVD88

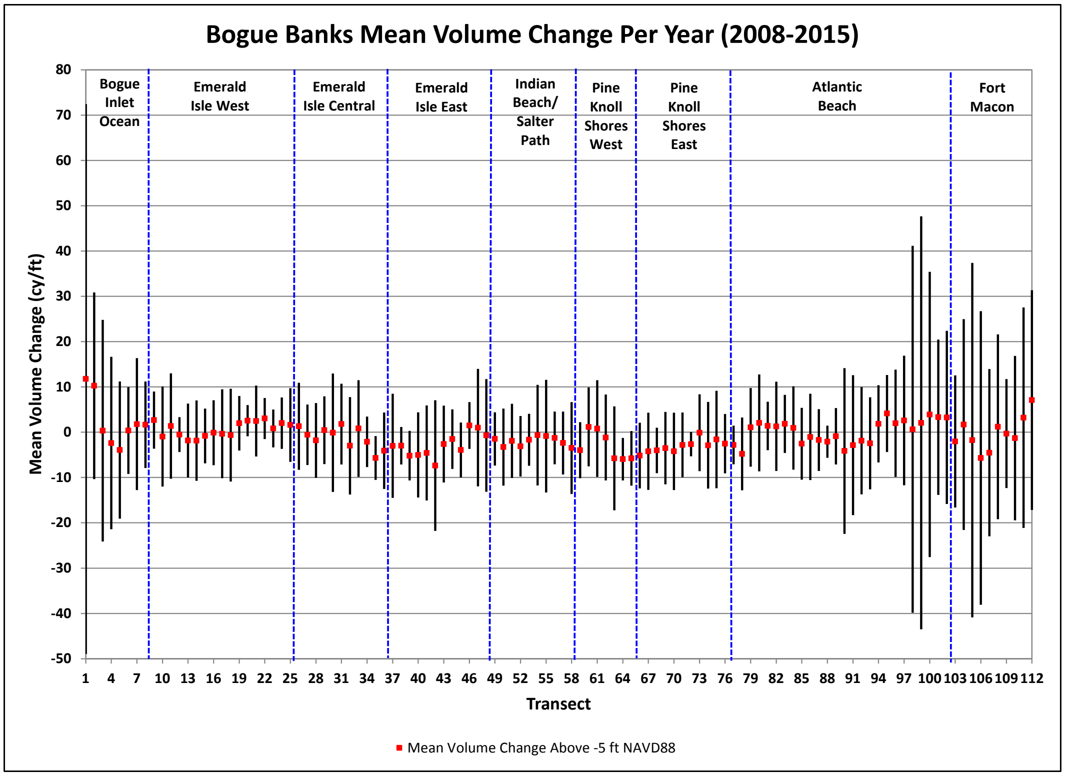


Figure 5-27. Bogue Banks Statistical Analysis of Volume Change Above -5.0 ft NAVD88

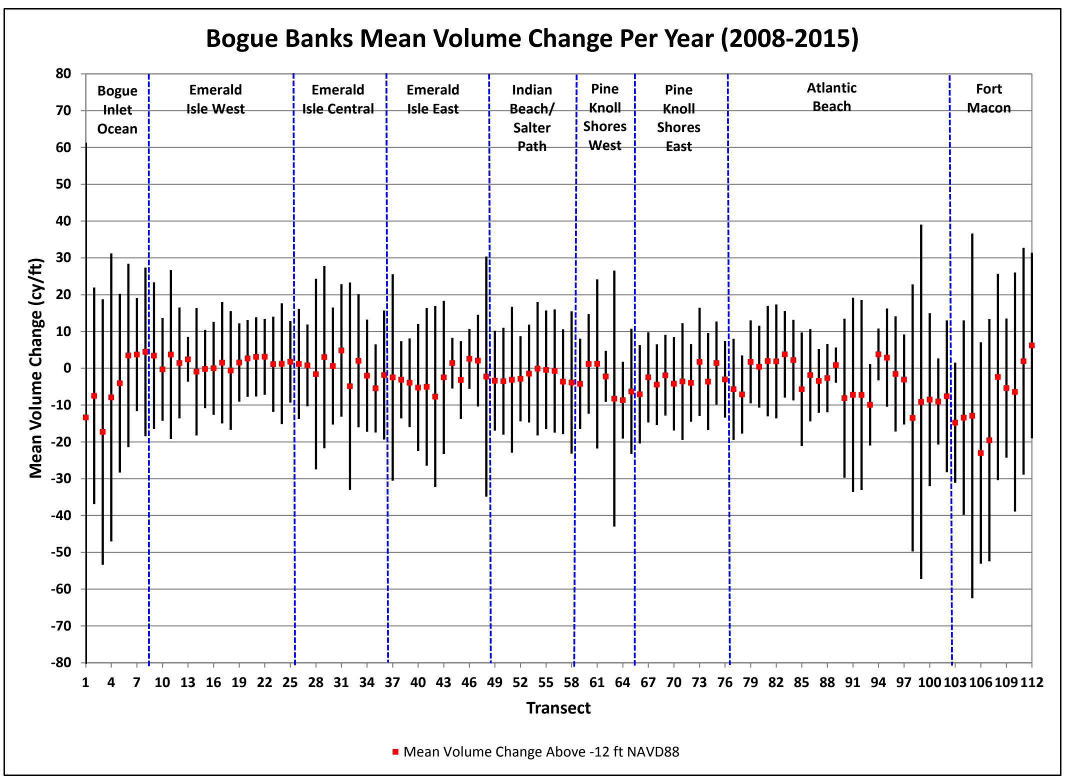


Figure 5-28. Bogue Banks Statistical Analysis of Volume Change Above -12.0 ft NAVD88

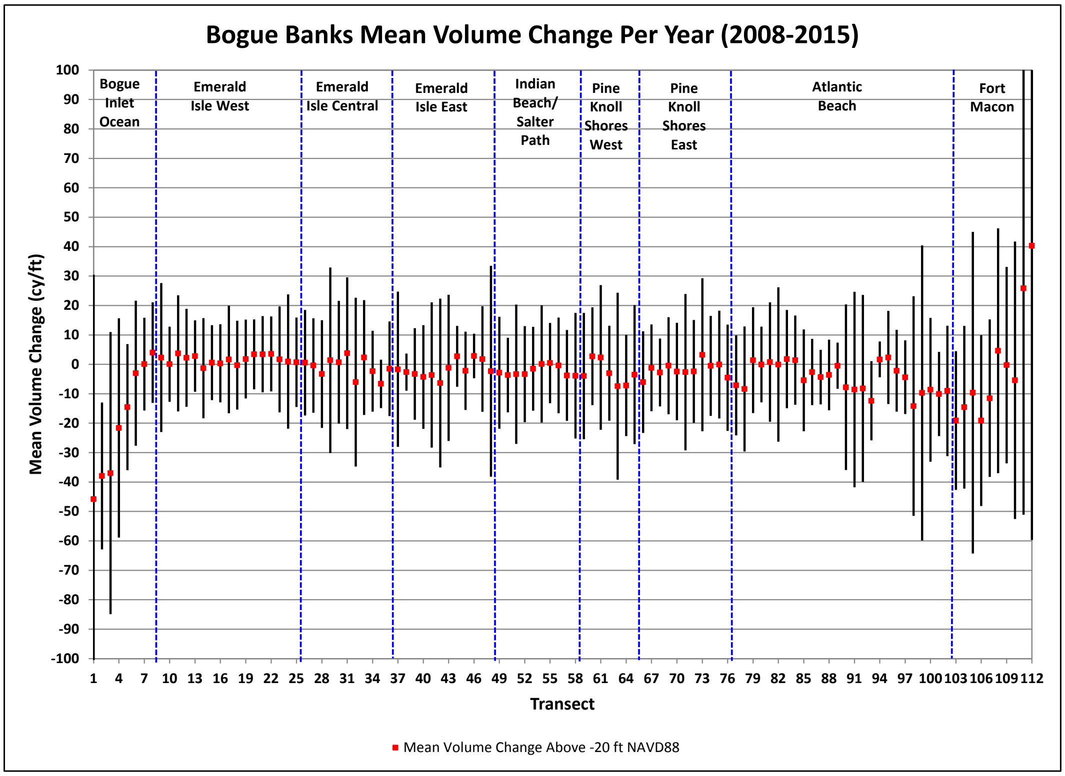


Figure 5-29. Bogue Banks Statistical Analysis of Volume Change Above -20.0 ft NAVD88

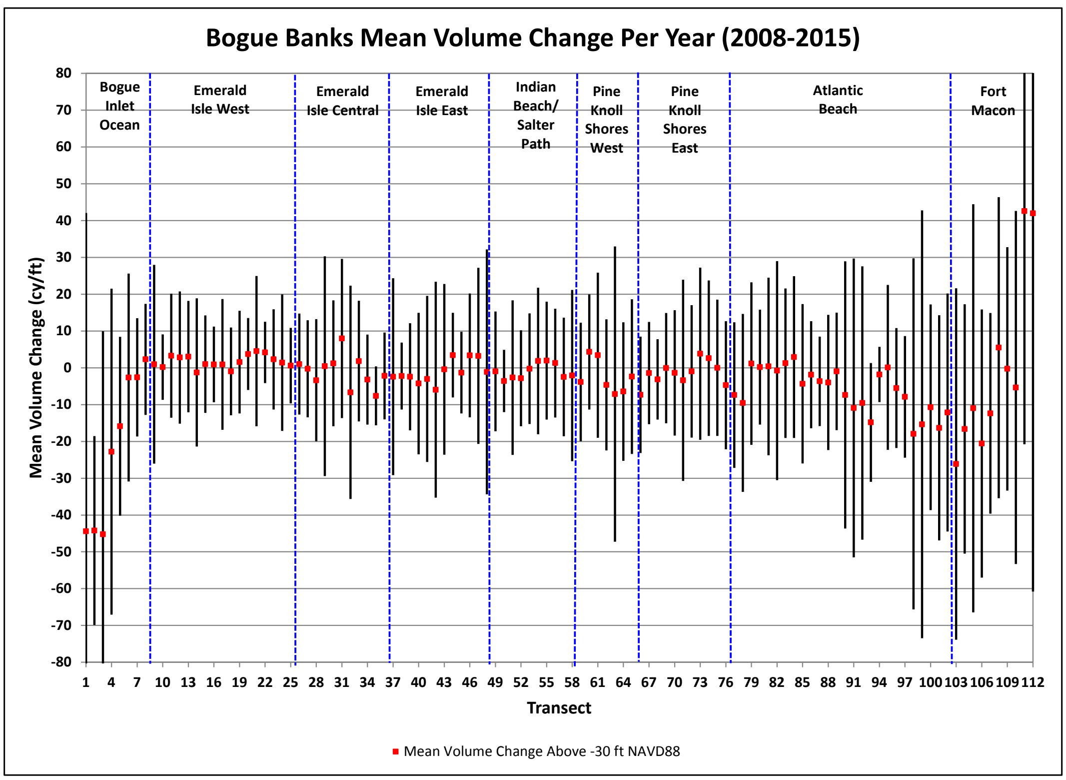


Figure 5-30. Bogue Banks Statistical Analysis of Volume Change Above -30.0 ft NAVD88

The variability in volume change increases with depth especially above MHW, -5 ft NAVD88, and -12 ft NAVD88. This is intuitive since the majority of sand movement historically happens in the subaerial profile with large fluctuations in the offshore bar position. The standard deviation of volume change above -20 ft NAVD88 and above -30 ft NAVD88 is not much higher than that values calculated for above -12 ft NAVD88. This implies there is not a large amount of additional sand movement at these lower depths. Also important is the standard deviation is much larger on either end of the island, as would be expected given the inlet effect on each end of the island. Changes near the inlets often fluctuate significantly each year. As more datasets are collected, average long-term trends will become more apparent.

5.7.2 Bear Island

To determine the longterm volume change trends along Bear Island, the average annual volume change rate was calculated at each transect based on changes calculated for the monitoring reports from 2008 to 2015. **Figure 5-31** shows the mean volume change per year from 2008-2015. Large changes near Bogue Inlet are very apparent.

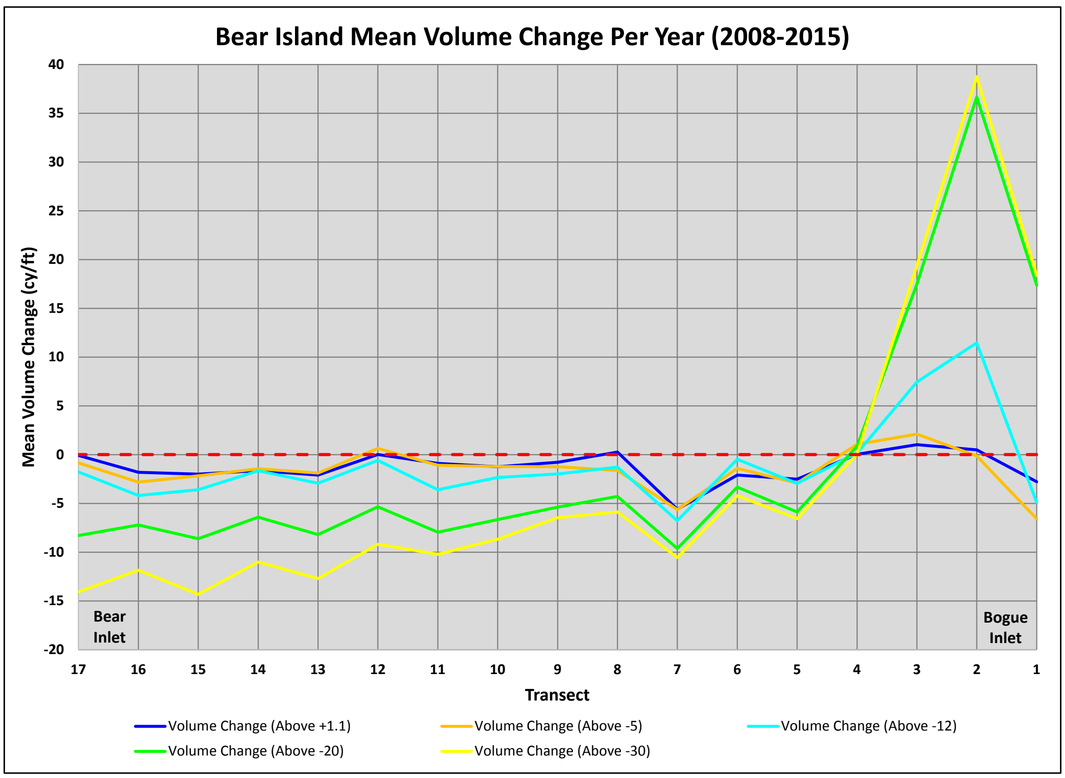


Figure 5-31. Bear Island Mean Volume Change

The standard deviations of the average annual volume change per year were also calculated for each referenced elevation included in the analysis. **Figure 5-32** through **Figure 5-36** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

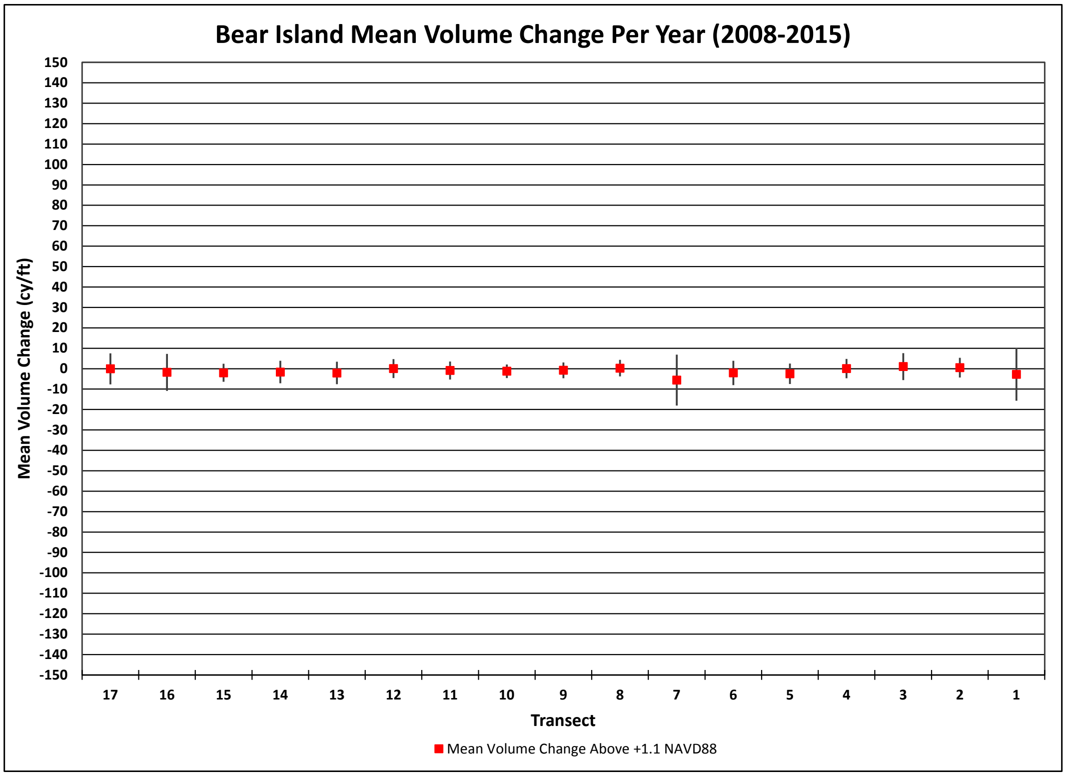


Figure 5-32. Bear Island Statistical Analysis of Volume Change Above +1.1 ft NAVD88

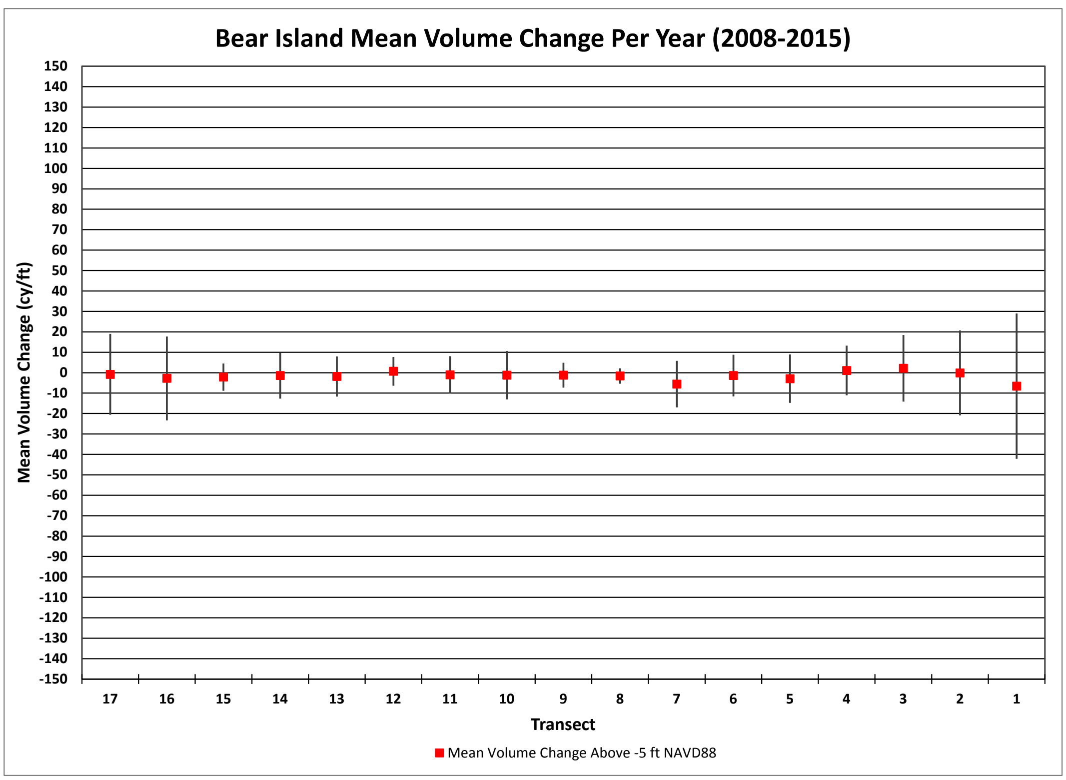


Figure 5-33. Bear Island Statistical Analysis of Volume Change Above -5.0 ft NAVD88

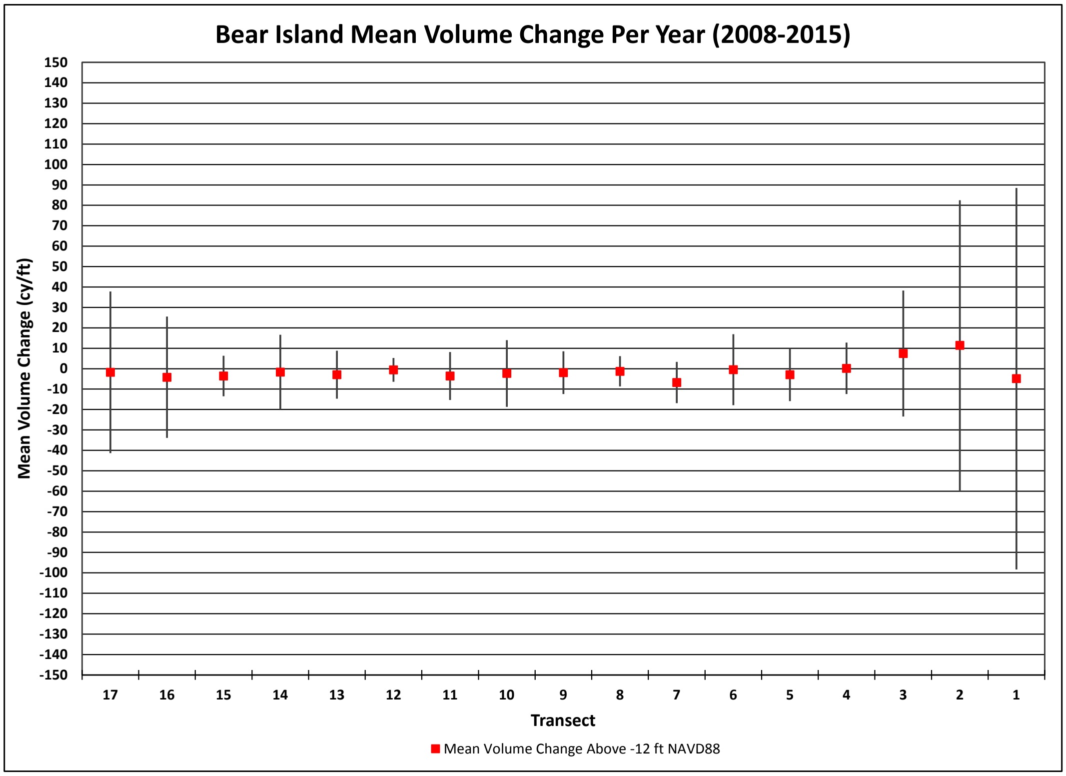


Figure 5-34. Bear Island Statistical Analysis of Volume Change Above -12.0 ft NAVD88

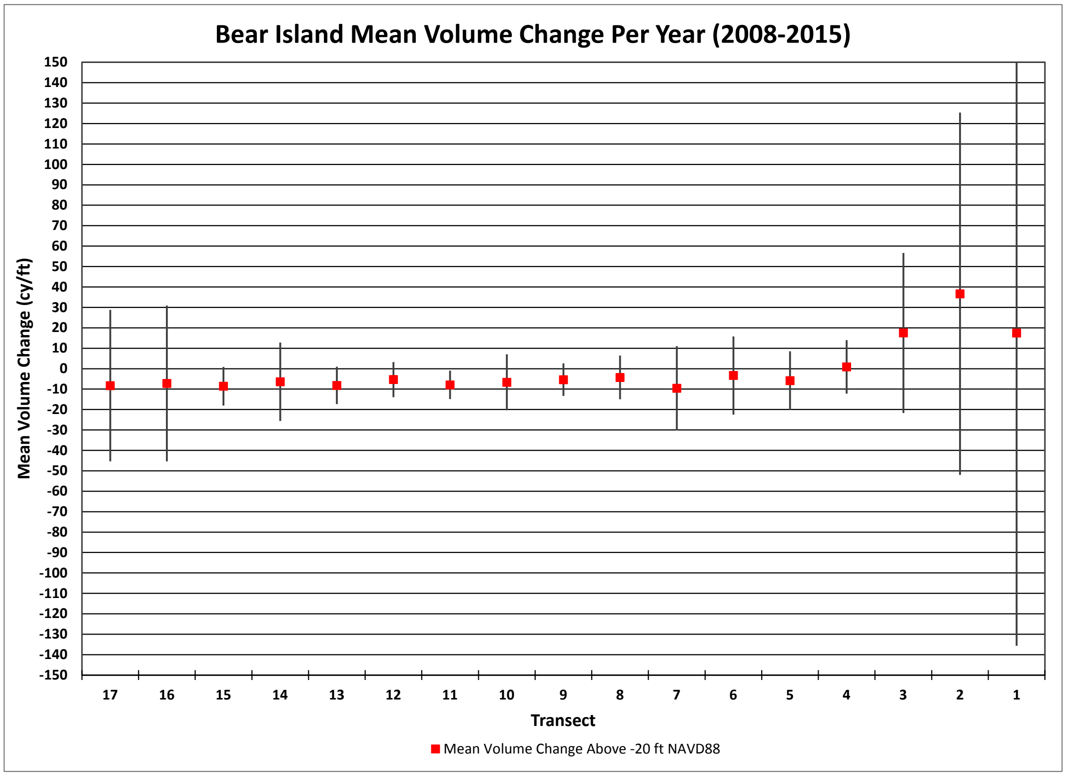


Figure 5-35. Bear Island Statistical Analysis of Volume Change Above -20.0 ft NAVD88

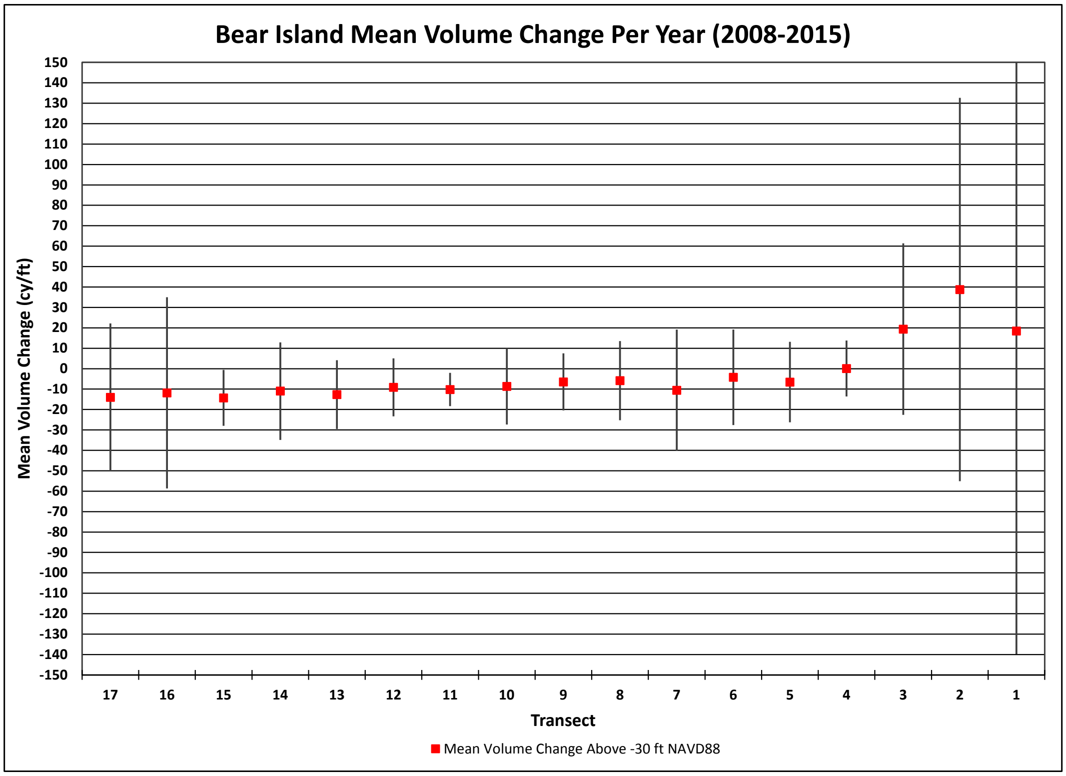


Figure 5-36. Bear Island Statistical Analysis of Volume Change Above -30.0 ft NAVD88

5.7.3 Shackleford Banks

To determine the longterm volume change trends along Shackleford Banks, the average annual volume change rate was calculated at each transect based on changes calculated for the monitoring reports from 2008 to 2015. **Figure 5-37** shows the mean volume change per year from 2008-2015. Large changes near Beaufort Inlet are very apparent.

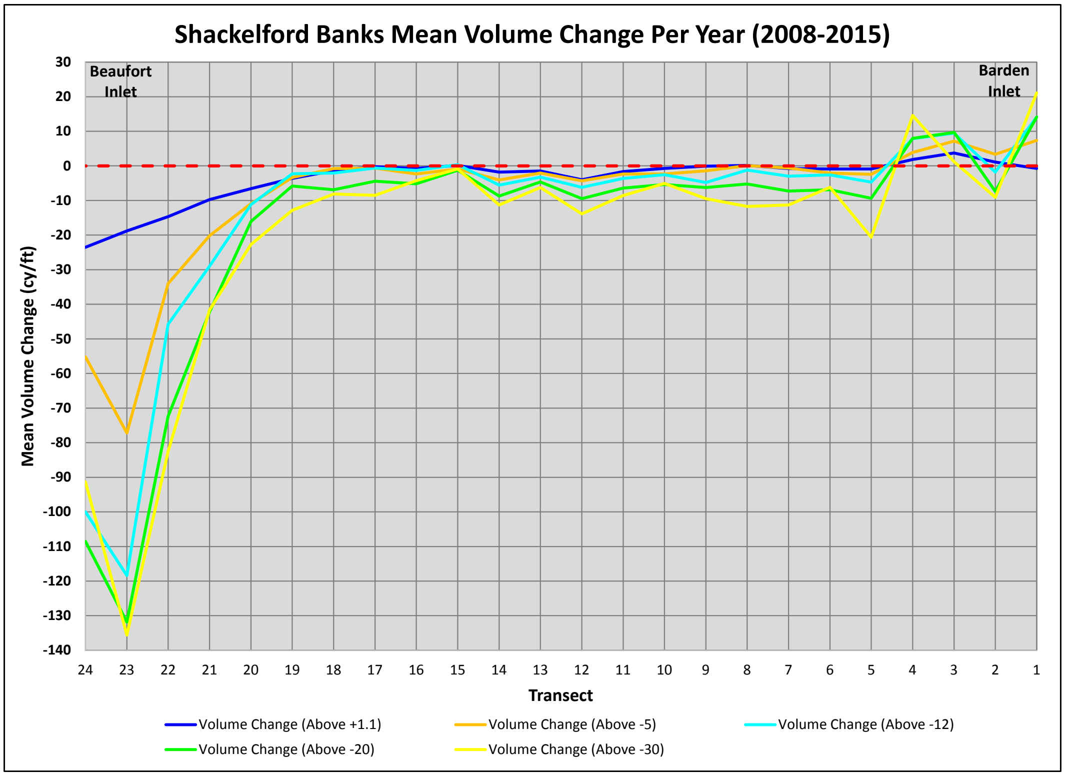


Figure 5-37. Shackleford Banks Mean Volume Change

The standard deviations of the average annual volume change were also calculated for each referenced elevation included in the analysis. **Figure 5-38** through **Figure 5-42** shows the mean volume change per year with standard deviation bars at plus and minus one standard deviation for each of the referenced elevations.

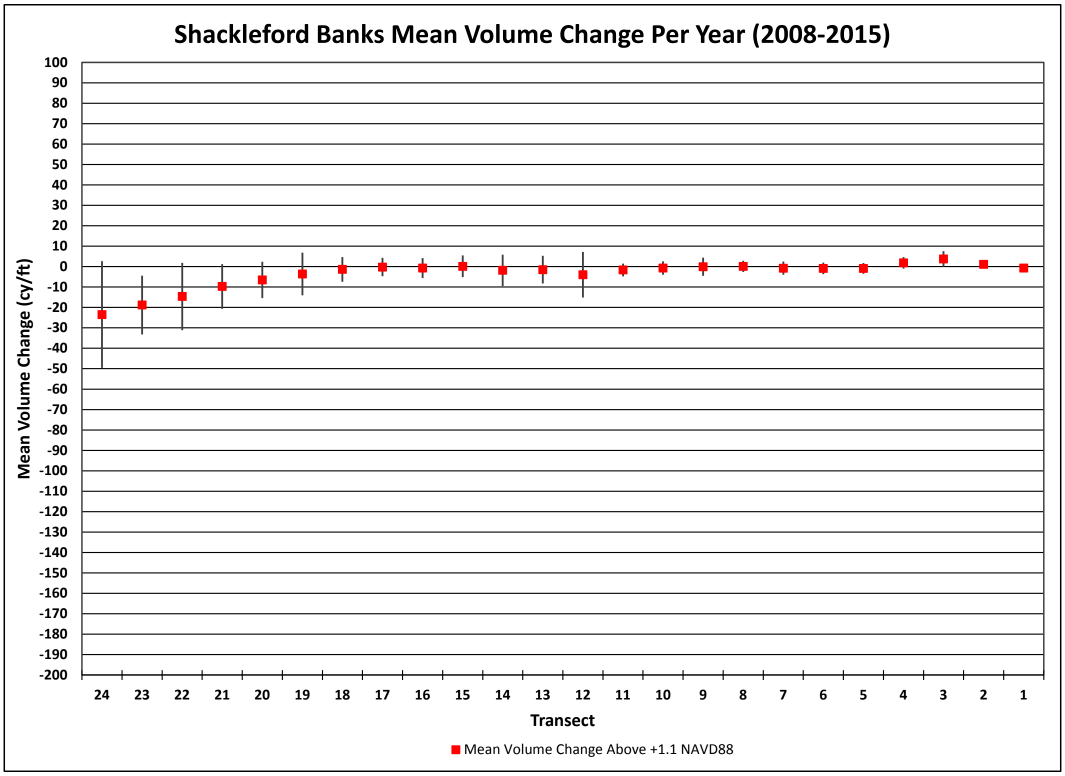


Figure 5-38. Shackleford Banks Statistical Analysis of Volume Change Above +1.1 ft NAVD88

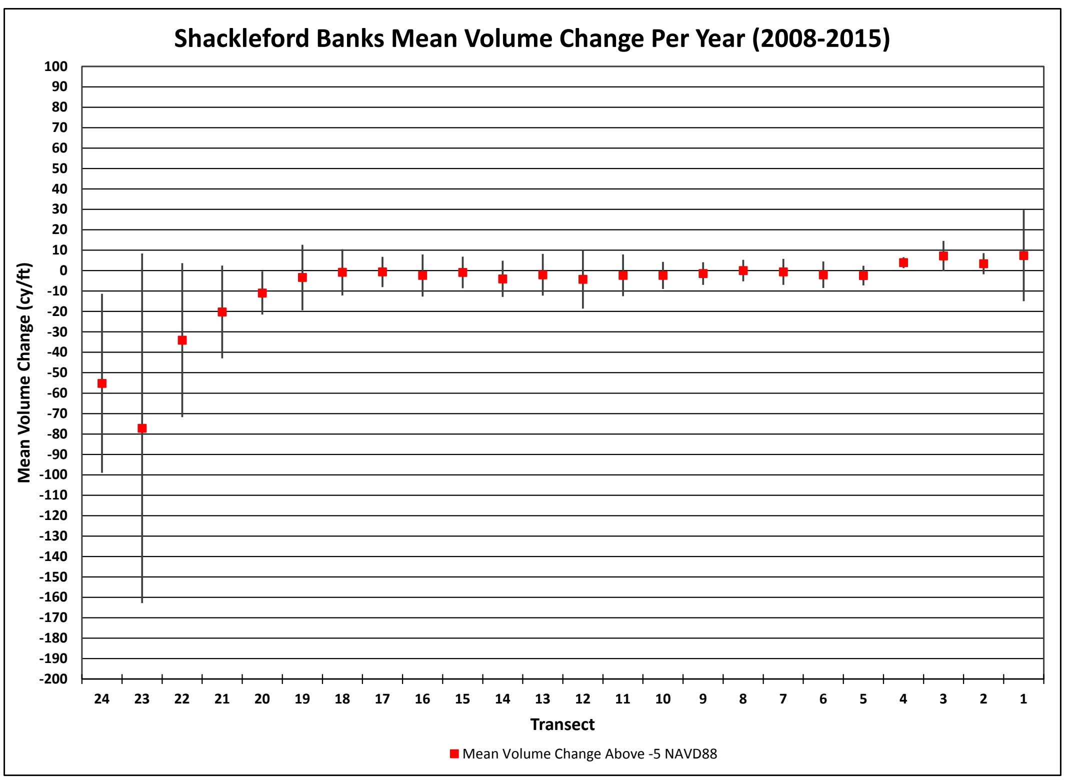


Figure 5-39. Shackleford Banks Statistical Analysis of Volume Change Above -5.0 ft NAVD88

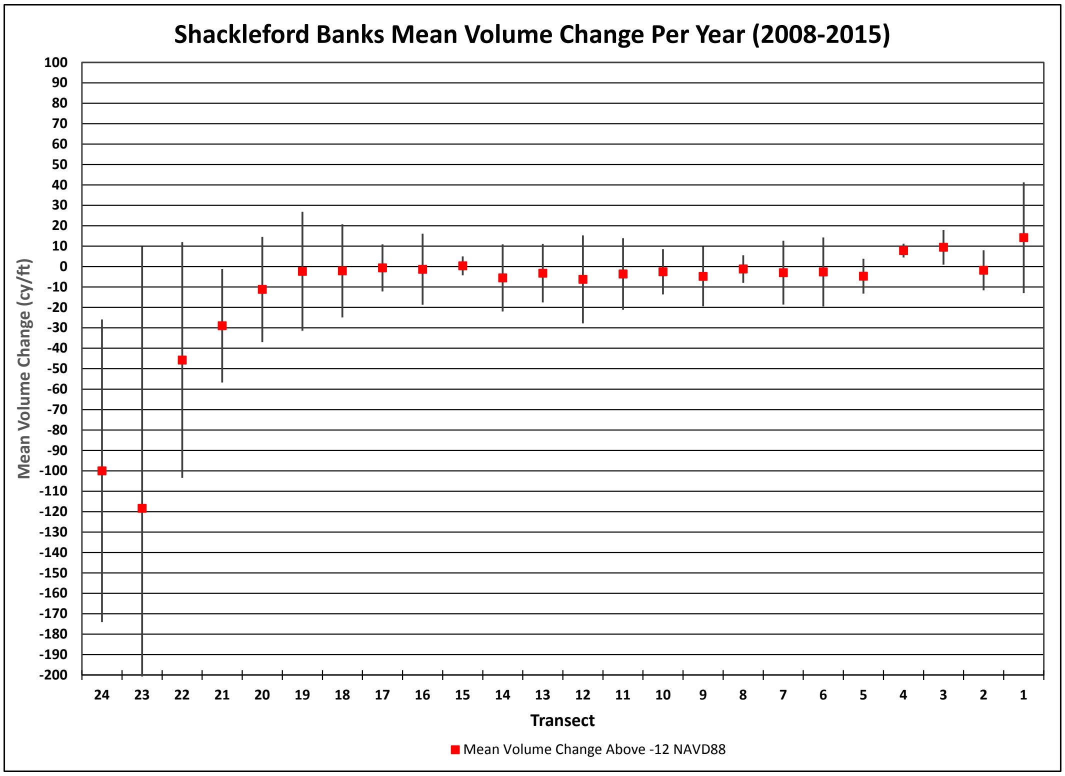


Figure 5-40. Shackleford Banks Statistical Analysis of Volume Change Above -12.0 ft NAVD88

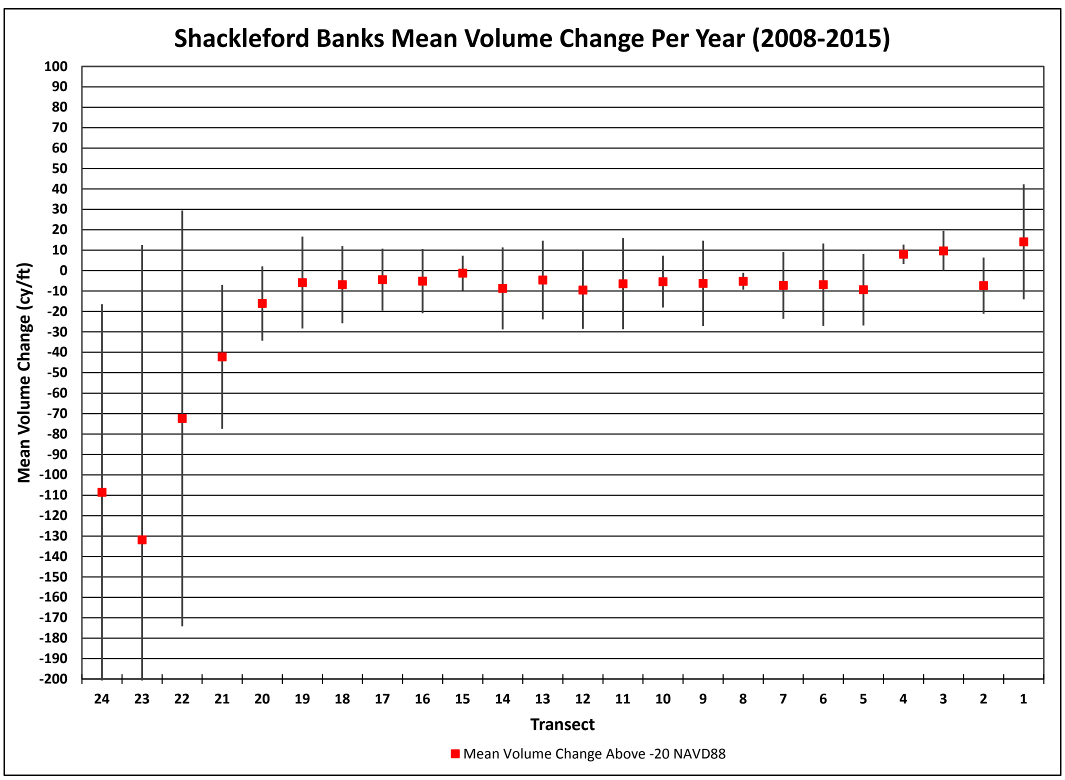


Figure 5-41. Shackleford Banks Statistical Analysis of Volume Change Above -20.0 ft NAVD88

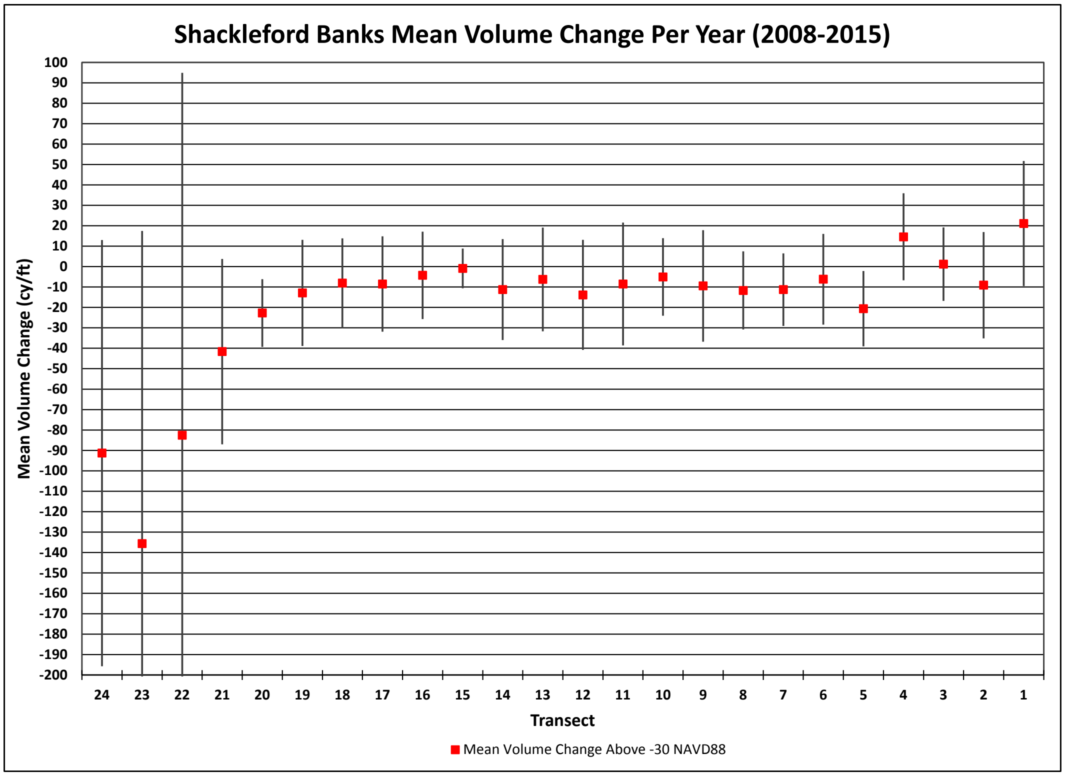


Figure 5-42. Shackleford Banks Statistical Analysis of Volume Change Above -30.0 ft NAVD88

6.0 Summary

Comprehensive beach surveying of the Bogue Banks shoreline began in 1999 as a way to formulate the Bogue Banks Beach Restoration Project. In spring 2004, the Bogue Banks Beach and Nearshore Mapping Program was codified to continue assessing beach conditions and form strategies for future beach nourishment projects. Bear Island was added to the project in October 2004 and Shackleford Banks was added in May 2005. Surveys are performed annually during the spring/summer timeframe along all three islands. In addition, after large storm events, surveying is performed along Bogue Banks to assess damages. The most recent annual monitoring survey was completed during spring/summer 2015 by Geodynamics. For this evaluation, the spring/summer 2015 survey was compared with the spring/summer 2014 survey. The profile data were used to compute shoreline change at MHW (+1.1 ft NAVD88) and volume change above MHW, -5 ft NAVD88 (wading depth), -12 ft NAVD88 (outer bar), -20 ft NAVD88 (approximate closure), and -30 ft NAVD88 (offshore).

Key statistics were computed for defined regions along the Bogue Banks shoreline, Bear Island, and Shackleford Banks between the 2014 and 2015 survey profiles including;

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Banks Oceanfront (Transects 1-112)	128,393	-9.0	-0.2	-20,768	-3.6	-465,760	2.7	341,840	-4.2	-542,511	-7.1	-908,778
Bogue Banks County Project (Transects 9-76)	88,094	-0.1	1.3	116,241	-3.2	-284,898	4.9	433,574	-2.5	-216,242	-5.9	-523,819
Bear Island (Transects 1-18)	16,500	19.2	3.5	57,316	0.8	13,323	-4.9	-81,411	-11.3	-187,109	-14.2	-234,599
Shackleford Banks (Transects 1-24)	46,001	-59.9	-2.9	-134,521	-19.7	-904,804	-34.3	-1,579,470	-44.9	-2,065,930	-51.1	-2,349,623

Key statistics for individual reaches along Bogue Banks were as follows:

Reach (Transects)	Reach Length	Average Shoreline Change @ MHW (+1.1 ft NAVD88)	Average Volume Change Above +1.1 ft NAVD88	Cumulative Volume Change Above +1.1 ft NAVD88	Average Volume Change Above -5 ft NAVD88	Cumulative Volume Change Above -5 ft NAVD88	Average Volume Change Above -12 ft NAVD88	Cumulative Volume Change Above -12 ft NAVD88	Average Volume Change Above -20 ft NAVD88	Cumulative Volume Change Above -20 ft NAVD88	Average Volume Change Above -30 ft NAVD88	Cumulative Volume Change Above -30 ft NAVD88
	ft	ft	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy	cy/ft	cy
Bogue Inlet-Ocean (Transects 1-8)	7,432	-30.9	-1.7	-12,553	-4.0	-29,375	-3.6	-27,015	-10.1	-74,774	-12.8	-94,884
Emerald Isle-West (Transects 9-25)	22,344	-11.1	-2.4	-53,943	-0.5	-11,189	5.3	118,263	-1.8	-40,559	-7.5	-167,683
Emerald Isle-Central (Transects 26-36)	15,802	18.1	2.5	39,018	-2.6	-40,989	6.5	102,953	-2.4	-38,704	-7.5	-118,855
Emerald Isle-East (Transects 37-48)	13,220	-27.6	-2.0	-25,885	-5.0	-66,699	1.1	15,048	-4.5	-59,716	-7.2	-95,622
Indian Beach/Salter Path (Transects 49-58)	12,850	-4.5	3.5	44,355	-4.9	-62,813	9.0	115,676	0.3	4,482	-1.3	-16,491
Pine Knoll Shores-West (Transects 59-65)	9,063	21.3	5.0	45,634	-4.5	-41,178	6.7	60,500	-2.4	-22,060	-5.2	-47,476
Pine Knoll Shores-East (Transects 66-76)	14,815	12.1	4.5	67,063	-4.2	-62,030	1.4	21,133	-4.0	-59,685	-5.2	-77,691
Atlantic Beach (Transects 77-102)	26,176	-24.3	-3.6	-94,165	-3.6	-94,604	-2.5	-64,358	-8.2	-215,186	-9.0	-235,065
Fort Macon State Park (Transects 103-112)	6,691	-41.0	-4.5	-30,291	-8.5	-56,882	-0.1	-361	-5.4	-36,309	-8.2	-55,011
Beaufort Inlet (Transects 112B-116)	2,000	-22.4	-1.6	-3,239	-1.6	-3,223	9.9	19,800	2.8	5,651	-3.1	-6,149
Bogue Inlet-Channel (Transects 117-120)*	2,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*Note: Due to the dynamic nature of Bogue Inlet, shoreline and volume calculations were not performed

The Bogue Banks oceanfront shoreline experienced an overall average recession at MHW of -9.0 ft over the past year. However, this is heavily influenced by the equilibration of the Morehead City Harbor Maintenance Dredging project which occurred in Fort Macon and Atlantic Beach. Measurements along the County Project indicate very little overall movement in the MHW position in the reaches that were not nourished (Emerald Isle, Indian Beach/Salter Path, and Pine Knoll Shores). In addition, volumetric measurements along the non-nourished reaches indicate a material gain of approximately 433,574 cy above -12 ft NAVD88. Volumetric measurements for the complete shoreline (Transects 1-112) show a gain of approximately 341,840 cy above -12 ft NAVD88. Looking at the table above, it would appear that there has been some movement of material towards the onshore from the lower depths (-20 ft NAVD88 and -30 ft NAVD88). Beyond the gains in material above -12 ft NAVD88, many reaches also experienced gains in material above MHW. Although there was a volumetric loss trend above -5 ft NAVD88, the intermediate elevation between MHW and -12 ft NAVD88, profile plots show many instances where material from the surfzone (between MHW and -5 ft NAVD88) migrated onshore, creating a new berm feature. In addition, many of these profiles show a gain in volume and landward shift of the offshore bar.

The Post-Irene Renourishment Project (February/March 2013) performance was also analyzed by comparing the 2015 survey data with post-fill surveys taken at the time of the project. Although all three reaches have experienced a loss in material from the berm out to -5 ft NAVD88, they all currently contain more material above -12 ft NAVD88 than was measured when the project was completed. The material captured landward of the offshore bar between -5 ft NAVD88 and -12 ft NAVD88 plays a vital role in absorbing wave energy and lessening the impact to material onshore.

Bear Island appears to have experienced a moderate amount of seaward advancement of the shoreline over the past year. Volumetric calculations indicate a gain in material above MHW and above -5 ft NAVD88 but a loss in material at lower elevations. Profile plots show relatively small changes in the profile shape and volume with the exception of Transect 2 near Bogue Inlet, which experienced a large amount of erosion. The significant erosion measured along Transect 2 accounts for an overwhelming majority of the volume loss calculated for the lower profile elevations along all of Bear Island. Review of the subsequent profiles show the remainder of the island was relatively stable and even showed volumetric gains at many transects.

Calculations indicate there was significant recession of the shoreline position at MHW and losses in material above all elevations analyzed on Shackleford Banks. However, profile plots indicate that Transects 1-20 experienced small to moderate recession of the shoreline at MHW and volume losses. The remaining transects located at the westernmost end of Shackleford Banks (21-23) experienced significant erosion of the dune and beachface. These remaining profiles account for a majority of the erosion experienced across the entire island. This behavior is not unexpected given the location of the deep draft channel being directly adjacent to this area of Shackleford Banks. The combination of the deep draft channel hydraulics, episodic dredging and shoaling, as well as barrier island morphology make this a very dynamic area. Calculations indicate that while Transects 1 – 20 lost approximately 200,320 cy of material above -12 ft NAVD88, Transects 21-23 lost approximately 1.36 Mcy of material above -12 ft NAVD88.

This year's analysis also included an assessment of the change in position of the base of the dune along Bogue Banks, performed using shore parallel survey lines collected in 2014 and 2015. The difference in position at each transect was calculated and plotted to determine any trends in movement along the oceanfront shoreline. An average landward movement of approximately 1.1 ft was calculated over the entire shoreline. It should be noted that the accuracy of the dune base position surveyed is highly subject to surveyor interpretation and other methods for tracking this feature are being investigated.

It is expected that next year's annual monitoring report will be performed under the new Bogue Banks Master Beach Nourishment Plan. The transition will bring with it slightly new management reaches and nourishment triggers. However, the types of analysis performed will remain consistent with previous monitoring reports. In fact, a preliminary assessment of current conditions compared to the new triggers was completed as part of this report. The new overall weighted trigger for the island is 233 cy/ft above -12 ft NAVD88, with varying triggers in each management reach. Using historical erosion rates (background and storm), it would appear that the next nourishment action may be needed within 3-6 years if there is a period of above normal storm activity. Otherwise, the next nourishment action is not expected for 7-12 years.

As noted, there are inevitable margins of uncertainty associated with hydrographic survey data that may reduce the accuracy of volumetric change analyses. The current estimate of uncertainty in the hydrographic portion of the survey is approximately ±0.11 ft. This results in a variability along the entire Bogue Banks shoreline of roughly ±811,000 cy when taking into account the portion of the profile seaward of the outer bar (approximately 1300 ft offshore) out to a depth of -30 ft NAVD88 (approximately 2850 ft offshore). Therefore, it is essential to thoroughly review the beach and bathymetric profiles using various analytical techniques and general engineering judgment to assure that results are not falsely interpreted. Future periodic survey evaluations will continue to improve on analysis techniques so that the rich survey data sets are best utilized.

APPENDIX A

MHW Shoreline Plots

Figure A-1. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-2. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-3. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

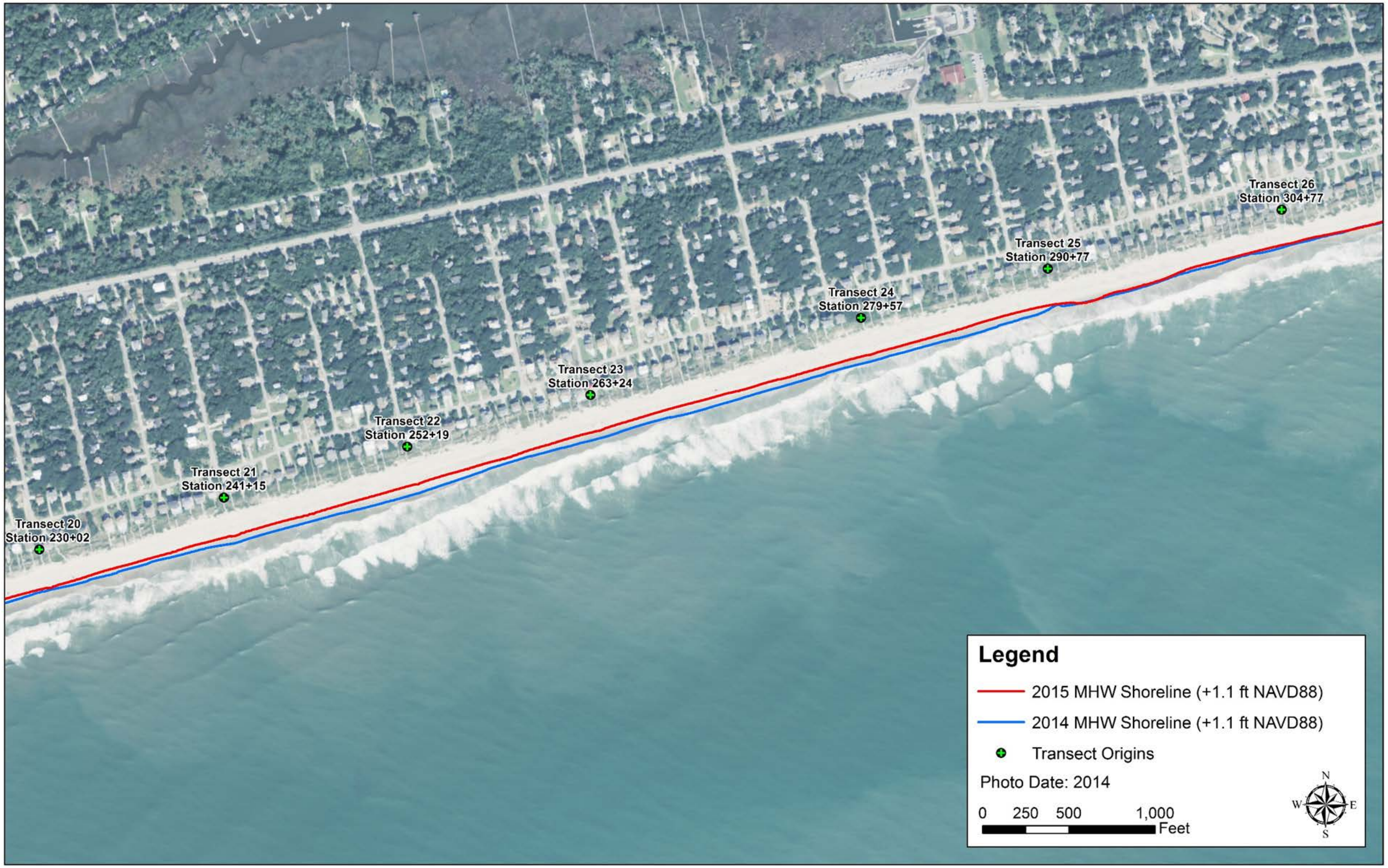


Figure A-4. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-5. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-6. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-7. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-8. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-9. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-10. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-11. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

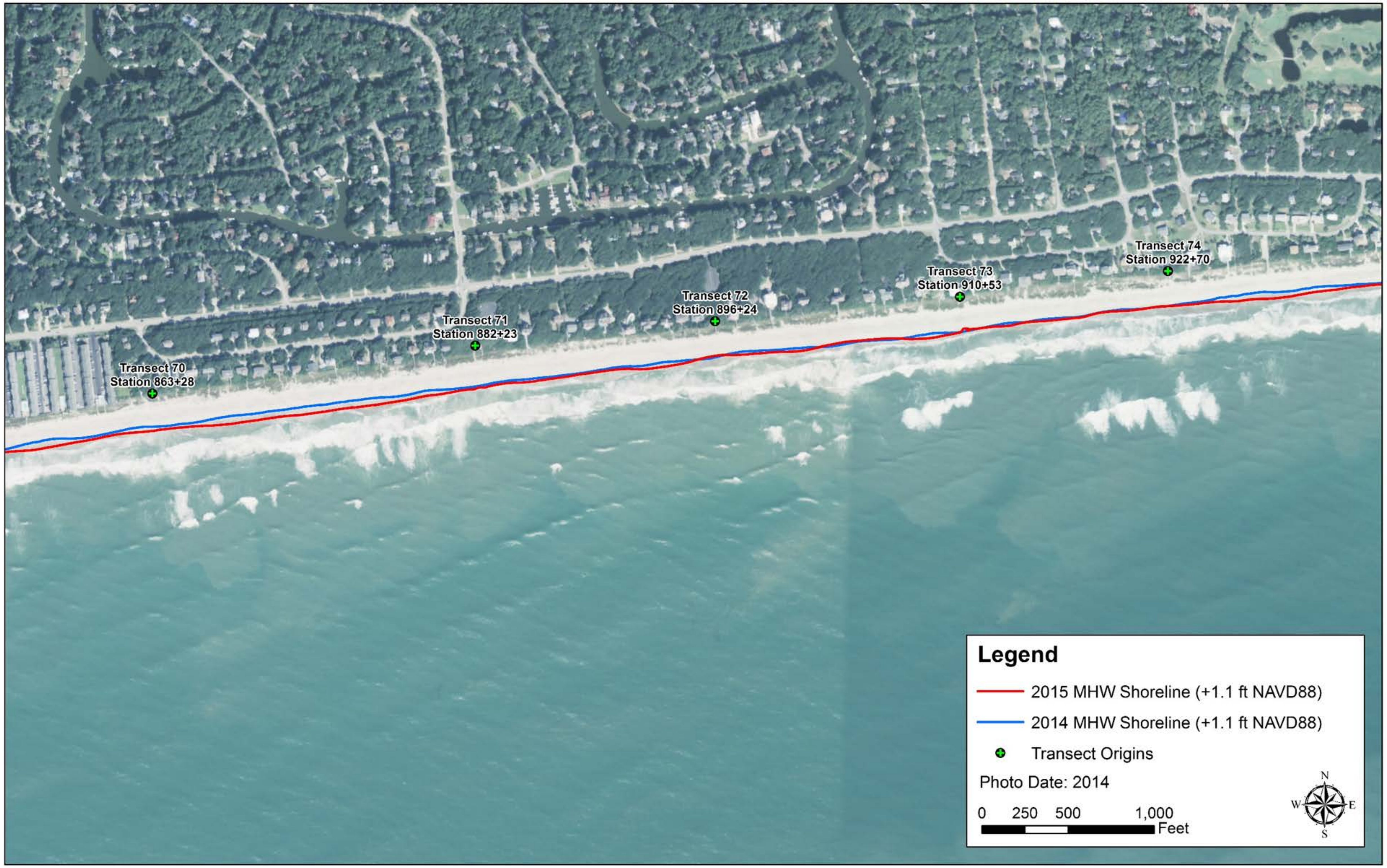


Figure A-12. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

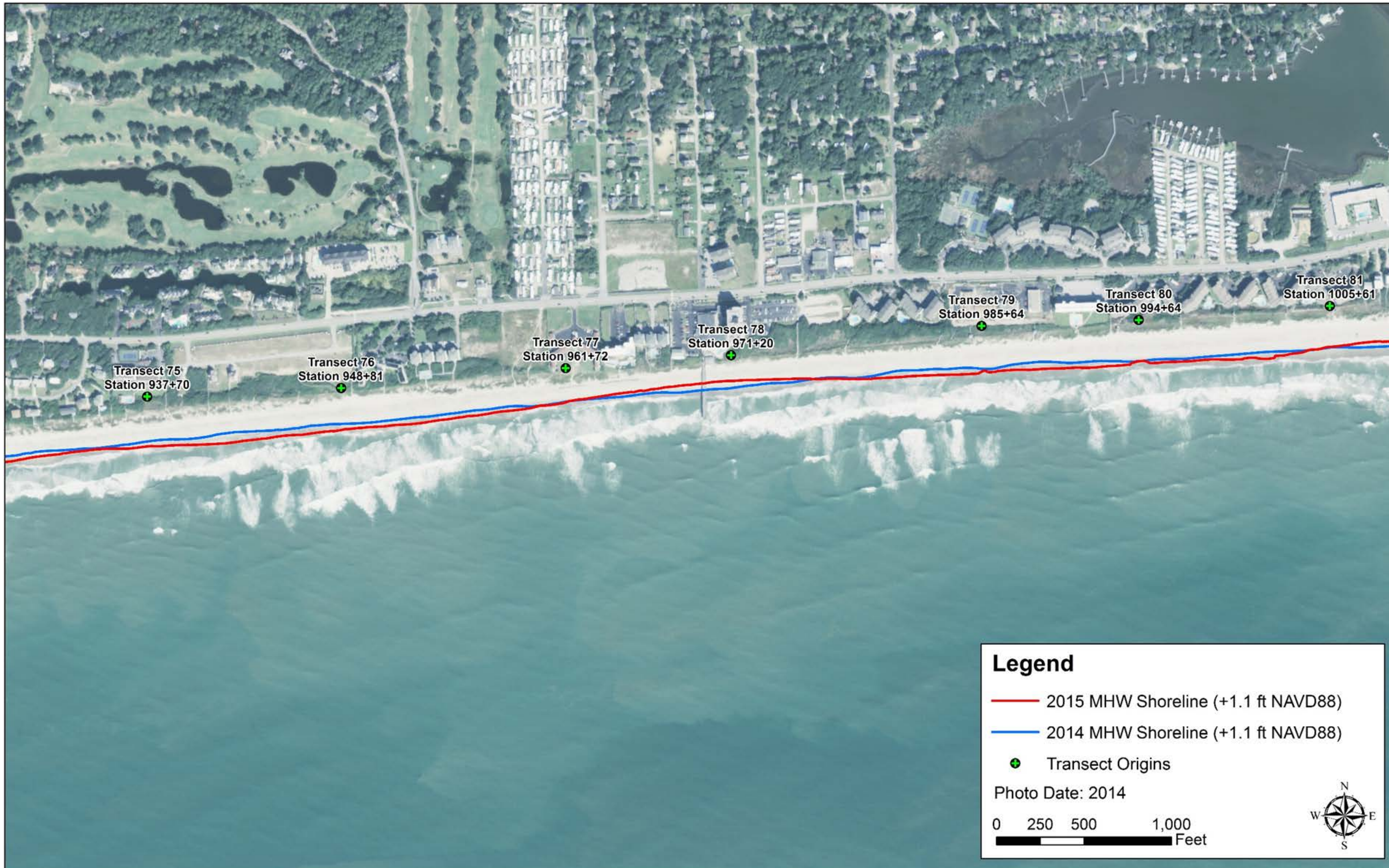


Figure A-13. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-14. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

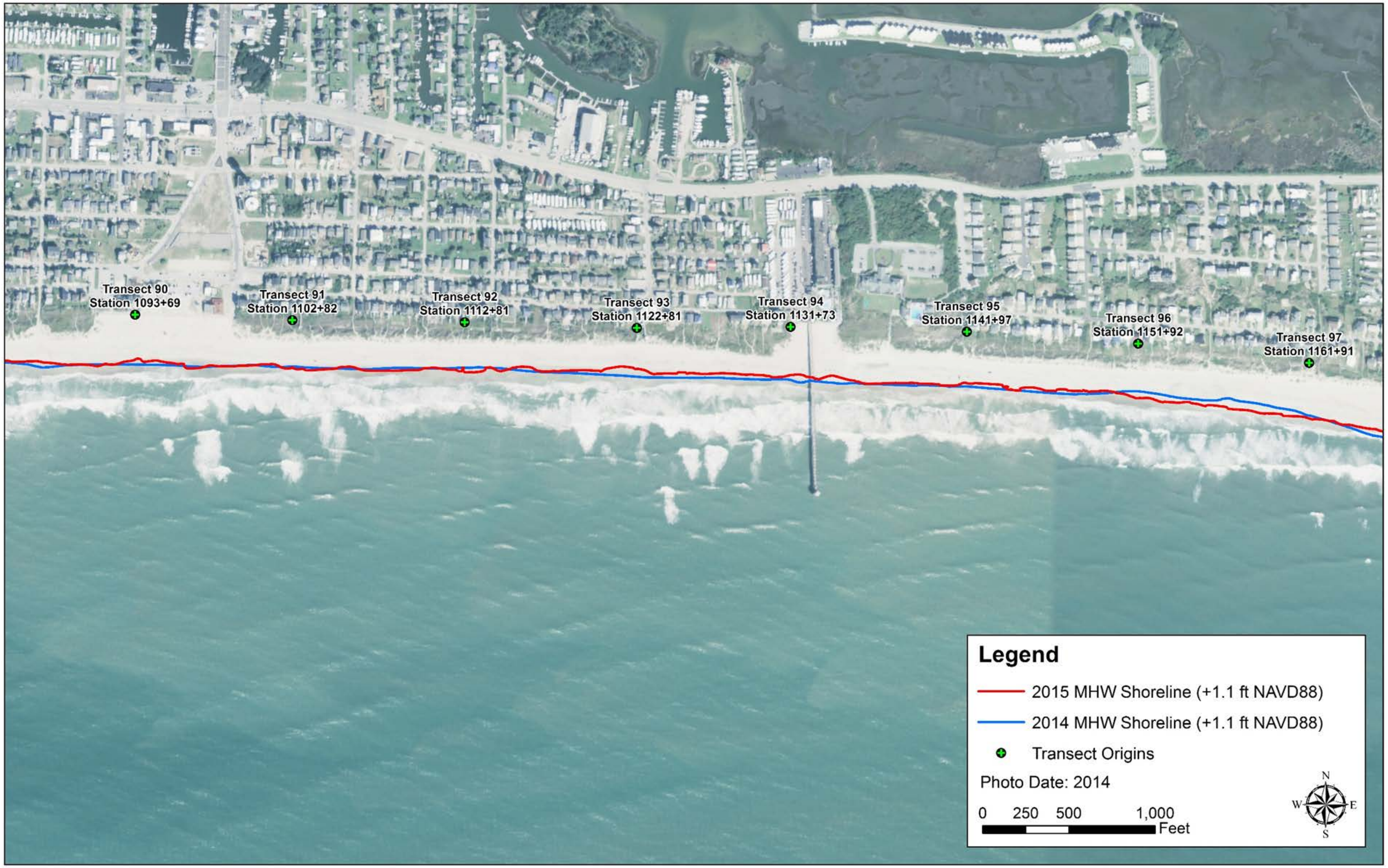


Figure A-15. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

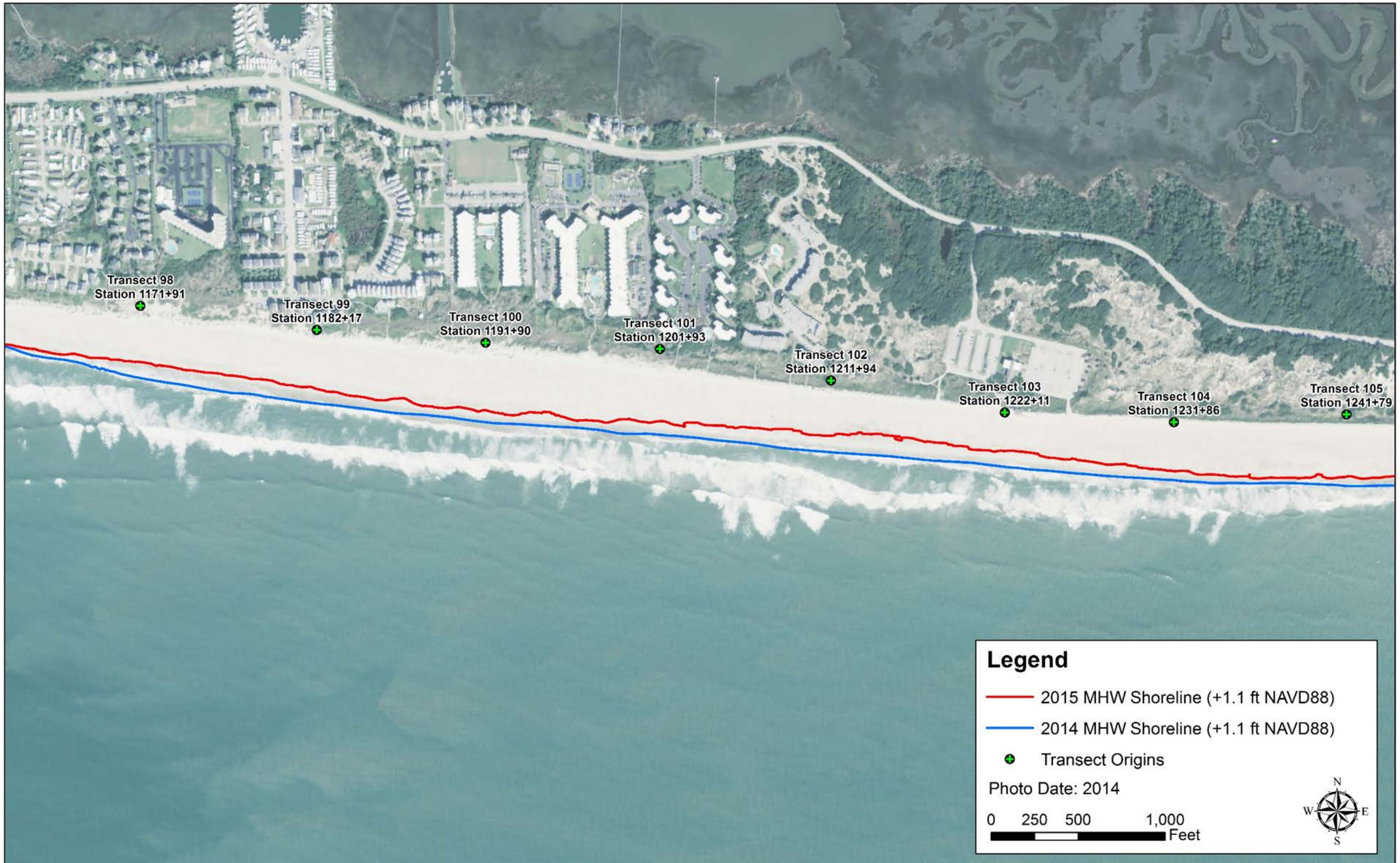


Figure A-16. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-17. Bogue Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

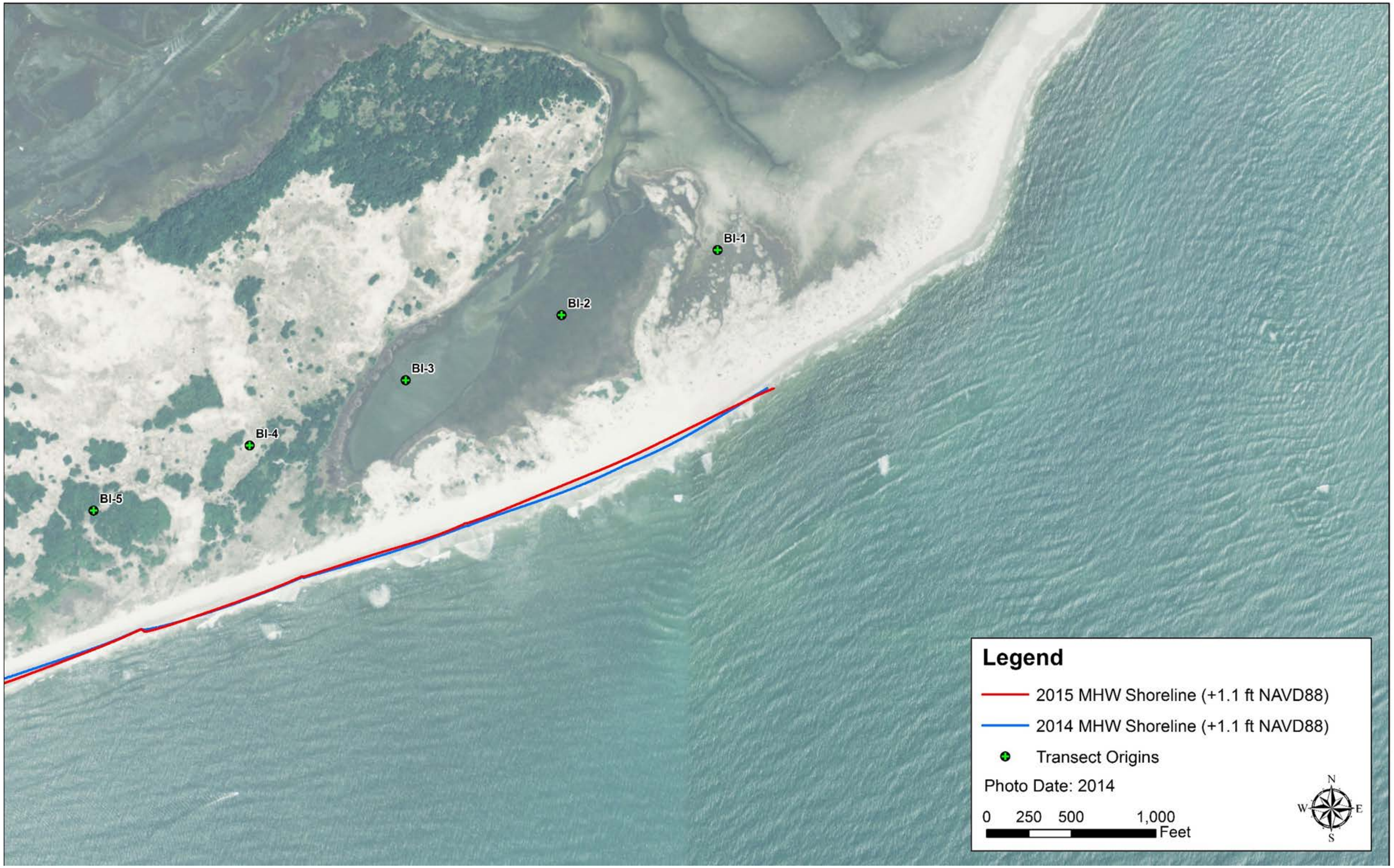


Figure A-18. Bear Island MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

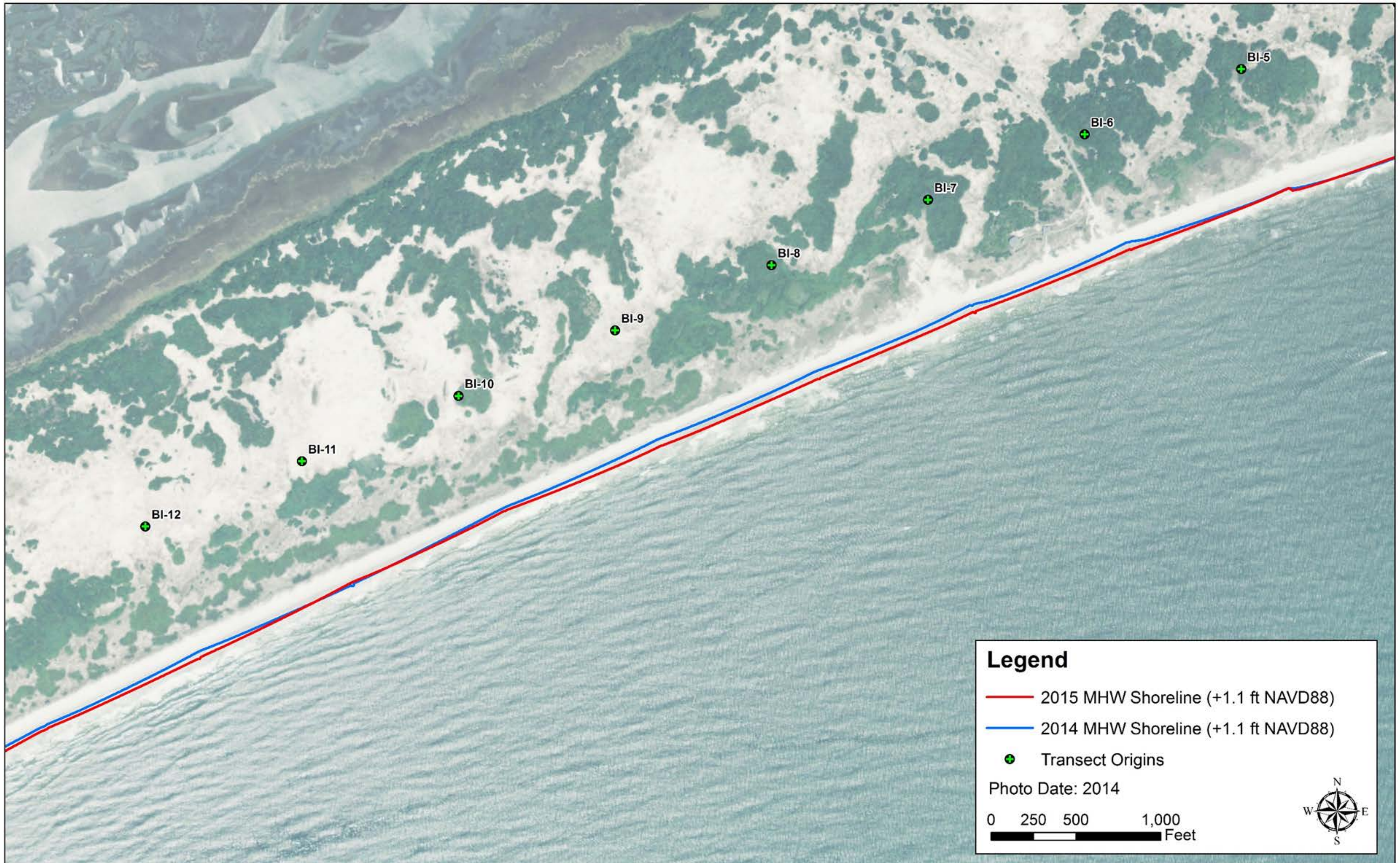


Figure A-19. Bear Island MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

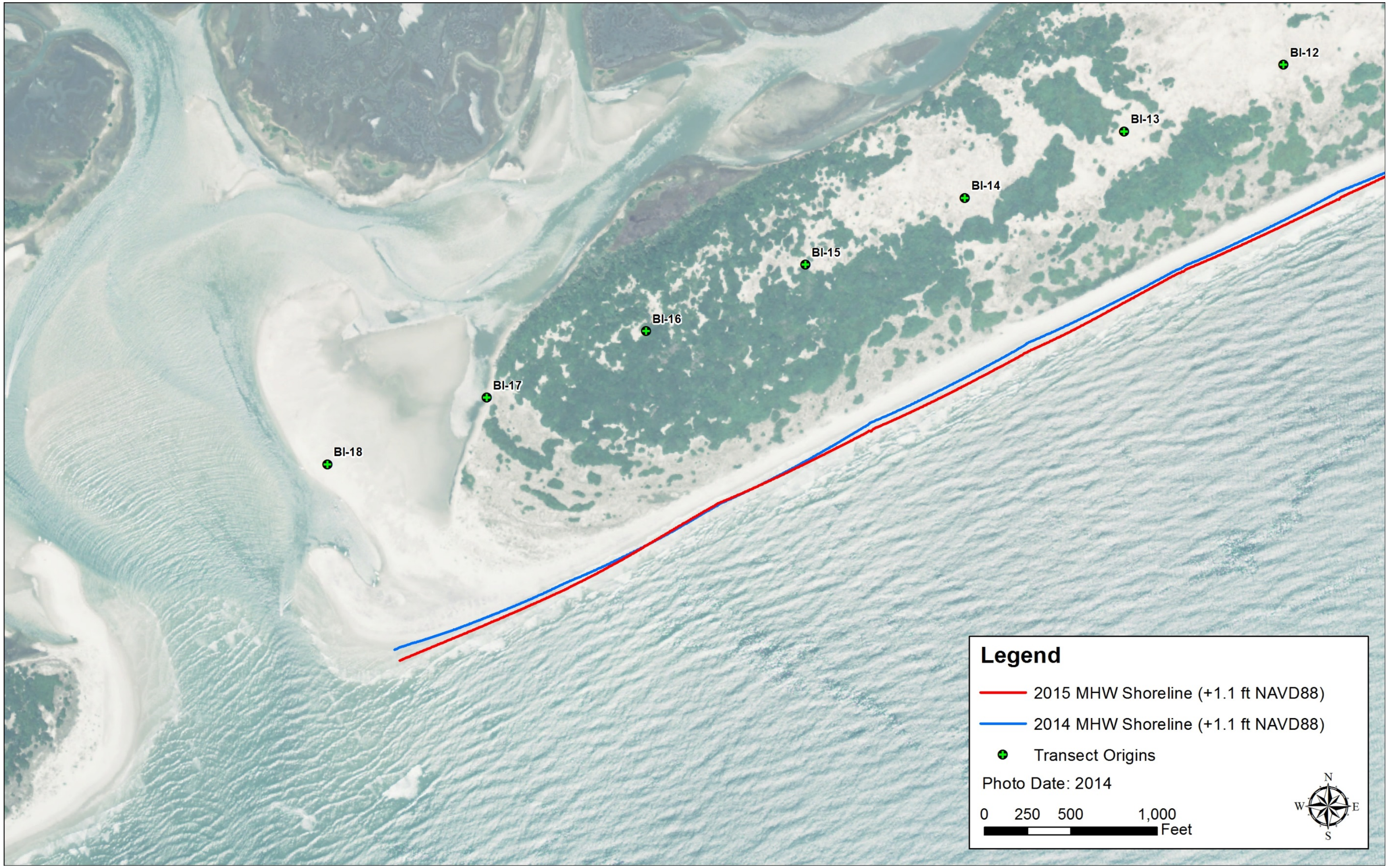


Figure A-20. Bear Island MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

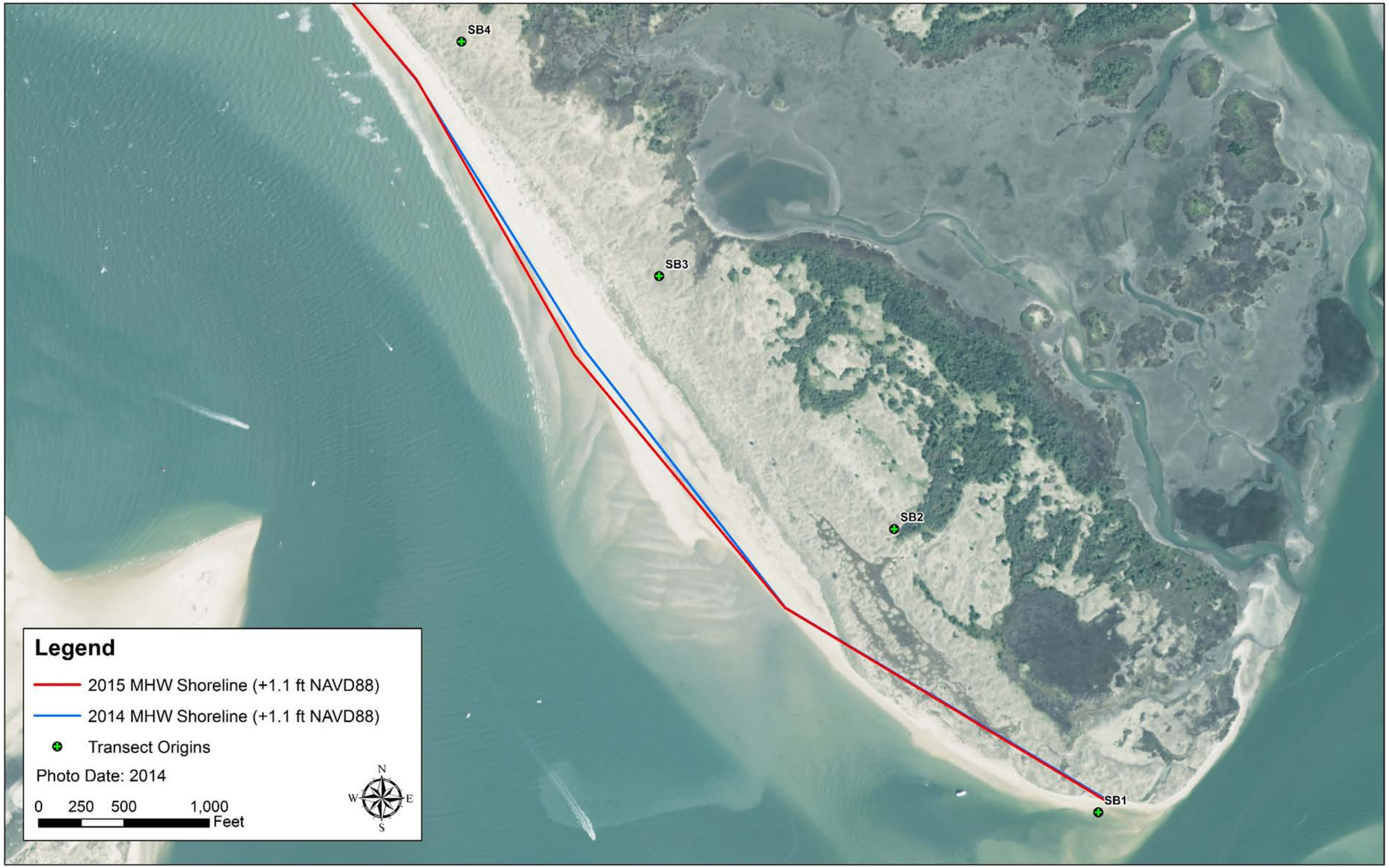


Figure A-21. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-22. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-23. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-24. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

Figure A-25. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

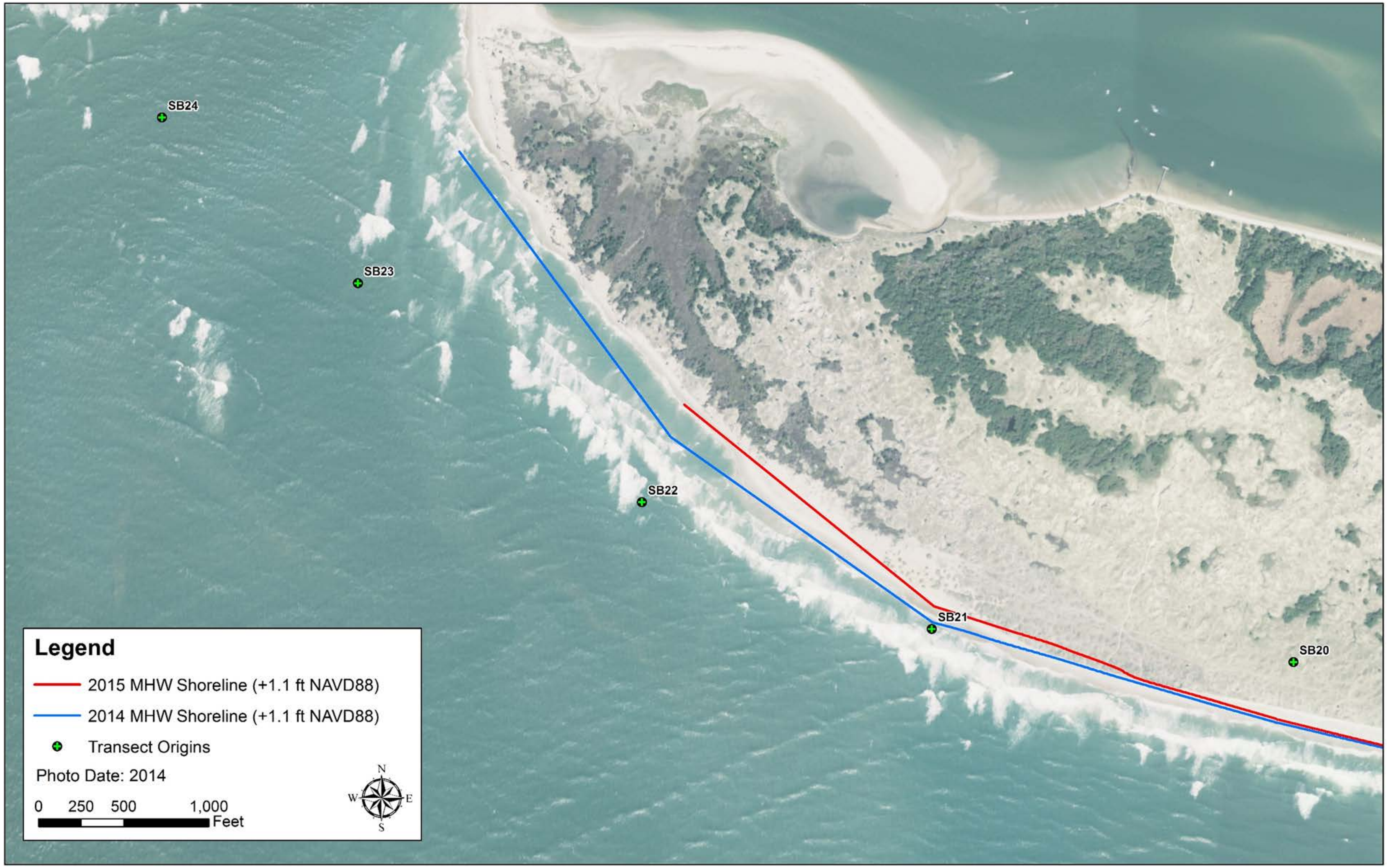


Figure A-26. Shackleford Banks MHW Shoreline Positions (Spring/Summer 2014 and Spring/Summer 2015)

APPENDIX B

Shoreline & Volume Change Plots

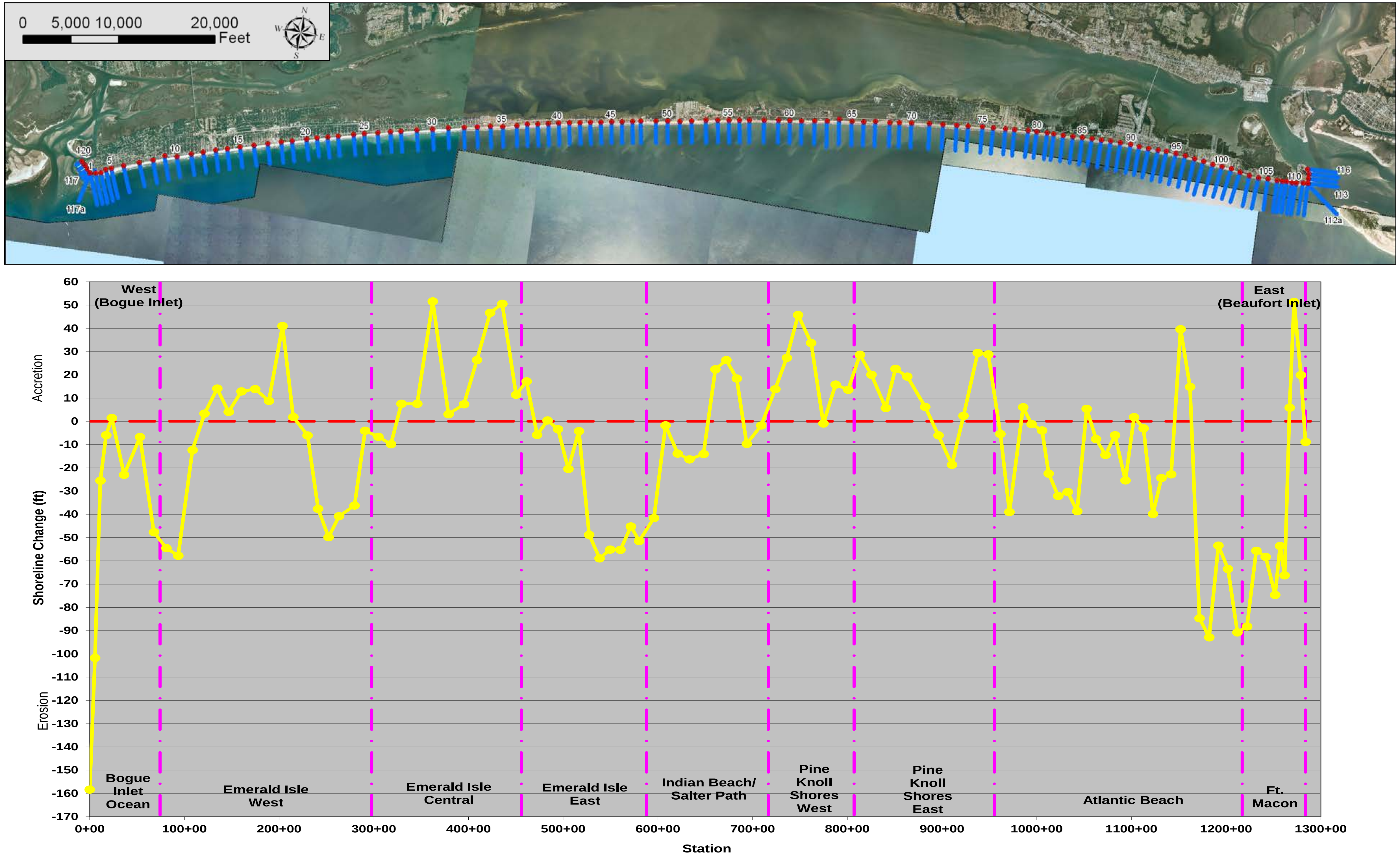


Figure B-1. Shoreline Change for Bogue Banks (Spring/Summer 2014 – Spring/Summer 2015)

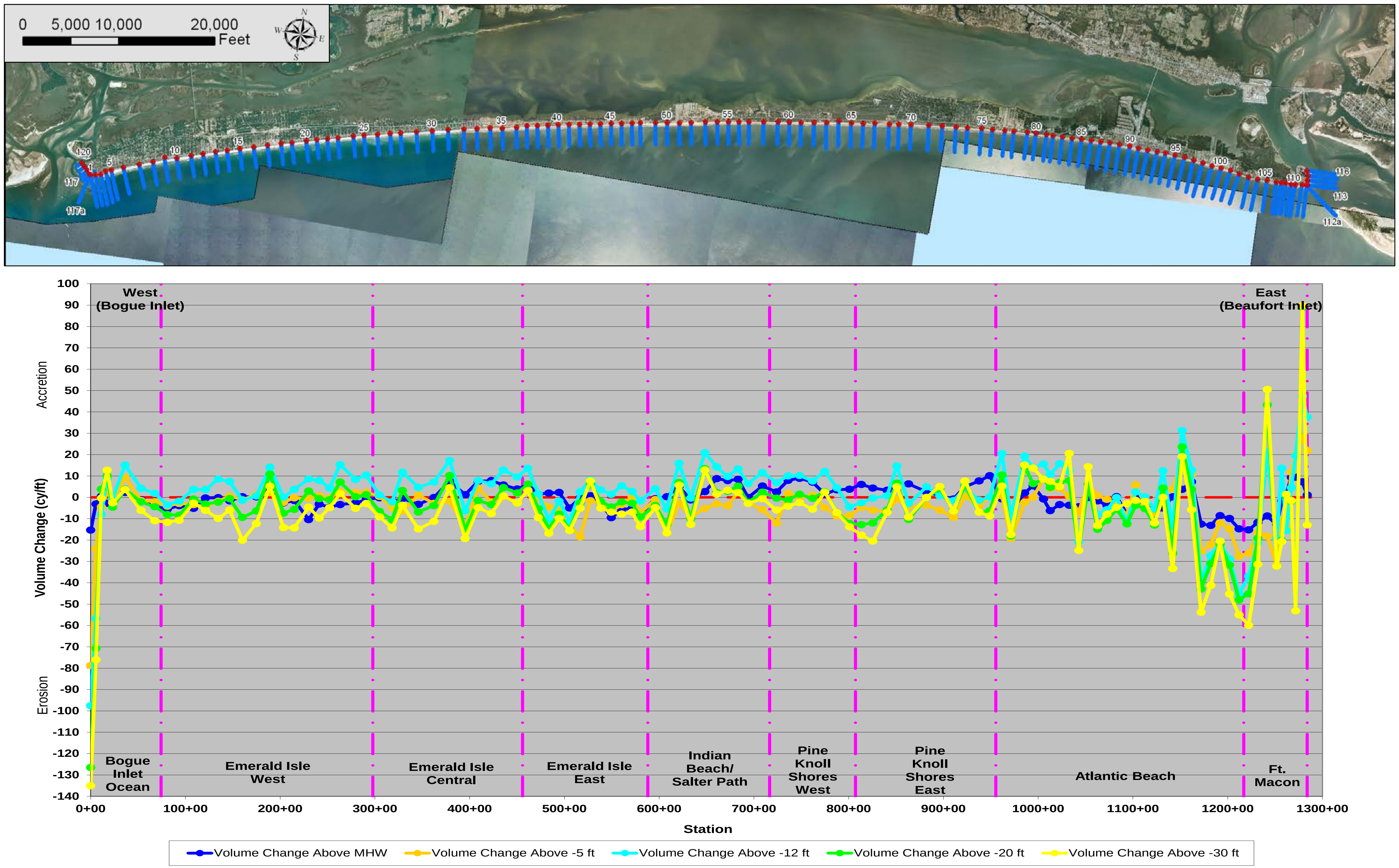


Figure B-2. Volume Change for Bogue Banks (Spring/Summer 2014 - Spring/Summer 2015)

Figure B-3. Shoreline Change for Bear Island (Spring/Summer 2014 - Spring/Summer 2015)

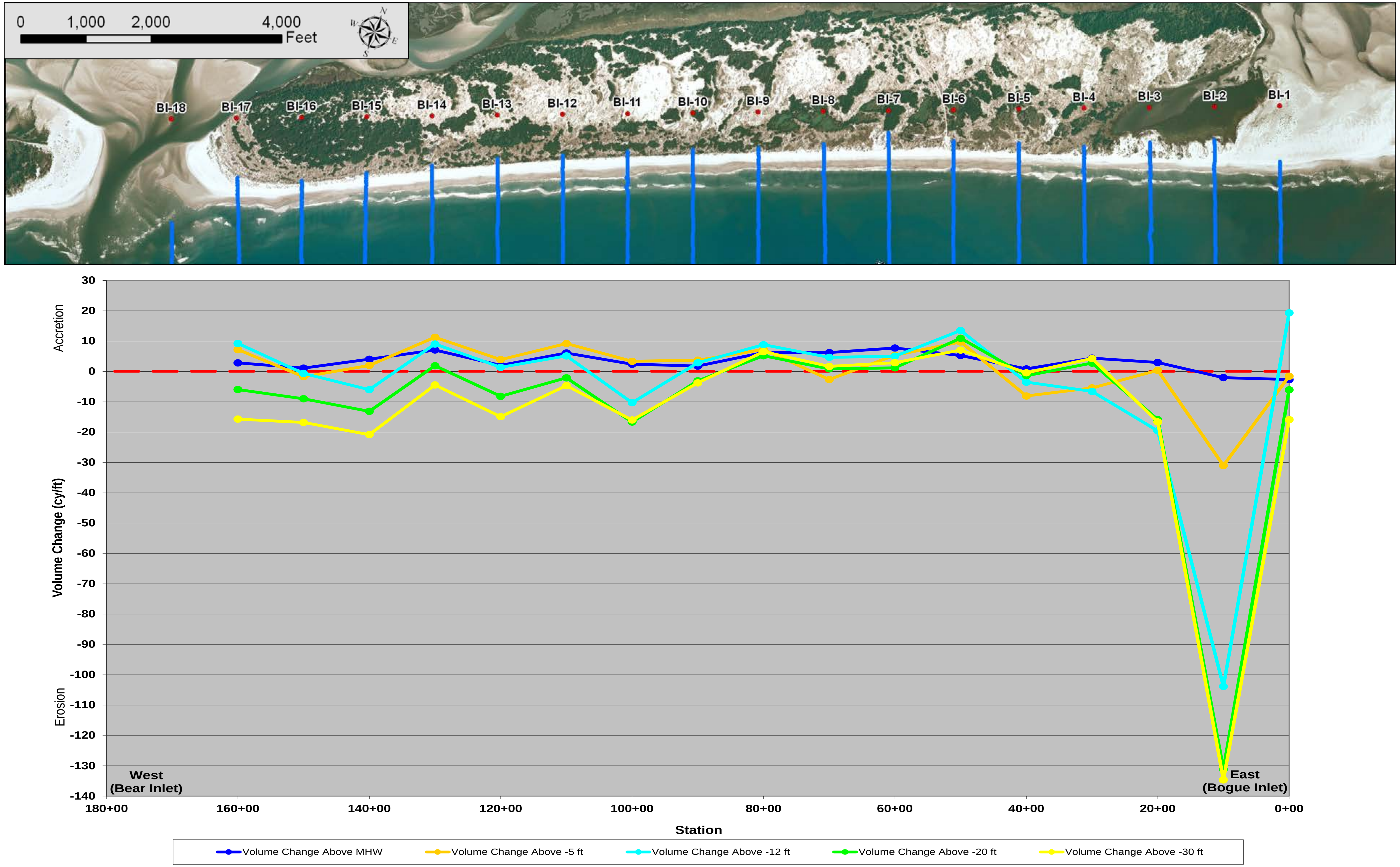


Figure B-4. Volume Change for Bear Island (Spring/Summer 2014 - Spring/Summer 2015)

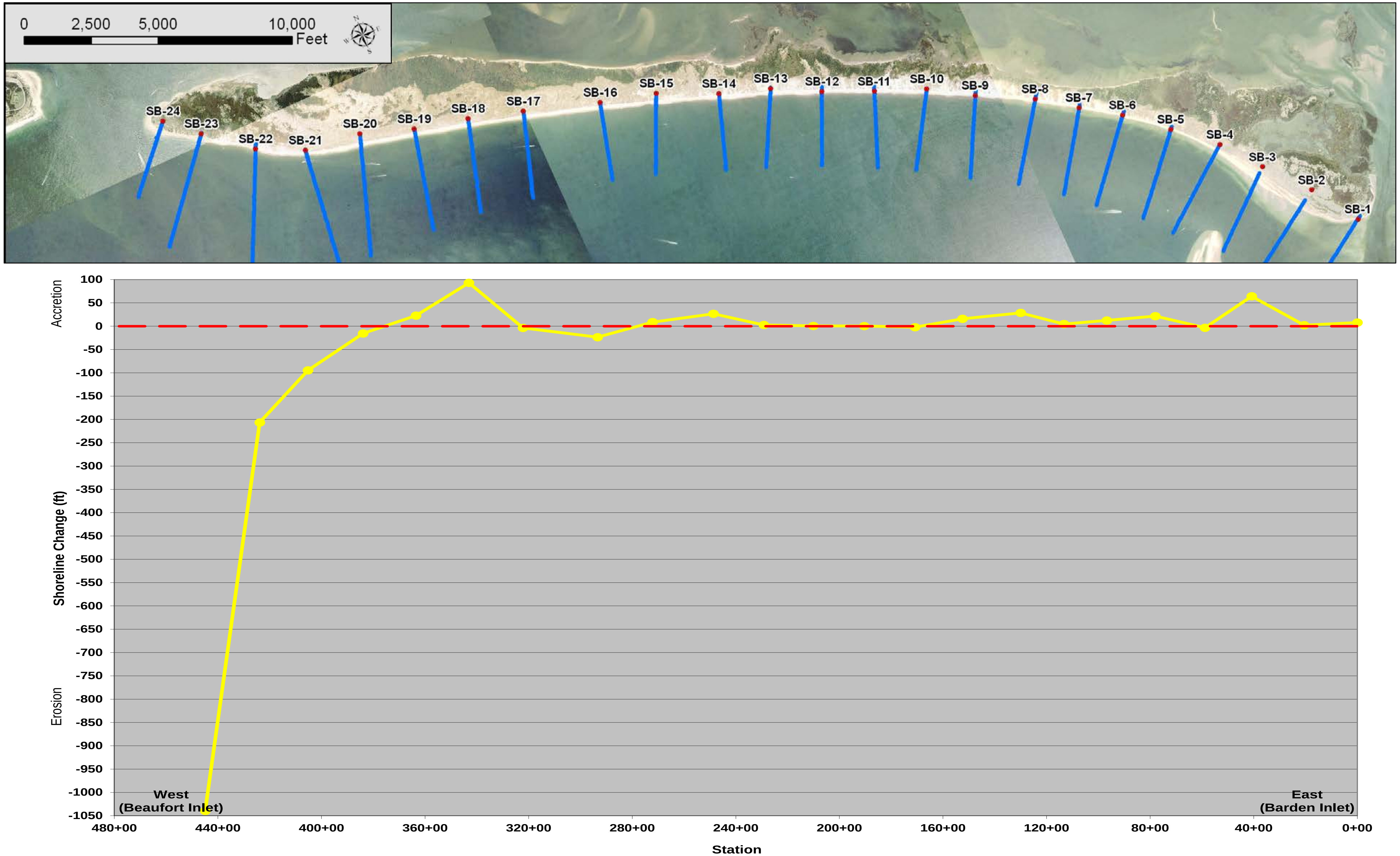


Figure B-5. Shoreline Change for Shackleford Banks (Spring/Summer 2014 - Spring/Summer 2015)

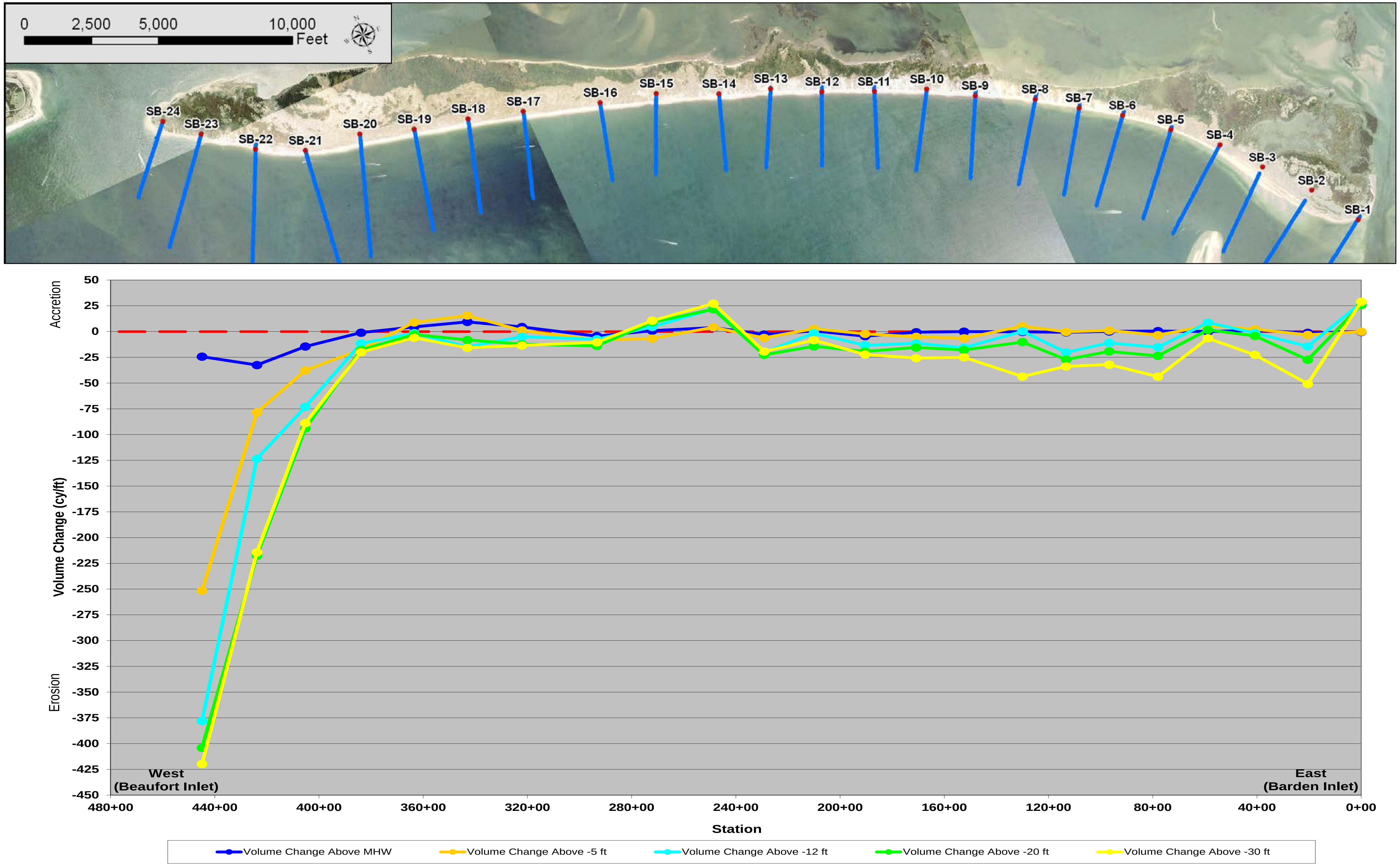


Figure B-6. Volume Change for Shackleford Banks (Spring/Summer 2014 - Spring/Summer 2015)

APPENDIX C

Survey Profile Comparison Plots

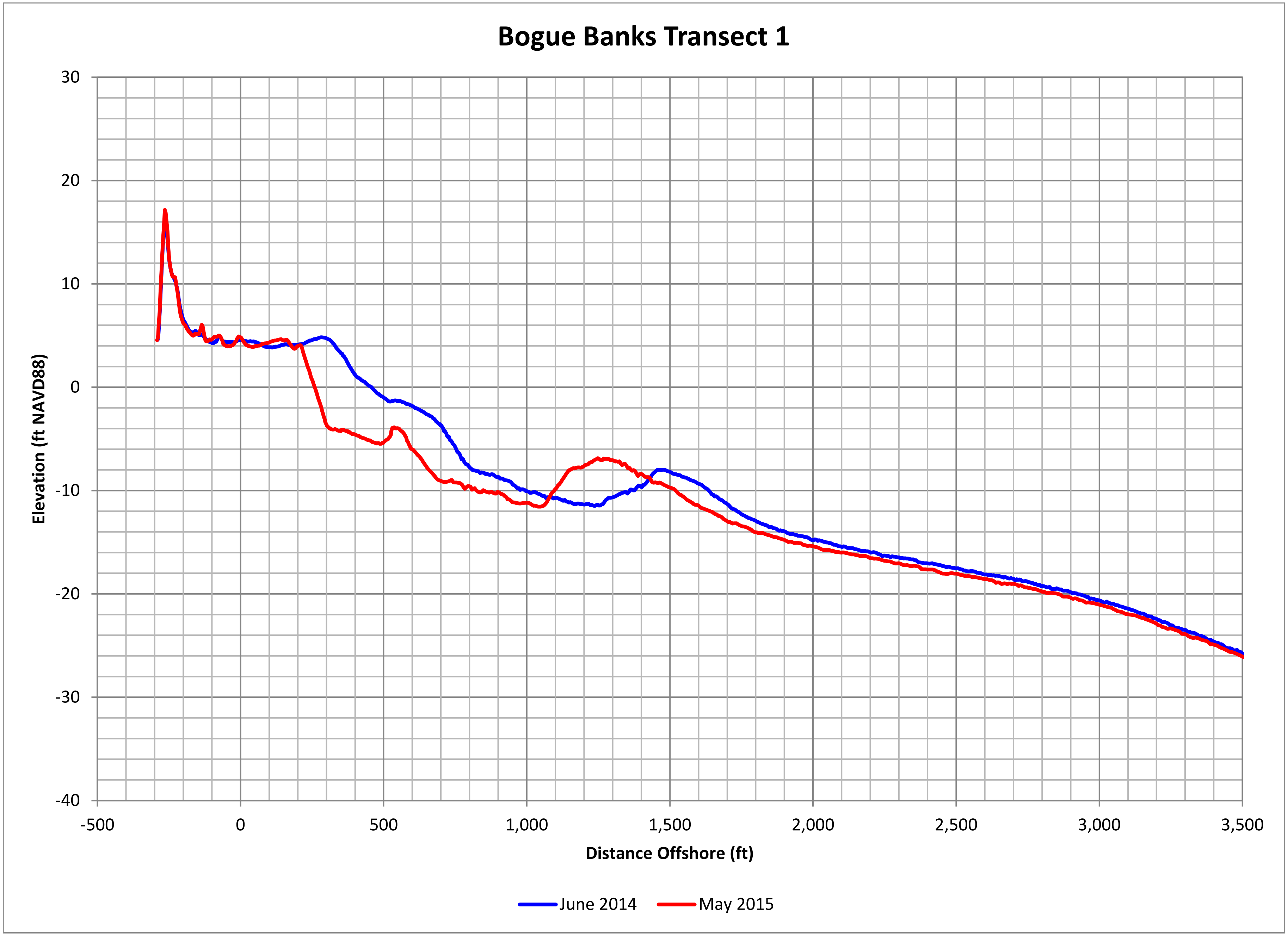


Figure C-1. Bogue Banks Profile Comparison Plot

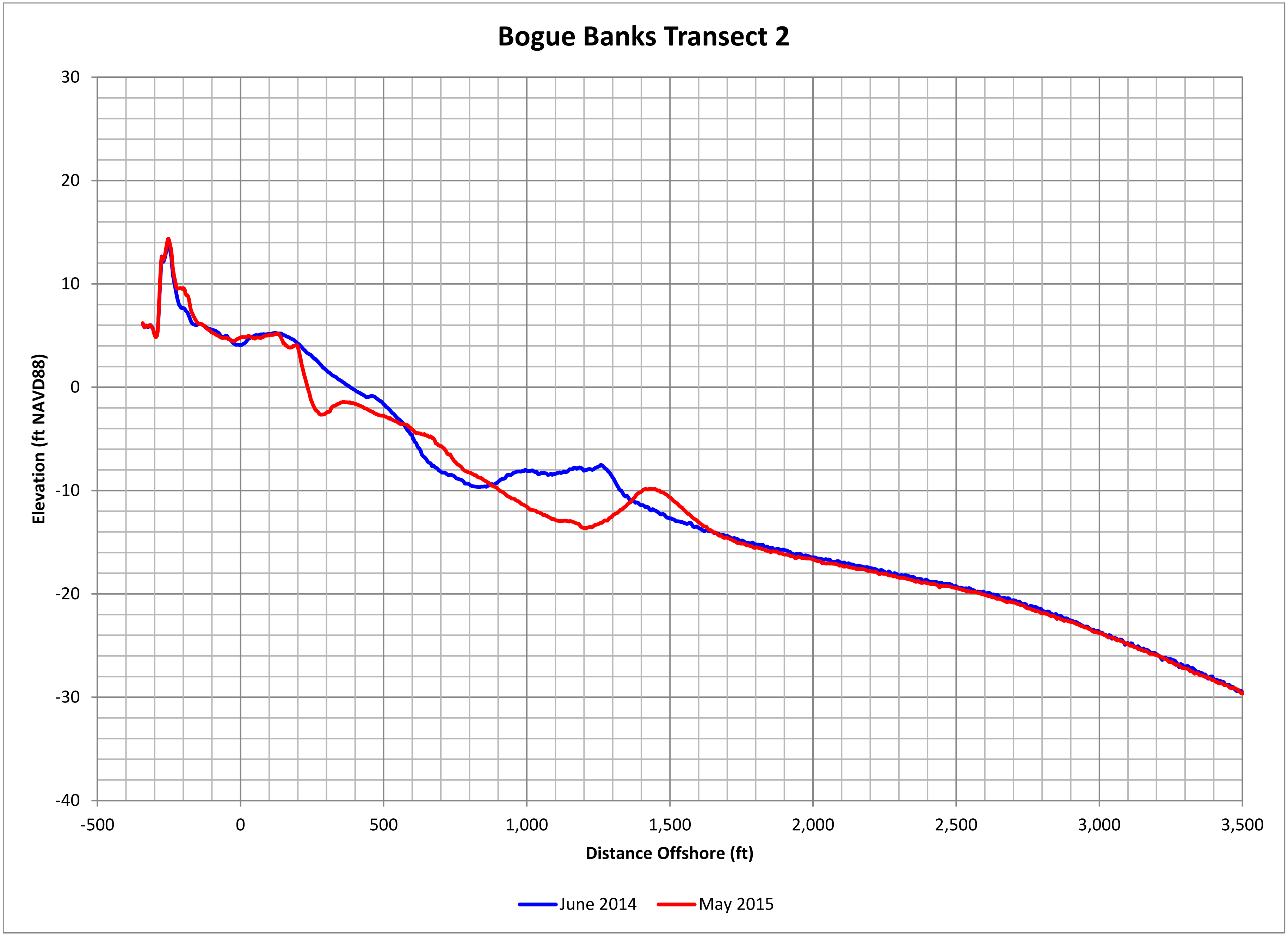


Figure C-2. Bogue Banks Profile Comparison Plot

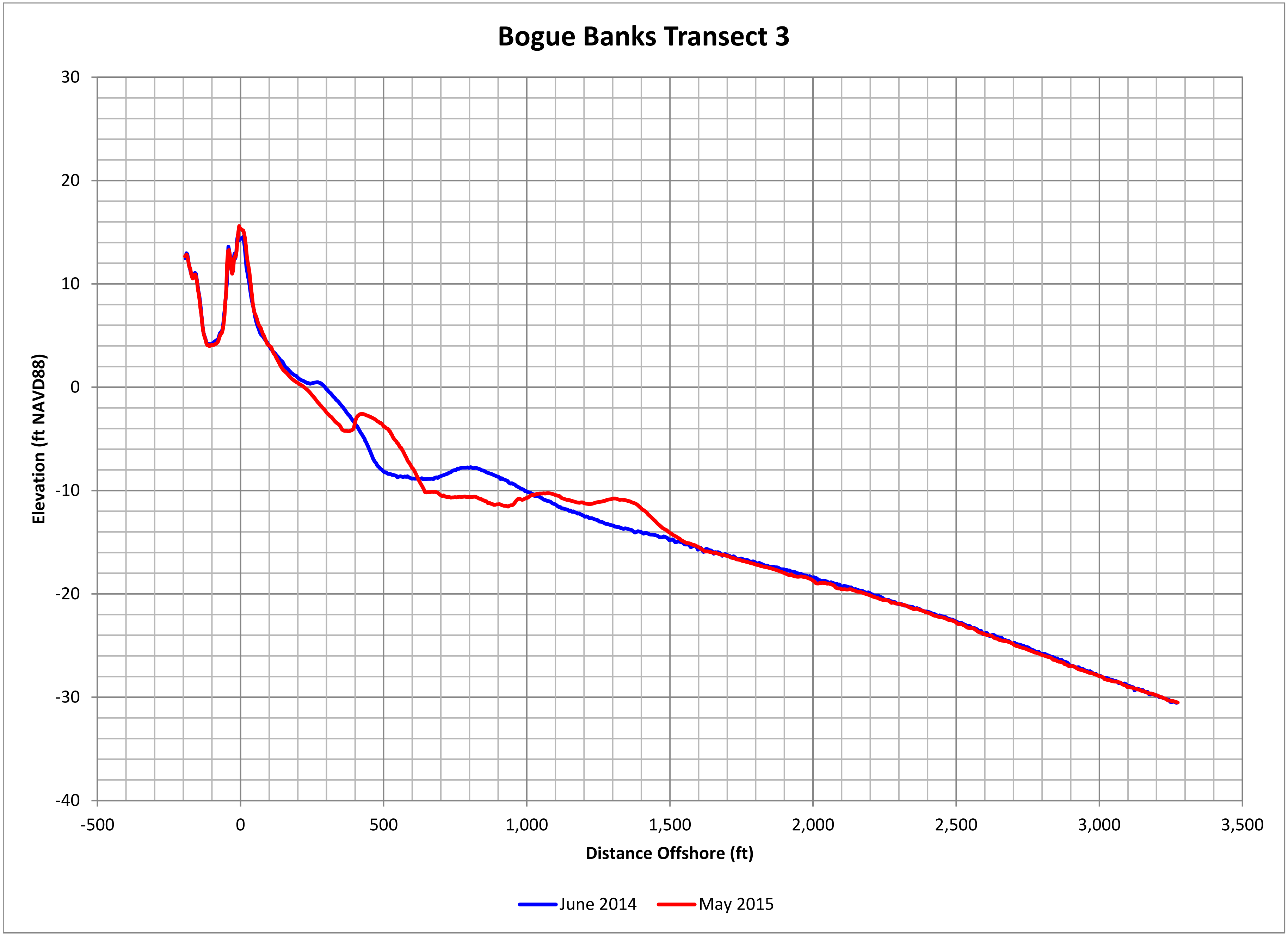


Figure C-3. Bogue Banks Profile Comparison Plot

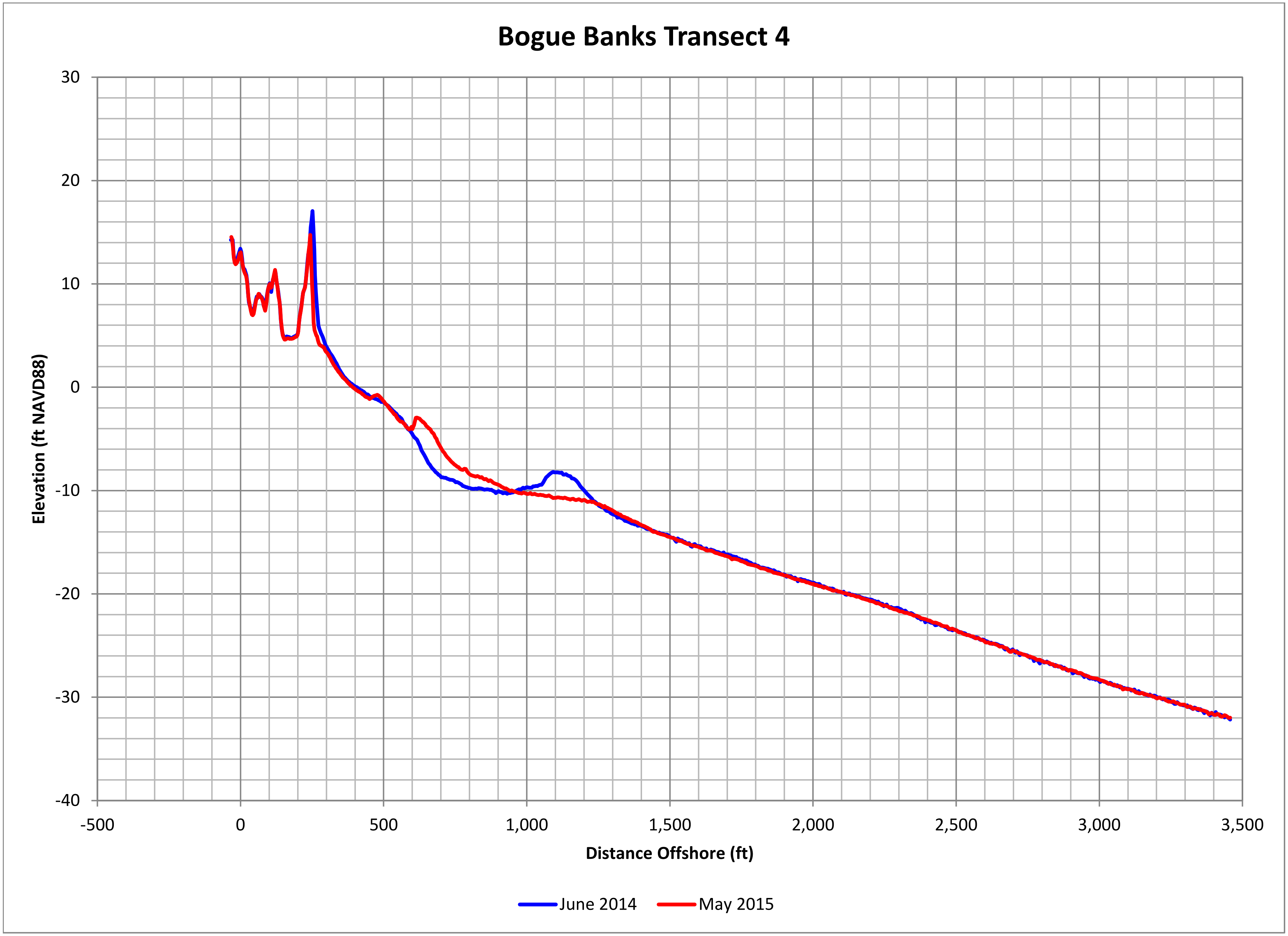


Figure C-4. Bogue Banks Profile Comparison Plot

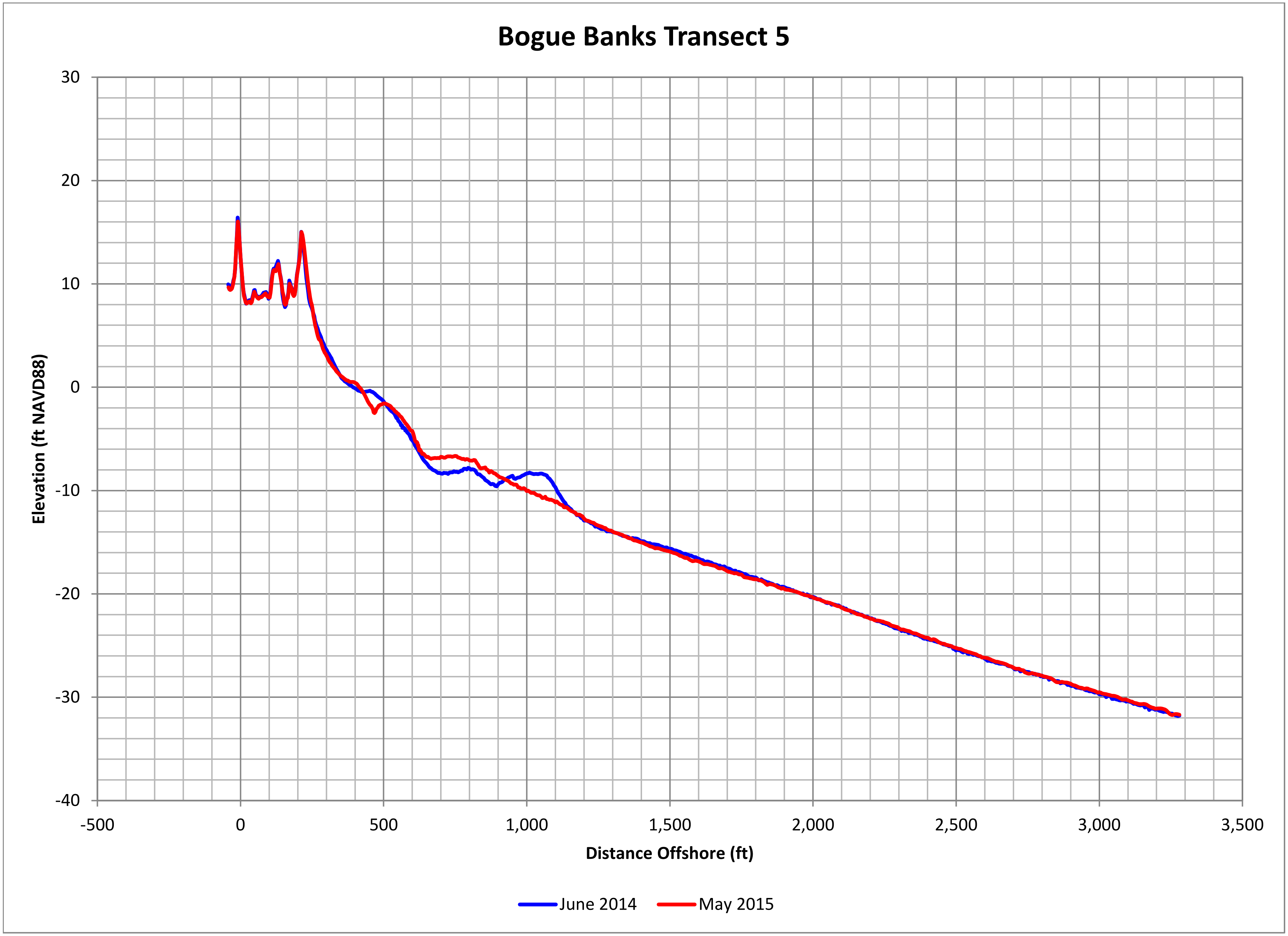


Figure C-5. Bogue Banks Profile Comparison Plot

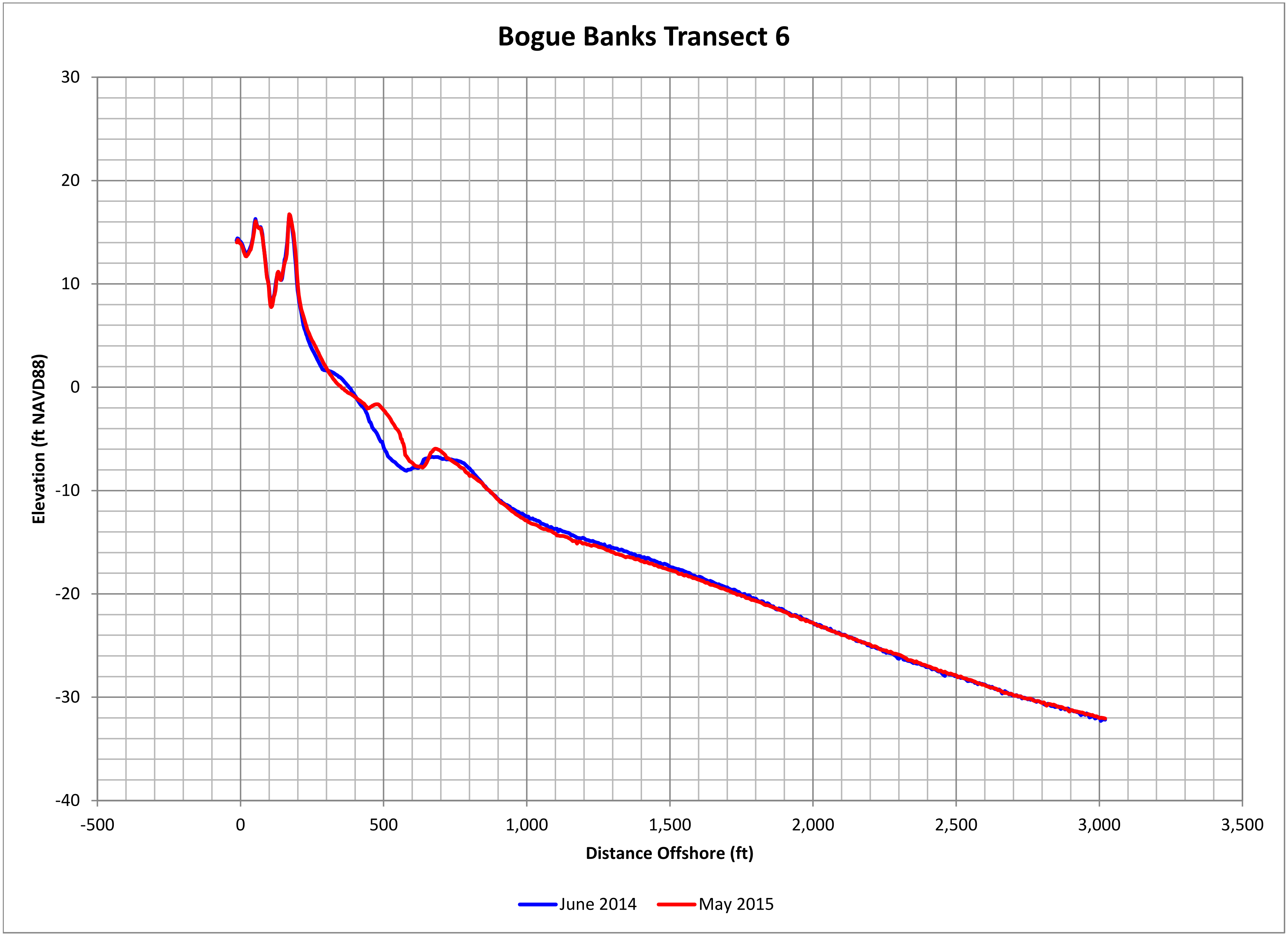


Figure C-6. Bogue Banks Profile Comparison Plot

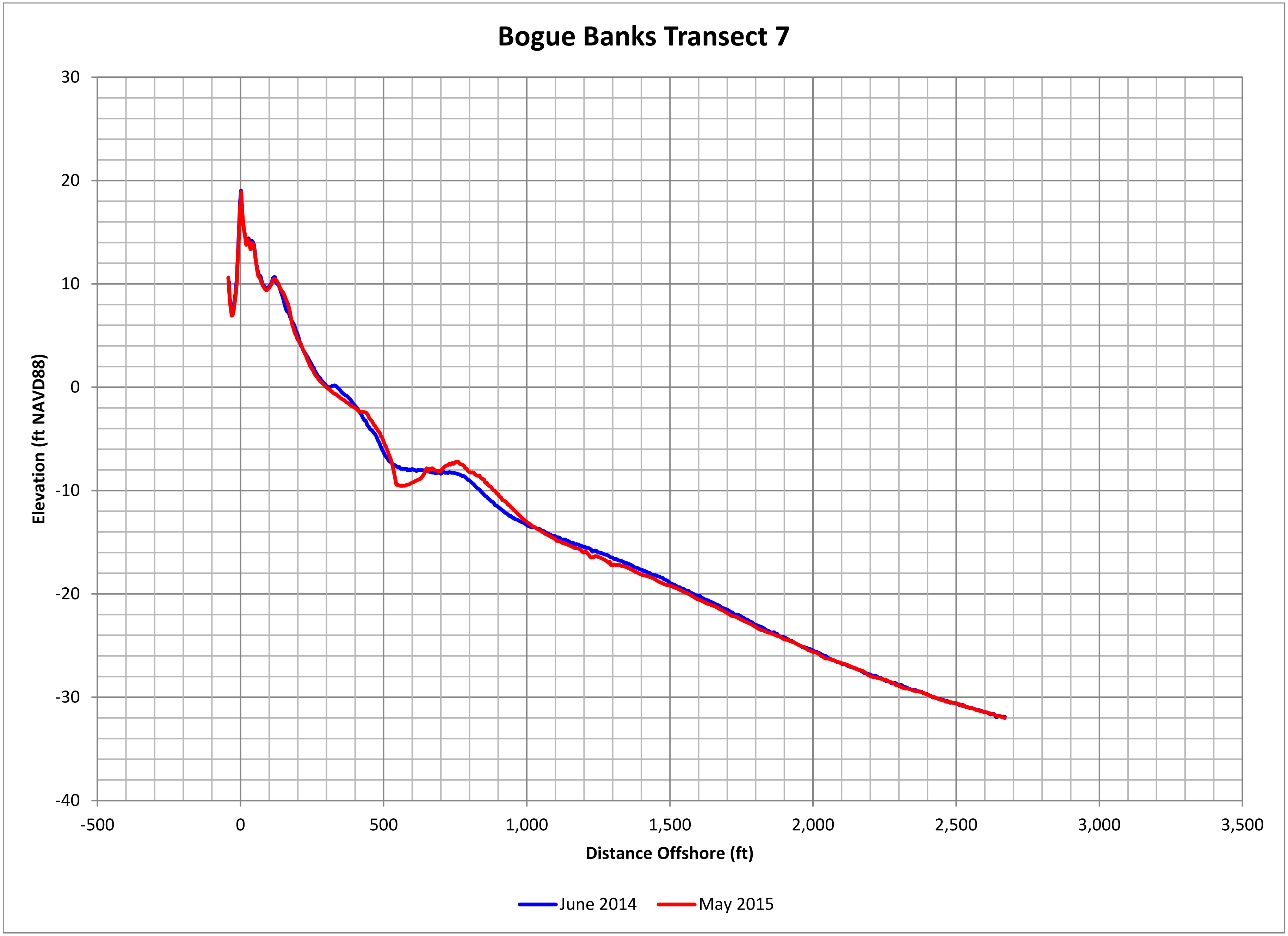


Figure C-7. Bogue Banks Profile Comparison Plot

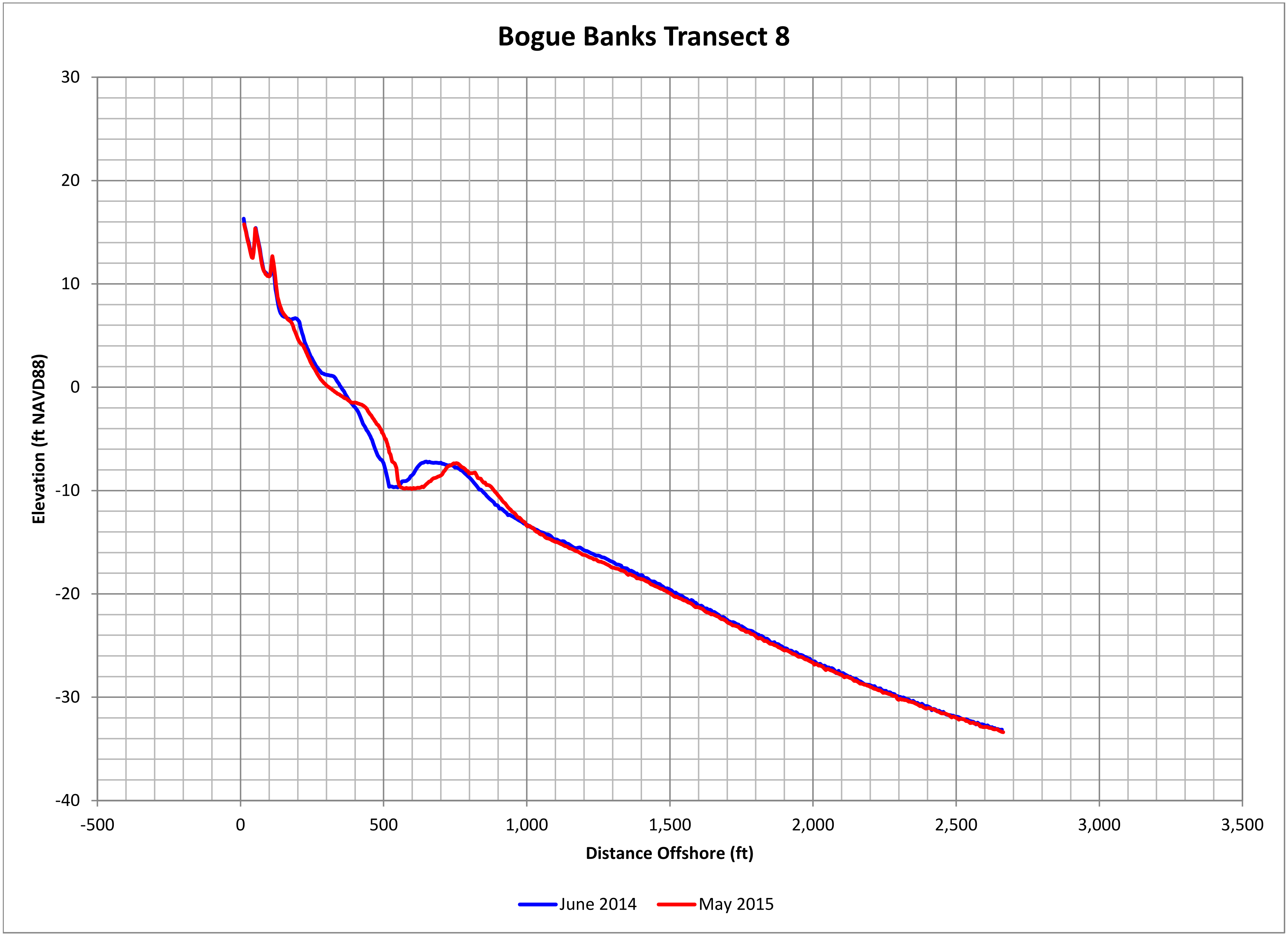


Figure C-8. Bogue Banks Profile Comparison Plot

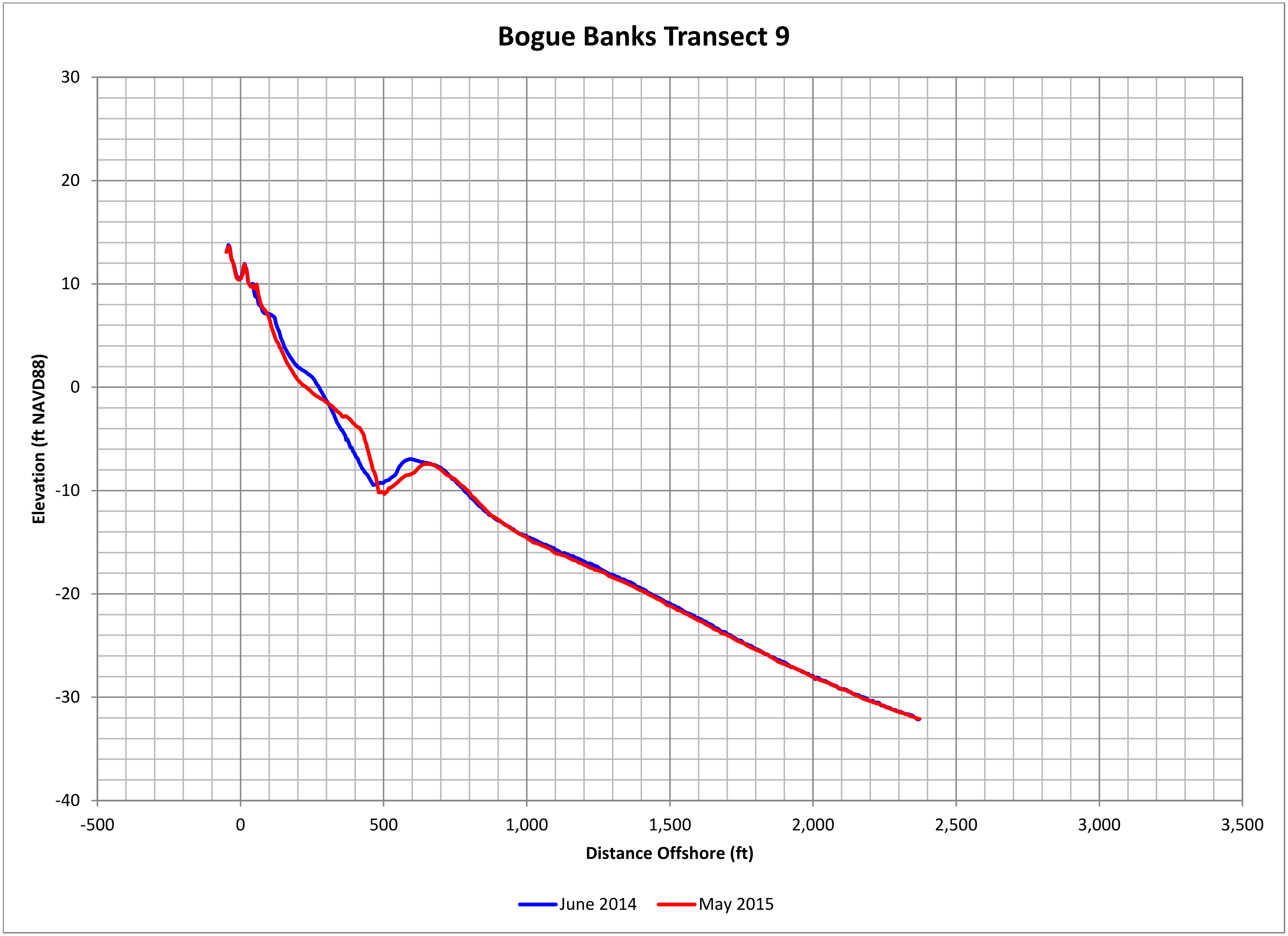


Figure C-9. Bogue Banks Profile Comparison Plot

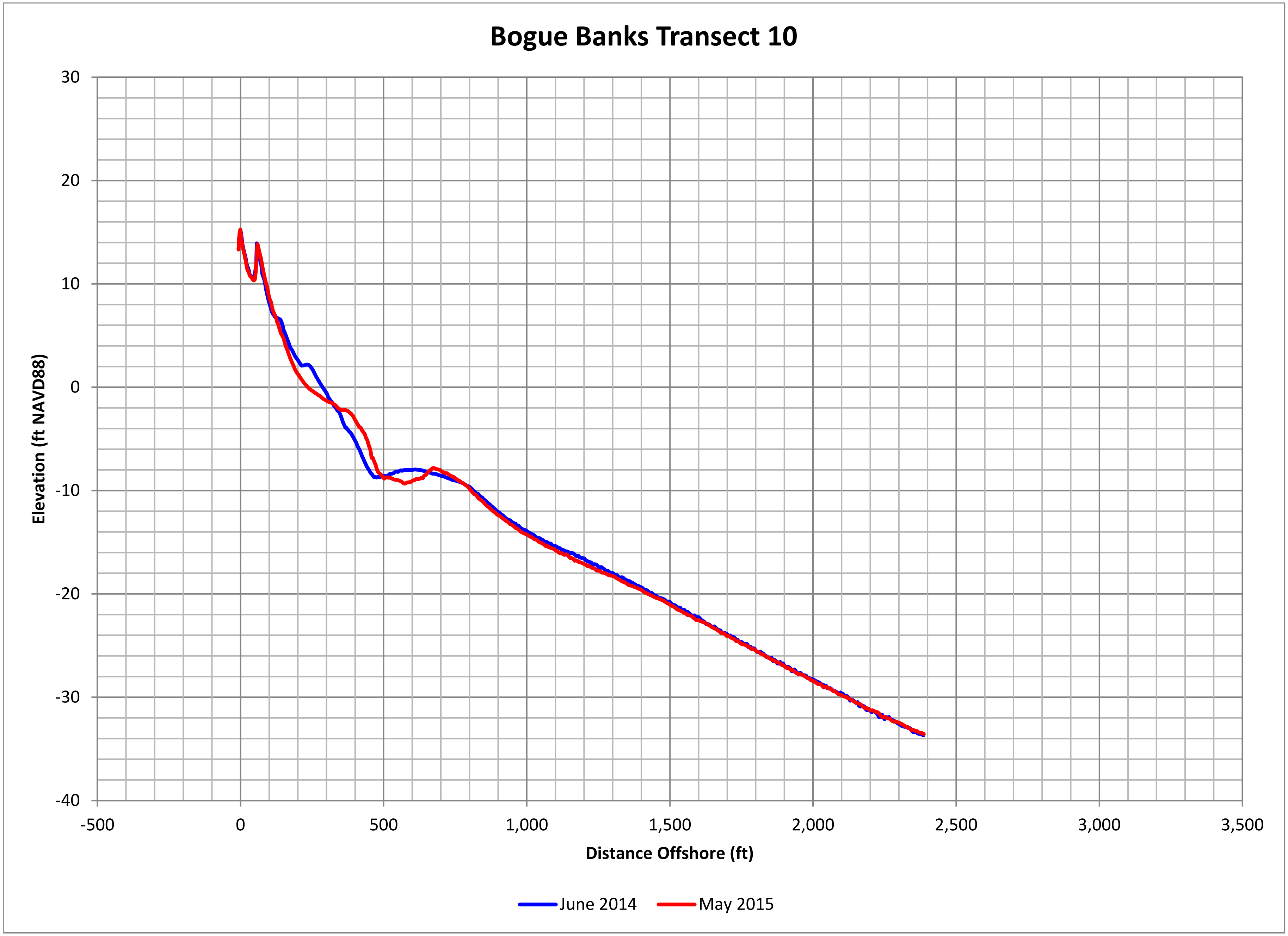


Figure C-10. Bogue Banks Profile Comparison Plot

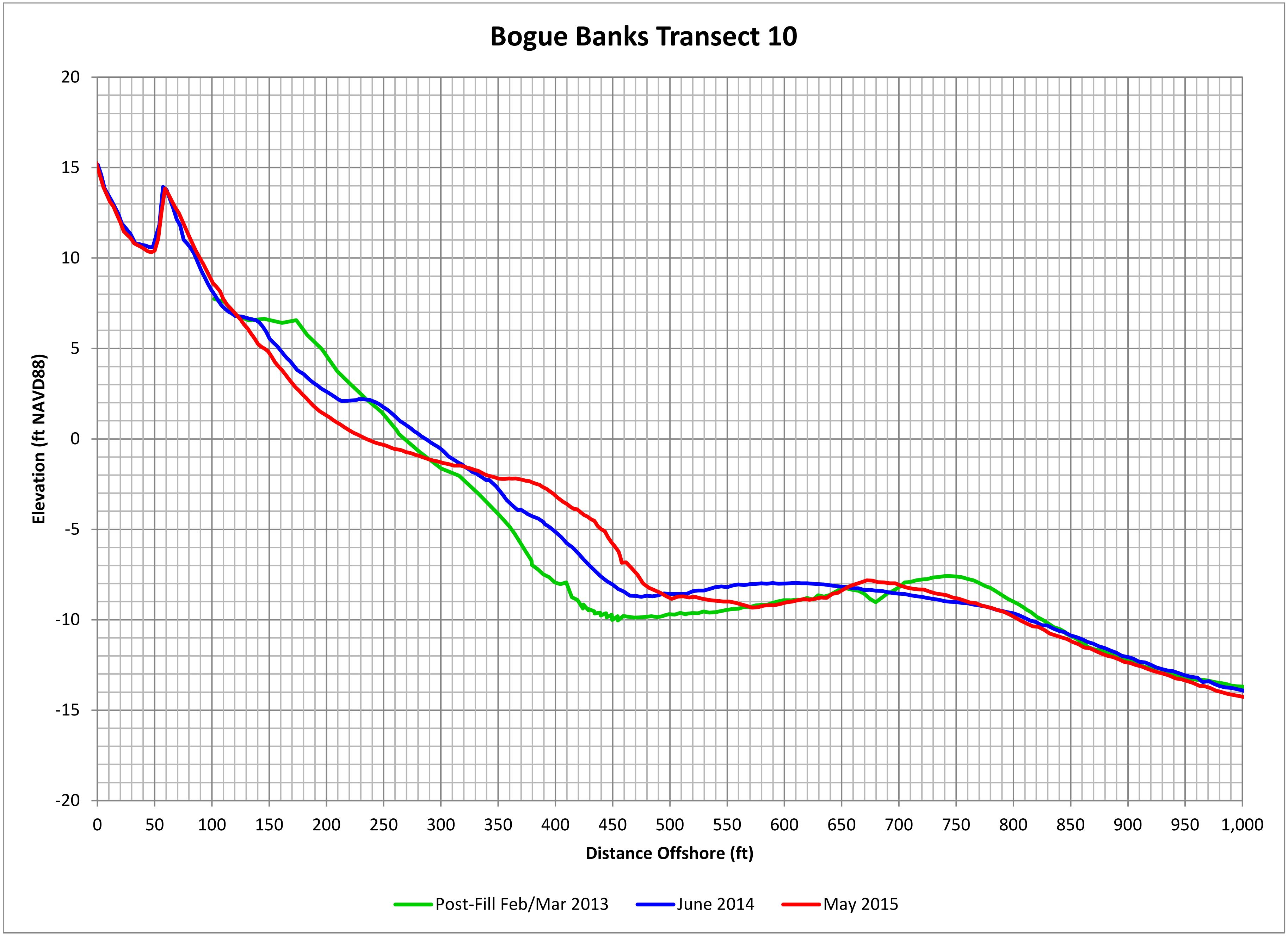


Figure C-11. Bogue Banks Profile Comparison Plot

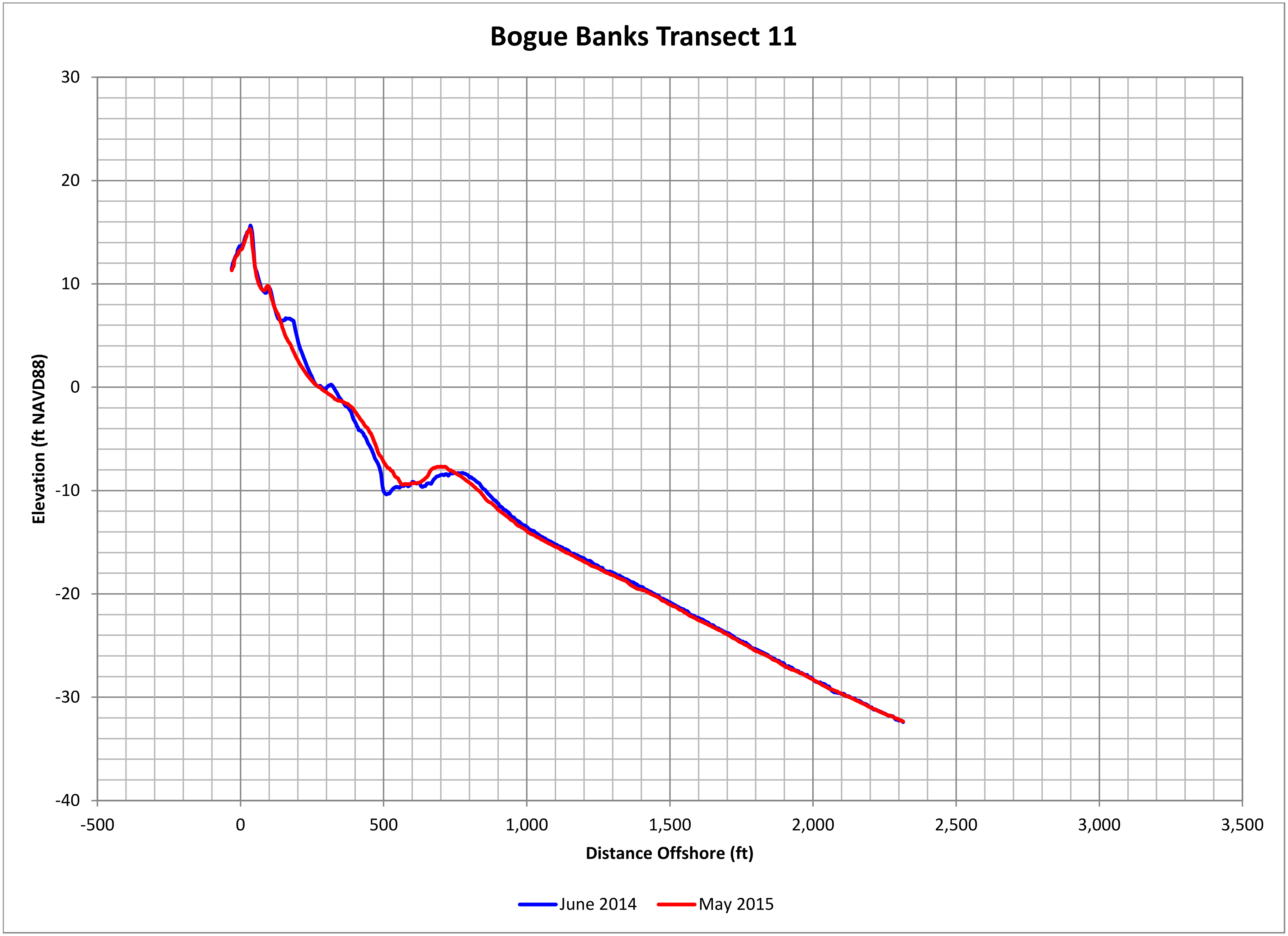


Figure C-12. Bogue Banks Profile Comparison Plot

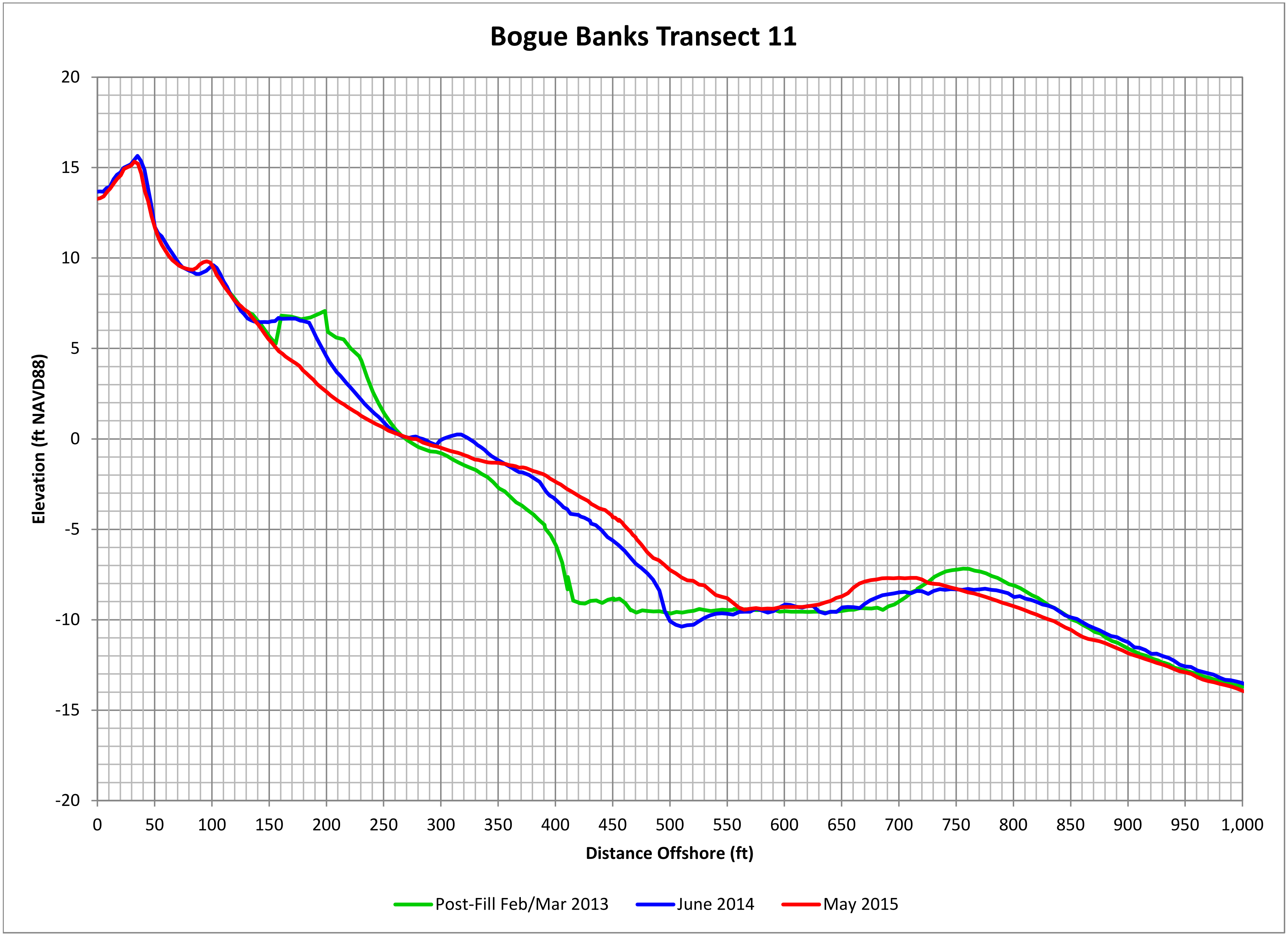


Figure C-13. Bogue Banks Profile Comparison Plot

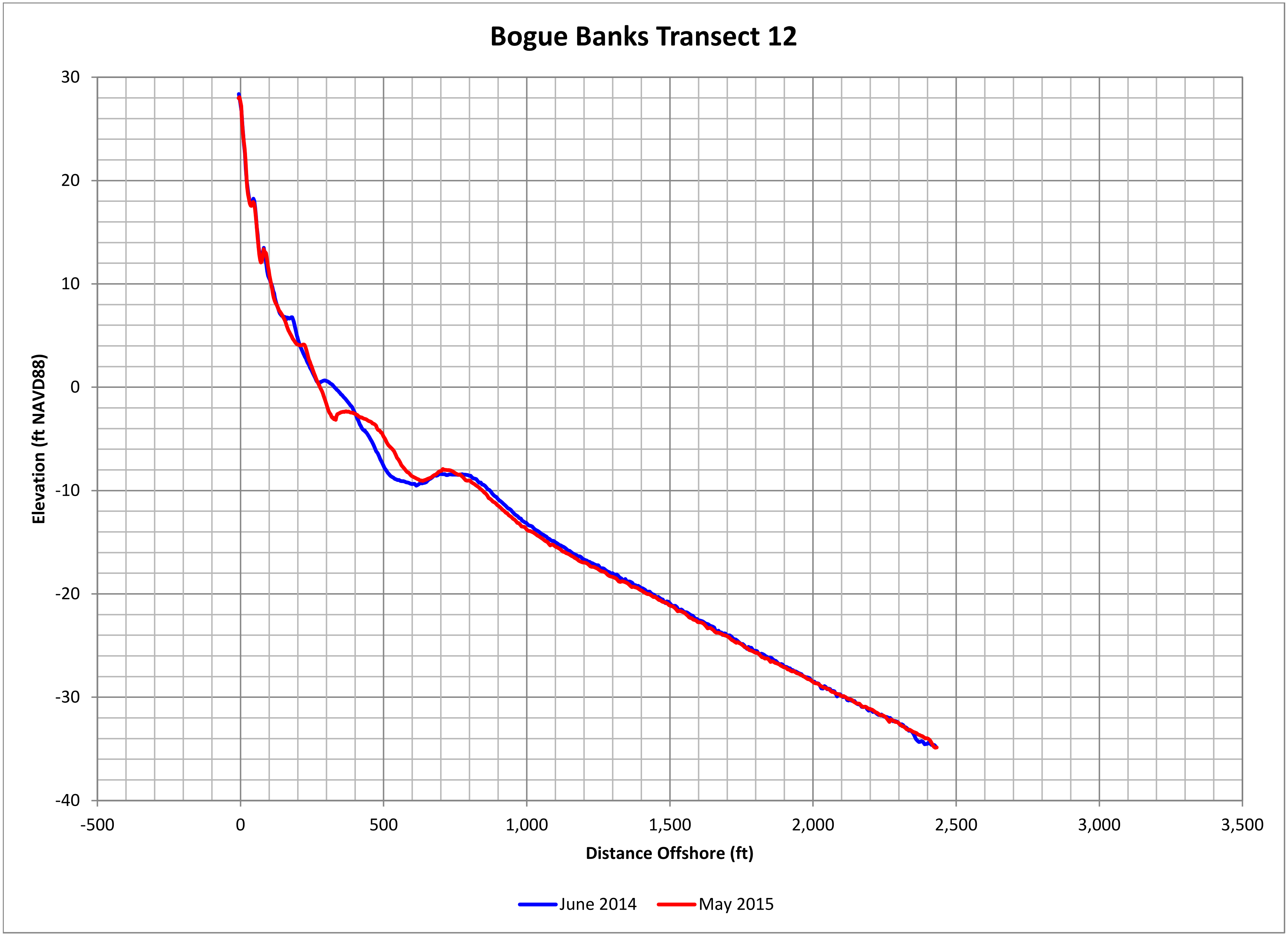


Figure C-14. Bogue Banks Profile Comparison Plot

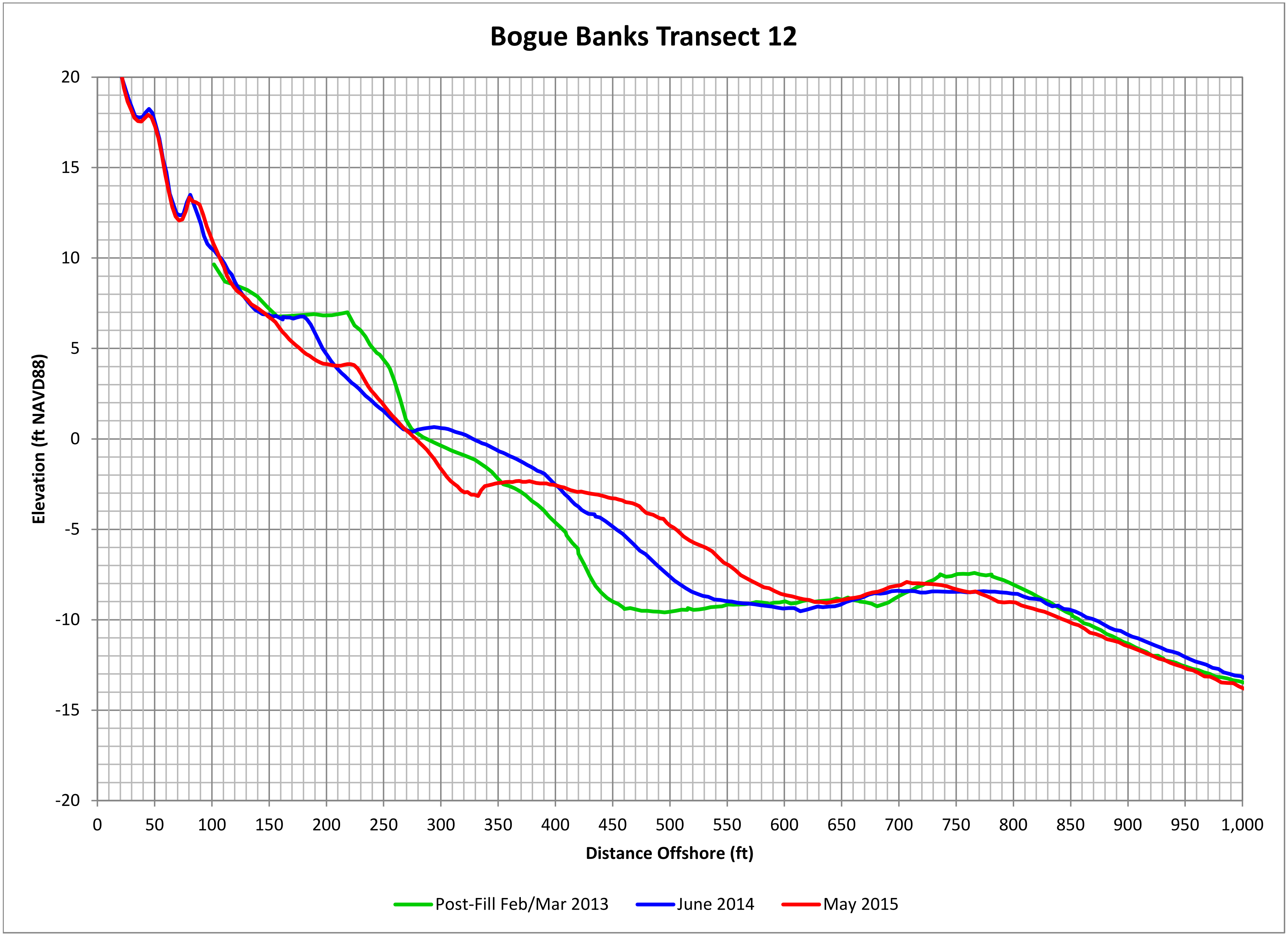


Figure C-15. Bogue Banks Profile Comparison Plot

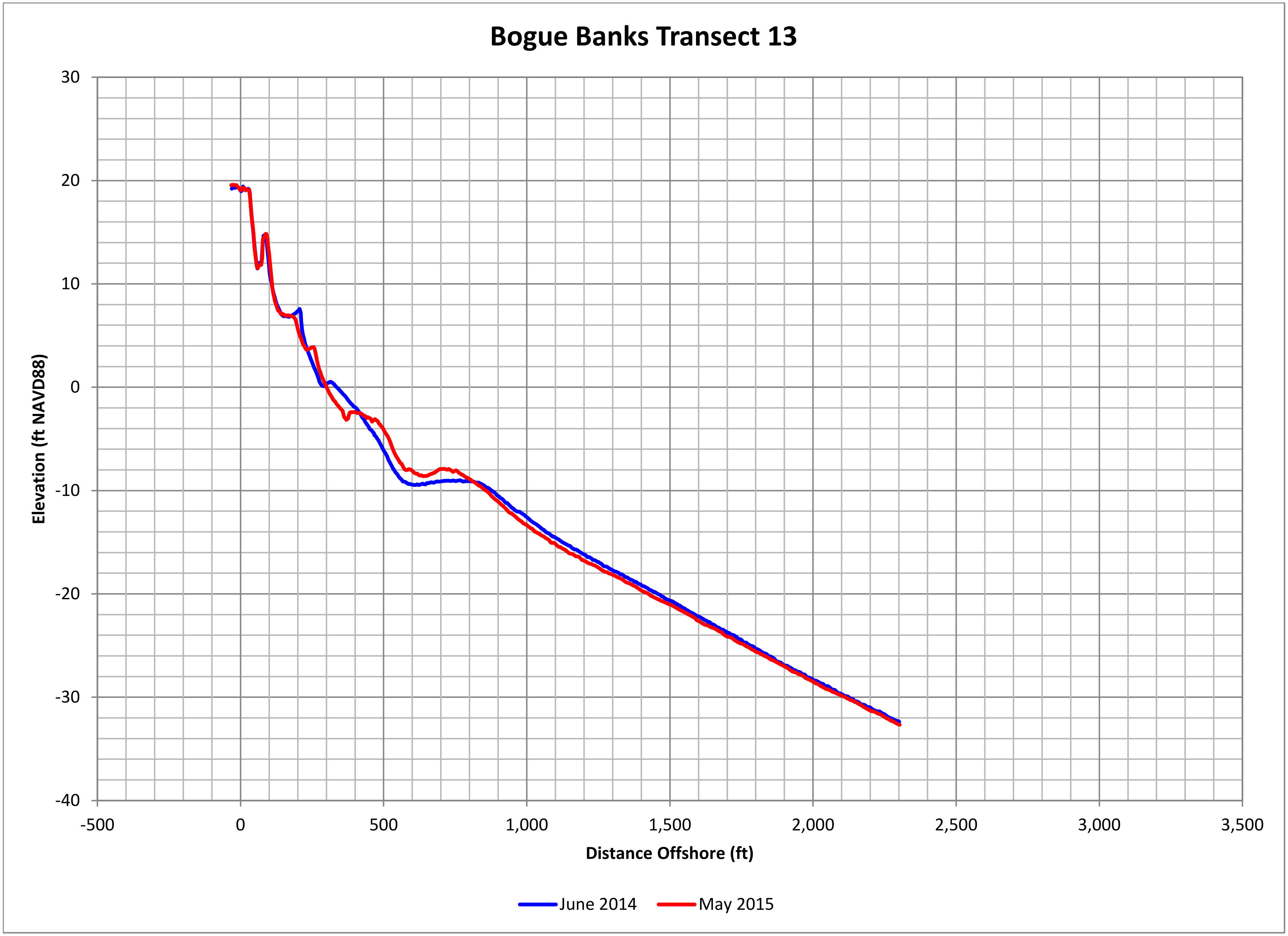


Figure C-16. Bogue Banks Profile Comparison Plot

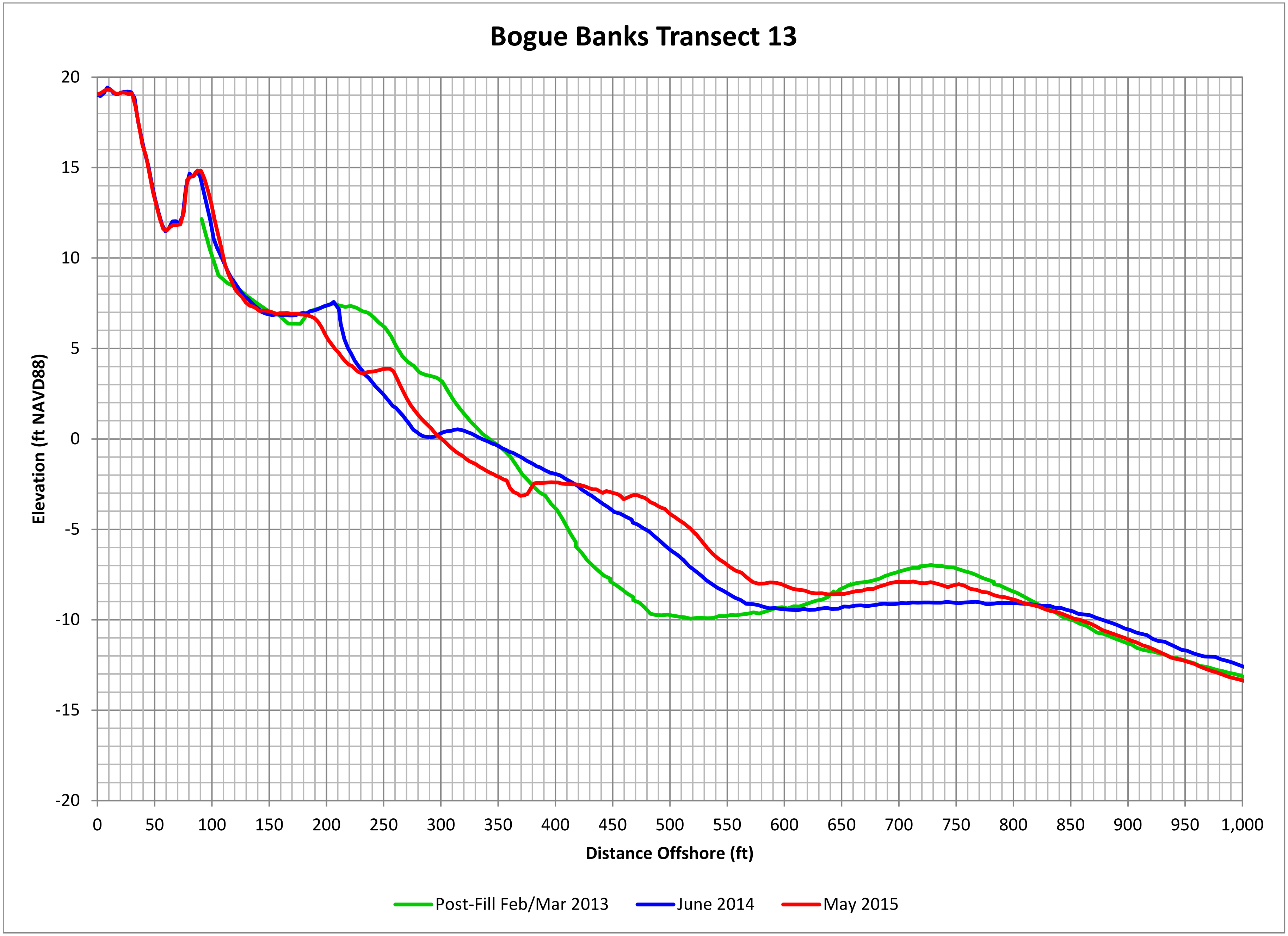


Figure C-17. Bogue Banks Profile Comparison Plot

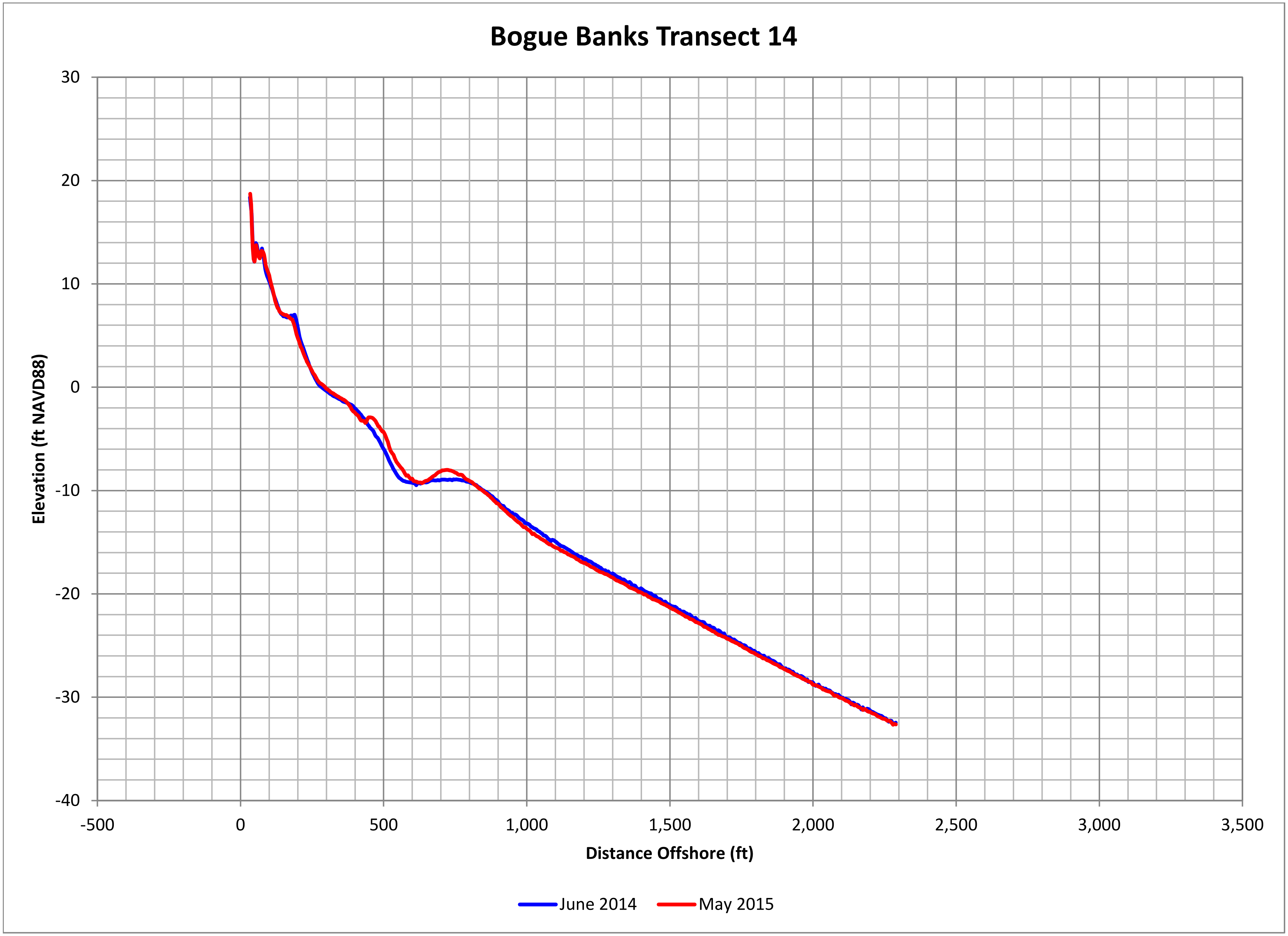


Figure C-18. Bogue Banks Profile Comparison Plot

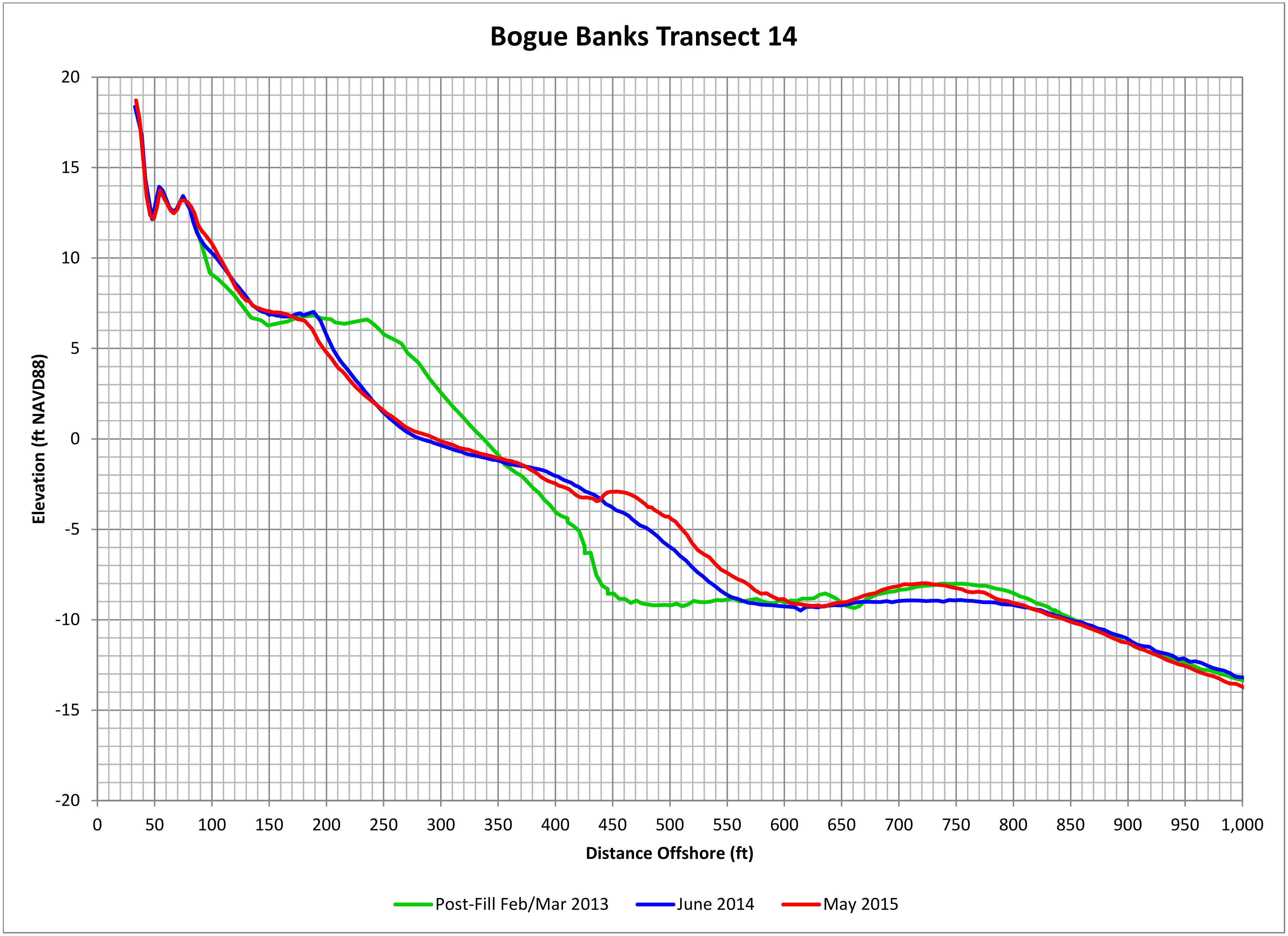


Figure C-19. Bogue Banks Profile Comparison Plot

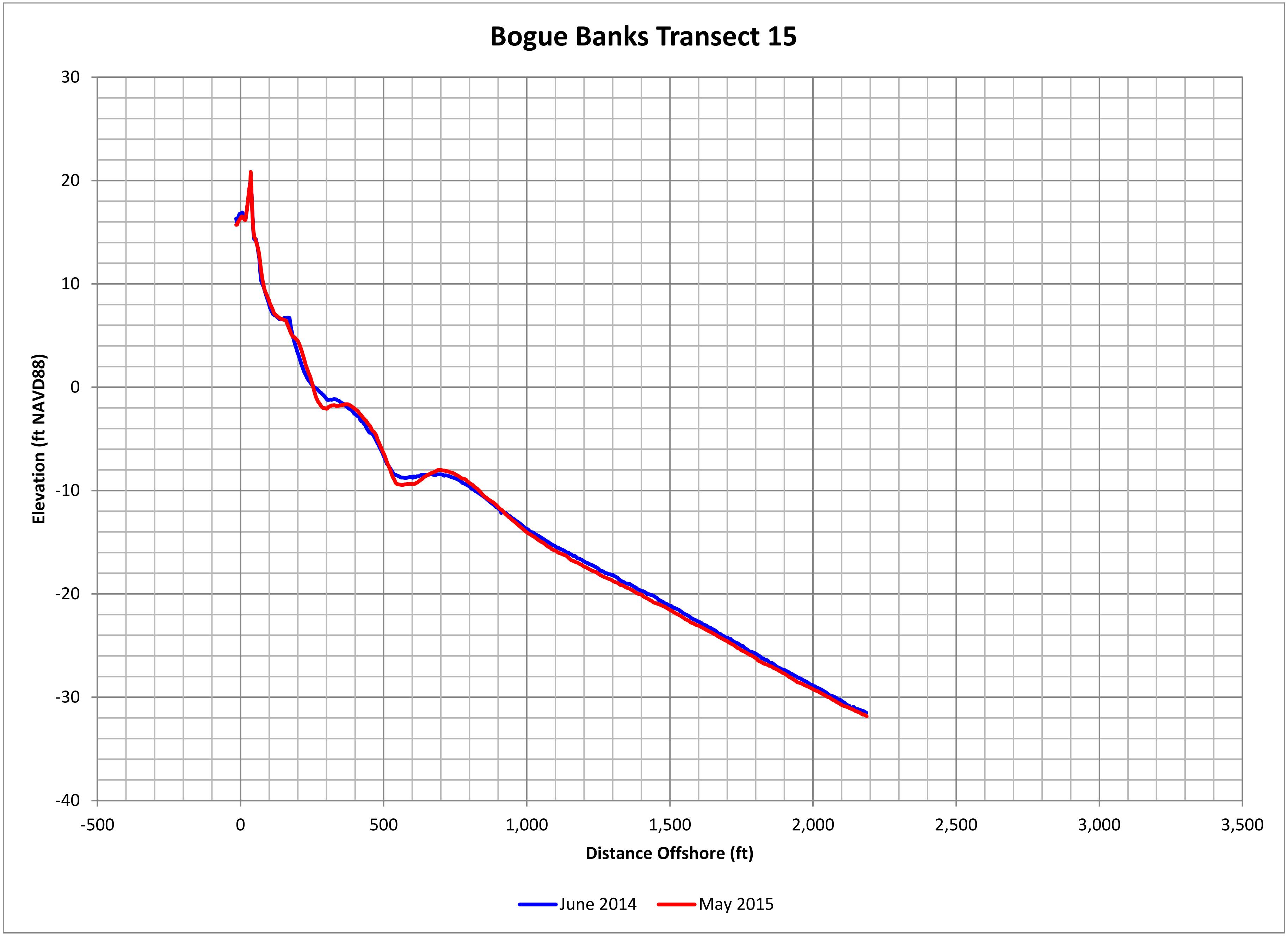


Figure C-20. Bogue Banks Profile Comparison Plot

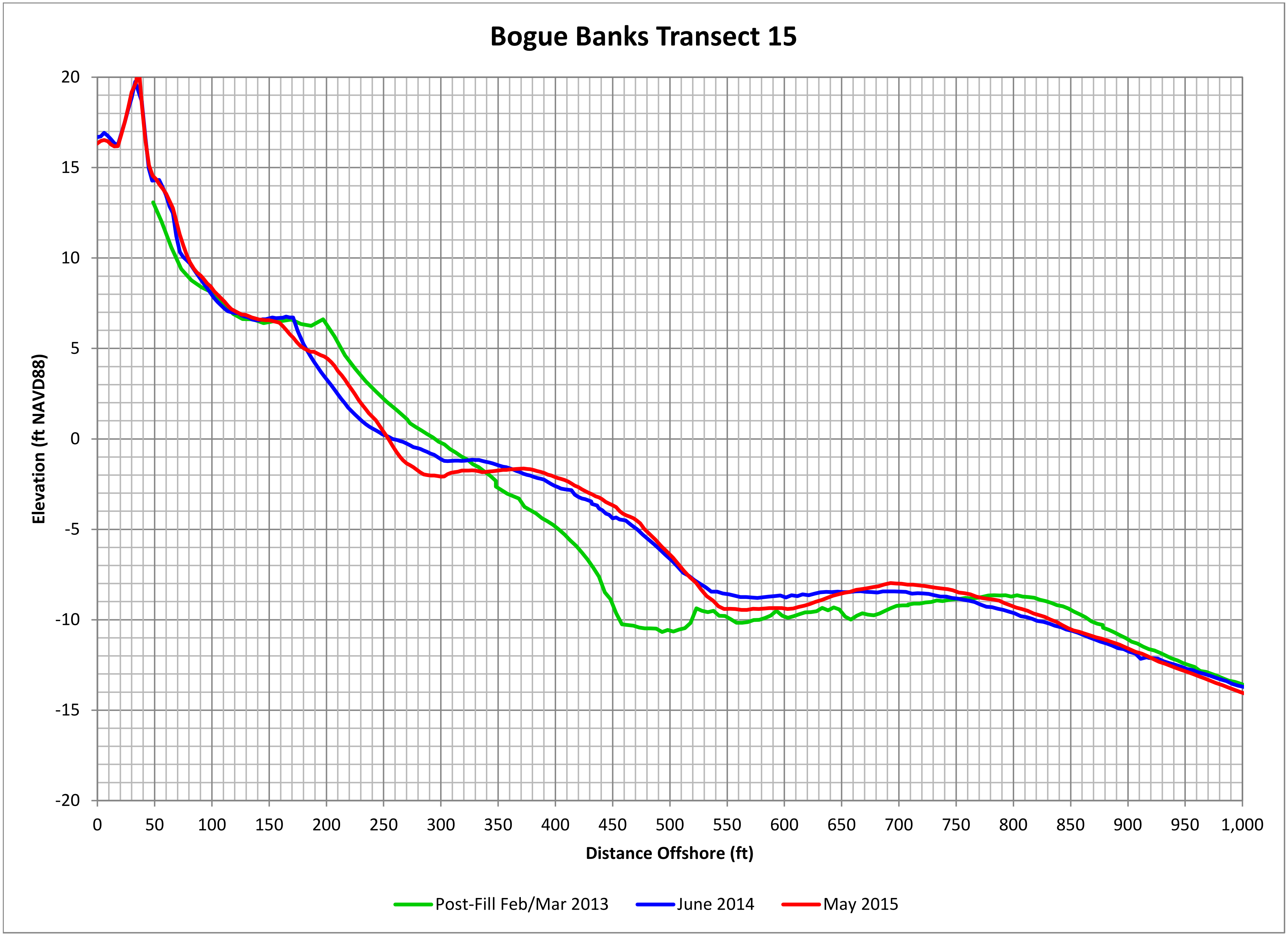


Figure C-21. Bogue Banks Profile Comparison Plot

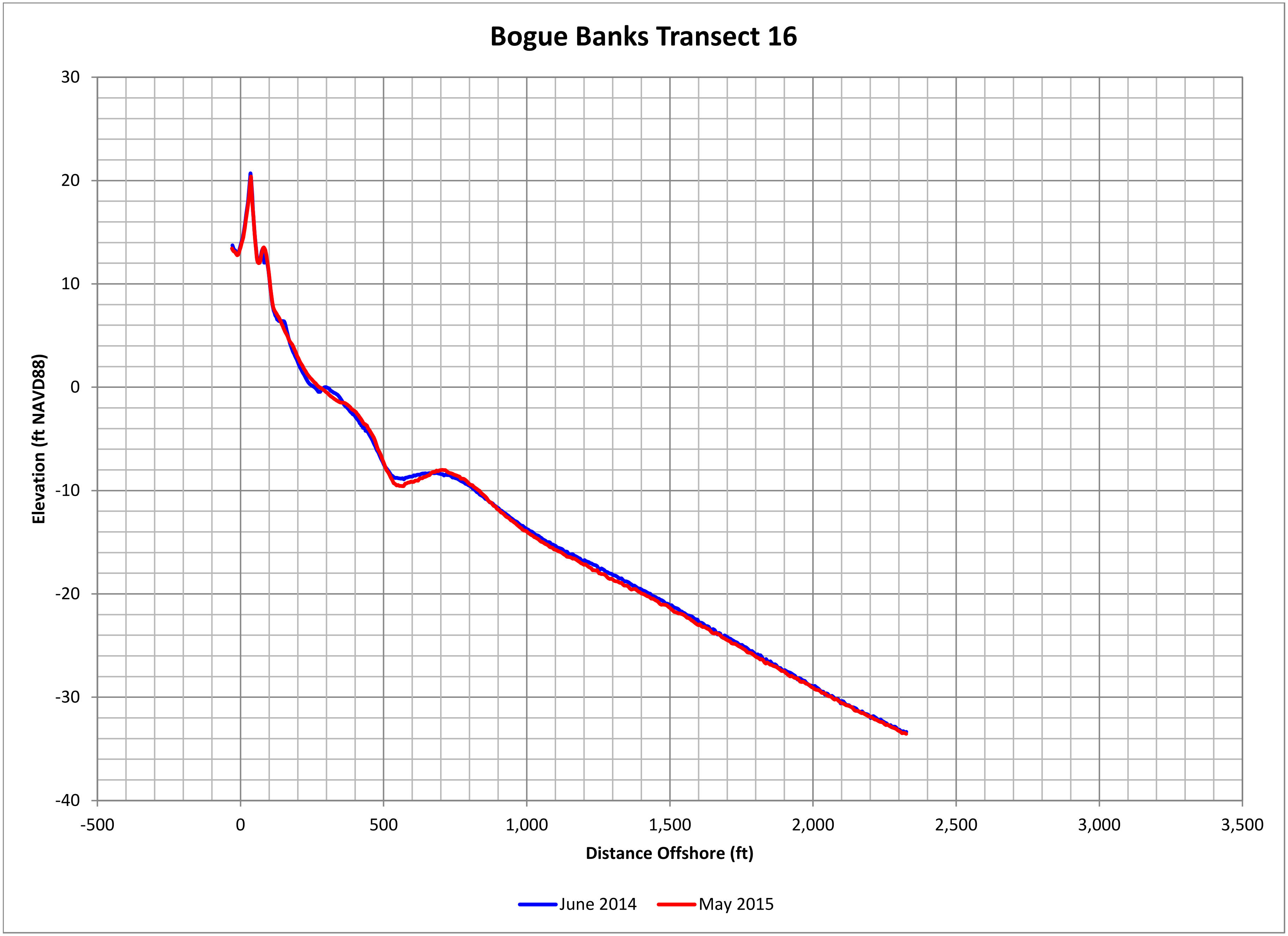


Figure C-22. Bogue Banks Profile Comparison Plot

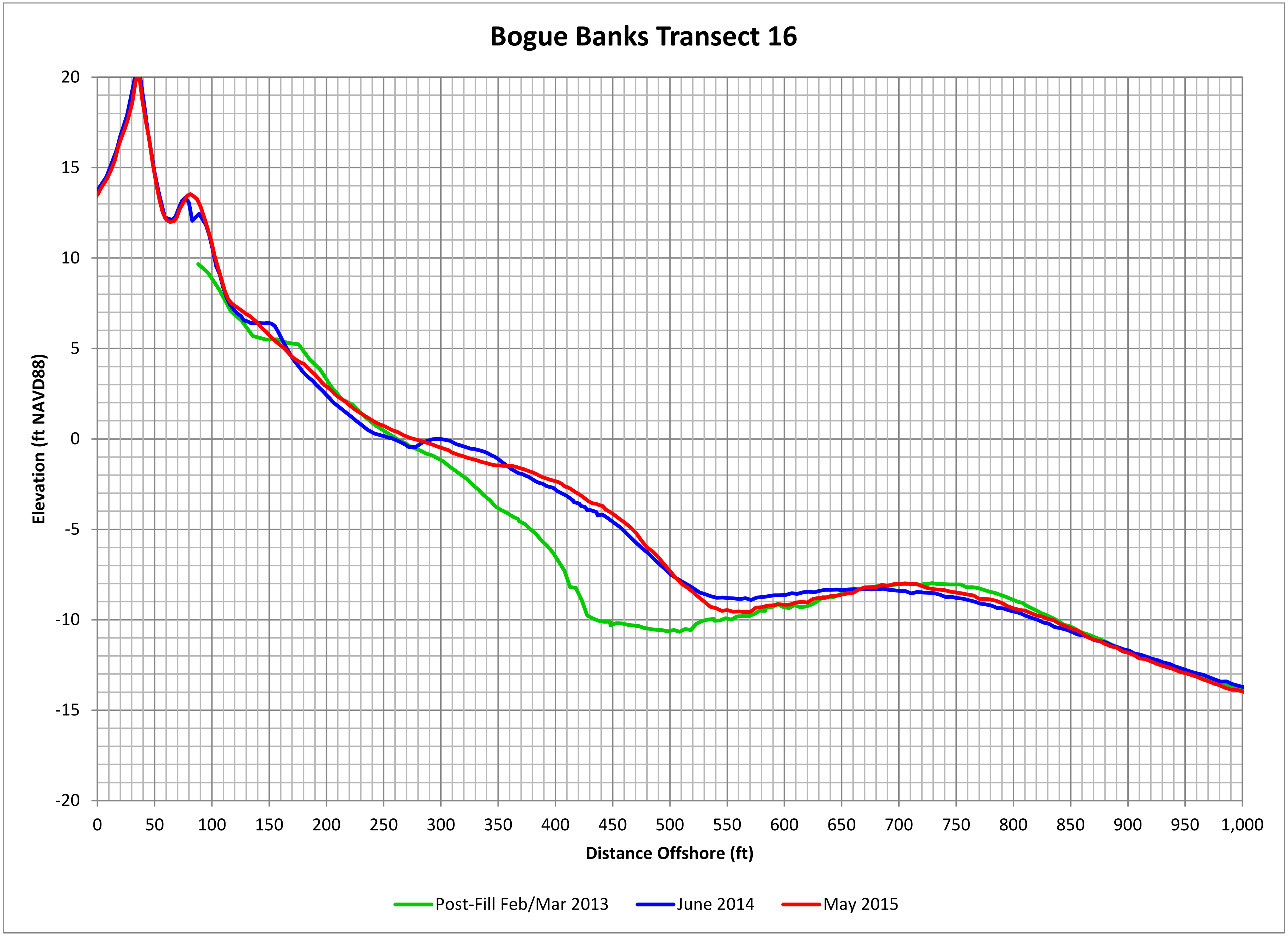


Figure C-23. Bogue Banks Profile Comparison Plot

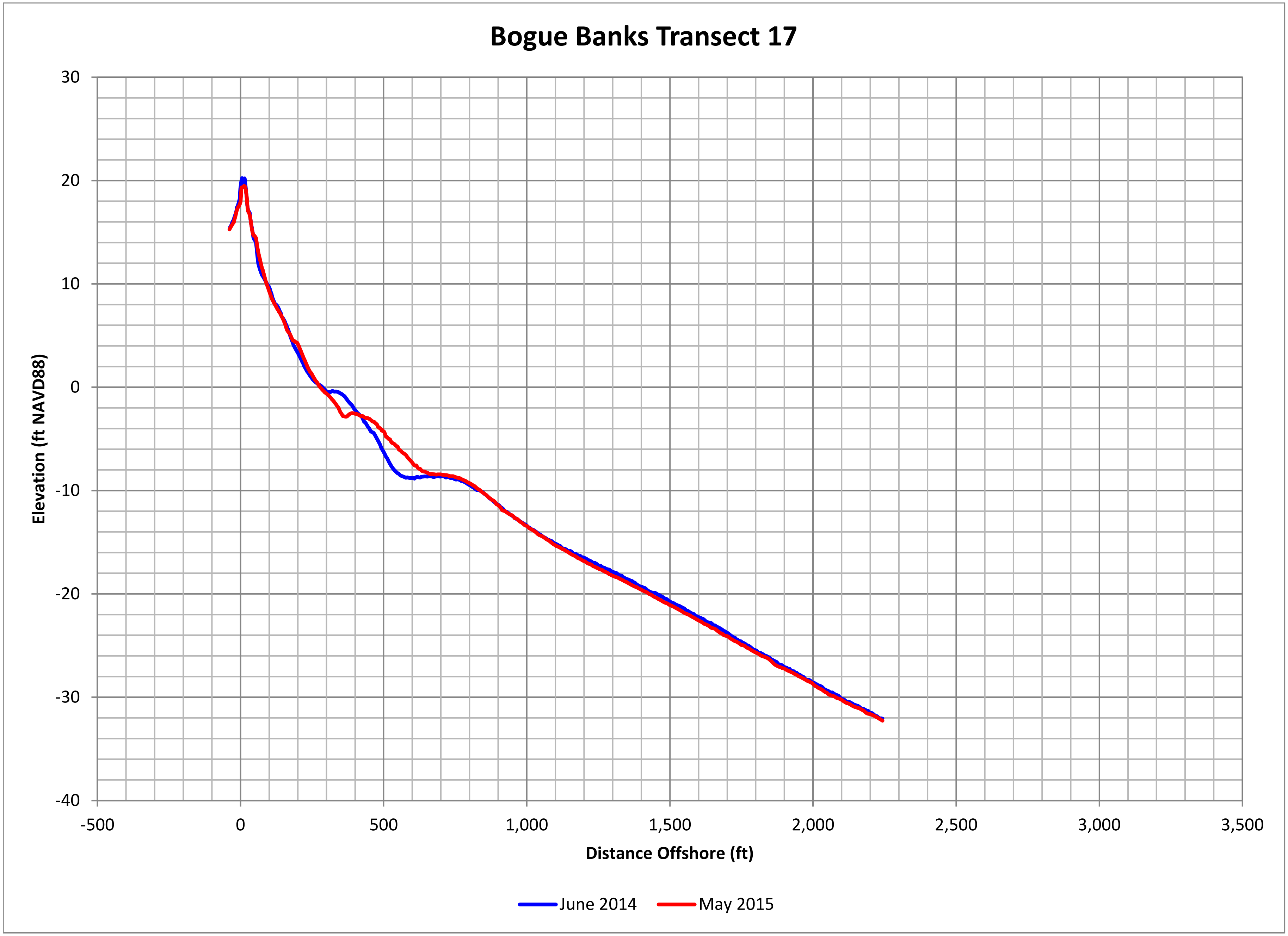


Figure C-24. Bogue Banks Profile Comparison Plot

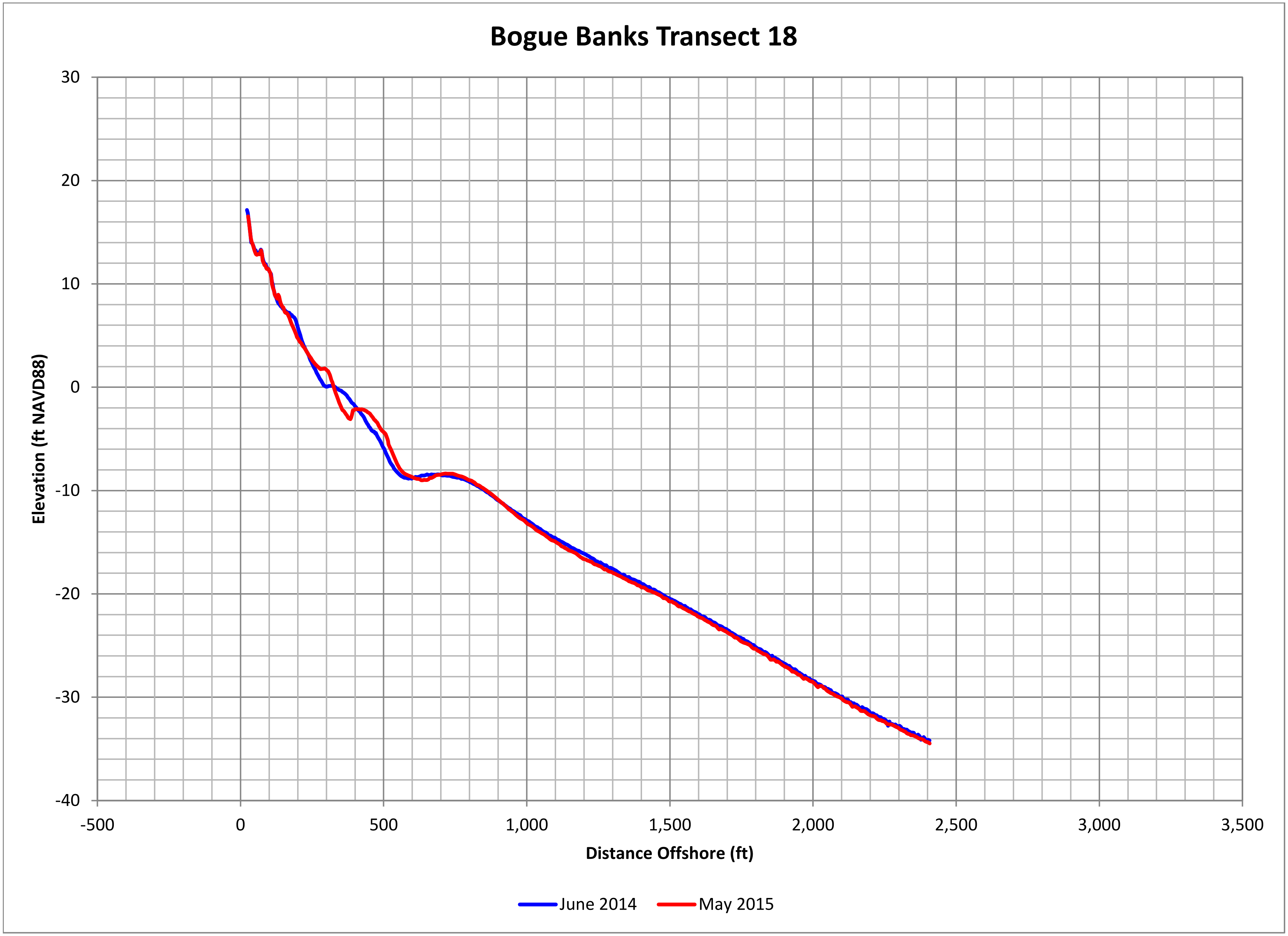


Figure C-25. Bogue Banks Profile Comparison Plot

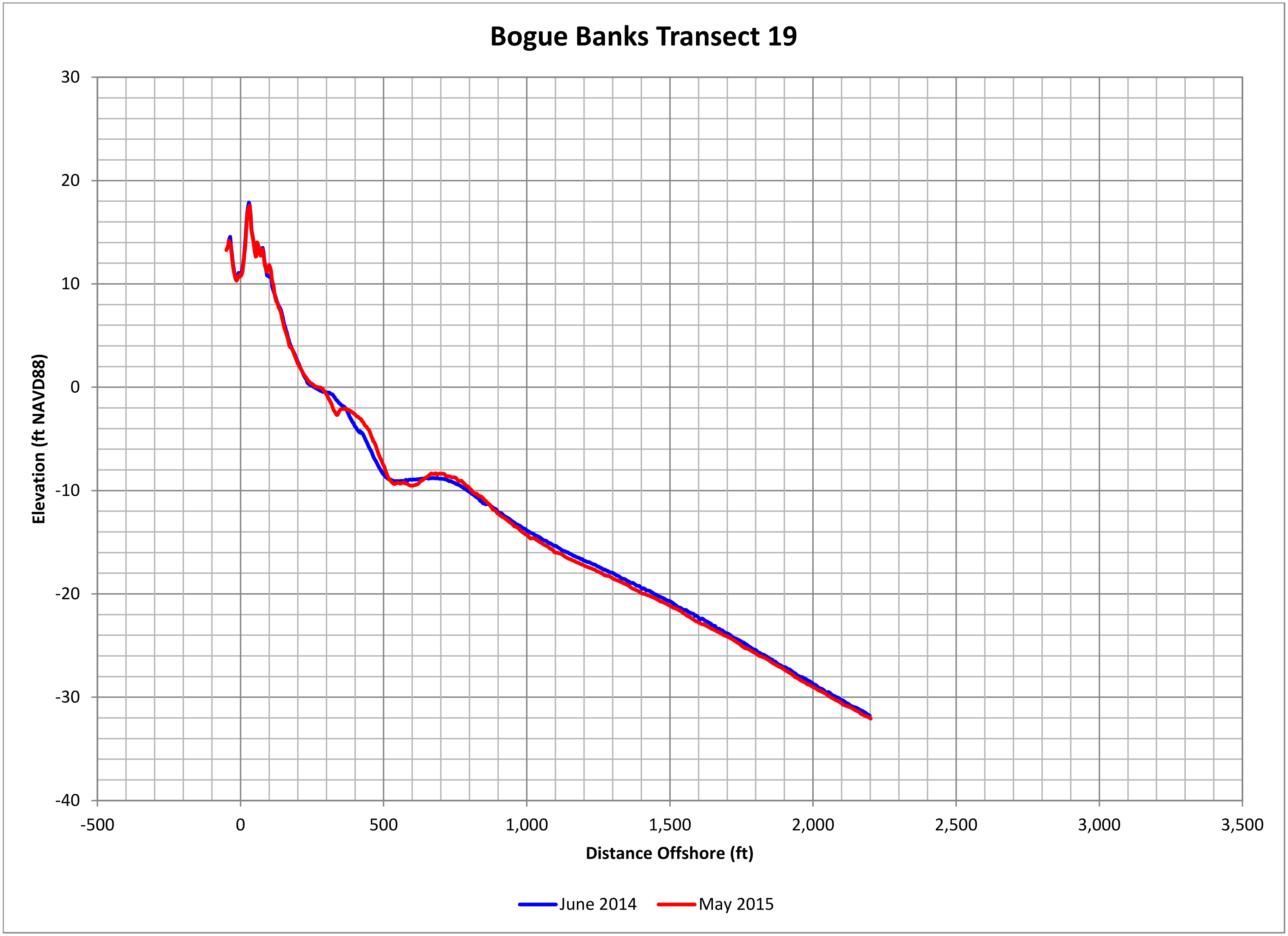


Figure C-26. Bogue Banks Profile Comparison Plot

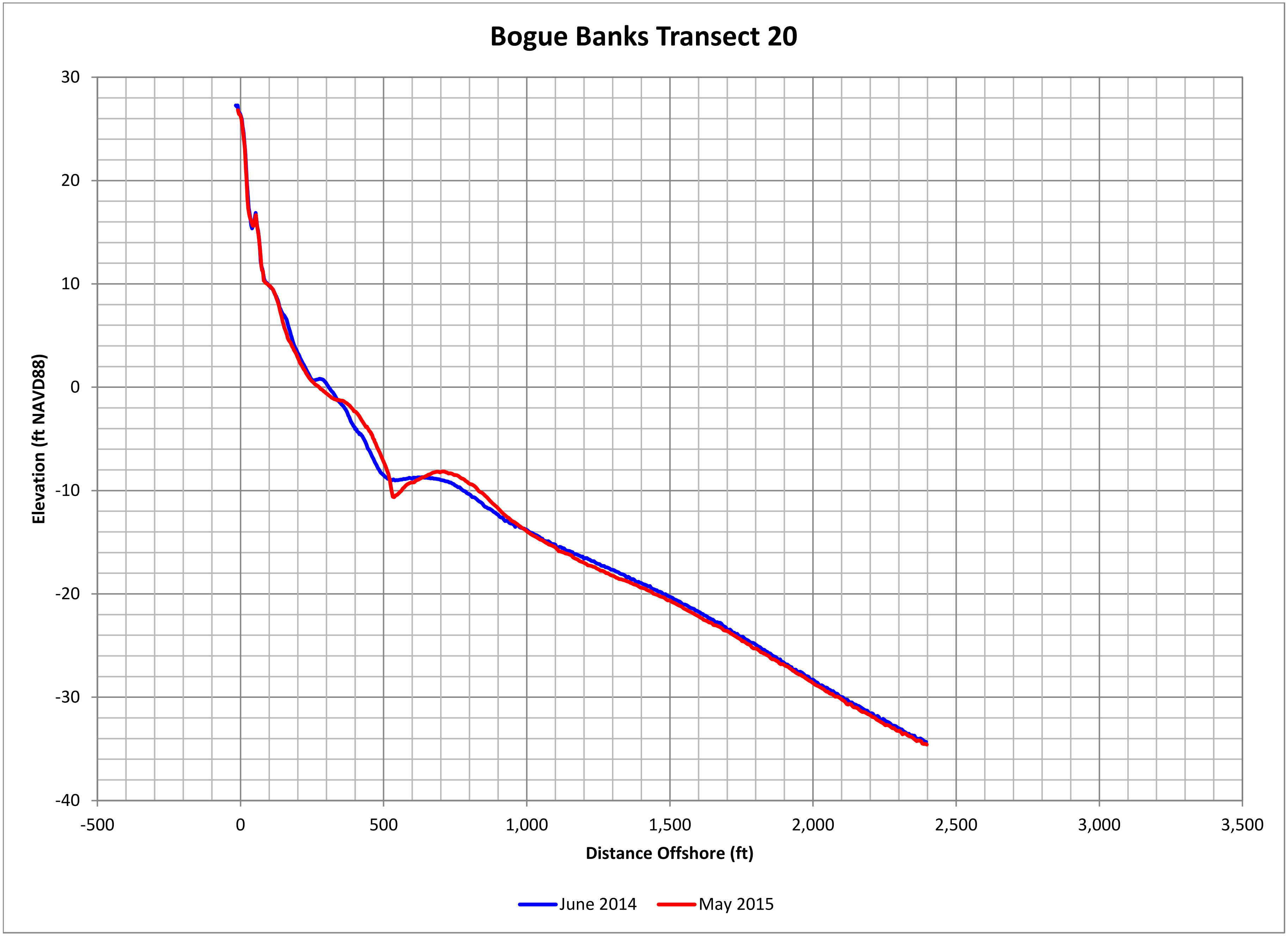


Figure C-27. Bogue Banks Profile Comparison Plot

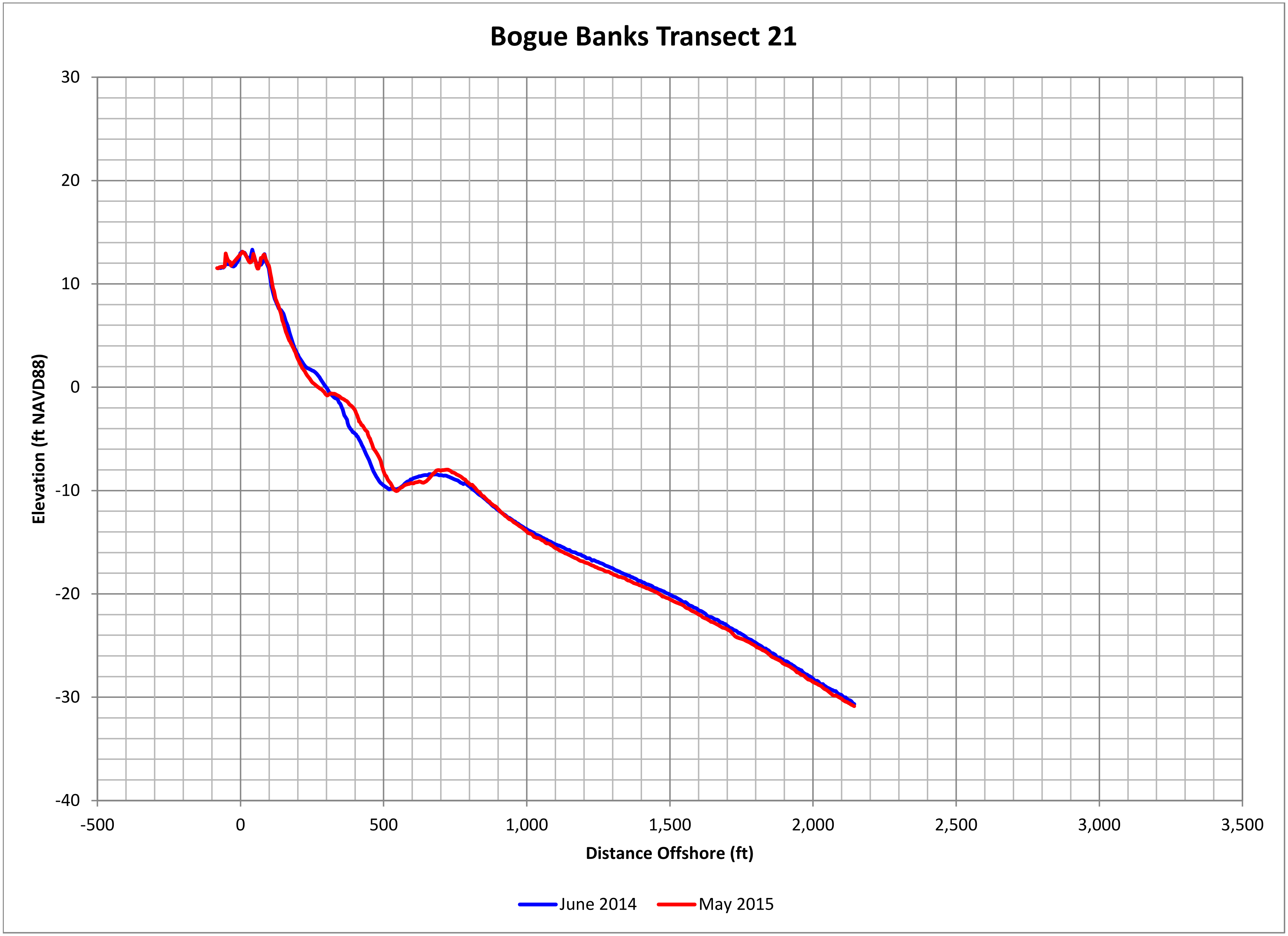


Figure C-28. Bogue Banks Profile Comparison Plot

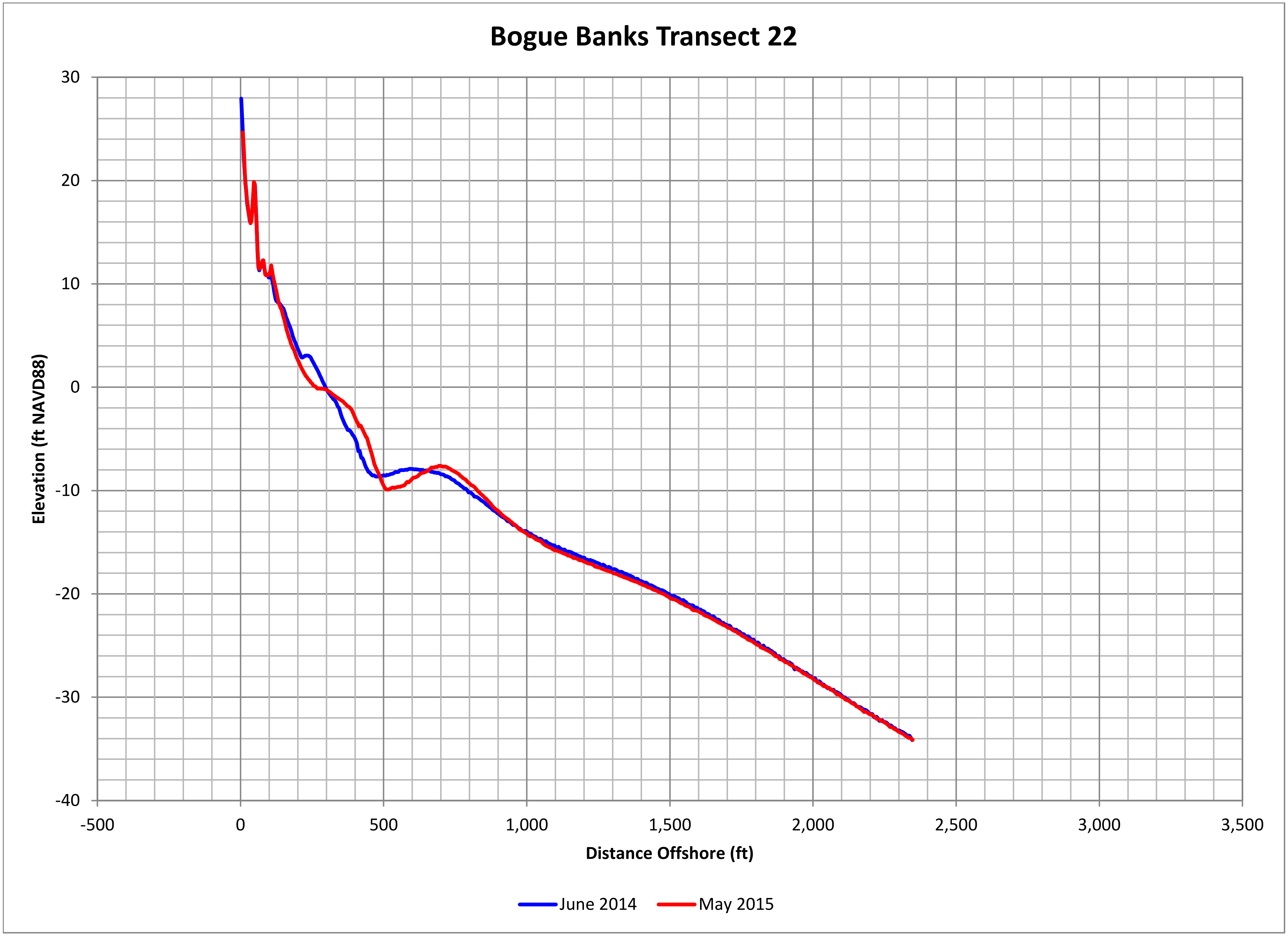


Figure C-29. Bogue Banks Profile Comparison Plot

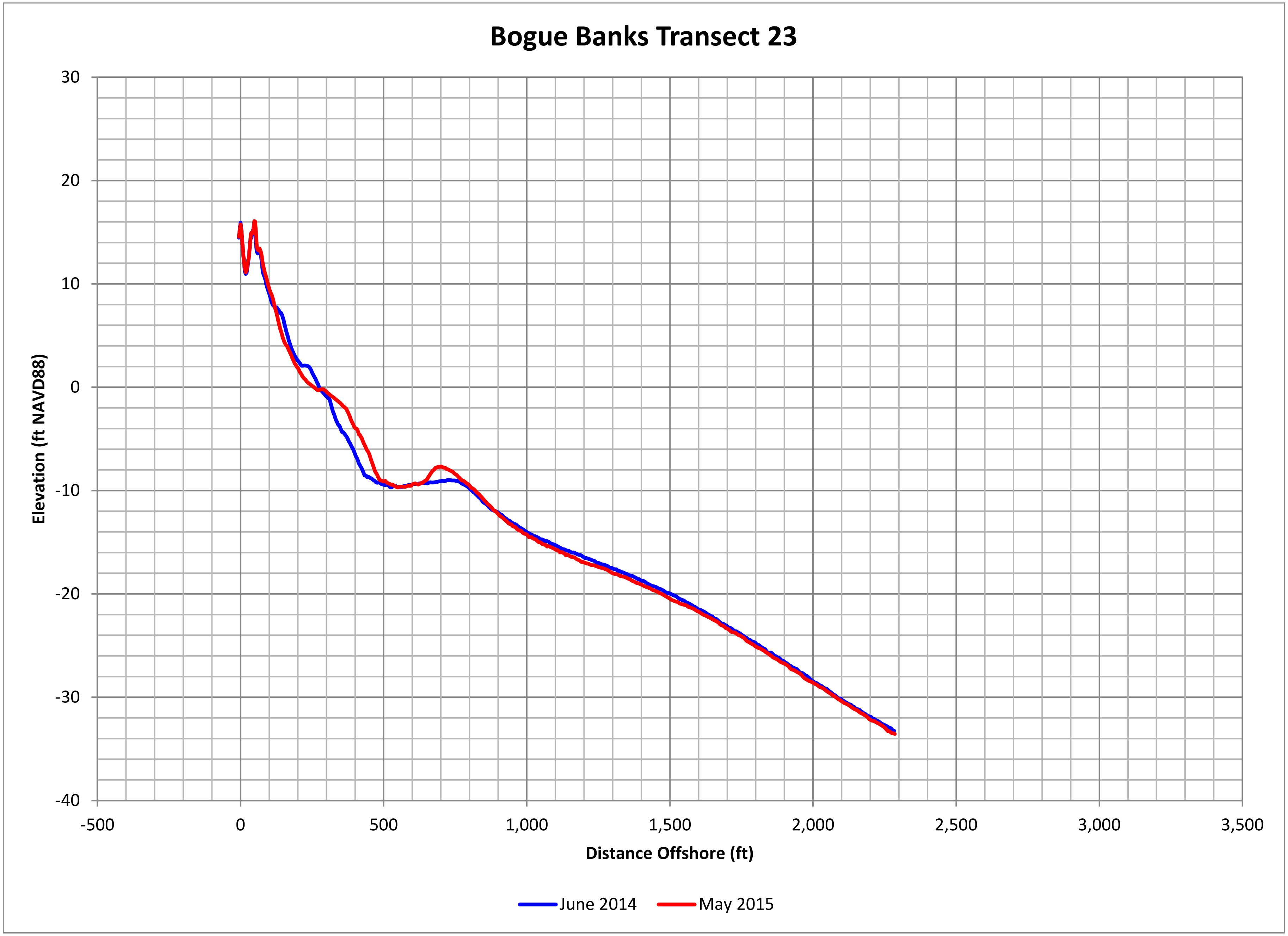


Figure C-30. Bogue Banks Profile Comparison Plot

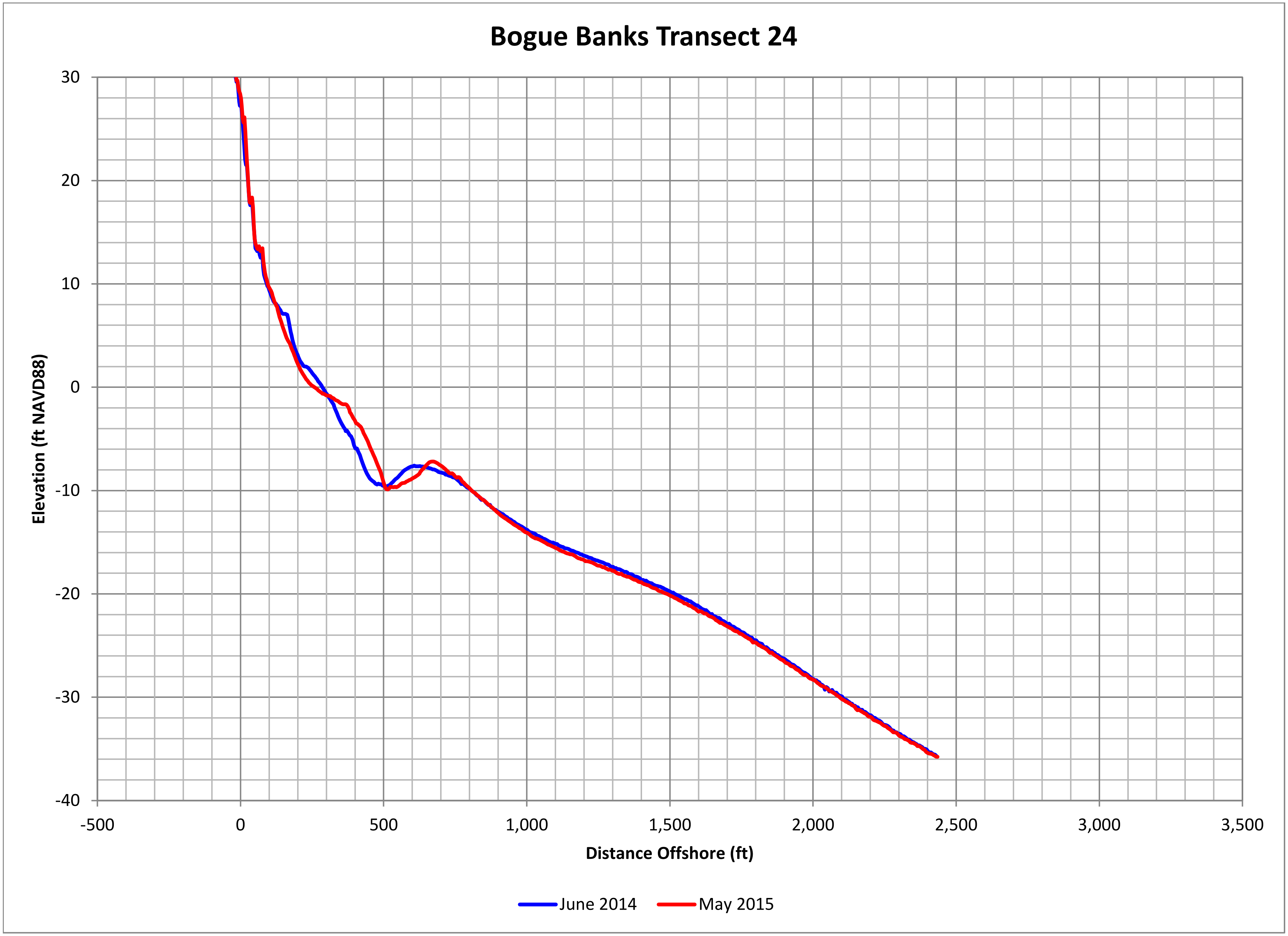


Figure C-31. Bogue Banks Profile Comparison Plot

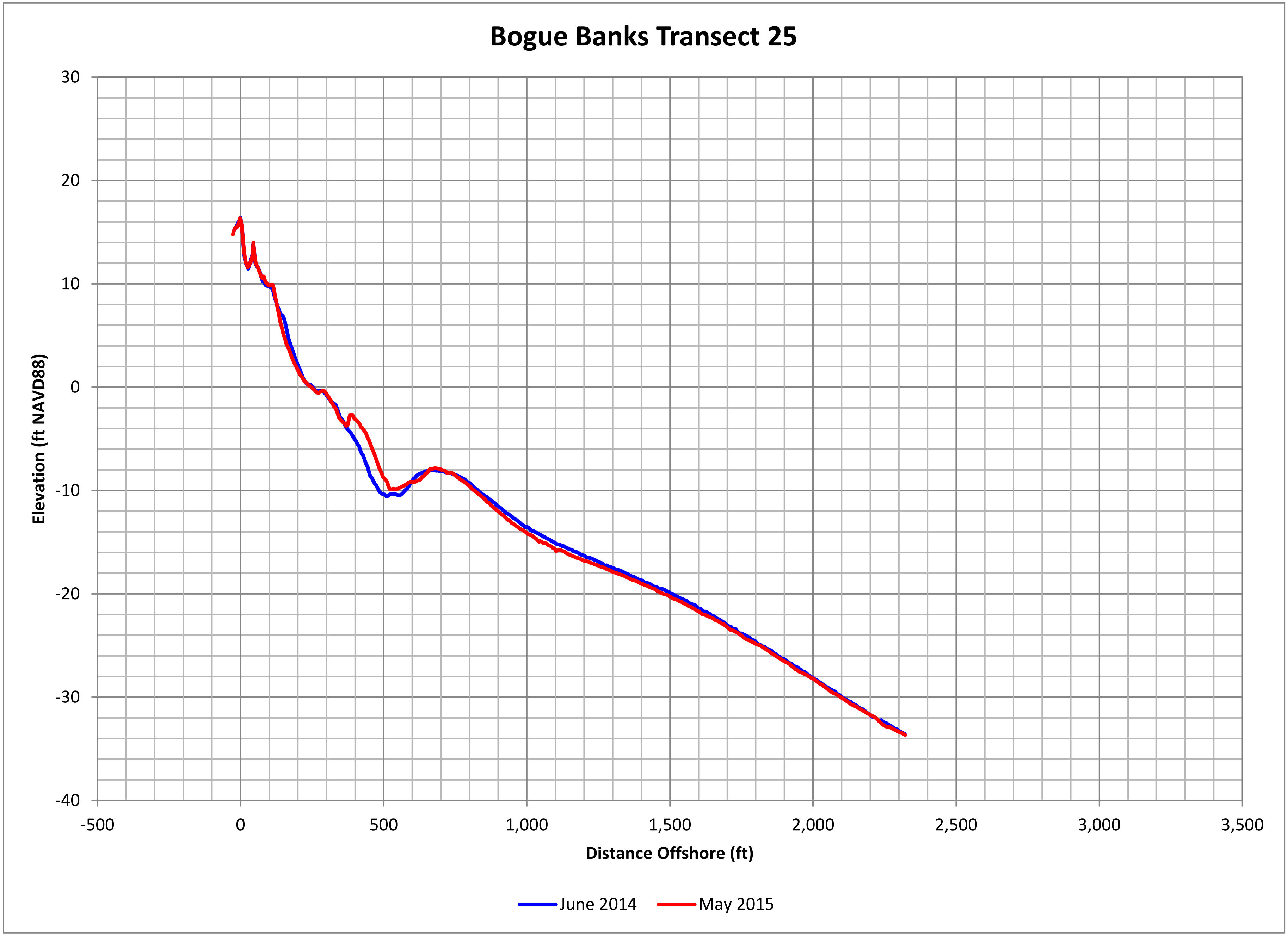


Figure C-32. Bogue Banks Profile Comparison Plot

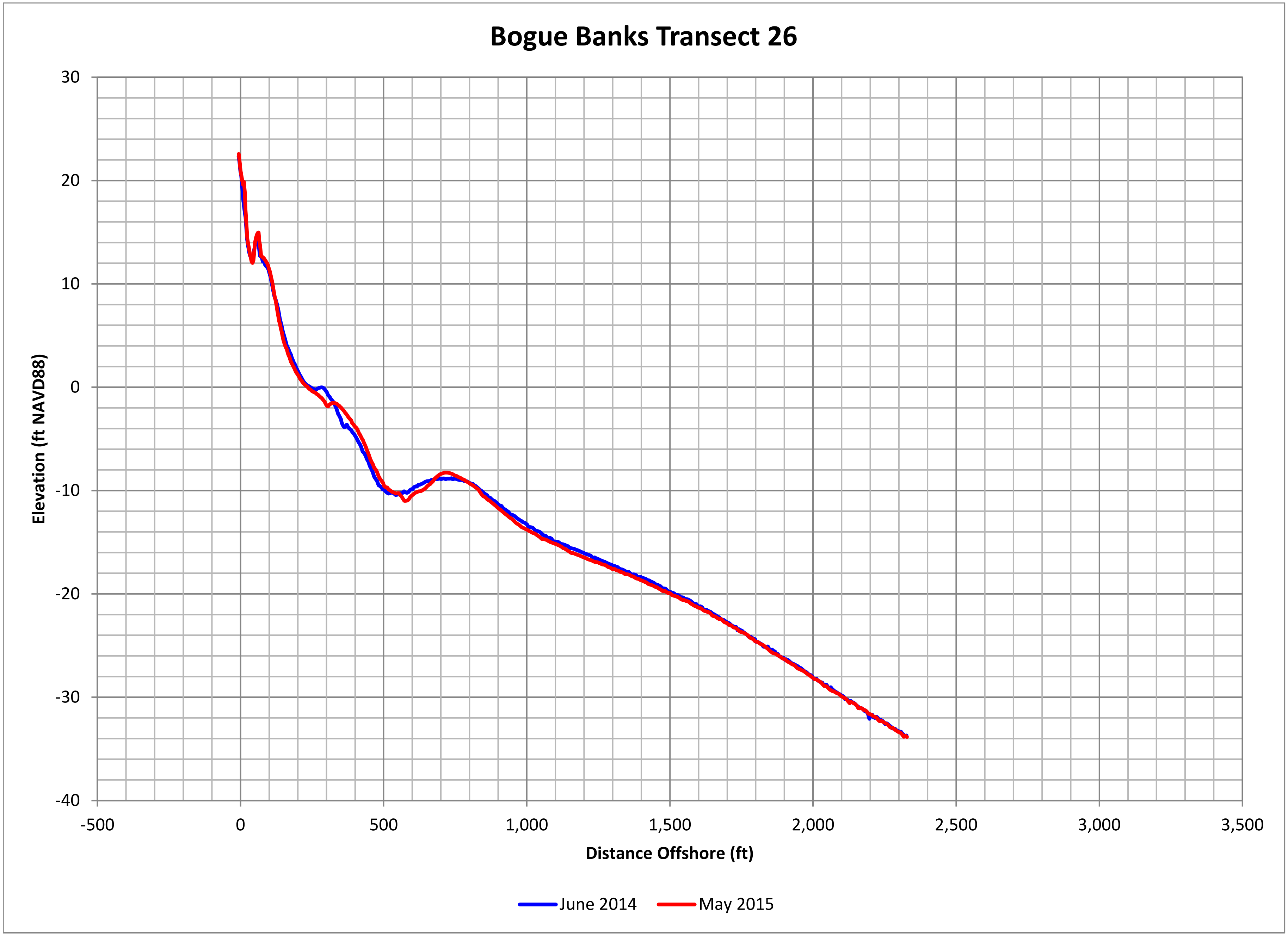


Figure C-33. Bogue Banks Profile Comparison Plot

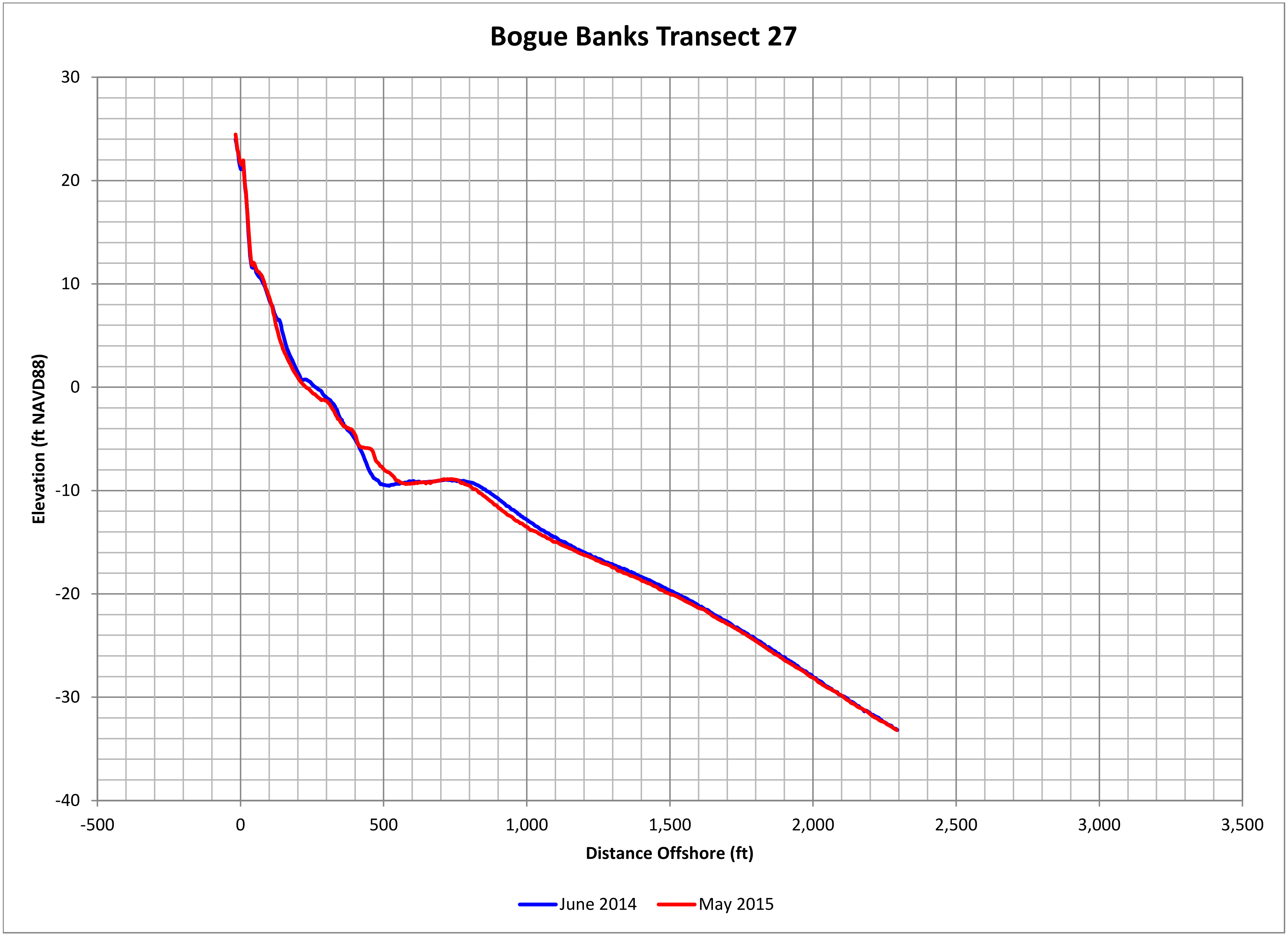


Figure C-34. Bogue Banks Profile Comparison Plot

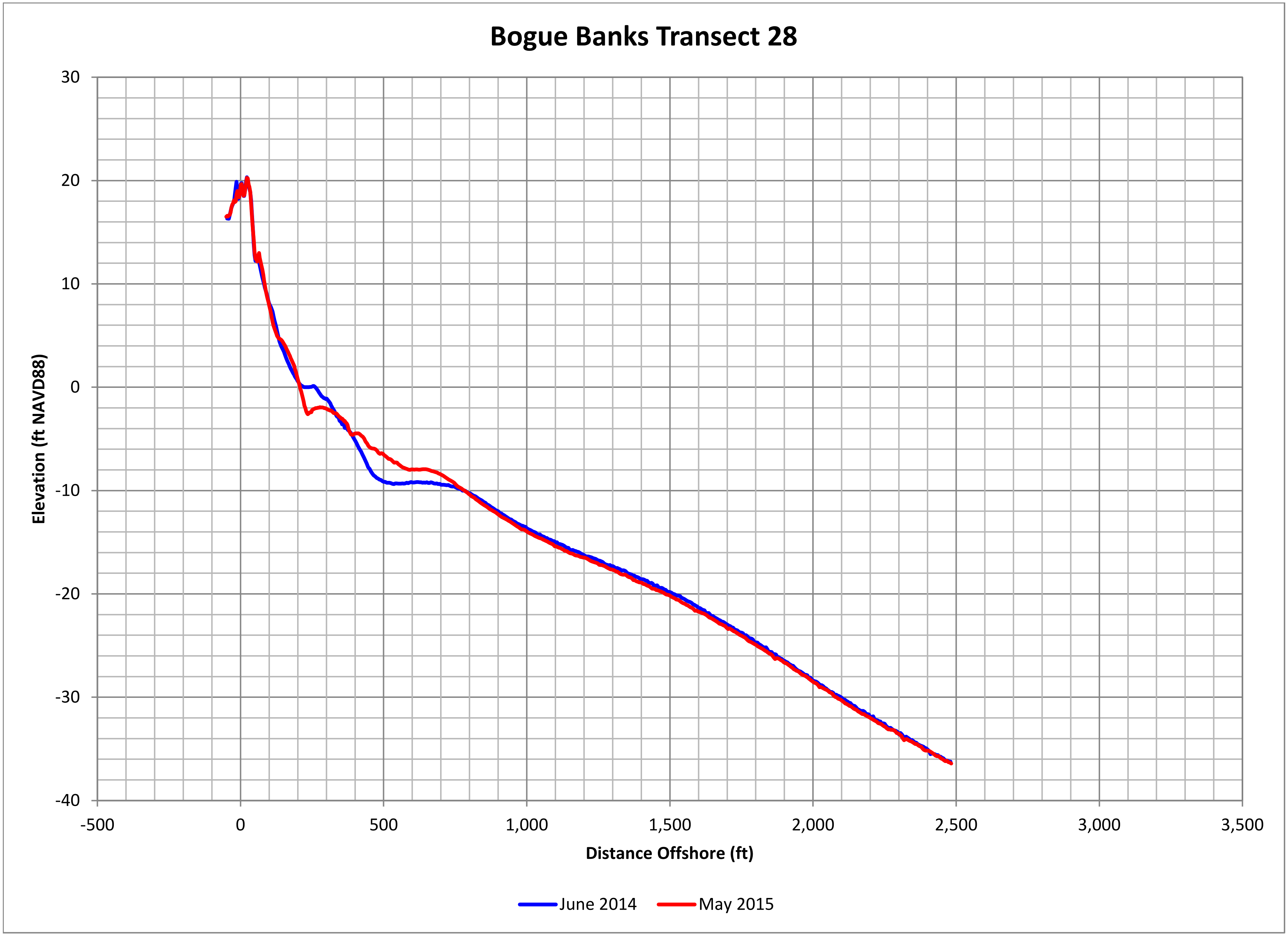


Figure C-35. Bogue Banks Profile Comparison Plot

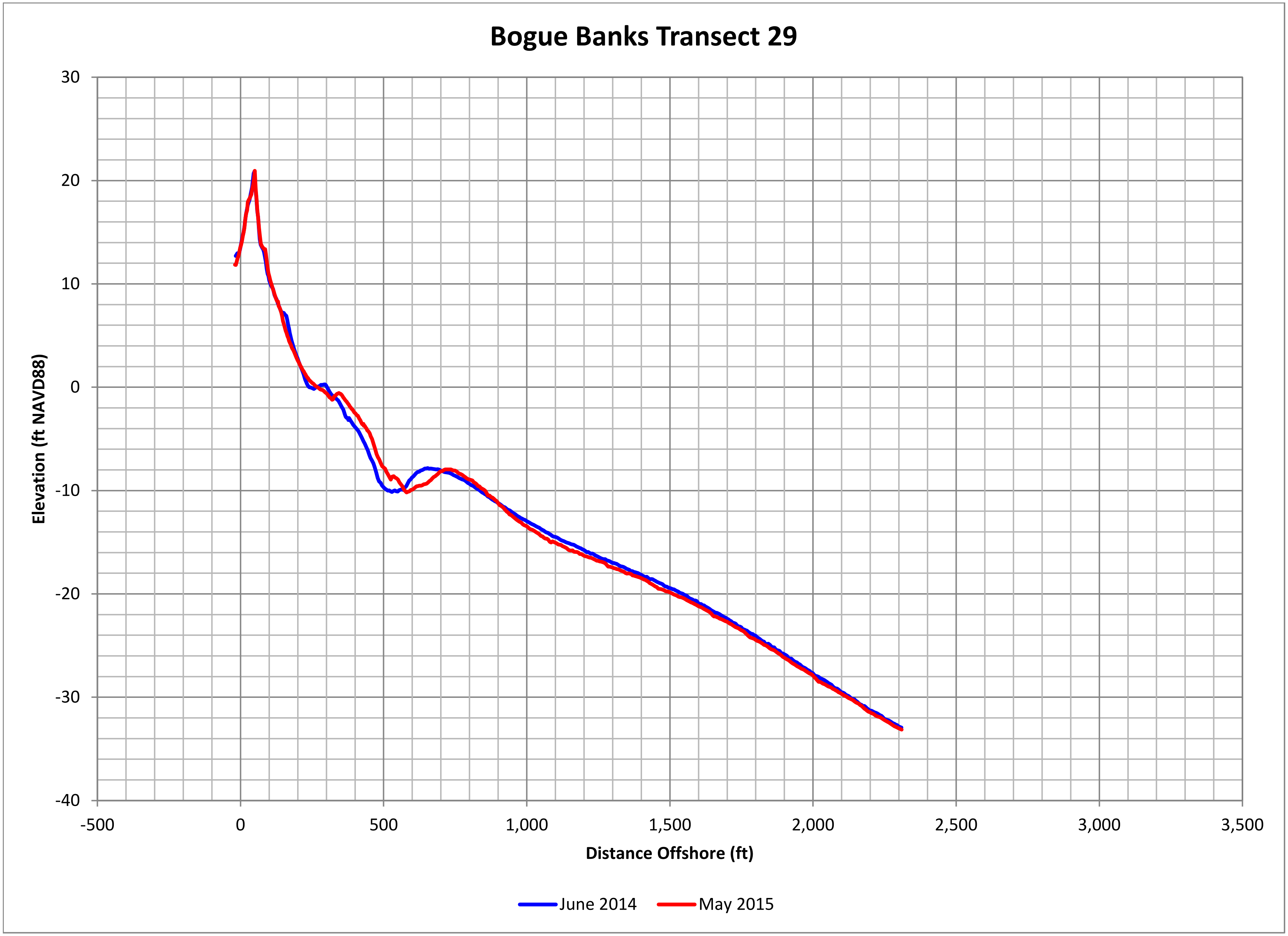


Figure C-36. Bogue Banks Profile Comparison Plot

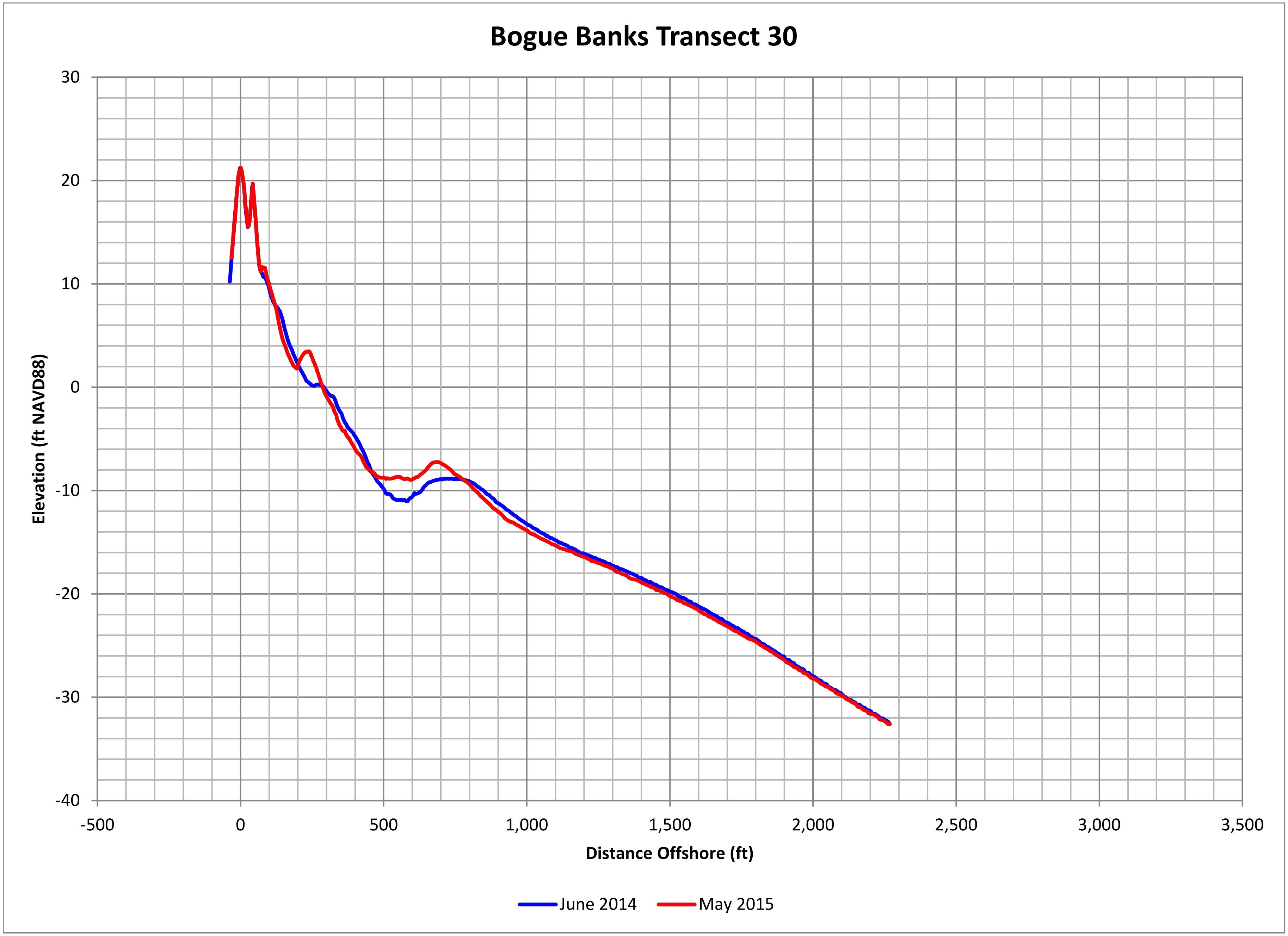


Figure C-37. Bogue Banks Profile Comparison Plot

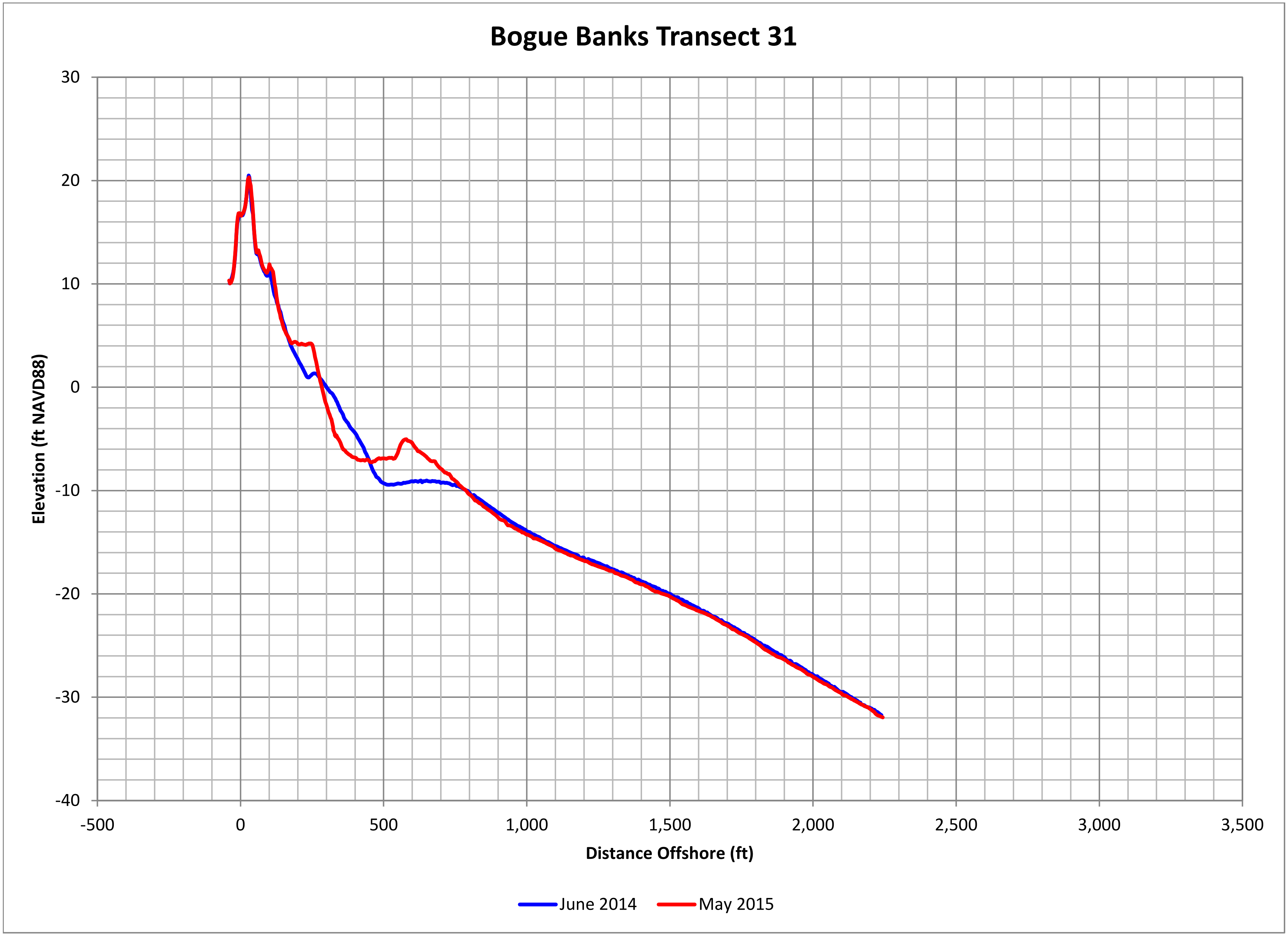


Figure C-38. Bogue Banks Profile Comparison Plot

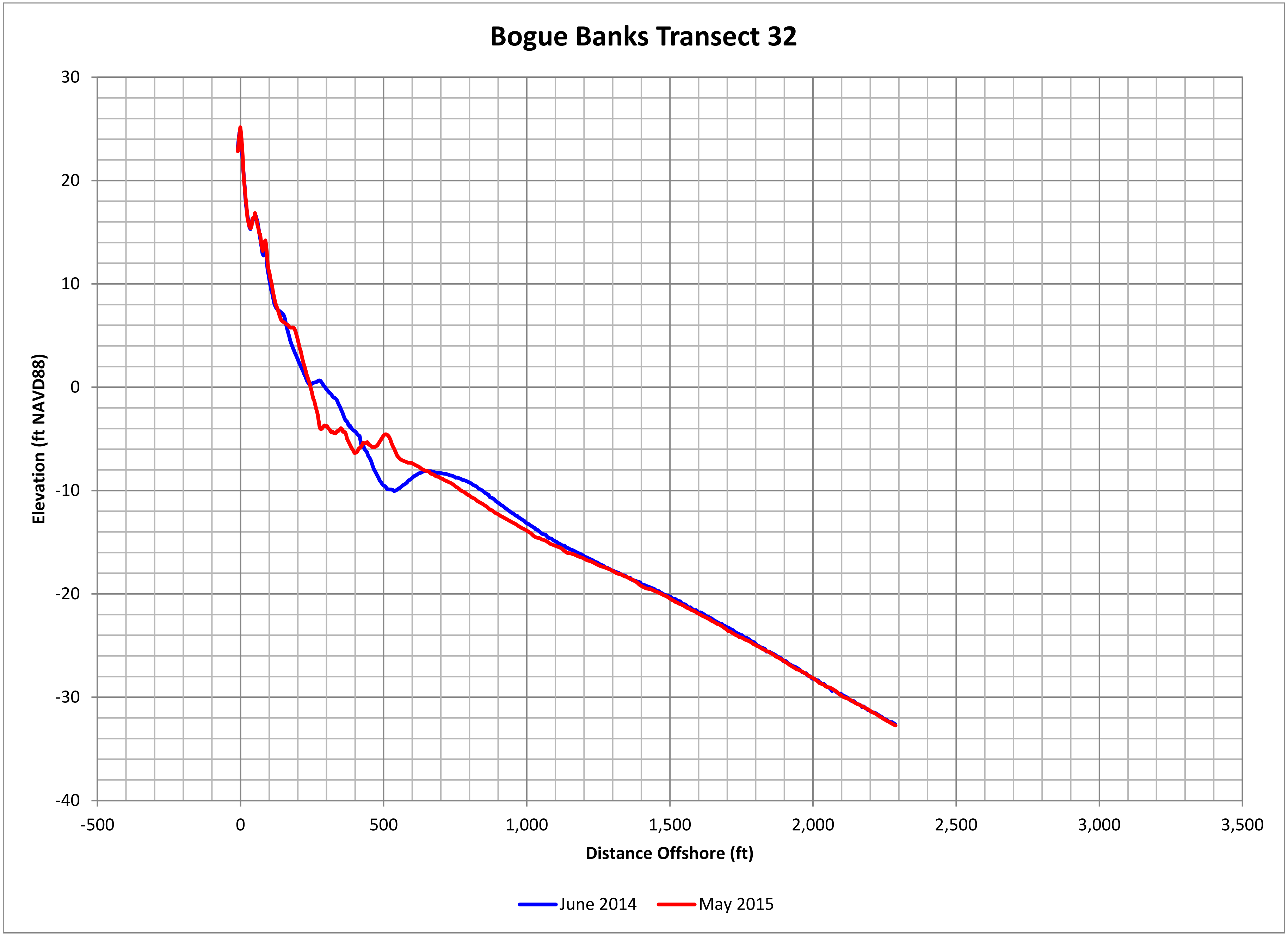


Figure C-39. Bogue Banks Profile Comparison Plot

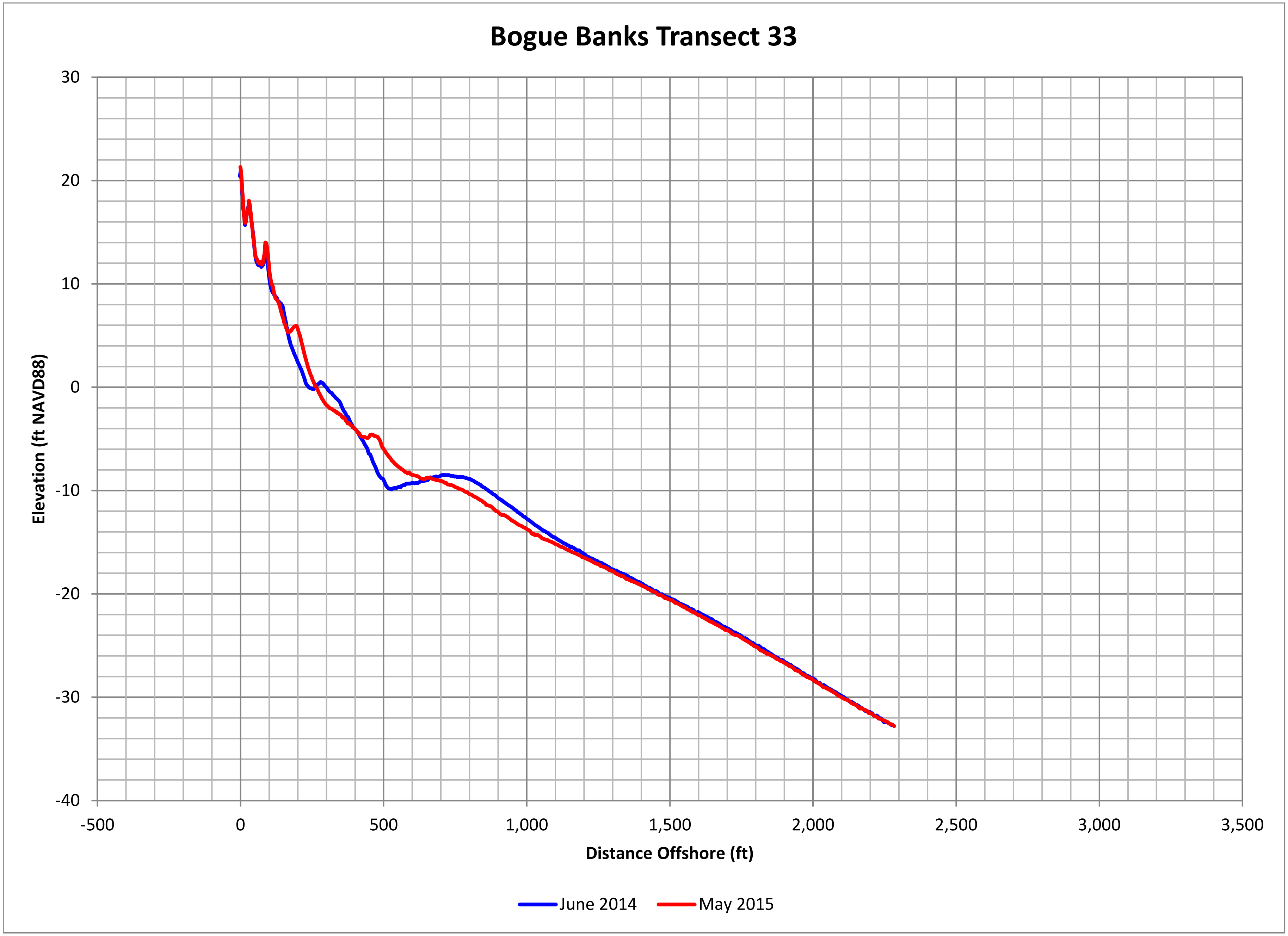


Figure C-40. Bogue Banks Profile Comparison Plot

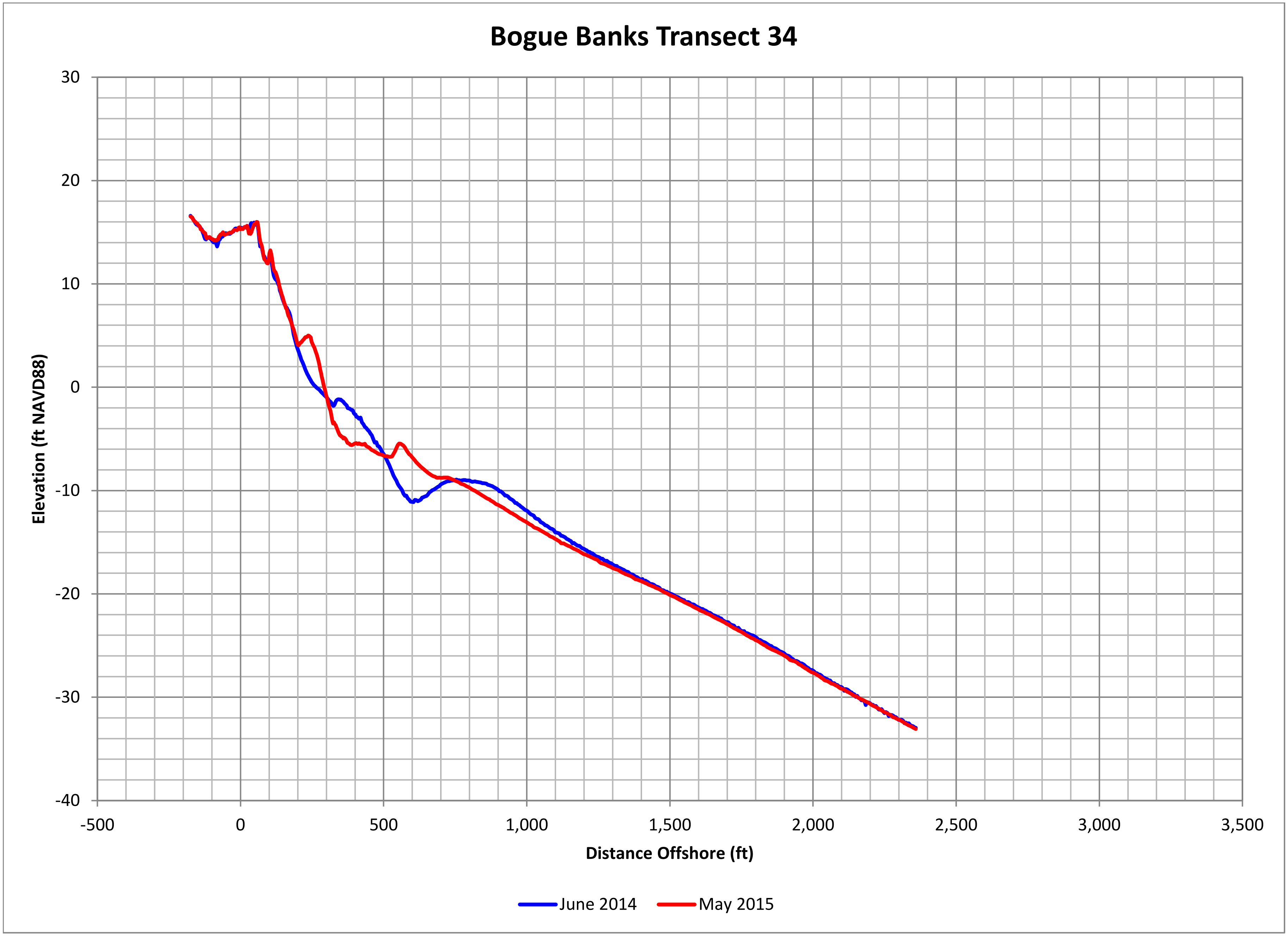


Figure C-41. Bogue Banks Profile Comparison Plot

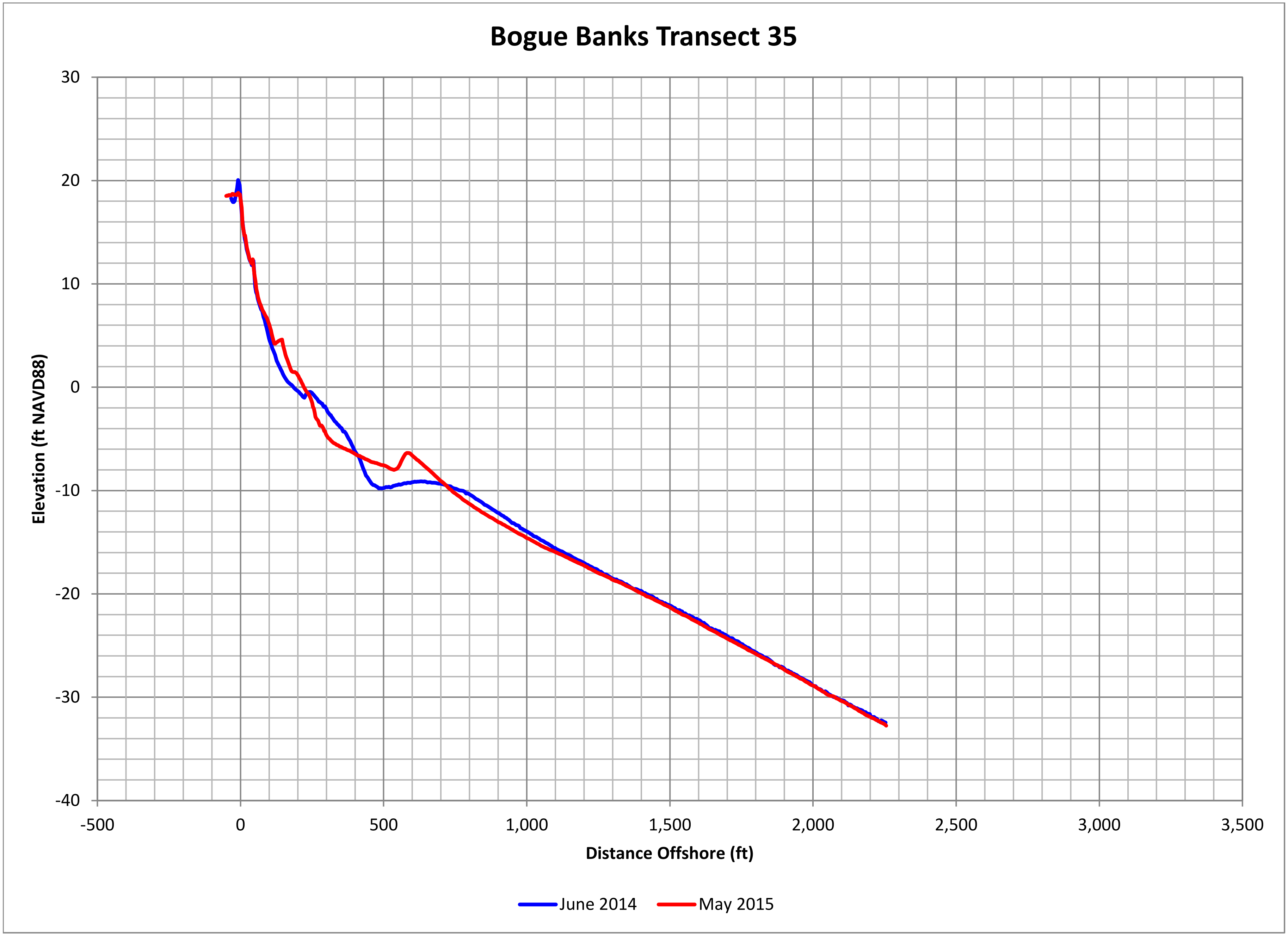


Figure C-42. Bogue Banks Profile Comparison Plot

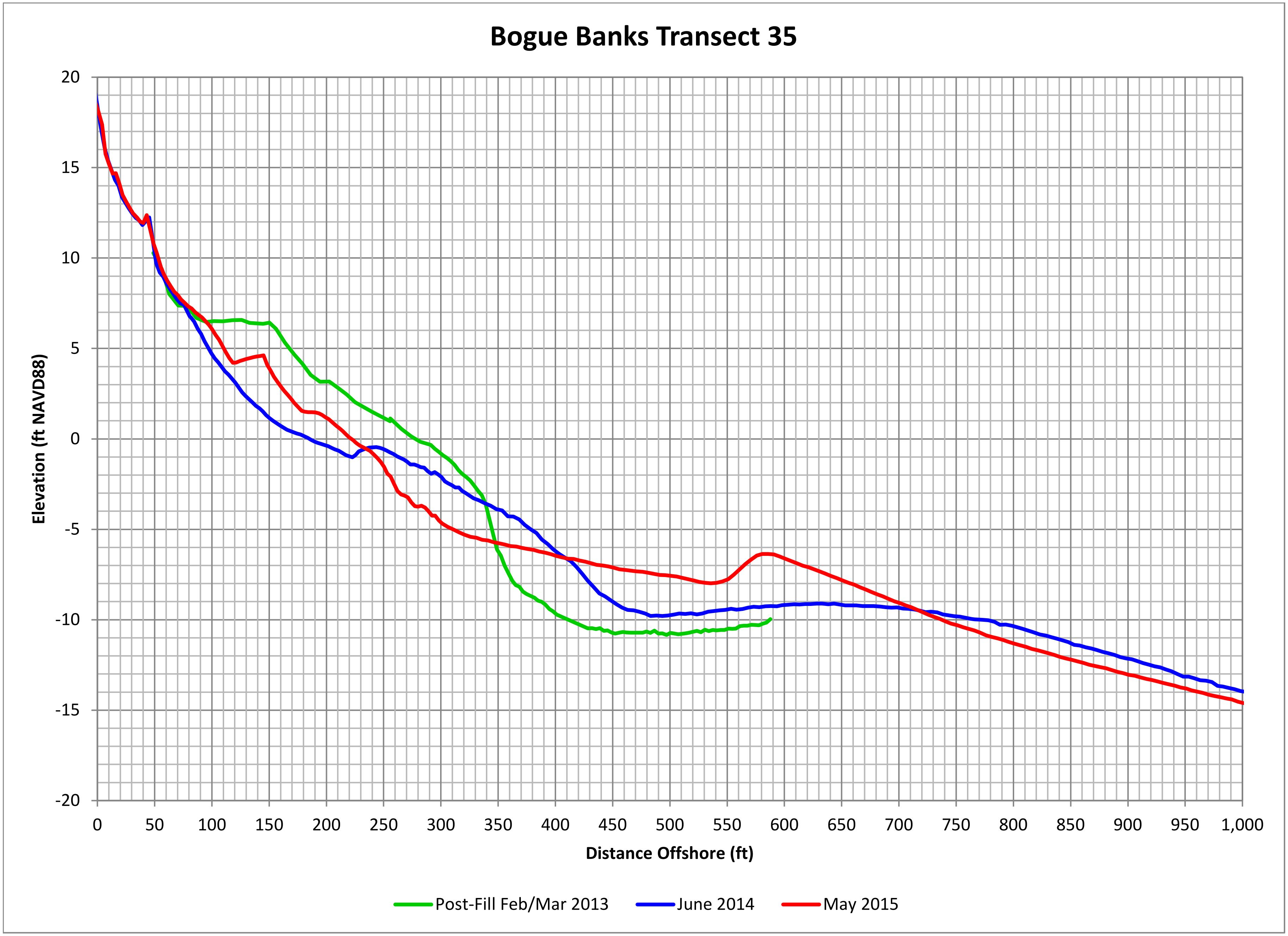


Figure C-43. Bogue Banks Profile Comparison Plot

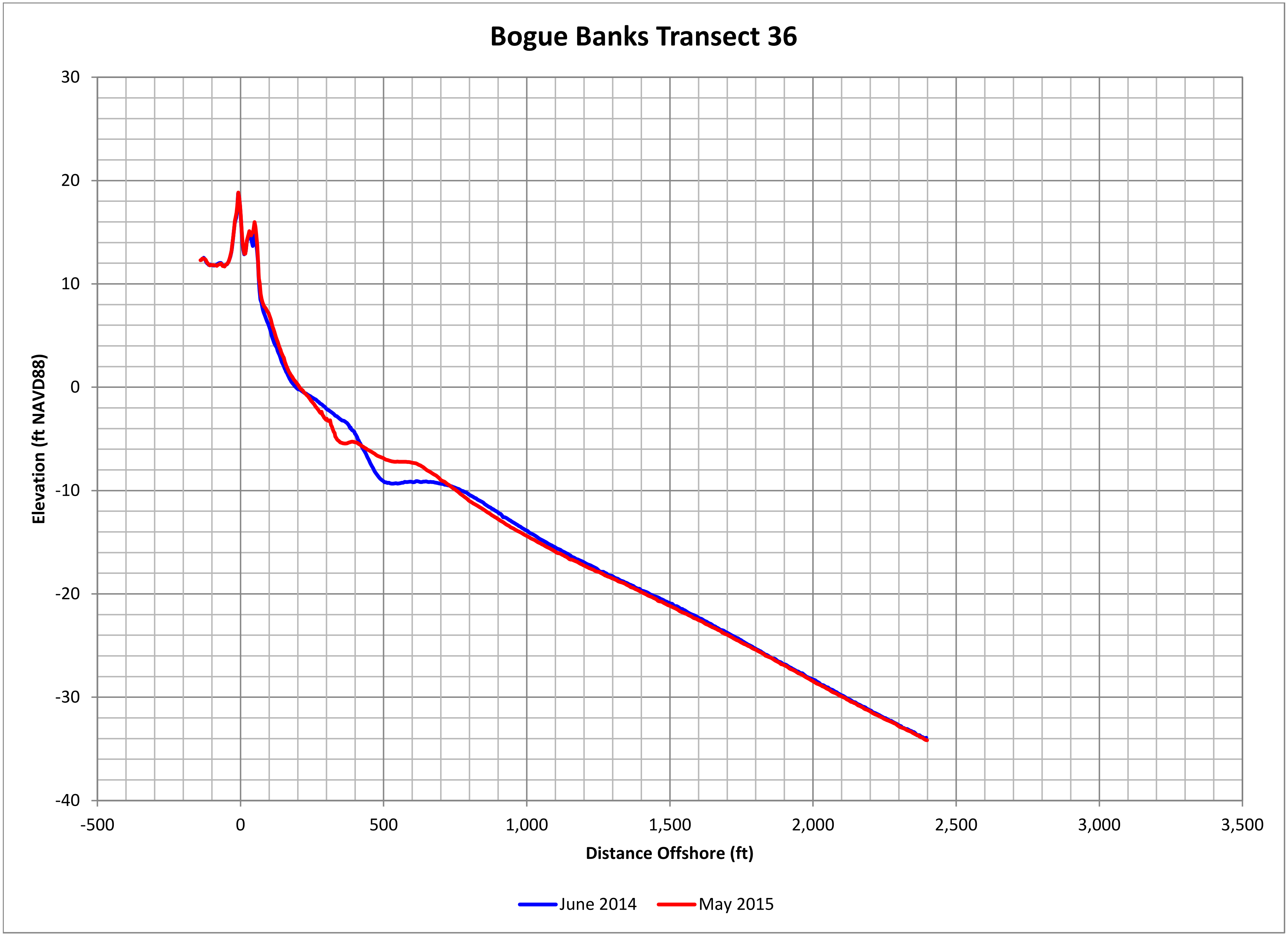


Figure C-44. Bogue Banks Profile Comparison Plot

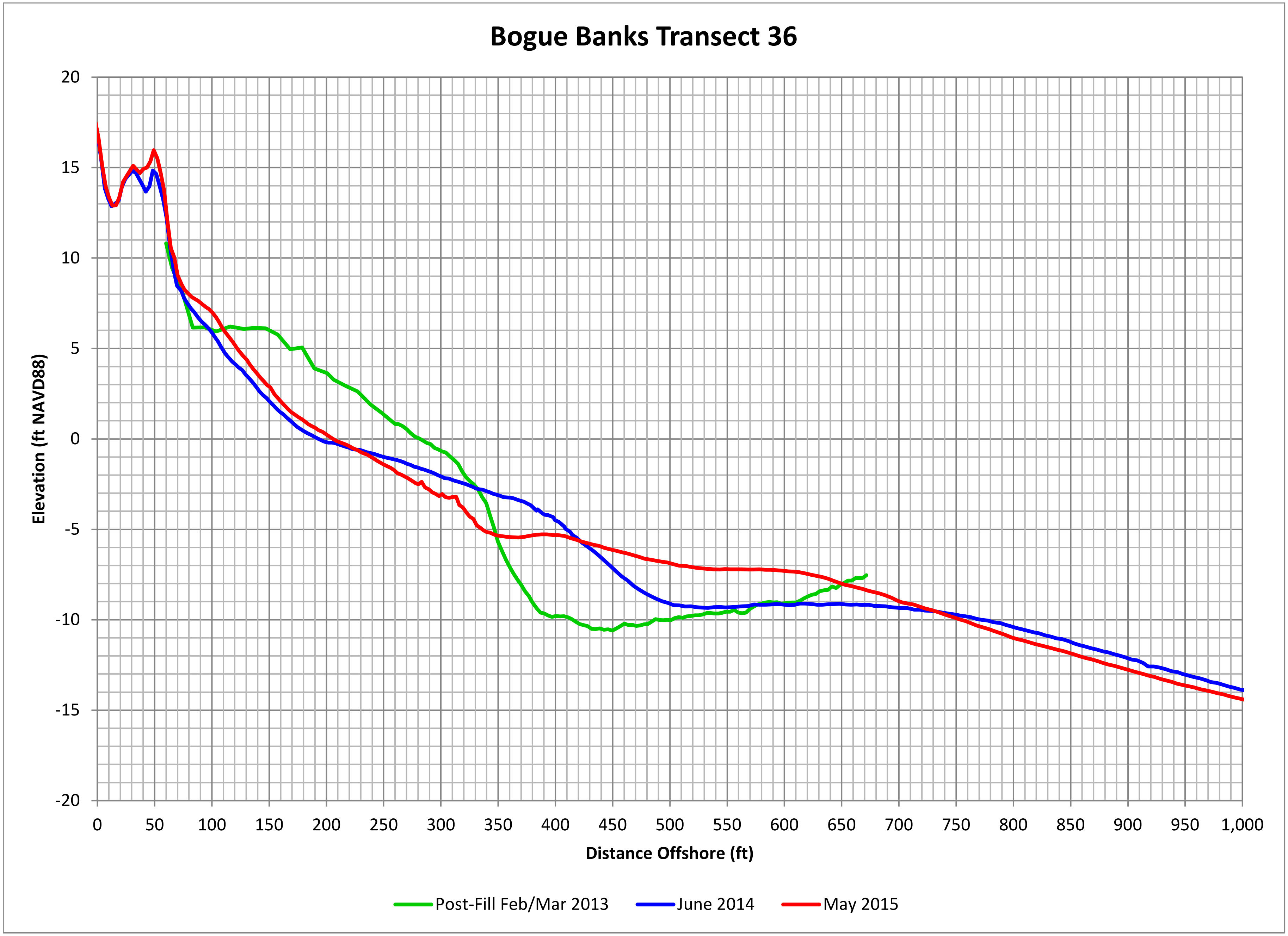


Figure C-45. Bogue Banks Profile Comparison Plot

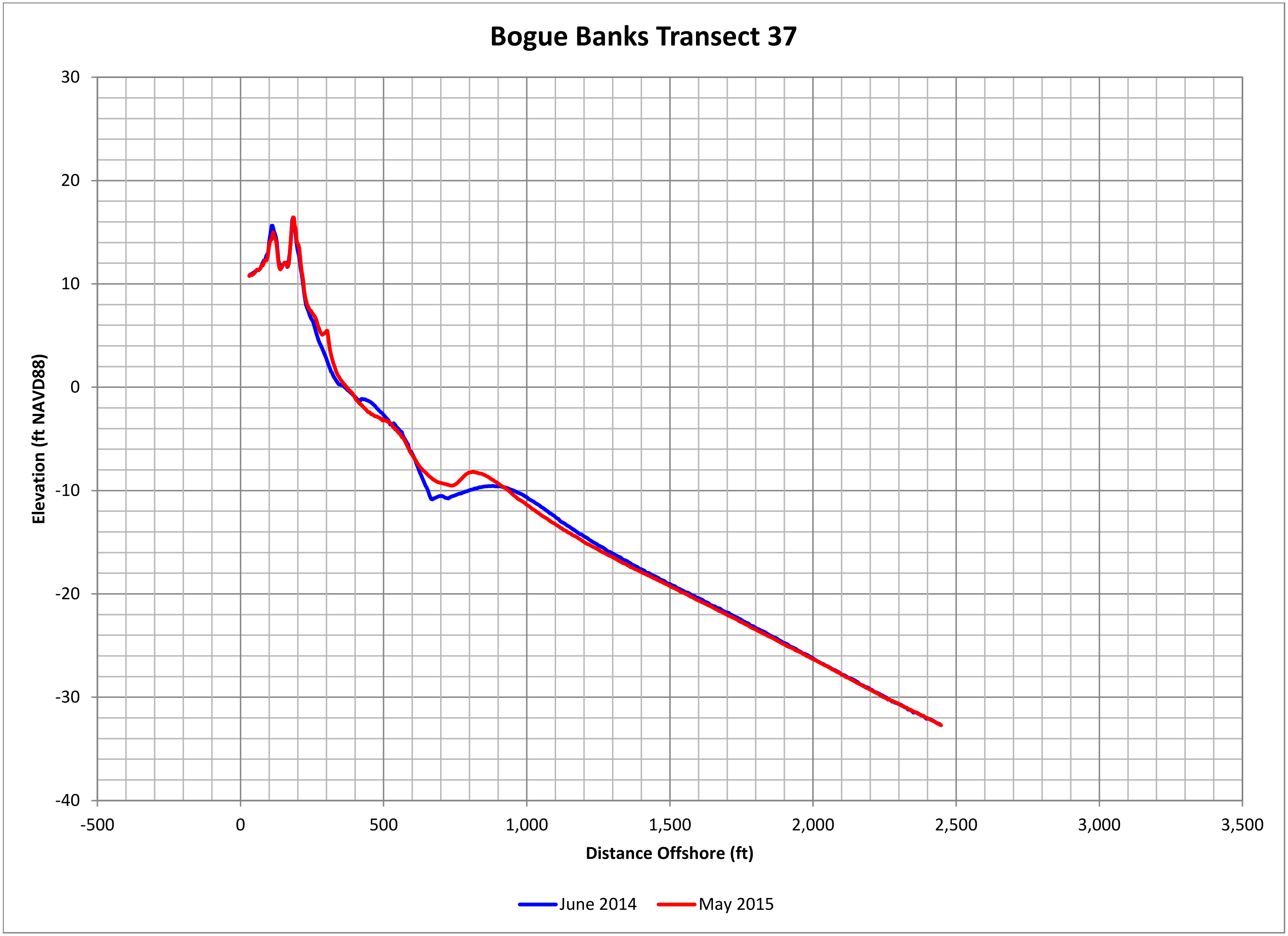


Figure C-46. Bogue Banks Profile Comparison Plot

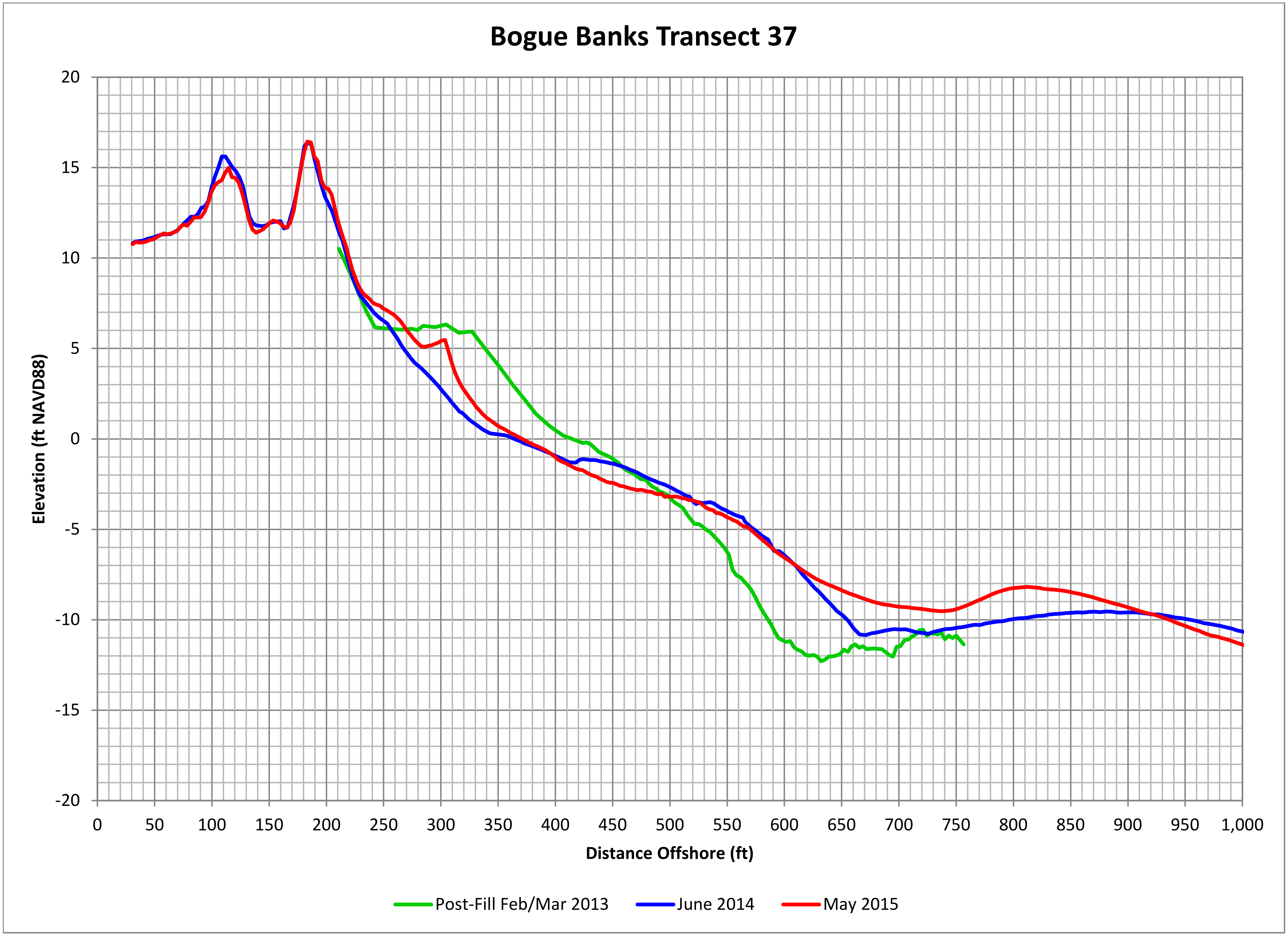


Figure C-47. Bogue Banks Profile Comparison Plot

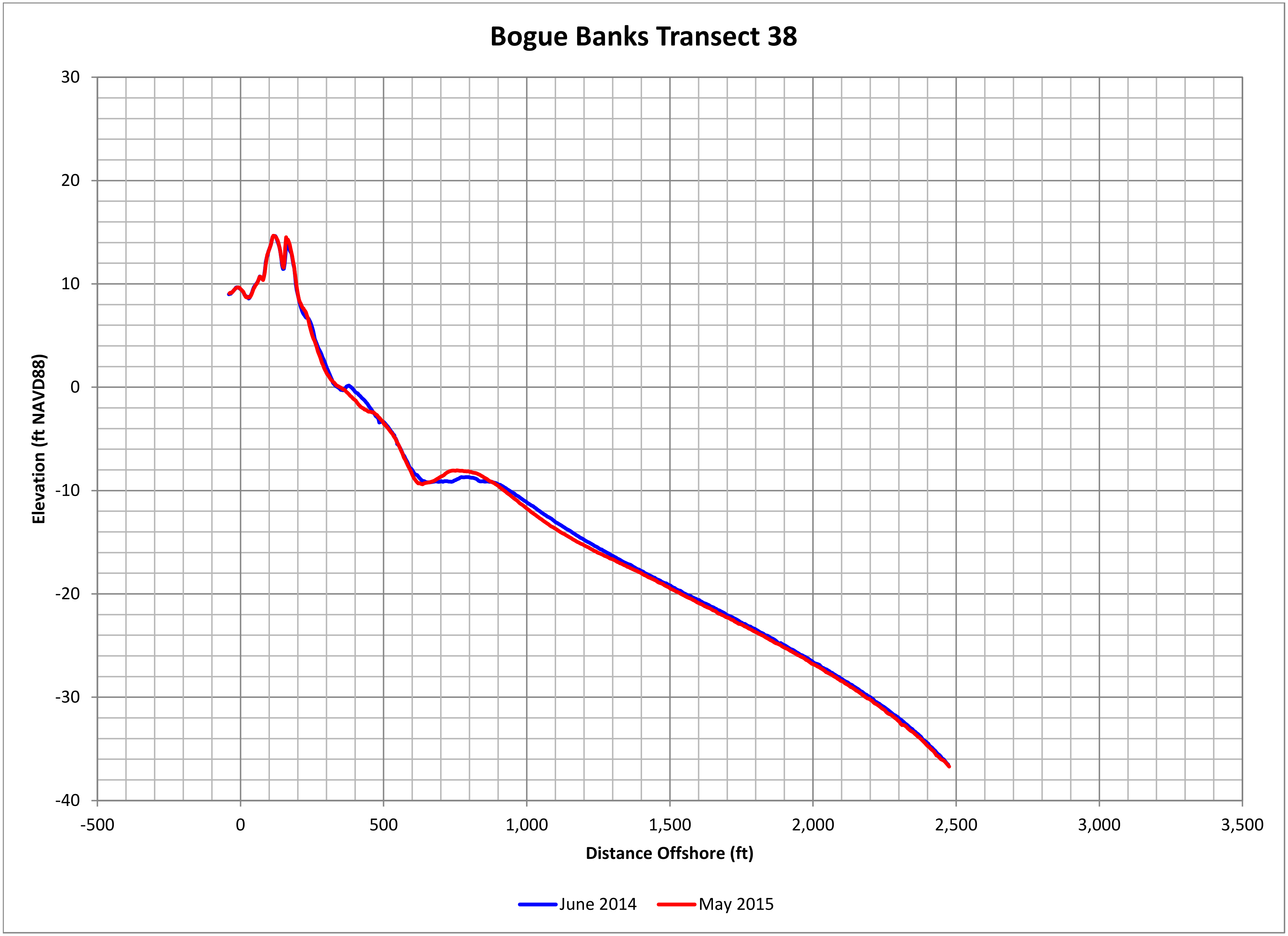


Figure C-48. Bogue Banks Profile Comparison Plot

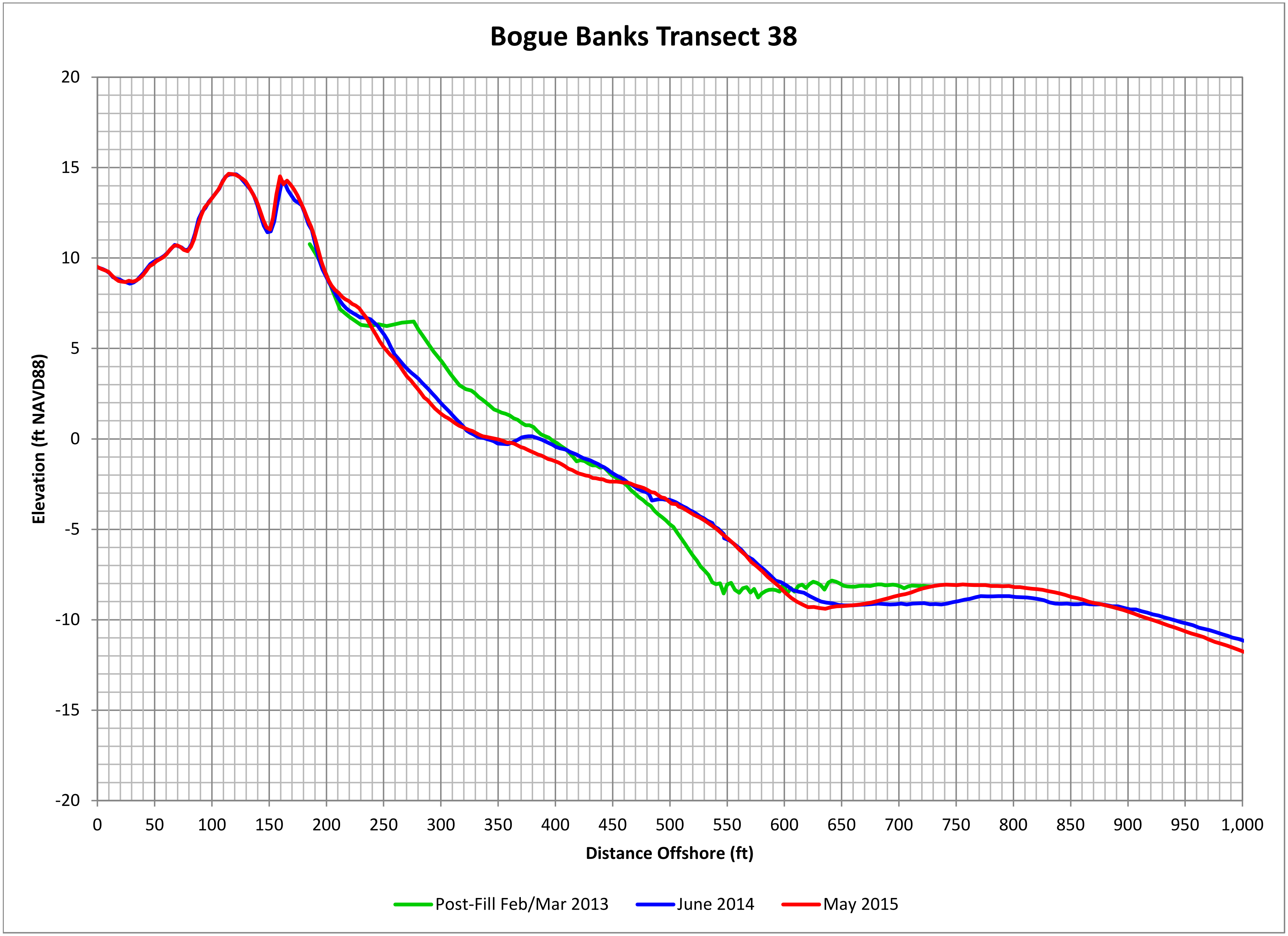


Figure C-49. Bogue Banks Profile Comparison Plot

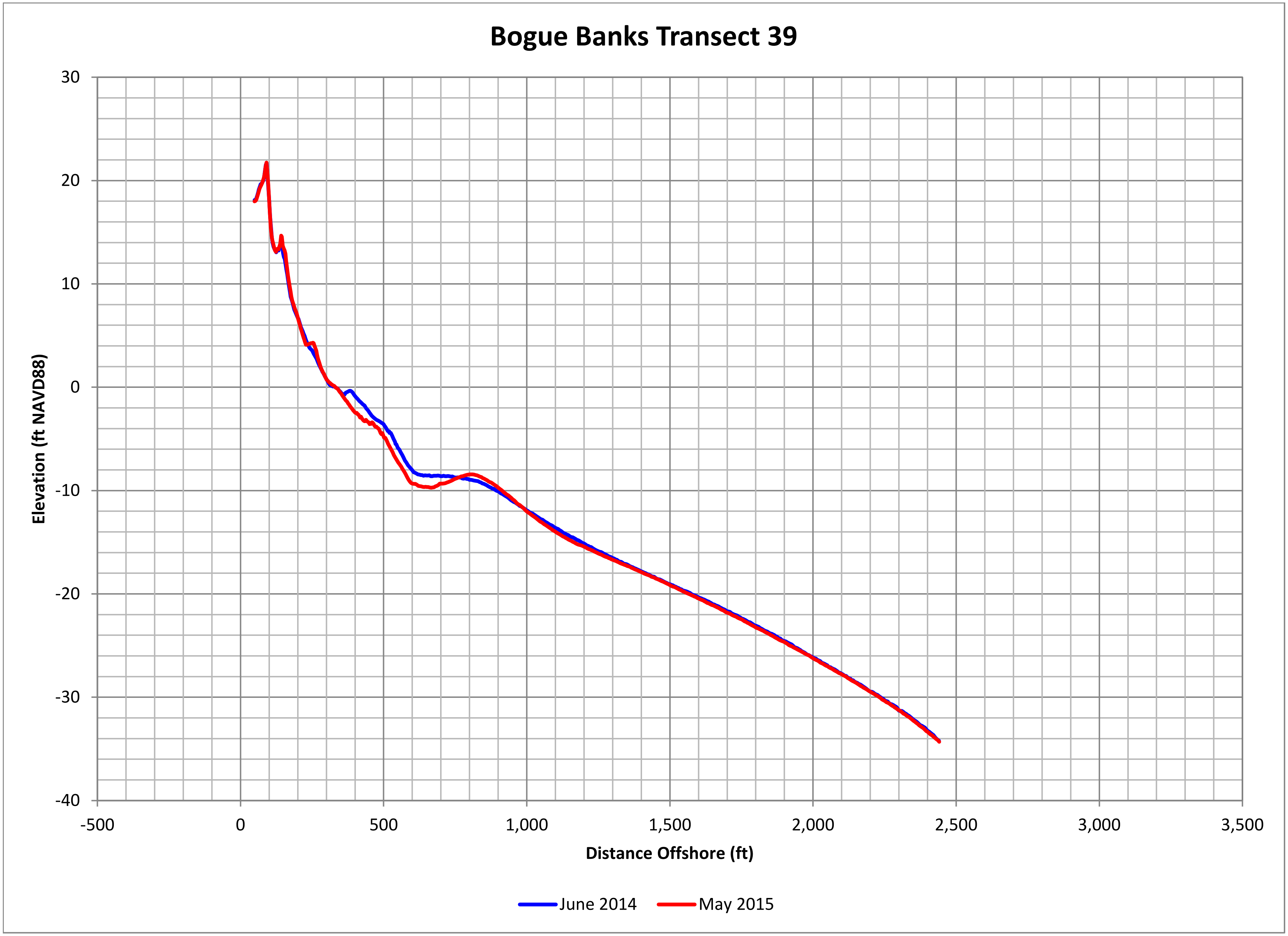


Figure C-50. Bogue Banks Profile Comparison Plot

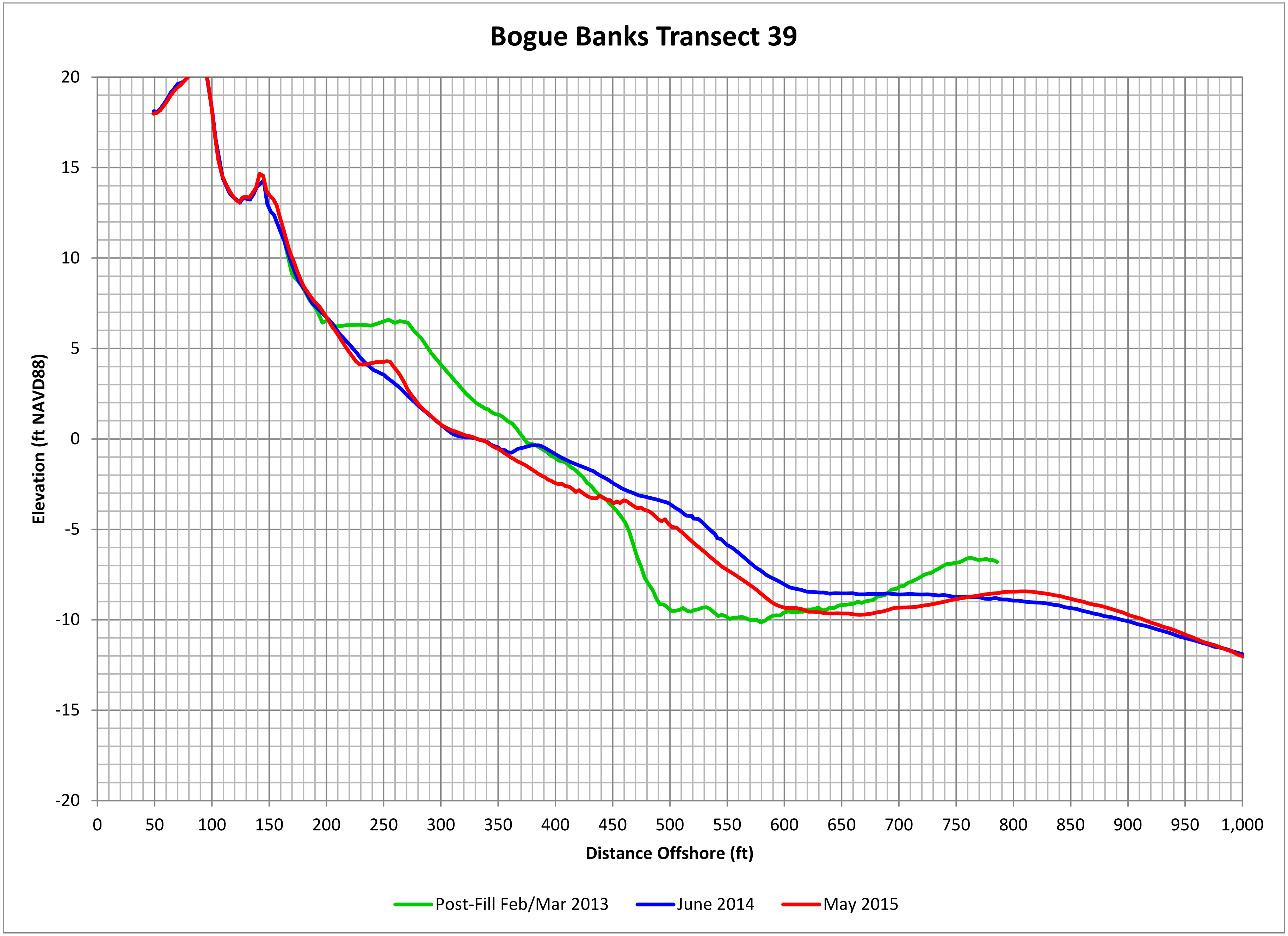


Figure C-51. Bogue Banks Profile Comparison Plot

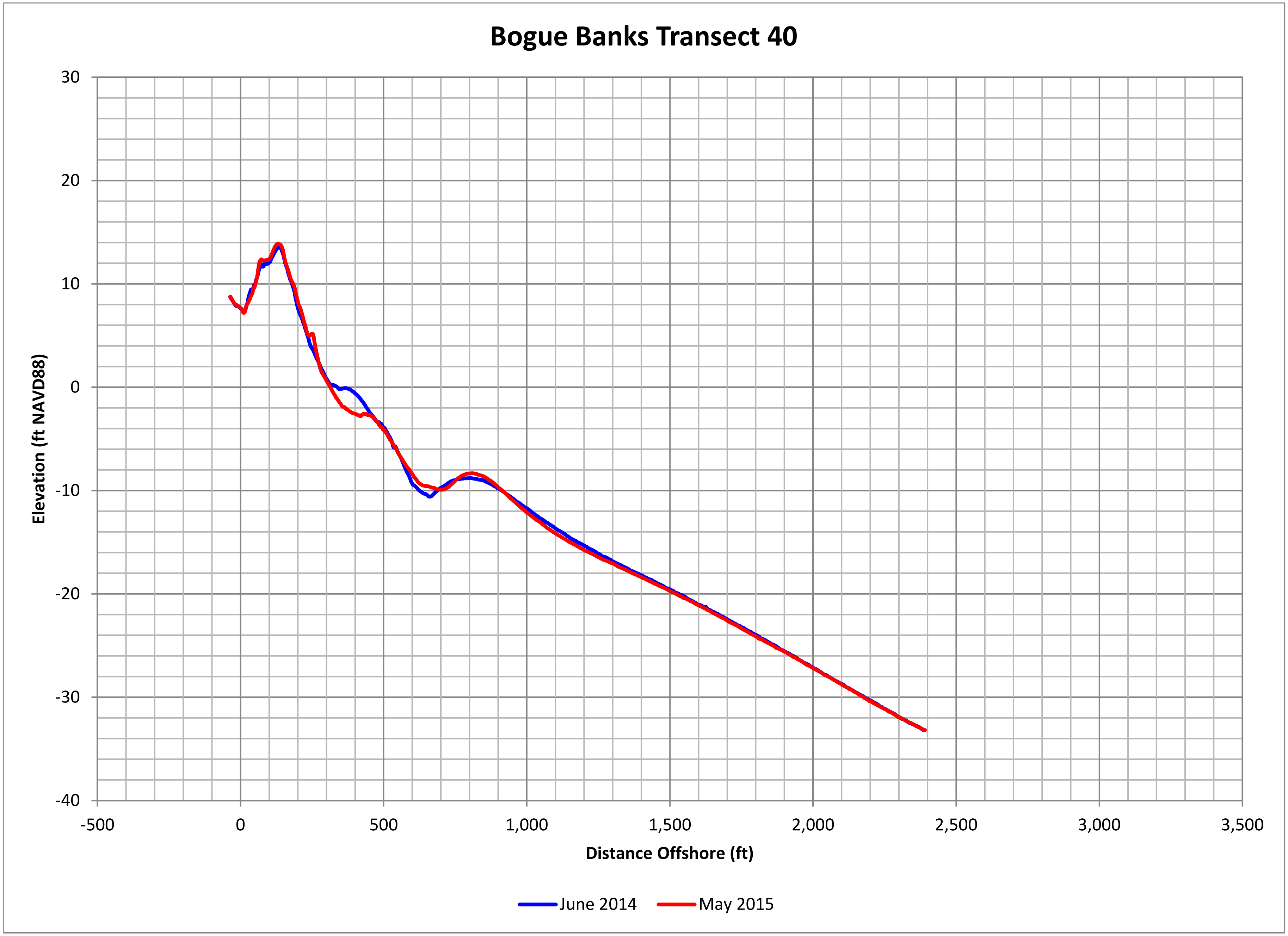


Figure C-52. Bogue Banks Profile Comparison Plot

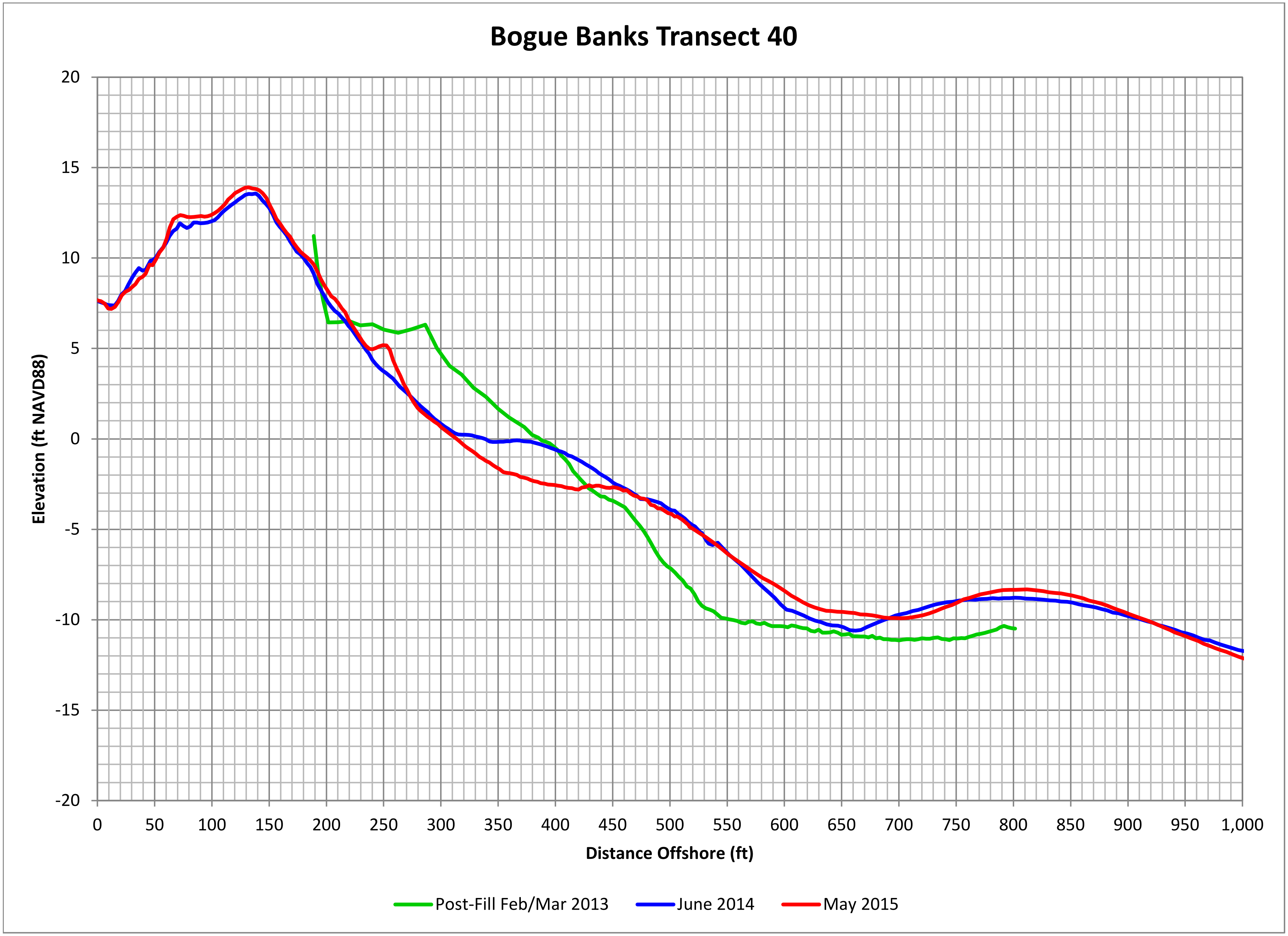


Figure C-53. Bogue Banks Profile Comparison Plot

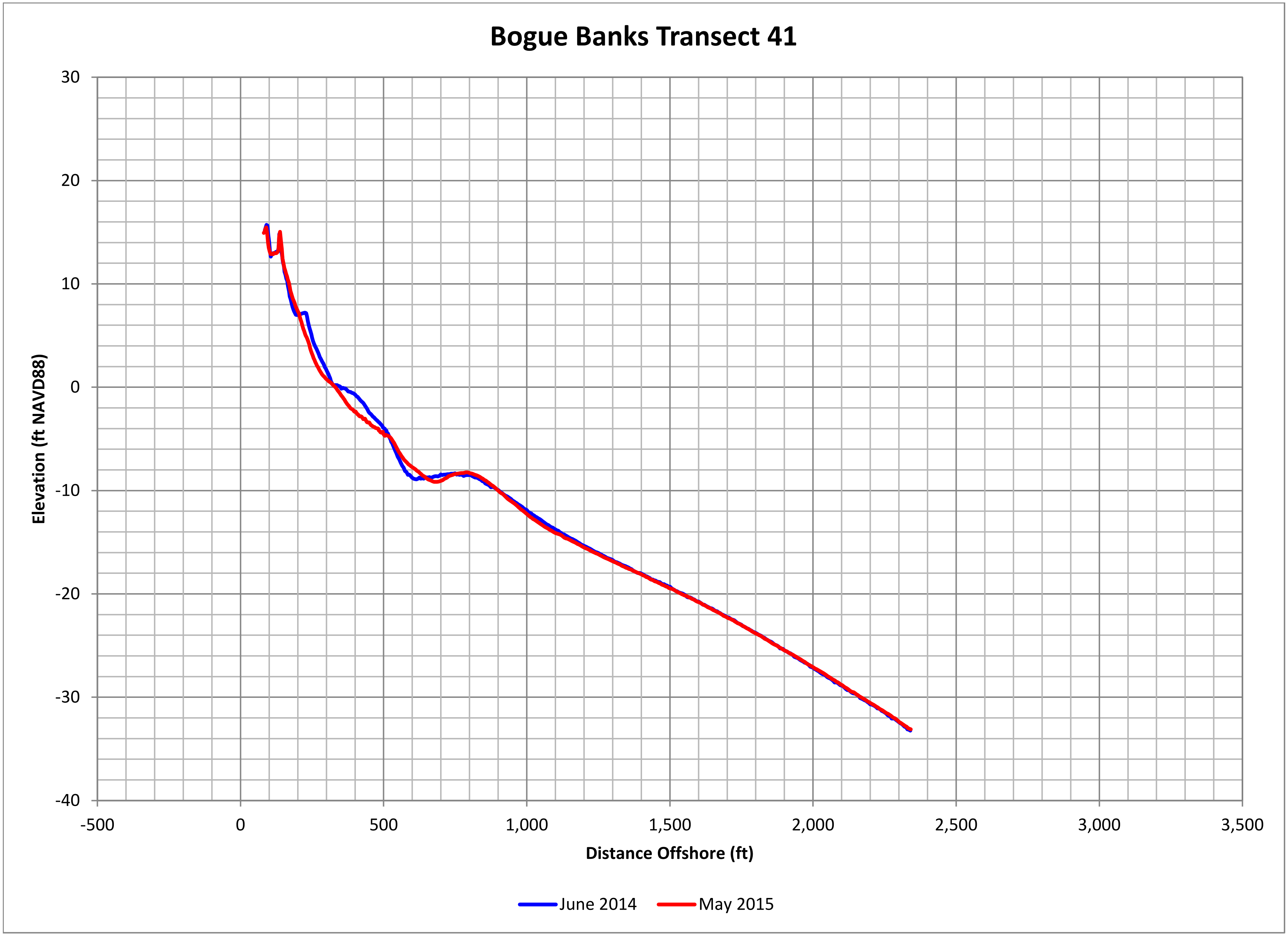


Figure C-54. Bogue Banks Profile Comparison Plot

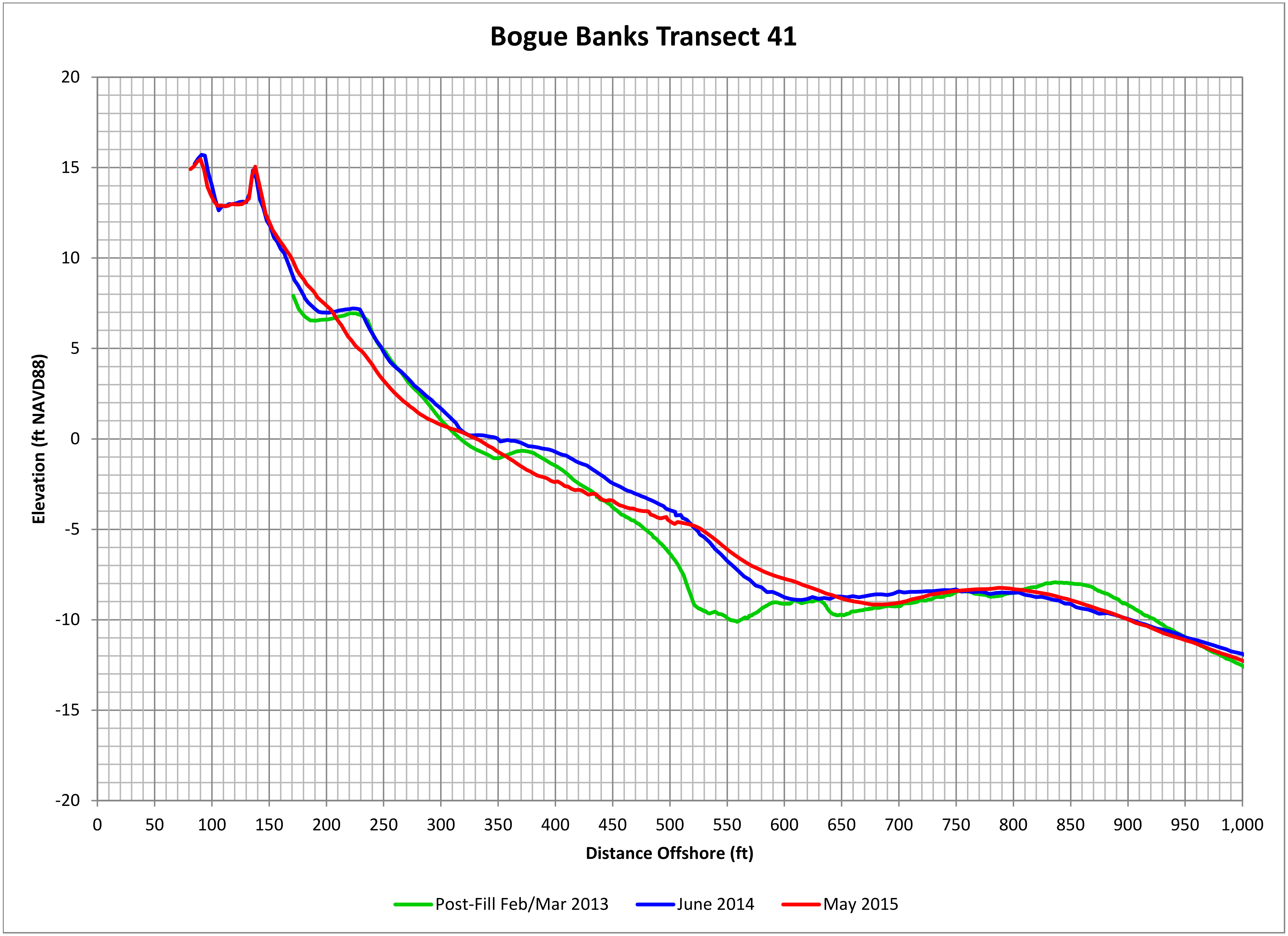


Figure C-55. Bogue Banks Profile Comparison Plot

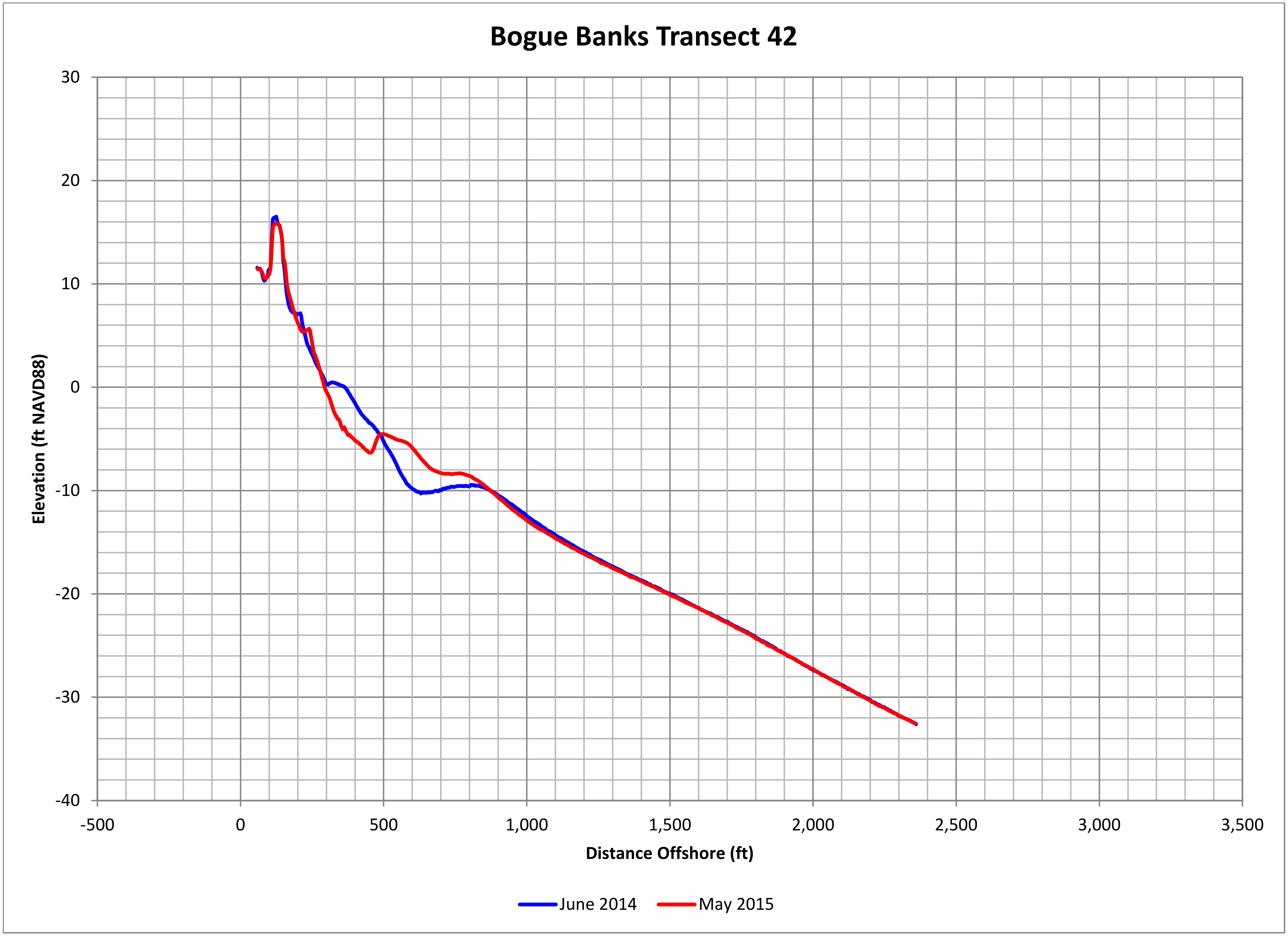


Figure C-56. Bogue Banks Profile Comparison Plot

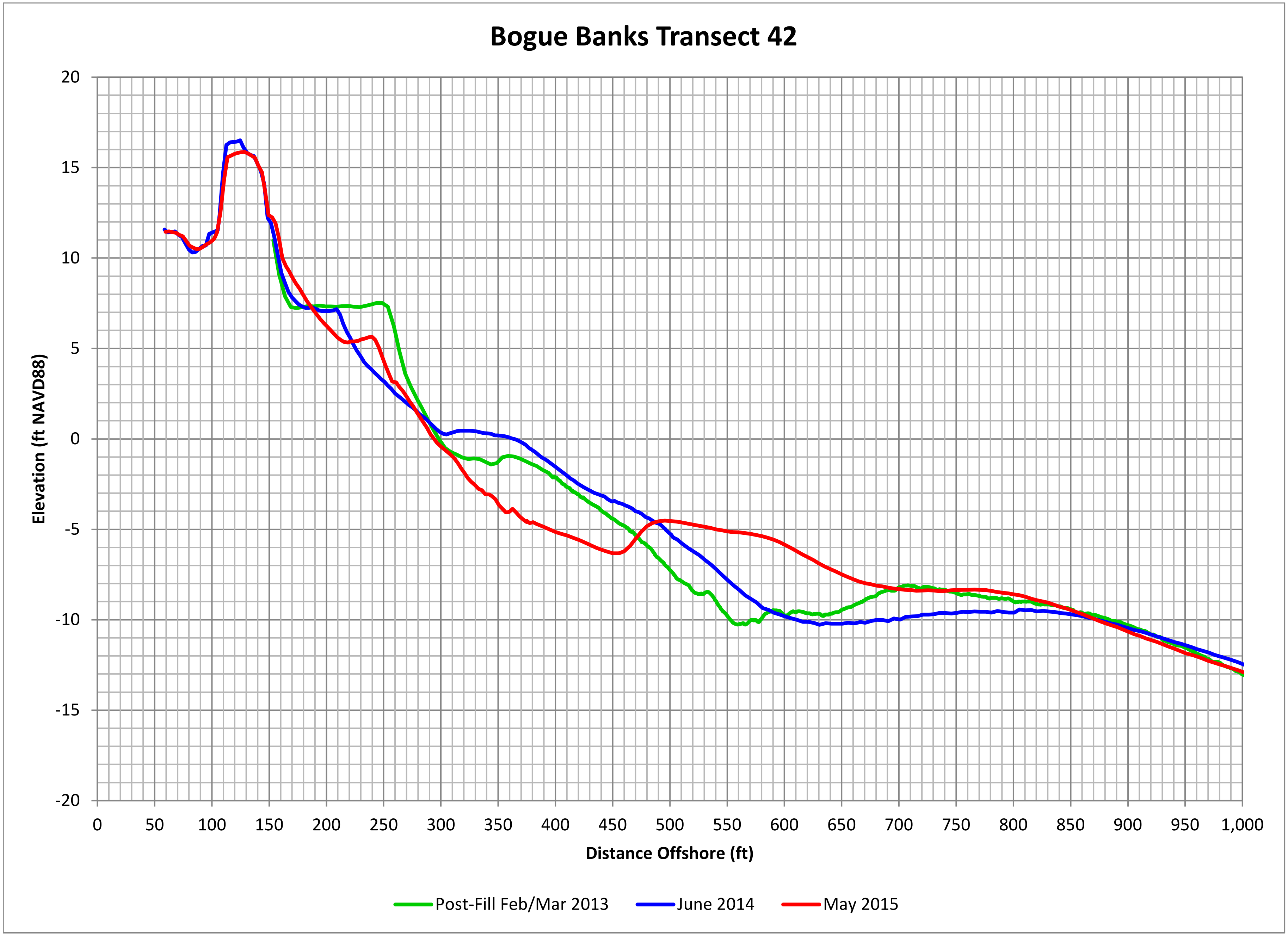


Figure C-57. Bogue Banks Profile Comparison Plot

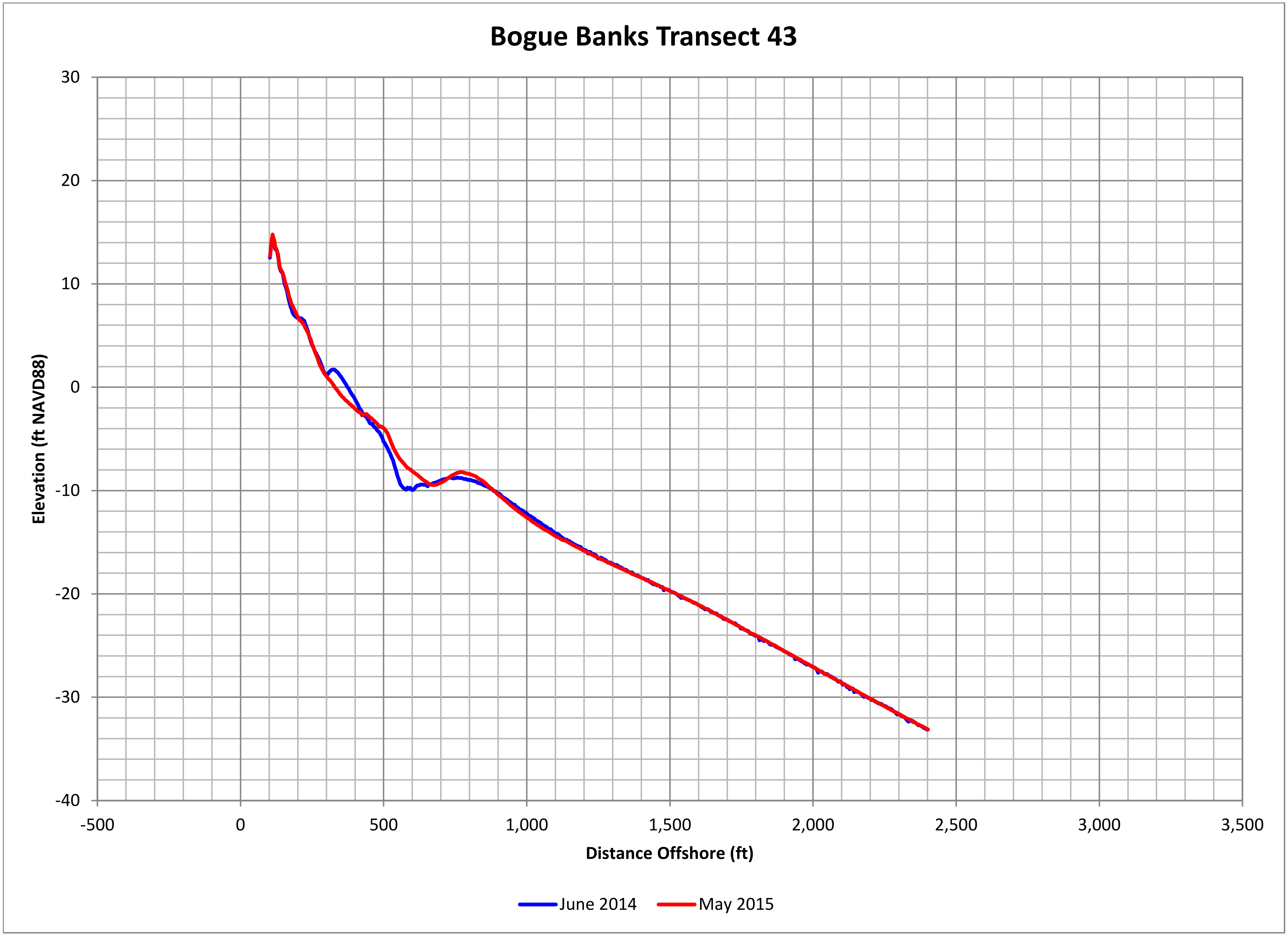


Figure C-58. Bogue Banks Profile Comparison Plot

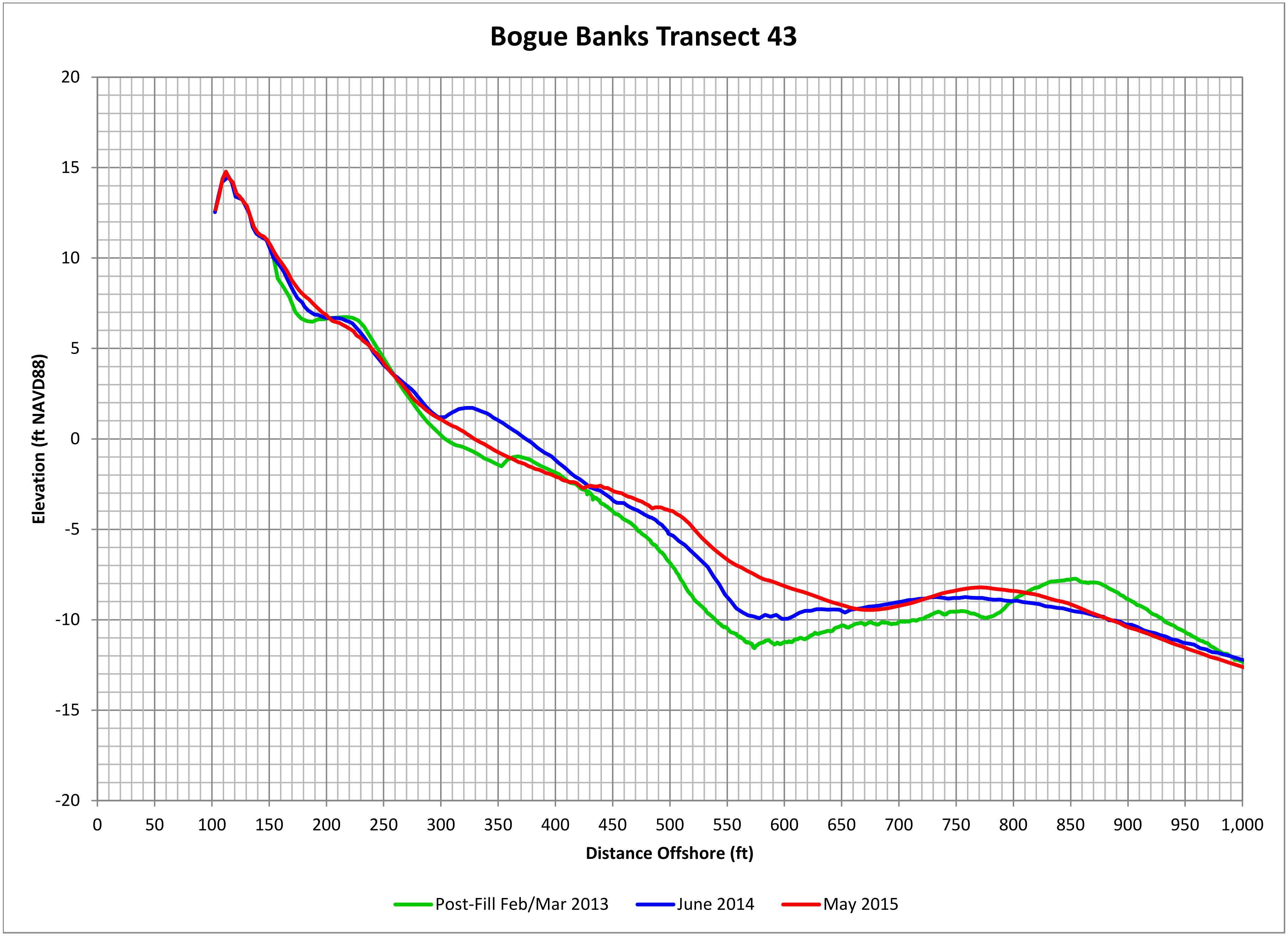


Figure C-59. Bogue Banks Profile Comparison Plot

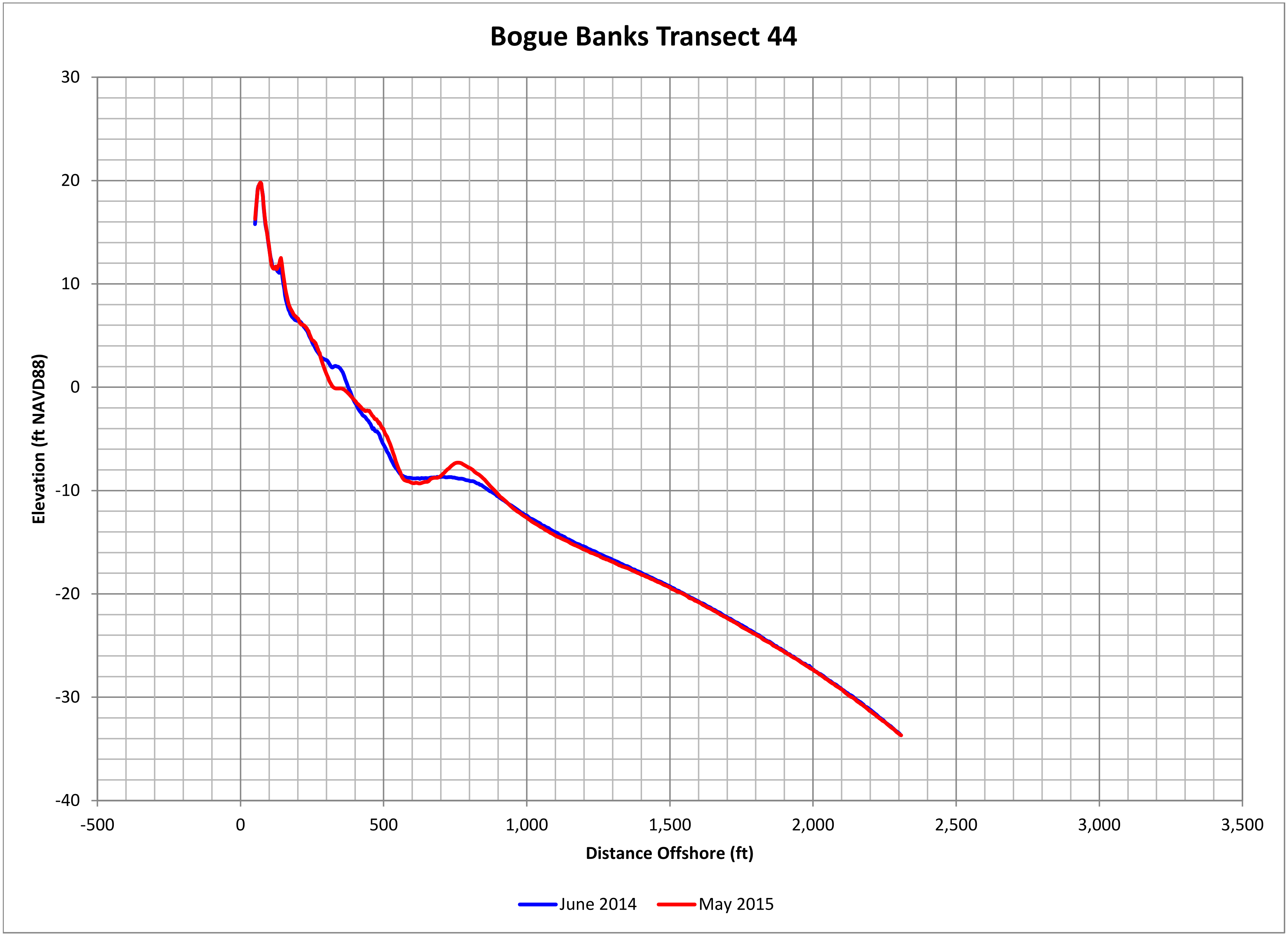


Figure C-60. Bogue Banks Profile Comparison Plot

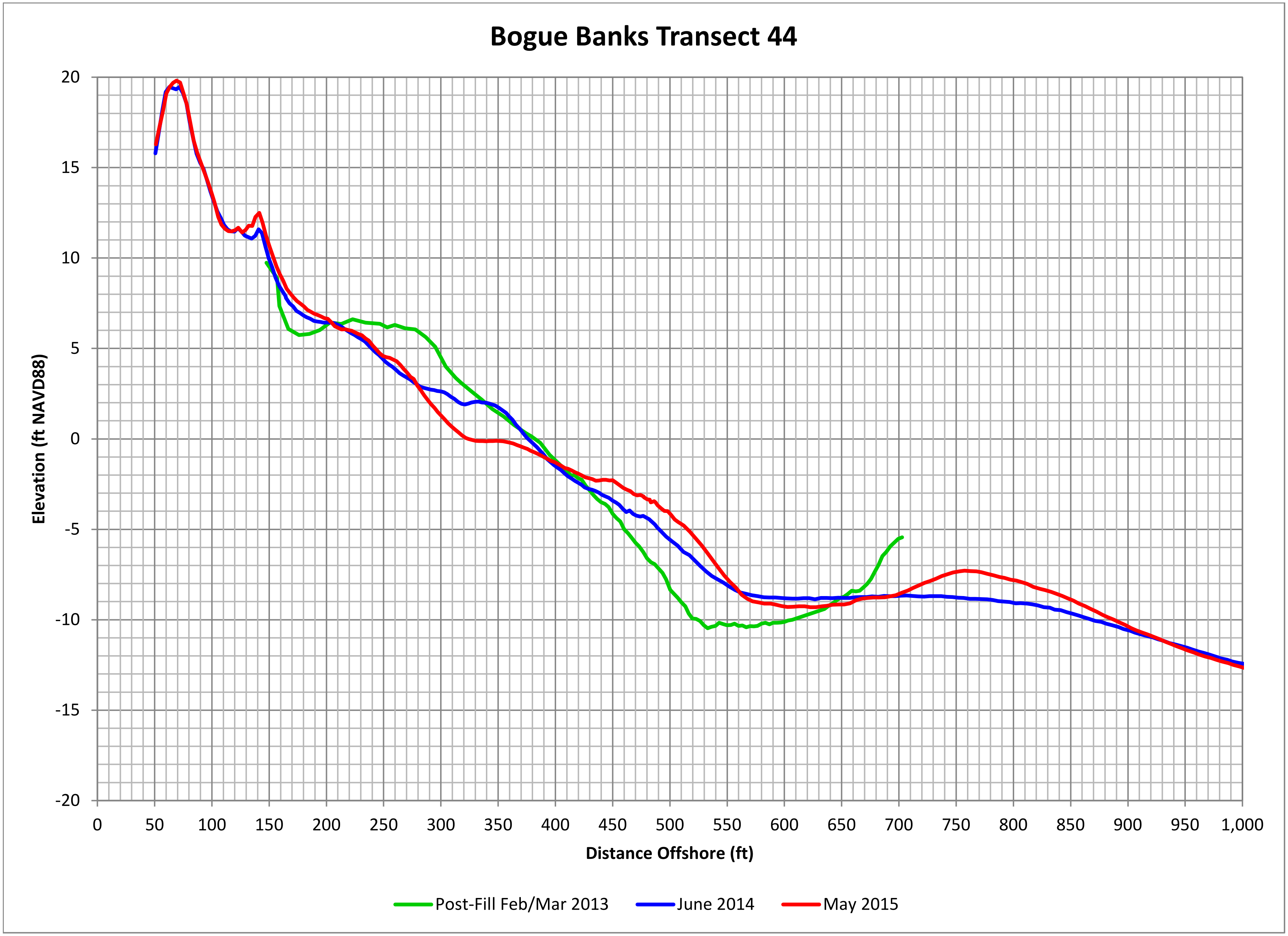


Figure C-61. Bogue Banks Profile Comparison Plot

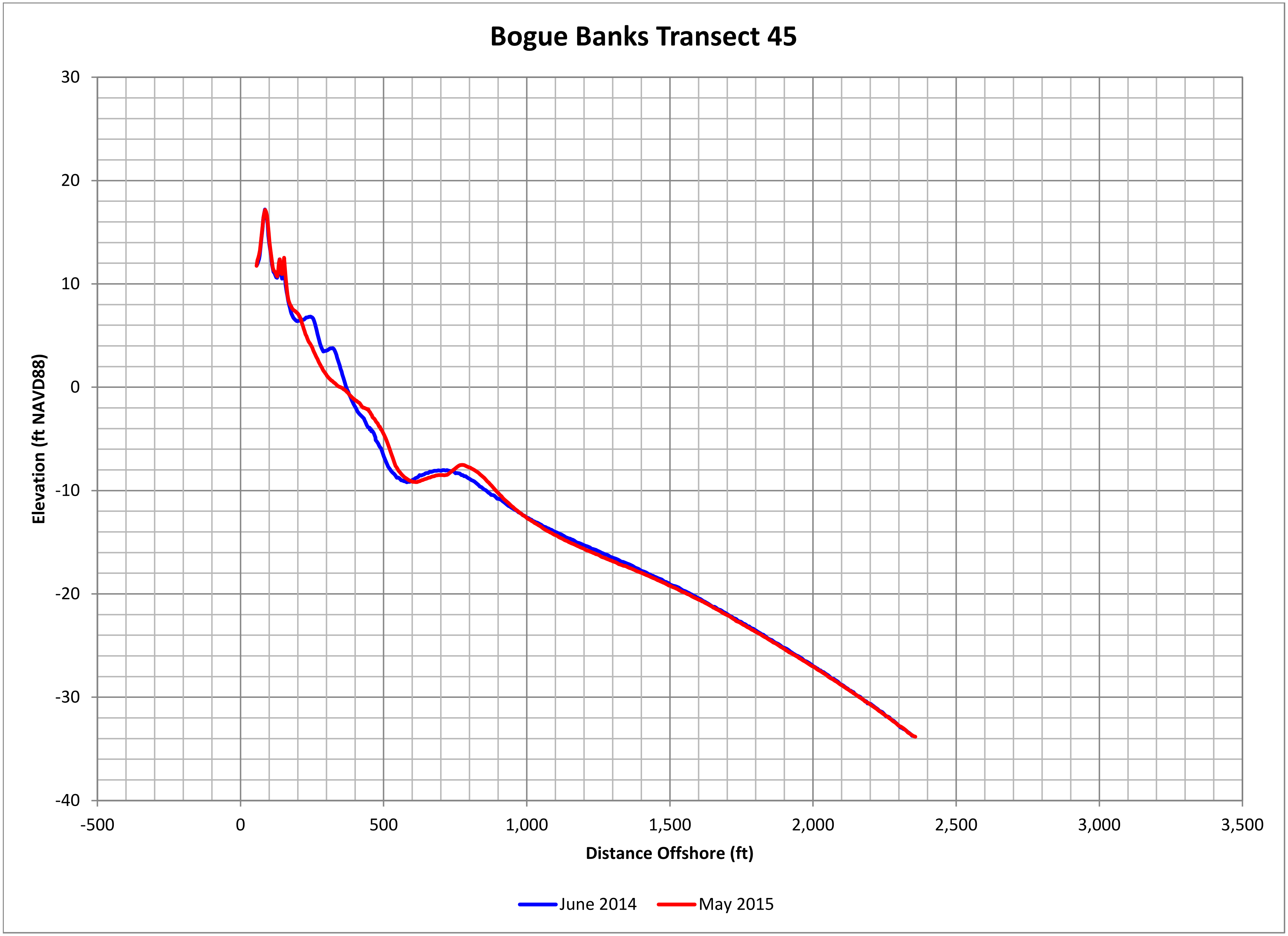


Figure C-62. Bogue Banks Profile Comparison Plot

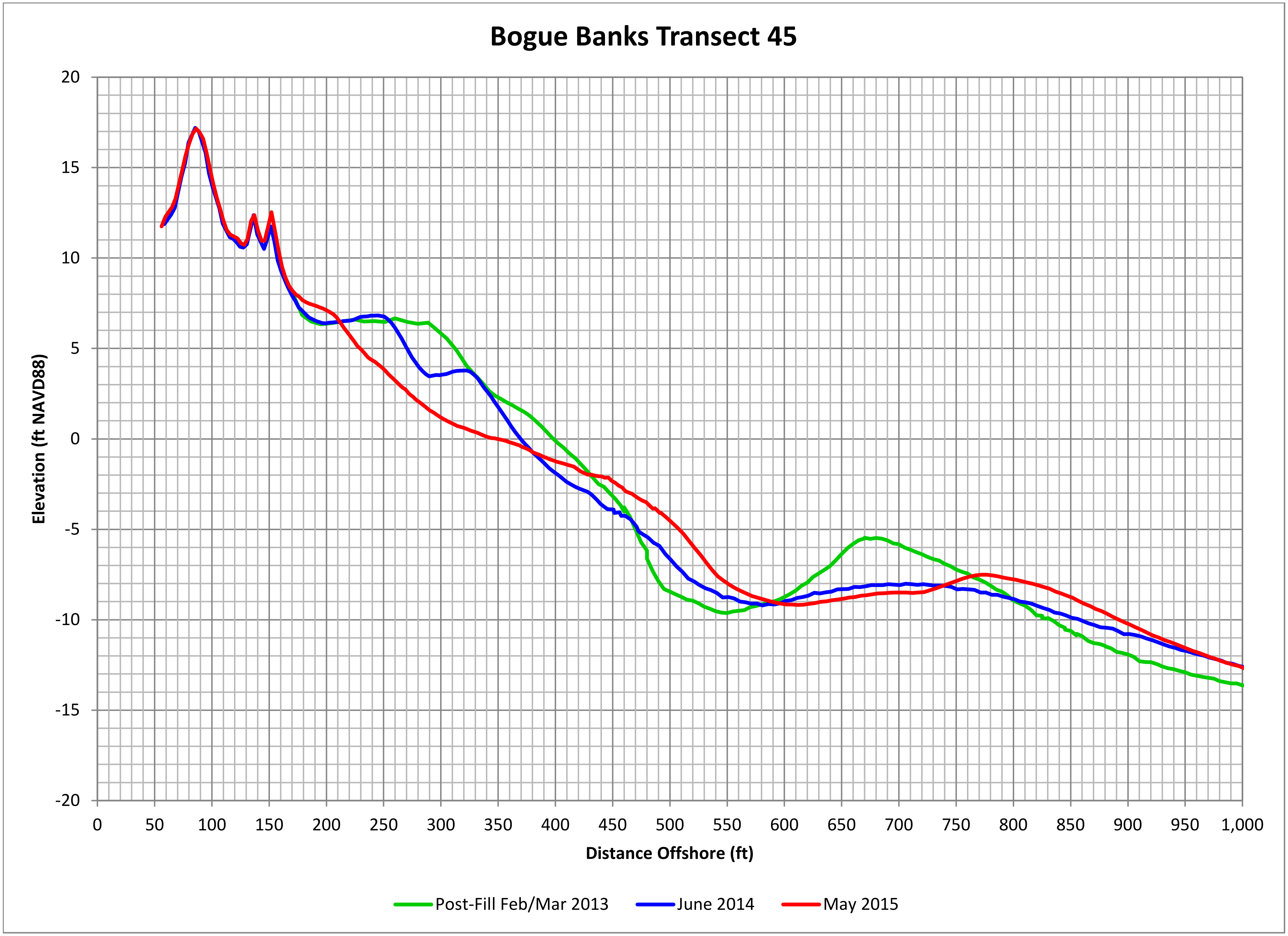


Figure C-63. Bogue Banks Profile Comparison Plot

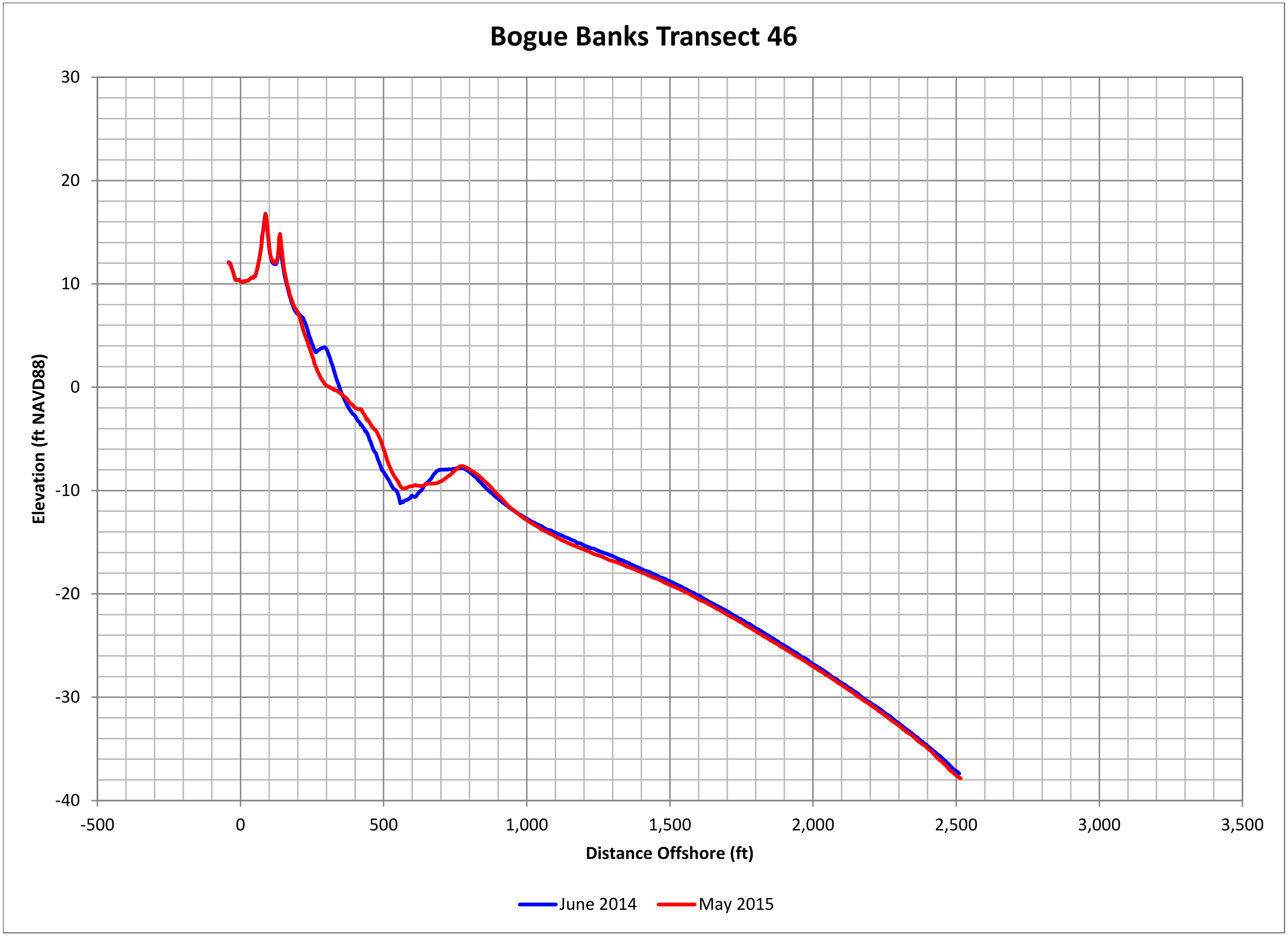


Figure C-64. Bogue Banks Profile Comparison Plot

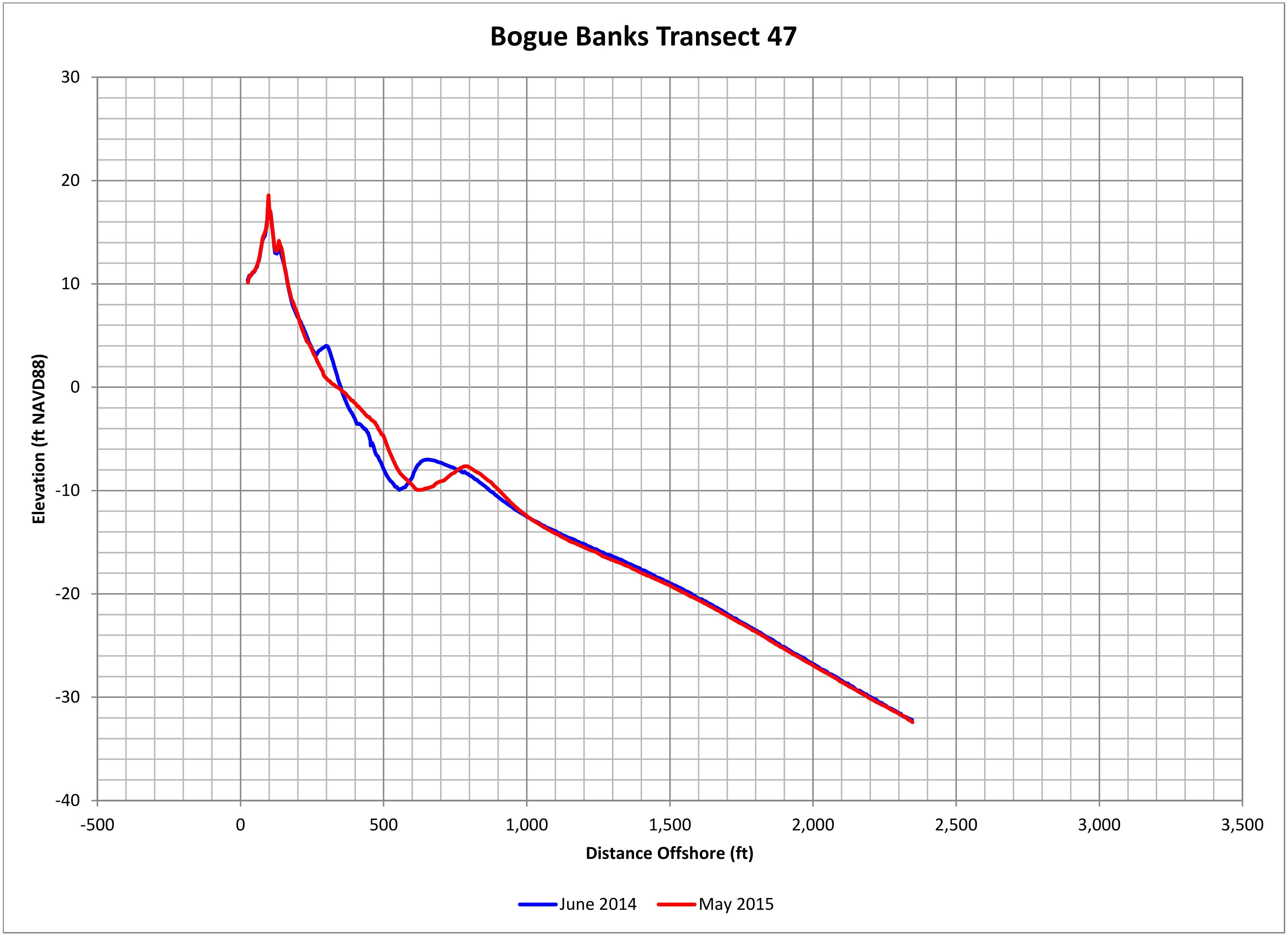


Figure C-65. Bogue Banks Profile Comparison Plot

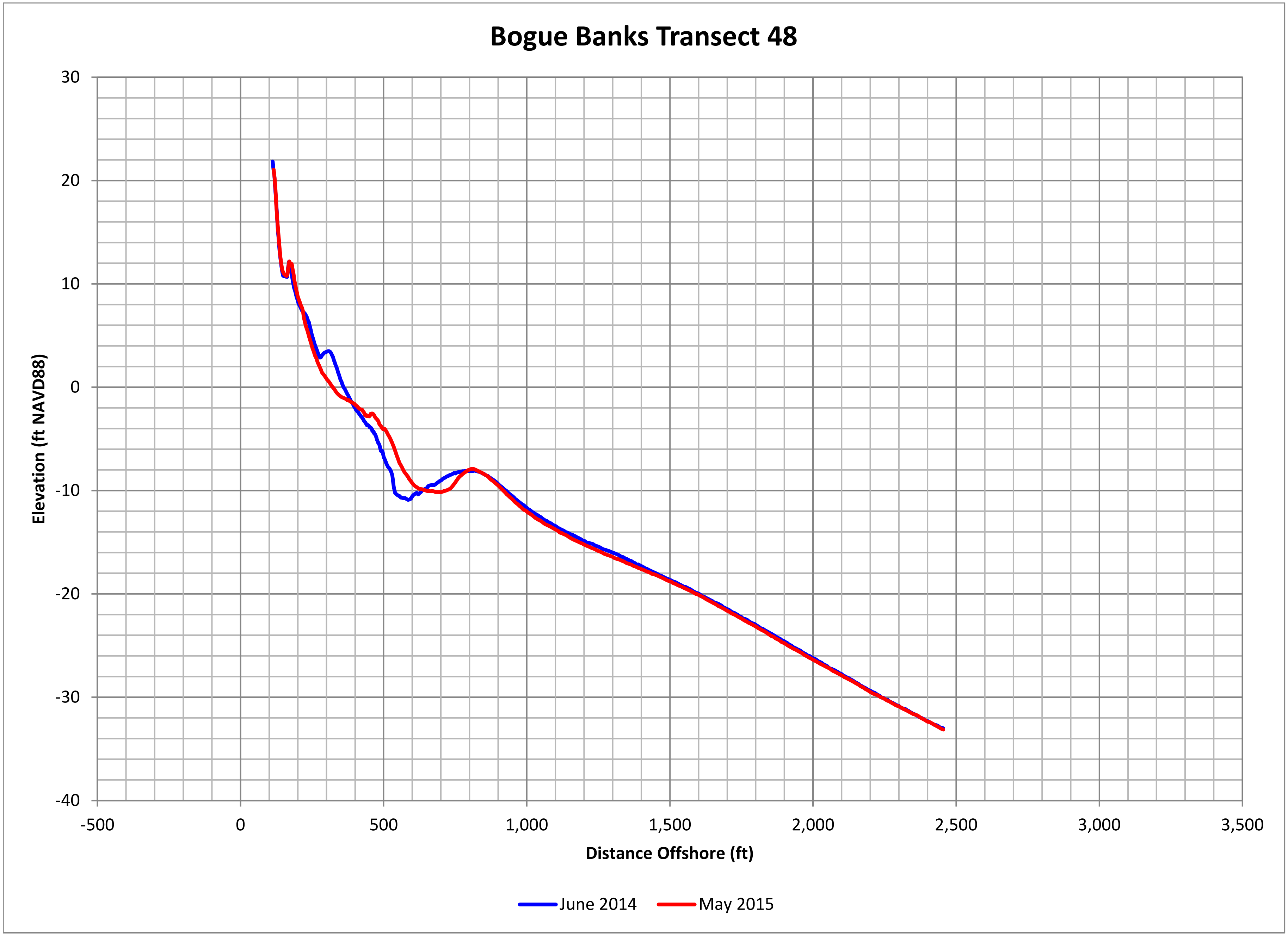


Figure C-66. Bogue Banks Profile Comparison Plot

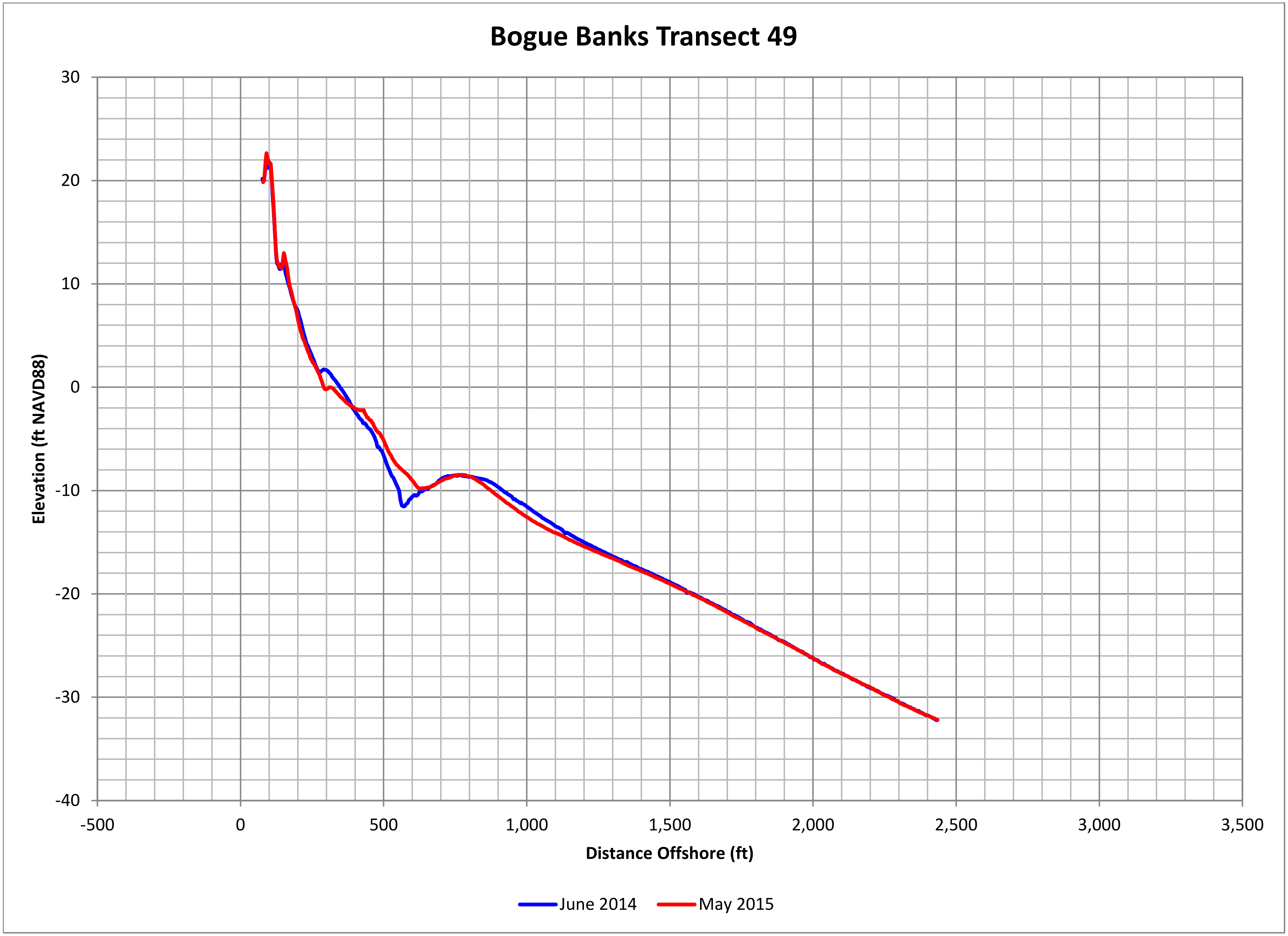


Figure C-67. Bogue Banks Profile Comparison Plot

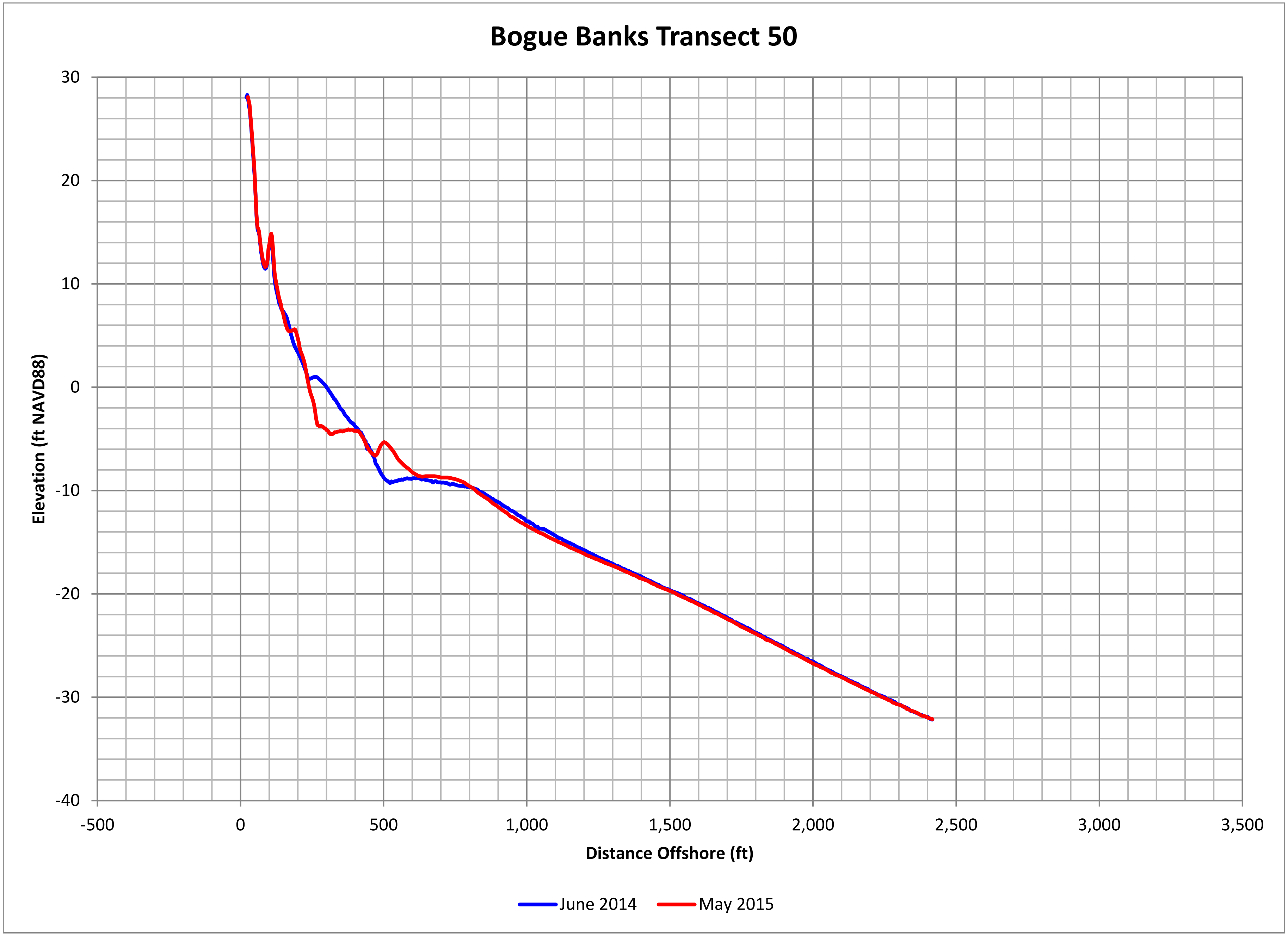


Figure C-68. Bogue Banks Profile Comparison Plot

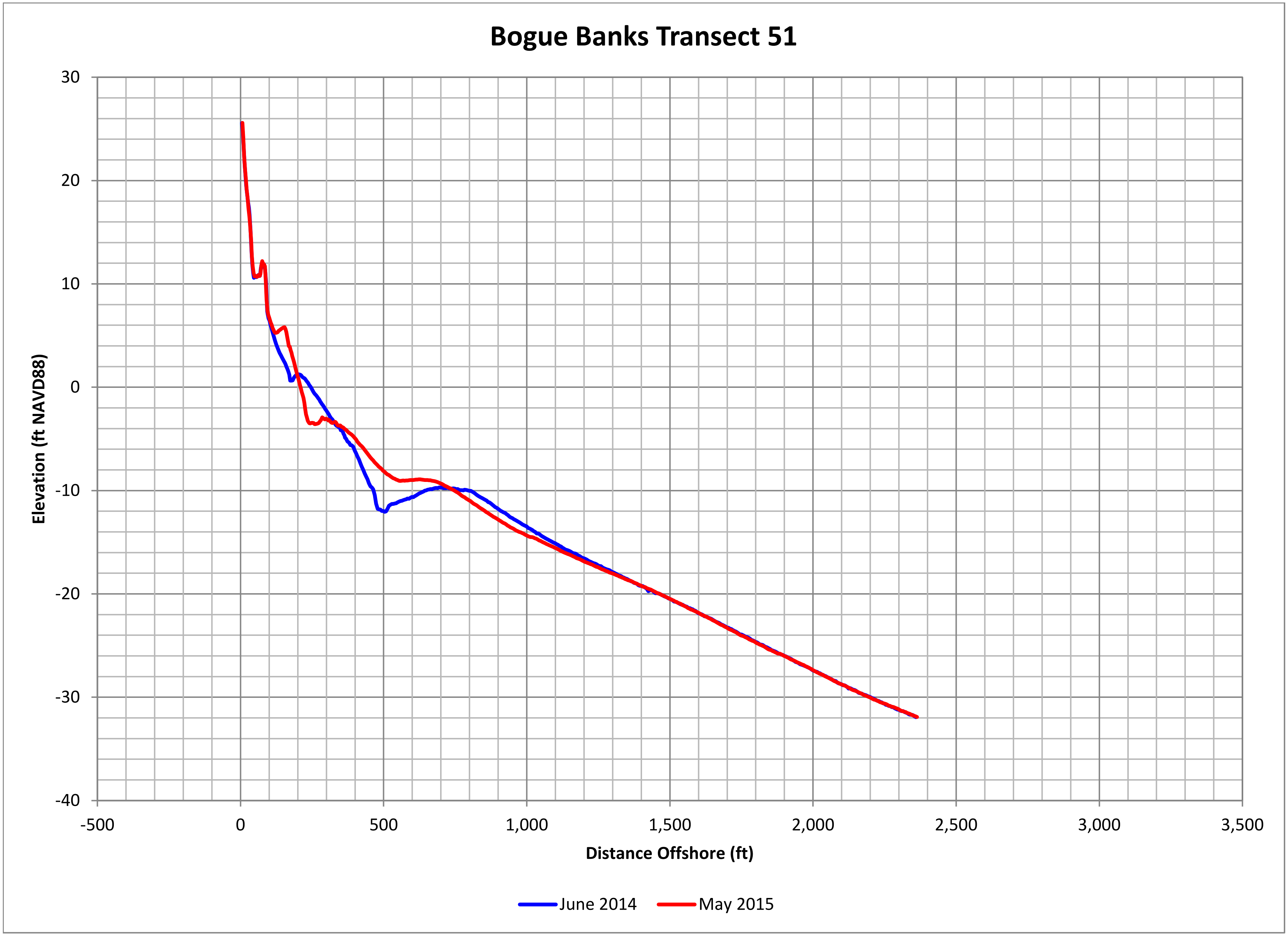


Figure C-69. Bogue Banks Profile Comparison Plot

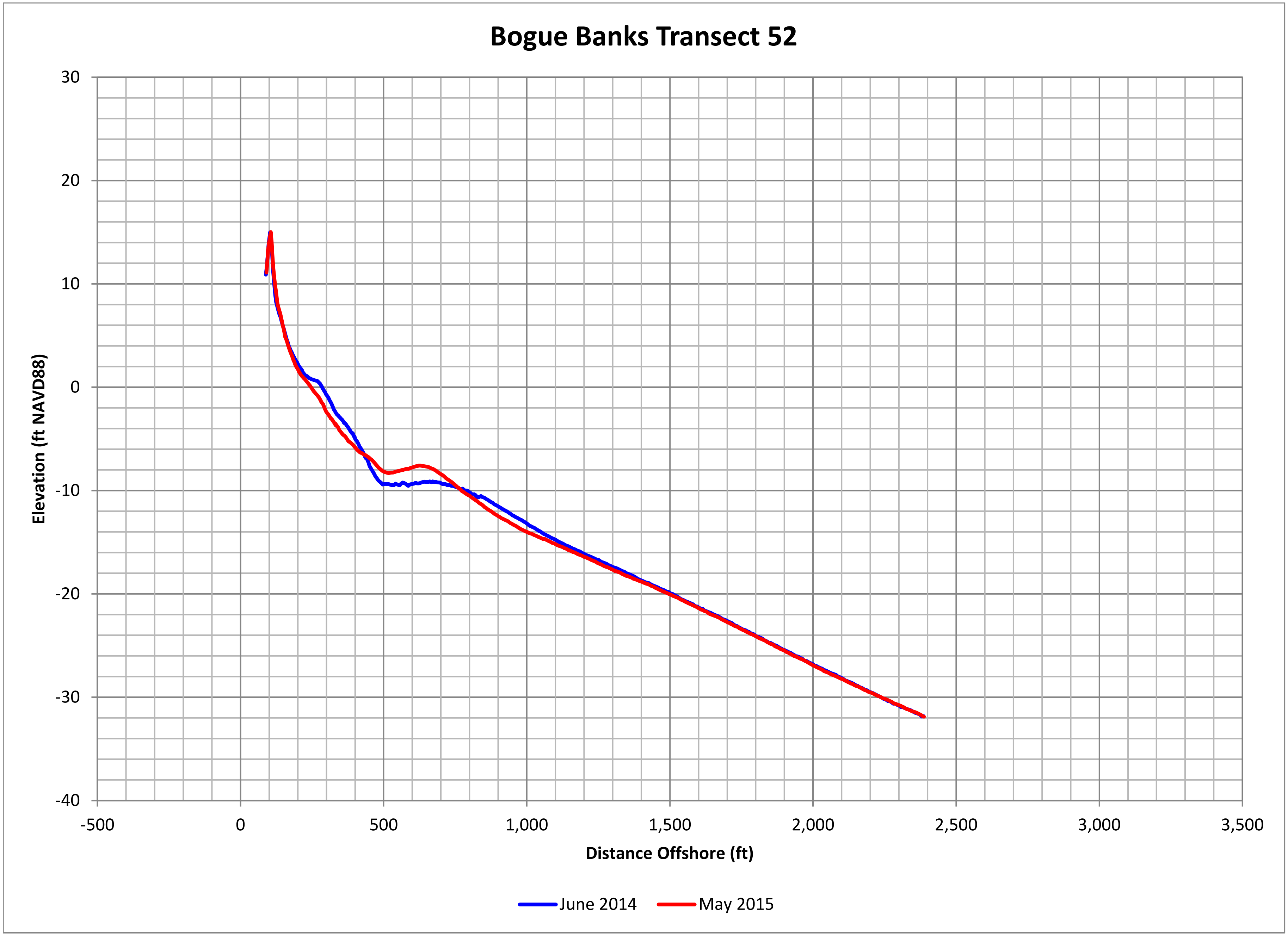


Figure C-70. Bogue Banks Profile Comparison Plot

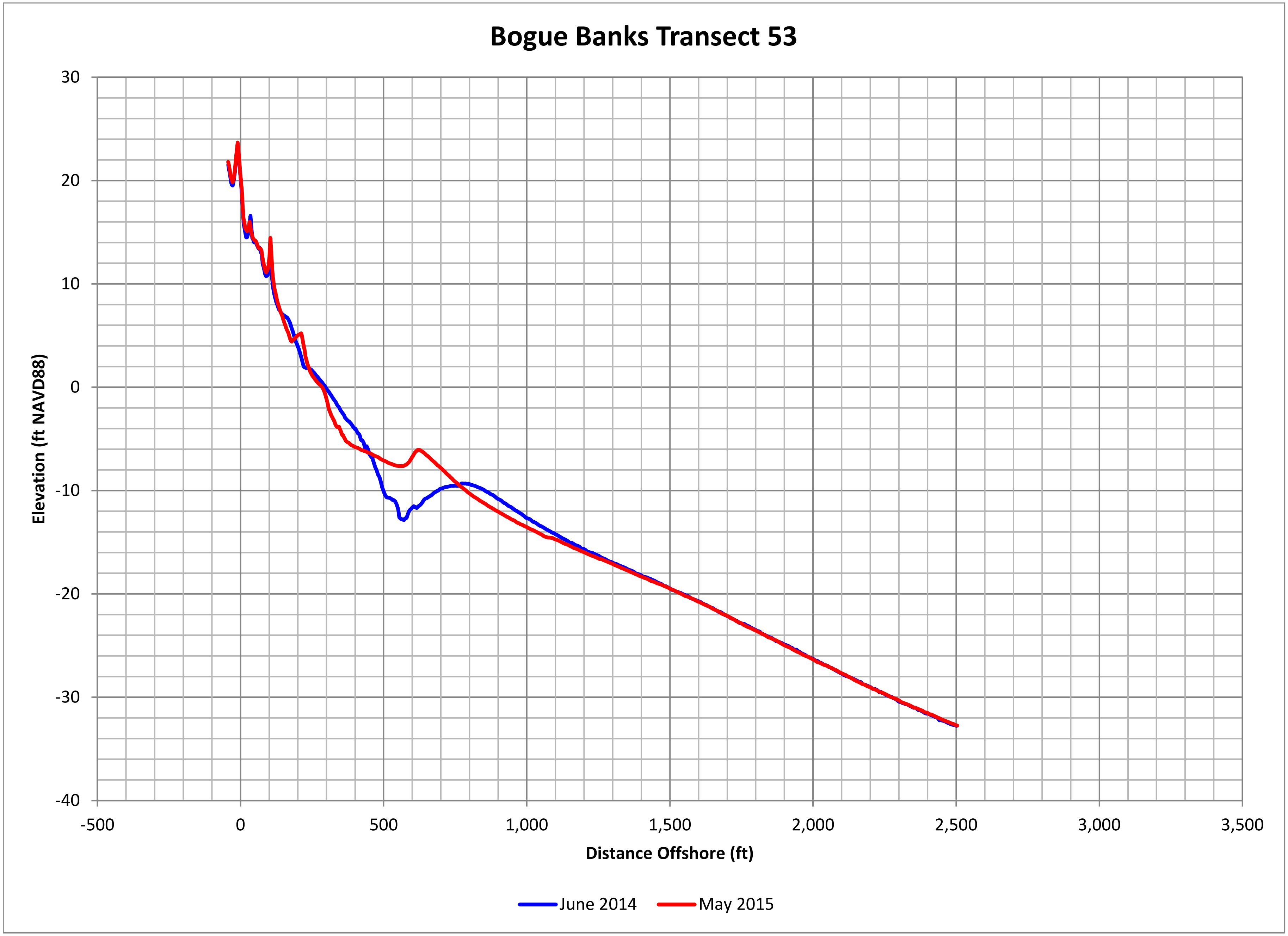


Figure C-71. Bogue Banks Profile Comparison Plot

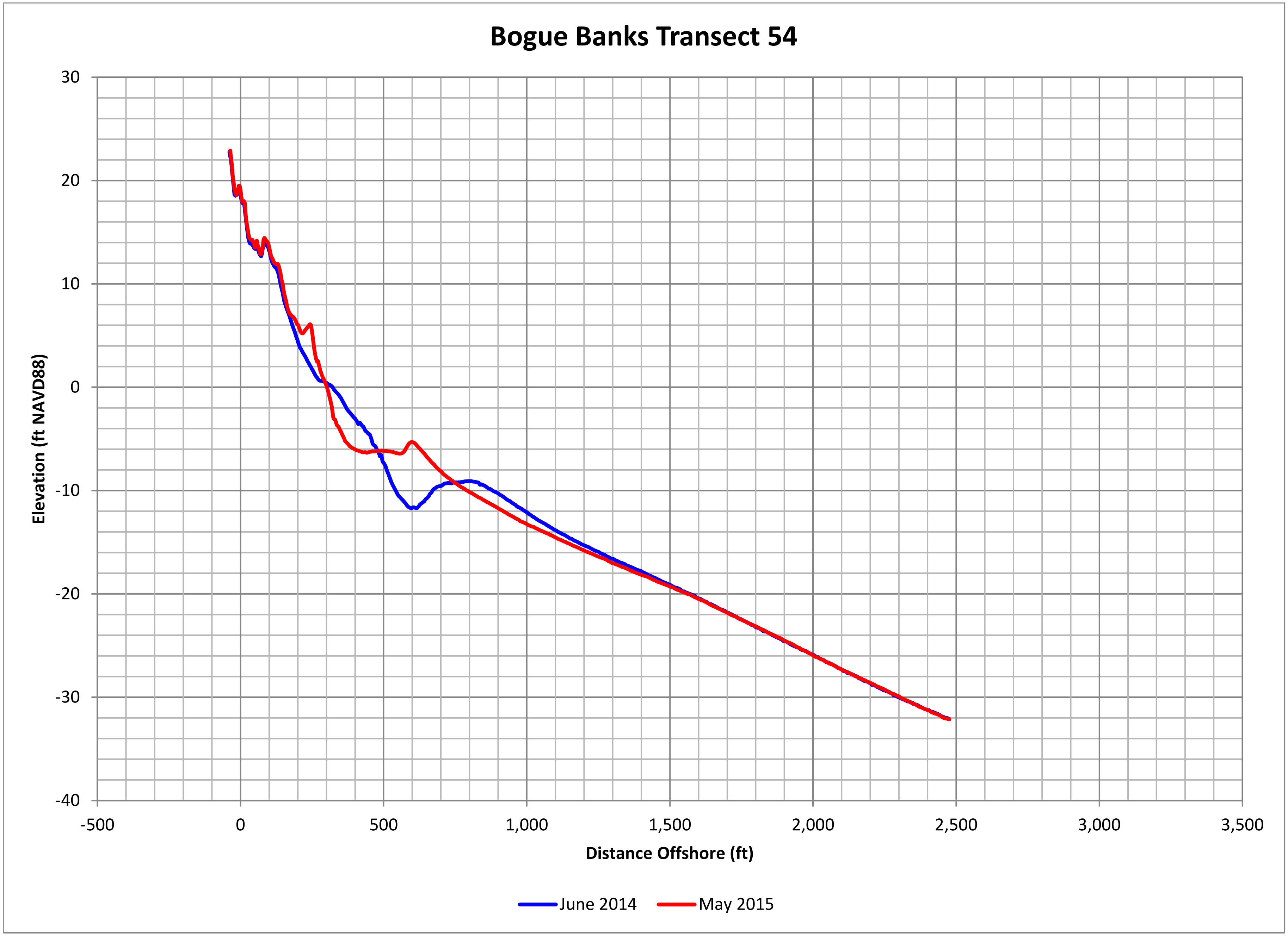


Figure C-72. Bogue Banks Profile Comparison Plot

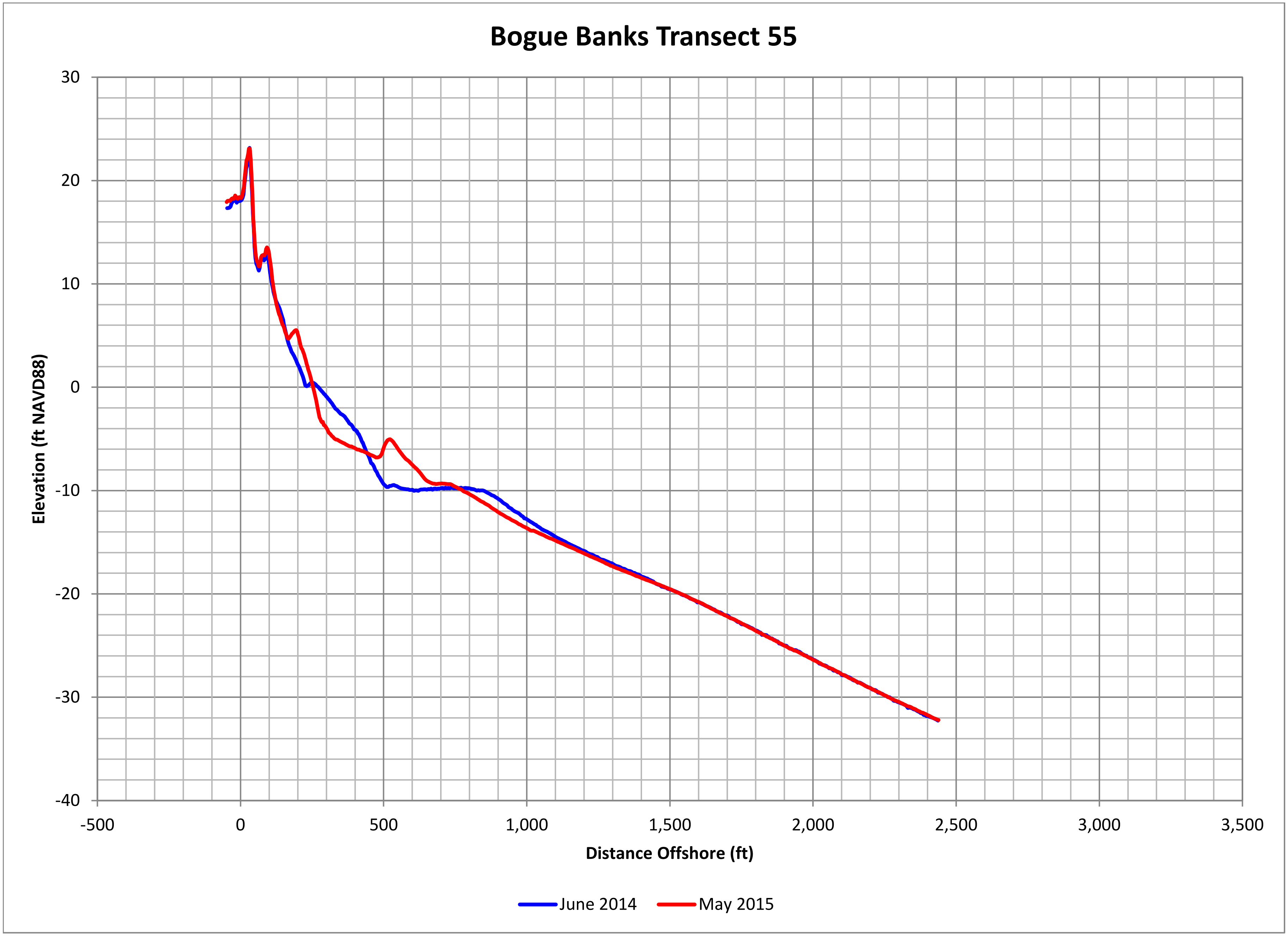
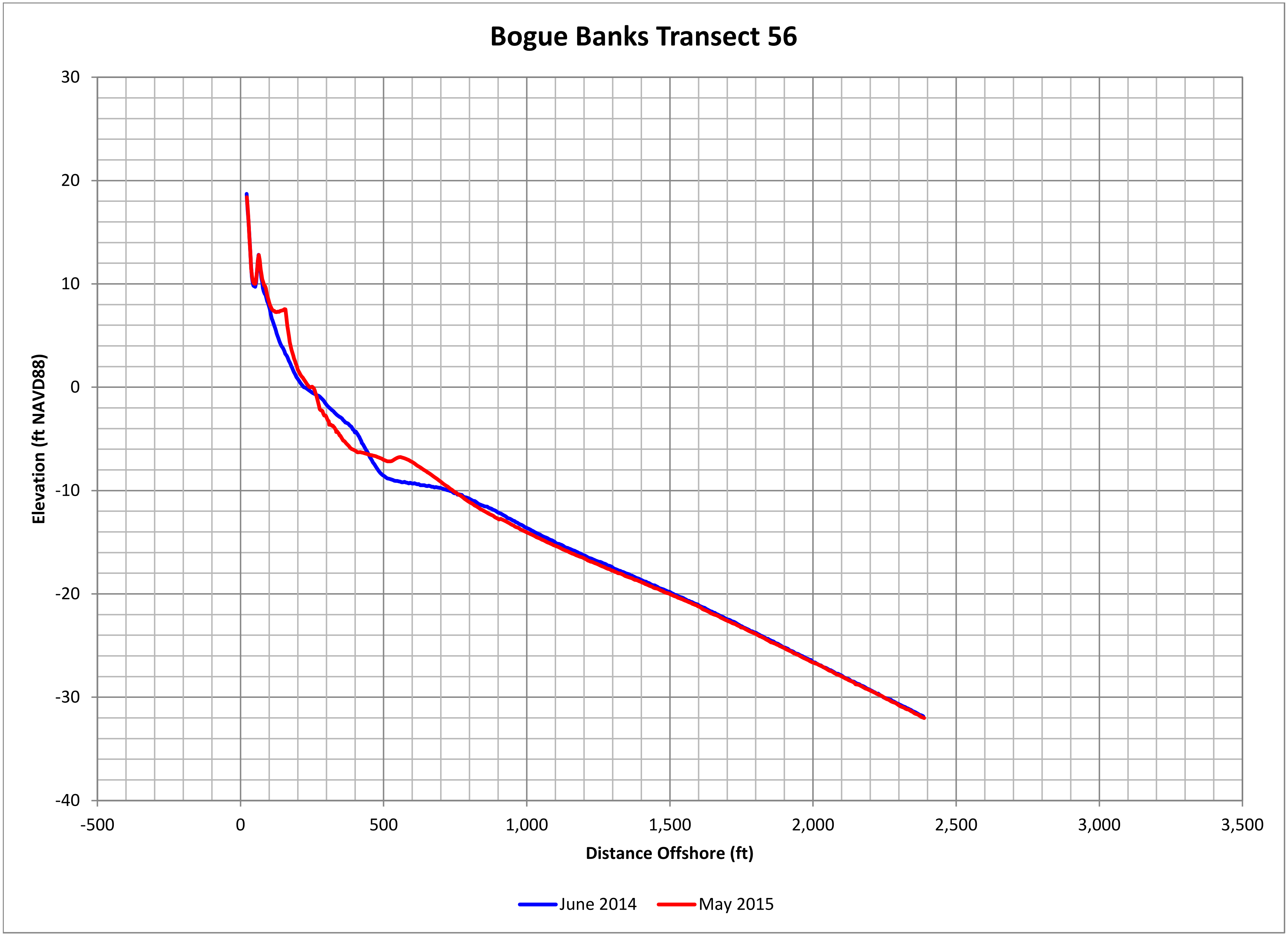


Figure C-73. Bogue Banks Profile Comparison Plot



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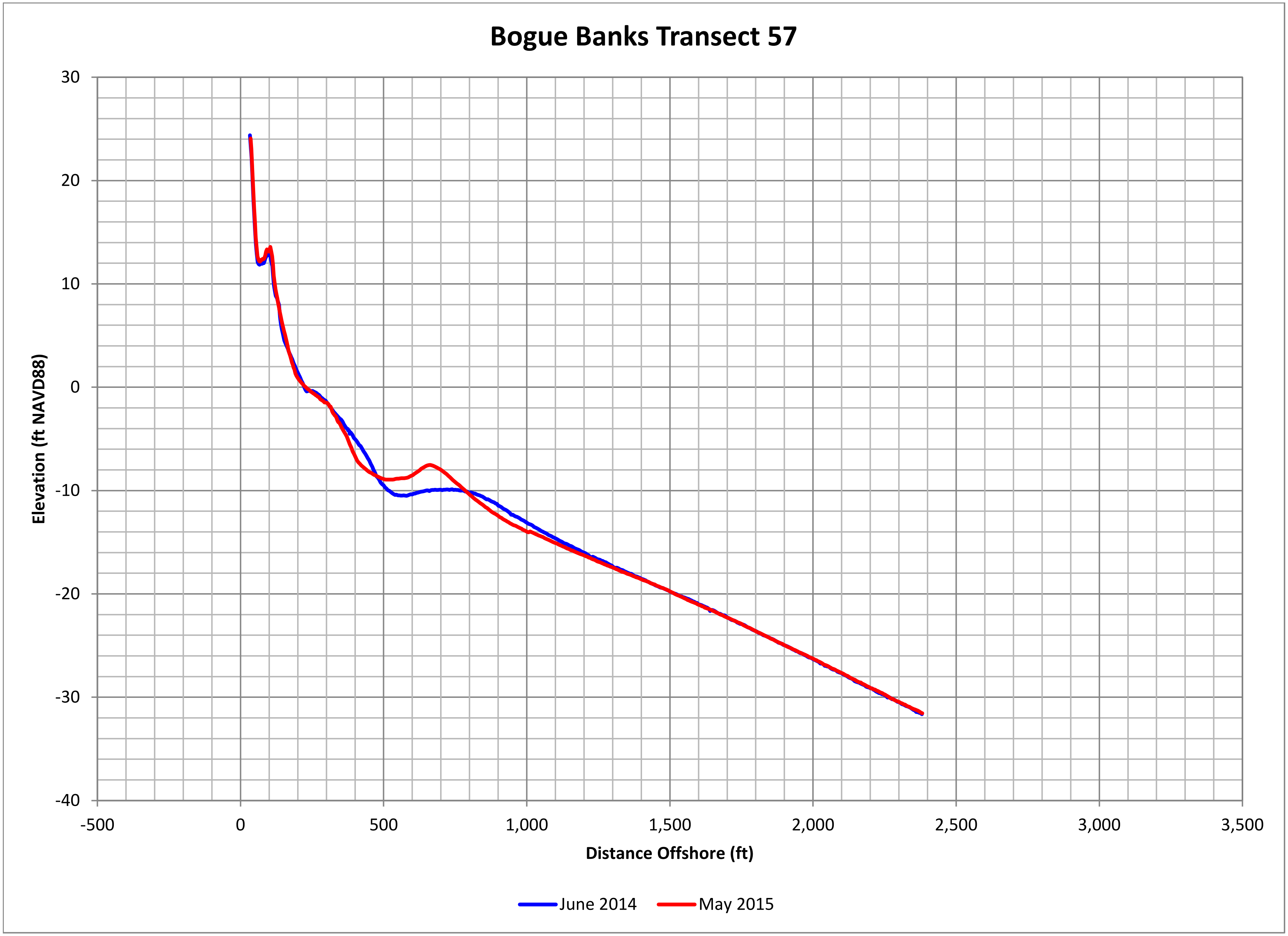

Figure C-75. Bogue Banks Profile Comparison Plot

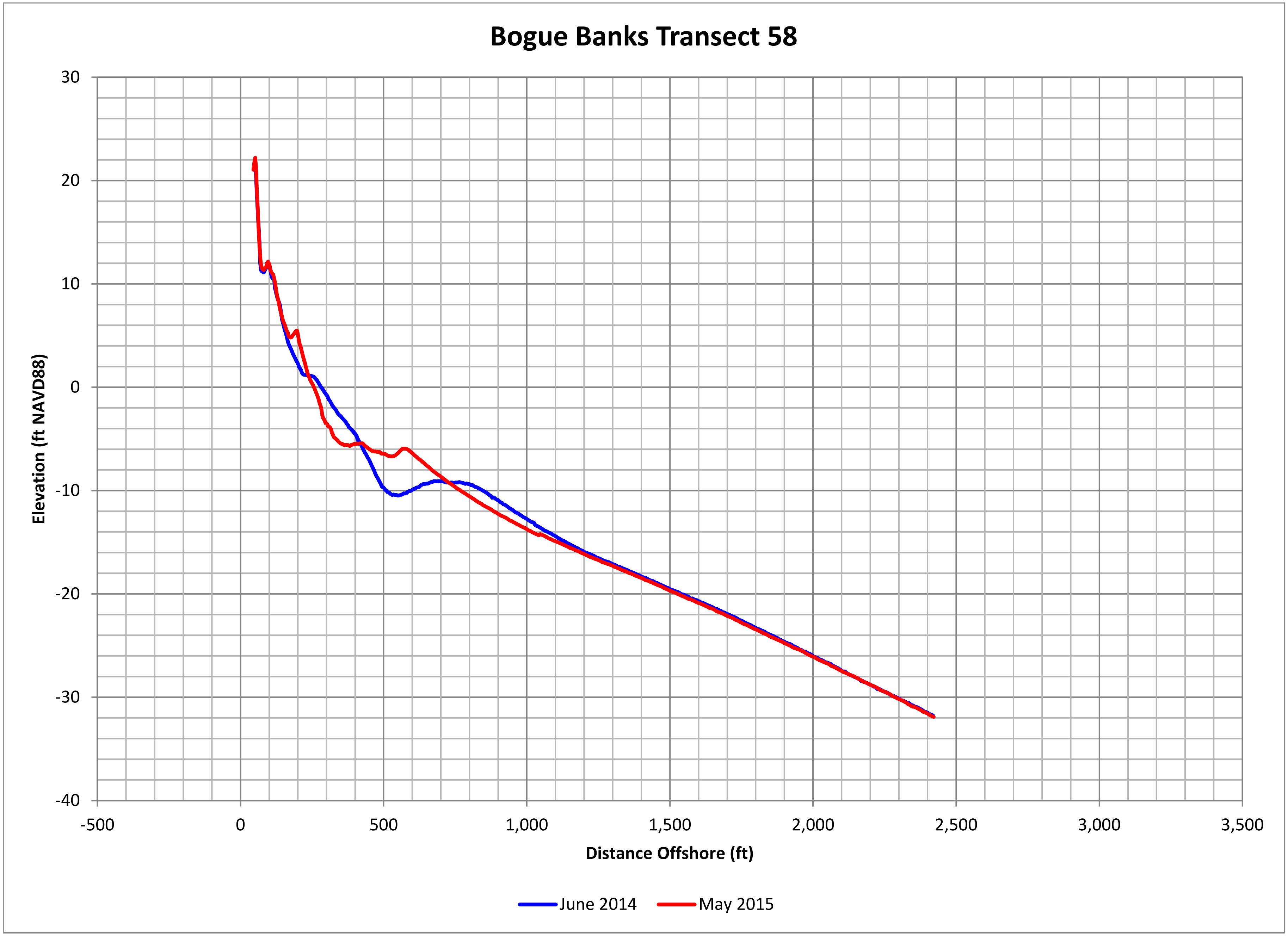

Figure C-76. Bogue Banks Profile Comparison Plot

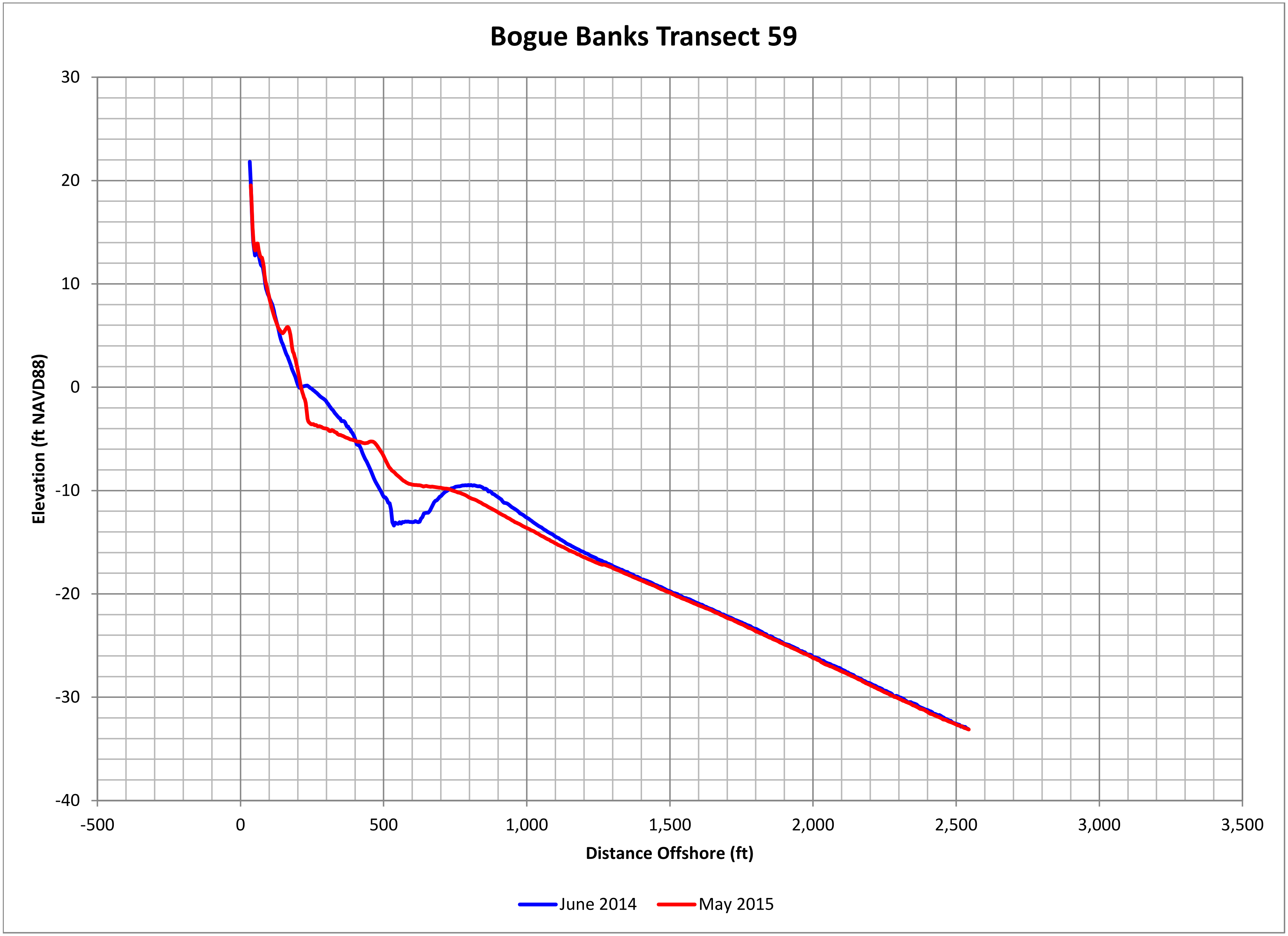

Figure C-77. Bogue Banks Profile Comparison Plot

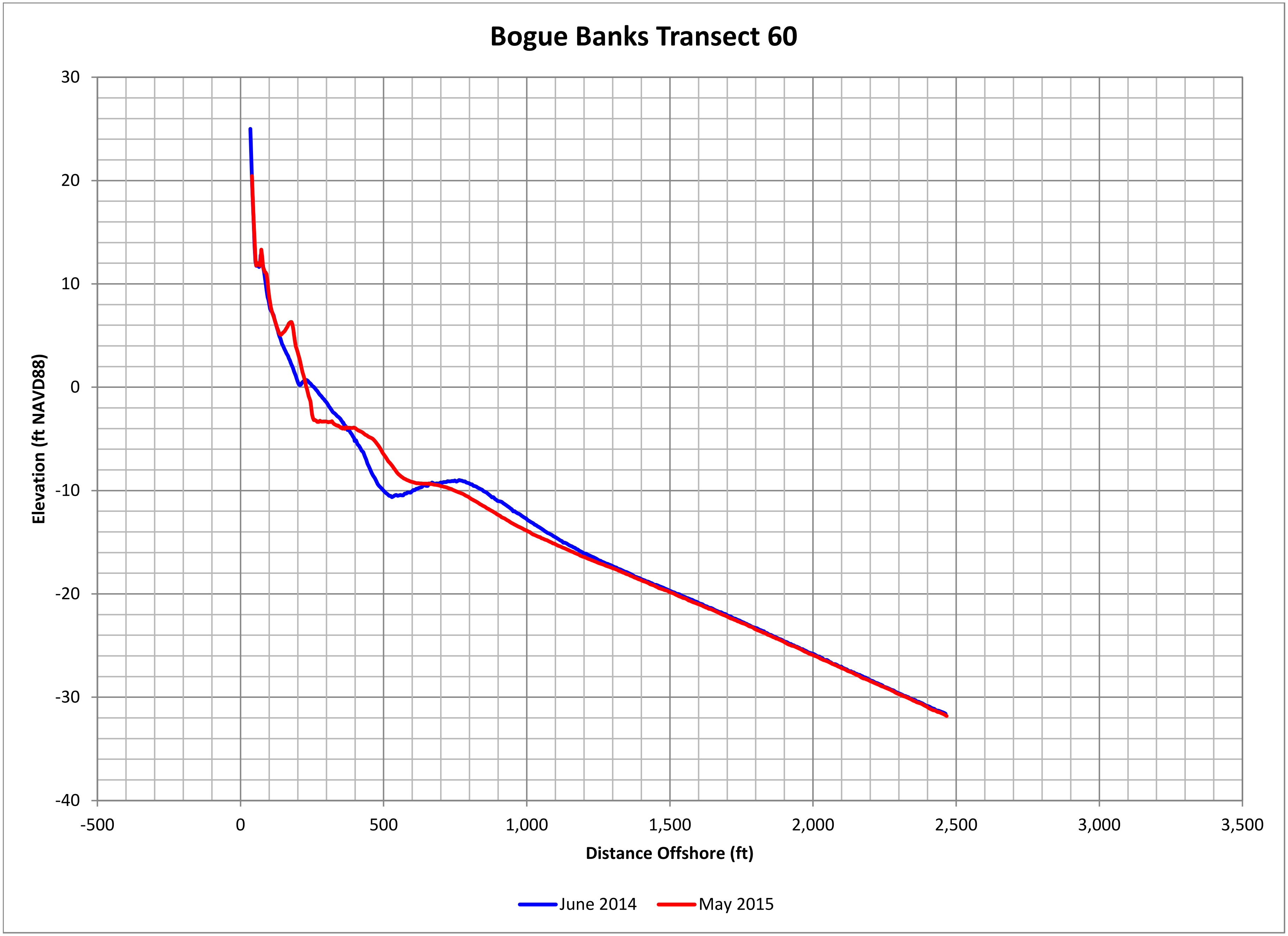

Figure C-78. Bogue Banks Profile Comparison Plot

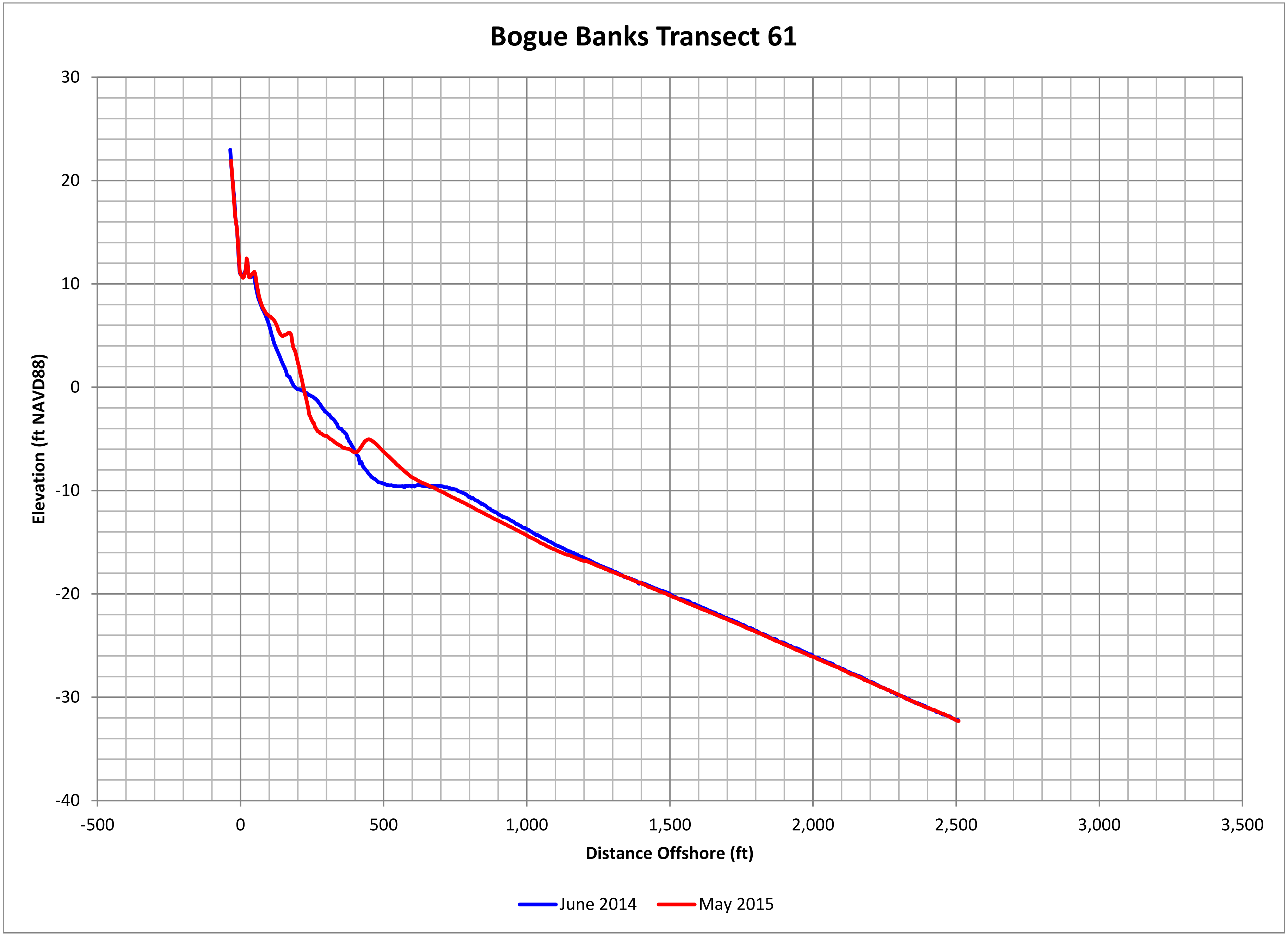

Figure C-79. Bogue Banks Profile Comparison Plot

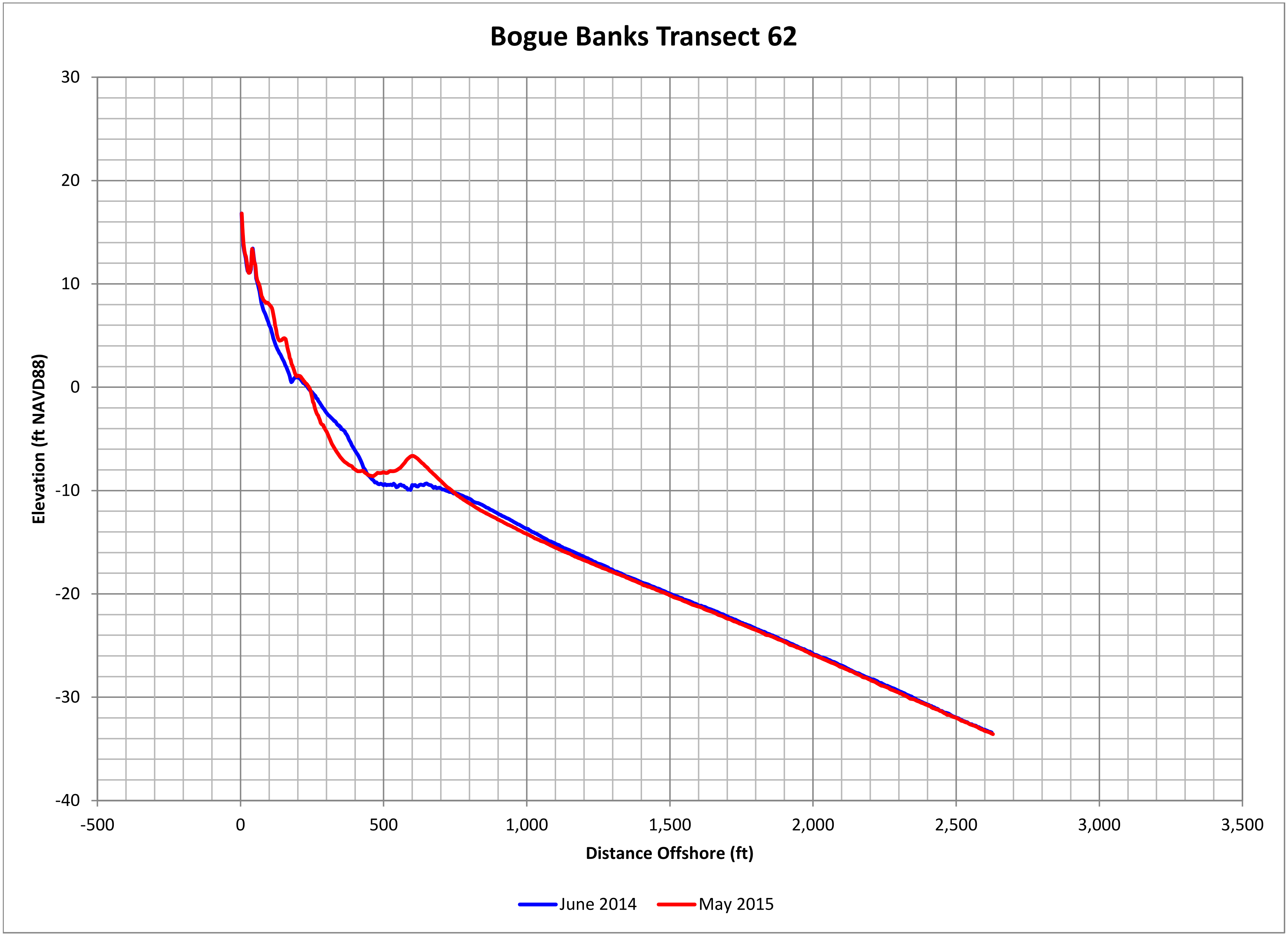

Figure C-80. Bogue Banks Profile Comparison Plot

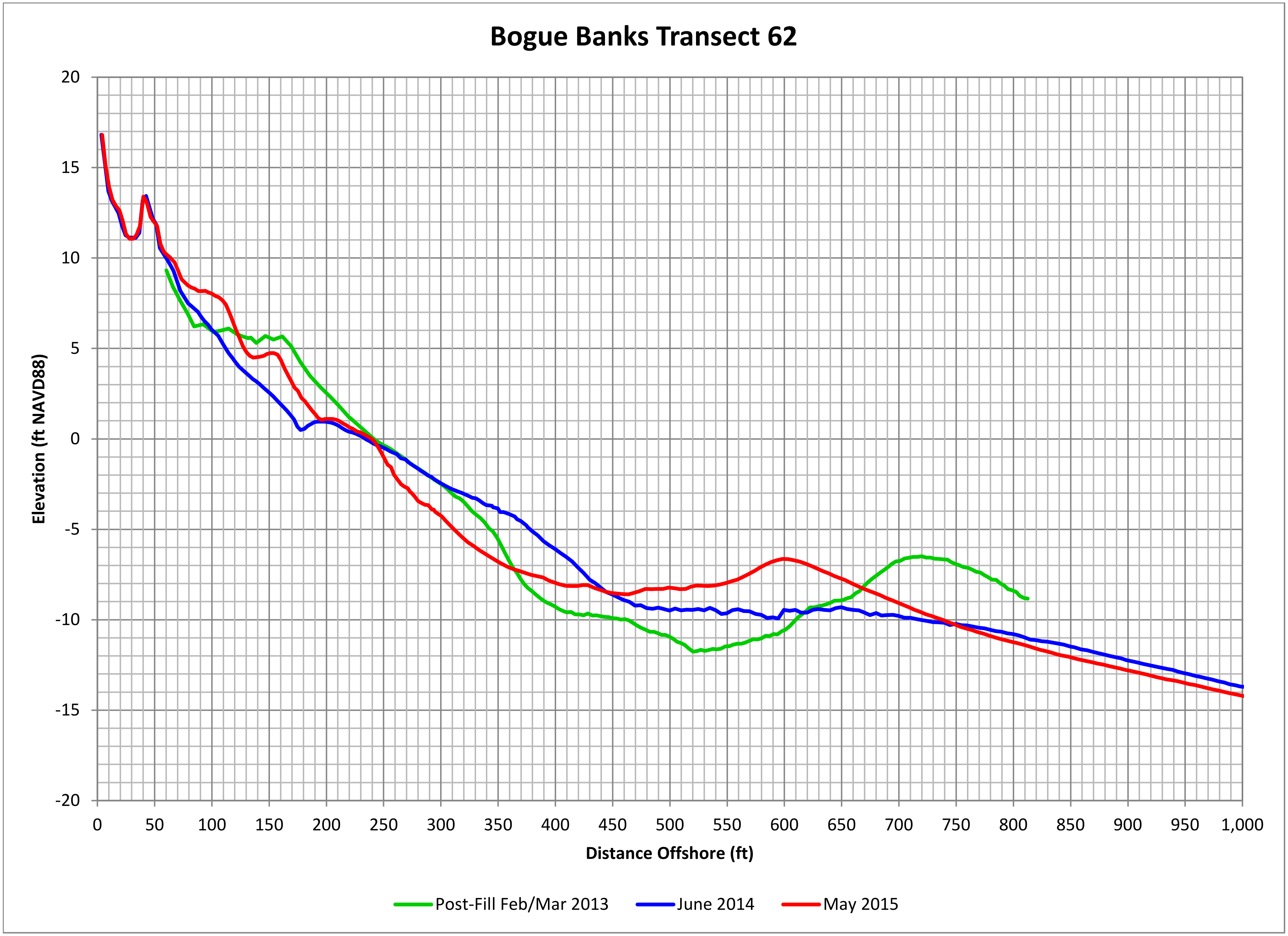

Figure C-81. Bogue Banks Profile Comparison Plot

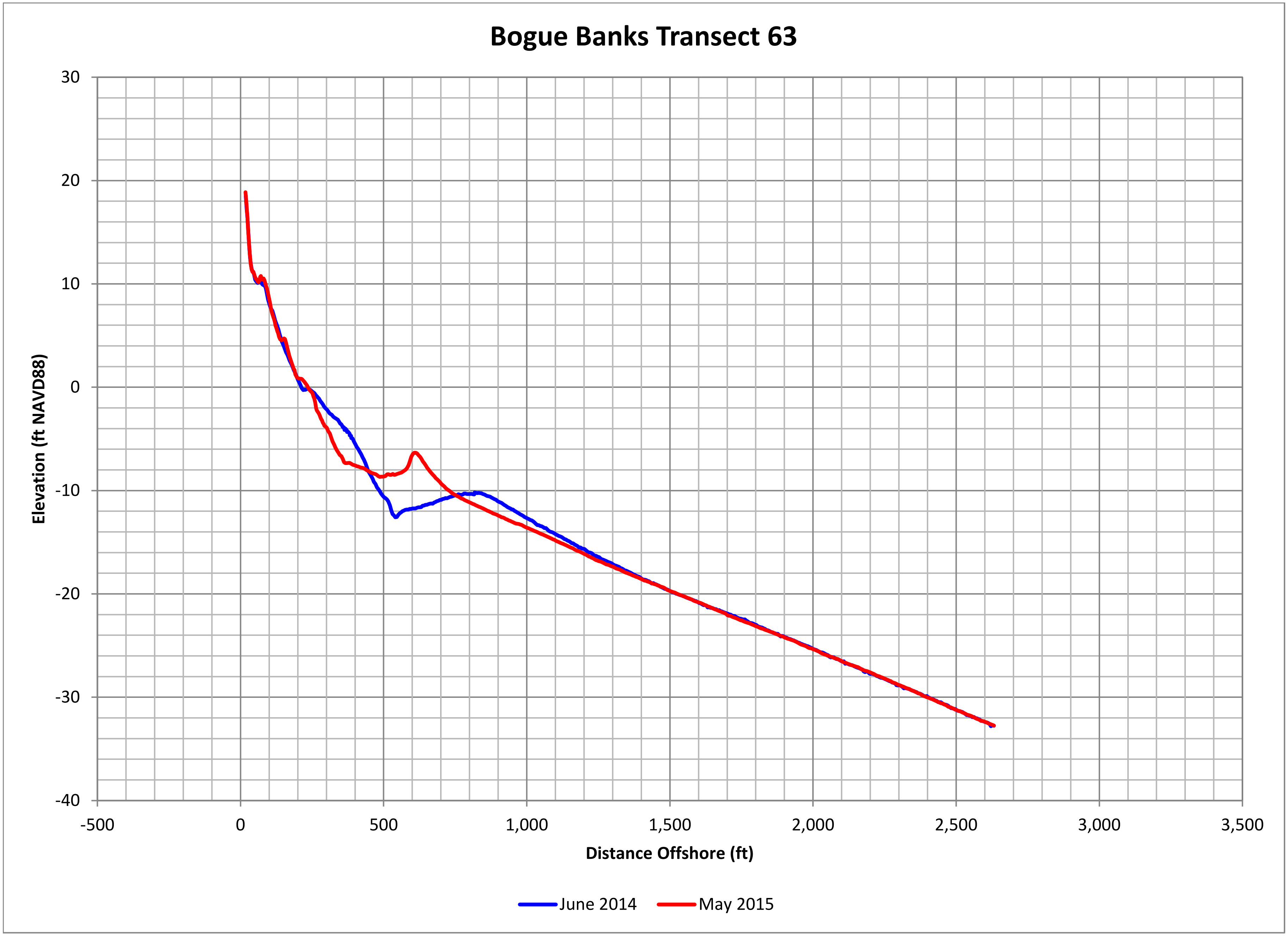

Figure C-82. Bogue Banks Profile Comparison Plot

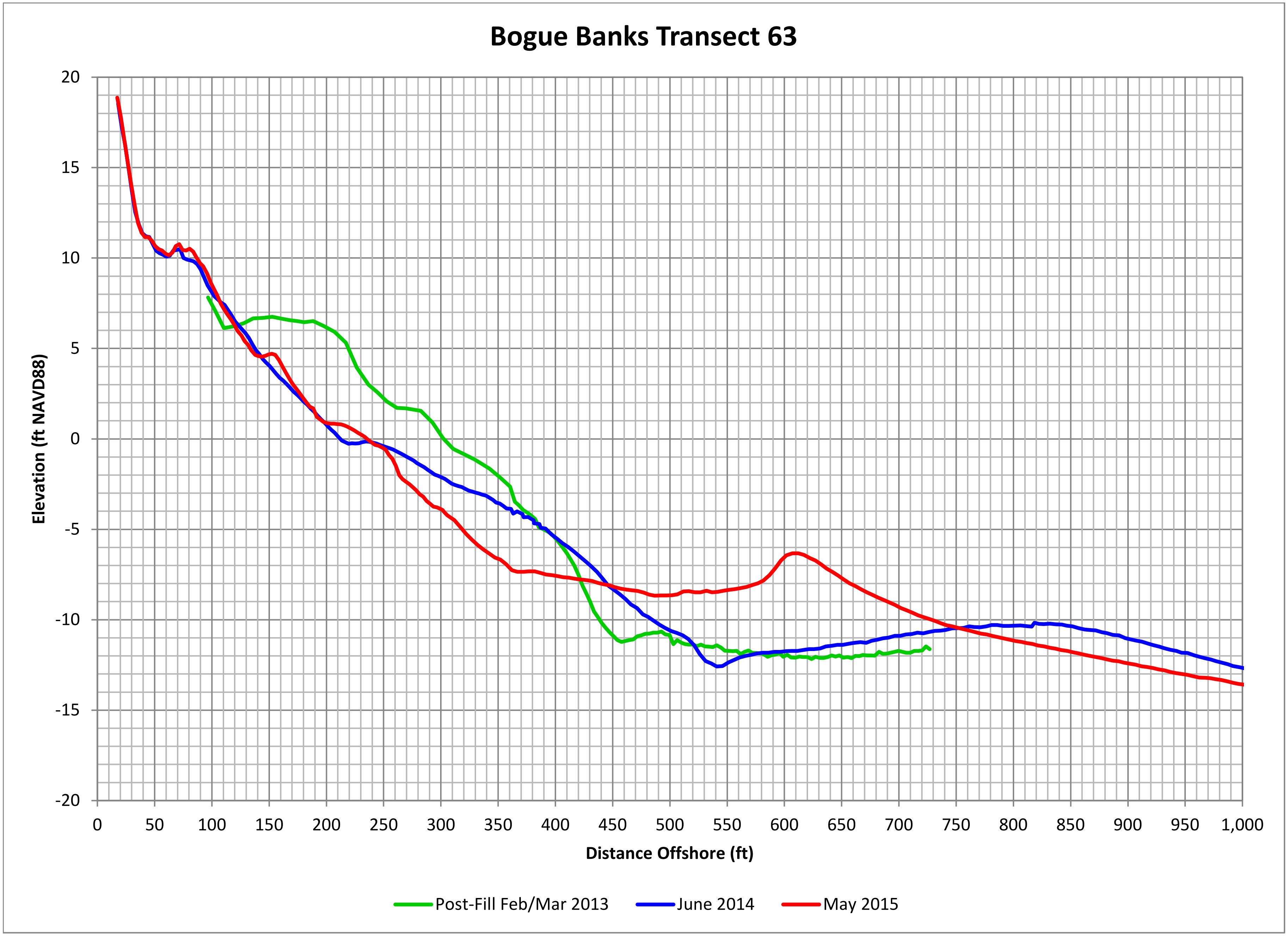

Figure C-83. Bogue Banks Profile Comparison Plot

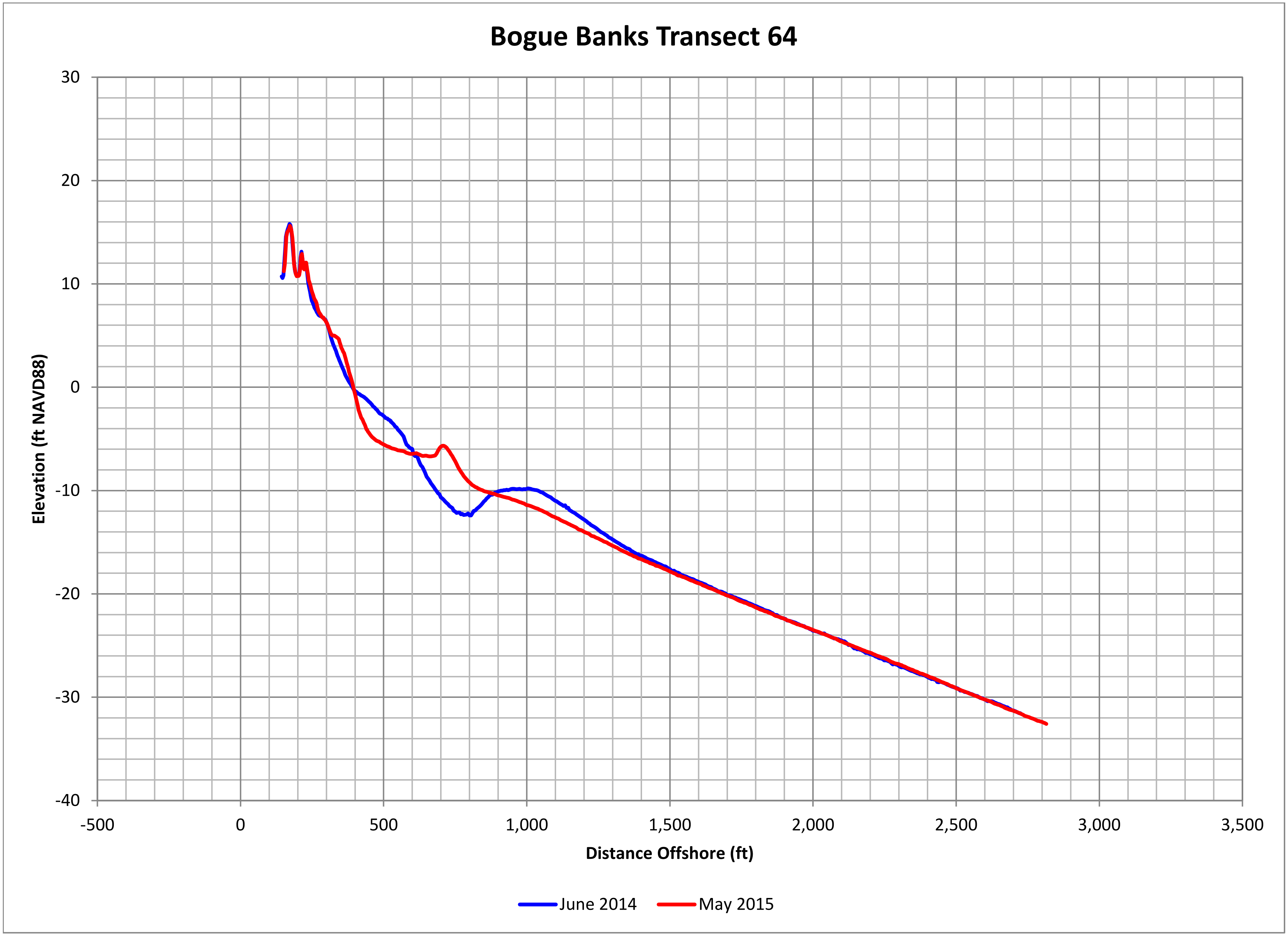

Figure C-84. Bogue Banks Profile Comparison Plot

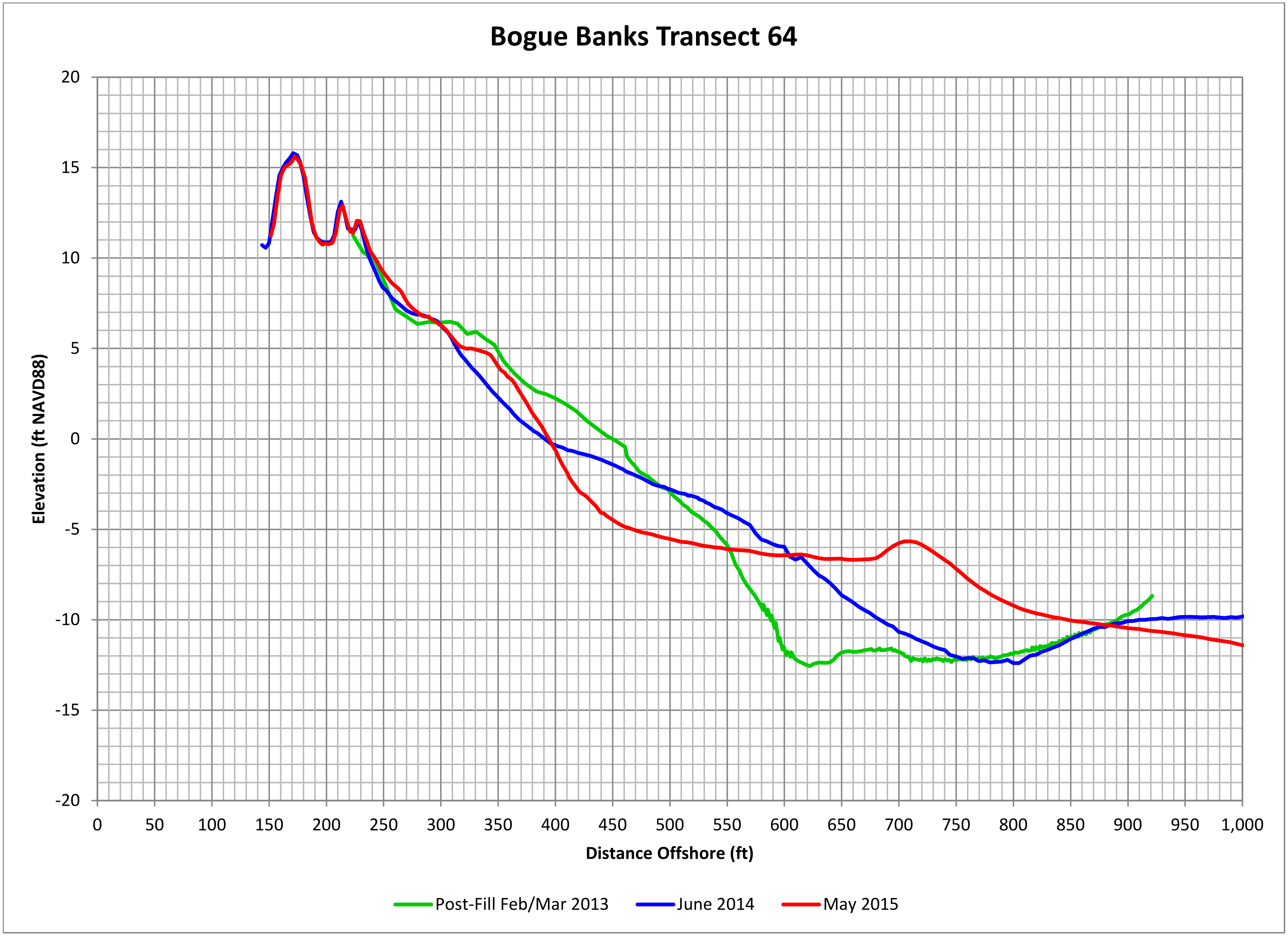

Figure C-85. Bogue Banks Profile Comparison Plot

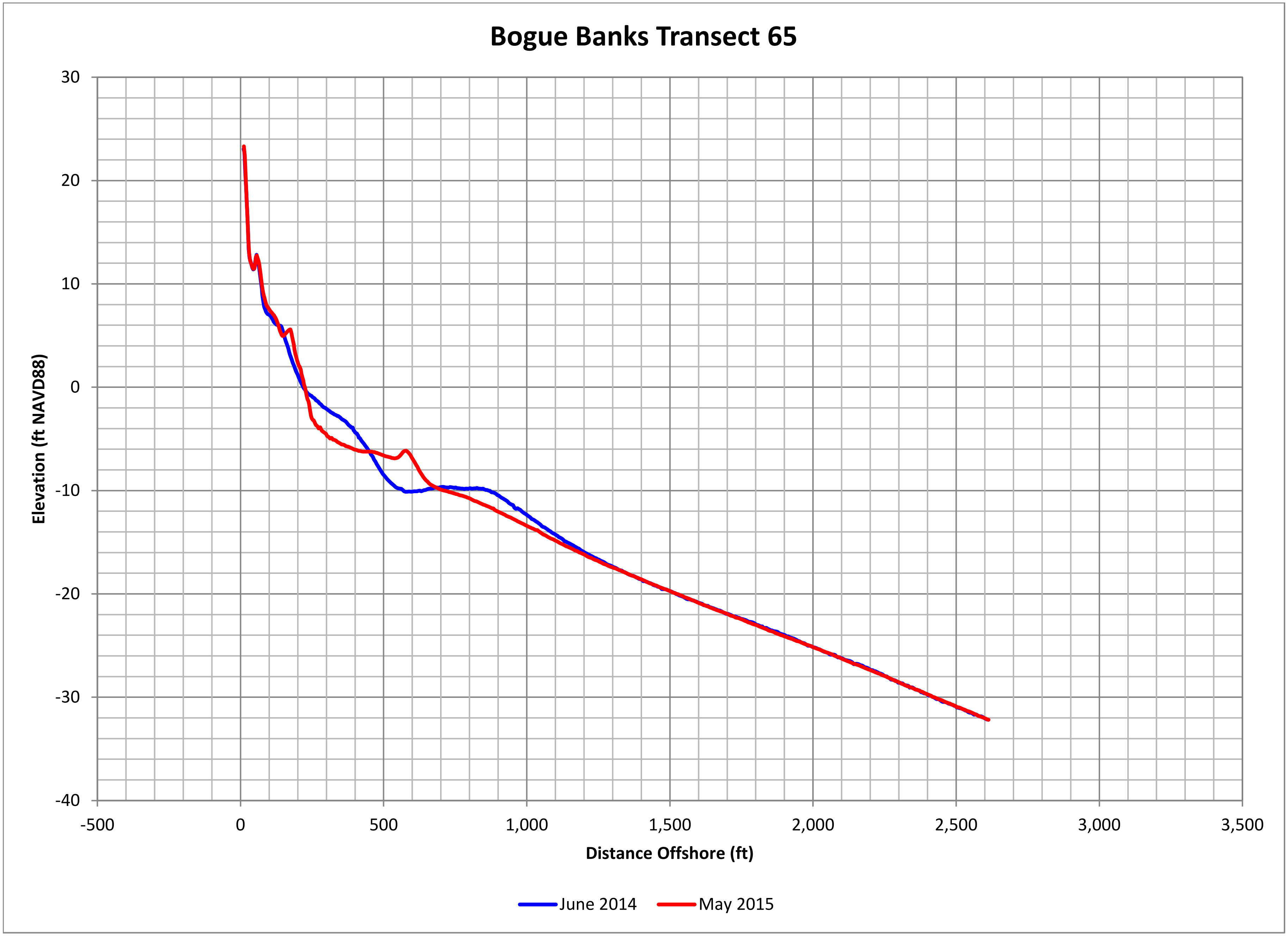

Figure C-86. Bogue Banks Profile Comparison Plot

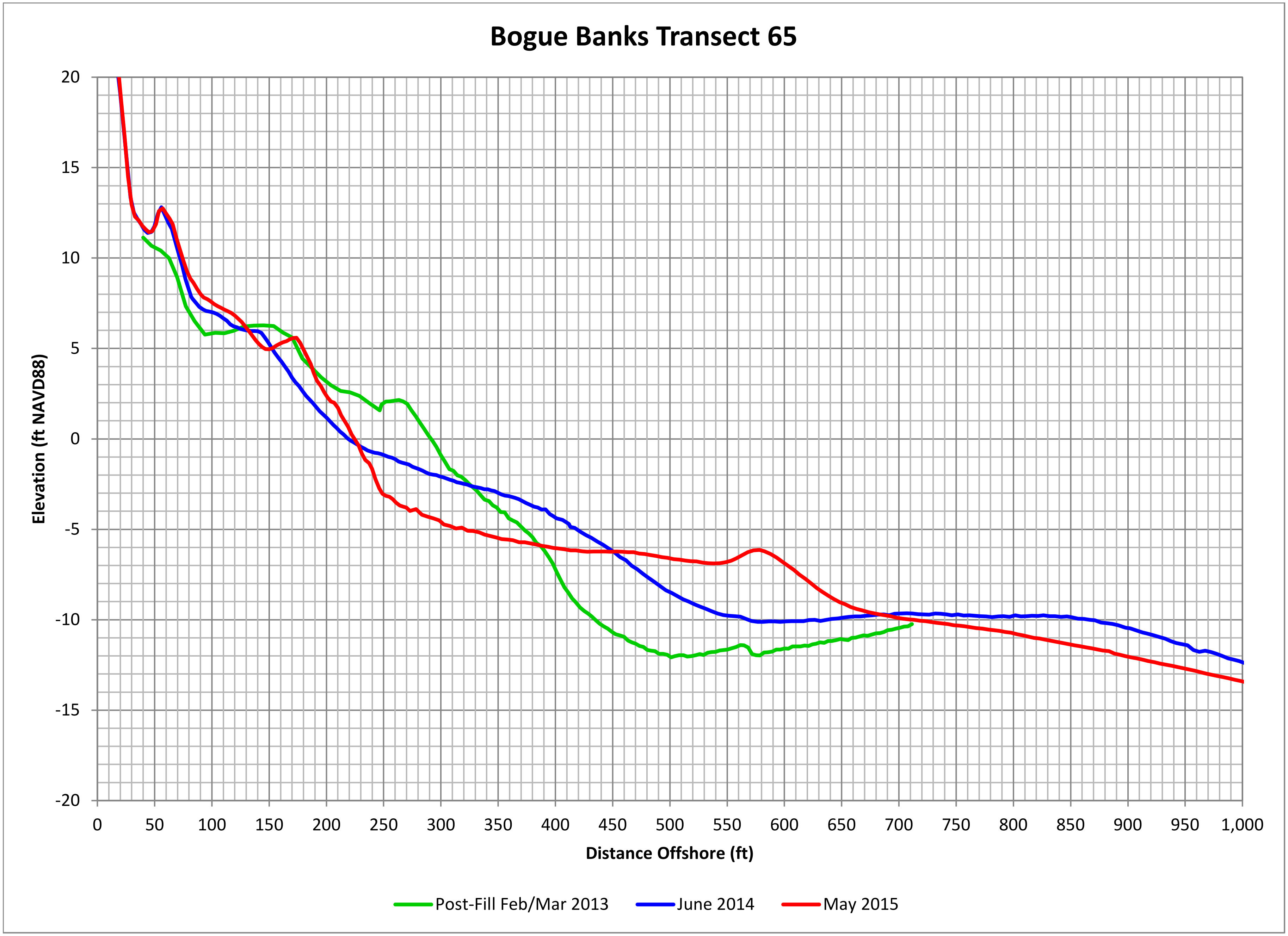

Figure C-87. Bogue Banks Profile Comparison Plot

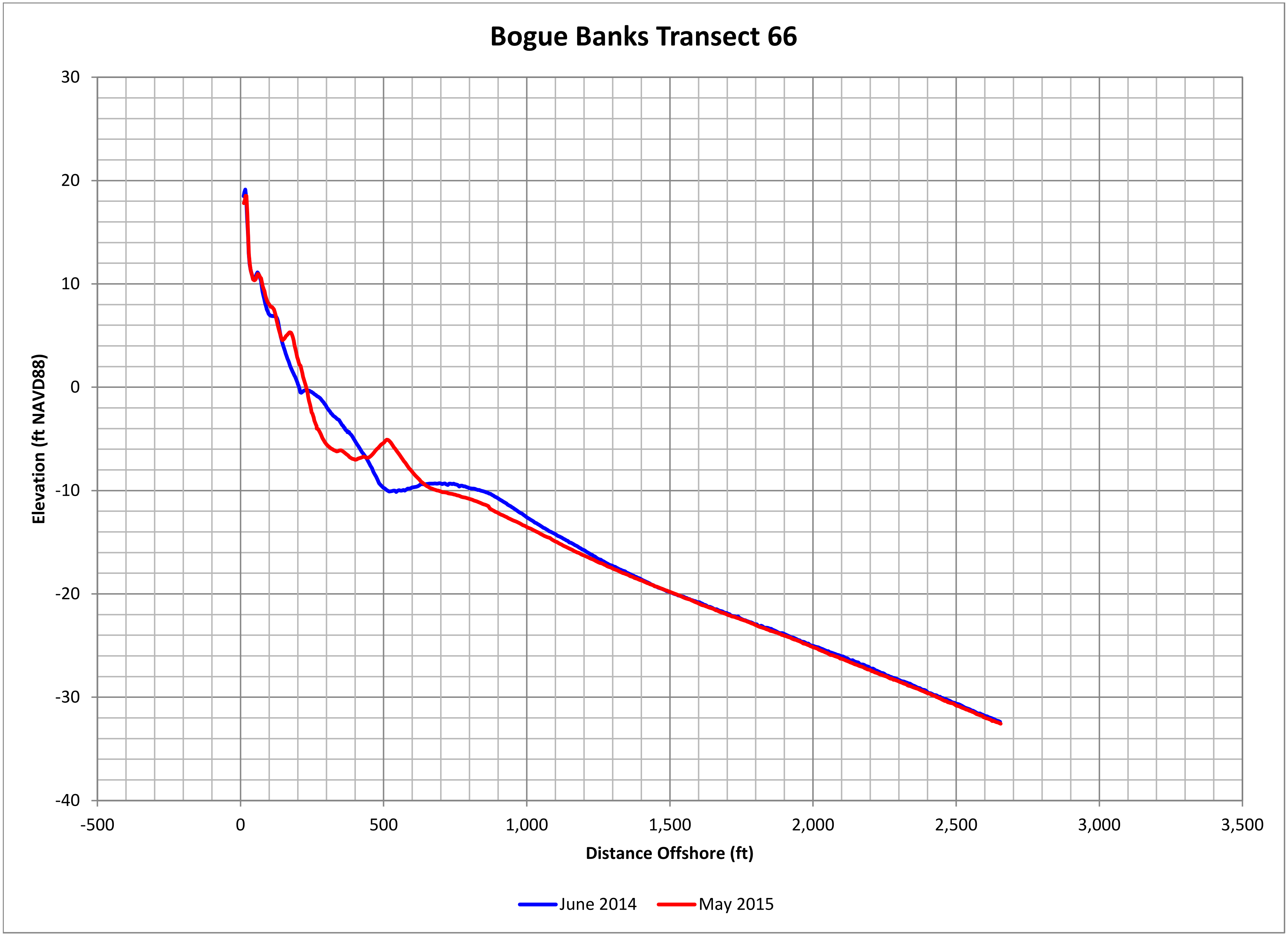

Figure C-88. Bogue Banks Profile Comparison Plot

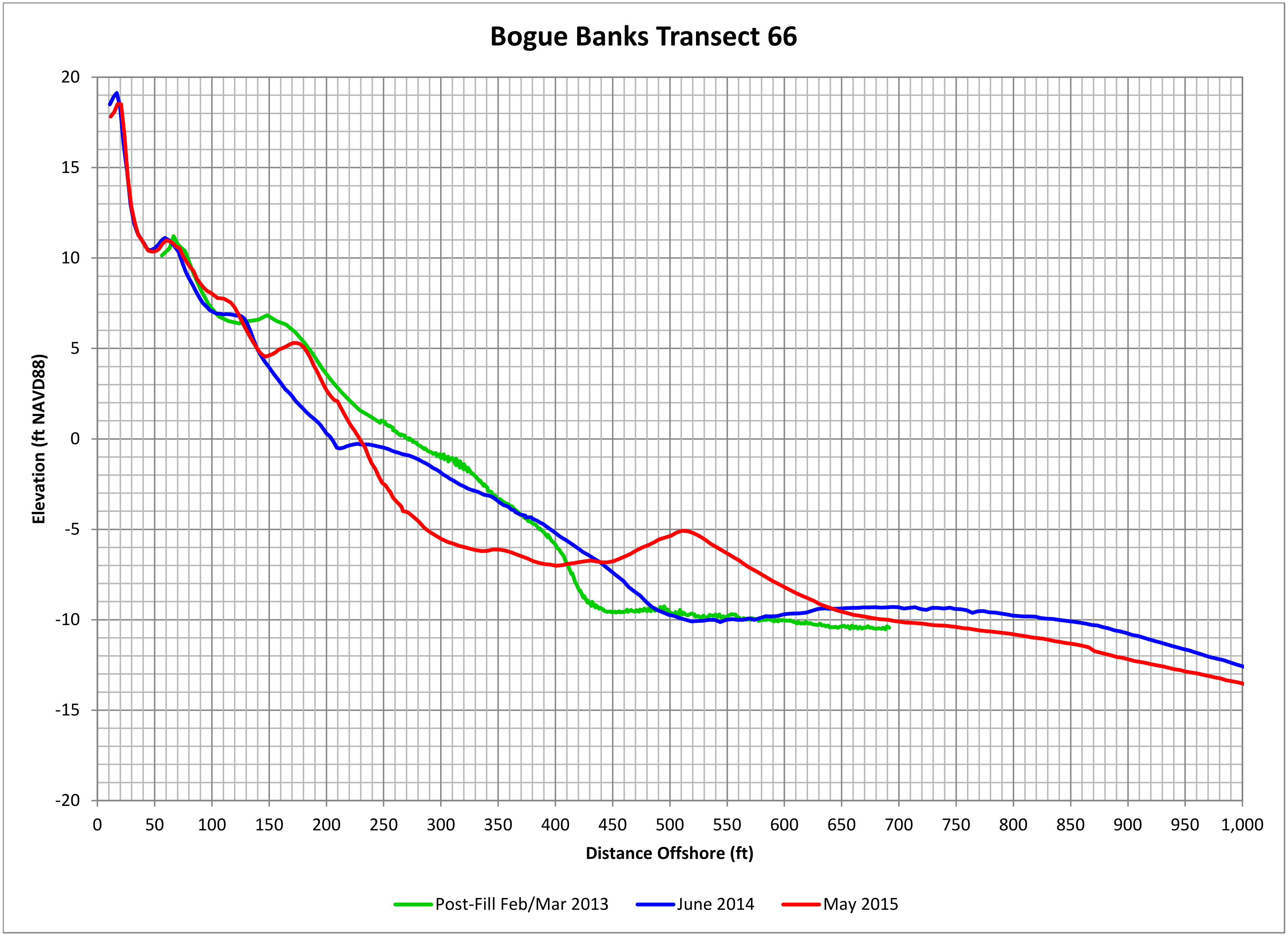

Figure C-89. Bogue Banks Profile Comparison Plot

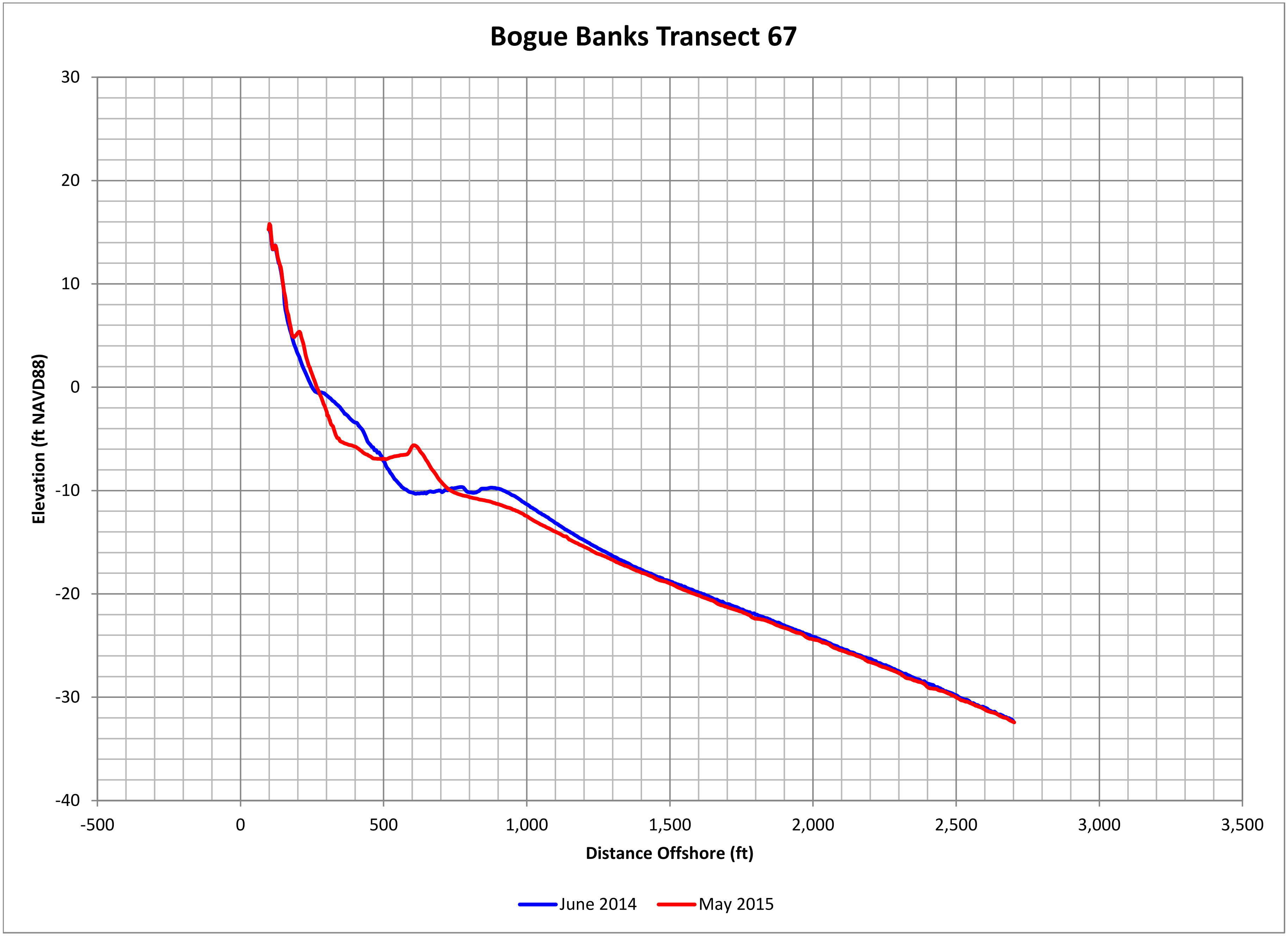

Figure C-90. Bogue Banks Profile Comparison Plot

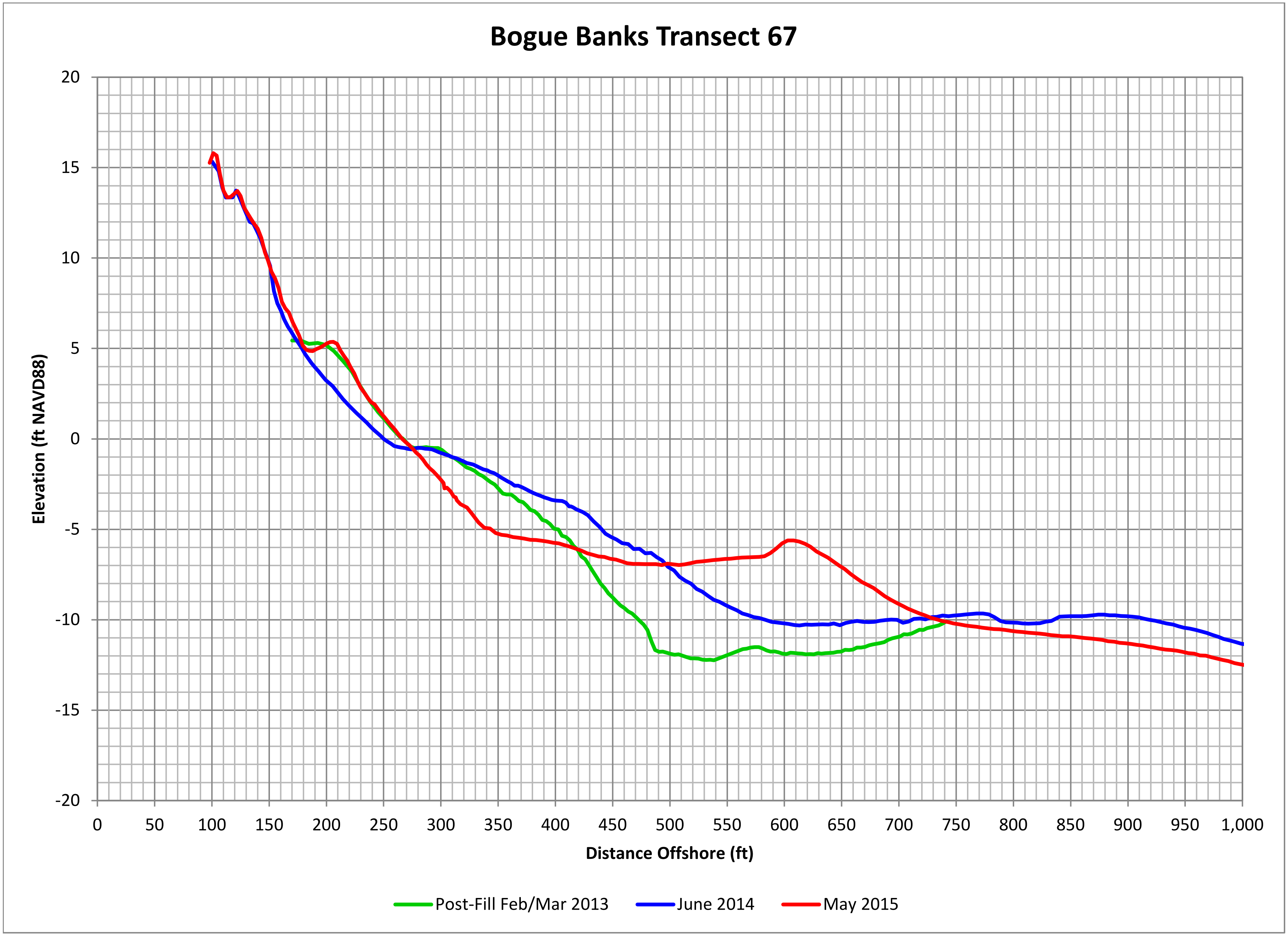

Figure C-91. Bogue Banks Profile Comparison Plot

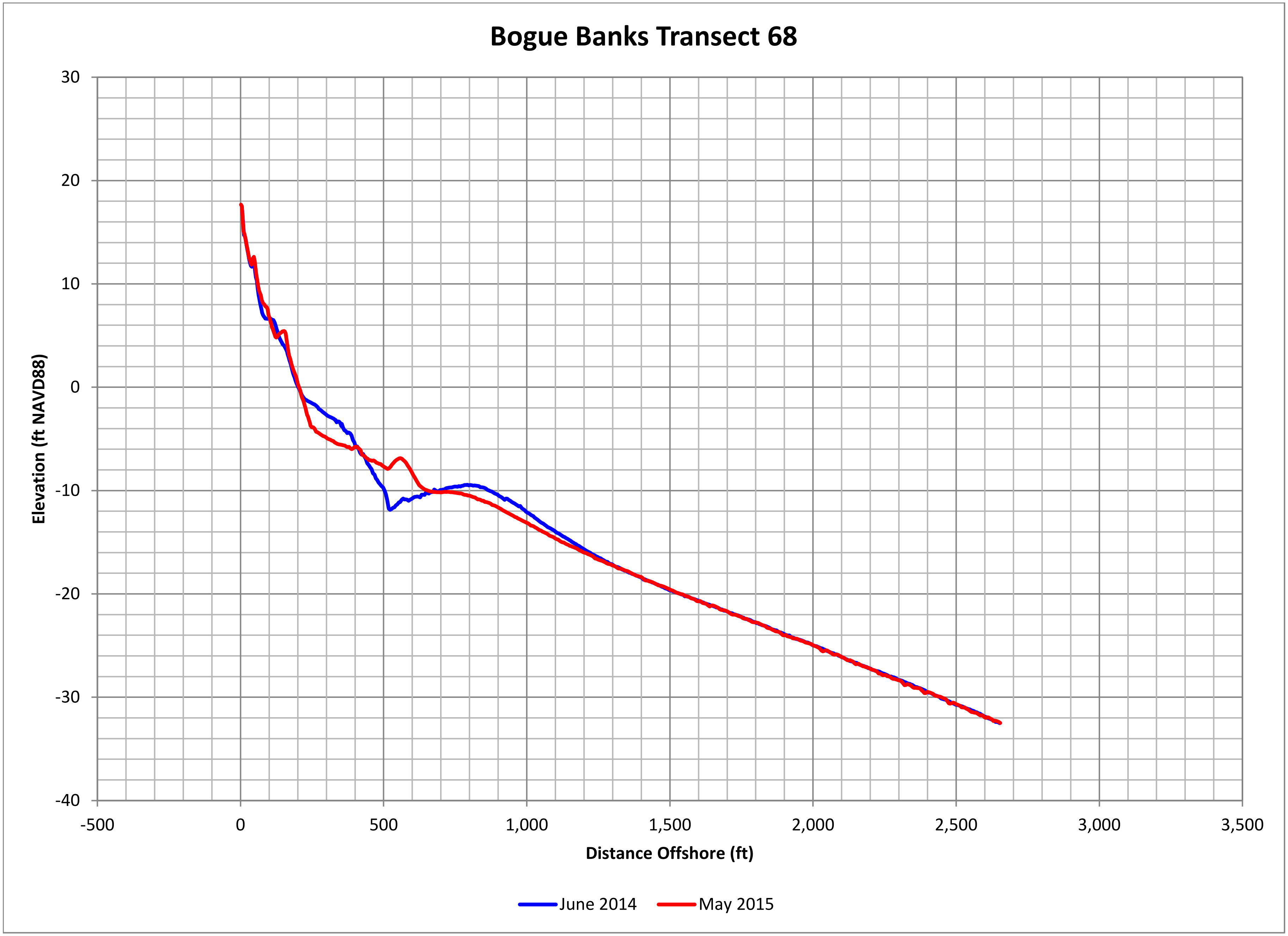

Figure C-92. Bogue Banks Profile Comparison Plot

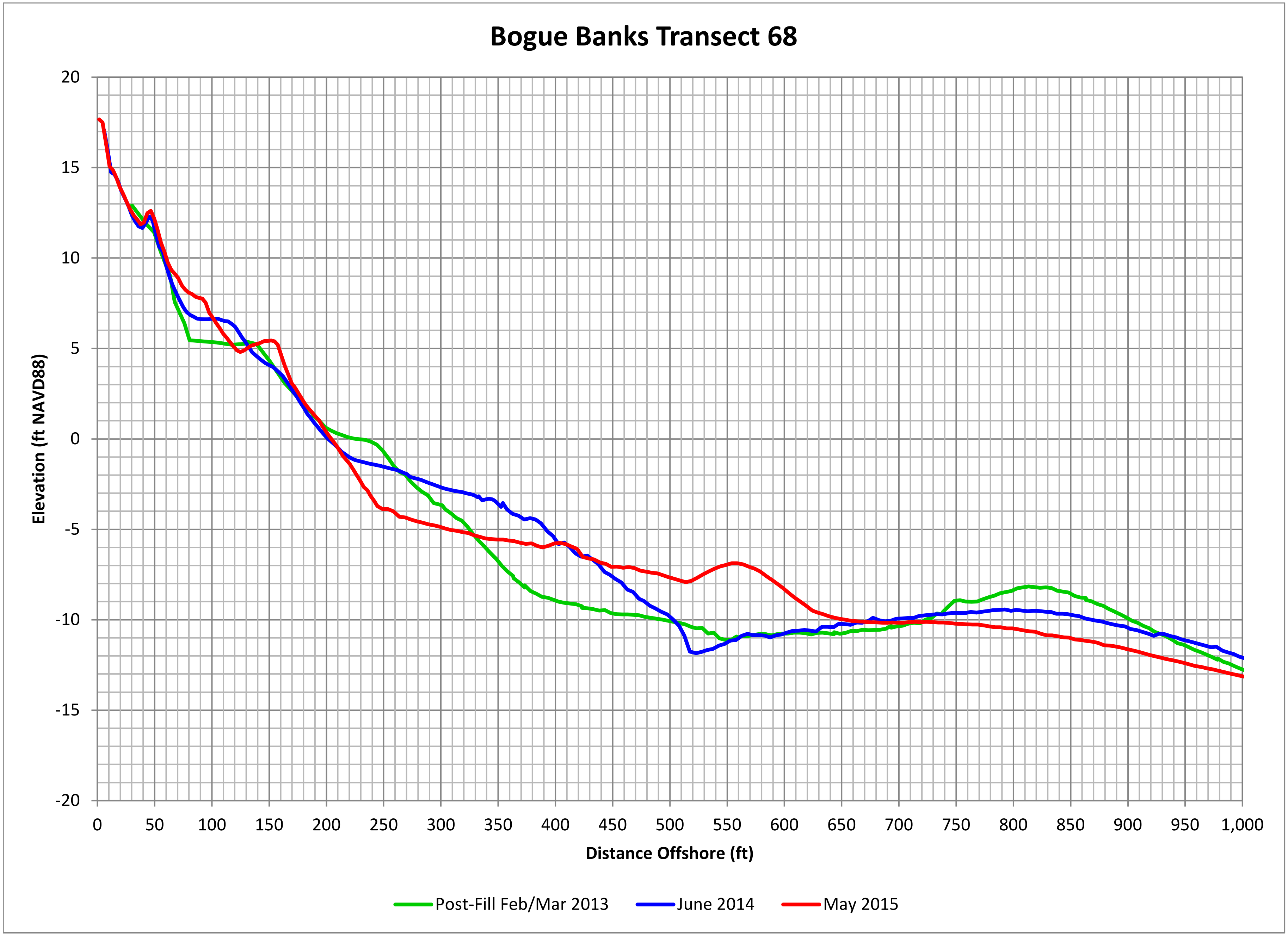

Figure C-93. Bogue Banks Profile Comparison Plot

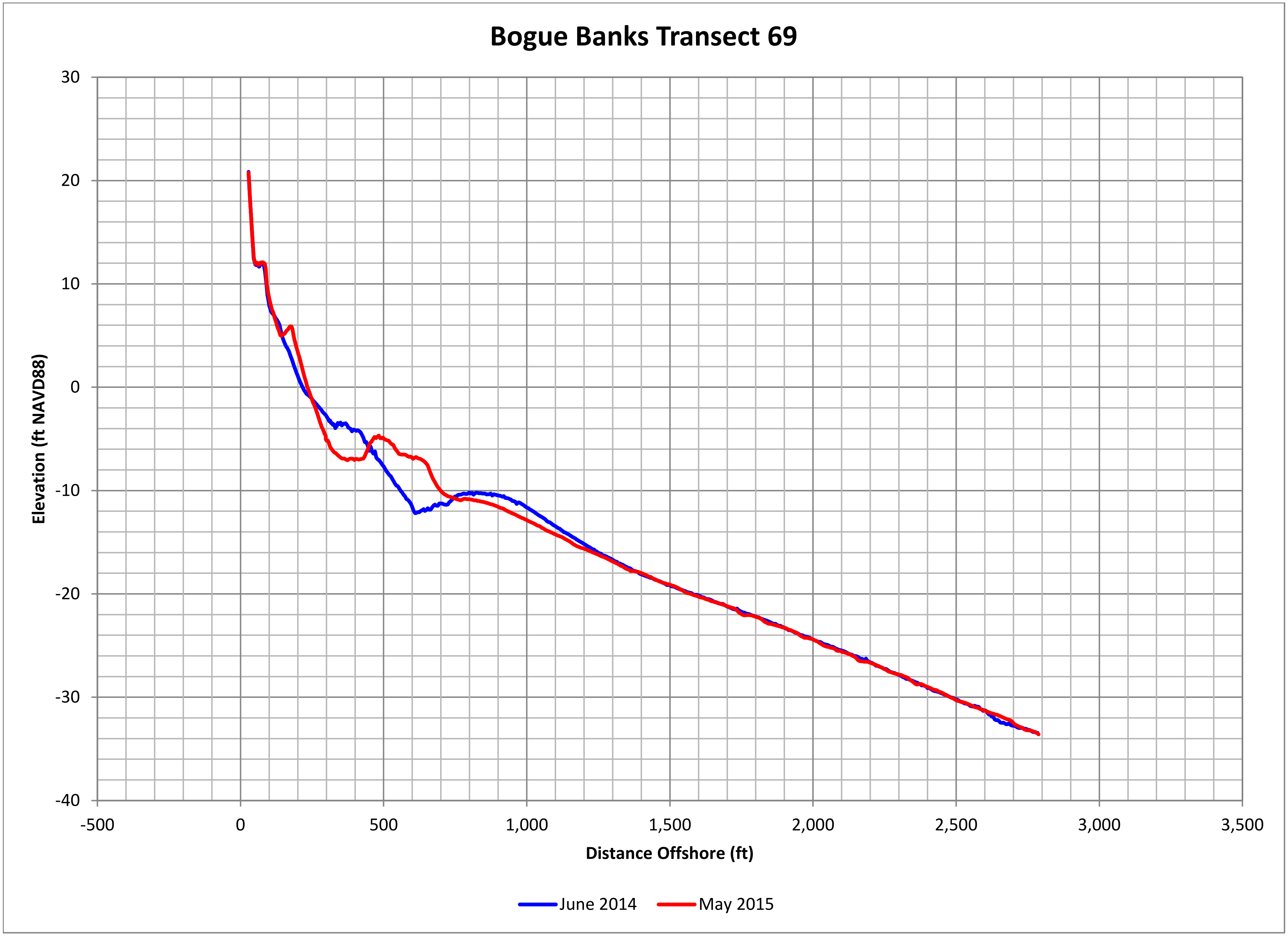

Figure C-94. Bogue Banks Profile Comparison Plot

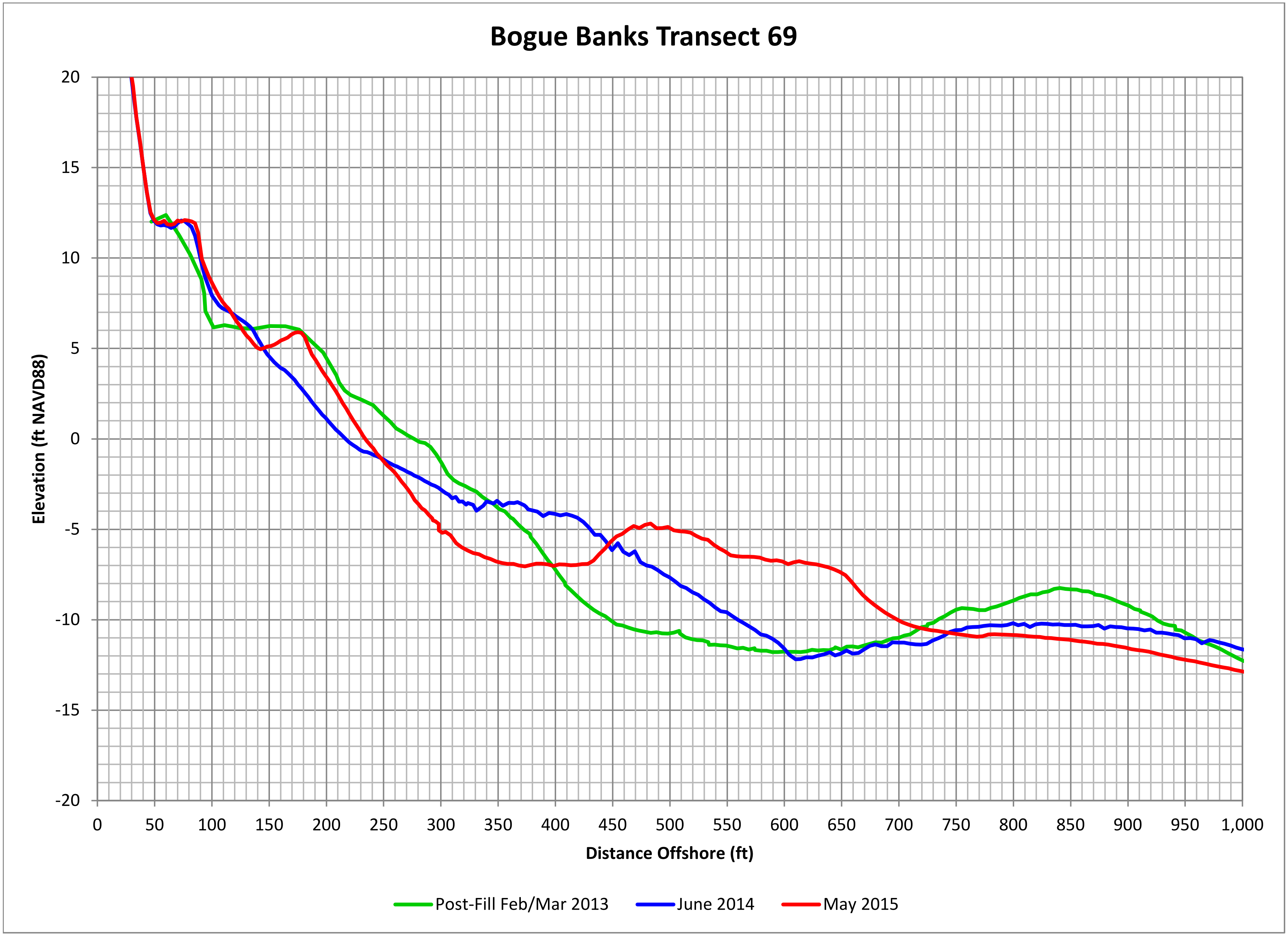

Figure C-95. Bogue Banks Profile Comparison Plot

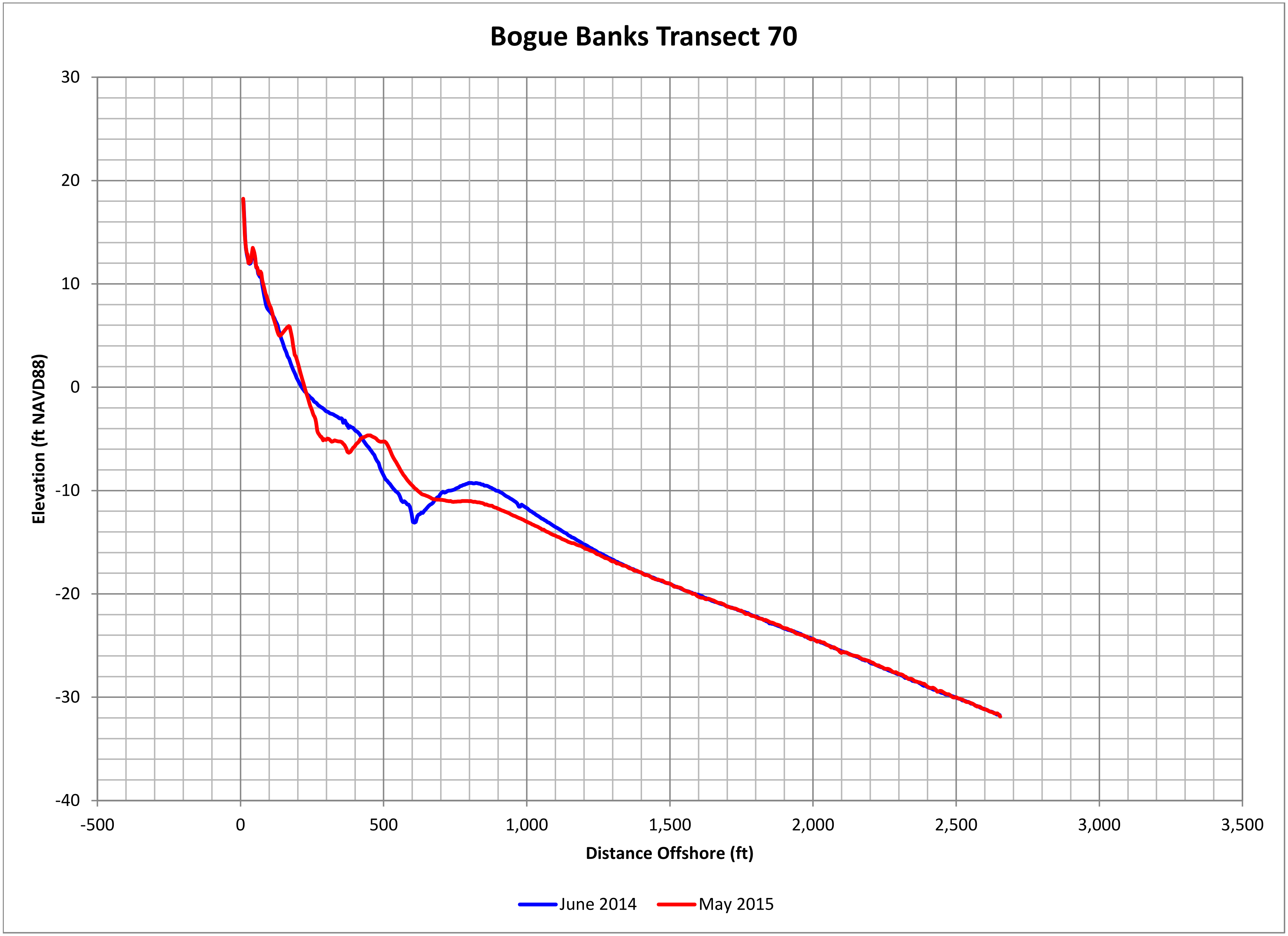

Figure C-96. Bogue Banks Profile Comparison Plot

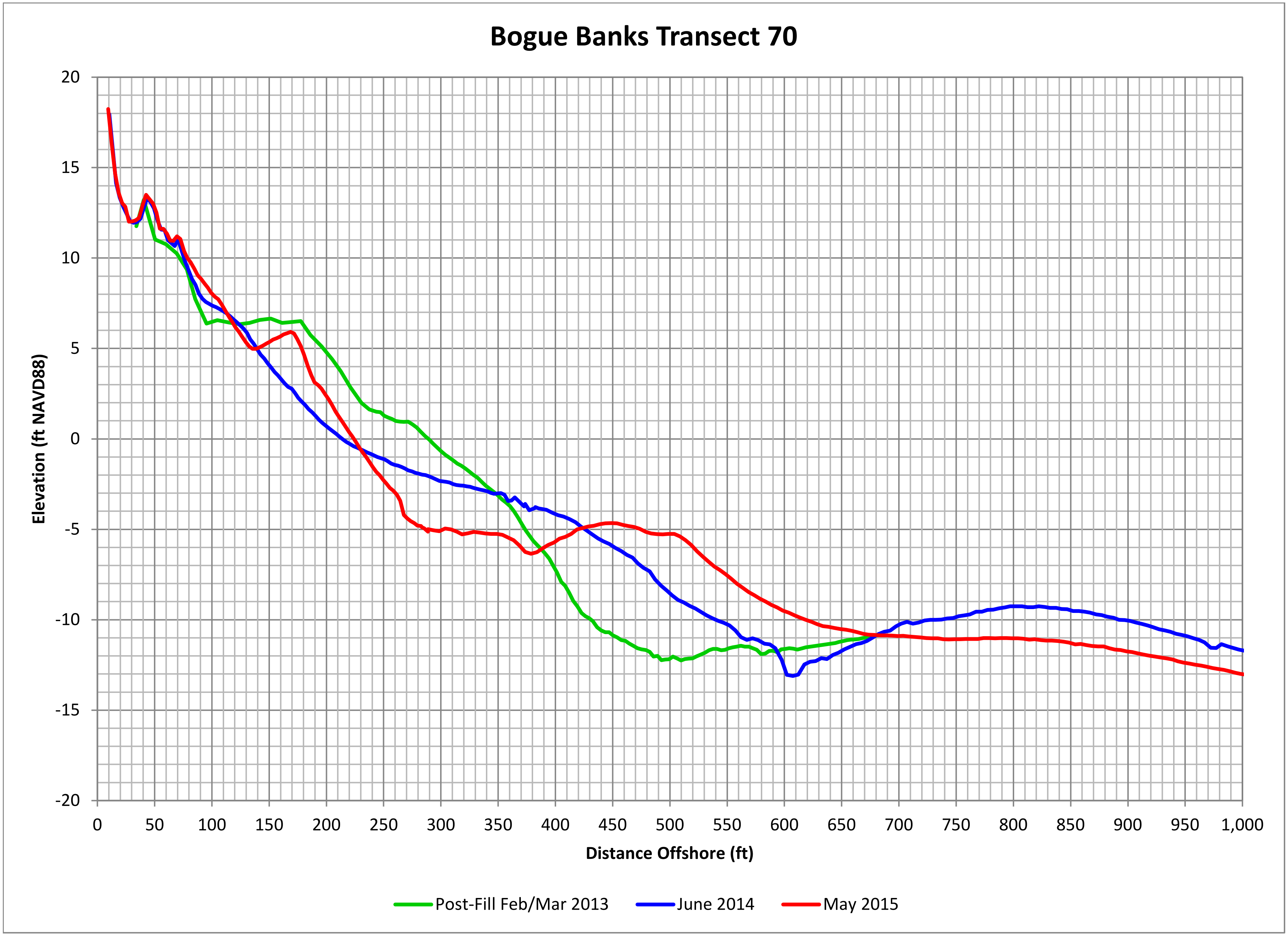

Figure C-97. Bogue Banks Profile Comparison Plot

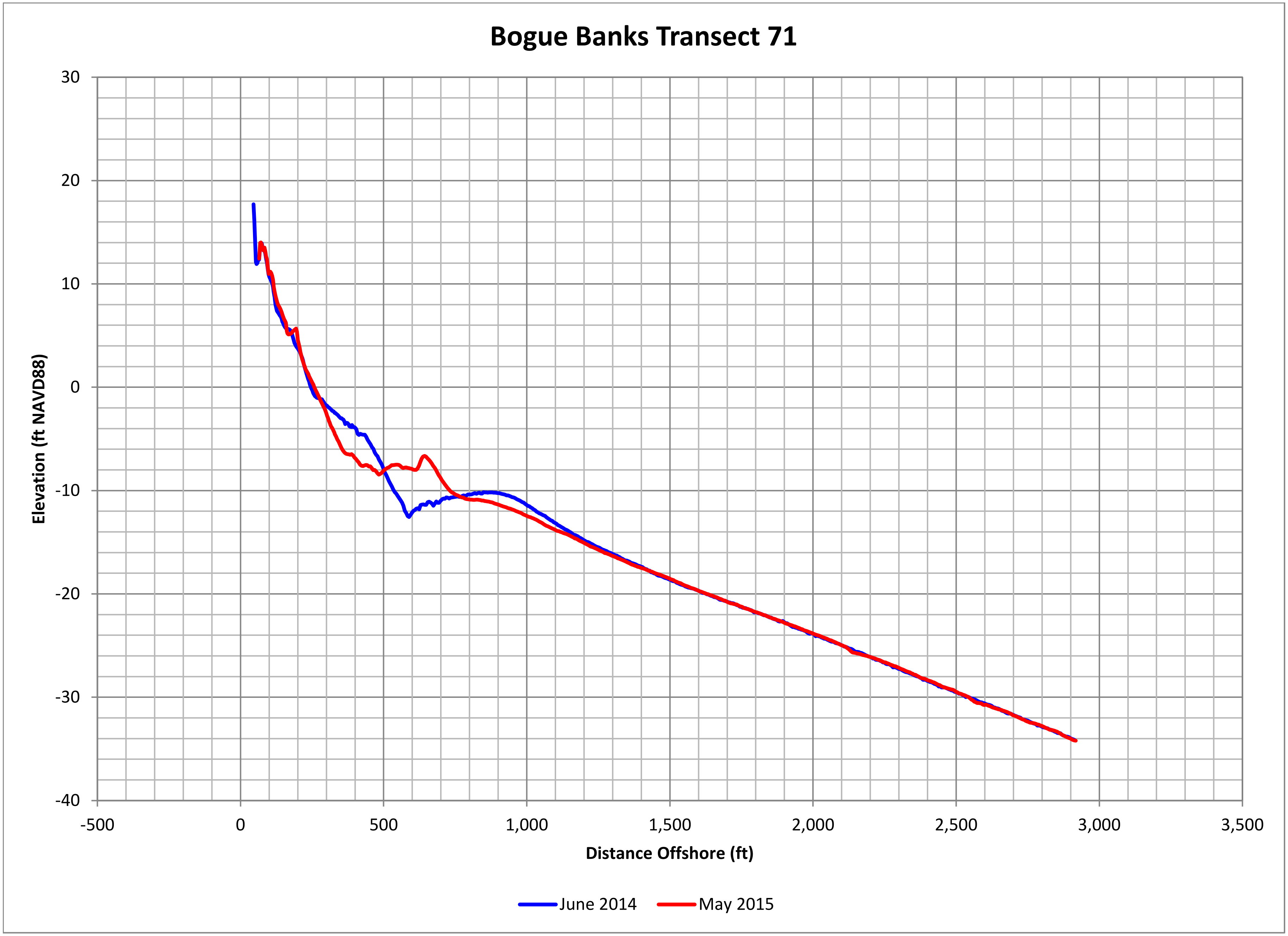

Figure C-98. Bogue Banks Profile Comparison Plot

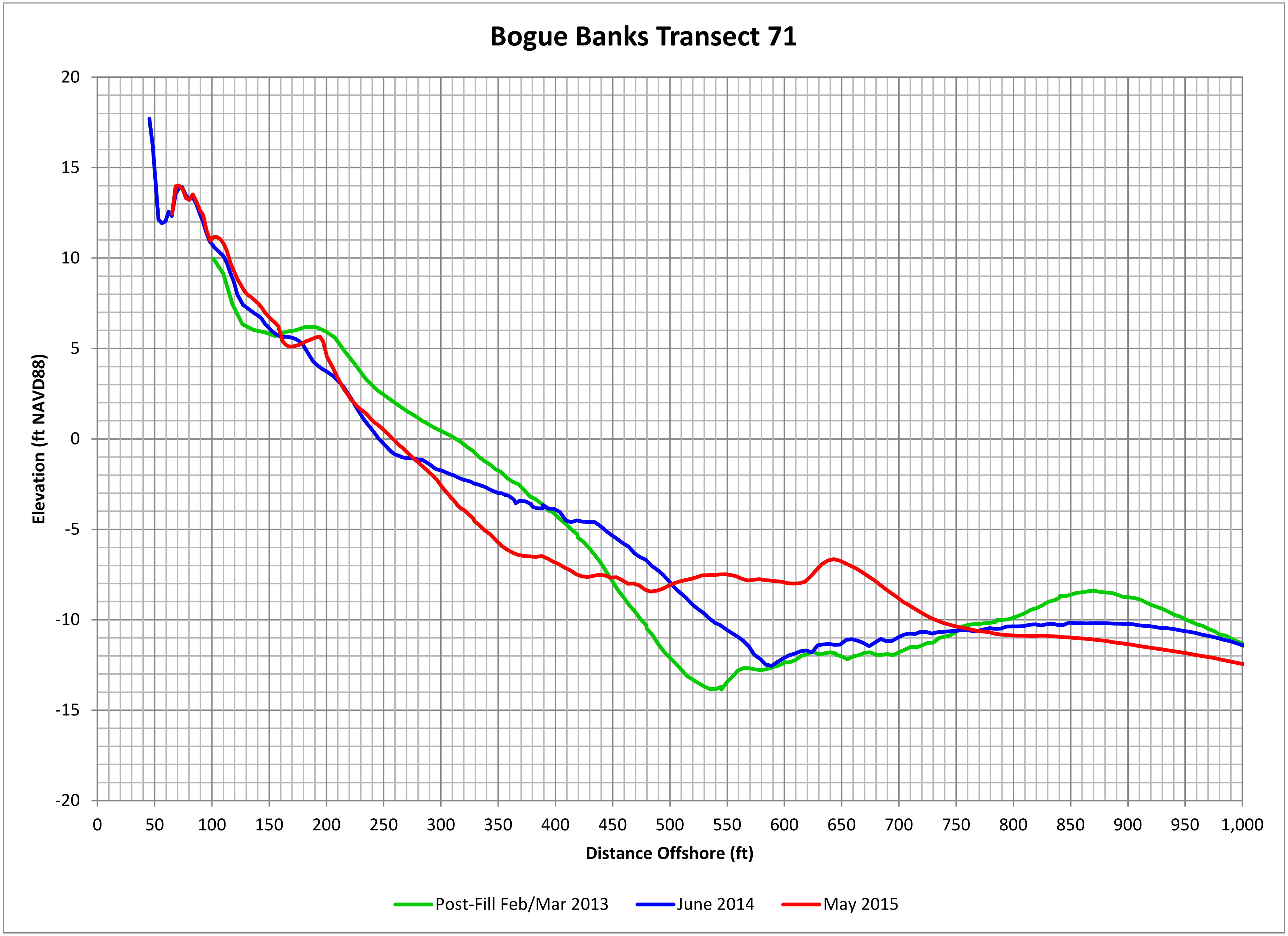

Figure C-99. Bogue Banks Profile Comparison Plot

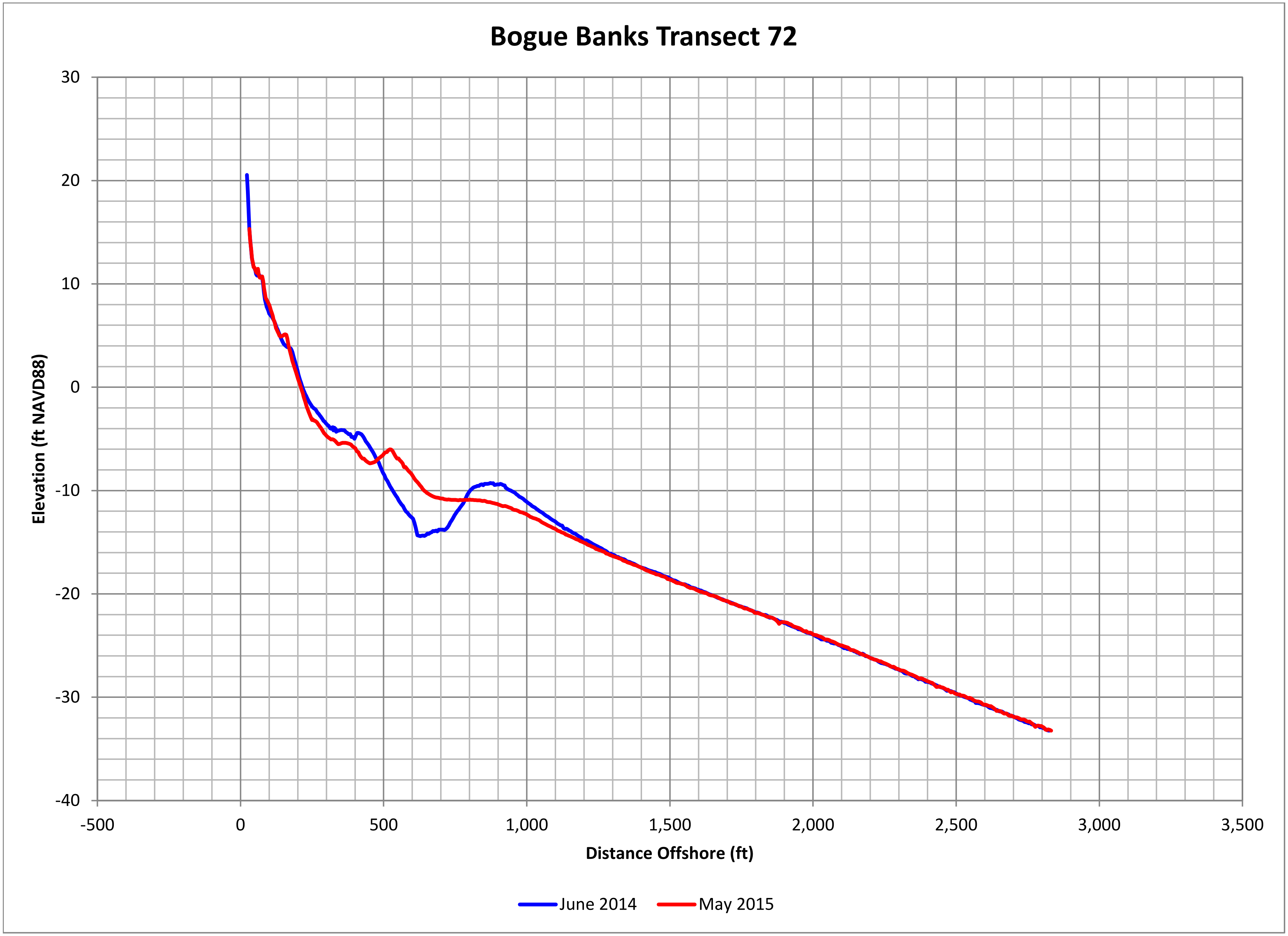

Figure C-100. Bogue Banks Profile Comparison Plot

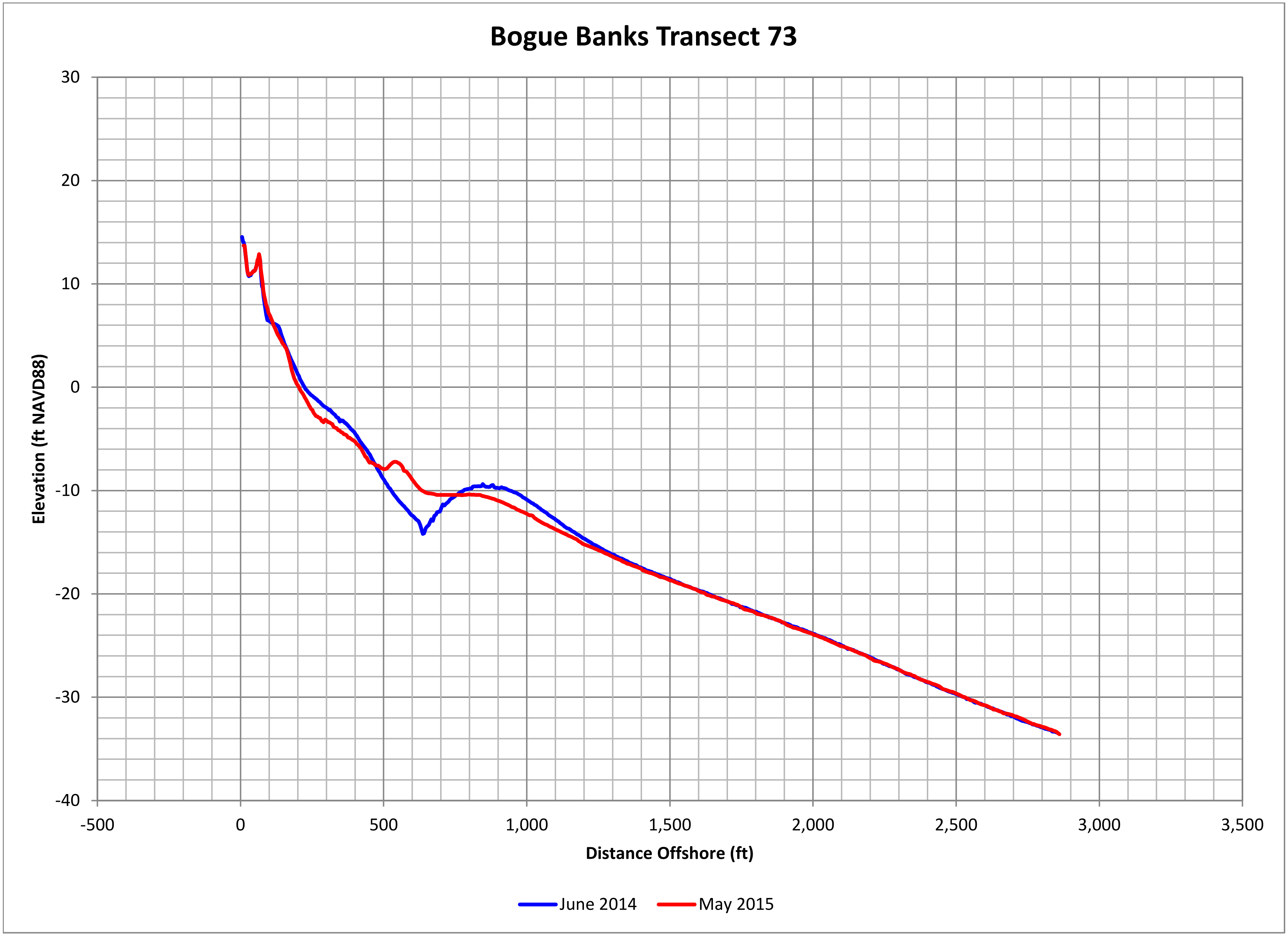

Figure C-101. Bogue Banks Profile Comparison Plot

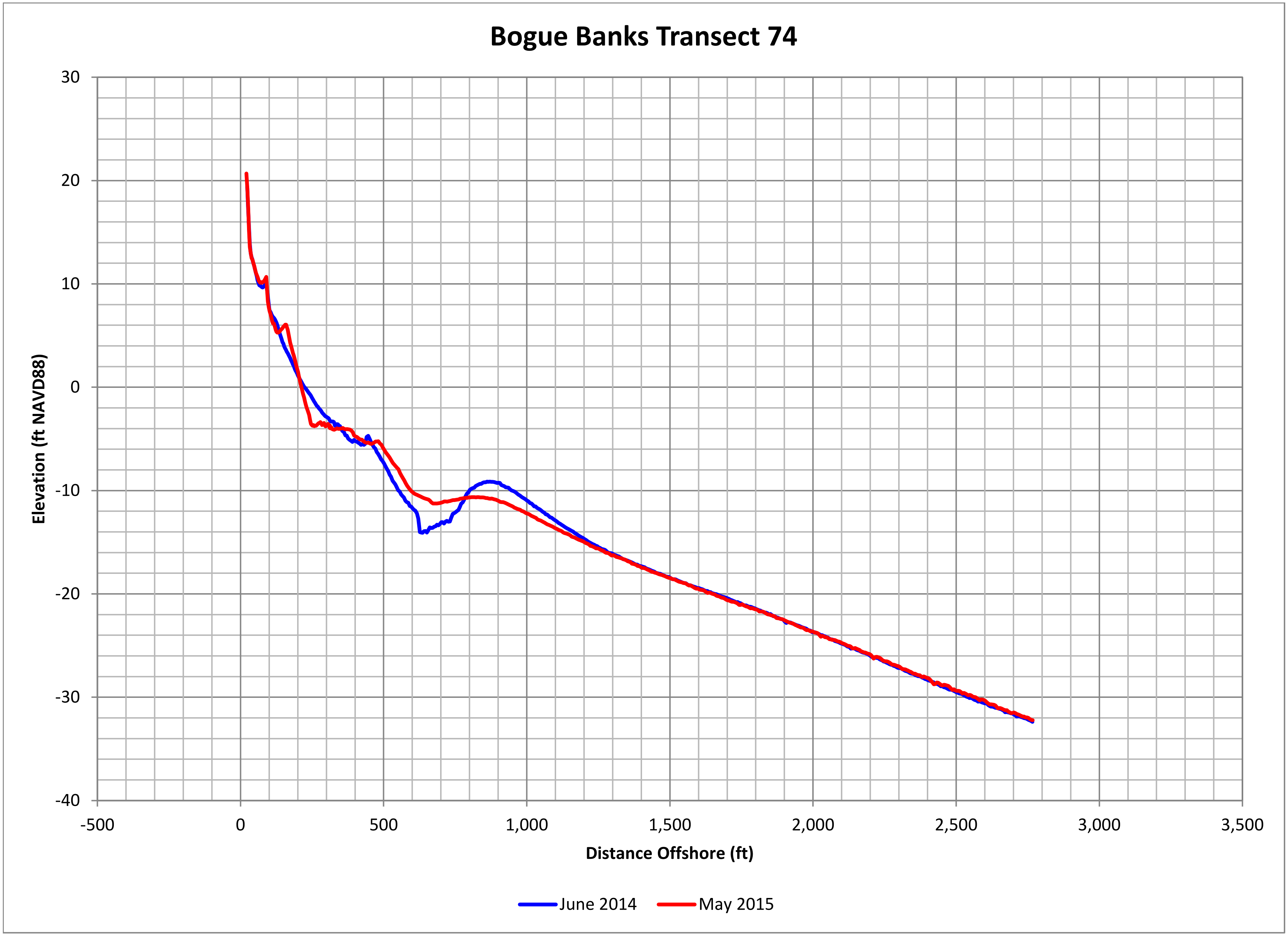

Figure C-102. Bogue Banks Profile Comparison Plot

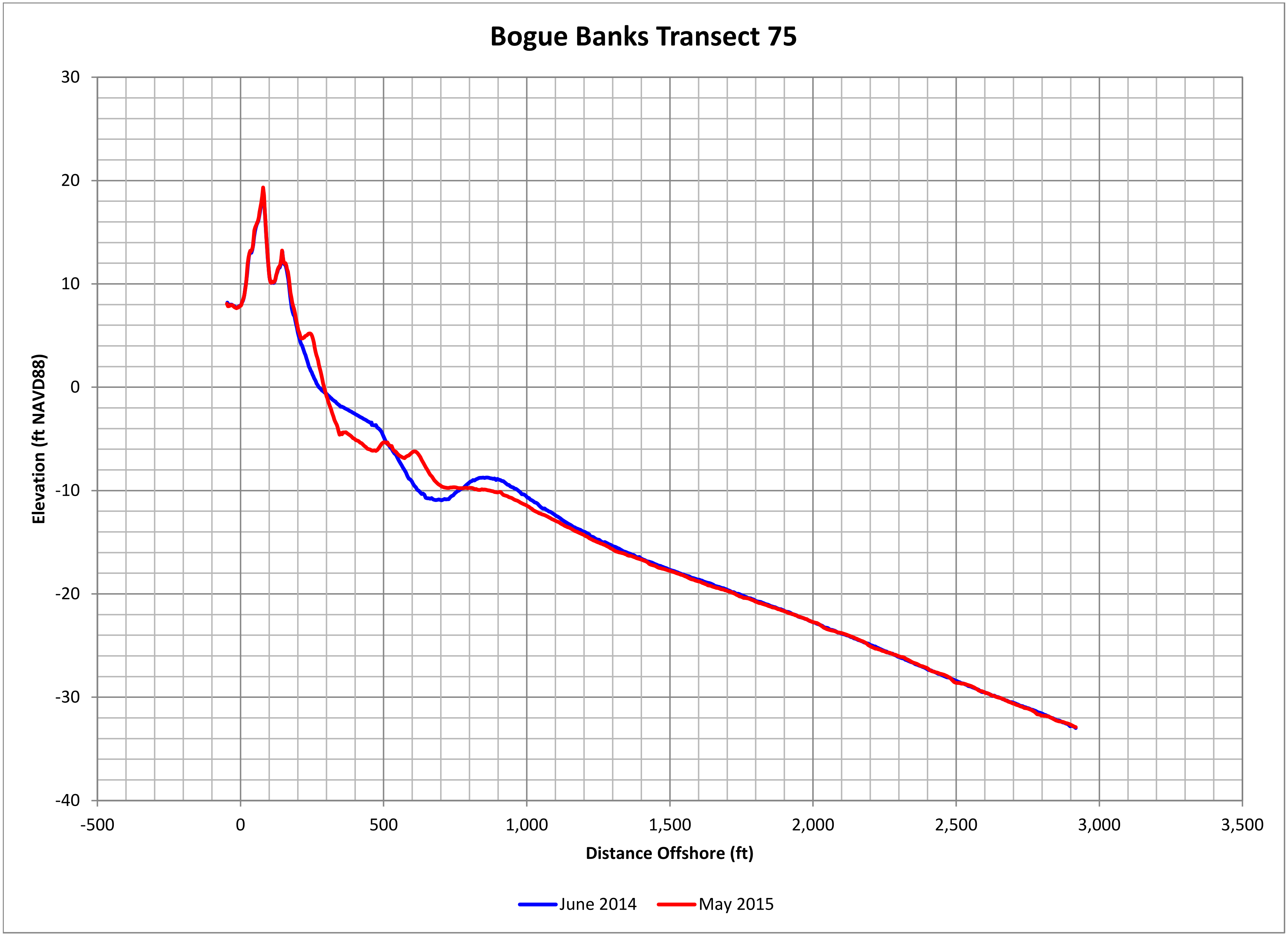

Figure C-103. Bogue Banks Profile Comparison Plot

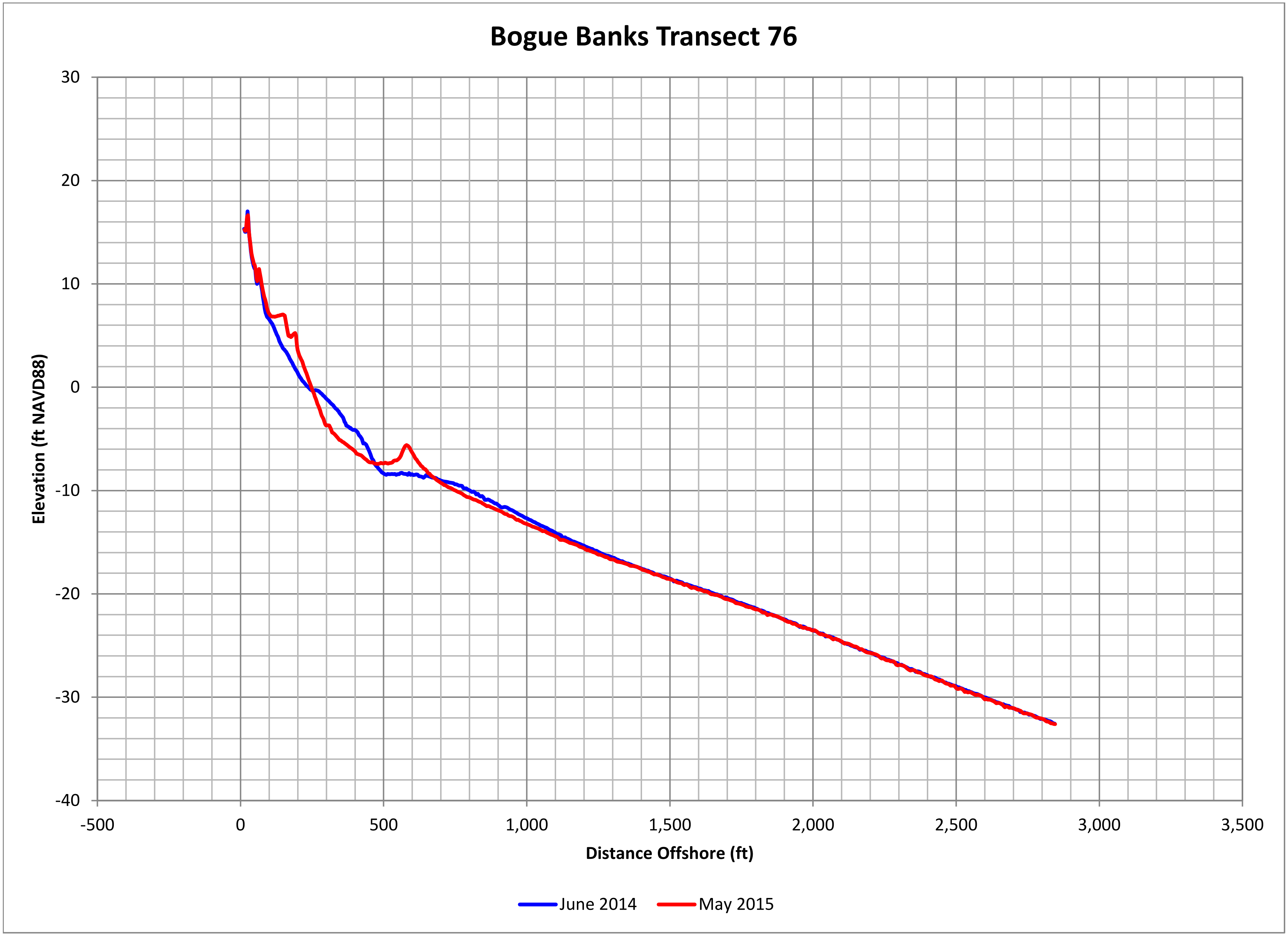

Figure C-104. Bogue Banks Profile Comparison Plot

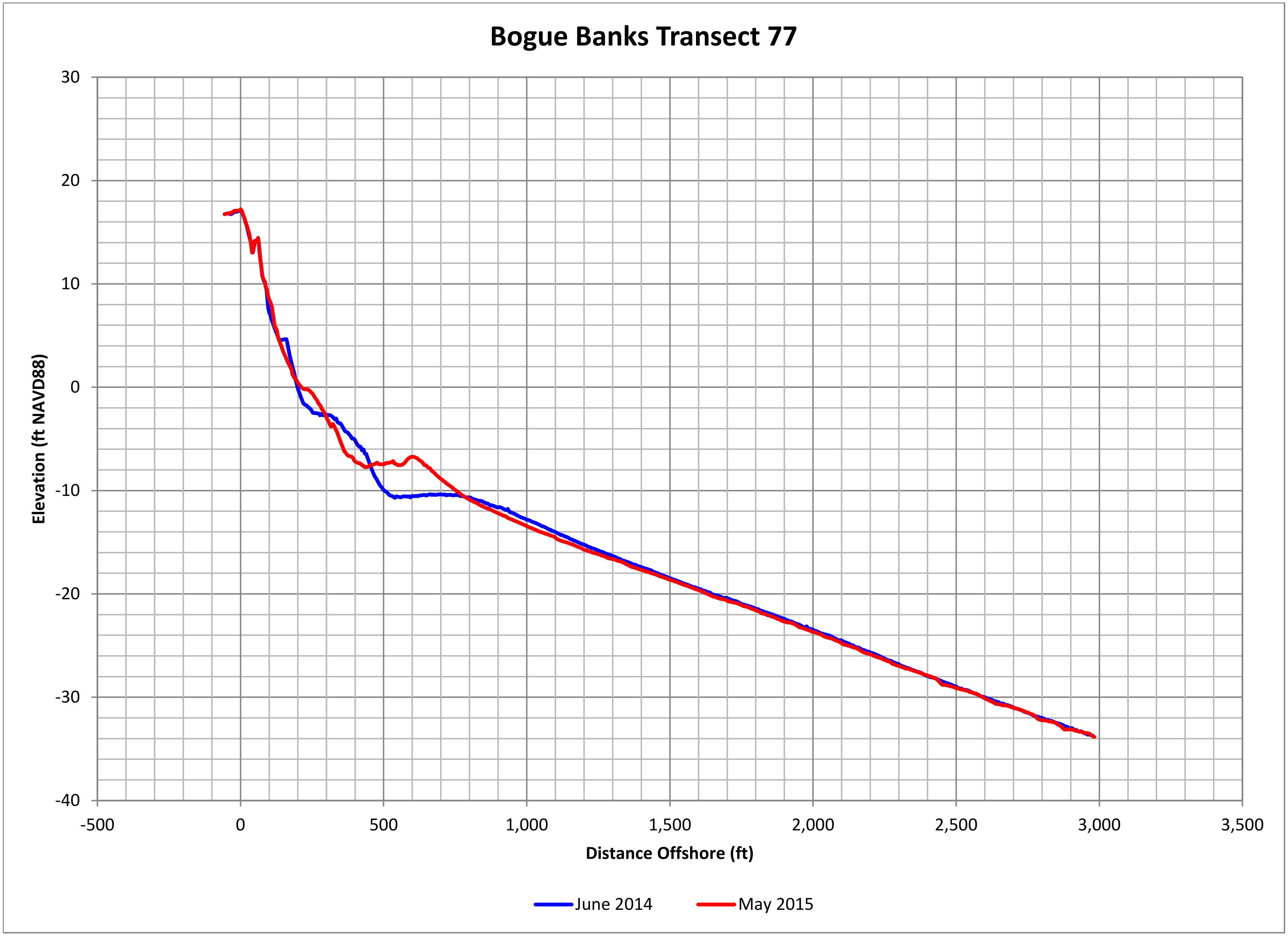

Figure C-105. Bogue Banks Profile Comparison Plot

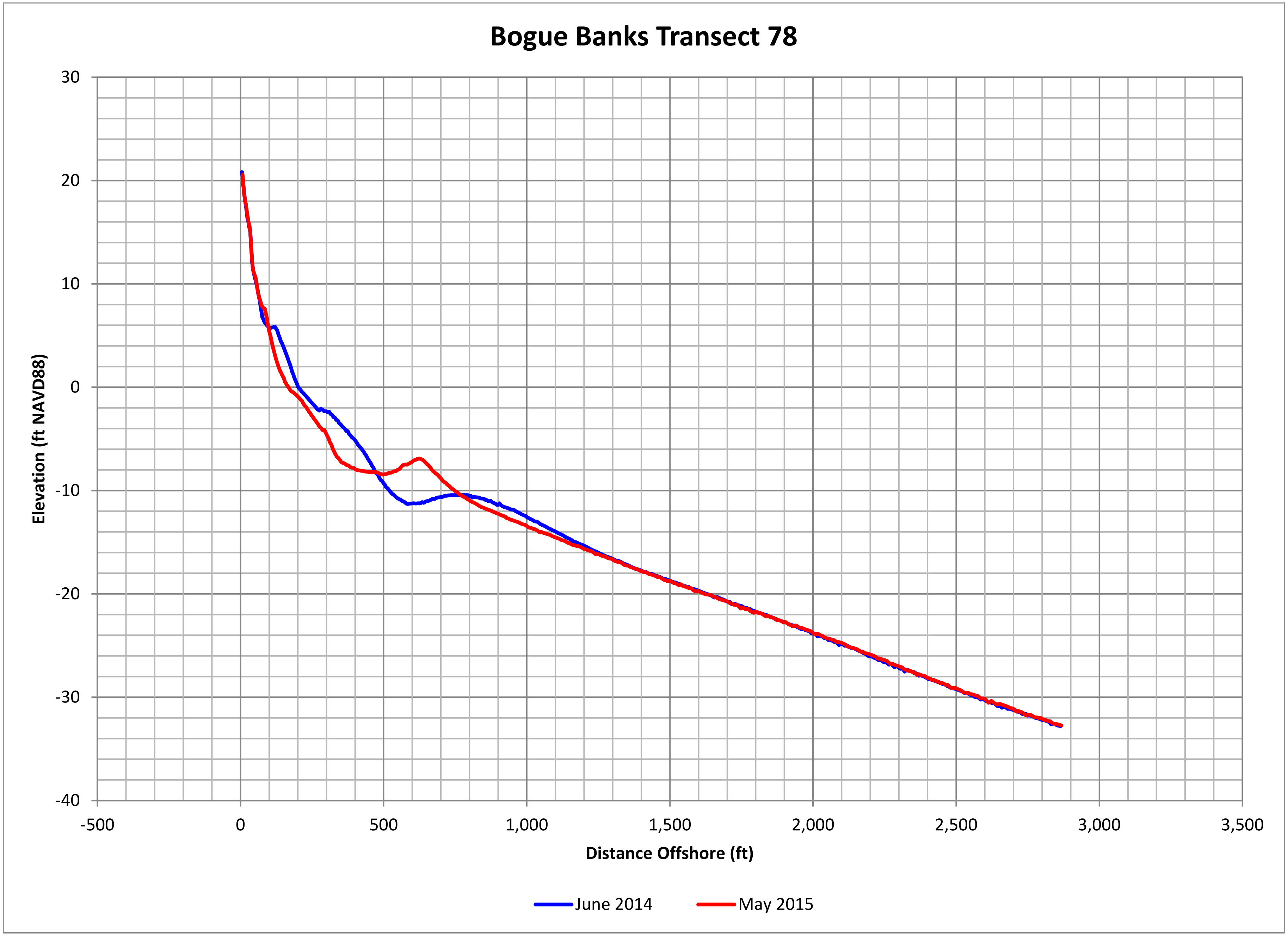

Figure C-106. Bogue Banks Profile Comparison Plot

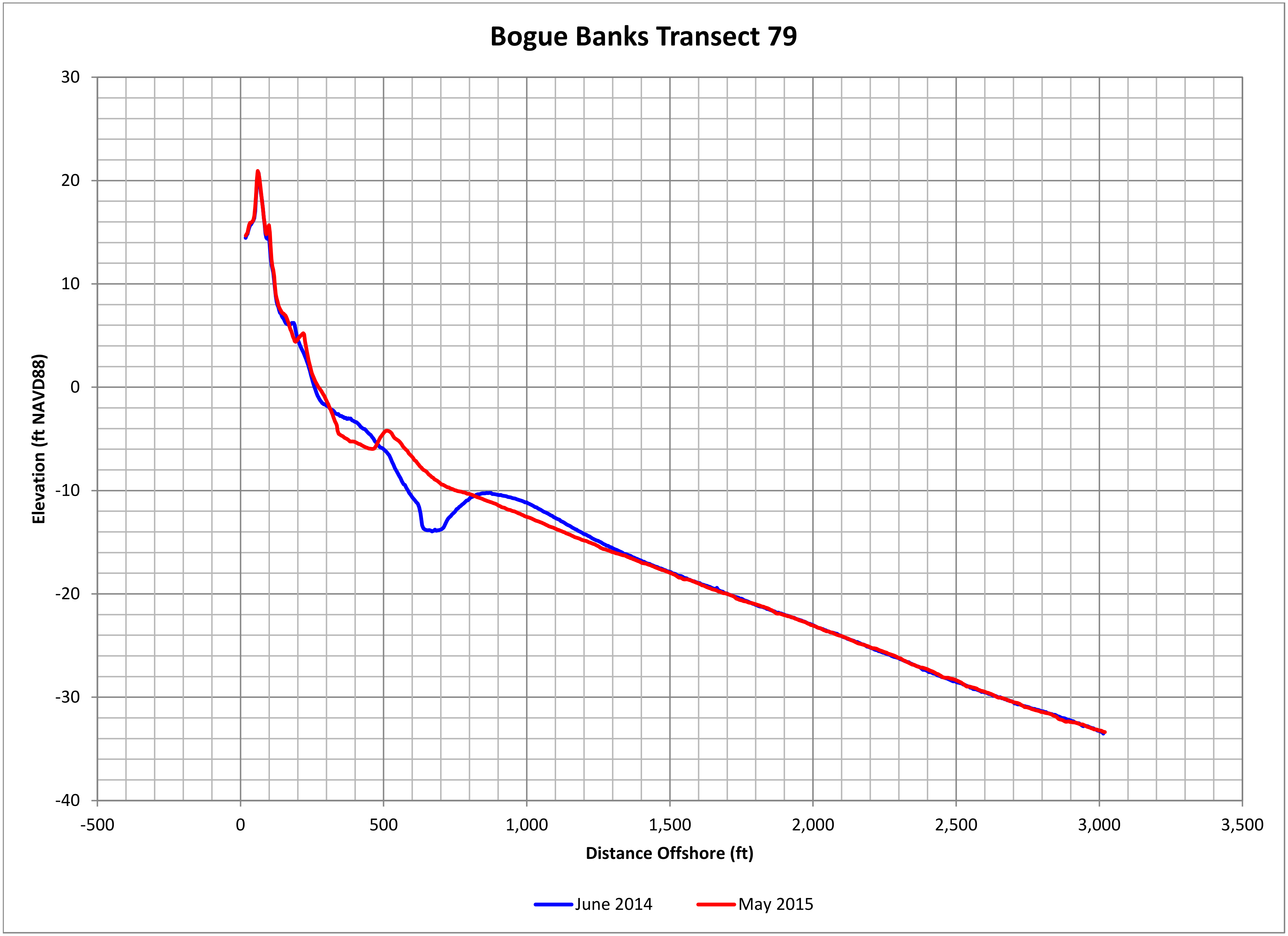

Figure C-107. Bogue Banks Profile Comparison Plot

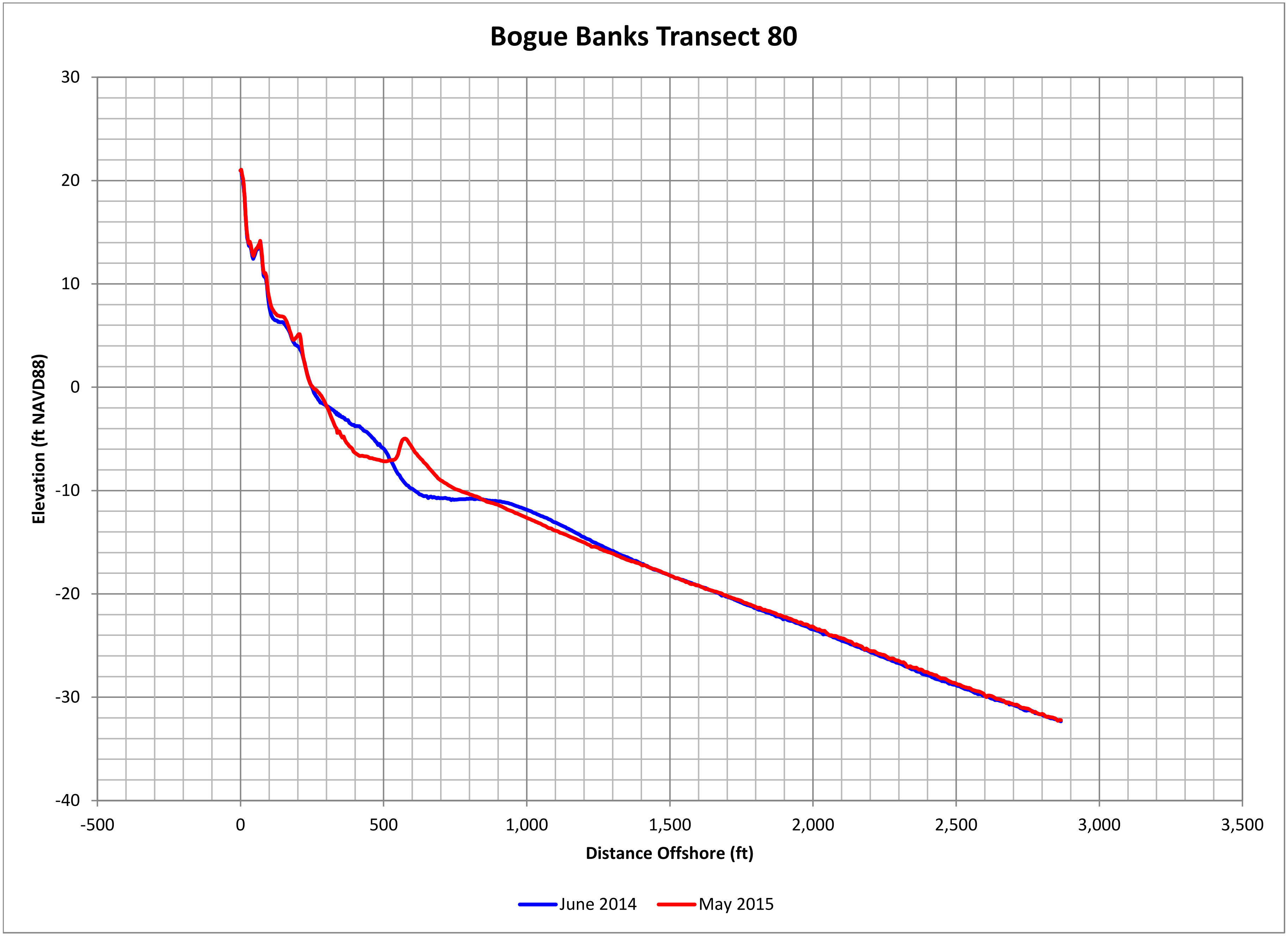

Figure C-108. Bogue Banks Profile Comparison Plot

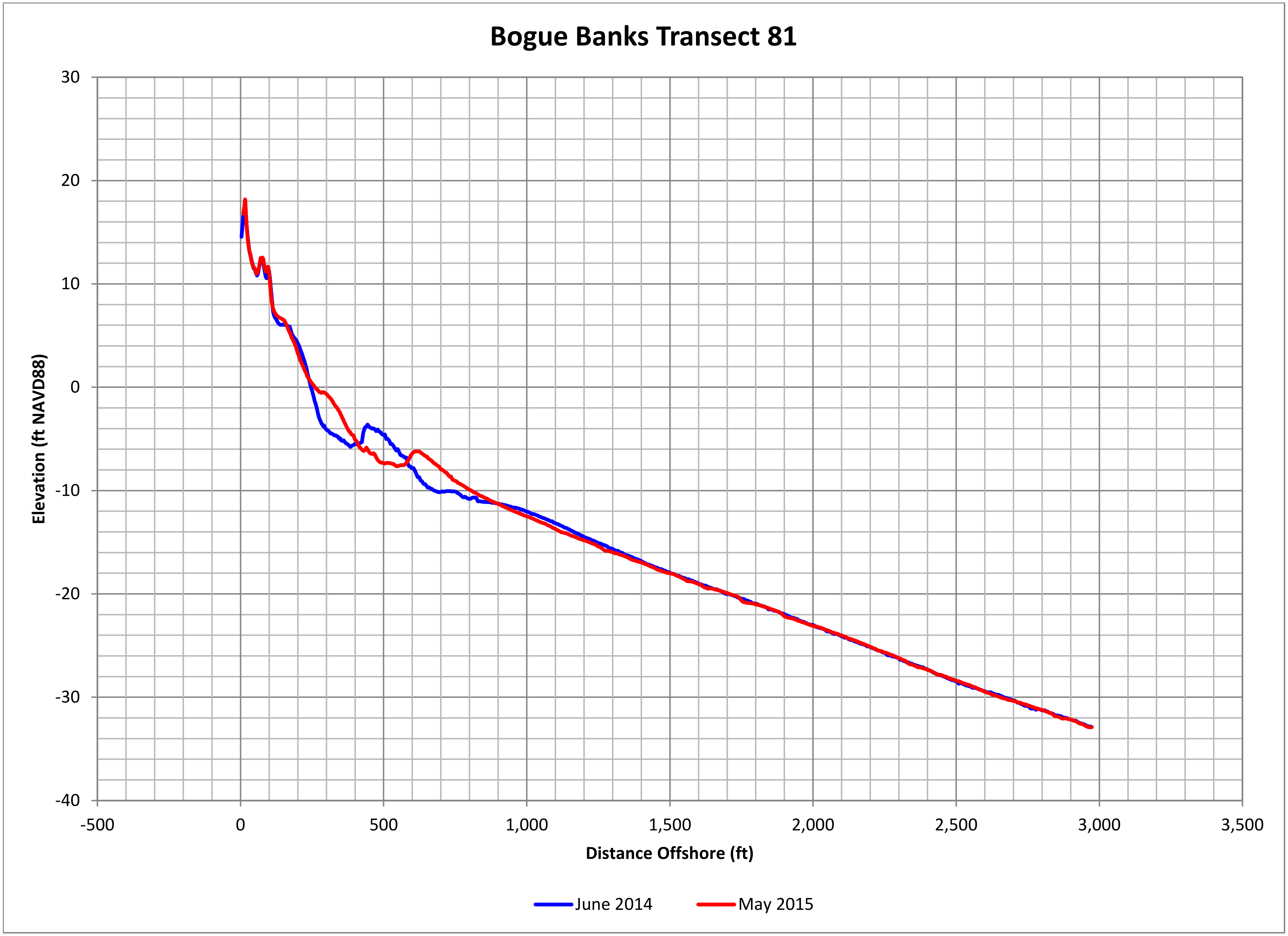

Figure C-109. Bogue Banks Profile Comparison Plot

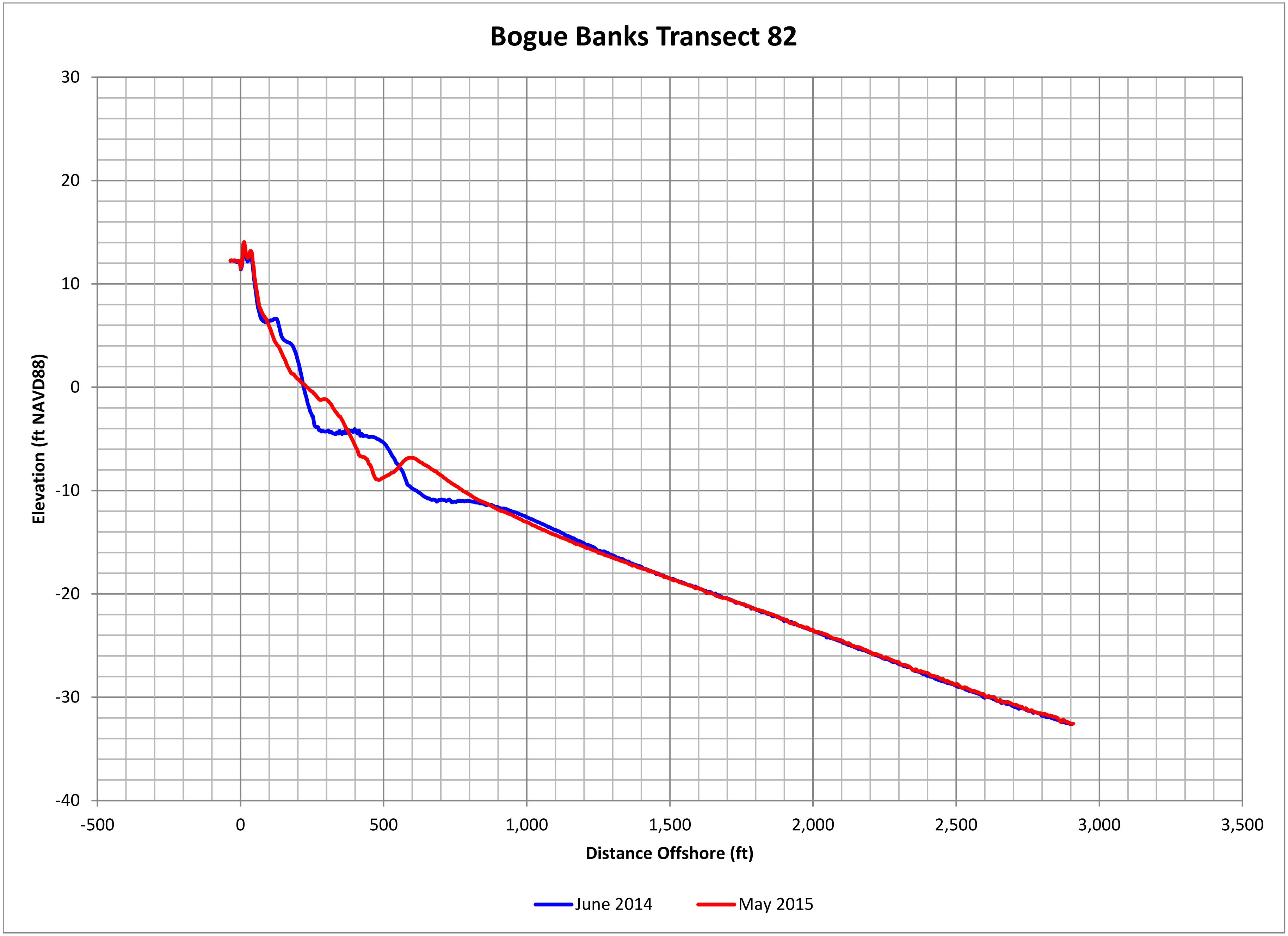

Figure C-110. Bogue Banks Profile Comparison Plot

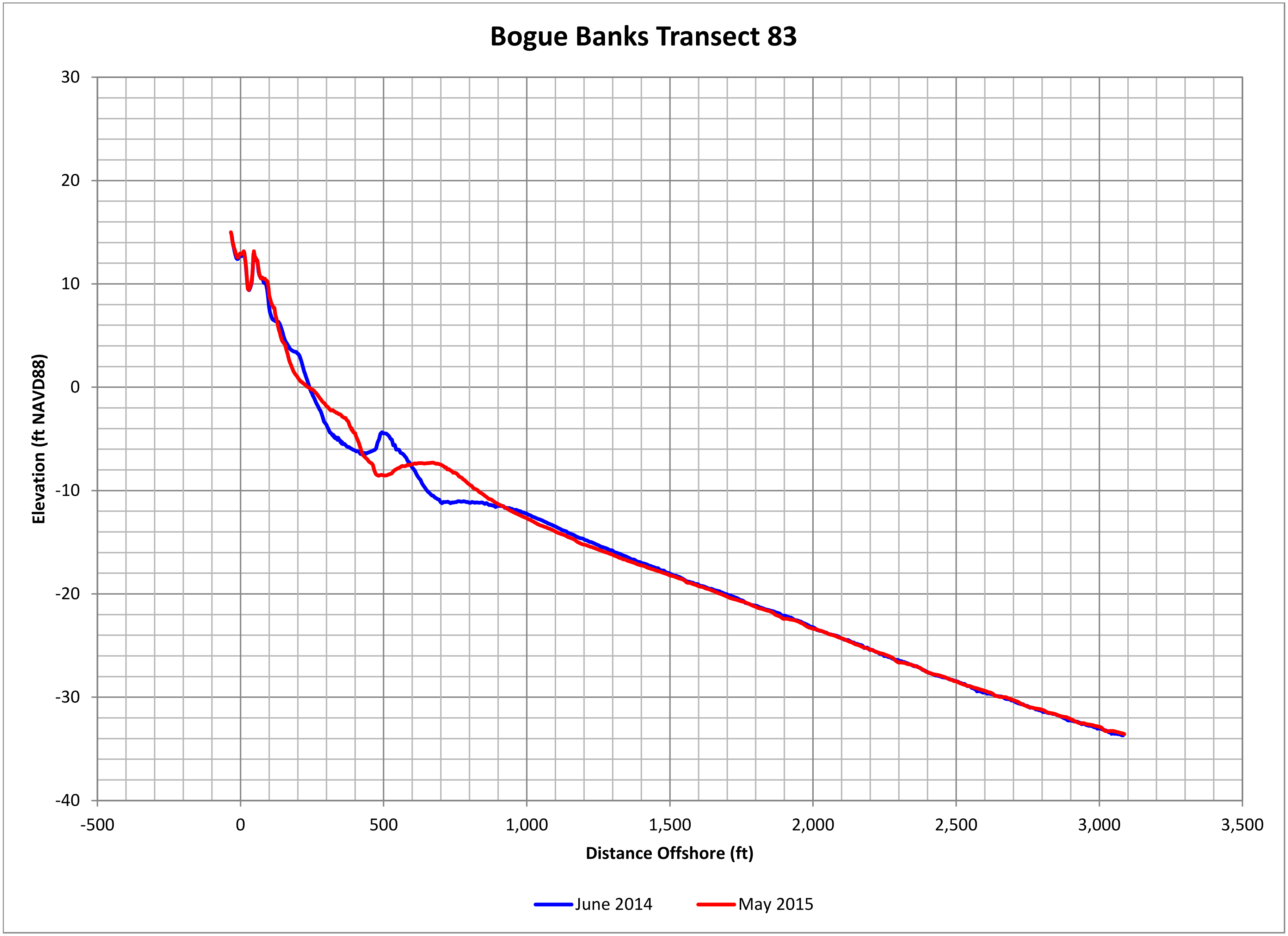

Figure C-111. Bogue Banks Profile Comparison Plot

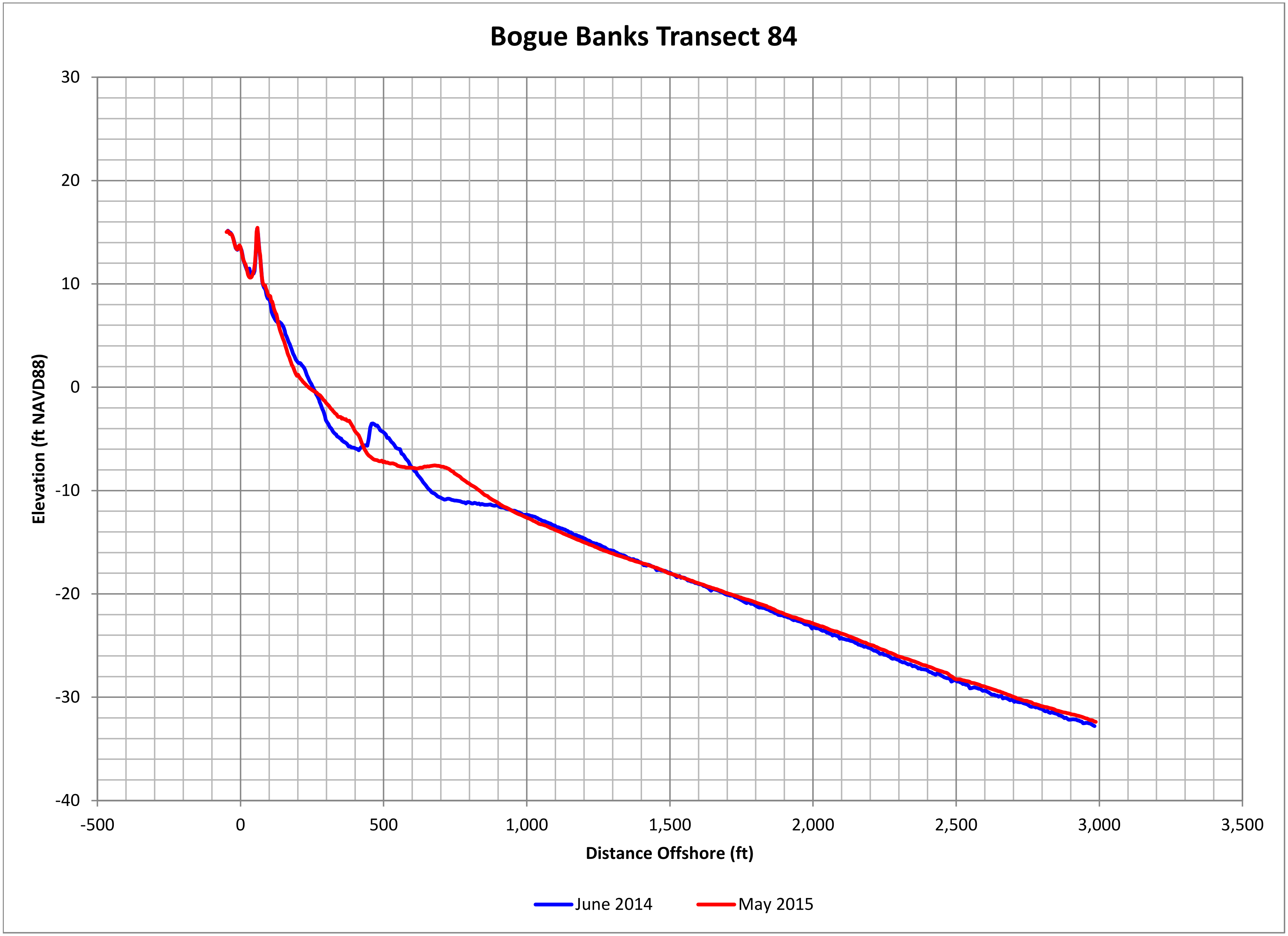

Figure C-112. Bogue Banks Profile Comparison Plot

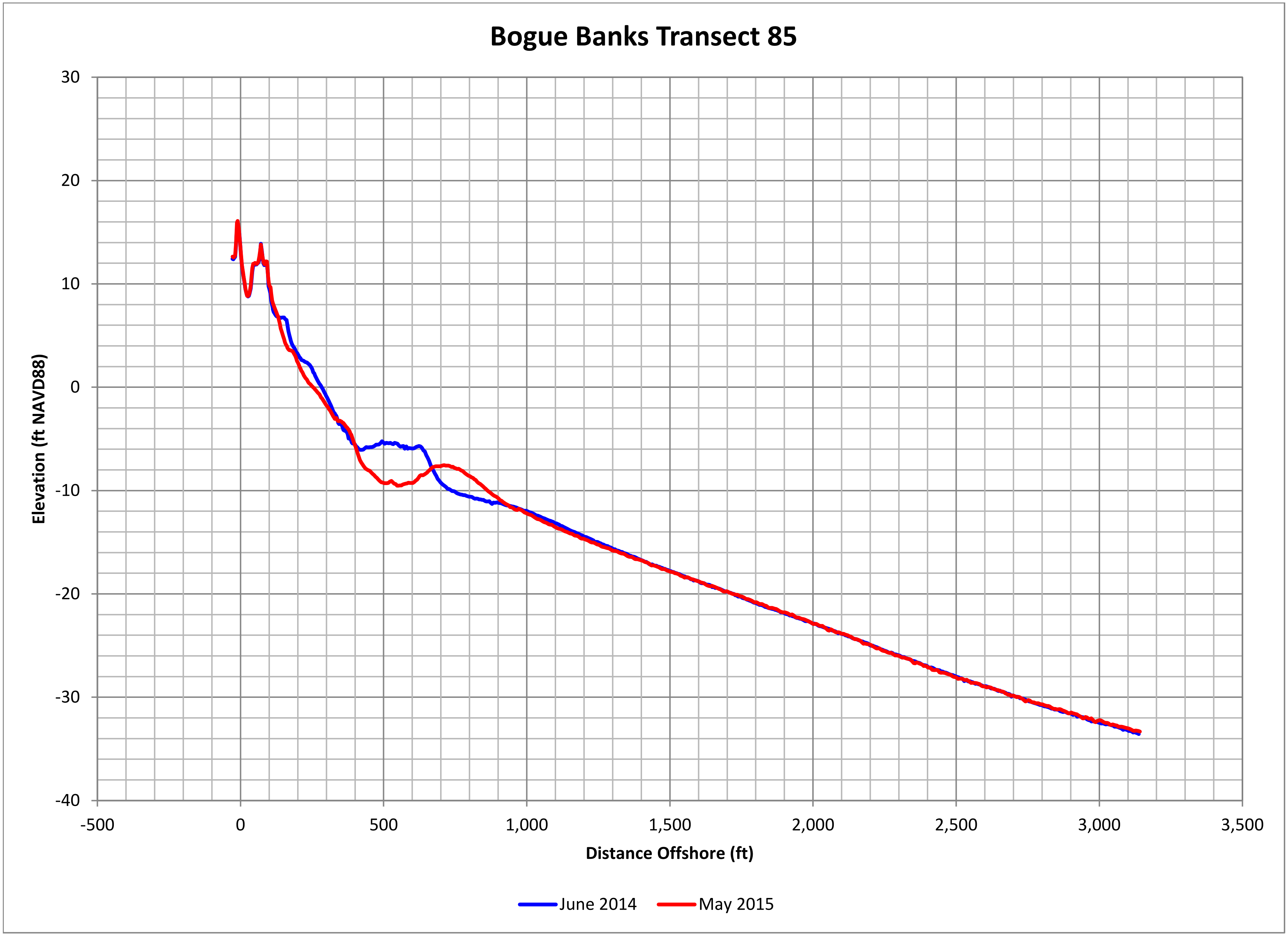

Figure C-113. Bogue Banks Profile Comparison Plot

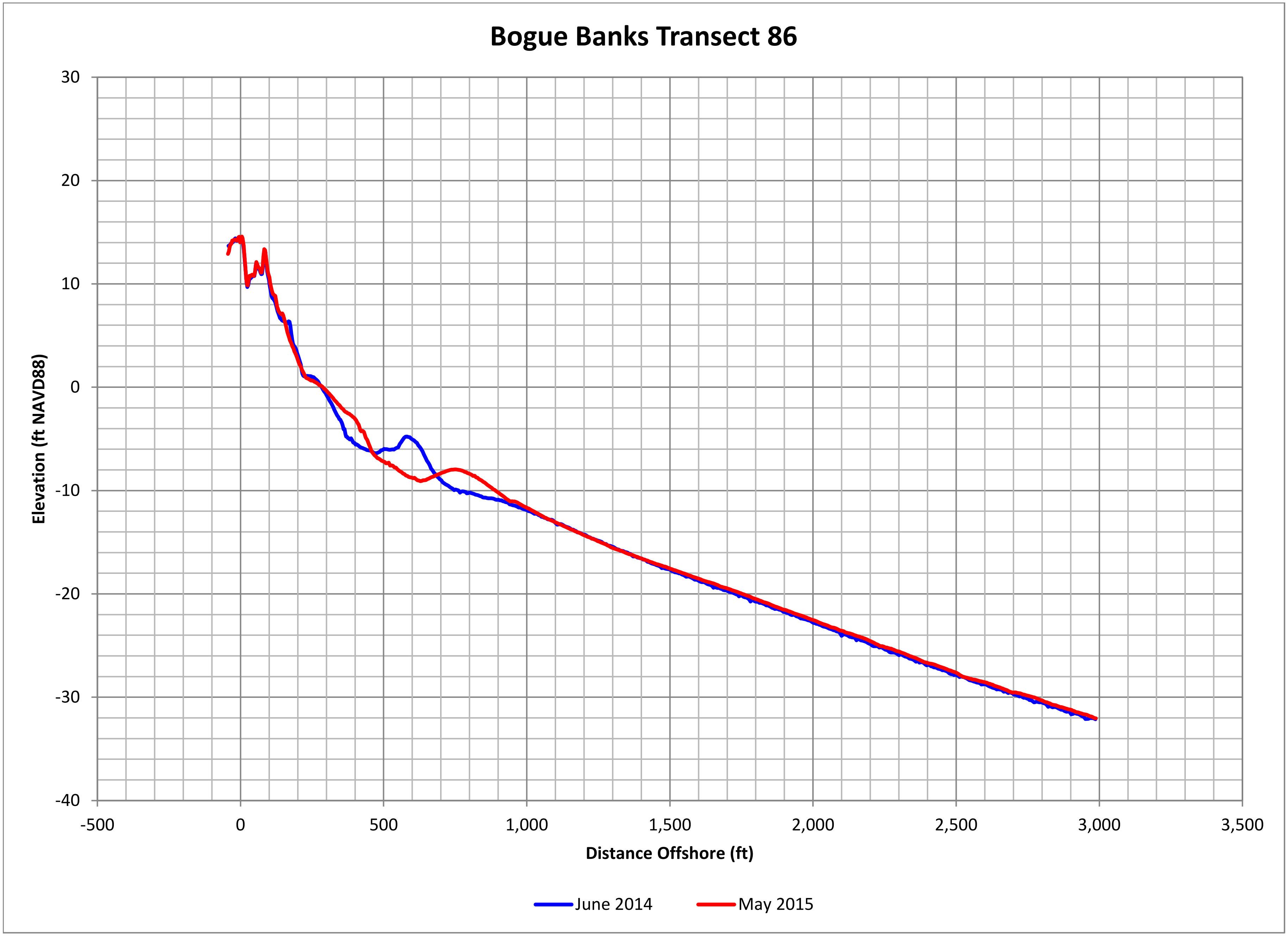

Figure C-114. Bogue Banks Profile Comparison Plot

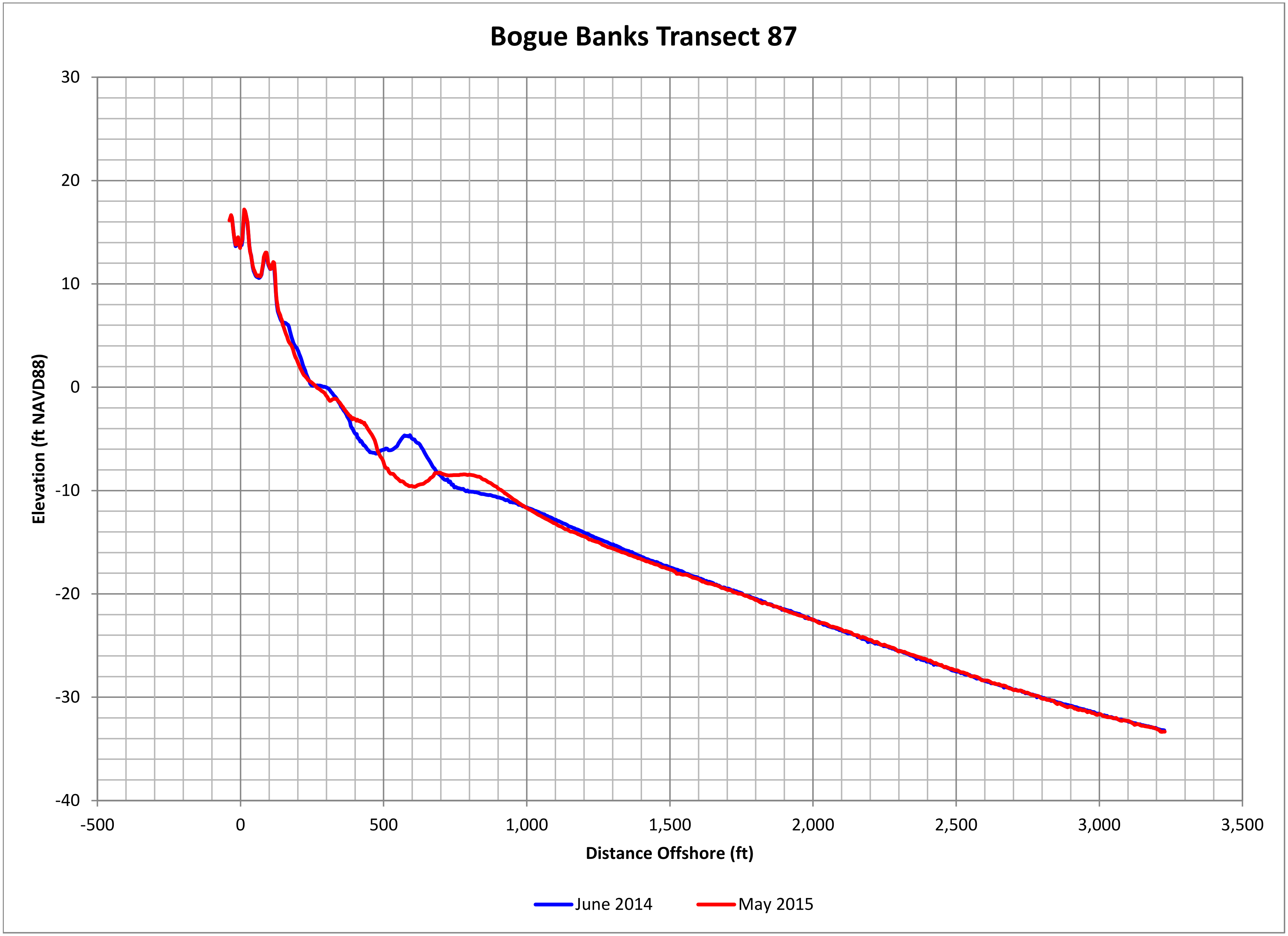

Figure C-115. Bogue Banks Profile Comparison Plot

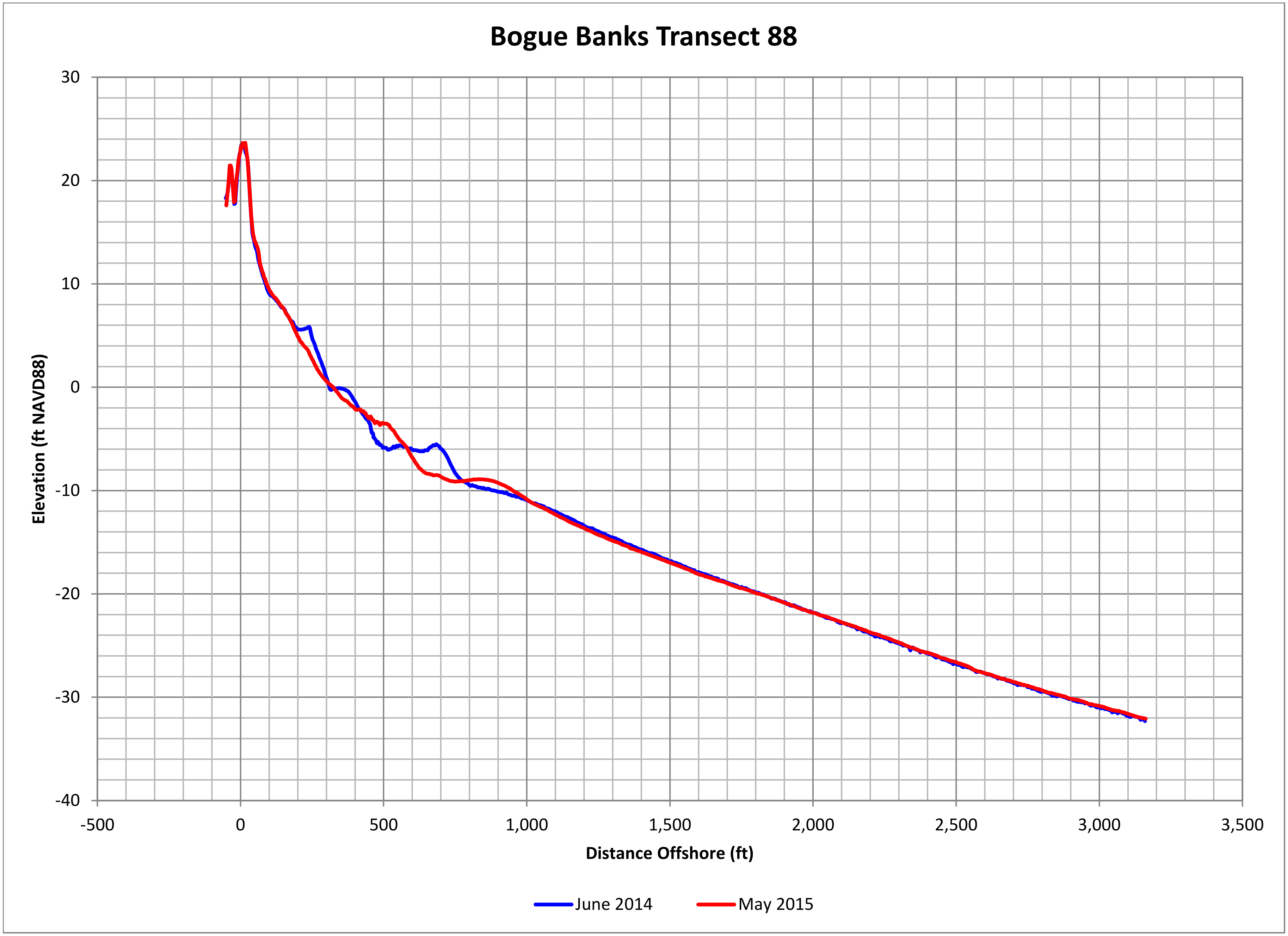

Figure C-116. Bogue Banks Profile Comparison Plot

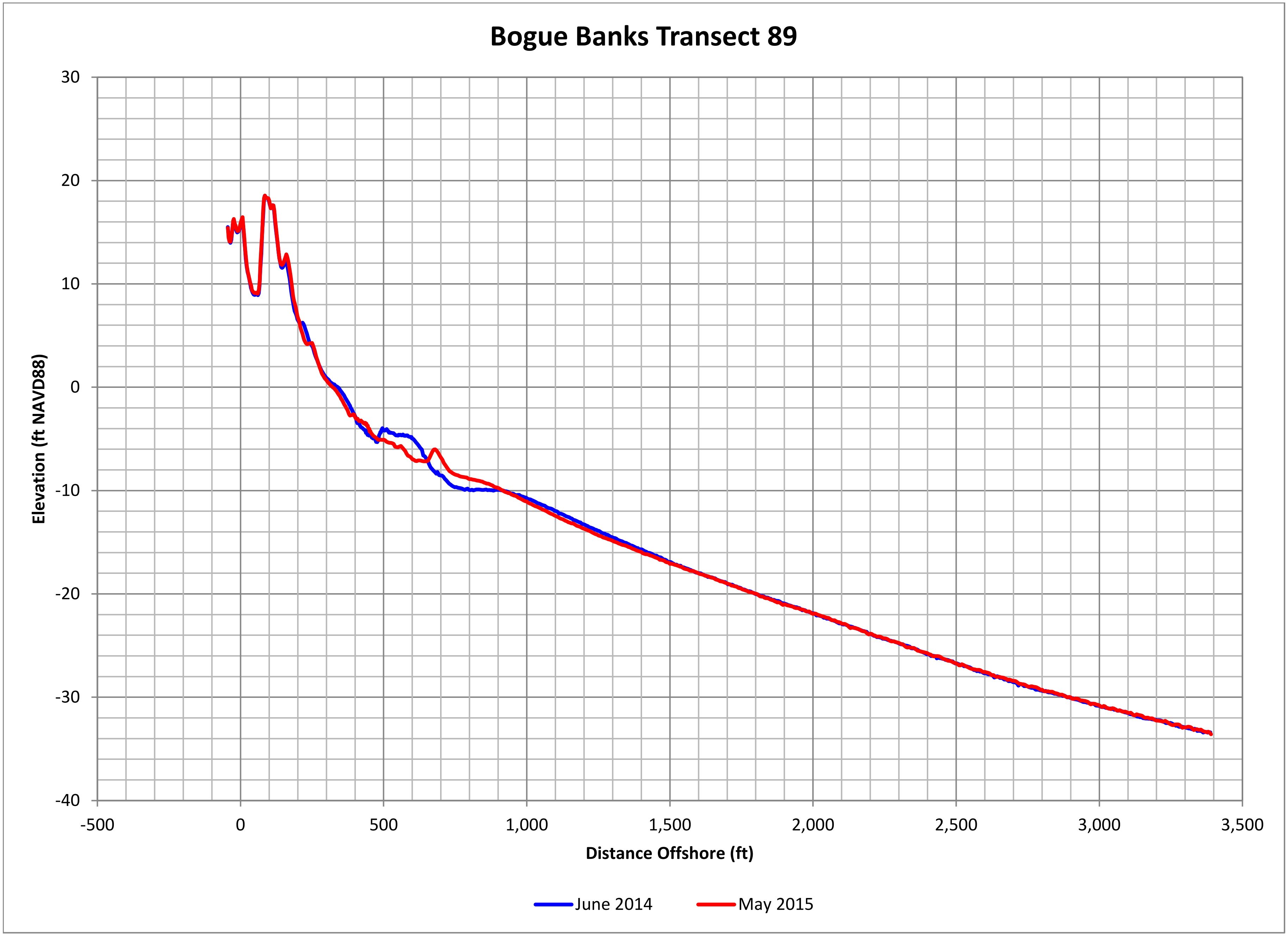

Figure C-117. Bogue Banks Profile Comparison Plot

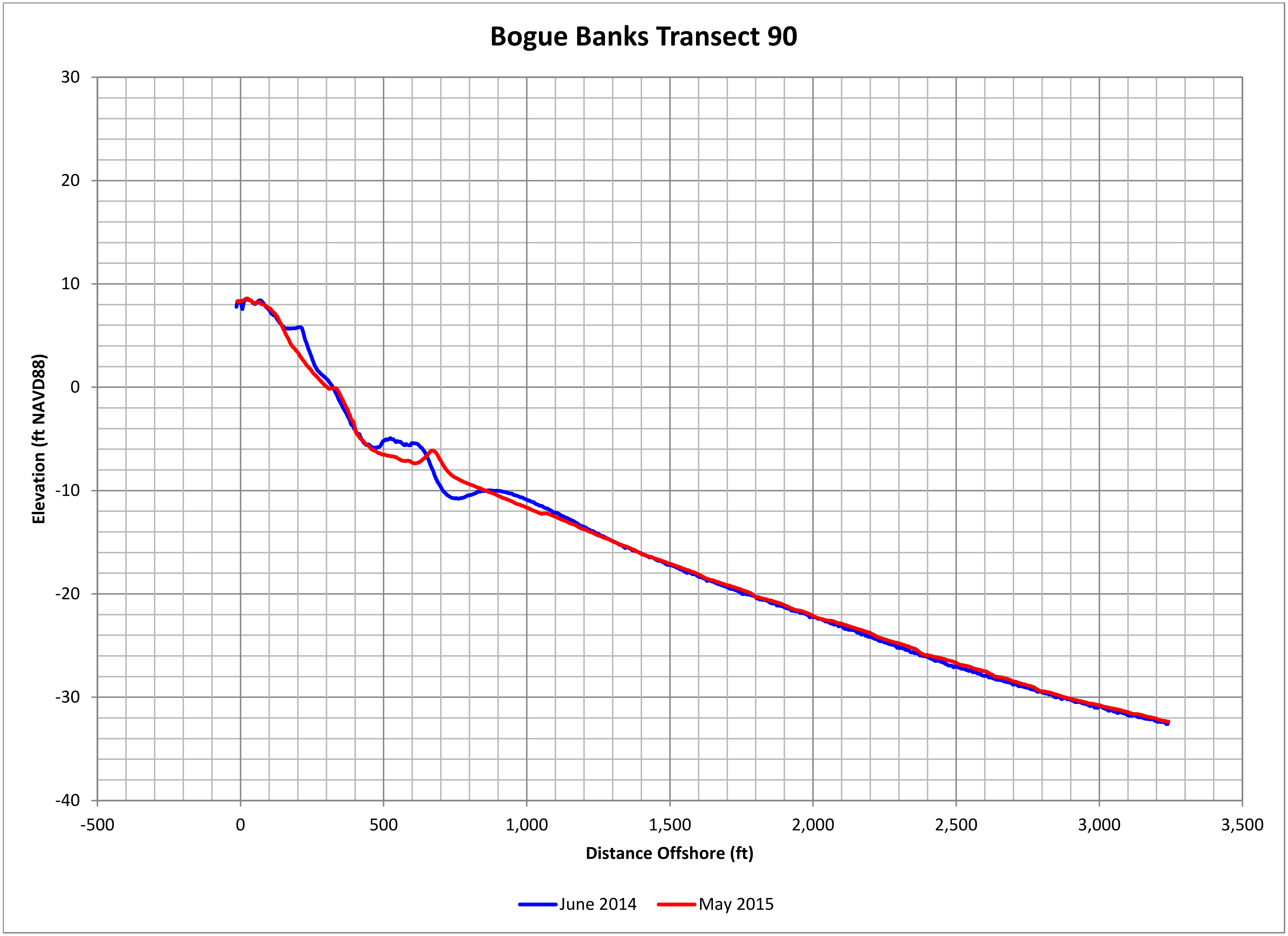

Figure C-118. Bogue Banks Profile Comparison Plot

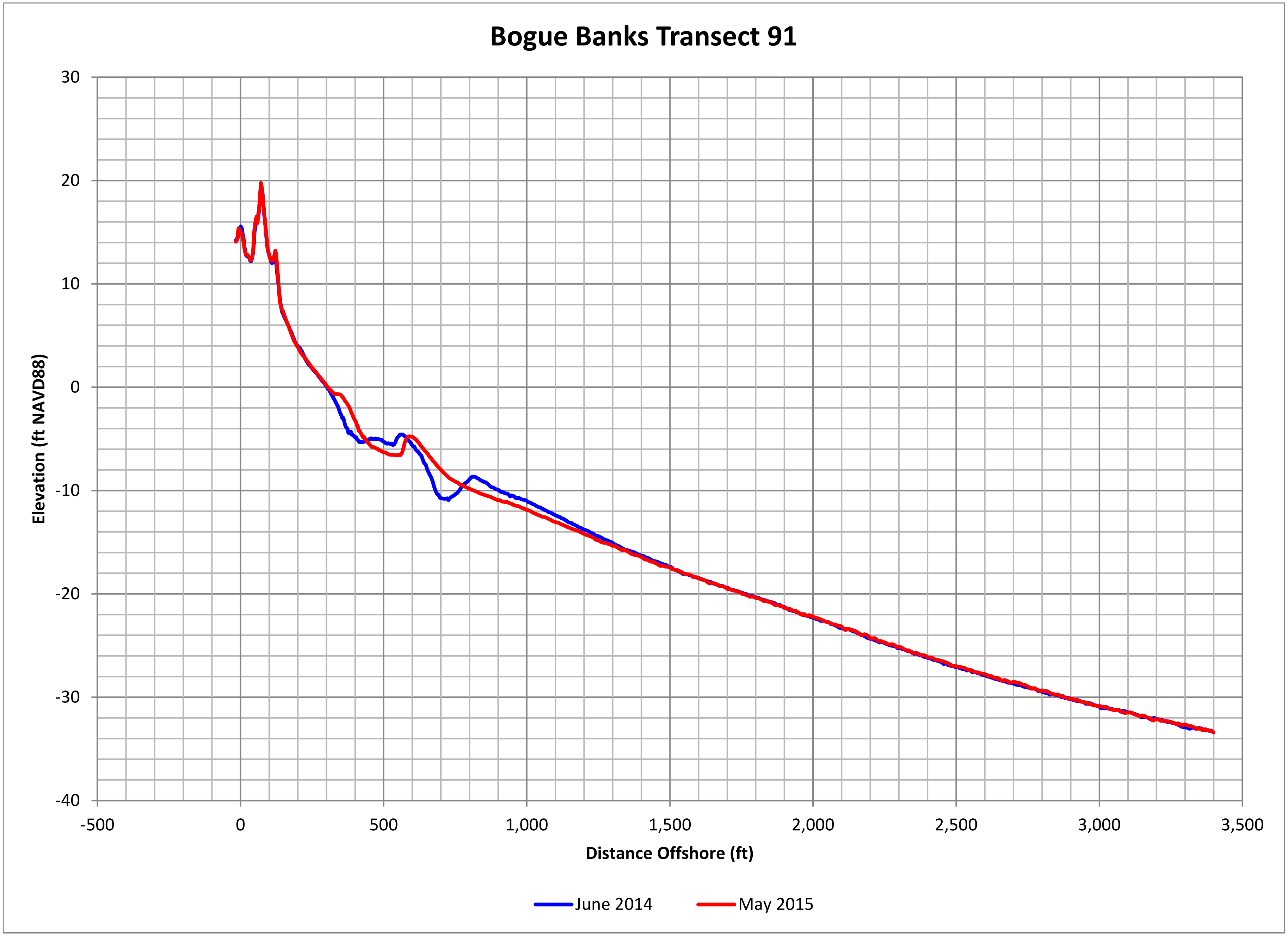

Figure C-119. Bogue Banks Profile Comparison Plot

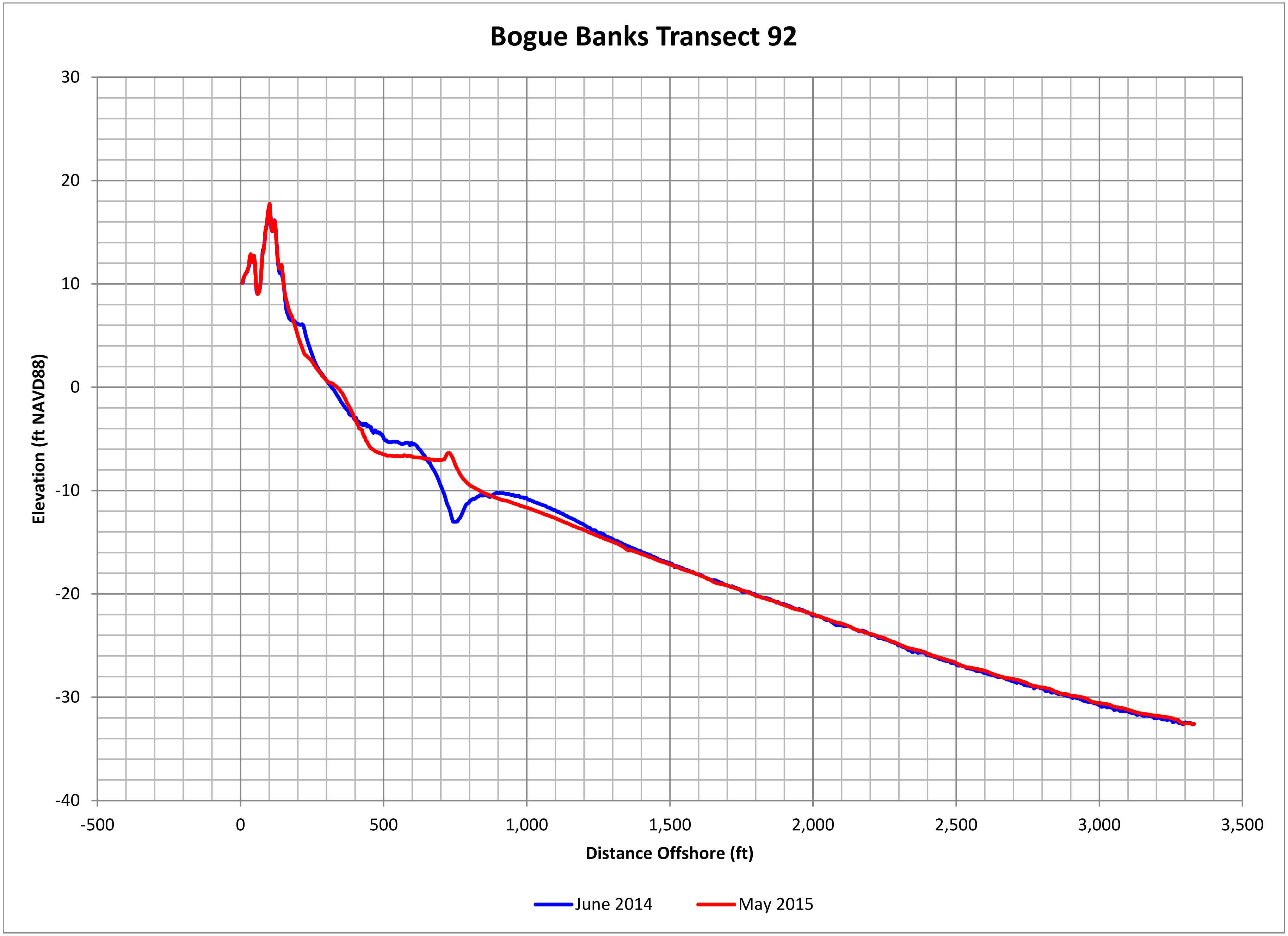

Figure C-120. Bogue Banks Profile Comparison Plot

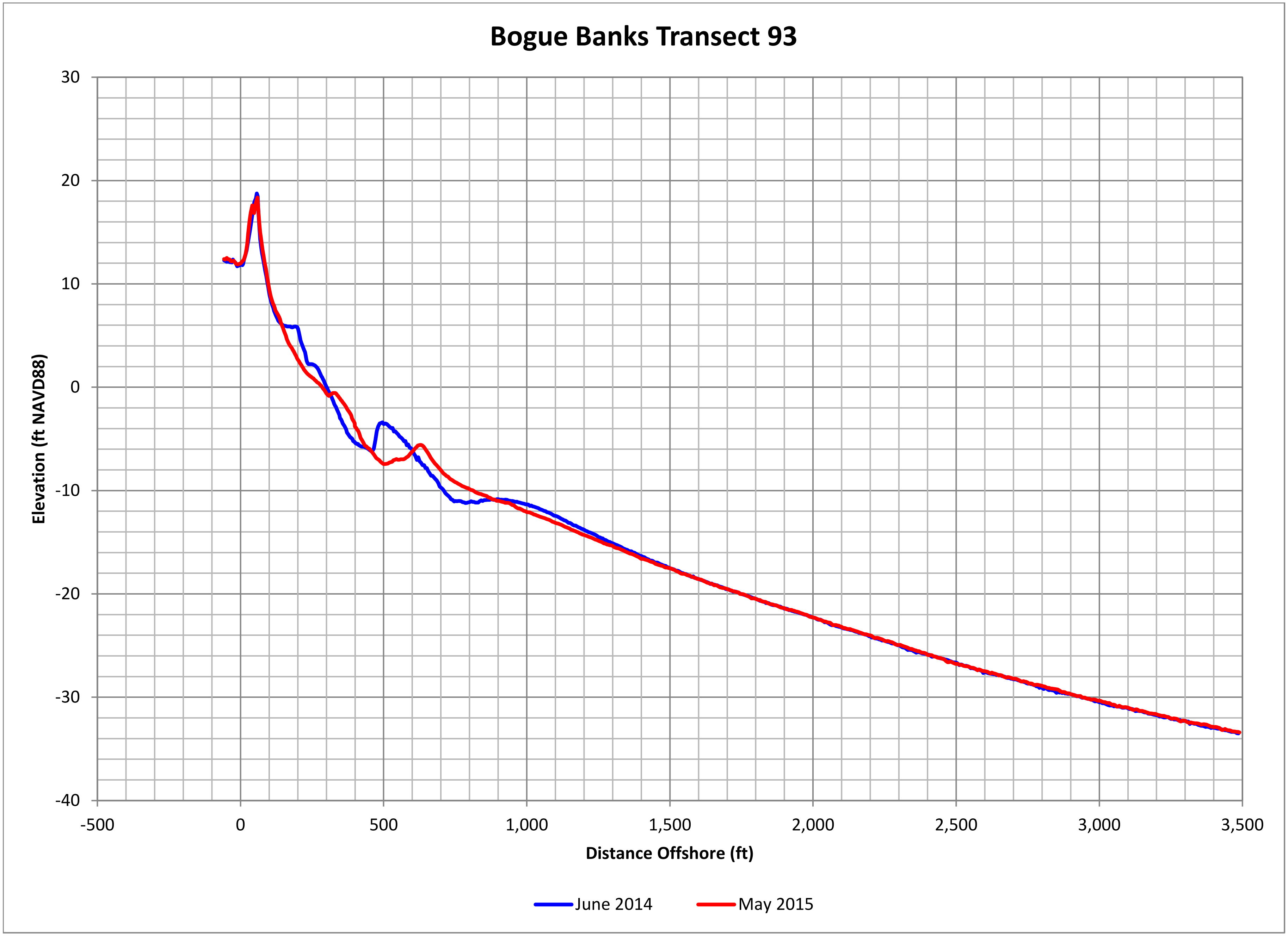

Figure C-121. Bogue Banks Profile Comparison Plot

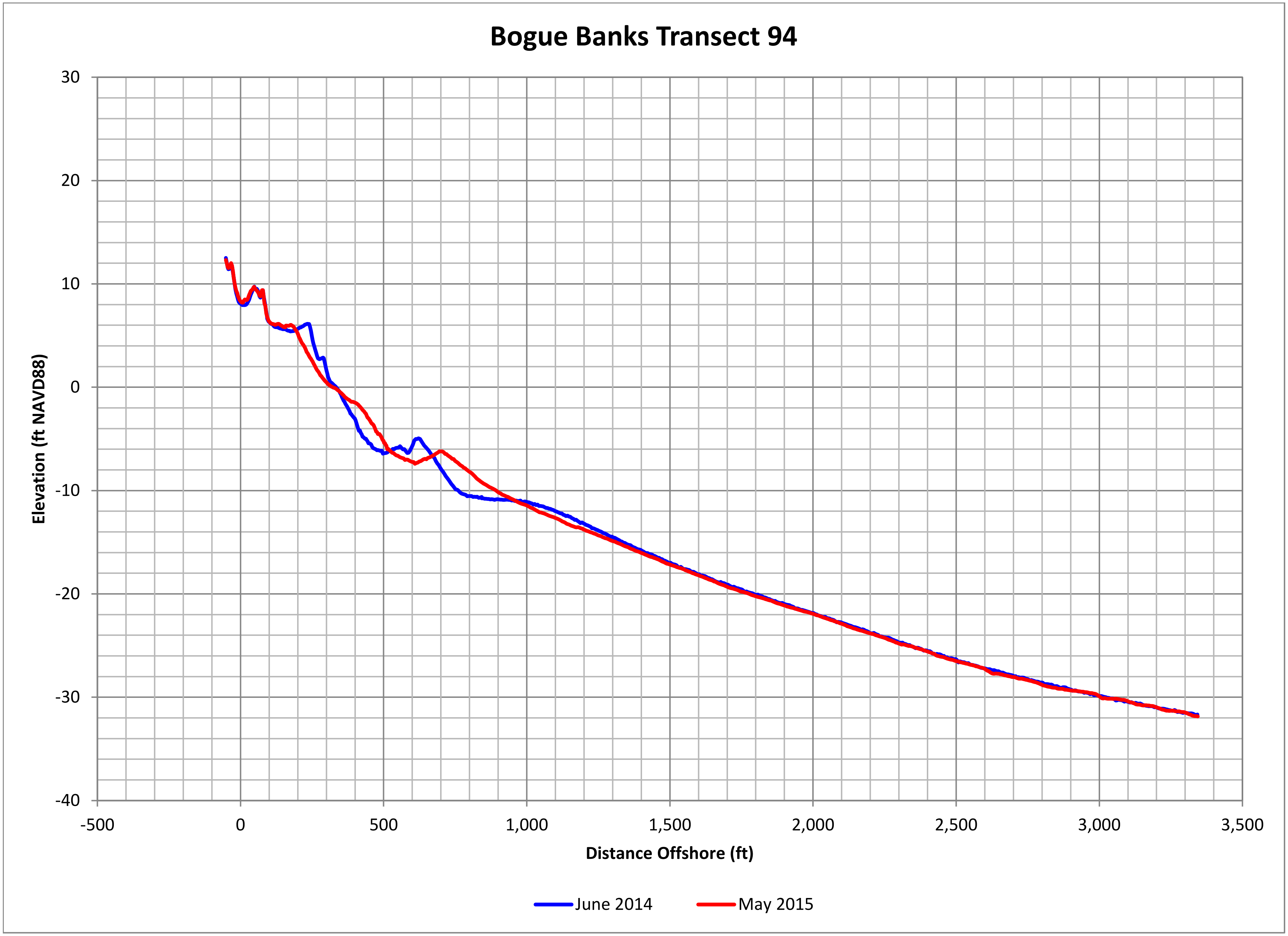

Figure C-122. Bogue Banks Profile Comparison Plot

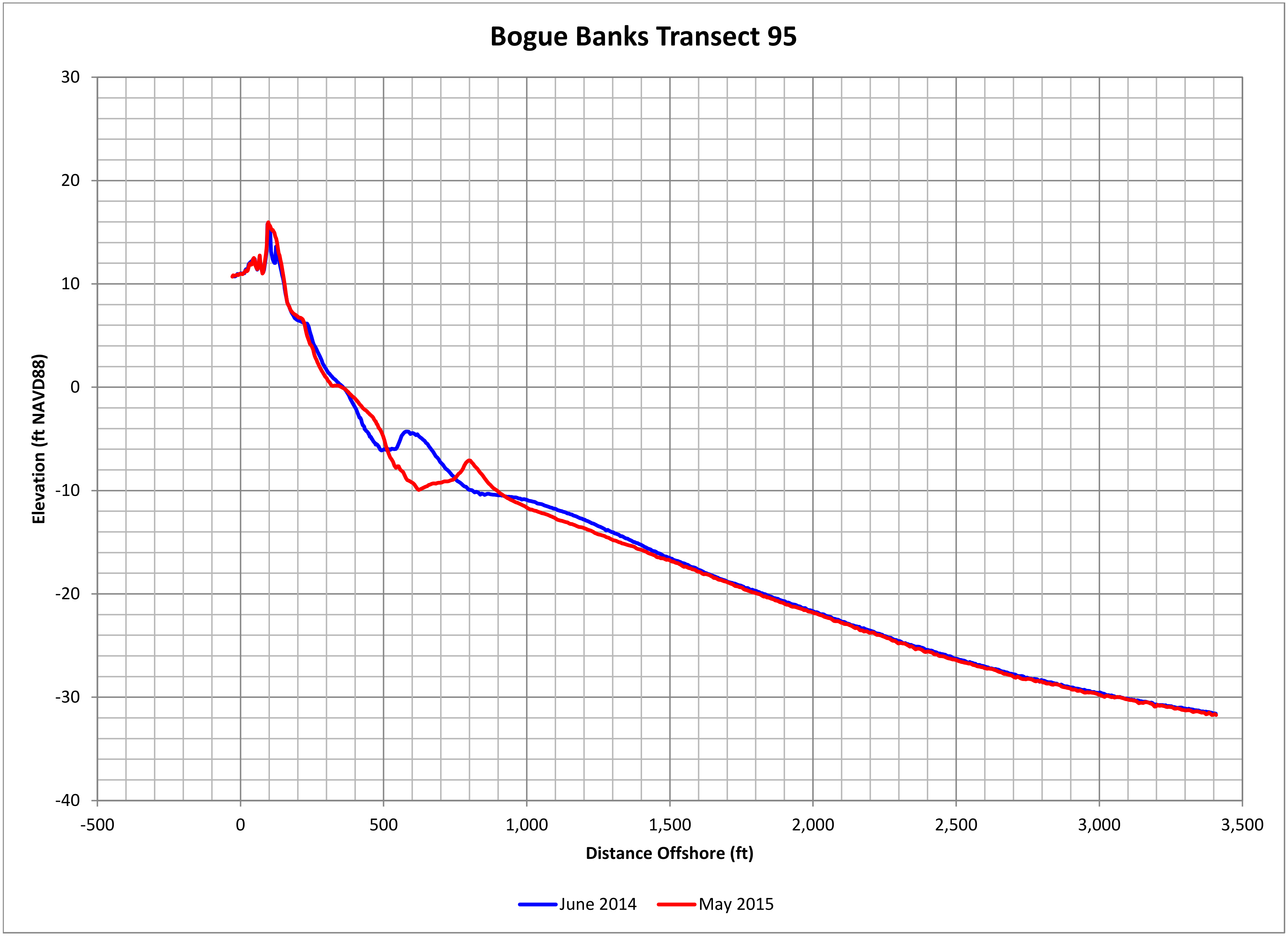

Figure C-123. Bogue Banks Profile Comparison Plot

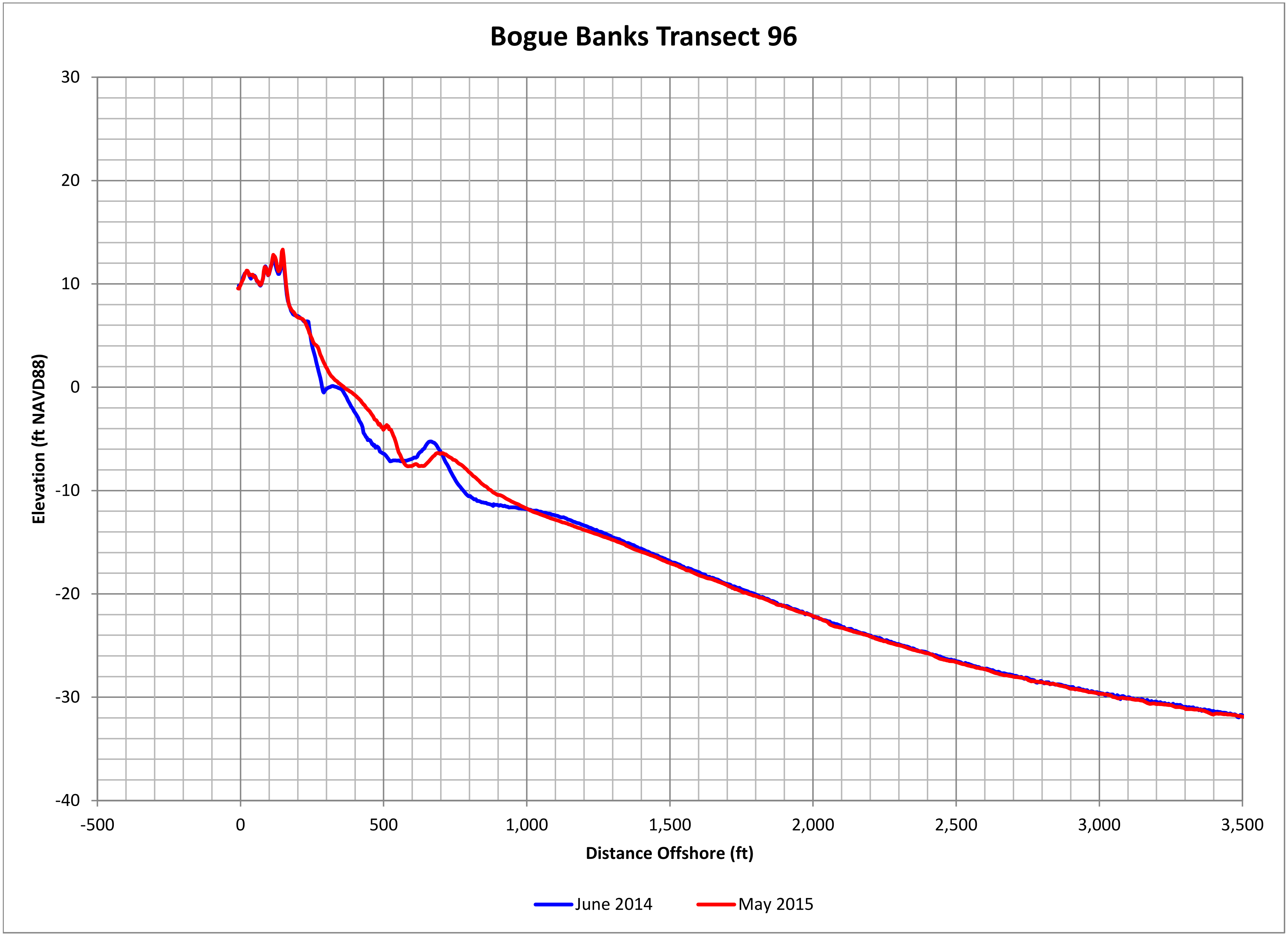

Figure C-124. Bogue Banks Profile Comparison Plot

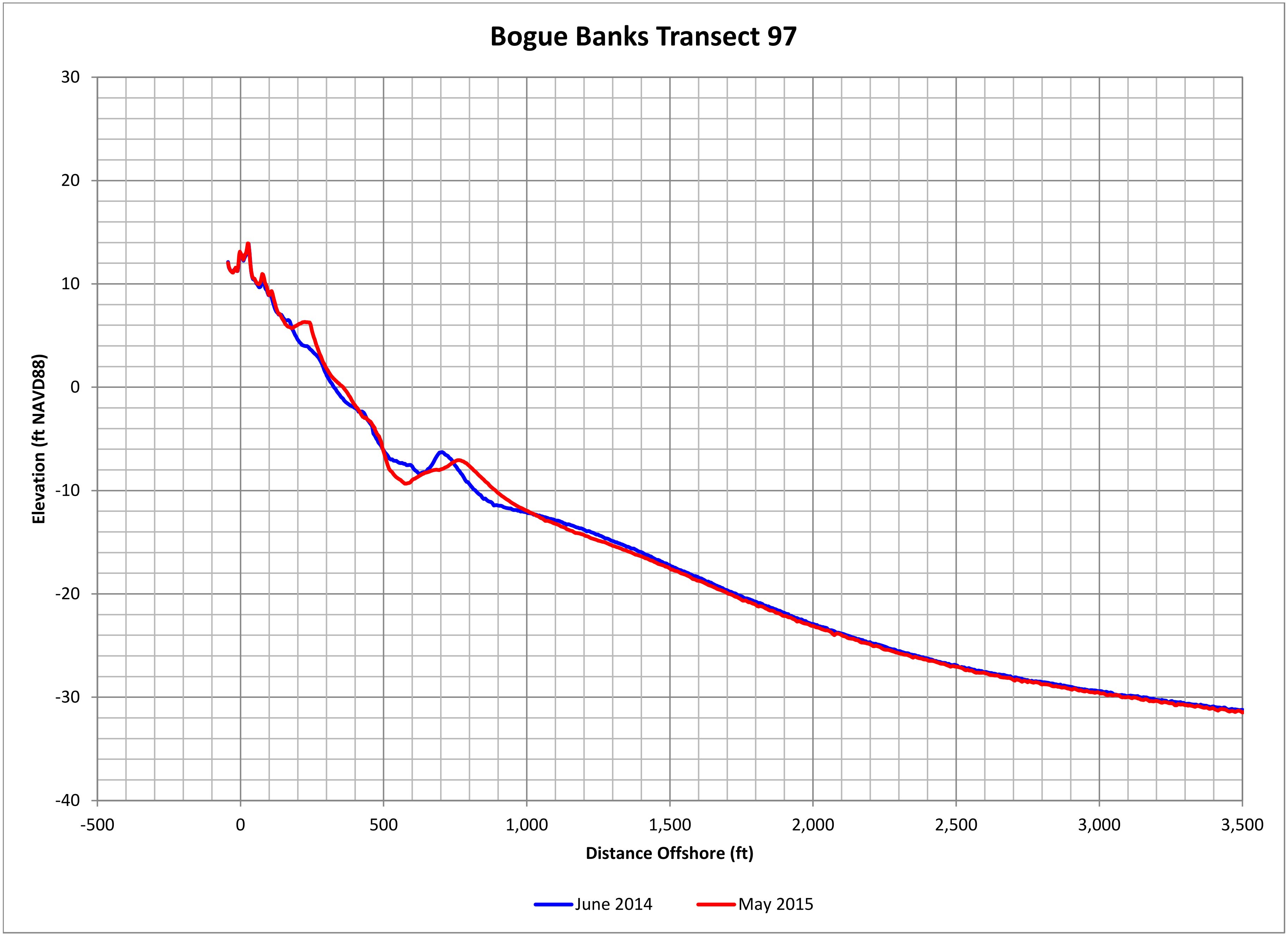

Figure C-125. Bogue Banks Profile Comparison Plot

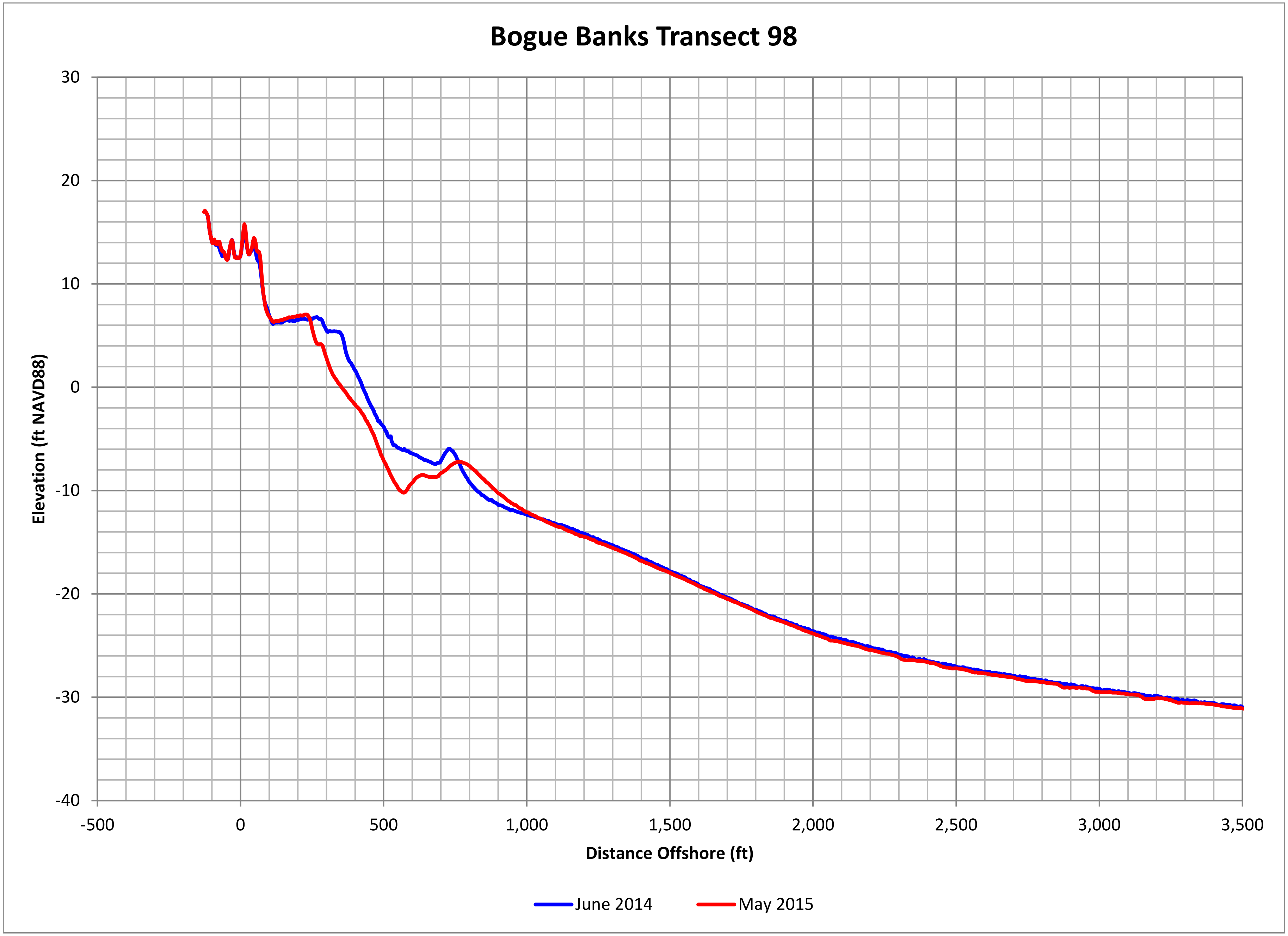

Figure C-126. Bogue Banks Profile Comparison Plot

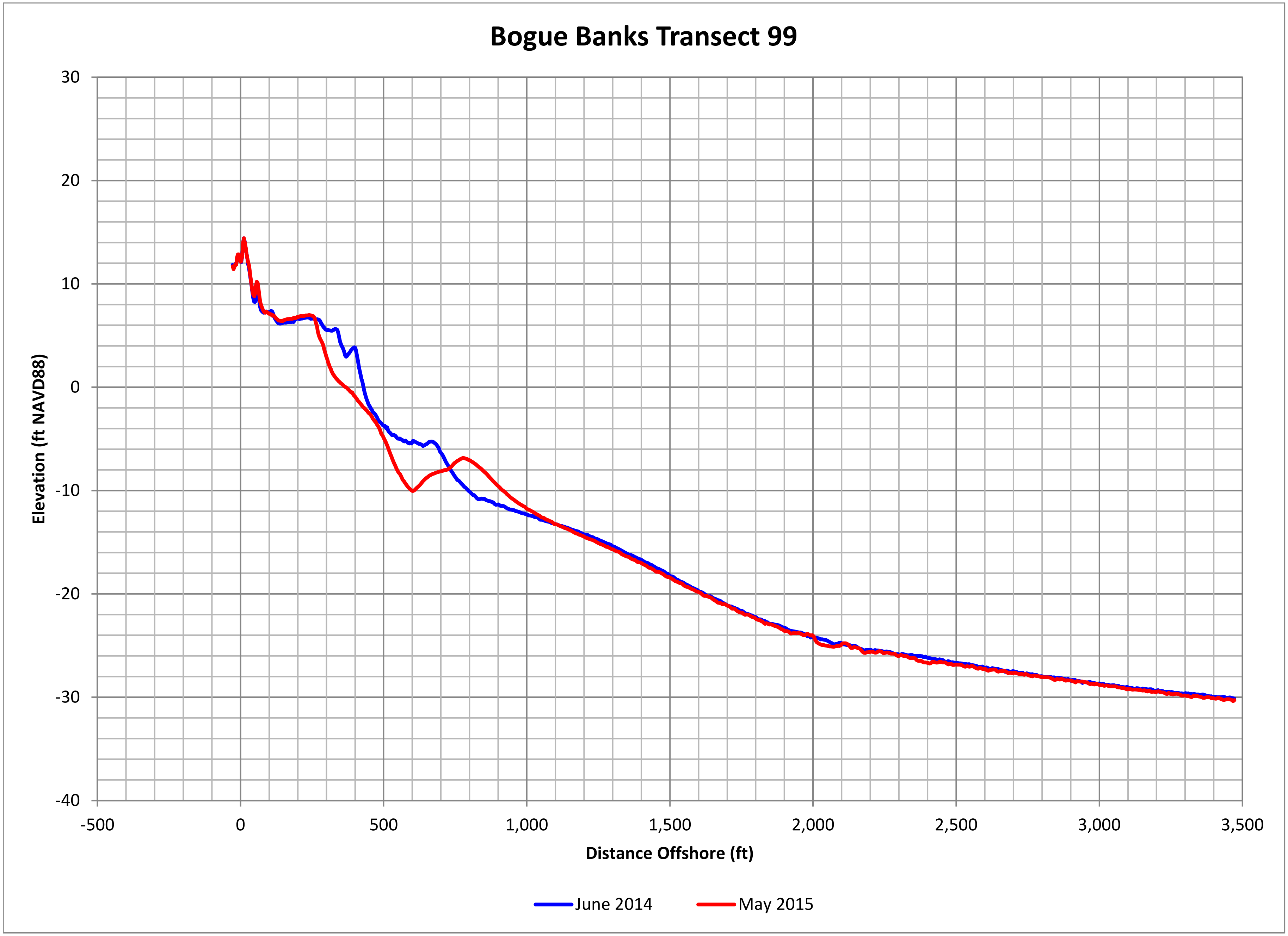

Figure C-127. Bogue Banks Profile Comparison Plot

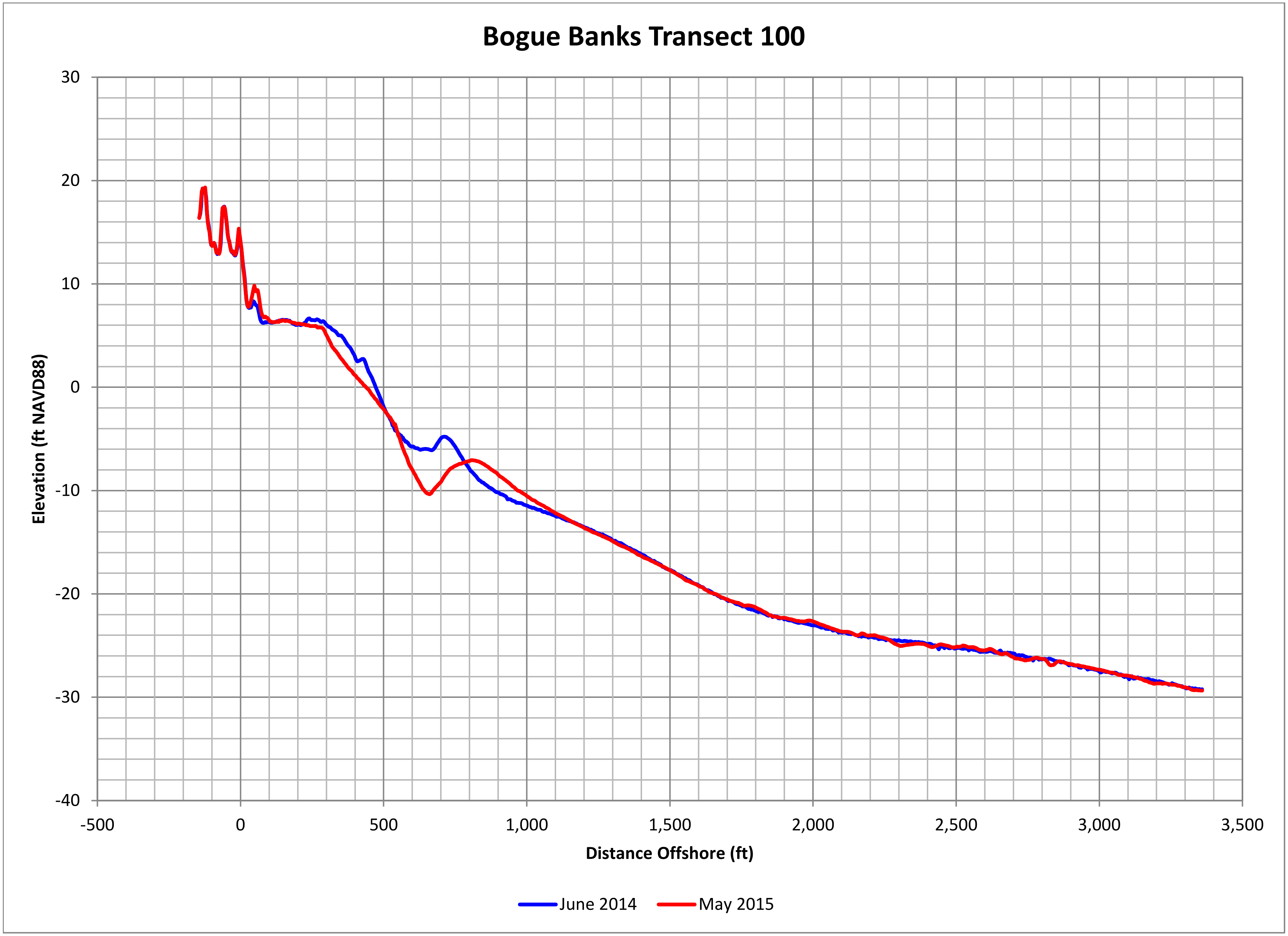

Figure C-128. Bogue Banks Profile Comparison Plot

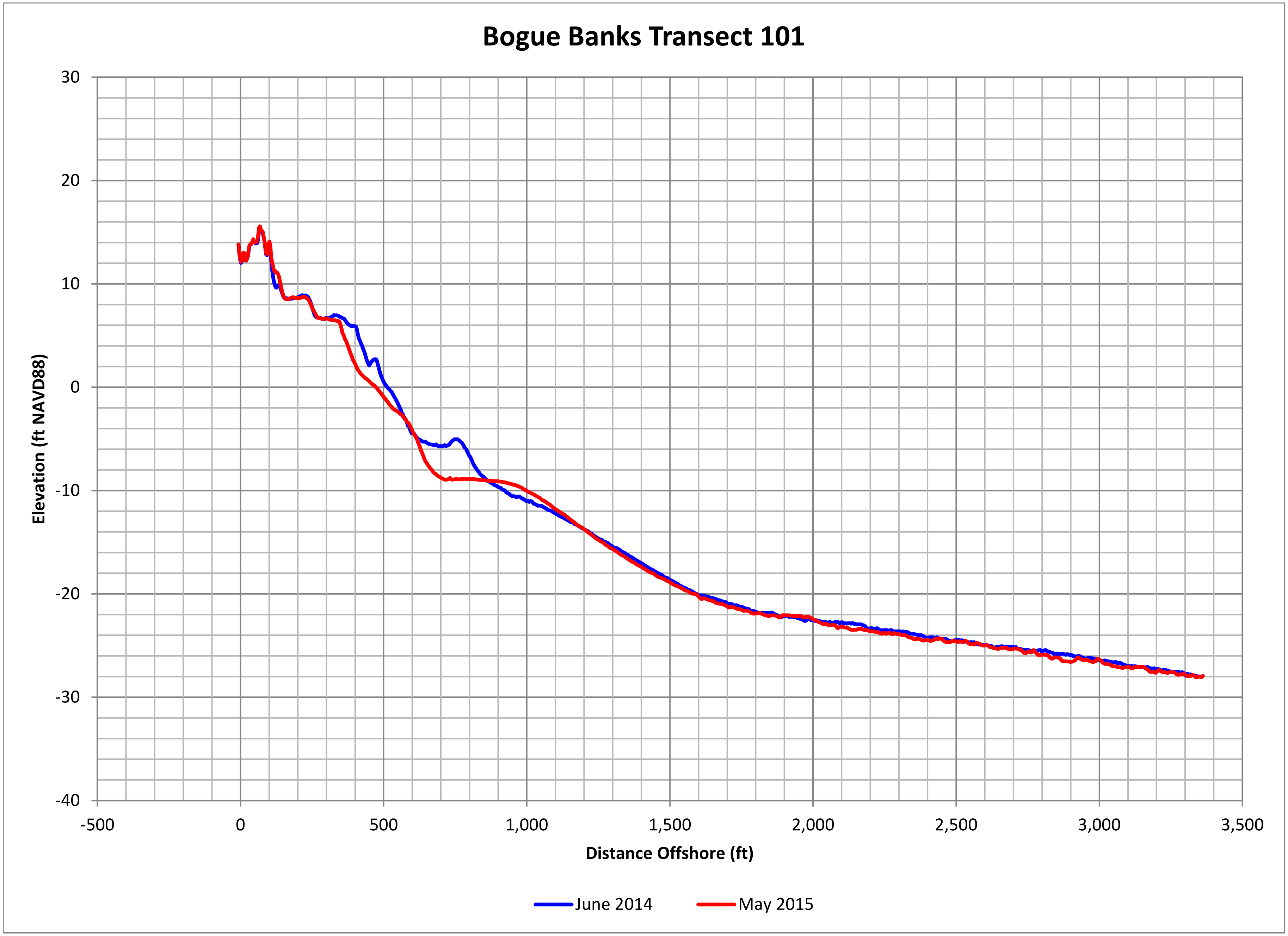

Figure C-129. Bogue Banks Profile Comparison Plot

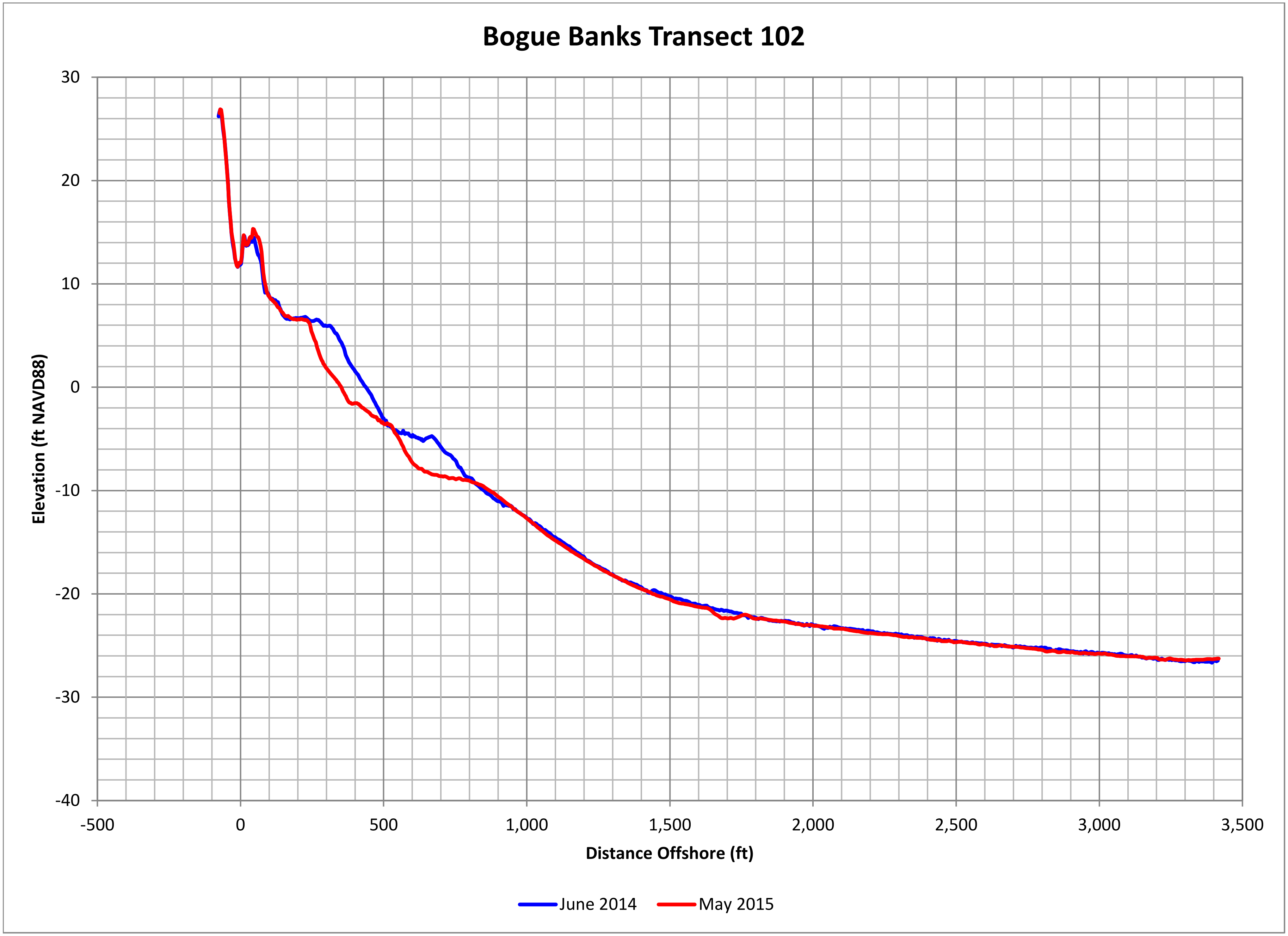

Figure C-130. Bogue Banks Profile Comparison Plot

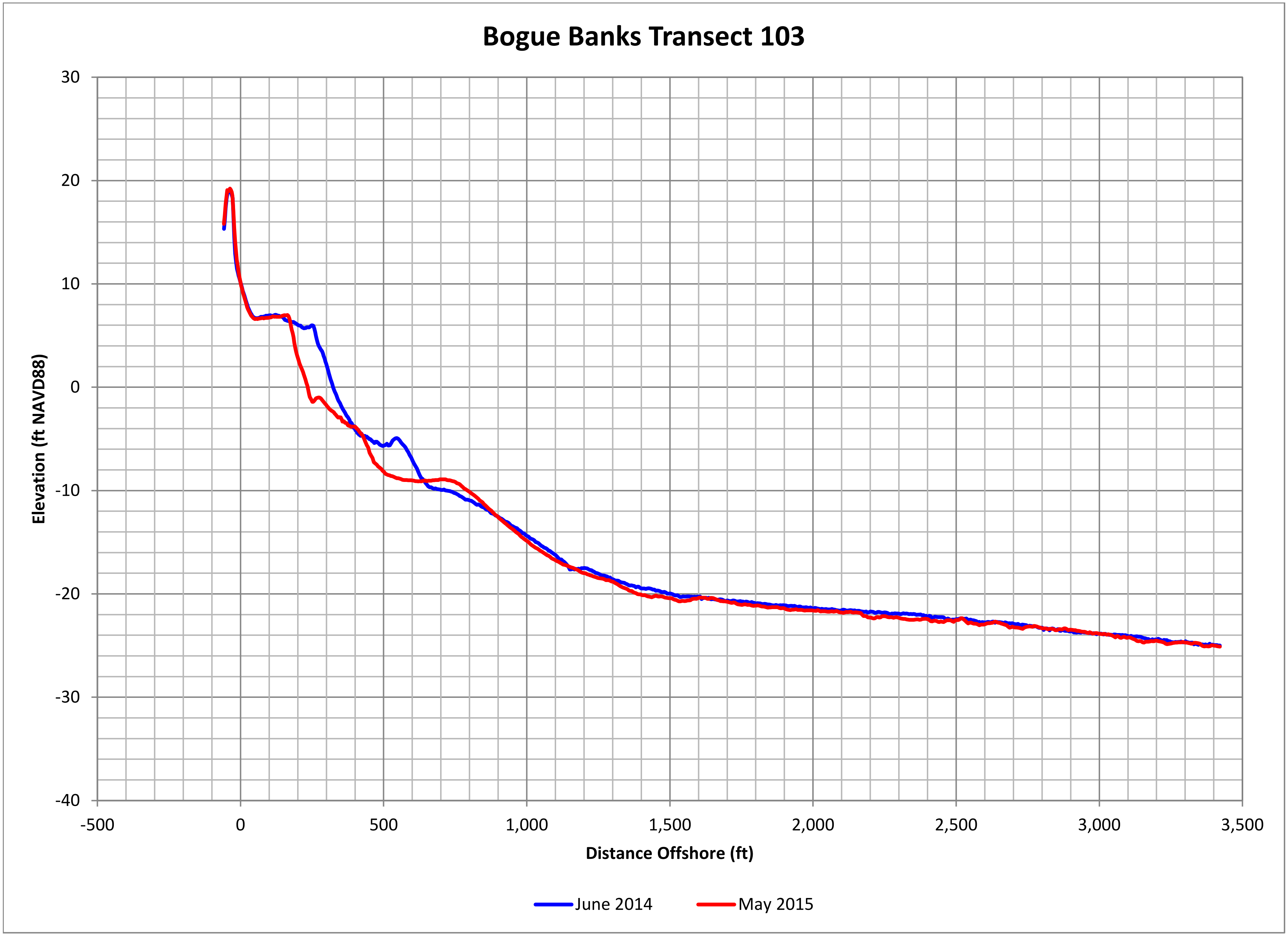

Figure C-131. Bogue Banks Profile Comparison Plot

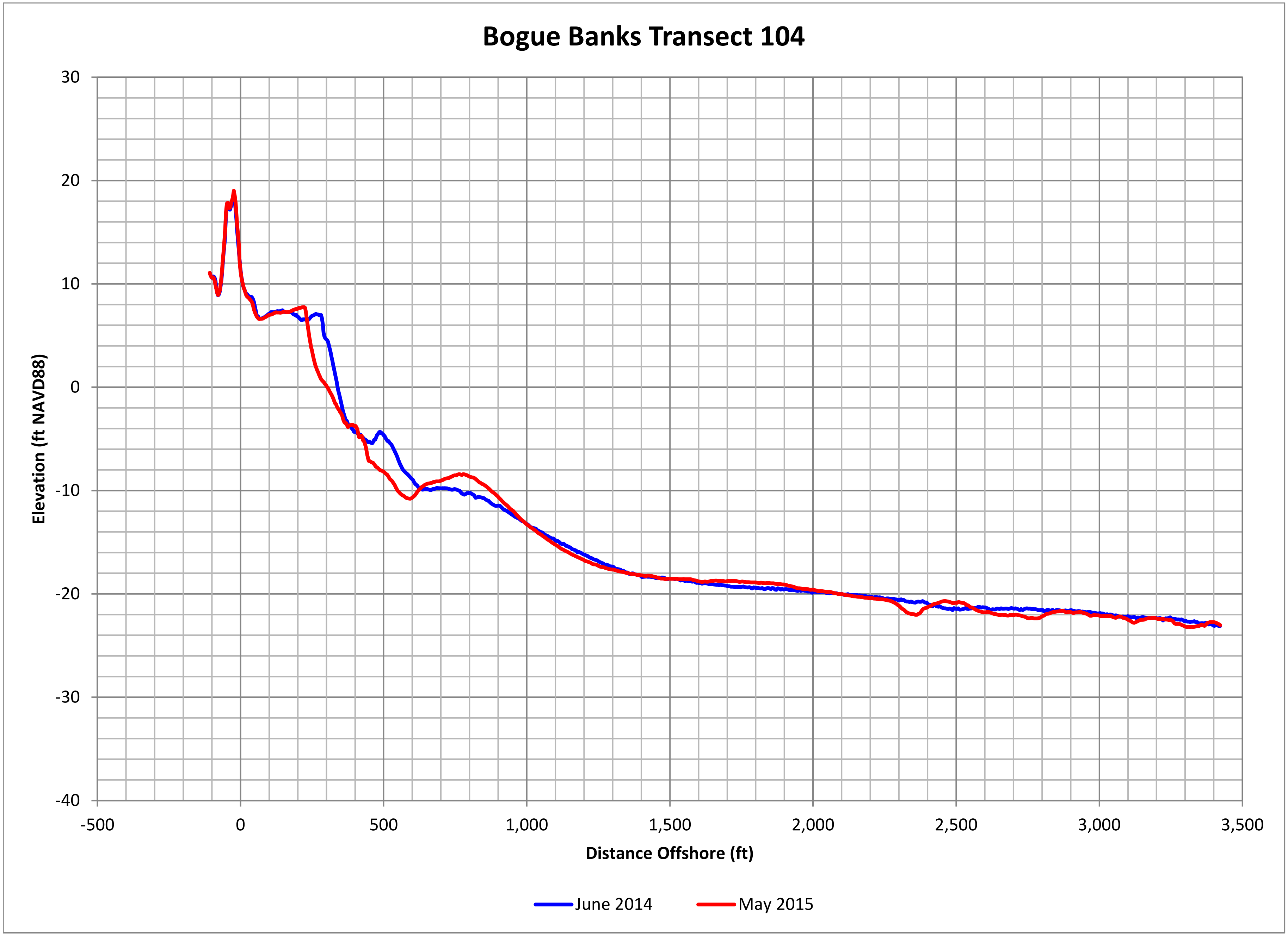

Figure C-132. Bogue Banks Profile Comparison Plot

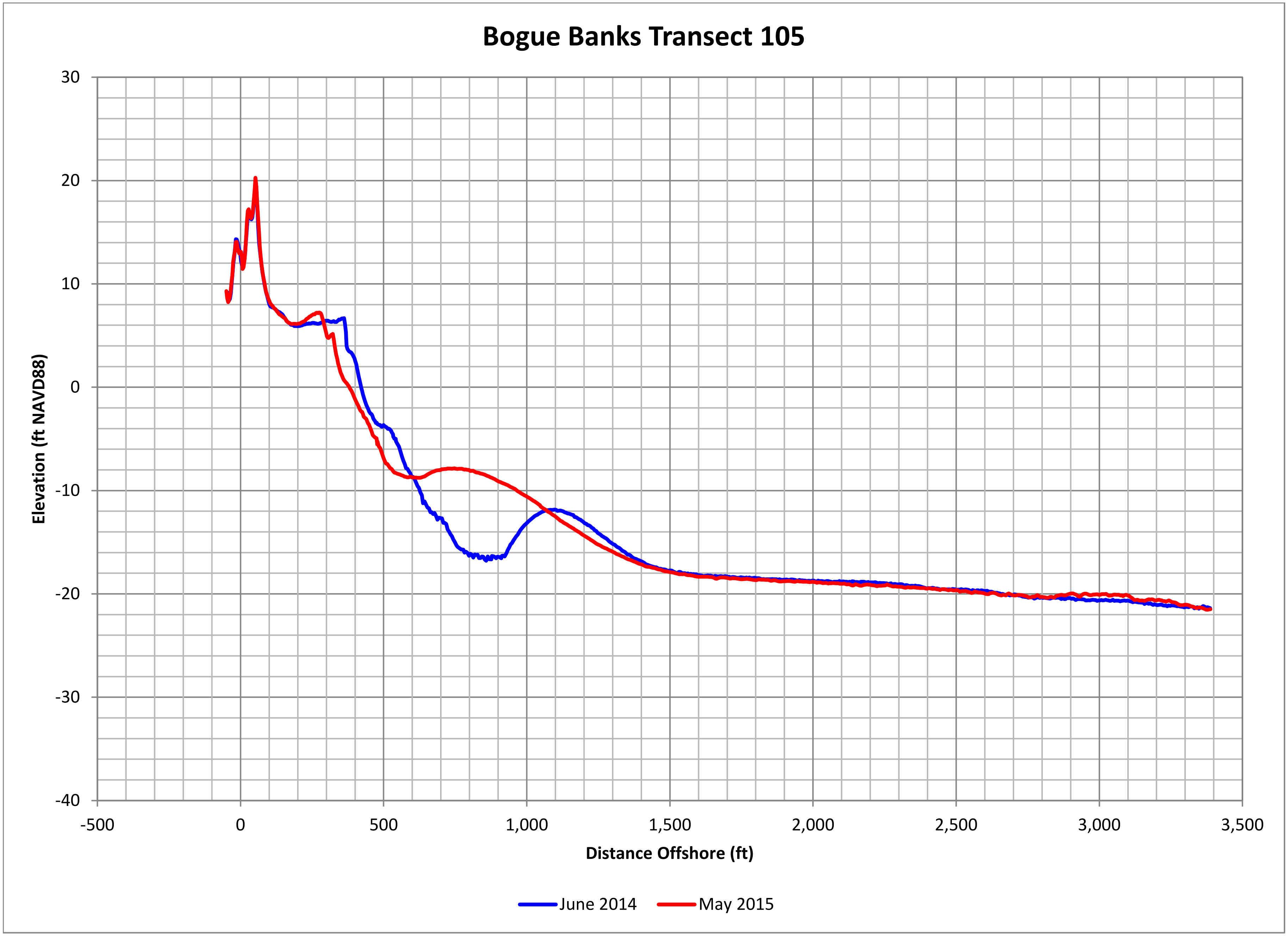

Figure C-133. Bogue Banks Profile Comparison Plot

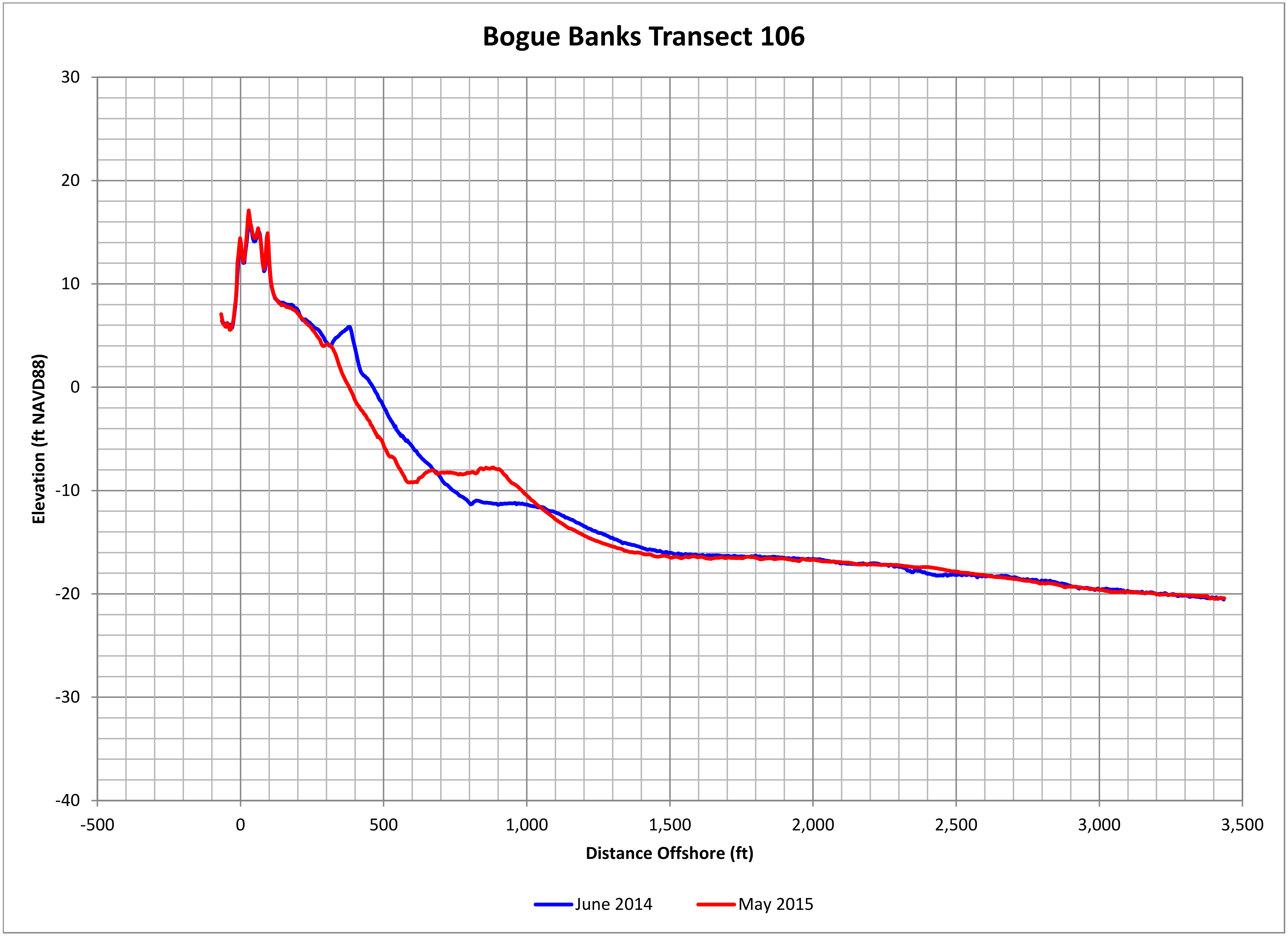

Figure C-134. Bogue Banks Profile Comparison Plot

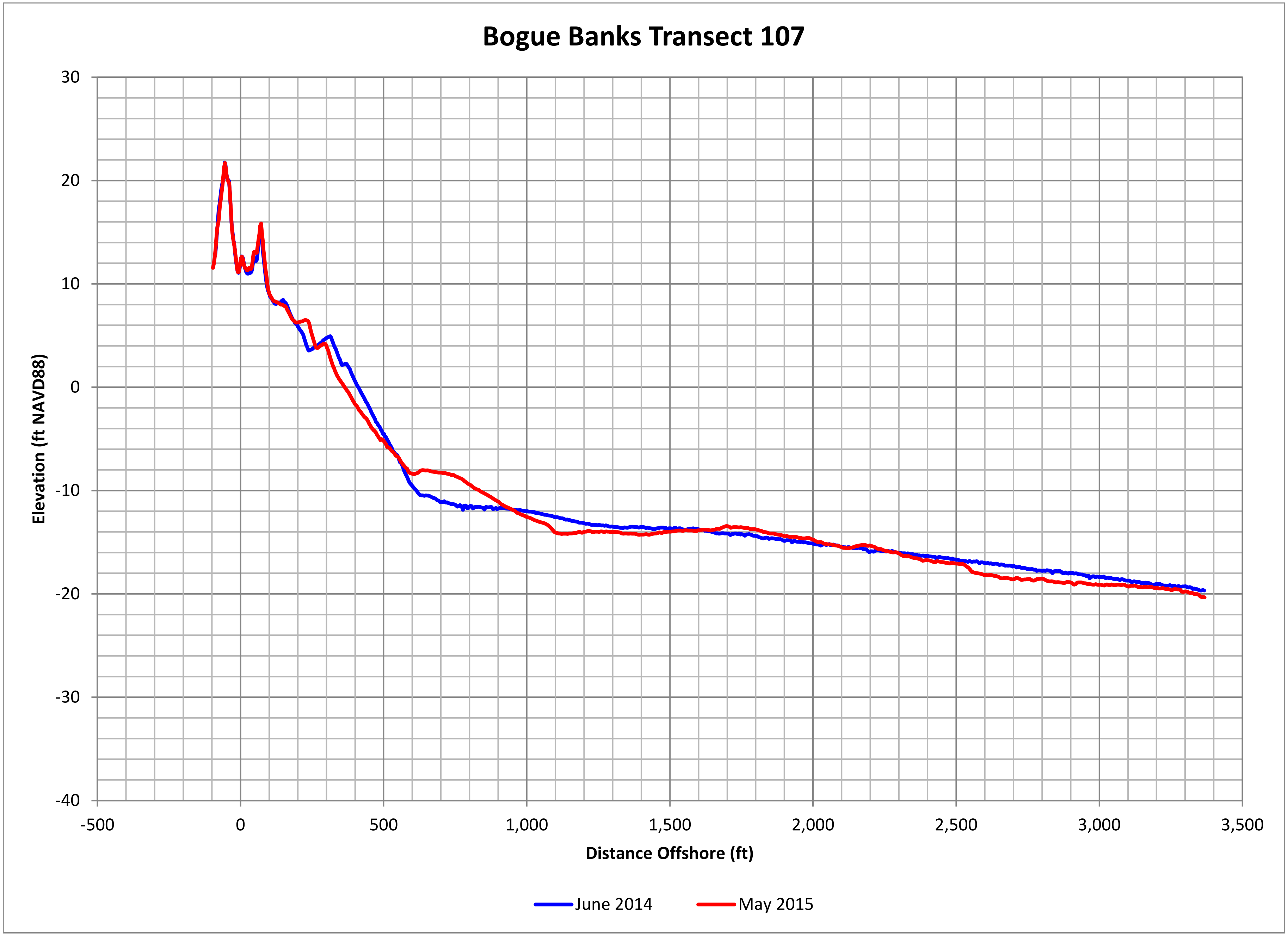

Figure C-135. Bogue Banks Profile Comparison Plot

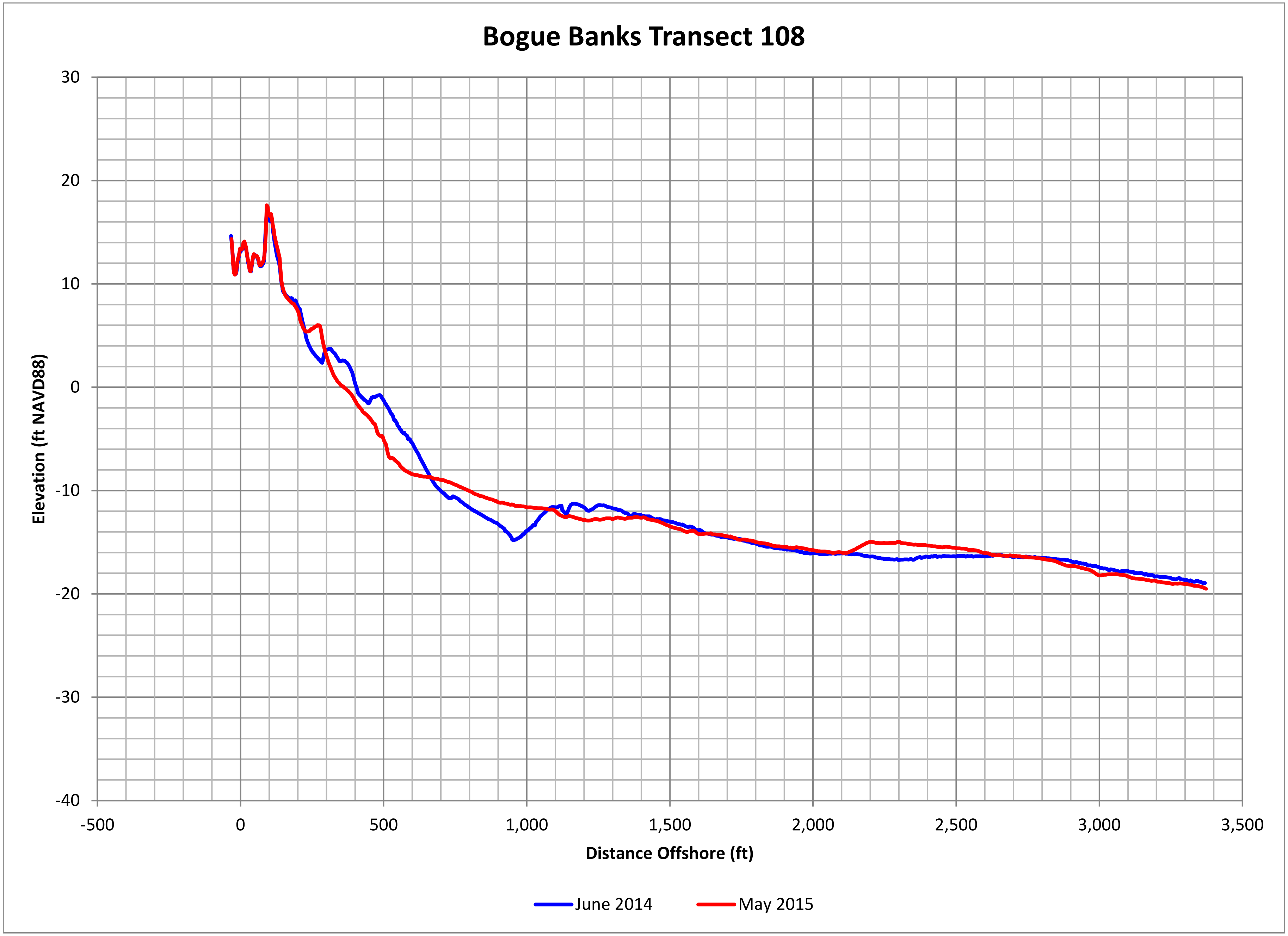

Figure C-136. Bogue Banks Profile Comparison Plot

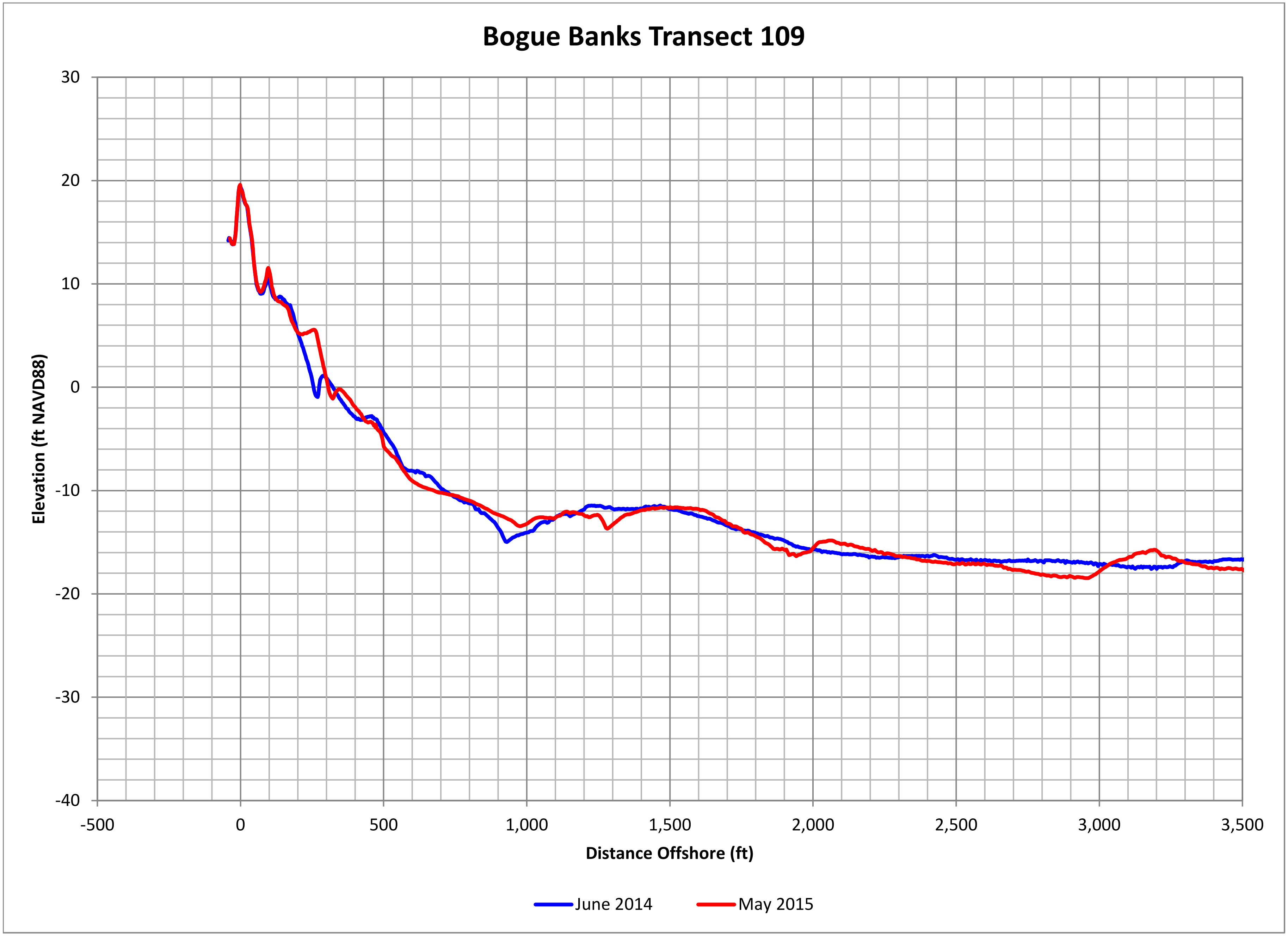

Figure C-137. Bogue Banks Profile Comparison Plot

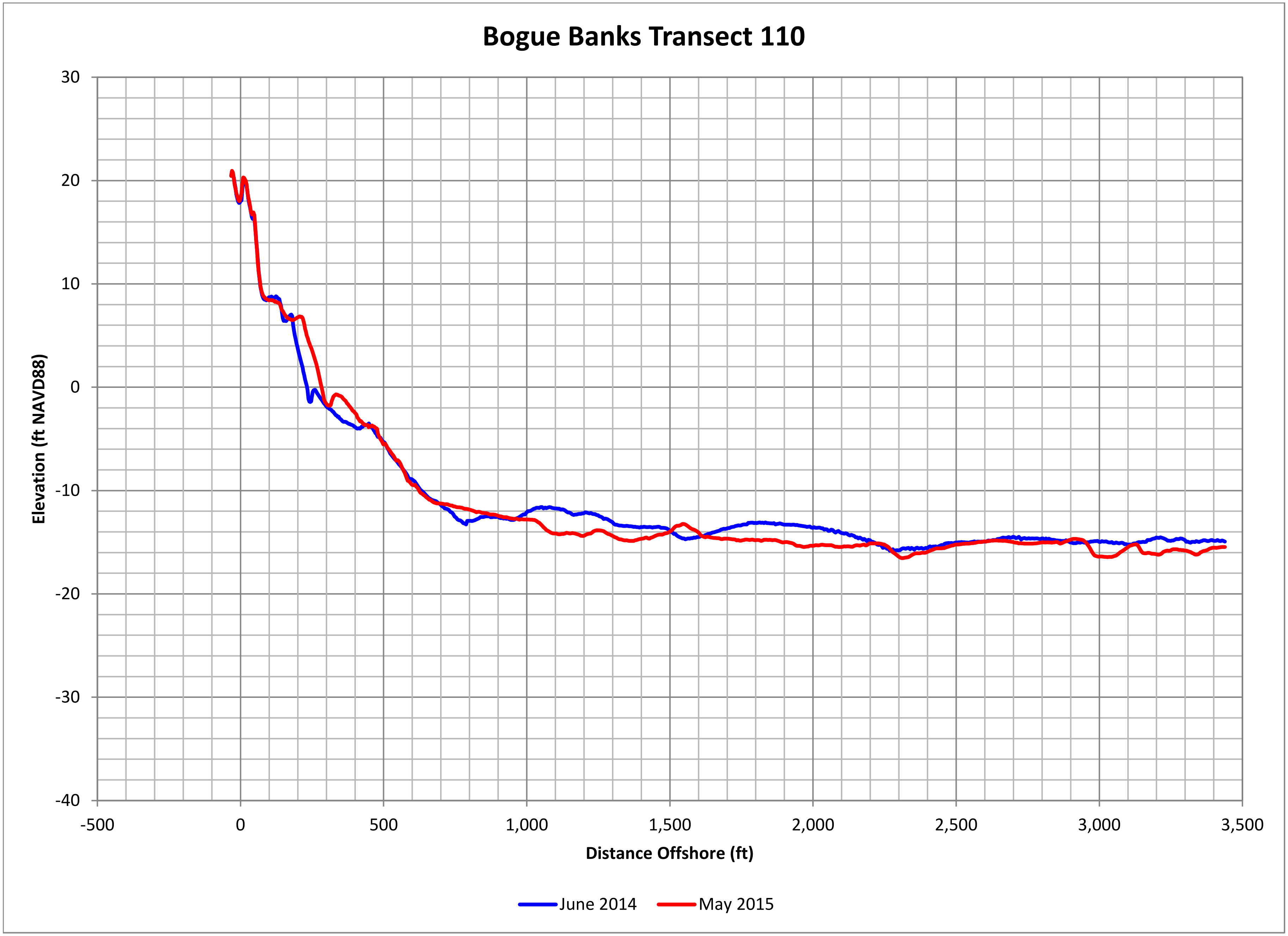

Figure C-138. Bogue Banks Profile Comparison Plot

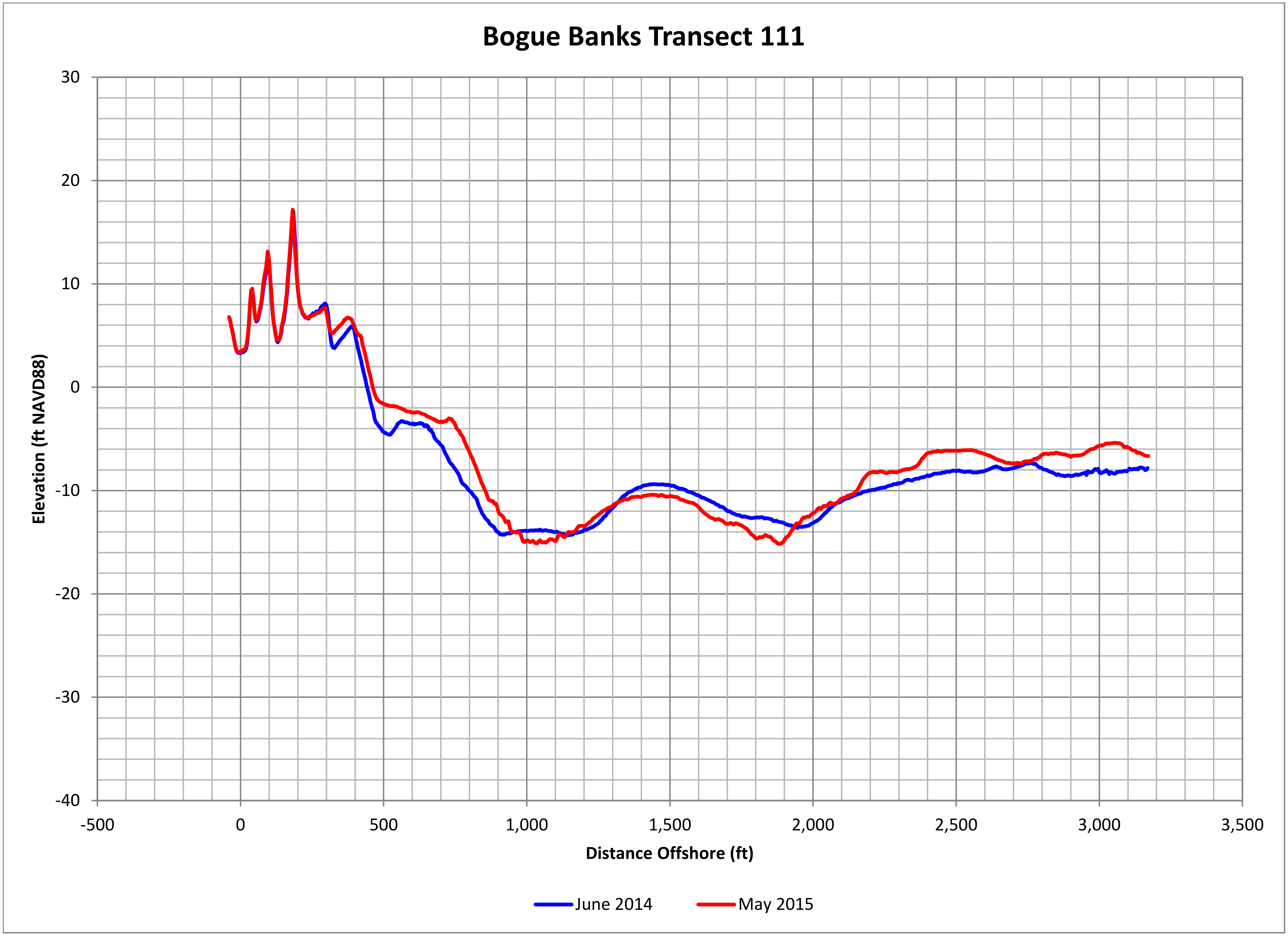

Figure C-139. Bogue Banks Profile Comparison Plot

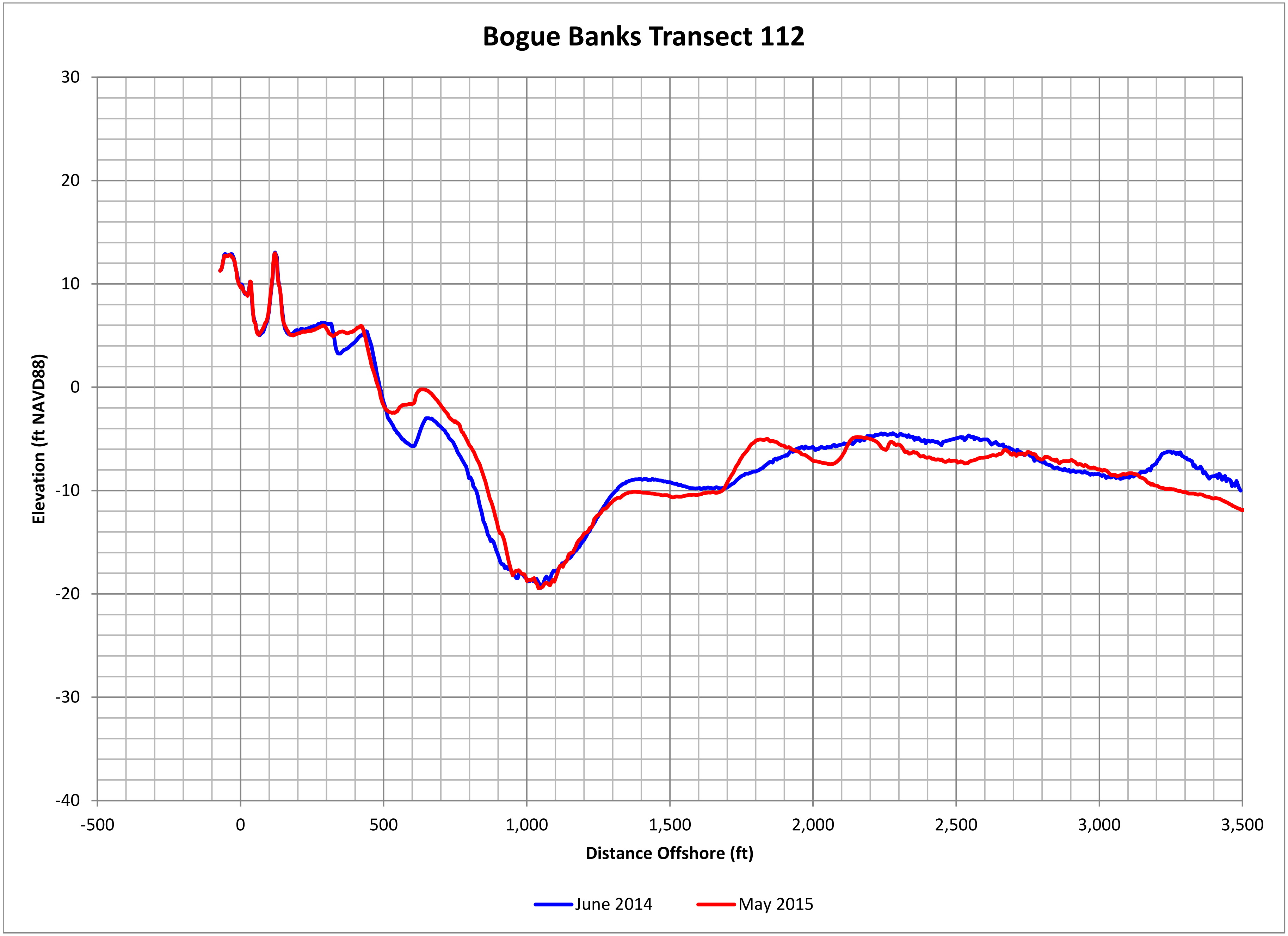

Figure C-140. Bogue Banks Profile Comparison Plot

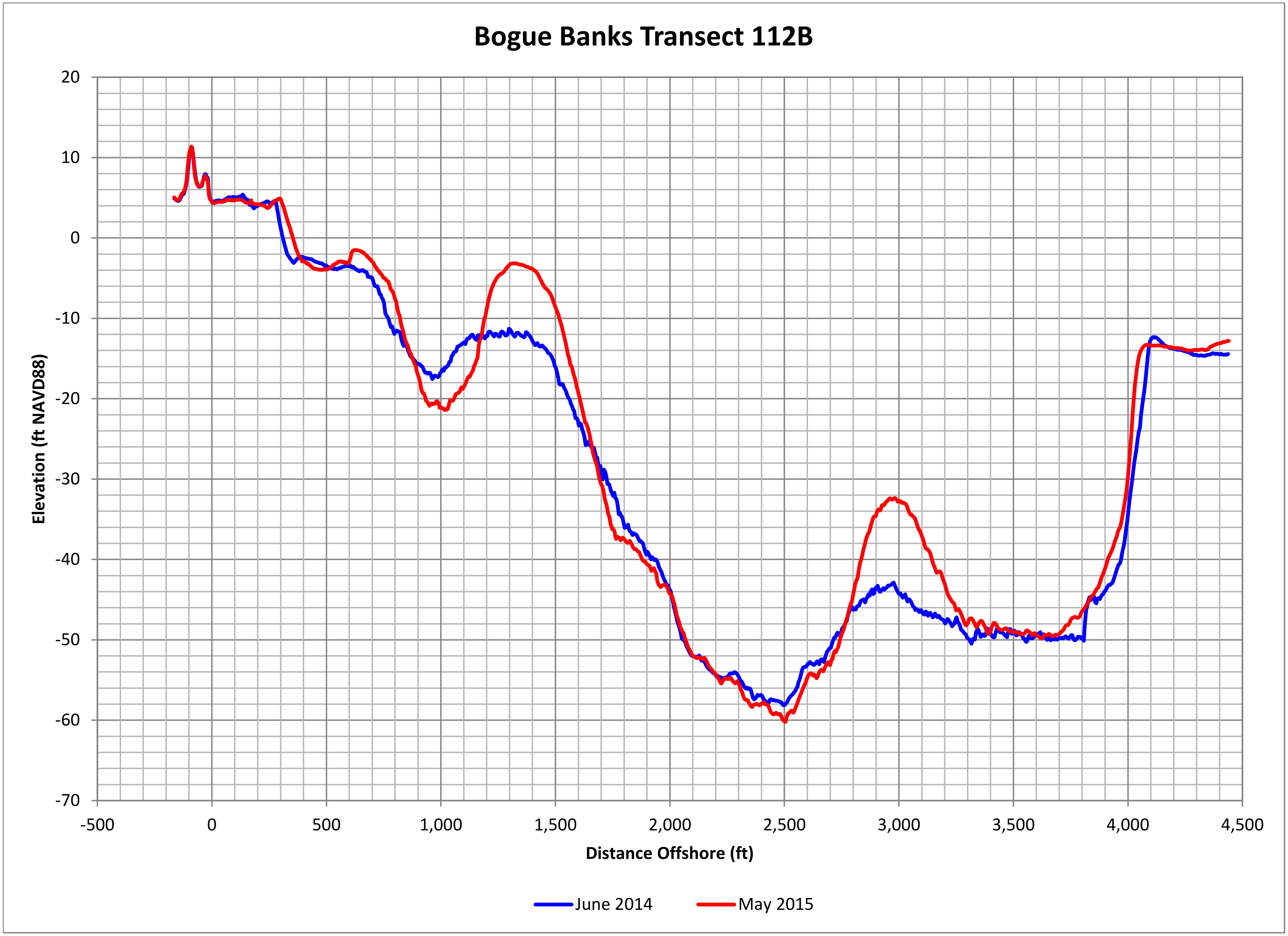

Figure C-141. Bogue Banks Profile Comparison Plot

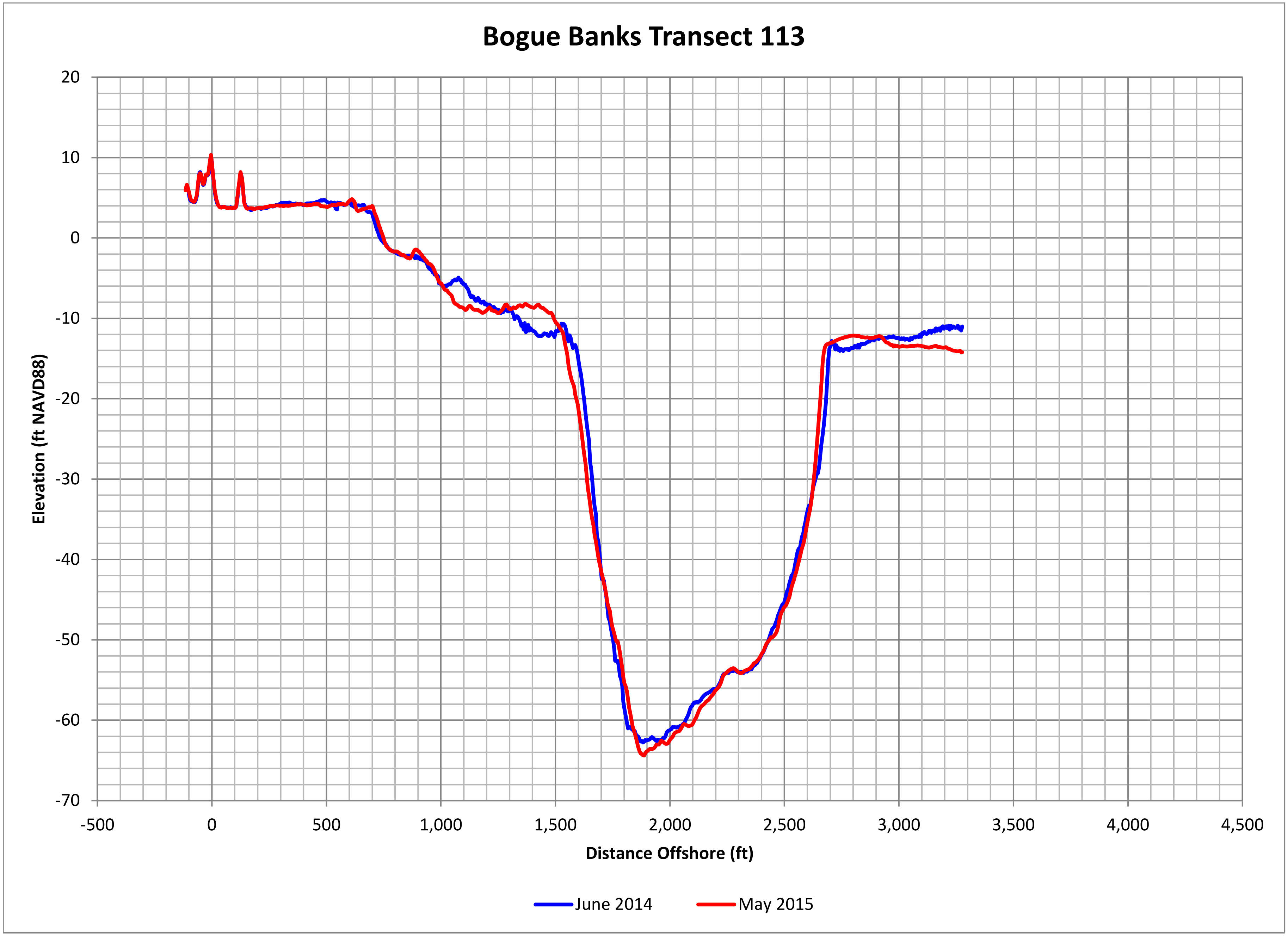

Figure C-142. Bogue Banks Profile Comparison Plot

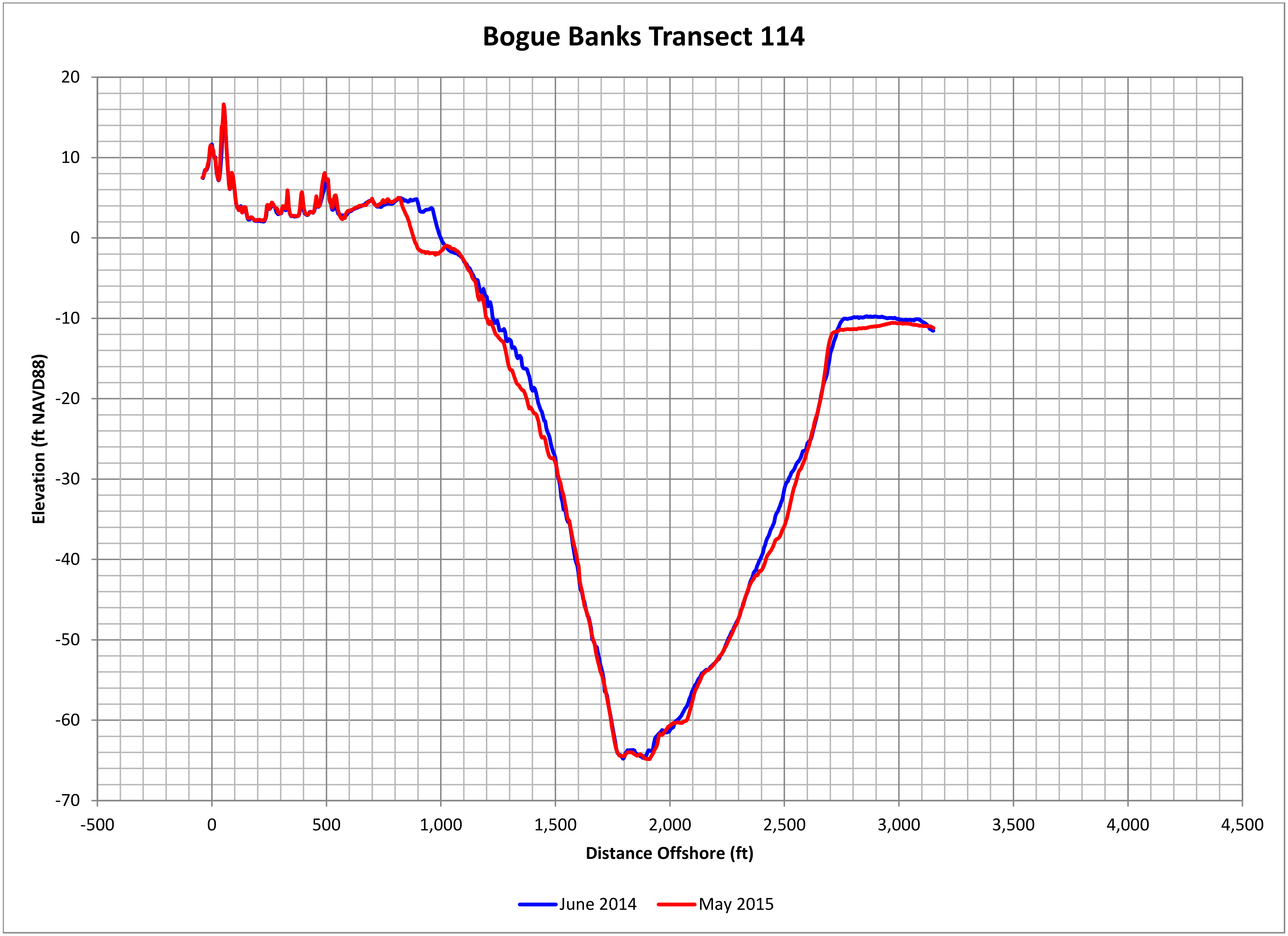

Figure C-143. Bogue Banks Profile Comparison Plot

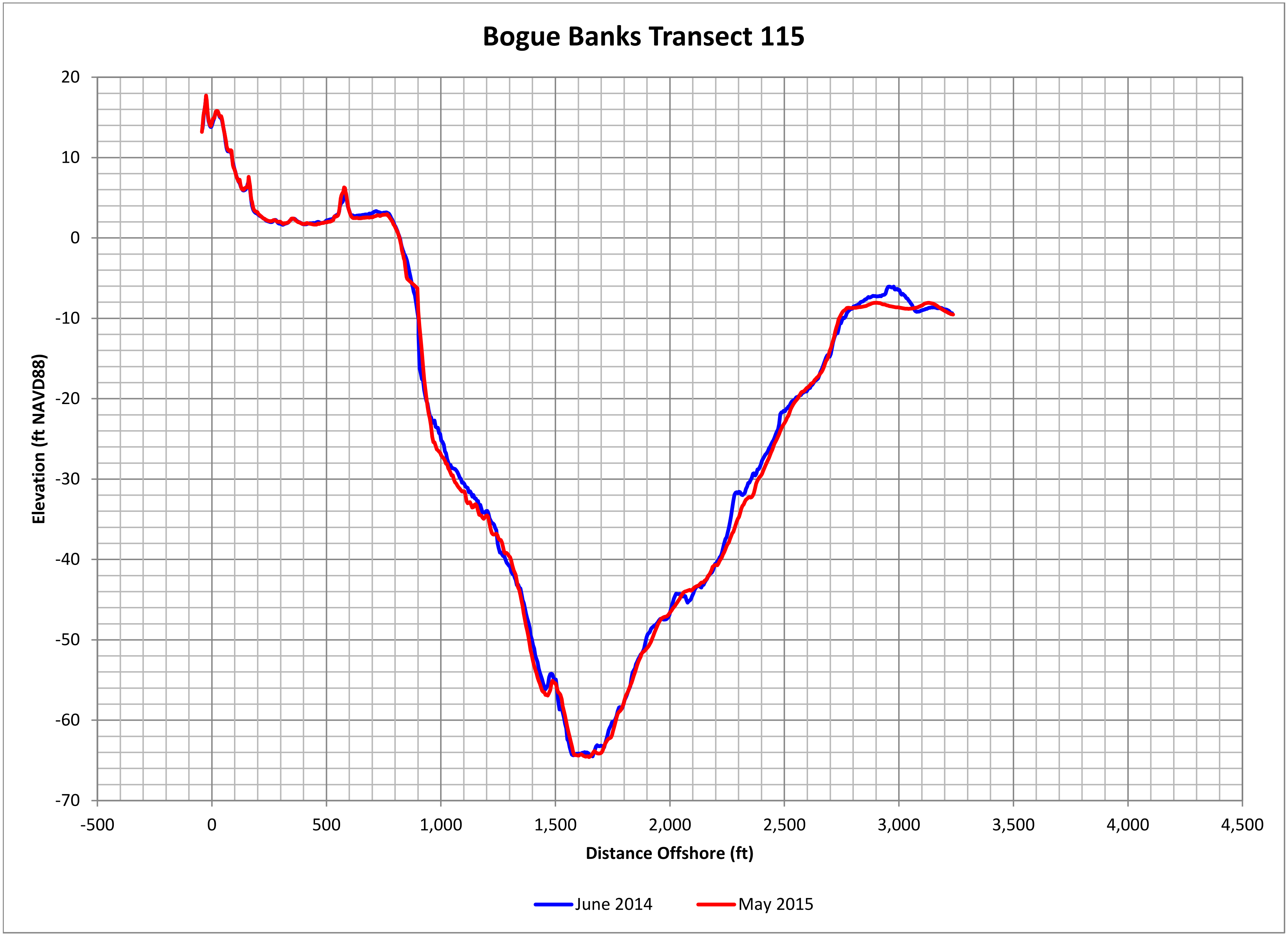

Figure C-144. Bogue Banks Profile Comparison Plot

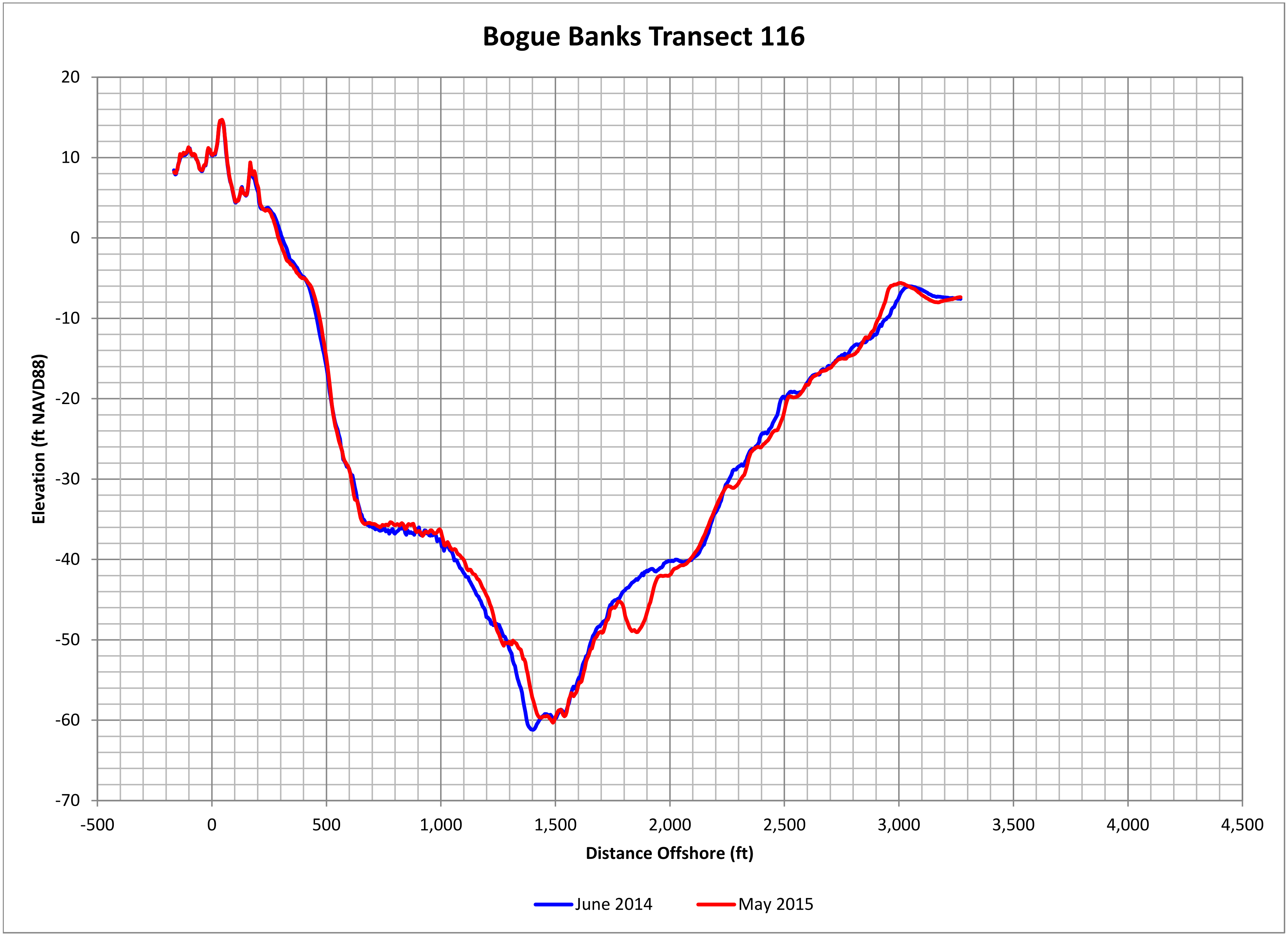

Figure C-145. Bogue Banks Profile Comparison Plot

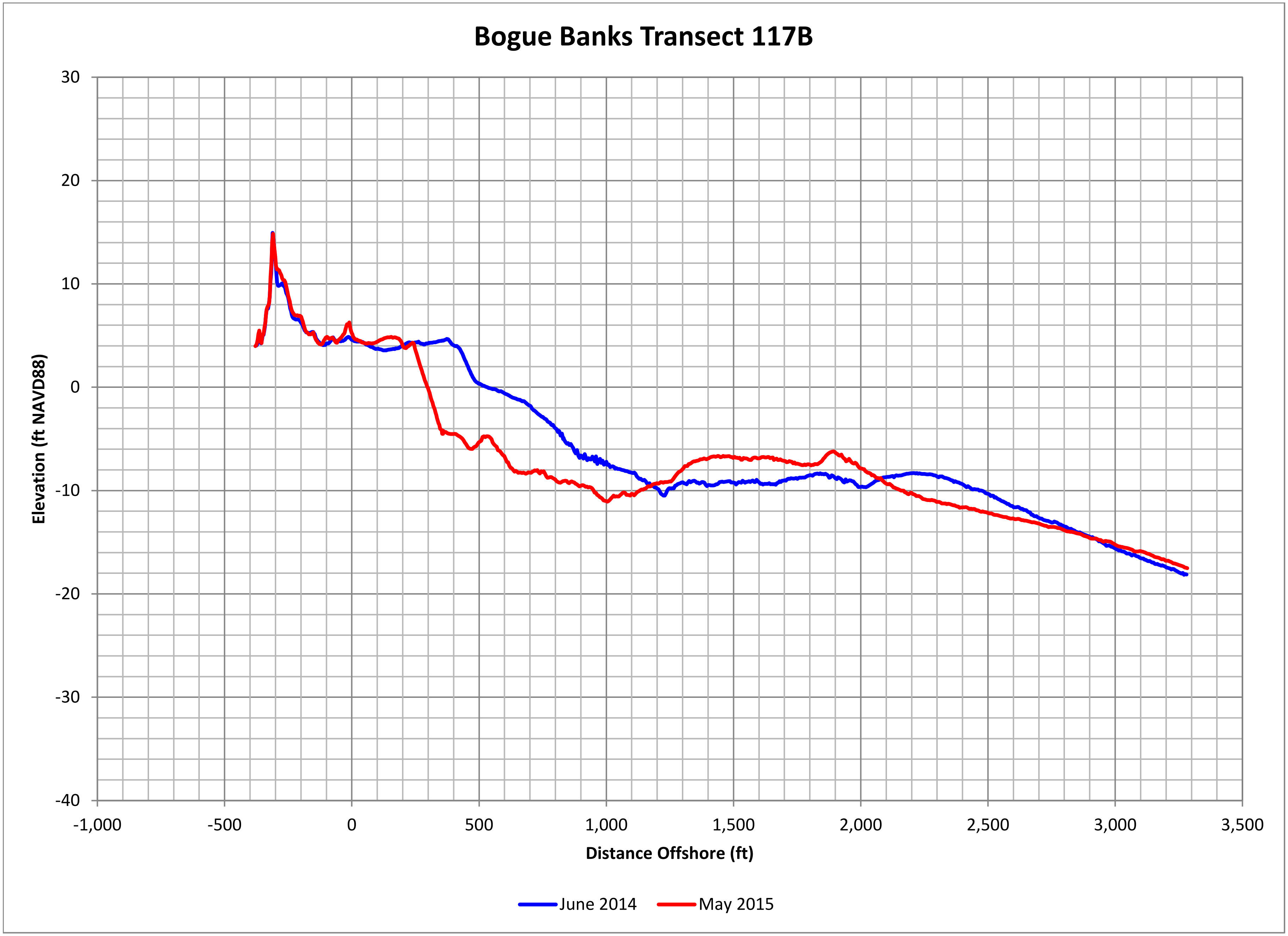

Figure C-146. Bogue Banks Profile Comparison Plot

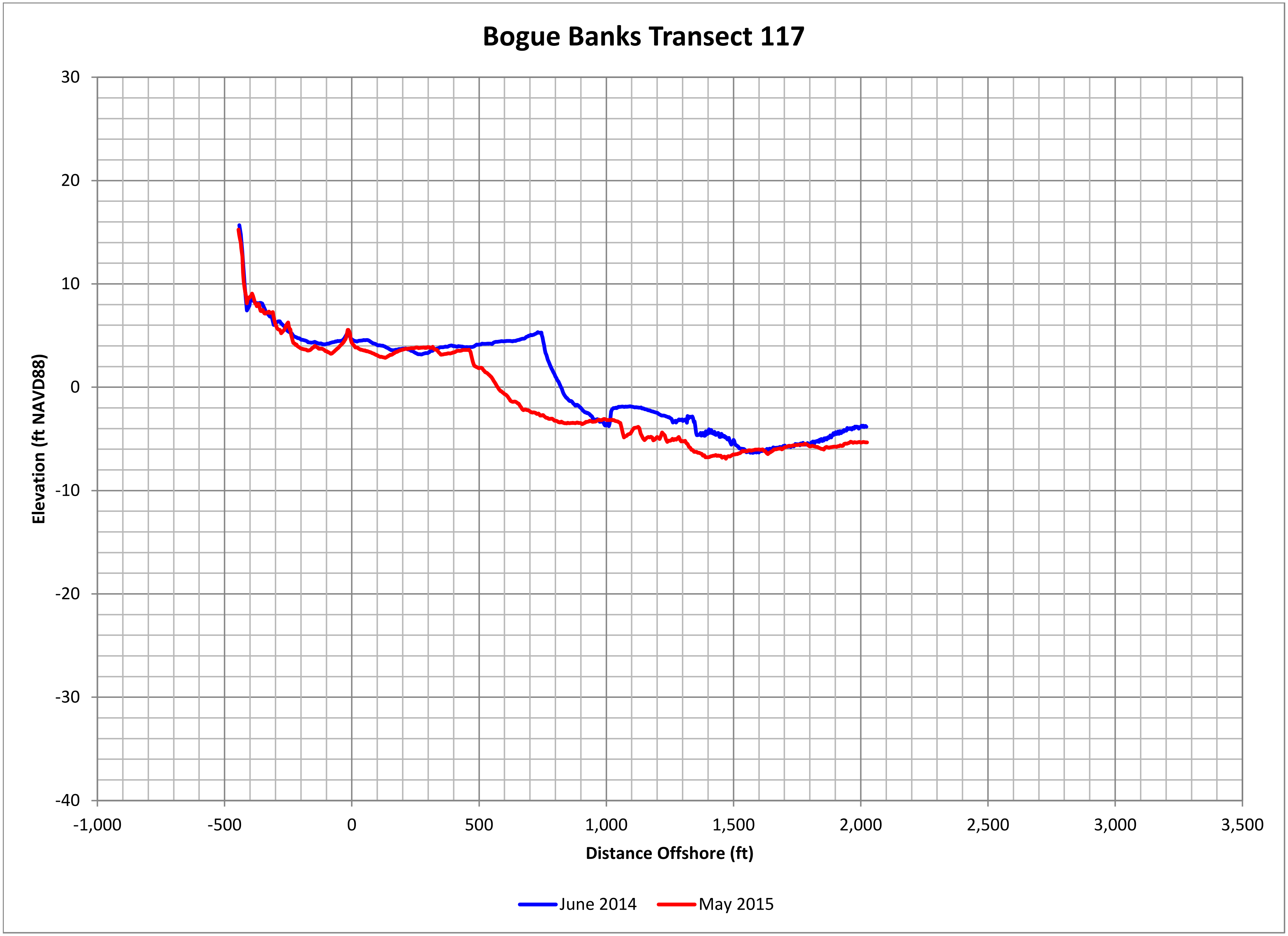

Figure C-147. Bogue Banks Profile Comparison Plot

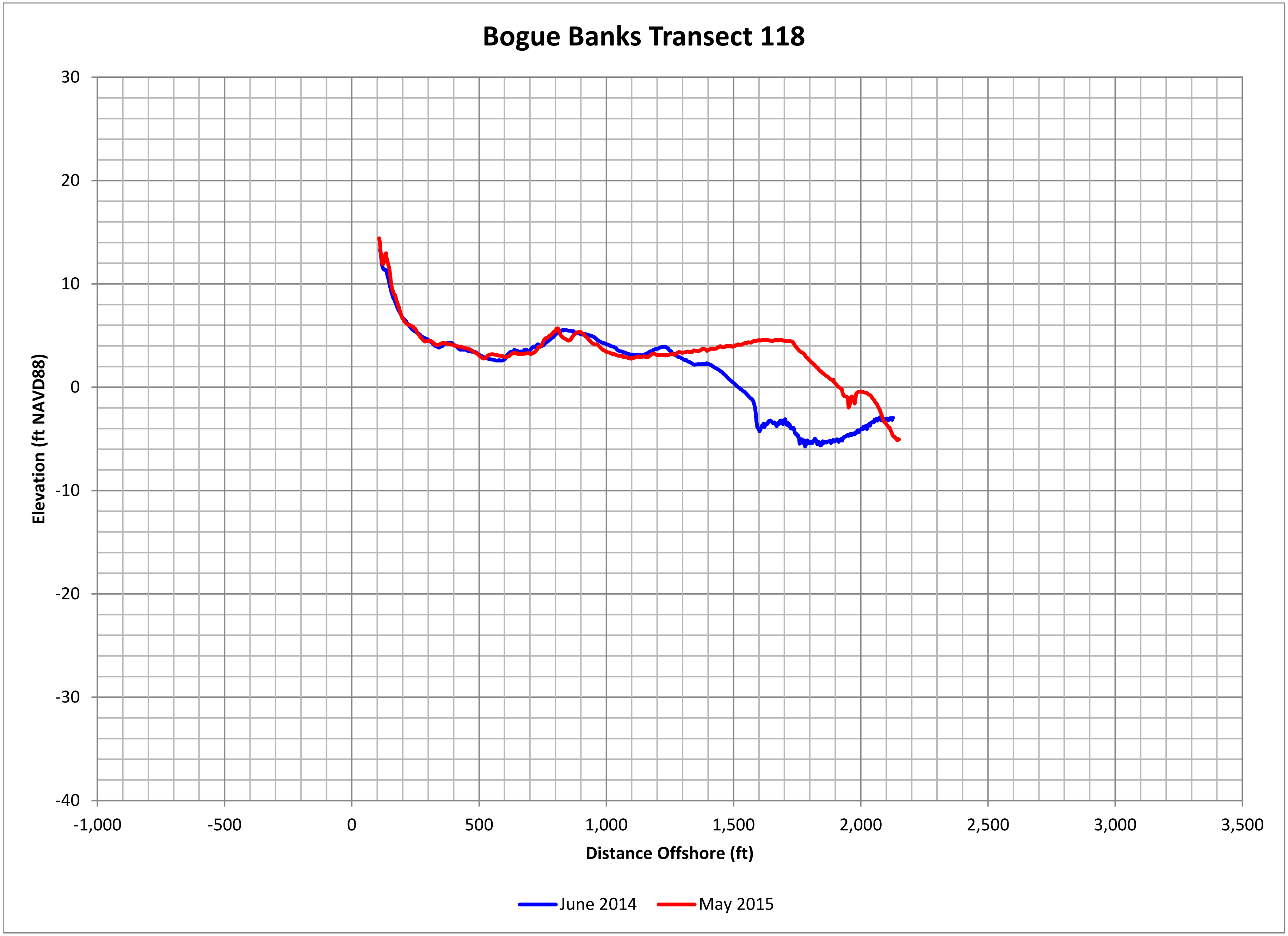

Figure C-148. Bogue Banks Profile Comparison Plot

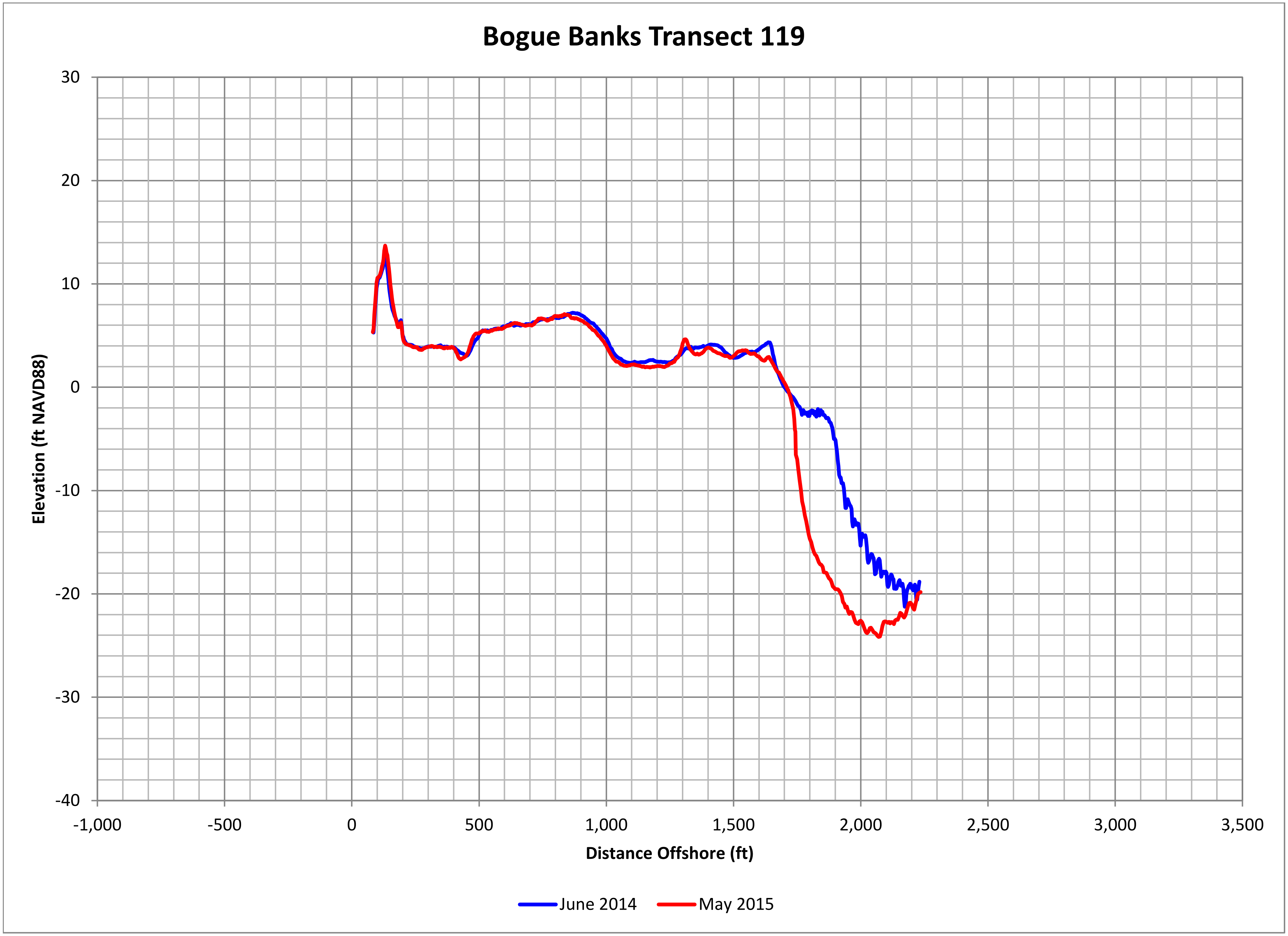

Figure C-149. Bogue Banks Profile Comparison Plot

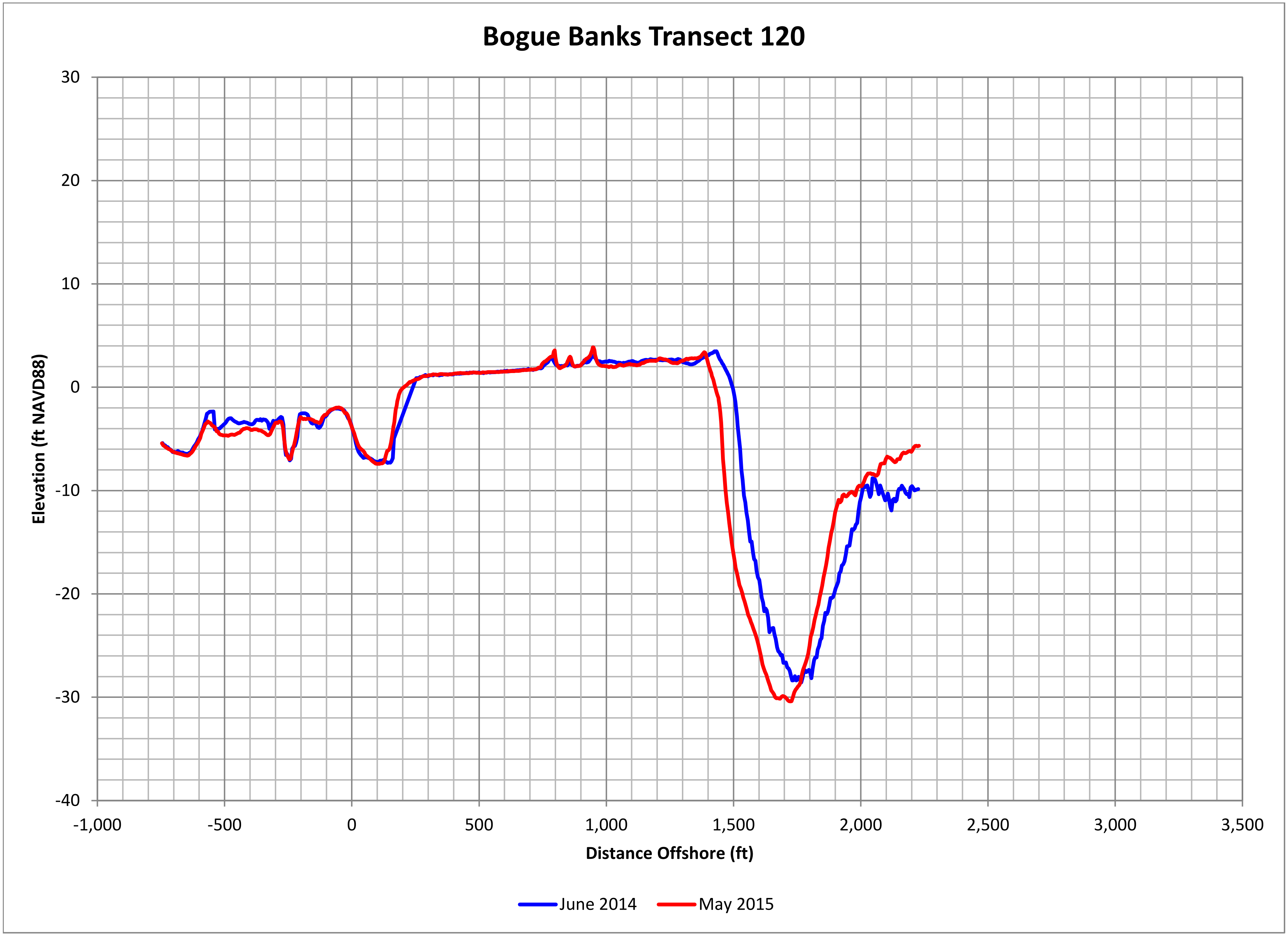

Figure C-150. Bogue Banks Profile Comparison Plot

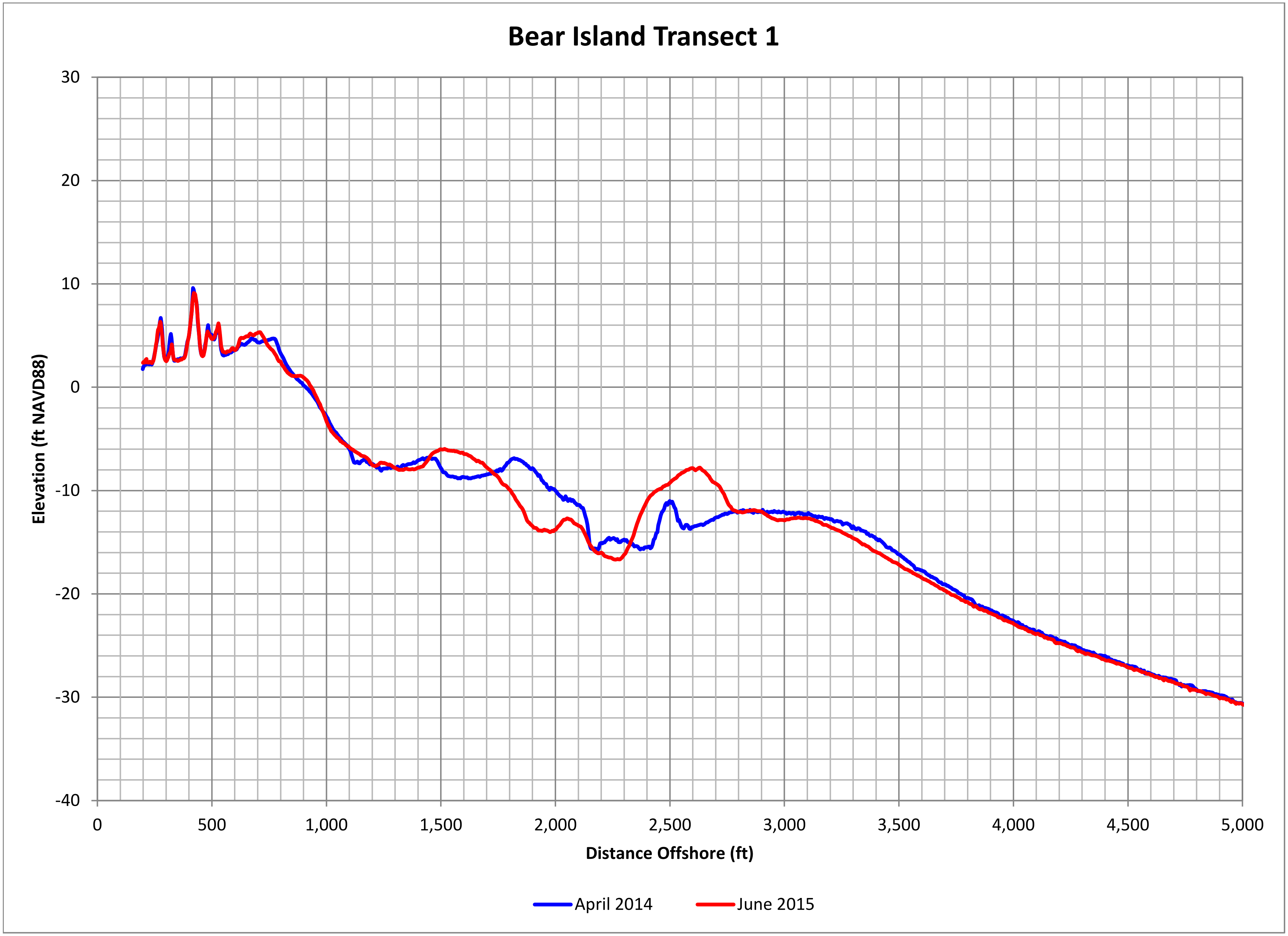

Figure C-151. Bear Island Profile Comparison Plot

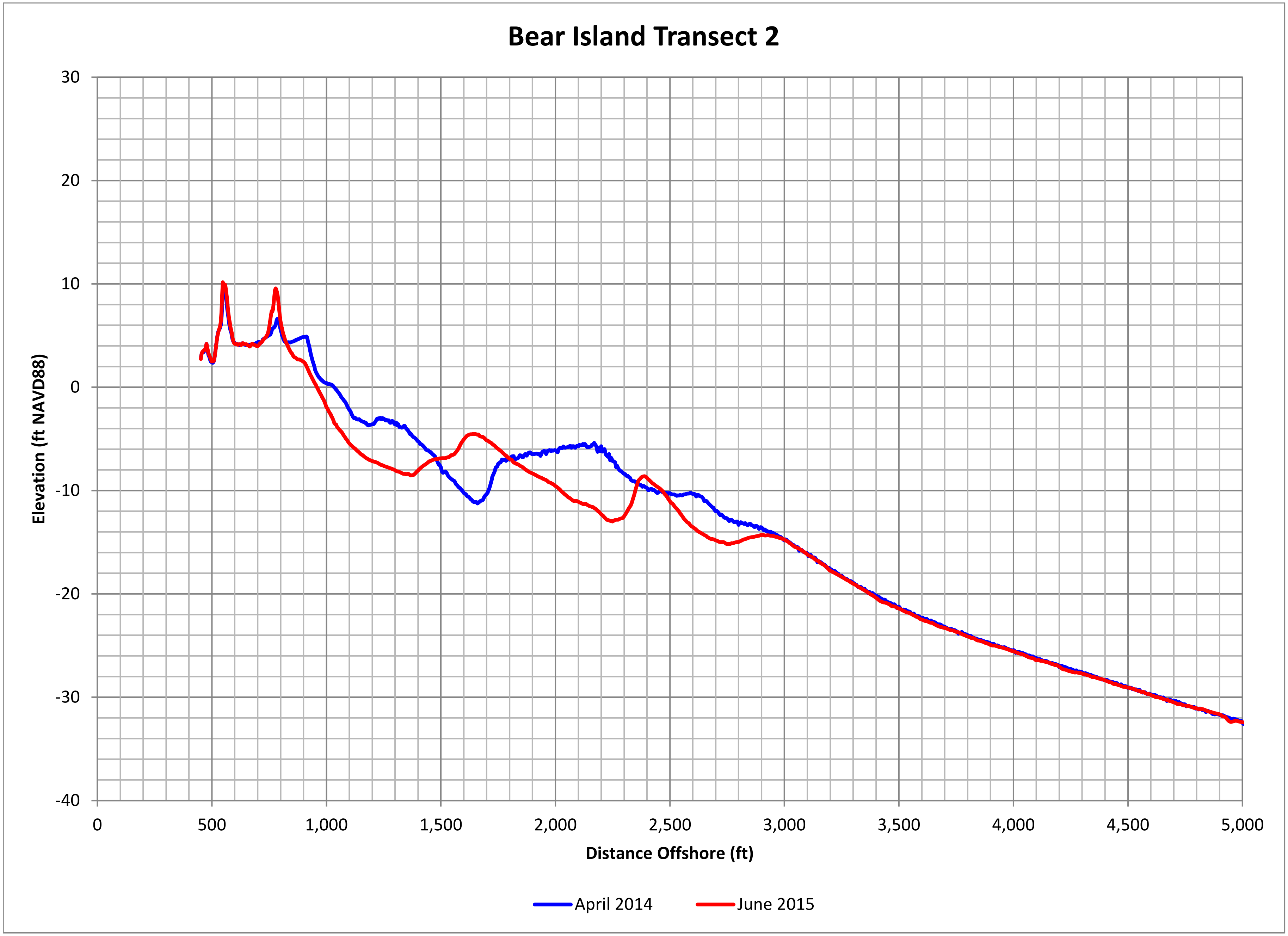

Figure C-152. Bear Island Profile Comparison Plot

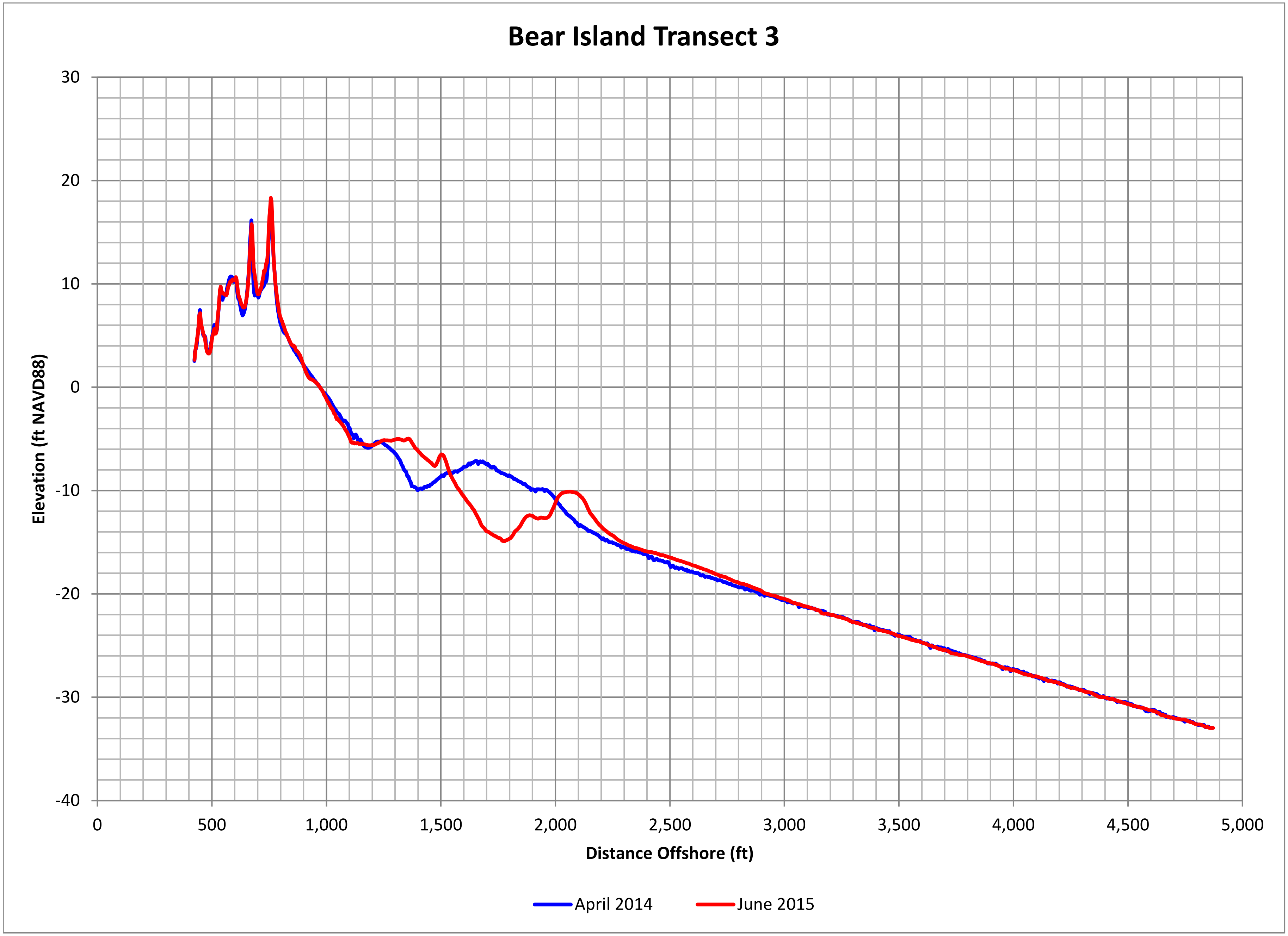

Figure C-153. Bear Island Profile Comparison Plot

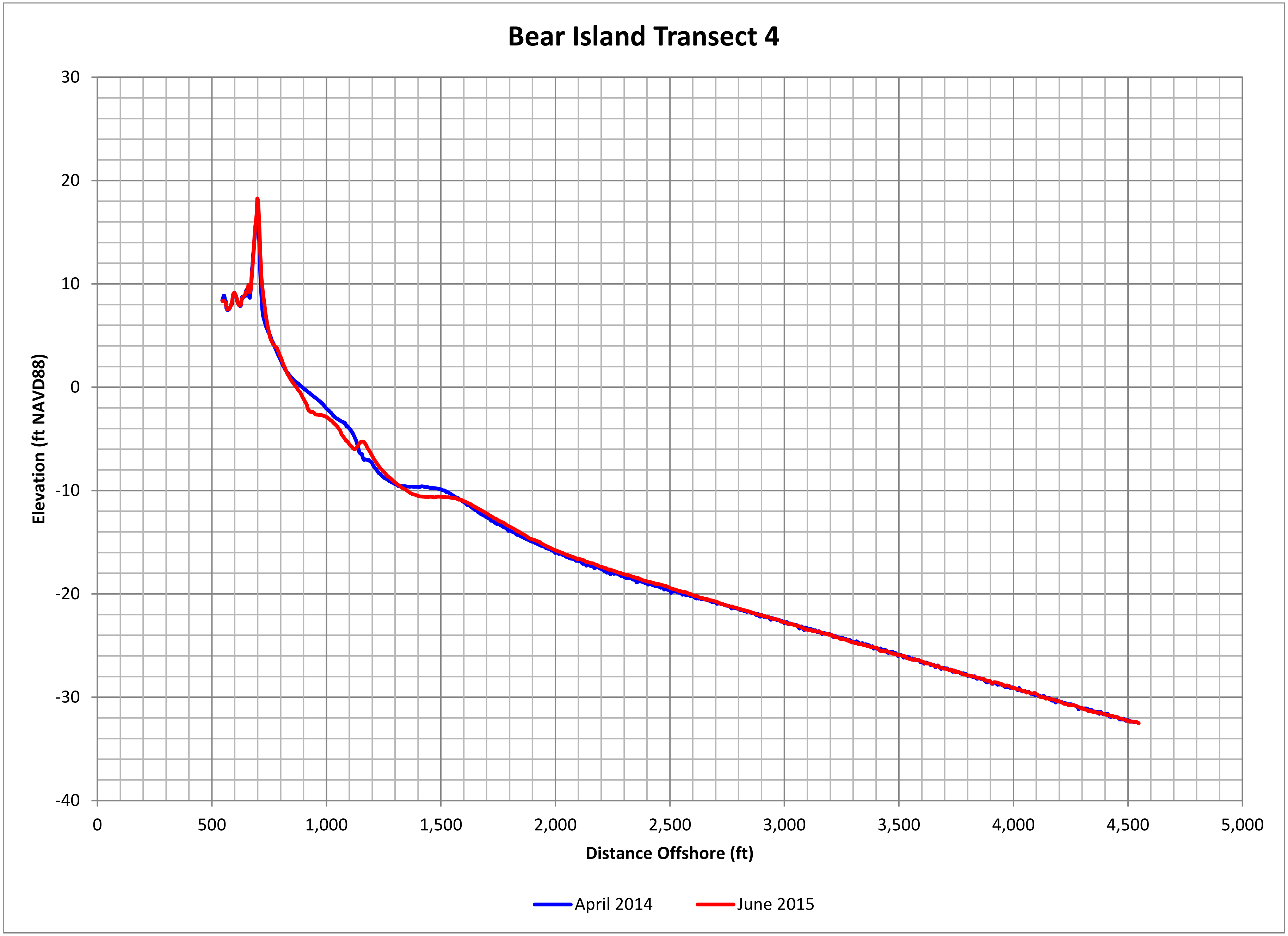

Figure C-154. Bear Island Profile Comparison Plot

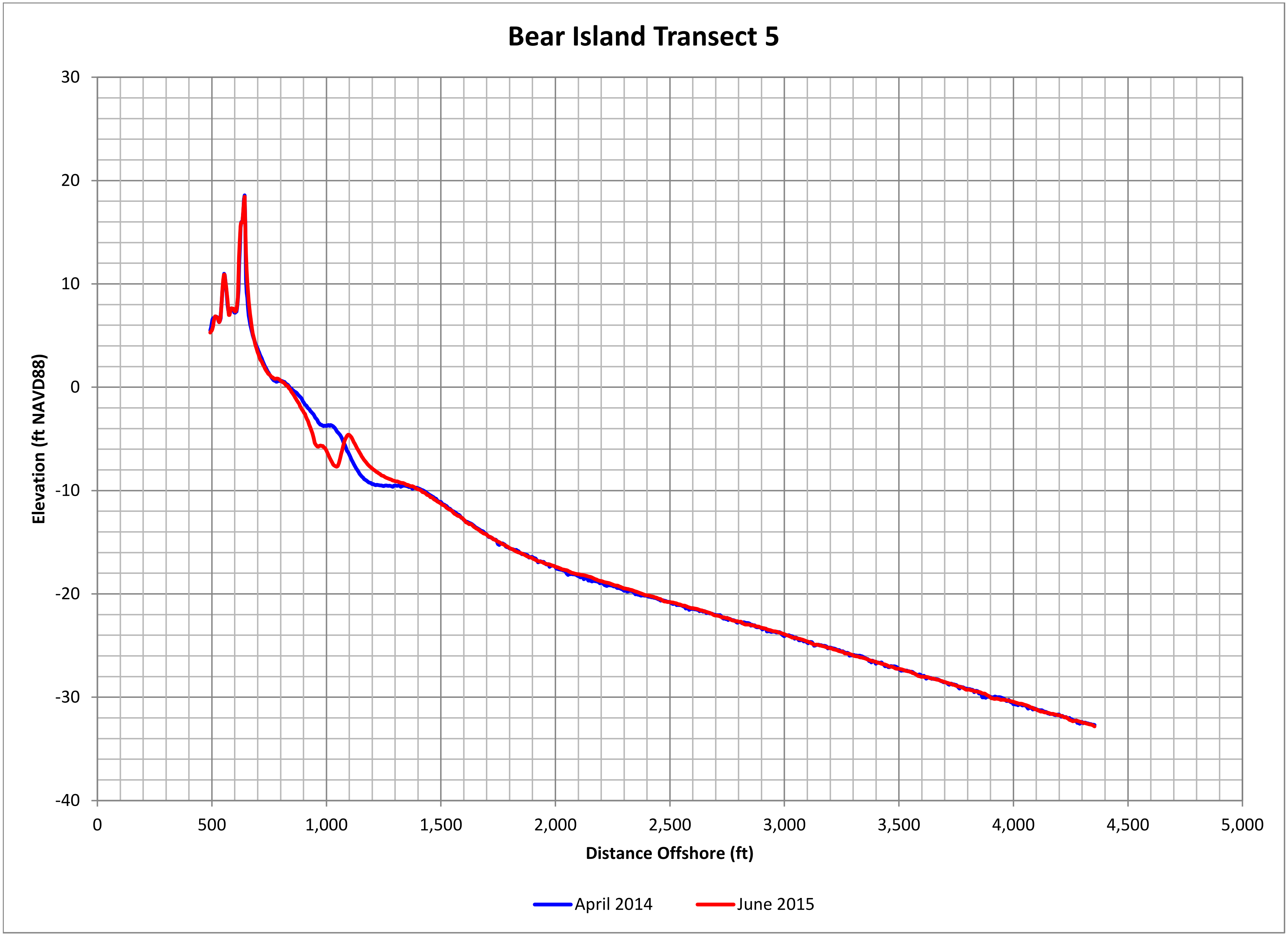

Figure C-155. Bear Island Profile Comparison Plot

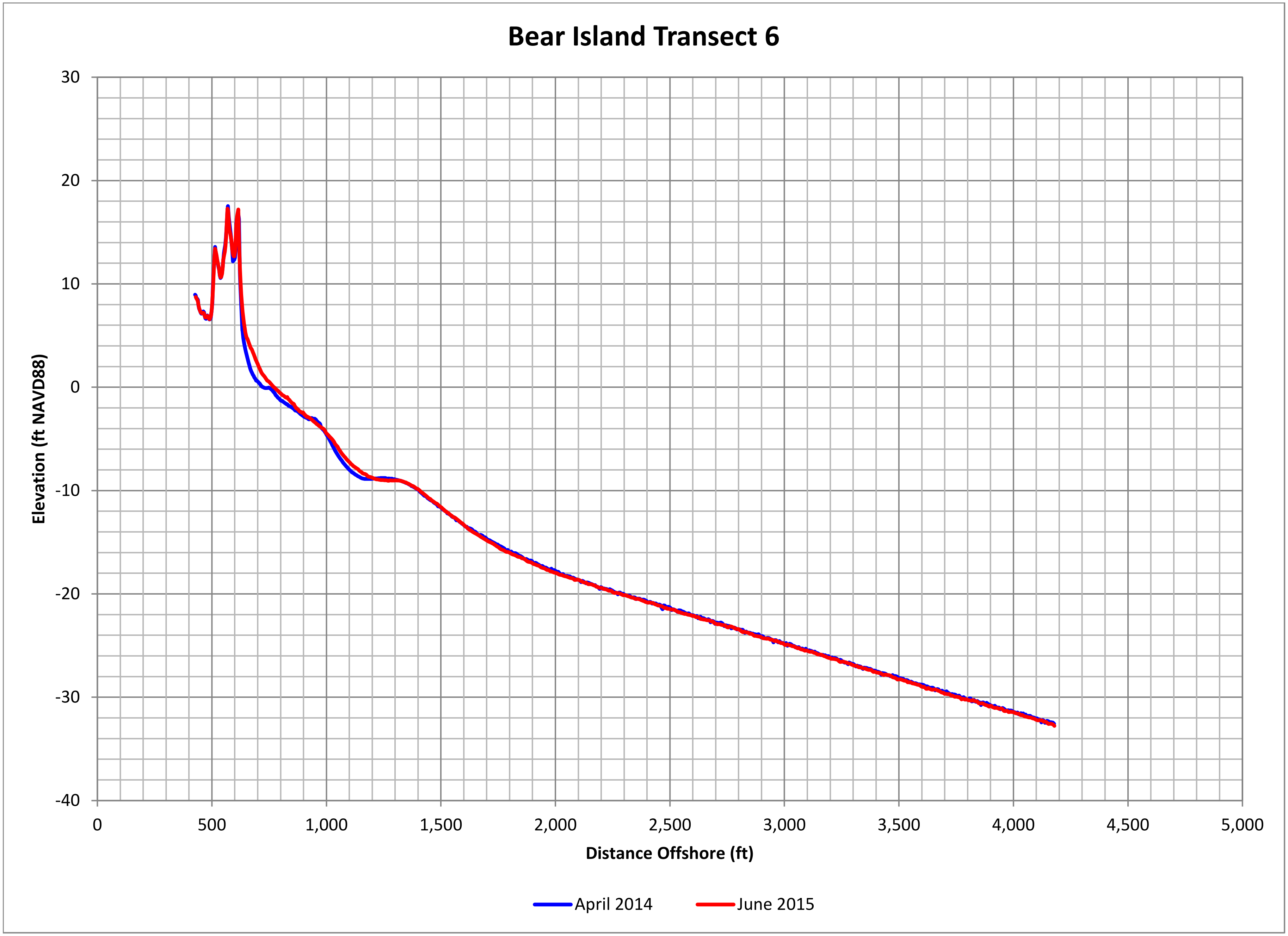

Figure C-156. Bear Island Profile Comparison Plot

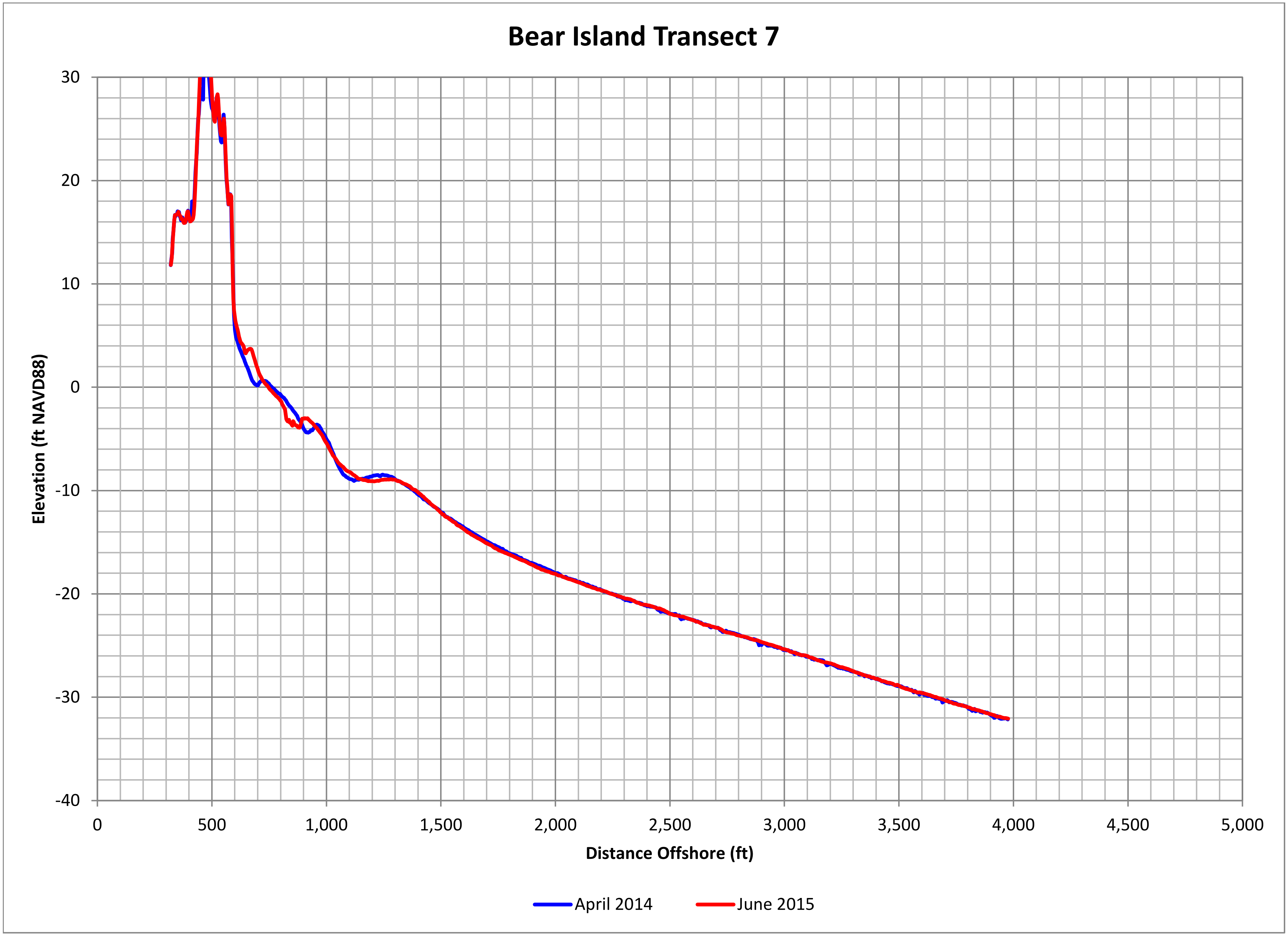

Figure C-157. Bear Island Profile Comparison Plot

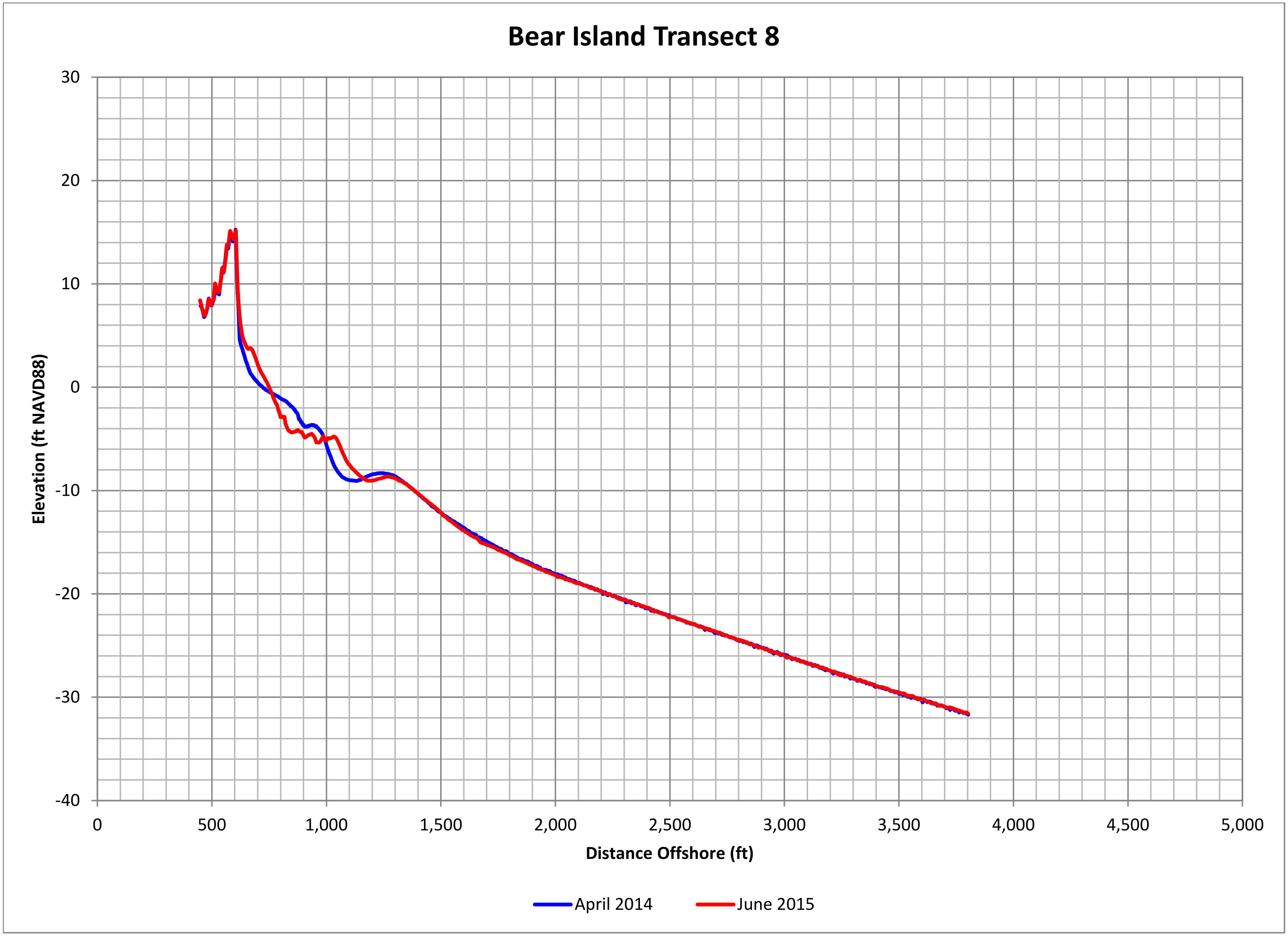

Figure C-158. Bear Island Profile Comparison Plot

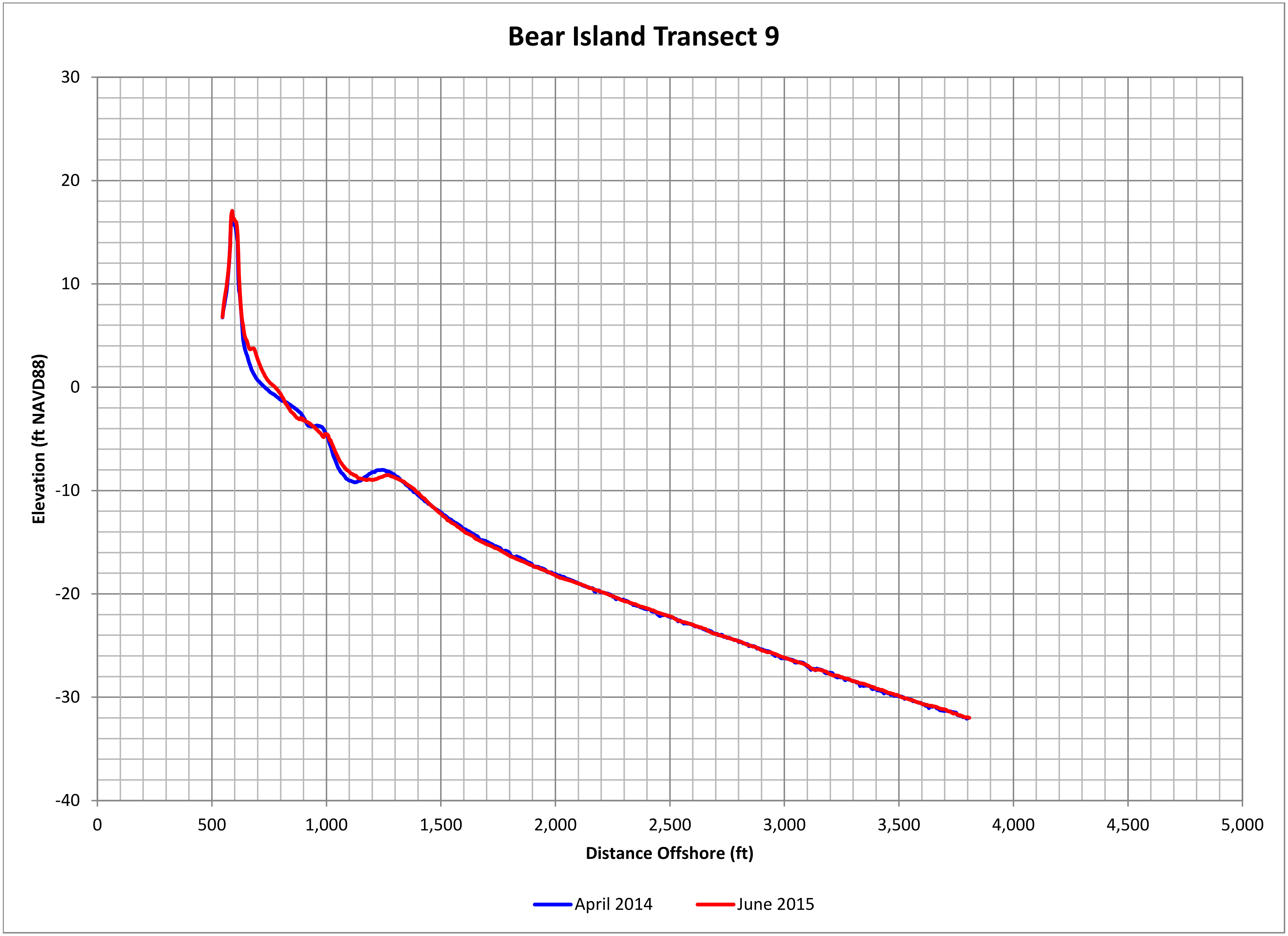

Figure C-159. Bear Island Profile Comparison Plot

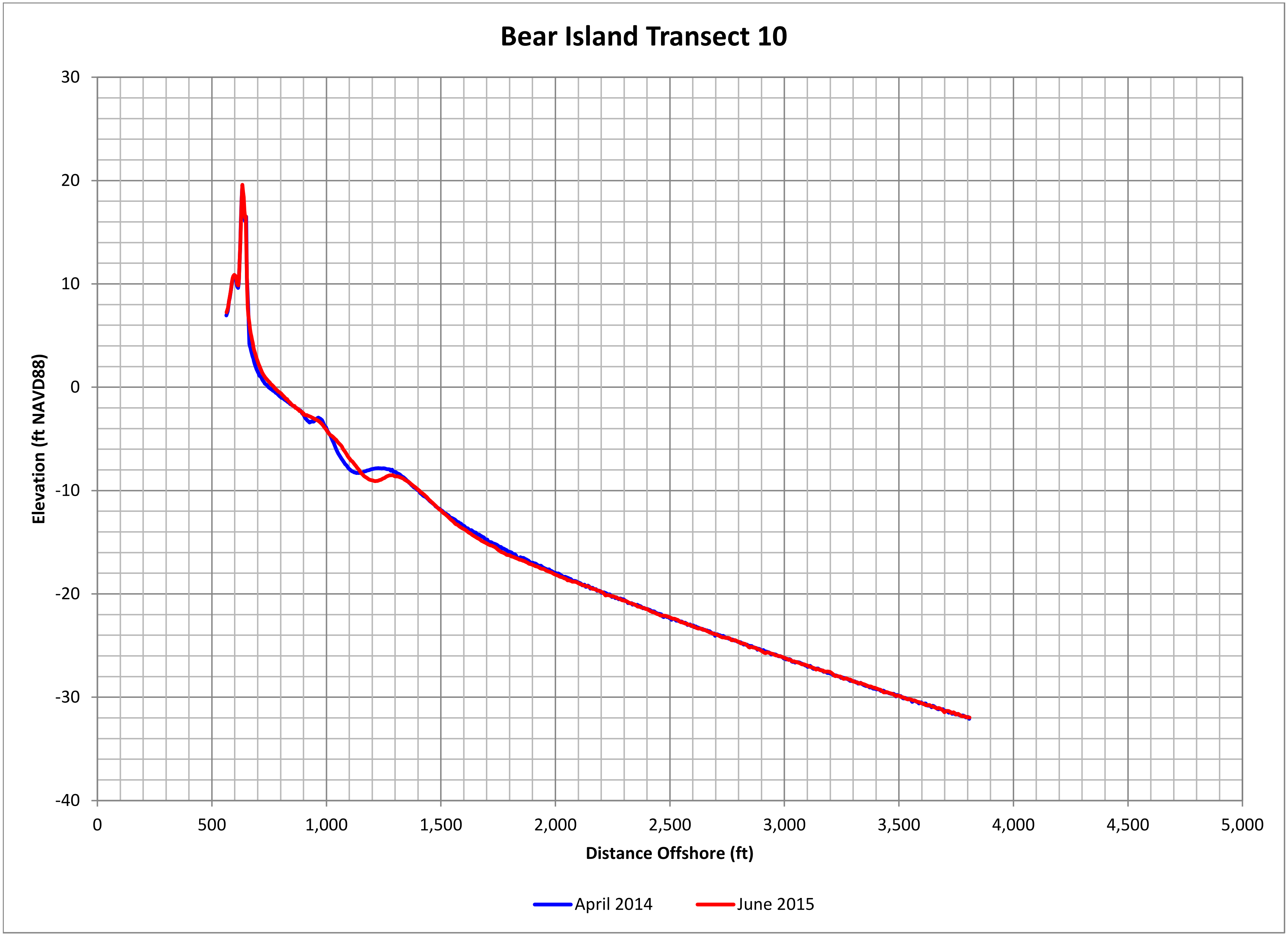

Figure C-160. Bear Island Profile Comparison Plot

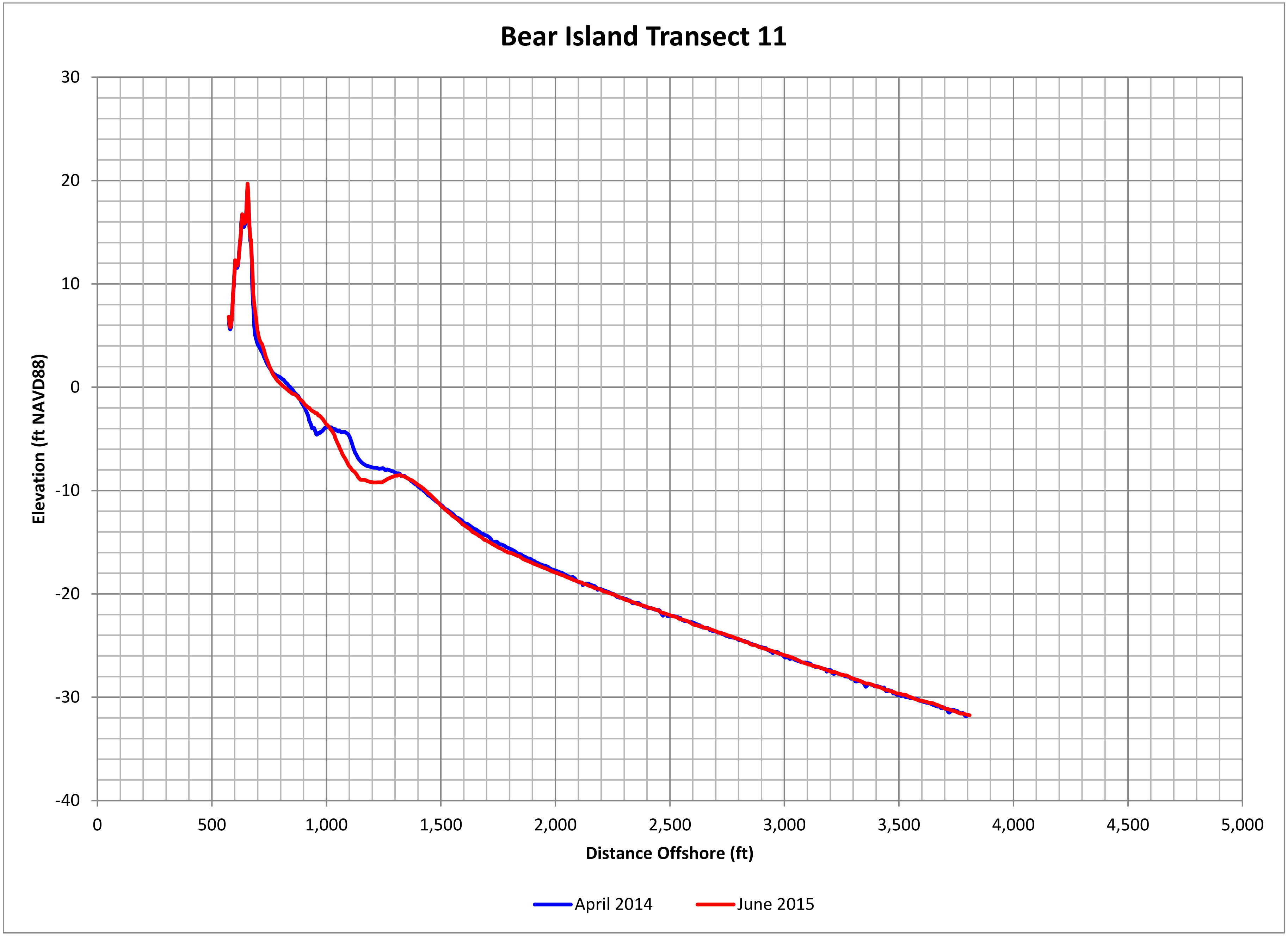

Figure C-161. Bear Island Profile Comparison Plot

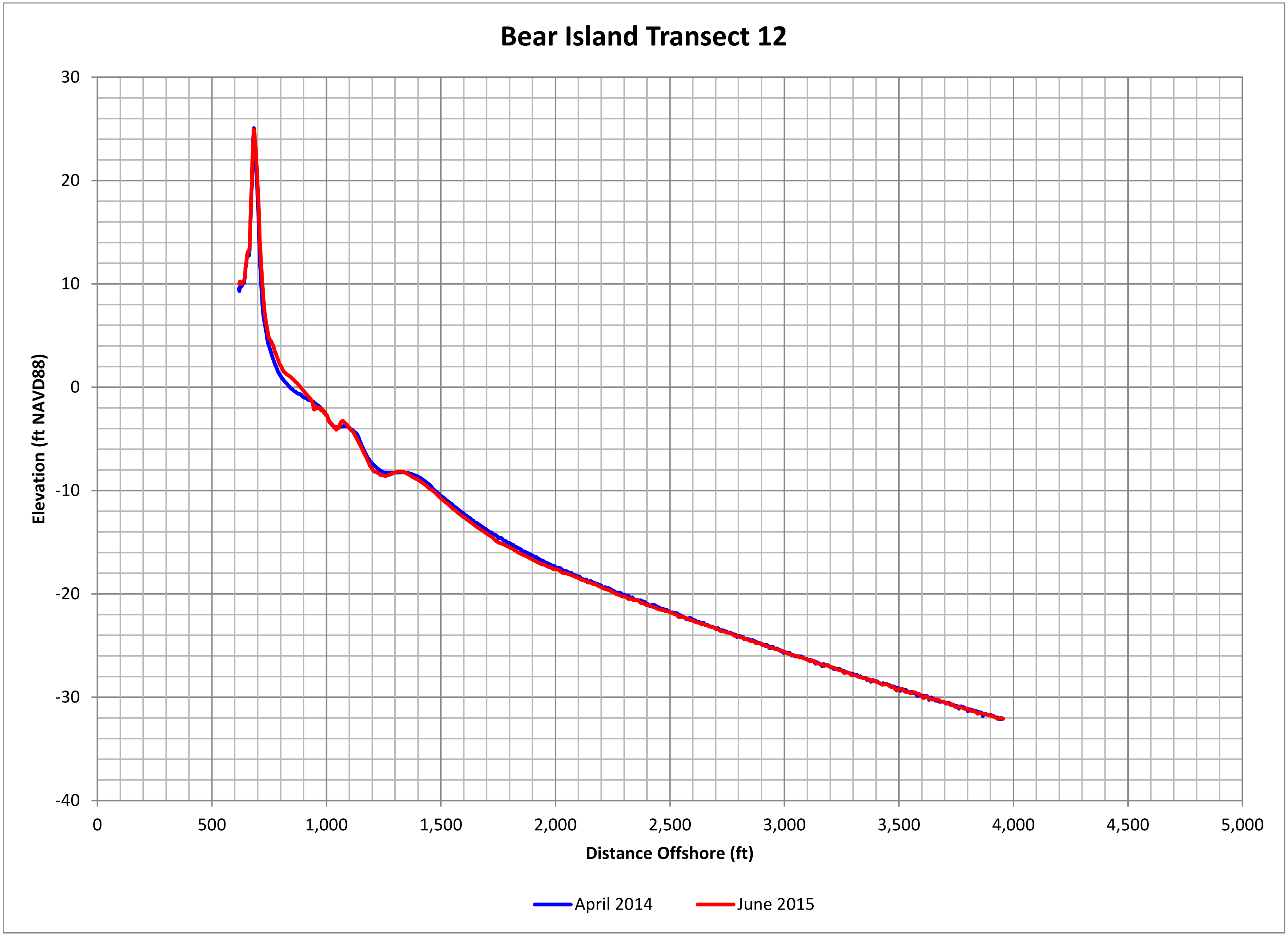

Figure C-162. Bear Island Profile Comparison Plot

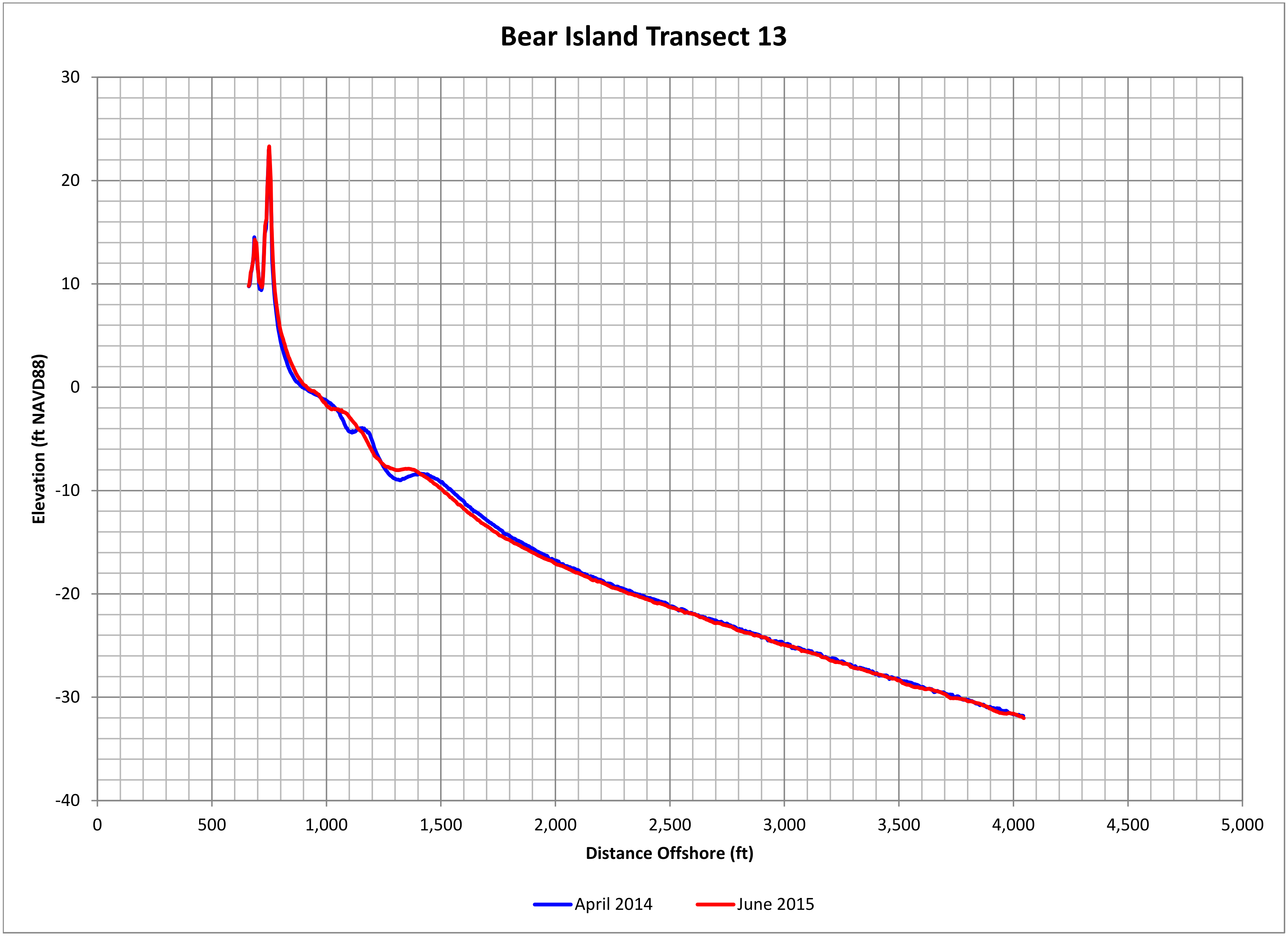

Figure C-163. Bear Island Profile Comparison Plot

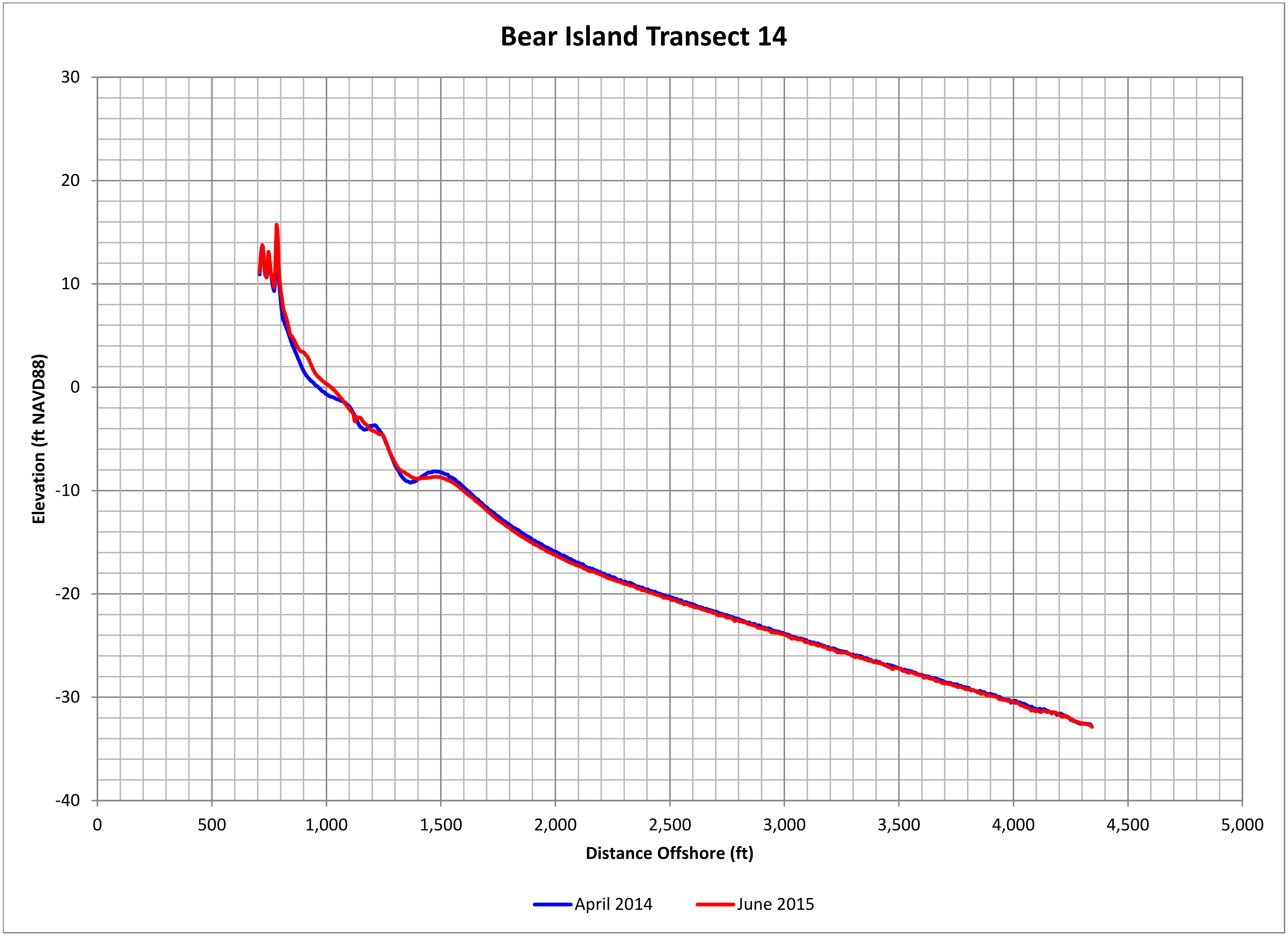

Figure C-164. Bear Island Profile Comparison Plot

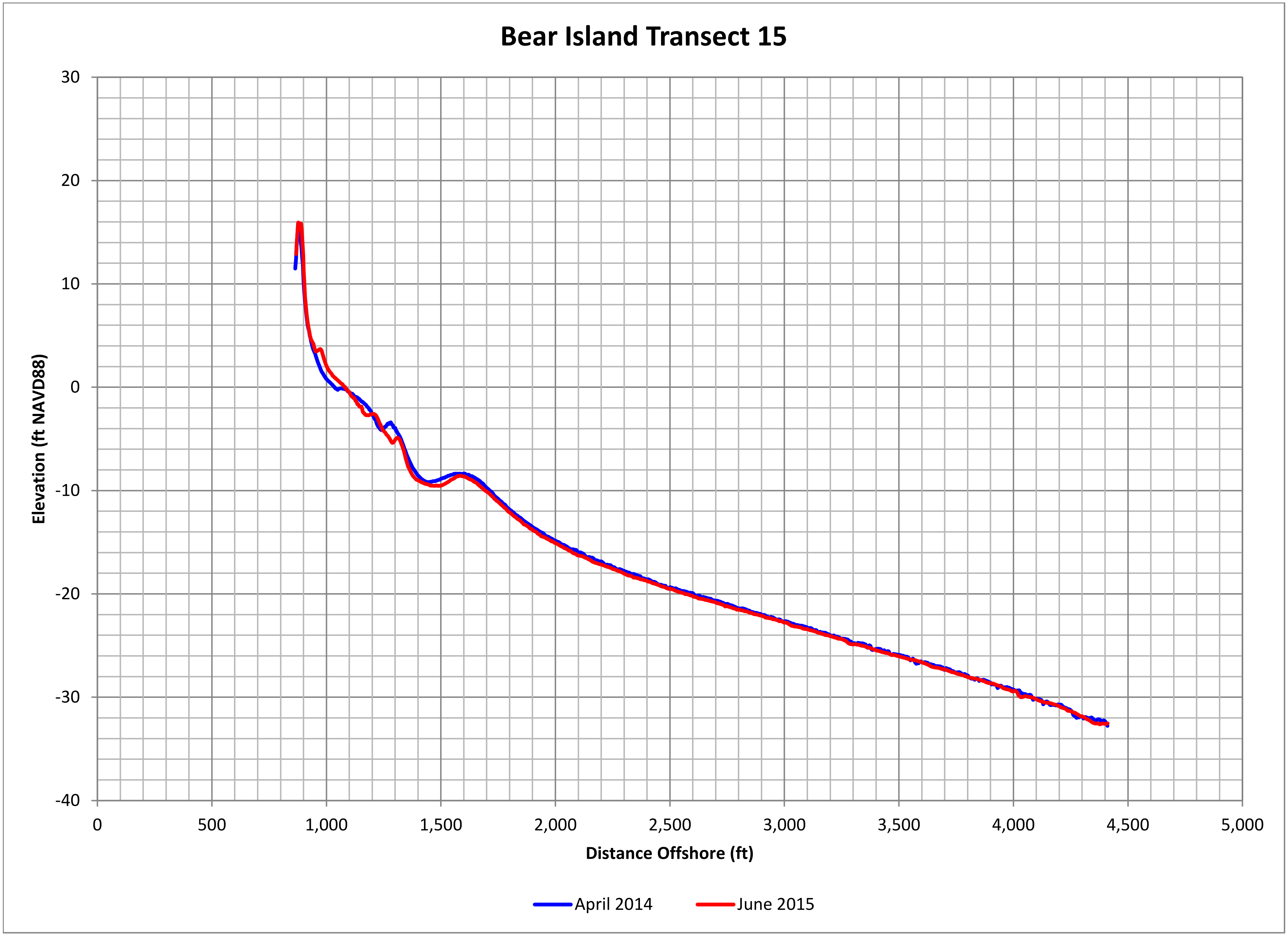

Figure C-165. Bear Island Profile Comparison Plot

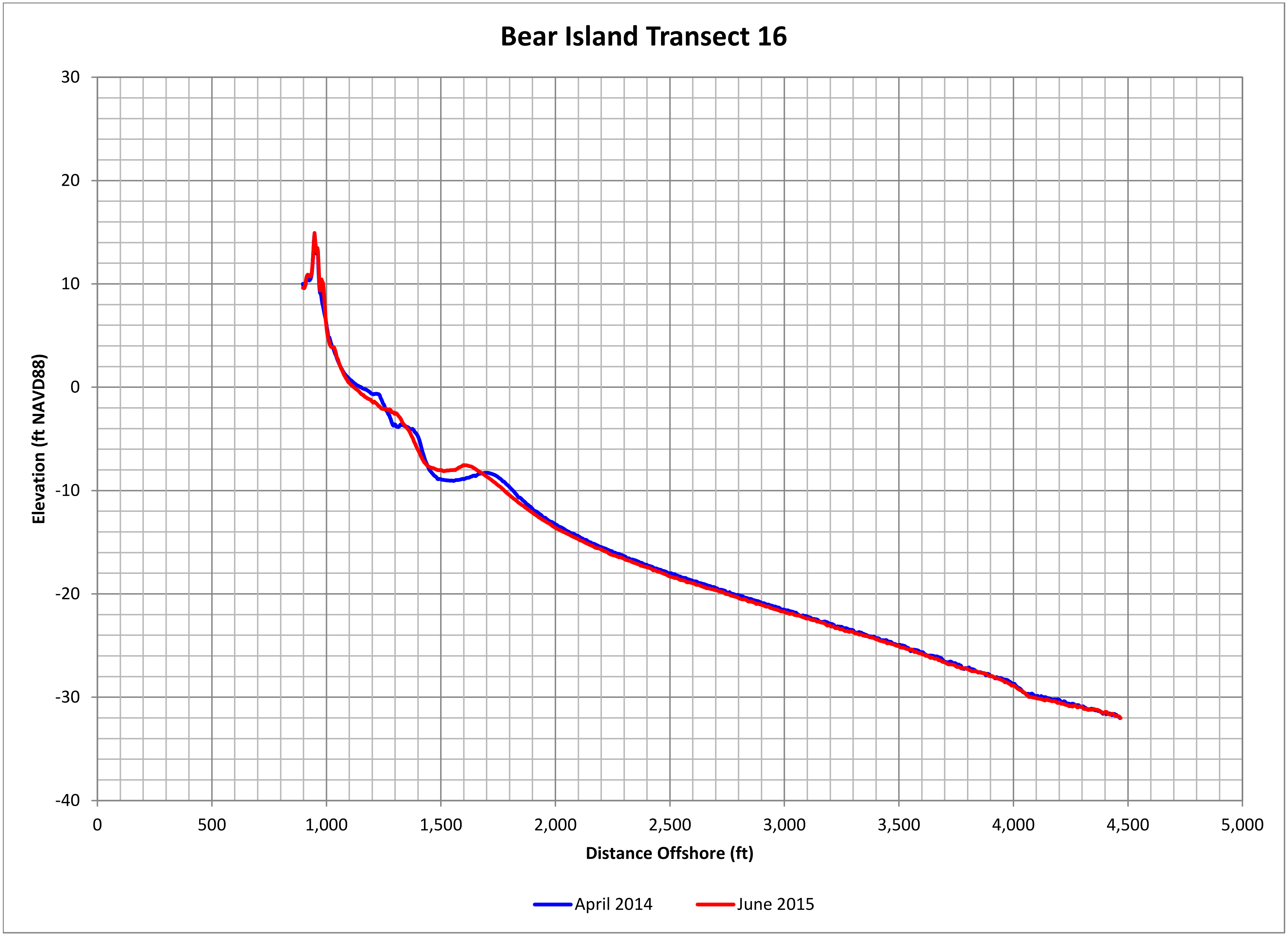

Figure C-166. Bear Island Profile Comparison Plot

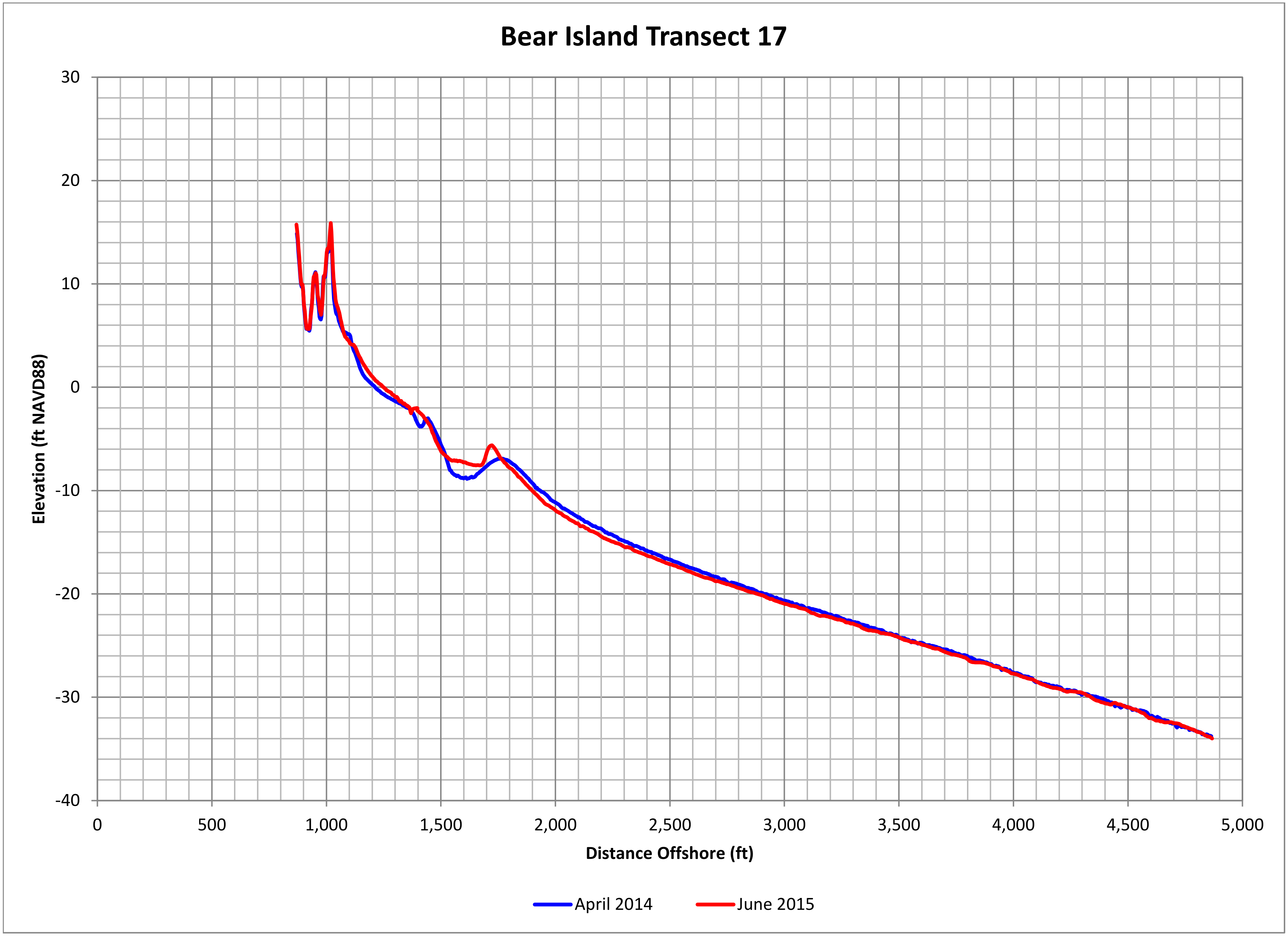

Figure C-167. Bear Island Profile Comparison Plot

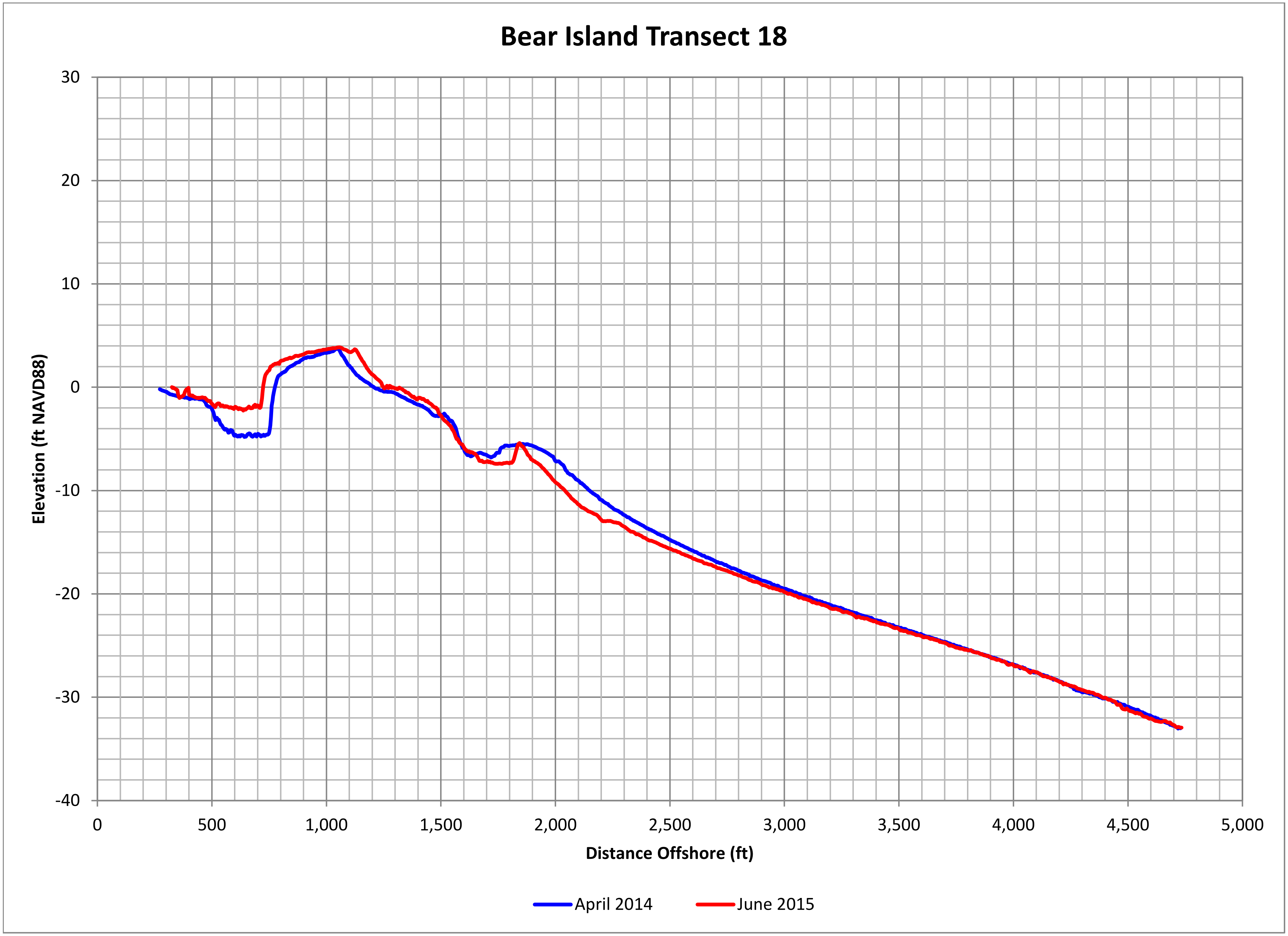

Figure C-168. Bear Island Profile Comparison Plot

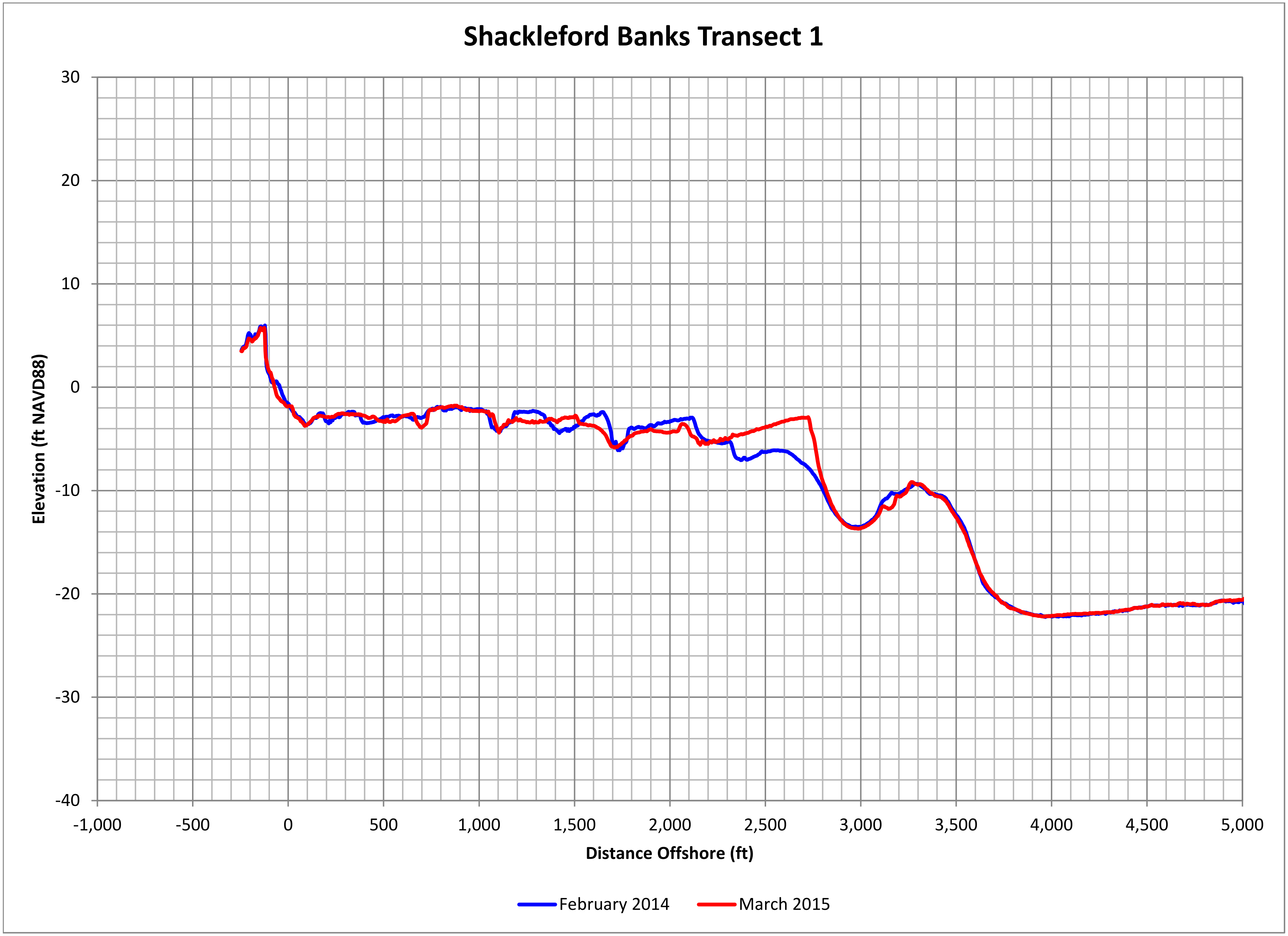

Figure C-169. Shackleford Banks Profile Comparison Plot

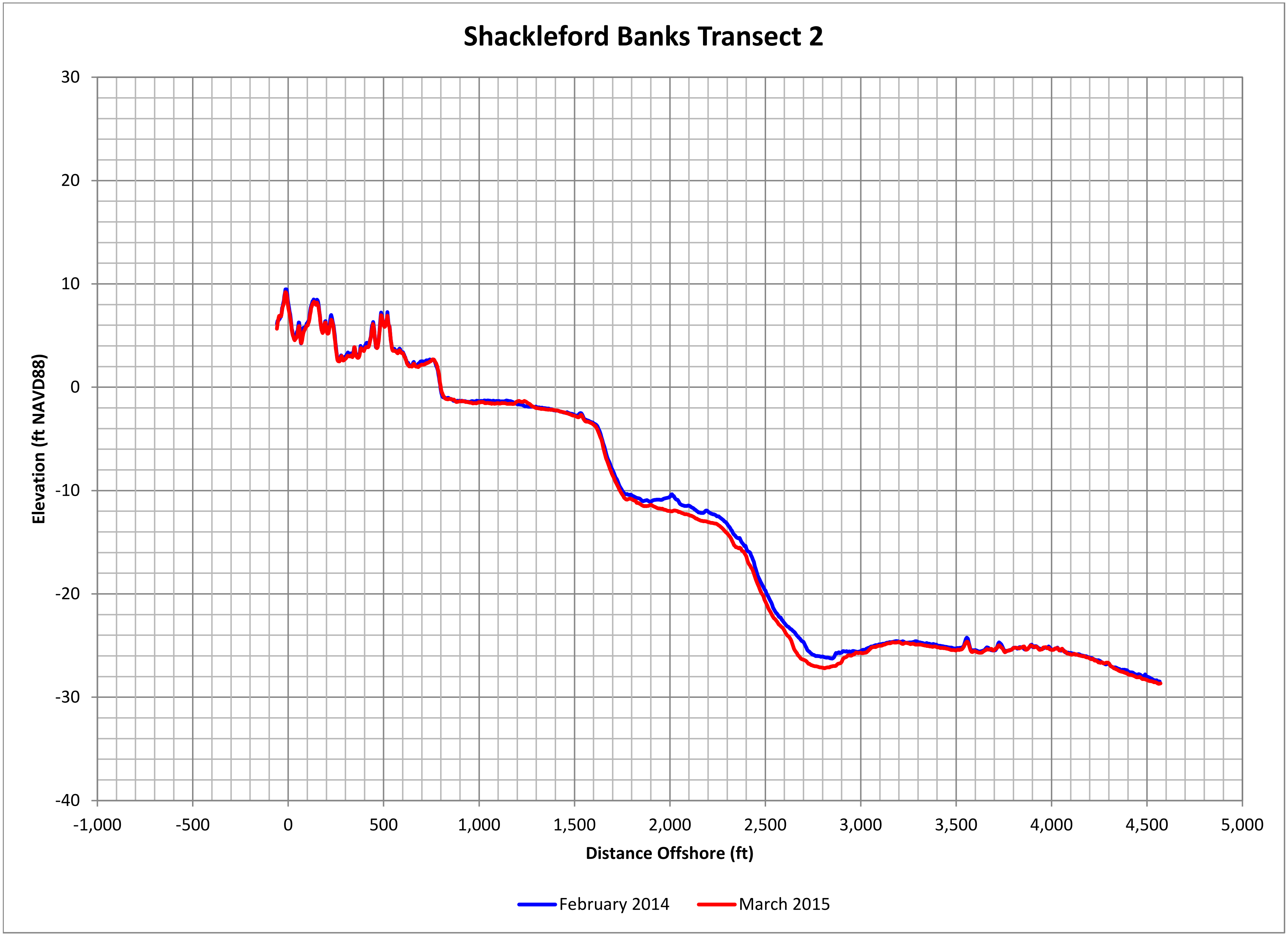

Figure C-170. Shackleford Banks Profile Comparison Plot

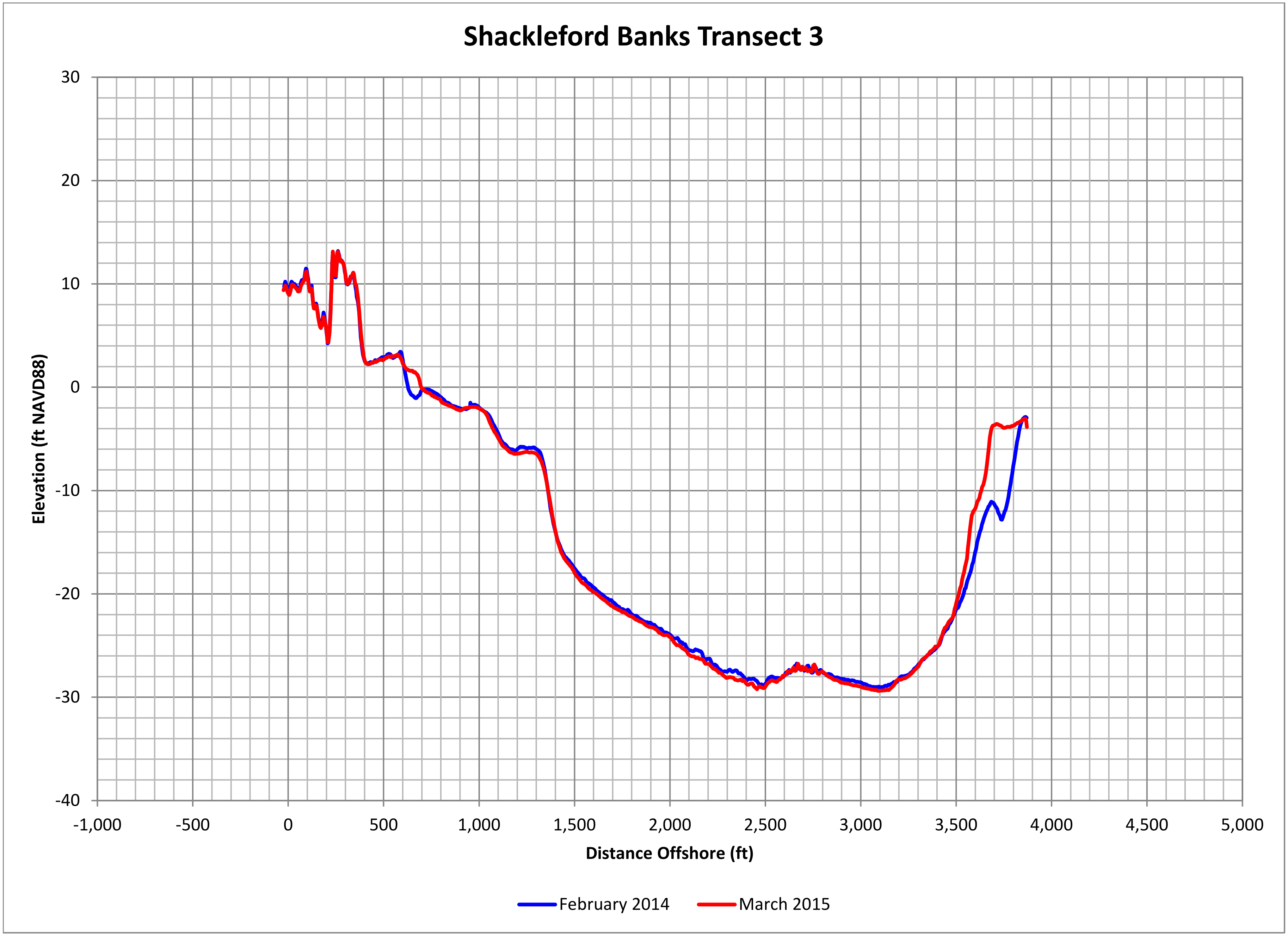

Figure C-171. Shackleford Banks Profile Comparison Plot

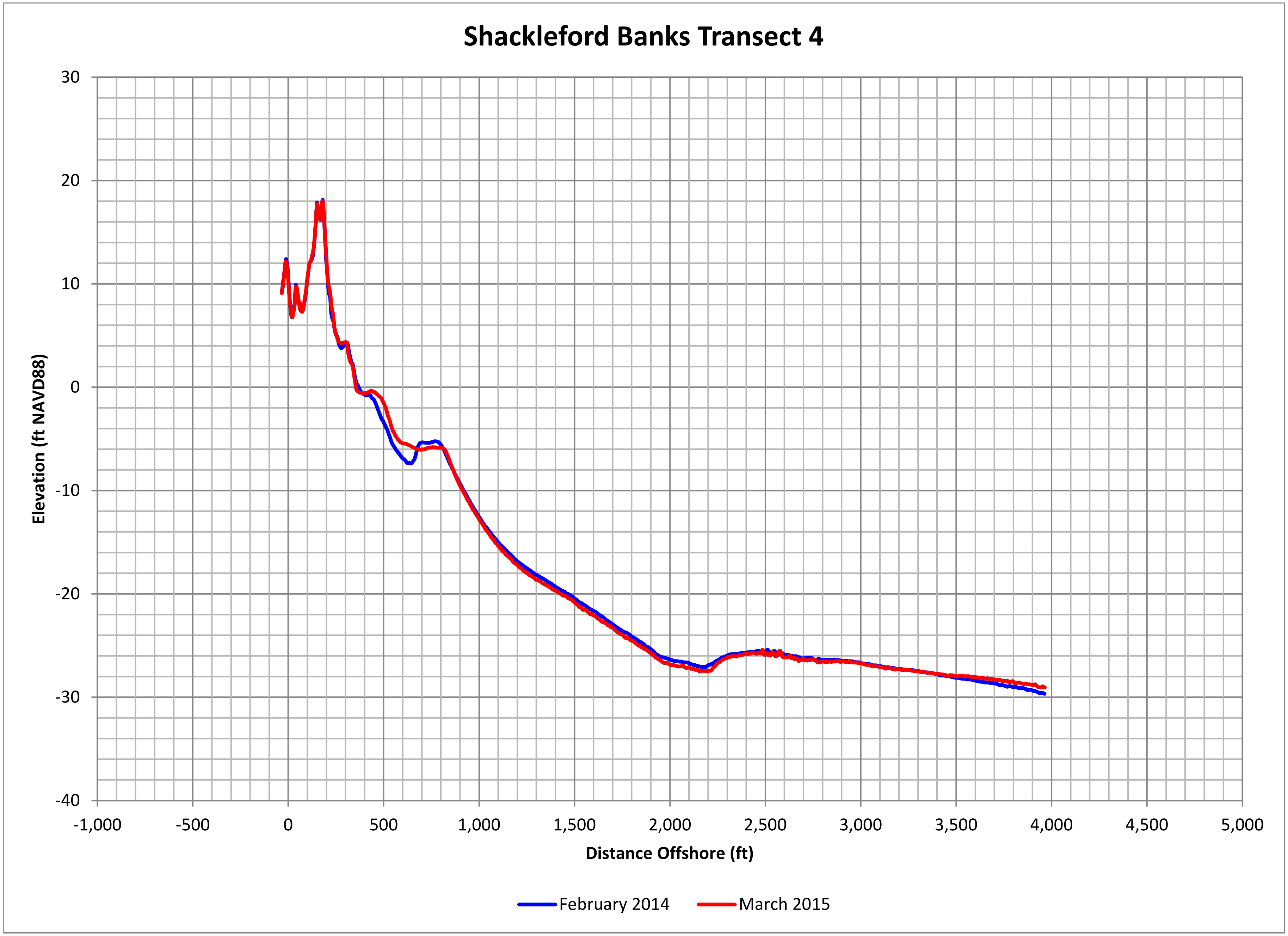

Figure C-172. Shackleford Banks Profile Comparison Plot

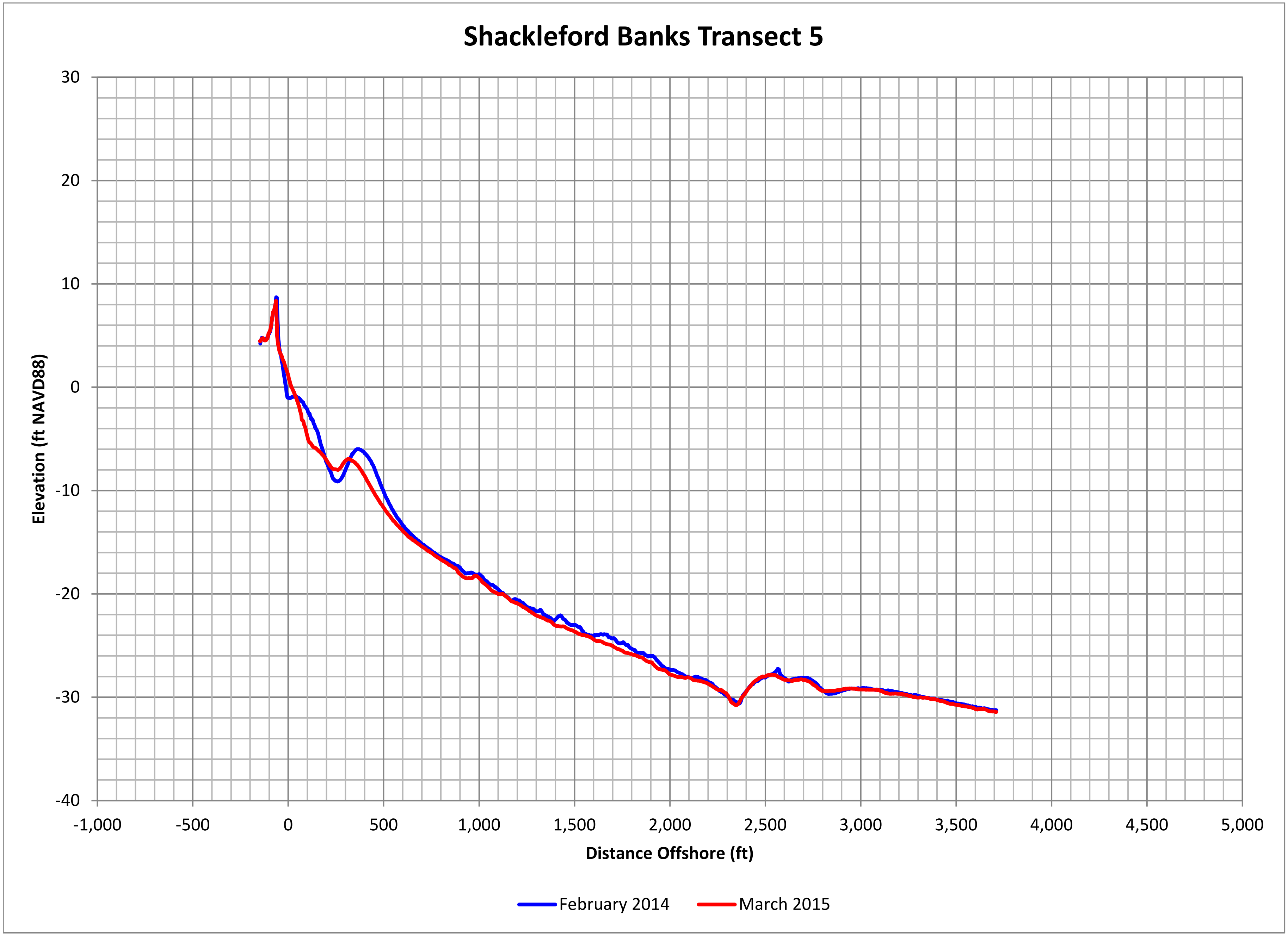

Figure C-173. Shackleford Banks Profile Comparison Plot

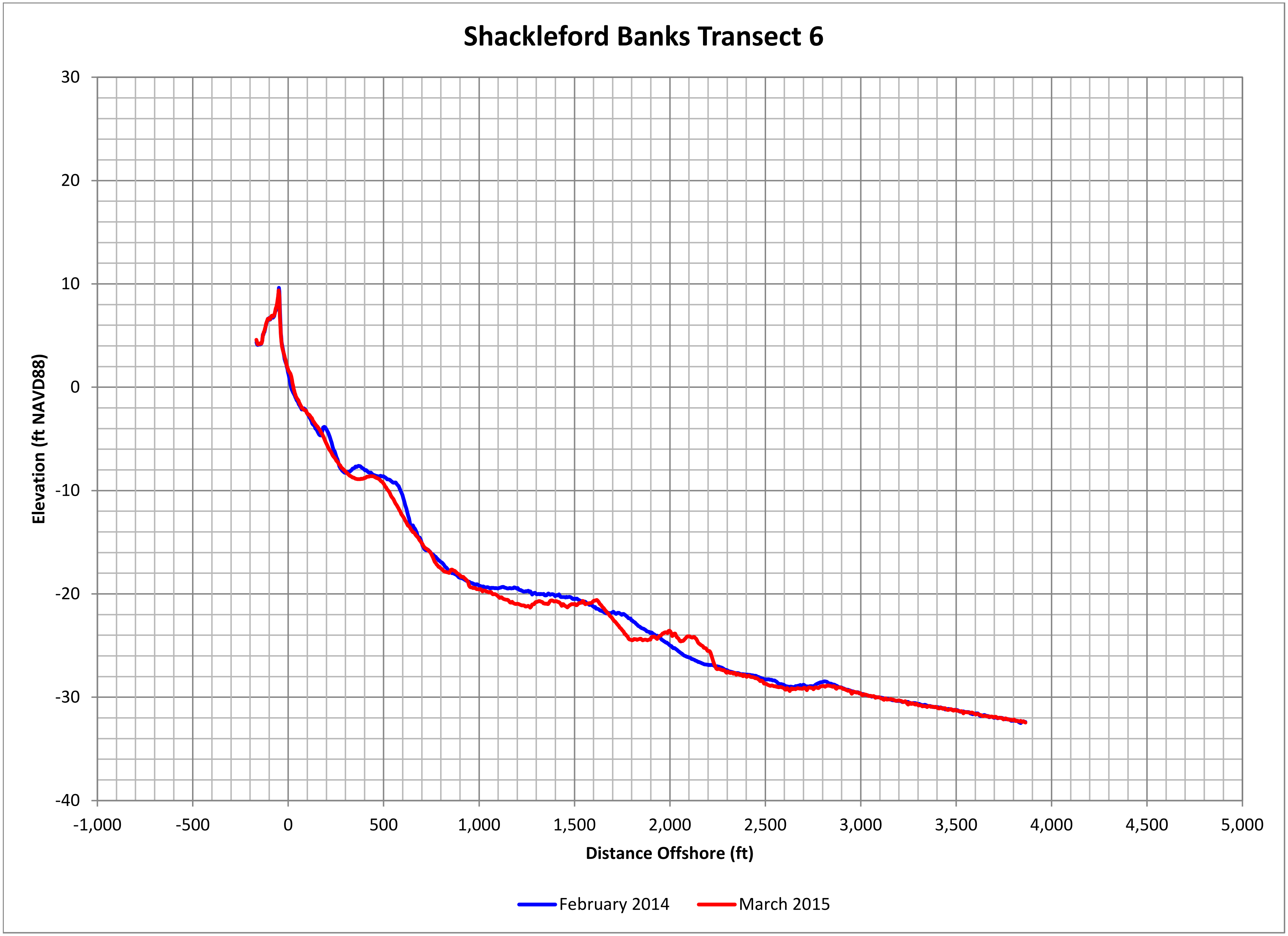

Figure C-174. Shackleford Banks Profile Comparison Plot

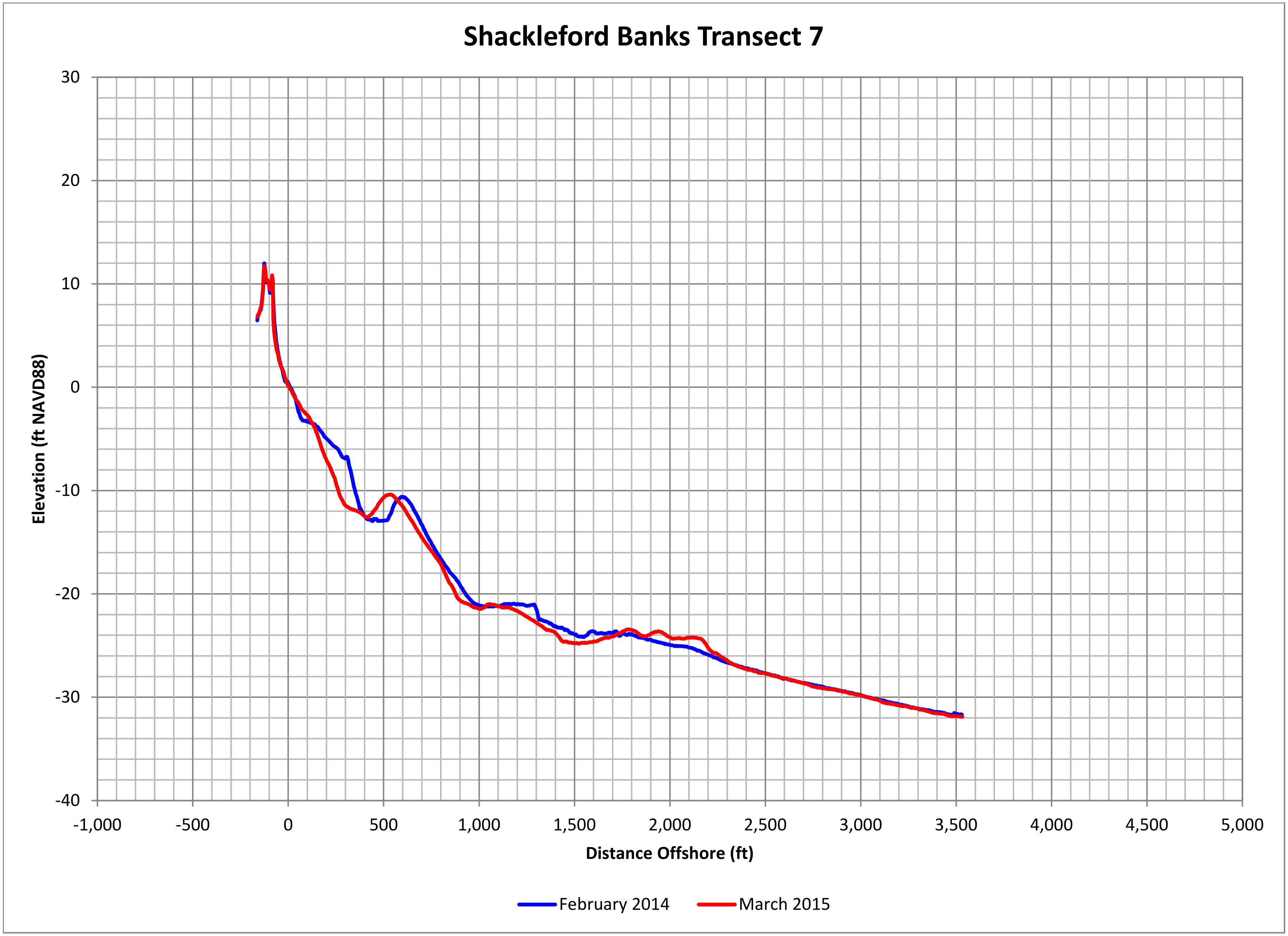

Figure C-175. Shackleford Banks Profile Comparison Plot

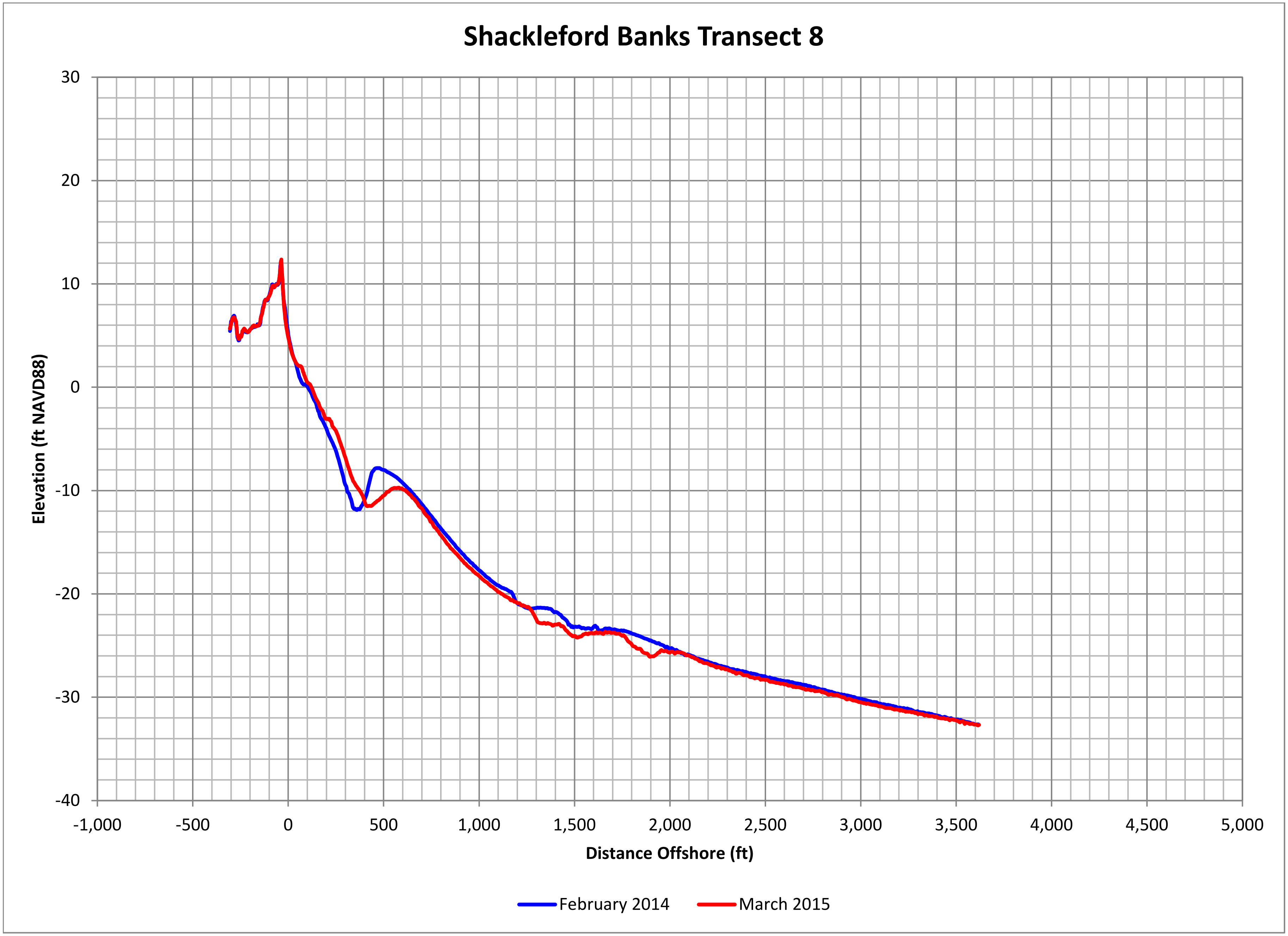

Figure C-176. Shackleford Banks Profile Comparison Plot

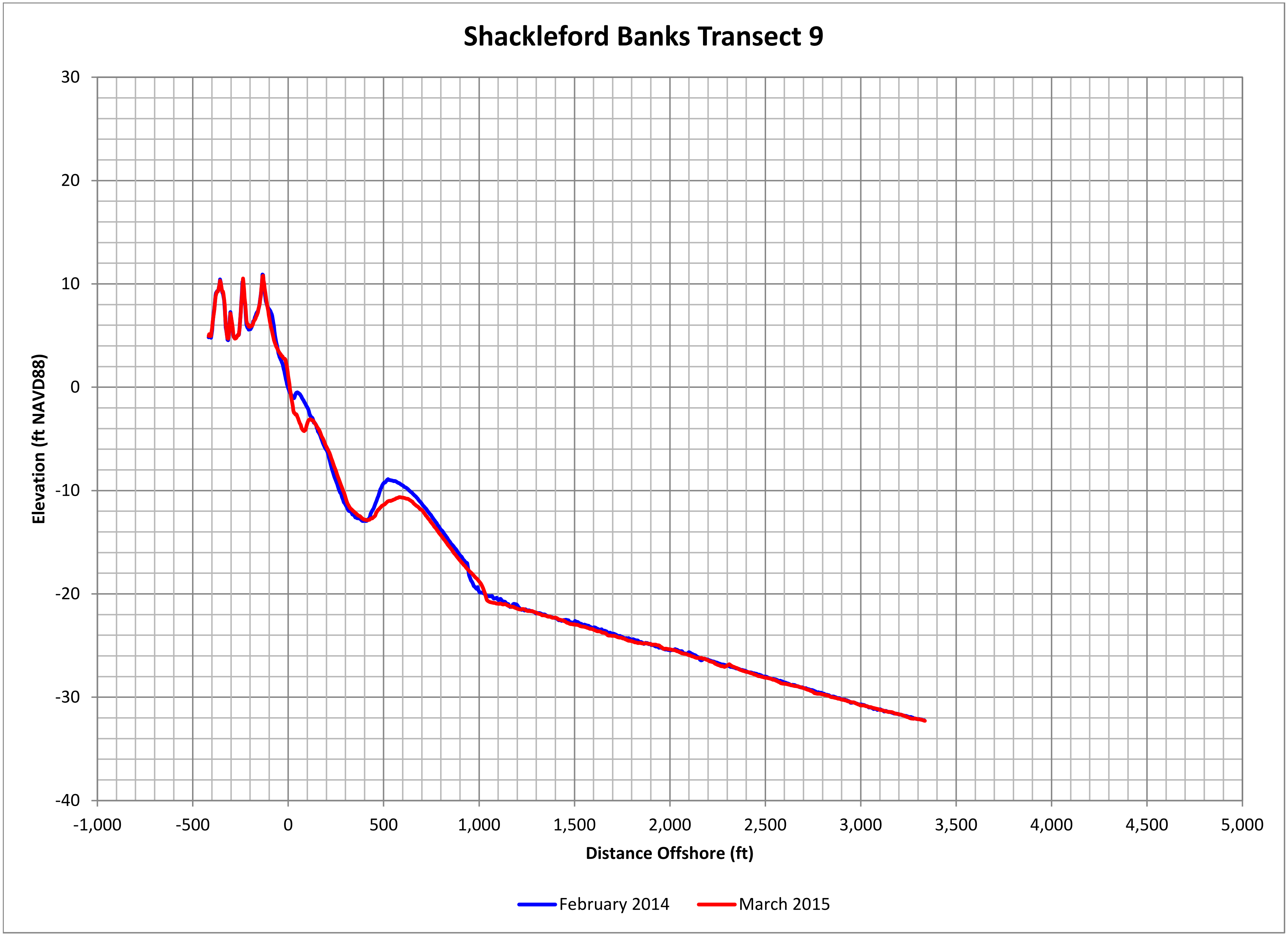

Figure C-177. Shackleford Banks Profile Comparison Plot

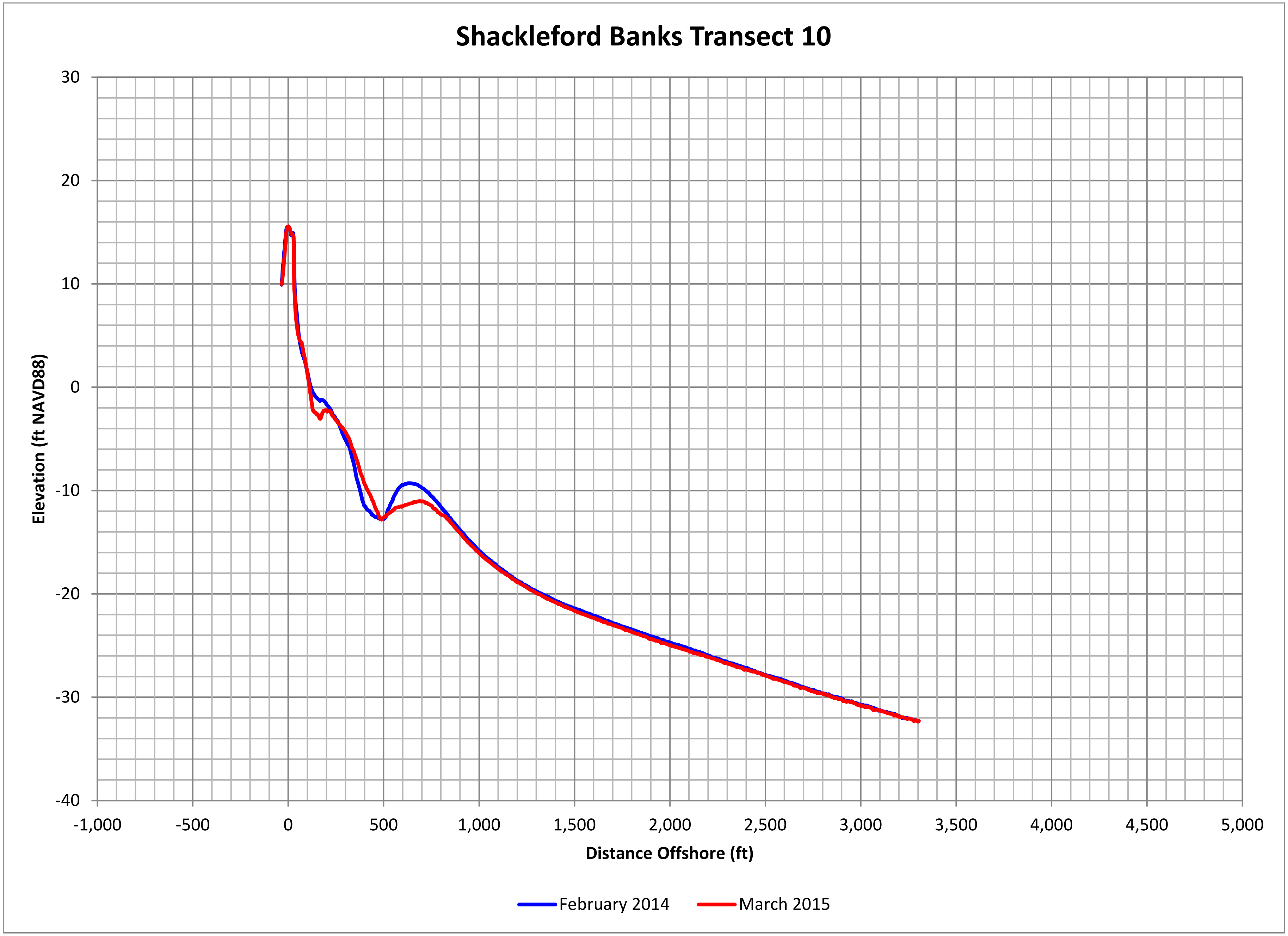

Figure C-178. Shackleford Banks Profile Comparison Plot

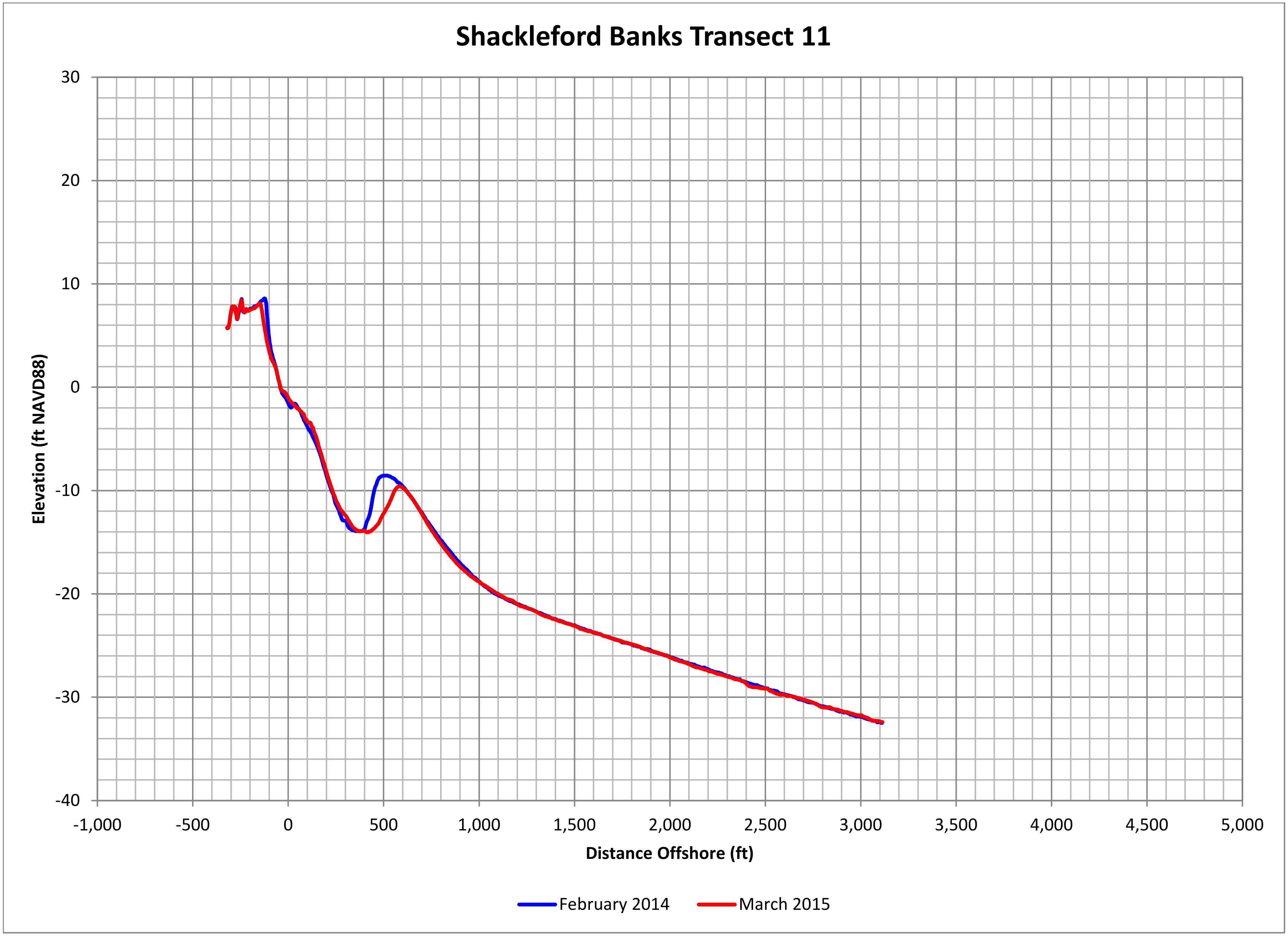

Figure C-179. Shackleford Banks Profile Comparison Plot

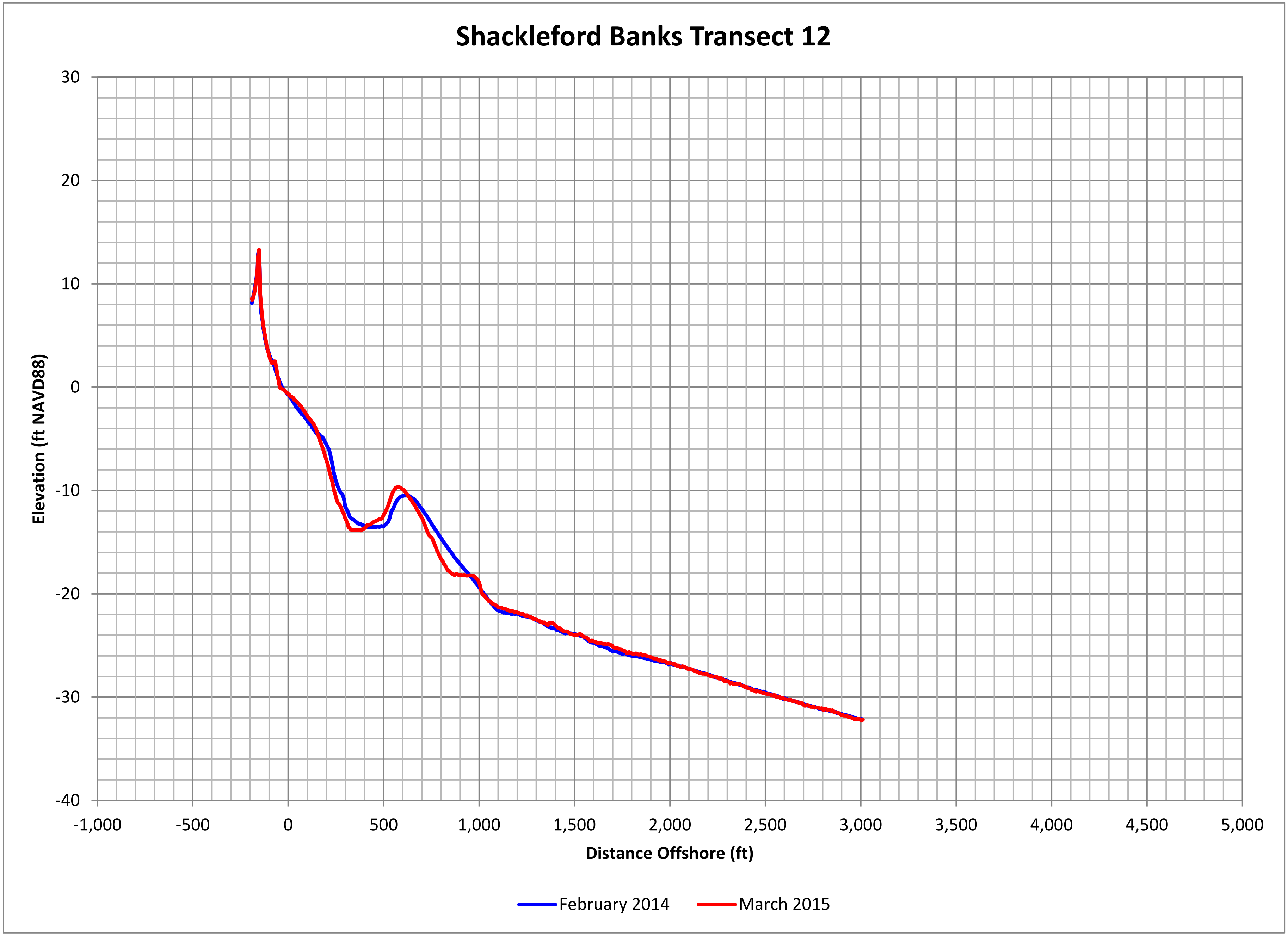

Figure C-180. Shackleford Banks Profile Comparison Plot

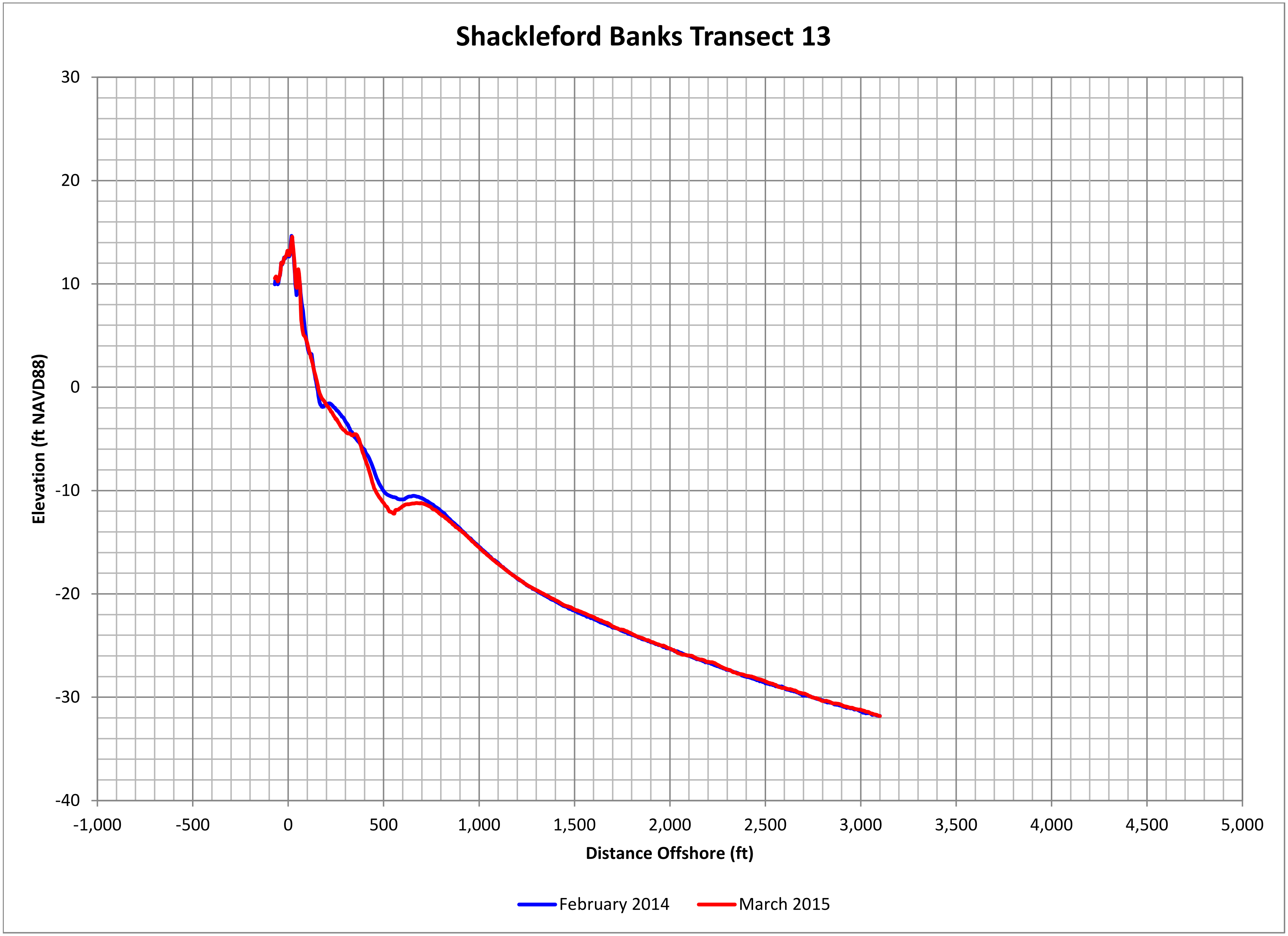

Figure C-181. Shackleford Banks Profile Comparison Plot

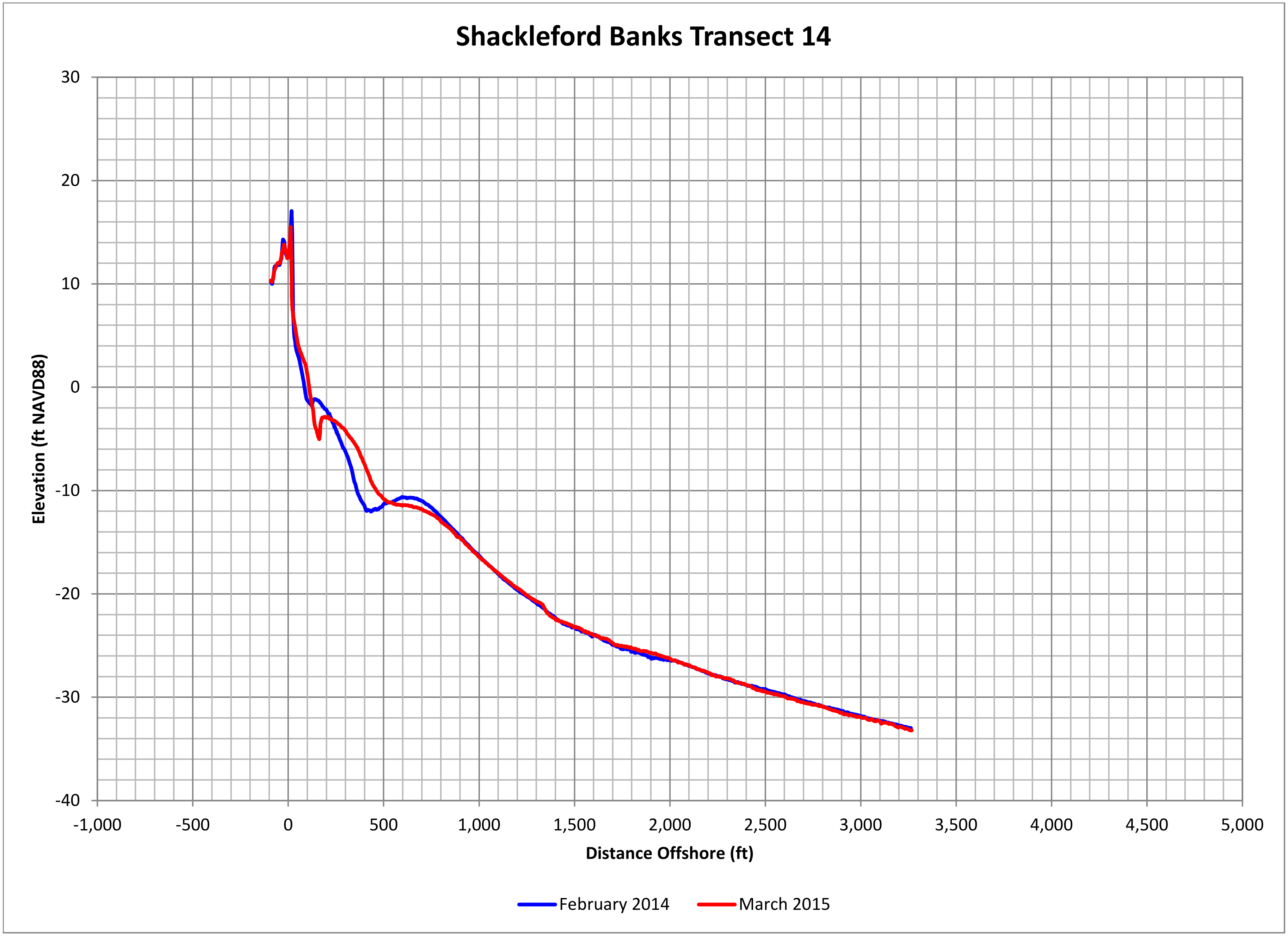

Figure C-182. Shackleford Banks Profile Comparison Plot

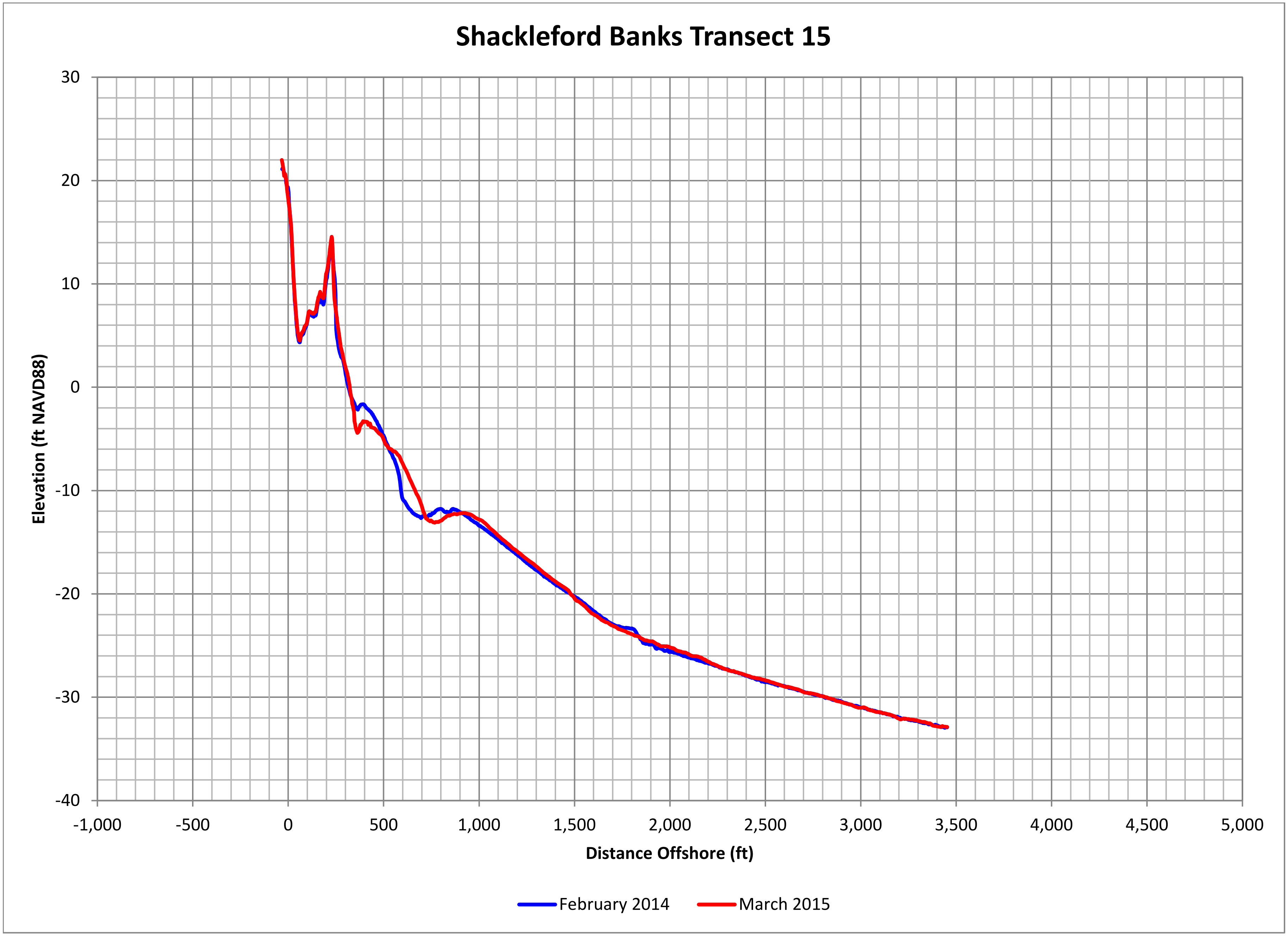

Figure C-183. Shackleford Banks Profile Comparison Plot

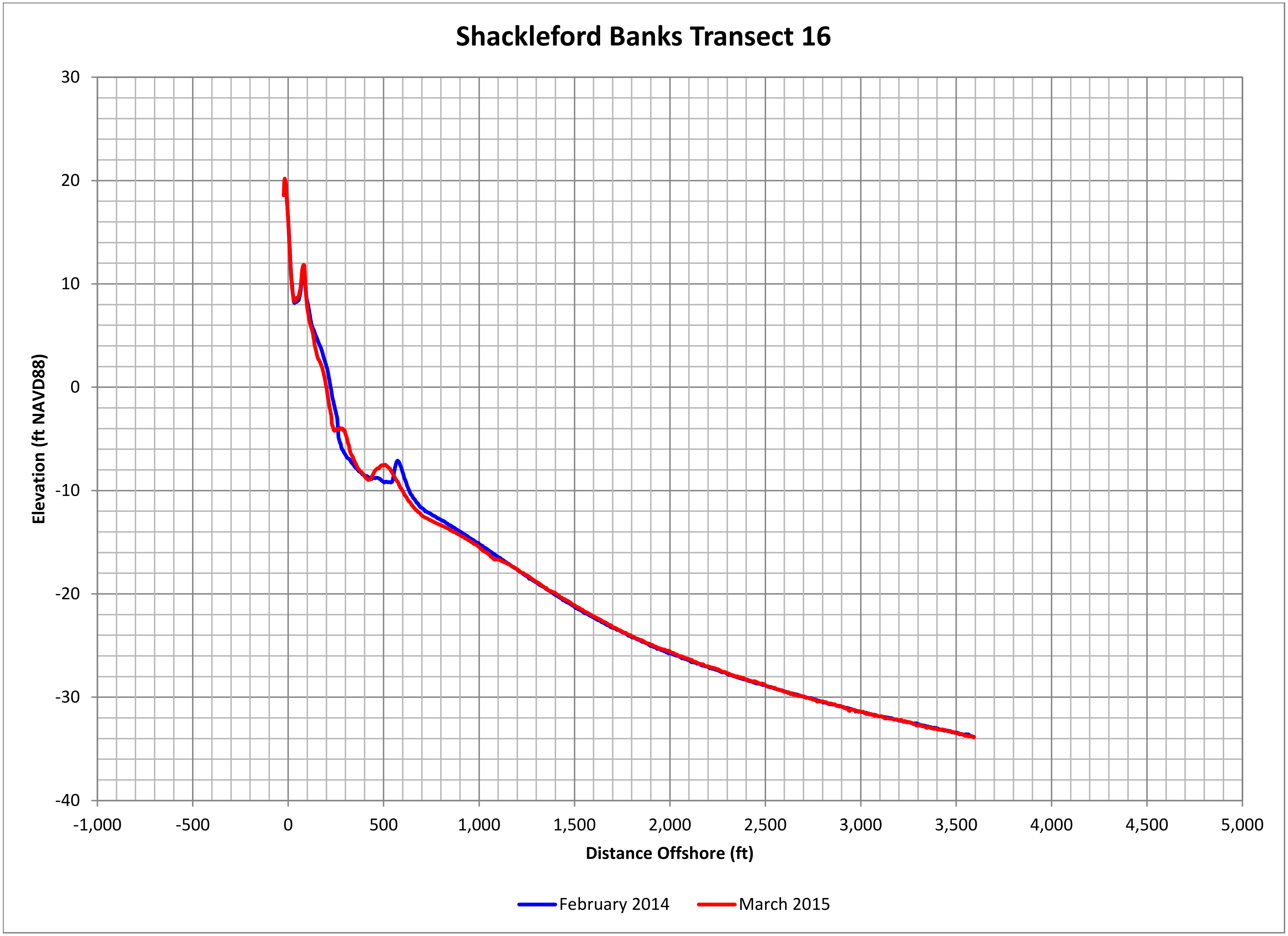

Figure C-184. Shackleford Banks Profile Comparison Plot

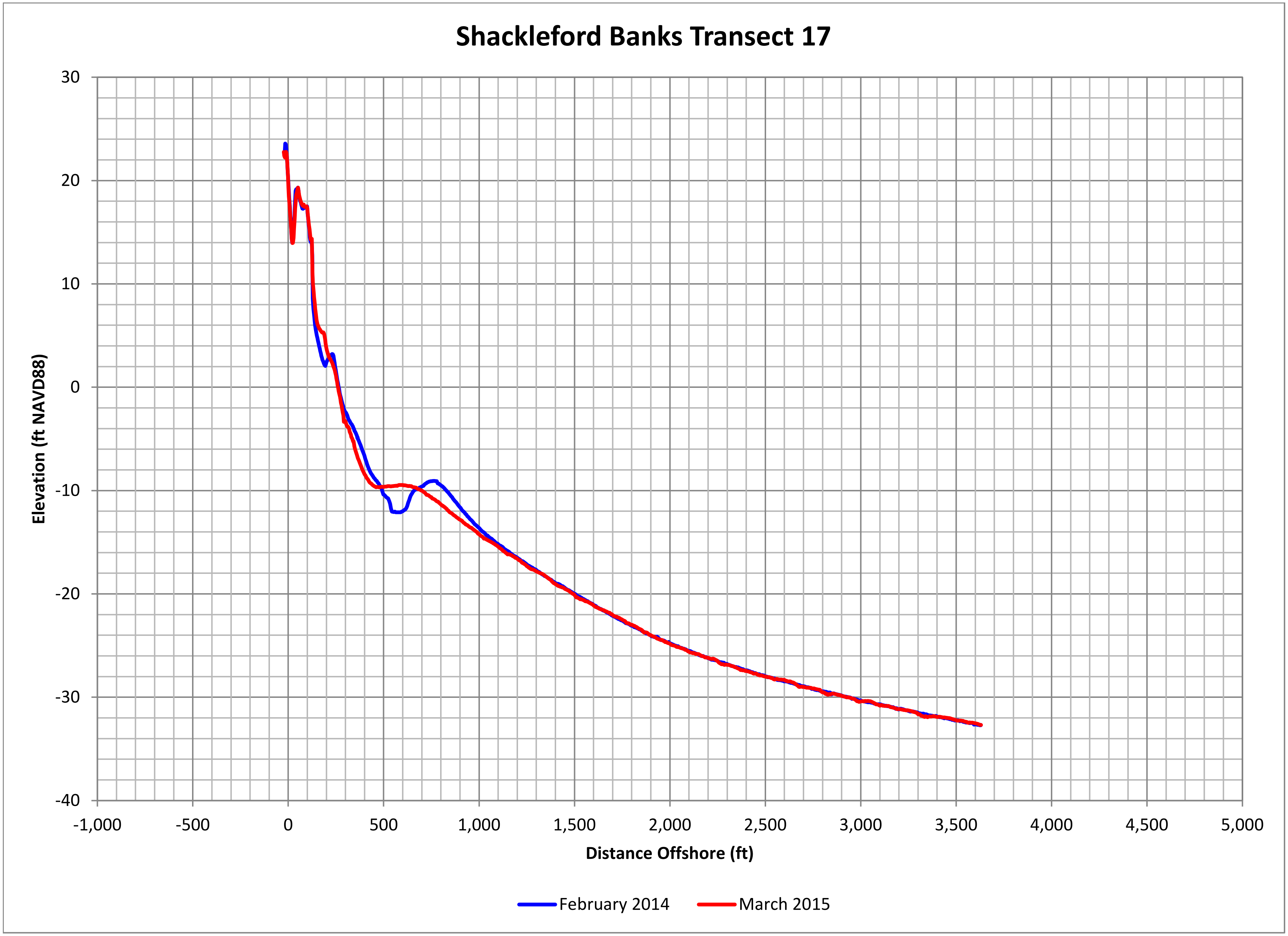

Figure C-185. Shackleford Banks Profile Comparison Plot

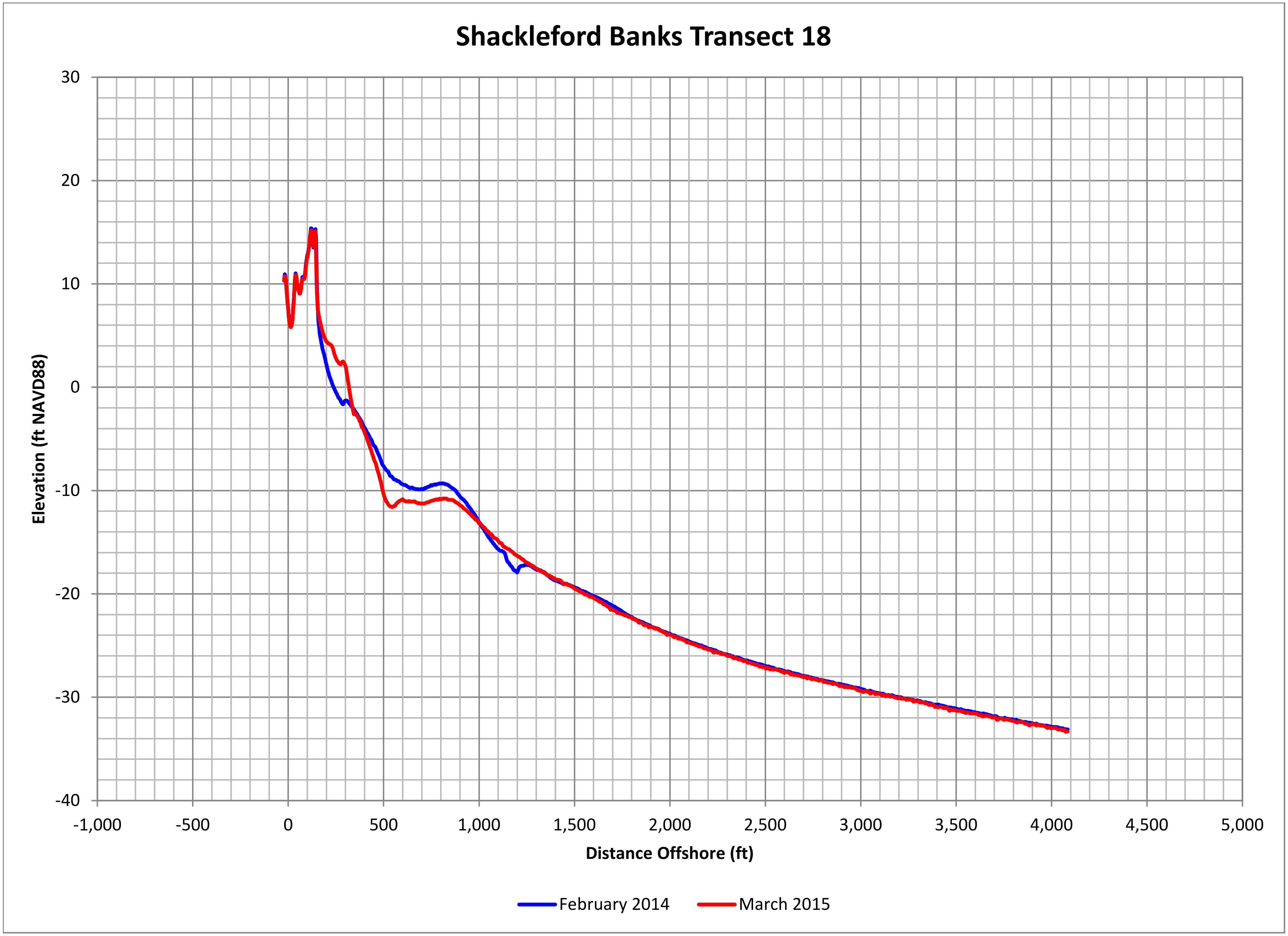

Figure C-186. Shackleford Banks Profile Comparison Plot

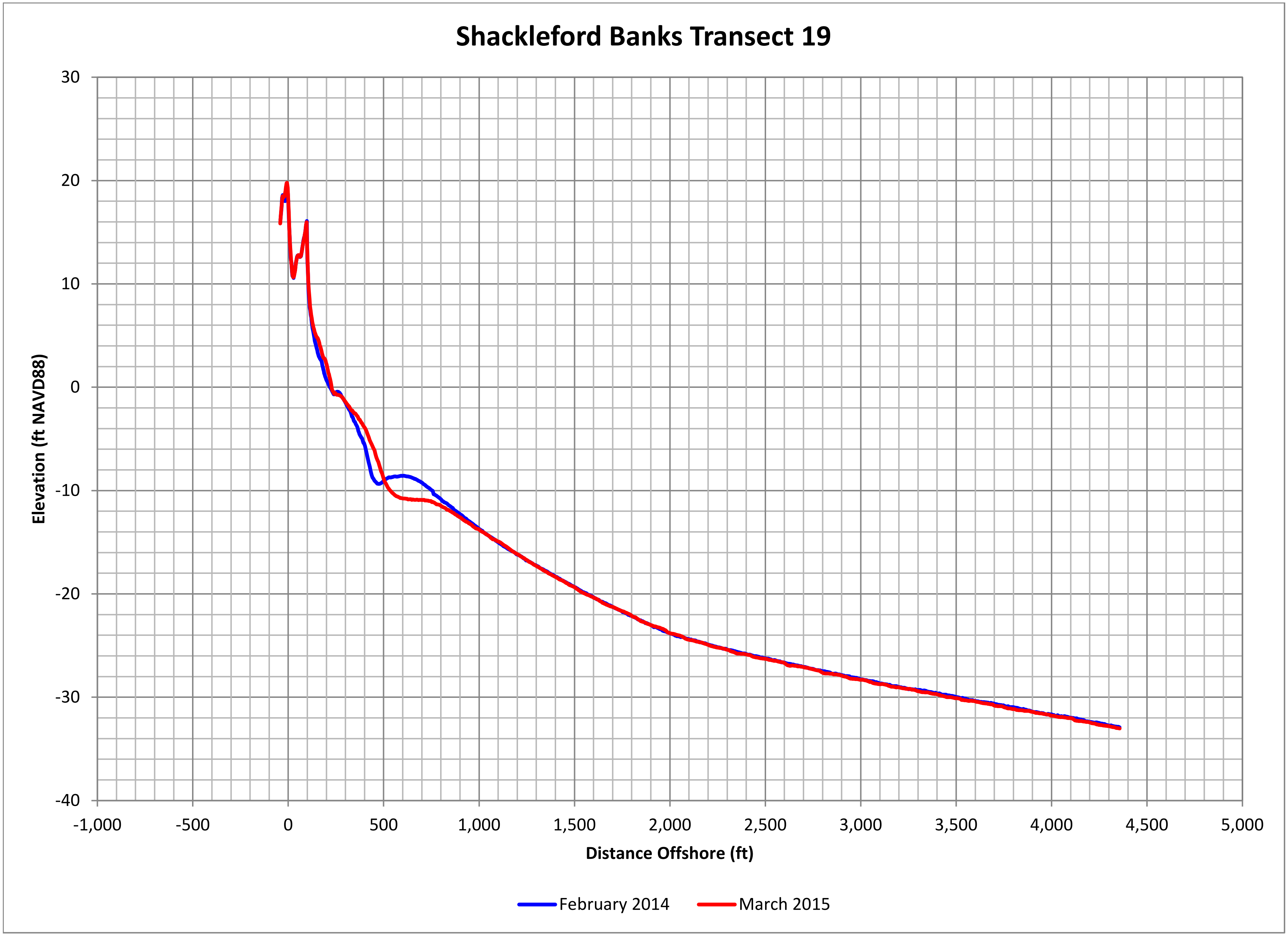

Figure C-187. Shackleford Banks Profile Comparison Plot

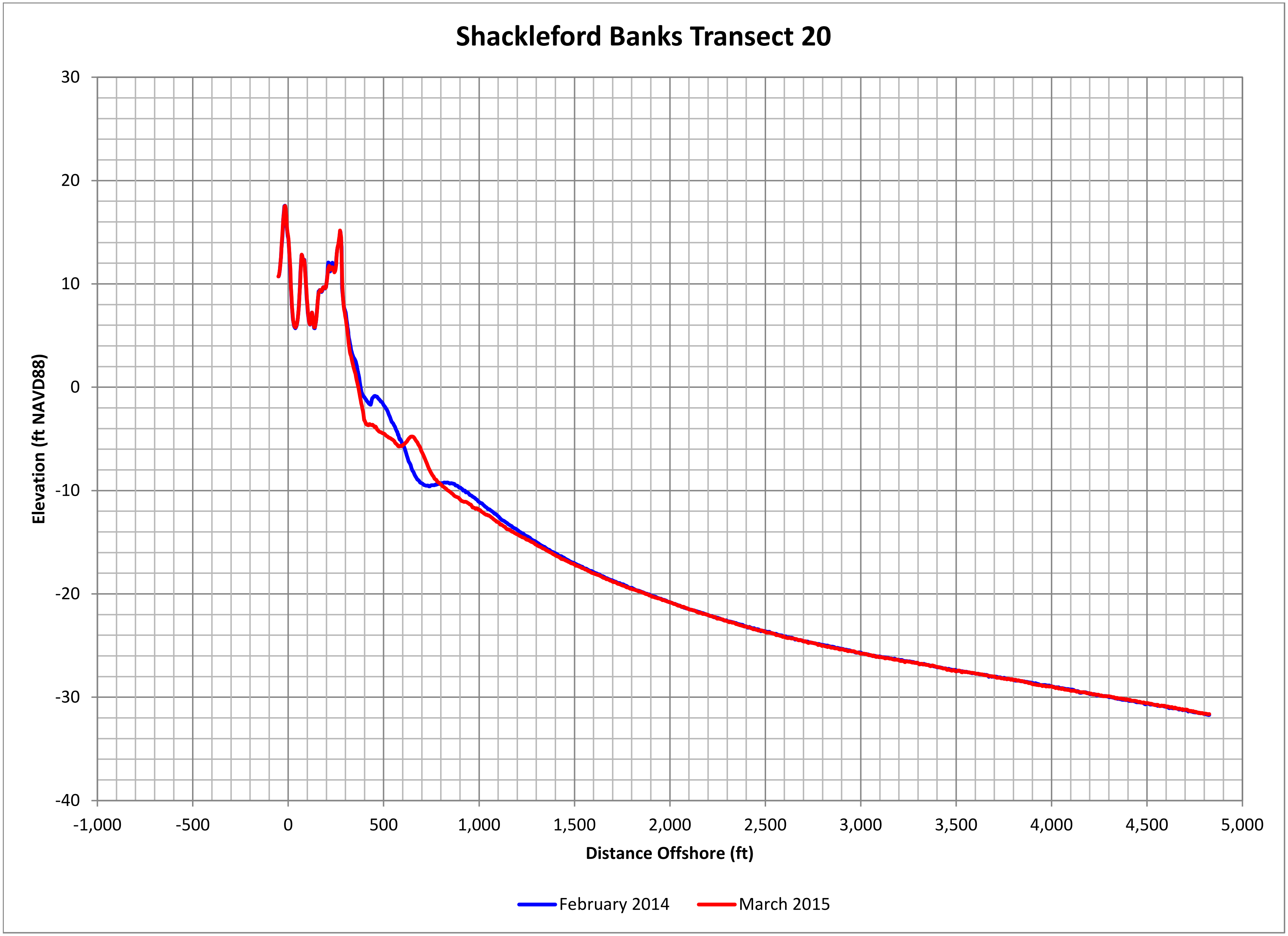

Figure C-188. Shackleford Banks Profile Comparison Plot

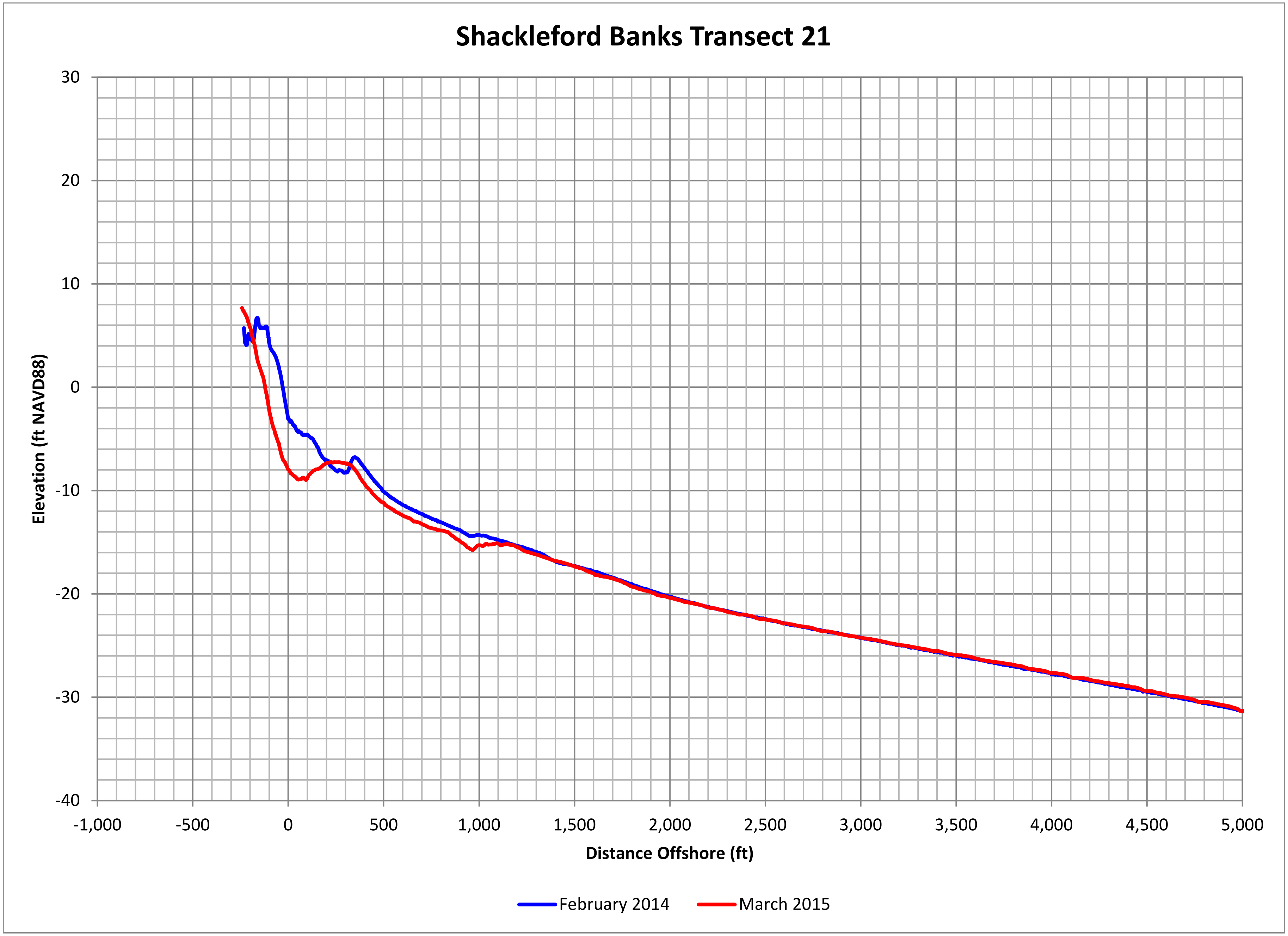

Figure C-189. Shackleford Banks Profile Comparison Plot

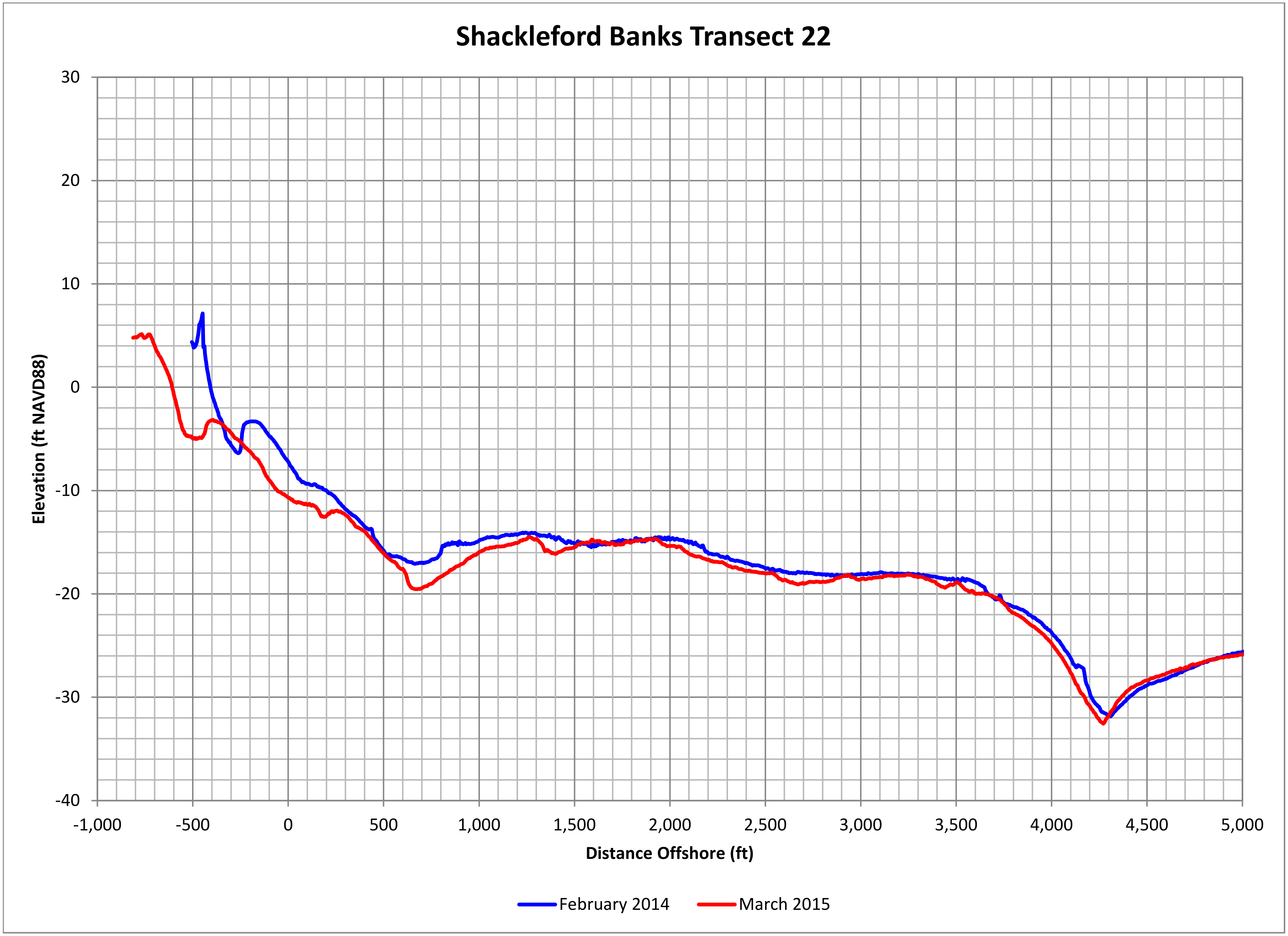

Figure C-190. Shackleford Banks Profile Comparison Plot

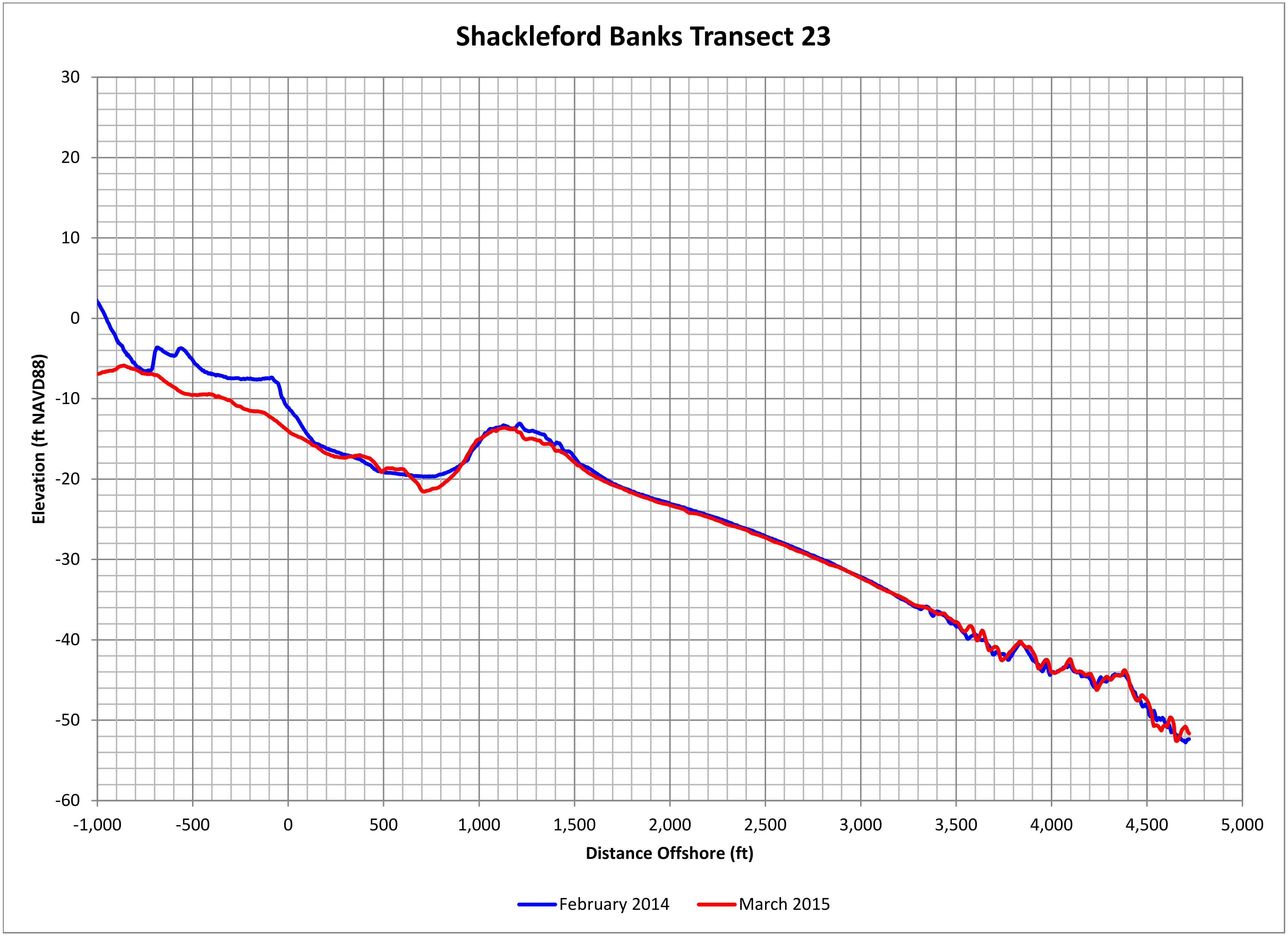

Figure C-191. Shackleford Banks Profile Comparison Plot

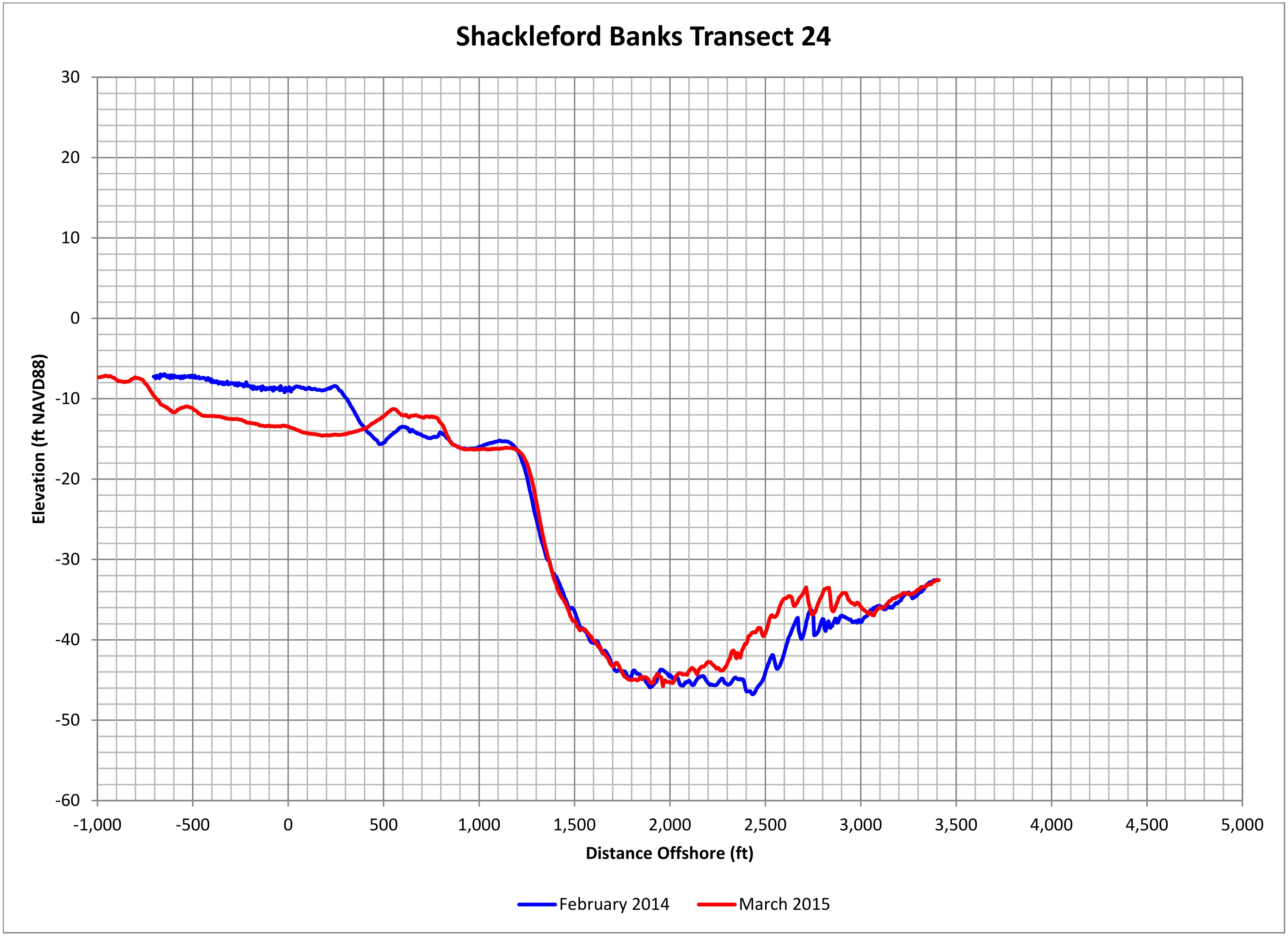

Figure C-192. Shackleford Banks Profile Comparison Plot

APPENDIX D

Results Tables

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2014 to 2015)

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 23, 2014 to May 20, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Bogue Inlet-Ocean	1	0+00	-158.33	77.21	-15.34	205.09	-78.72	532.20	-97.55	1248.81	-126.50	2577.46	-135.05
	2	5+59	-101.71	92.05	-3.14	243.99	-24.17	541.81	-56.74	1192.17	-70.71	2441.02	-76.05
	3	11+23	-25.50	49.75	0.52	132.66	-4.38	333.51	-7.95	852.08	3.83	1870.53	-0.42
	4	17+39	-5.89	11.72	-2.75	73.13	2.19	239.92	8.77	663.04	10.06	1554.76	12.70
	5	23+22	1.49	49.35	-1.31	131.90	-1.32	325.29	-0.32	736.71	-4.61	1608.78	-2.58
	6	36+28	-22.95	28.68	2.30	92.90	9.32	248.20	15.13	587.24	3.87	1344.07	3.65
	7	53+10	-6.75	71.95	-1.08	159.80	-1.49	344.53	4.26	707.26	-2.10	1433.78	-6.10
	8	67+74	-47.62	68.87	-4.07	157.64	-2.07	335.77	1.83	687.08	-4.41	1378.39	-10.96
Emerald Isle West	9	80+91	-54.49	54.14	-5.52	135.47	-4.14	307.13	-3.57	650.57	-8.07	1324.51	-11.69
	10	93+40	-57.79	52.89	-3.84	128.30	-2.83	292.46	-1.79	627.73	-8.37	1282.63	-10.72
	11	108+58	-12.31	42.66	-5.16	117.83	-3.43	281.48	3.76	612.18	-0.76	1256.53	-2.68
	12	121+18	3.34	91.13	-0.31	173.62	-4.27	356.43	3.63	698.59	-3.09	1352.62	-6.10
	13	134+61	14.11	79.17	-0.15	163.65	-1.81	346.30	8.57	687.71	-2.25	1337.67	-9.90
	14	146+67	4.07	56.30	-1.64	136.24	0.62	307.40	7.38	636.47	-0.53	1271.02	-5.96
	15	160+16	12.92	48.54	0.29	120.22	-1.12	283.43	-1.33	606.72	-9.41	1231.48	-20.08
	16	174+79	13.88	48.76	0.23	123.21	1.39	284.12	0.65	608.90	-6.35	1237.91	-12.27
	17	189+23	8.83	70.37	3.30	153.51	2.18	337.77	14.14	679.96	10.86	1329.13	5.21
	18	203+53	41.02	63.59	-2.60	147.42	-2.39	321.69	0.03	662.31	-7.41	1310.09	-14.15
	19	214+90	1.88	50.94	-1.46	123.06	-0.23	280.66	3.77	604.73	-5.62	1240.45	-14.28
	20	230+02	-6.03	84.36	-10.40	177.92	-0.53	350.86	8.60	695.66	2.98	1360.08	-4.57
	21	241+15	-37.61	59.54	-3.16	140.25	0.79	305.28	7.94	644.46	-0.60	1303.78	-9.74
	22	252+19	-49.80	75.88	-4.67	155.94	-0.29	321.90	4.45	661.89	-1.09	1329.09	-4.80
	23	263+24	-40.79	41.82	-3.36	110.13	2.65	261.74	15.35	589.70	7.17	1238.67	1.76
	24	279+57	-36.18	110.65	-2.64	196.33	2.28	371.17	8.37	724.06	0.28	1404.55	-5.13
	25	290+77	-4.02	58.39	-1.10	134.16	2.41	300.05	10.35	643.34	1.25	1312.19	-2.83

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2014 to 2015) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 23, 2014 to May 20, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Emerald Isle Central	26	304+77	-6.64	69.71	-0.18	144.48	0.47	302.69	1.10	654.04	-6.54	1330.19	-9.07
	27	318+11	-9.82	71.06	-2.04	144.08	-5.02	311.66	-2.12	669.73	-10.46	1349.61	-14.29
	28	329+10	7.56	68.41	-0.53	135.36	-6.42	309.13	11.78	657.60	3.22	1327.41	-3.70
	29	345+80	7.56	45.46	-3.29	116.57	1.01	273.66	4.69	612.23	-6.89	1270.82	-14.77
	30	362+22	51.61	70.53	-0.08	142.81	-2.82	306.43	7.17	653.03	-3.85	1323.00	-11.27
	31	378+80	3.13	61.79	7.52	123.80	-1.78	290.09	17.24	621.80	10.19	1282.00	4.49
	32	395+22	7.36	80.17	1.27	142.50	-13.94	315.86	-6.31	659.92	-15.20	1326.04	-19.26
	33	408+86	26.37	77.27	7.46	151.24	4.44	320.93	7.93	666.73	-1.46	1329.47	-4.84
	34	422+83	46.72	67.77	7.84	130.48	-2.13	299.52	6.30	644.61	-3.40	1309.67	-7.59
	35	435+62	50.59	49.38	5.80	108.55	0.34	269.78	12.82	600.98	4.55	1249.94	0.63
	36	450+22	11.46	53.52	3.90	114.86	-2.74	283.00	9.52	616.71	2.06	1273.95	-2.61
Emerald Isle East	37	461+34	17.19	36.38	6.00	95.72	3.47	246.68	13.65	570.78	6.14	1208.90	3.16
	38	472+44	-5.79	52.58	1.52	123.92	-0.15	288.03	1.66	627.24	-5.32	1280.55	-9.45
	39	483+48	0.41	56.34	2.01	125.28	-4.57	285.71	-10.51	631.56	-14.42	1306.88	-16.79
	40	494+44	-3.36	38.19	2.30	97.32	-5.55	249.63	-1.81	576.06	-7.84	1214.82	-9.83
	41	505+39	-20.46	52.00	-5.00	121.06	-13.00	288.76	-11.31	631.10	-15.15	1289.57	-15.54
	42	516+57	-4.18	35.12	-0.20	80.45	-18.49	240.96	2.66	559.46	-2.61	1194.93	-5.06
	43	527+37	-48.75	40.89	0.79	107.42	-1.57	264.41	8.20	593.87	6.26	1242.11	7.82
	44	538+39	-58.88	65.01	-2.59	144.81	-2.83	314.47	3.54	661.13	-1.91	1324.05	-5.04
	45	549+45	-55.13	51.67	-9.49	127.32	-6.65	291.68	1.42	634.34	-4.49	1296.80	-6.91
	46	560+42	-55.24	51.91	-5.75	121.30	-3.43	276.61	5.47	618.28	-2.17	1281.62	-7.81
	47	571+43	-45.18	50.02	-5.12	120.42	0.13	278.48	2.76	619.84	-2.79	1279.86	-6.91
	48	580+13	-51.45	47.72	-7.71	114.23	-7.18	268.37	-1.63	612.08	-9.18	1278.42	-13.64

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2014 to 2015) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 23, 2014 to May 20, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Indian Beach/Salter Path	49	595+84	-41.57	55.80	-0.61	123.89	-1.03	279.63	4.01	625.31	-3.81	1302.11	-4.78
	50	608+06	-1.71	73.21	0.33	129.61	-16.79	298.52	-5.41	646.87	-12.81	1334.05	-16.59
	51	620+90	-13.82	56.09	5.05	113.20	-2.72	265.99	15.99	602.00	7.03	1276.03	5.74
	52	633+31	-16.36	17.82	-1.19	60.18	-9.15	196.14	-0.34	511.64	-9.98	1163.22	-12.65
	53	648+17	-14.05	83.74	2.68	156.08	-5.15	332.79	20.94	693.56	13.45	1403.10	12.83
	54	660+65	22.42	117.67	8.77	198.31	-3.05	387.82	14.34	761.43	2.23	1491.11	1.50
	55	672+30	26.36	59.90	7.88	115.15	-3.95	276.18	9.76	622.84	2.82	1316.65	3.33
	56	683+24	18.42	47.68	8.43	106.63	2.47	264.14	13.38	601.64	5.28	1289.26	2.24
	57	693+79	-9.66	51.47	-0.09	110.70	-2.54	258.76	6.43	598.42	-2.33	1289.35	-2.83
	58	709+05	-1.76	48.47	5.29	100.55	-5.72	260.74	11.62	599.38	2.42	1290.04	-0.59
Pine Knoll Shores West	59	723+93	13.90	43.57	2.54	90.93	-12.05	240.80	6.89	580.56	-0.38	1273.37	-5.96
	60	736+01	27.36	48.02	7.96	104.05	1.88	257.06	10.03	595.53	-1.19	1295.81	-4.14
	61	748+06	45.76	65.70	8.95	127.73	0.07	292.34	10.26	640.80	1.48	1359.50	-2.45
	62	761+80	33.71	46.57	7.13	104.85	0.97	253.95	7.63	593.28	-0.46	1303.45	-5.59
	63	774+77	-0.93	43.89	1.54	100.01	-4.75	245.68	12.12	594.10	2.69	1316.33	2.41
	64	787+61	15.83	51.95	3.55	106.81	-8.82	263.80	4.48	615.35	-6.98	1341.92	-7.09
	65	800+91	13.59	53.00	3.83	106.33	-8.50	266.93	-4.51	617.73	-12.25	1346.89	-13.75
Pine Knoll Shores East	66	813+33	28.65	47.26	6.08	99.23	-4.69	252.41	-2.51	599.13	-12.74	1326.25	-17.73
	67	825+53	20.03	35.46	4.36	79.27	-5.97	225.63	-0.32	567.69	-12.01	1290.03	-20.44
	68	840+55	5.74	46.50	3.32	97.42	-6.89	252.68	0.77	610.45	-5.96	1347.71	-6.96
	69	850+84	22.59	49.22	5.46	101.81	-0.94	260.82	14.77	619.95	6.66	1365.97	5.01
	70	863+28	19.27	51.61	6.31	105.49	-4.48	259.12	-2.96	623.87	-10.37	1379.70	-9.24
	71	882+23	6.23	49.07	2.57	104.17	-3.69	252.44	4.96	619.53	0.00	1378.49	0.00
	72	896+24	-6.01	43.20	0.83	85.31	-5.99	233.16	0.70	604.66	4.02	1368.22	5.08
	73	910+53	-18.63	45.05	-0.76	98.83	-9.46	254.20	-1.52	630.49	-5.95	1400.26	-6.35
	74	922+70	2.37	45.85	4.94	99.48	0.39	252.17	4.34	629.23	5.50	1404.57	7.65
	75	937+70	29.46	54.51	7.69	108.65	-3.98	273.05	-1.31	649.95	-6.95	1434.79	-6.97
	76	948+81	28.84	46.84	10.15	103.76	0.35	262.33	0.18	625.88	-6.34	1404.60	-8.73

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2014 to 2015) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 23, 2014 to May 20, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Atlantic Beach	77	961+72	-5.44	64.03	-0.71	129.35	0.73	293.71	20.49	666.36	10.46	1456.61	5.26
	78	971+20	-38.98	39.08	-6.68	88.75	-19.19	238.44	-9.13	603.34	-18.08	1382.23	-17.47
	79	985+64	6.08	53.34	2.08	110.24	-2.35	272.63	19.31	644.42	14.47	1429.23	15.13
	80	994+64	-1.14	70.53	5.42	137.94	-0.01	310.83	13.84	695.46	6.43	1494.80	13.75
	81	1005+61	-3.88	55.73	-0.79	125.44	8.66	299.33	15.58	683.76	8.56	1485.82	8.49
	82	1012+68	-22.44	35.01	-6.22	101.25	4.12	262.39	10.68	633.32	4.60	1420.95	7.52
	83	1022+69	-32.04	32.28	-3.37	92.07	4.23	253.80	15.75	622.66	6.94	1406.62	5.10
	84	1032+70	-30.33	28.21	-3.68	86.01	0.67	248.16	12.35	618.31	7.88	1413.34	20.54
	85	1042+73	-38.61	59.36	-4.40	131.26	-6.94	301.45	-20.73	699.00	-24.68	1520.44	-24.83
	86	1052+75	5.40	68.35	-0.06	151.43	6.21	337.69	4.23	746.33	6.09	1583.60	14.30
	87	1062+69	-7.64	58.67	-1.64	135.60	0.76	312.44	-7.96	709.41	-14.96	1540.62	-13.22
	88	1072+62	-14.44	78.32	-3.73	169.64	-0.94	367.63	-5.78	785.41	-10.81	1646.86	-7.87
	89	1082+69	-5.95	61.50	0.38	127.69	-2.74	308.51	-0.06	702.42	-5.56	1533.22	-4.73
	90	1093+69	-25.37	40.31	-8.01	117.28	-8.39	301.41	-11.61	712.18	-12.43	1564.91	-2.92
	91	1102+82	1.81	45.75	-0.01	112.60	5.89	284.22	2.62	668.54	-3.74	1493.14	-1.39
	92	1112+81	-2.96	39.36	-2.77	101.26	-3.46	266.66	0.23	650.86	-5.32	1476.12	-1.95
	93	1122+81	-39.82	36.26	-7.87	102.57	-7.35	270.22	-5.42	655.81	-12.99	1492.33	-11.99
	94	1131+73	-24.31	62.30	-4.97	160.43	1.63	370.70	12.44	795.34	4.37	1677.48	0.05
	95	1141+97	-22.76	75.12	0.24	162.38	3.82	338.75	-13.61	750.77	-26.20	1614.55	-33.36
	96	1151+92	39.66	75.45	3.78	168.89	16.92	363.54	31.31	773.33	23.63	1631.45	19.06
	97	1161+91	14.86	73.67	7.29	166.27	10.62	353.89	12.79	756.37	3.75	1598.05	-5.77
	98	1171+91	-84.66	72.04	-12.47	160.33	-25.22	338.89	-38.72	729.09	-42.91	1552.13	-53.82
	99	1182+17	-92.83	67.30	-13.12	160.86	-22.02	349.93	-27.29	736.44	-30.99	1565.32	-41.17
	100	1191+90	-53.40	139.57	-8.57	280.23	-11.87	520.11	-21.10	966.50	-22.01	1933.46	-20.49
	101	1201+93	-63.47	100.17	-9.90	210.41	-14.75	409.48	-28.88	789.88	-31.71	1721.00	-45.27
	102	1211+94	-90.74	125.44	-14.73	238.60	-27.52	446.68	-45.25	816.28	-47.98	1803.09	-55.00

Table D-1. Summary of Shoreline Change and Volume Change Along Bogue Banks (2014 to 2015) Cont.

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from June 23, 2014 to May 20, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Fort Macon	103	1222+11	-88.19	61.00	-15.21	139.58	-26.31	309.63	-36.89	642.82	-45.16	1733.62	-59.95
	104	1231+86	-55.60	84.93	-11.75	172.82	-16.55	348.45	-21.34	737.25	-19.16	1933.64	-31.30
	105	1241+79	-58.25	81.49	-8.72	168.79	-18.21	355.70	21.02	779.19	43.30	2011.55	50.55
	106	1251+79	-74.60	81.89	-12.76	170.16	-31.56	361.90	-19.22	890.74	-32.31	2150.49	-32.24
	107	1257+09	-53.57	112.38	-1.61	217.44	-10.44	413.94	13.70	1061.22	-20.11	2327.87	-20.71
	108	1261+80	-66.19	59.16	1.40	132.73	-14.89	286.37	-15.62	956.34	0.83	2170.34	1.42
	109	1267+13	5.90	83.80	9.40	173.81	11.78	338.60	4.51	1058.41	-1.88	2357.65	-1.51
	110	1271+73	51.40	75.62	9.47	157.48	20.30	309.06	19.62	1047.85	-53.06	2317.92	-53.09
	111	1278+93	19.92	54.94	7.27	146.70	28.34	315.97	47.34	1366.60	88.86	2472.79	89.73
	112	1283+93	-8.83	57.39	1.11	174.05	21.87	361.24	37.58	1629.74	-12.87	2878.98	-12.90
Beaufort Inlet	112B	0+00	40.85	60.15	3.21	198.47	27.06	505.54	115.74	923.84	103.58	1565.05	106.17
	113	5+00	15.64	95.05	0.17	300.02	3.24	637.41	8.01	1115.25	-3.25	1733.24	-12.73
	114	10+00	-117.11	92.14	-6.93	308.73	-18.27	603.26	-24.04	975.34	-38.44	1493.39	-45.80
	115	15+00	-1.68	105.39	-1.40	299.29	-3.27	538.53	-1.99	819.42	0.54	1192.09	-7.19
	116	20+00	-13.60	47.76	0.17	112.86	-3.35	221.72	-0.52	360.52	1.32	553.93	0.68
Bogue Inlet	117B	0+00	-	-	-	-	-	-	-	-	-	-	-
	117	5+00	-	-	-	-	-	-	-	-	-	-	-
	118	10+00	-	-	-	-	-	-	-	-	-	-	-
	119	15+00	-	-	-	-	-	-	-	-	-	-	-
	120	20+00	-	-	-	-	-	-	-	-	-	-	-

Table D-2. Summary of Shoreline Change and Volume Change Along Bear Island (2014 to 2015)

NOTES:

1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from April 25, 2014 to June 4, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Bear Island	1	0+00	29.06	3.14	-2.68	49.81	-1.59	299.38	19.29	1029.07	-6.08	2322.58	-15.90
	2	10+00	-31.44	52.29	-2.05	156.54	-31.06	487.64	-103.84	1206.90	-131.22	2465.29	-134.67
	3	20+00	-16.34	27.95	2.95	87.51	0.36	291.14	-19.60	779.58	-15.88	1849.84	-16.64
	4	30+00	-6.14	23.67	4.38	79.97	-5.44	240.49	-6.60	646.78	2.74	1631.13	4.25
	5	40+00	0.57	15.49	0.82	69.55	-8.10	230.15	-3.55	599.75	-1.42	1530.40	-0.45
	6	50+00	46.15	14.60	5.24	72.67	9.71	235.18	13.49	596.15	10.95	1487.61	7.04
	7	60+00	43.75	118.38	7.71	199.08	5.31	389.16	5.03	785.21	1.19	1701.57	2.87
	8	70+00	47.13	26.68	6.22	76.02	-2.67	244.84	4.64	607.01	0.83	1458.86	1.66
	9	80+00	44.12	28.14	6.21	87.78	7.24	251.20	8.81	610.42	5.15	1450.46	6.51
	10	90+00	19.09	18.75	1.76	73.87	3.70	233.82	2.86	581.92	-3.09	1403.09	-3.77
	11	100+00	-13.64	21.65	2.37	80.81	3.35	234.32	-10.30	582.35	-16.70	1406.96	-16.01
	12	110+00	37.60	35.20	6.08	101.38	9.18	268.25	5.11	620.10	-2.12	1450.52	-4.66
	13	120+00	20.51	23.50	2.00	86.37	3.88	250.05	1.35	597.74	-8.21	1437.64	-14.94
	14	130+00	45.94	25.46	7.06	97.32	11.26	268.88	9.02	631.86	1.87	1512.34	-4.46
	15	140+00	38.32	25.33	4.02	88.93	1.98	251.27	-6.03	617.84	-13.16	1528.30	-20.84
	16	150+00	-7.37	24.32	1.08	89.98	-1.76	265.09	-0.67	653.54	-9.03	1585.99	-16.81
	17	160+00	33.34	32.55	2.81	112.04	7.18	311.20	9.22	722.56	-5.97	1685.65	-15.72
	18	170+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table D-3. Summary of Shoreline Change and Volume Change Along Shackleford Banks (2014 to 2015)

NOTES:
1. Positive changes indicate accretion or gain in volume along the profile and negative changes indicate erosion or loss of volume along the profile.
2. Shoreline Change and Volume Change is calculated for the period between surveys from February 25, 2014 to March 10, 2015.

Reach	Transect Number	Station	Shoreline Change @ MHW (+1.1 ft NAVD)	Above MHW (+1.1 ft NAVD)		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
				2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)	2015 Measured Volume (cy/ft)	2014-2015 Volume Change (cy/ft)
Shackleford Banks	1	0+00	7.82	4.91	-0.41	186.76	-0.09	966.94	27.76	2061.42	25.70	3941.73	28.90
	2	20+51	2.19	23.43	-1.16	187.94	-3.14	508.78	-14.41	1060.42	-27.38	2125.44	-50.74
	3	40+80	64.21	58.28	1.06	202.99	2.28	475.29	-1.31	830.20	-4.22	1534.81	-22.58
	4	58+81	-3.29	49.63	0.07	123.09	5.75	305.11	8.69	602.29	1.72	1420.14	-6.54
	5	77+99	21.63	4.82	0.48	31.66	-3.38	136.03	-15.18	382.53	-23.57	1066.69	-43.74
	6	96+76	12.27	5.53	0.18	36.47	1.05	148.27	-10.97	389.53	-19.28	1167.49	-32.04
	7	113+28	4.66	20.34	-0.73	64.66	-0.25	164.31	-20.16	423.57	-27.16	1183.90	-33.84
	8	130+01	28.60	13.62	-0.28	61.26	5.43	173.51	0.36	447.25	-10.16	1154.61	-43.66
	9	152+46	15.85	19.87	-0.05	62.89	-6.53	172.12	-15.59	468.02	-17.85	1223.78	-25.04
	10	170+79	-2.10	28.42	-0.63	70.95	-5.04	178.76	-11.32	480.87	-15.42	1236.34	-25.72
	11	190+43	0.37	45.60	-4.43	121.97	-2.20	261.66	-13.30	590.76	-19.31	1374.00	-22.27
	12	210+07	0.59	12.98	0.68	61.34	2.72	167.81	-1.57	445.73	-14.34	1140.22	-8.33
	13	229+21	2.67	24.69	-2.84	69.91	-6.12	181.77	-20.02	483.45	-22.61	1212.25	-19.34
	14	248+63	26.65	11.43	3.80	45.82	4.15	157.42	22.04	444.58	21.73	1113.20	27.21
	15	272+15	8.72	14.07	0.87	44.59	-6.83	146.48	4.57	433.11	8.99	1095.94	10.51
	16	293+38	-23.61	54.30	-4.45	109.32	-8.24	239.09	-7.39	553.31	-13.89	1287.18	-10.42
	17	322+18	-3.69	66.42	4.47	121.18	1.10	242.32	-4.91	571.14	-12.22	1329.87	-13.46
	18	343+08	92.99	31.18	9.39	83.19	15.64	188.28	-14.84	509.25	-8.12	1287.21	-15.72
	19	363+54	22.70	66.58	4.54	140.44	8.89	282.19	-1.55	638.34	-2.88	1504.73	-6.03
	20	383+92	-15.52	14.30	-1.02	44.36	-17.38	176.75	-11.52	509.83	-17.89	1489.65	-19.91
	21	405+26	-94.70	1.05	-14.51	15.99	-37.69	121.28	-73.09	531.61	-94.04	1796.69	-88.91
	22	423+85	-206.42	13.45	-32.51	63.53	-78.47	238.04	-123.37	927.64	-217.62	2909.72	-214.29
	23	444+92	-1039.74	0.00	-24.35	26.91	-251.54	372.61	-378.07	1144.30	-404.05	2704.41	-419.85
	24	460+01	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E

Statistics Tables

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2015)

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Bogue Inlet-Ocean	1	0+00	8.90	17.58	11.76	60.71	-13.35	74.64	-45.84	76.29	-44.43	86.47
	2	5+59	7.03	12.52	10.25	20.62	-7.48	29.40	-37.94	24.95	-44.22	25.67
	3	11+23	0.15	9.83	0.32	24.46	-17.30	36.08	-36.97	47.92	-45.23	55.17
	4	17+39	-2.61	5.00	-2.40	19.03	-7.90	39.14	-21.59	37.25	-22.78	44.26
	5	23+22	-1.76	7.42	-3.94	15.13	-4.07	24.28	-14.55	21.45	-15.87	24.29
	6	36+28	-0.18	5.13	0.39	9.58	3.49	24.90	-3.01	24.63	-2.63	28.24
	7	53+10	-0.05	6.48	1.79	14.57	3.76	15.38	0.06	15.74	-2.60	16.08
	8	67+74	0.09	6.05	1.66	9.55	4.45	22.90	3.96	17.09	2.28	15.06
Emerald Isle West	9	80+91	0.74	6.64	2.67	6.31	3.42	19.92	2.30	25.29	0.96	27.00
	10	93+40	-1.35	8.57	-0.97	11.04	-0.31	13.97	0.05	12.79	0.20	8.89
	11	108+58	-1.51	4.93	1.37	11.63	3.72	22.94	3.71	19.73	3.27	16.85
	12	121+18	-1.39	3.62	-0.53	3.86	1.44	15.06	2.23	16.63	2.79	17.95
	13	134+61	-2.21	6.05	-1.83	8.15	2.44	6.08	2.80	12.14	3.02	15.13
	14	146+67	-2.40	6.00	-1.86	8.86	-0.91	17.31	-1.33	17.02	-1.27	20.13
	15	160+16	-1.44	4.99	-0.82	6.05	-0.18	10.64	0.59	12.72	1.00	13.24
	16	174+79	-1.36	5.16	-0.11	7.17	0.00	12.64	0.35	13.25	0.89	10.28
	17	189+23	-0.49	7.06	-0.34	9.80	1.53	16.48	1.64	18.28	0.90	17.75
	18	203+53	0.02	5.72	-0.65	10.25	-0.61	16.13	-0.28	15.11	-0.98	11.91
	19	214+90	0.13	6.05	1.98	6.02	1.56	10.63	1.78	13.39	1.56	13.94
	20	230+02	-0.95	6.05	2.56	3.45	2.67	10.43	3.40	11.88	3.73	9.79
	21	241+15	0.15	3.73	2.47	7.82	3.10	10.76	3.44	12.94	4.53	20.40
	22	252+19	0.89	5.11	3.02	4.54	3.12	10.31	3.56	12.74	4.17	8.33
	23	263+24	-0.72	5.40	0.83	4.18	1.10	12.95	1.69	18.02	2.28	13.63
	24	279+57	0.05	7.71	2.01	5.68	1.24	16.43	0.98	22.82	1.37	18.54
	25	290+77	-0.64	7.83	1.59	8.14	1.78	11.10	0.71	15.20	0.57	10.26

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2015) Cont.

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Emerald Isle Central	26	304+77	-0.76	6.10	1.31	9.61	1.19	14.95	0.55	17.92	1.01	13.71
	27	318+11	-1.32	4.92	-0.57	6.67	0.80	11.11	-0.39	16.03	-0.28	13.18
	28	329+10	-0.86	4.60	-1.81	8.27	-1.60	25.89	-3.30	18.34	-3.40	16.58
	29	345+80	-1.46	7.54	0.45	7.47	3.02	24.75	1.42	31.52	0.43	29.86
	30	362+22	-0.63	5.40	-0.11	13.07	0.61	15.90	0.70	20.87	1.21	17.11
	31	378+80	0.97	3.83	1.80	8.90	4.84	18.00	3.80	25.78	7.97	21.63
	32	395+22	-0.60	4.24	-2.99	10.77	-4.88	28.16	-6.05	28.66	-6.66	28.96
	33	408+86	0.06	5.29	0.82	10.68	2.03	18.08	2.31	19.54	1.81	16.39
	34	422+83	-1.07	8.72	-2.12	5.58	-2.01	15.21	-2.31	13.75	-3.20	12.24
	35	435+62	-2.88	4.20	-5.69	4.85	-5.45	11.97	-6.64	8.20	-7.63	8.00
	36	450+22	-2.15	4.44	-4.10	8.45	-1.83	17.50	-1.49	16.08	-2.21	11.79
Emerald Isle East	37	461+34	-2.85	7.46	-3.01	11.49	-2.47	28.06	-1.67	26.35	-2.43	26.74
	38	472+44	-1.88	3.63	-2.98	4.13	-3.12	10.47	-2.65	6.30	-2.23	9.10
	39	483+48	-3.97	3.85	-5.18	5.47	-3.93	12.05	-3.27	15.56	-2.44	14.56
	40	494+44	-3.03	6.60	-5.02	9.39	-5.23	17.27	-4.31	17.63	-4.28	19.23
	41	505+39	-3.79	4.83	-4.57	10.50	-5.04	21.44	-3.64	24.68	-3.03	22.53
	42	516+57	-4.05	7.04	-7.37	14.42	-7.68	24.59	-6.34	28.69	-5.97	29.31
	43	527+37	-2.62	6.53	-2.61	8.50	-2.47	20.80	-1.16	24.83	-0.43	23.19
	44	538+39	-1.98	6.37	-1.51	6.58	1.40	6.89	2.73	10.33	3.43	11.50
	45	549+45	-3.22	5.17	-3.94	6.06	-3.19	10.55	-2.21	13.30	-1.31	11.09
	46	560+42	0.40	3.54	1.49	5.15	2.56	8.13	2.85	7.58	3.37	16.81
	47	571+43	-0.16	7.03	1.01	12.95	2.08	12.46	1.79	17.93	3.23	23.90
	48	580+13	-0.93	6.60	-0.70	12.43	-2.27	32.61	-2.34	35.83	-1.11	33.26

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2015) Cont.

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Indian Beach/Salter Path	49	595+84	-1.32	4.76	-1.48	5.87	-3.35	13.56	-2.83	19.01	-1.00	16.27
	50	608+06	-1.32	7.25	-3.28	8.50	-3.51	14.53	-3.63	12.67	-3.58	8.44
	51	620+90	-1.11	6.34	-1.93	8.19	-3.11	19.84	-3.33	23.67	-2.67	20.99
	52	633+31	-1.77	4.68	-3.10	6.67	-2.86	11.58	-3.33	16.34	-2.87	13.03
	53	648+17	-0.07	3.62	-1.68	5.74	-1.44	13.28	-1.50	14.26	-0.26	15.02
	54	660+65	1.05	6.50	-0.66	11.11	-0.10	18.12	0.16	19.91	1.85	19.89
	55	672+30	0.32	6.59	-0.86	12.43	-0.43	16.10	0.43	13.65	1.95	16.02
	56	683+24	-0.66	5.56	-1.26	5.82	-0.75	16.75	-0.36	16.29	1.27	14.79
	57	693+79	-1.63	5.71	-2.38	6.94	-3.64	14.25	-3.77	15.44	-2.51	16.10
	58	709+05	-1.36	6.70	-3.49	10.15	-3.85	19.32	-3.87	21.33	-2.11	23.27
Pine Knoll Shores West	59	723+93	-0.75	3.17	-3.94	6.18	-4.23	12.26	-3.98	21.48	-3.85	16.12
	60	736+01	0.74	4.54	1.18	8.69	1.19	13.55	2.75	16.62	4.30	15.62
	61	748+06	0.71	5.98	0.80	10.68	1.20	22.98	2.35	24.60	3.40	22.43
	62	761+80	-0.89	5.88	-1.17	9.48	-2.20	6.94	-3.00	16.14	-4.65	17.79
	63	774+77	-3.20	7.83	-5.76	11.48	-8.24	34.75	-7.42	31.76	-7.16	40.12
	64	787+61	-2.22	5.40	-5.95	4.69	-8.65	10.43	-7.20	17.20	-6.46	18.83
	65	800+91	-2.30	8.05	-5.76	6.03	-6.29	17.02	-3.50	23.60	-2.40	21.02
Pine Knoll Shores East	66	813+33	-2.28	5.59	-5.15	7.24	-7.04	13.36	-6.04	17.29	-7.36	15.81
	67	825+53	-1.53	5.18	-4.22	8.52	-2.45	12.26	-1.19	14.76	-1.44	13.89
	68	840+55	-1.04	4.54	-4.02	5.00	-4.44	10.97	-2.77	11.51	-3.16	10.90
	69	850+84	-2.04	6.54	-3.52	7.98	-1.89	10.97	-0.44	16.49	-0.08	14.98
	70	863+28	-1.88	8.17	-4.23	8.55	-4.19	12.69	-2.45	16.58	-1.37	17.02
	71	882+23	-0.97	6.42	-2.80	7.16	-3.59	15.85	-2.65	26.56	-3.43	27.33
	72	896+24	-0.85	3.99	-2.64	2.70	-3.98	10.53	-2.40	17.49	-0.99	17.97
	73	910+53	-0.02	5.04	-0.09	8.48	1.75	14.71	3.25	26.01	3.79	23.38
	74	922+70	-1.29	5.73	-2.88	9.58	-3.61	13.17	-0.51	17.00	2.60	21.11
	75	937+70	0.25	5.38	-1.60	10.75	1.40	11.29	-0.07	18.29	-0.01	18.52
	76	948+81	-0.90	7.99	-2.54	6.56	-3.01	10.42	-4.54	18.05	-4.73	17.41

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2015) Cont.

			Average Annual Volume Change (2008-2015)									
			Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
Reach	Transect Number	Station	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Atlantic Beach	77	961+72	-1.76	3.81	-2.82	4.27	-5.71	13.75	-7.13	17.00	-7.41	19.77
	78	971+20	-2.57	3.57	-4.76	8.03	-7.12	10.63	-8.38	21.25	-9.56	24.16
	79	985+64	0.77	4.93	1.08	8.69	1.74	11.28	1.41	17.99	1.14	22.08
	80	994+64	1.81	4.12	2.08	10.69	0.42	11.13	-0.04	12.87	0.17	15.60
	81	1005+61	0.66	4.10	1.39	5.33	1.95	14.98	0.76	20.30	0.37	24.11
	82	1012+68	0.19	6.07	1.29	9.85	1.89	15.47	-0.07	26.23	-0.77	29.74
	83	1022+69	0.15	5.17	1.83	6.43	3.79	11.76	1.76	16.70	1.26	20.30
	84	1032+70	-0.58	3.17	0.93	9.21	2.22	10.93	1.42	15.16	2.92	21.97
	85	1042+73	-1.24	2.49	-2.55	7.94	-5.68	15.42	-5.43	17.28	-4.35	21.64
	86	1052+75	-1.26	3.34	-1.05	9.53	-1.86	12.53	-2.62	11.25	-1.91	14.55
	87	1062+69	-1.48	4.76	-1.73	6.81	-3.42	8.69	-4.37	9.27	-3.68	12.15
	88	1072+62	-2.42	4.39	-2.09	3.55	-2.68	9.27	-3.61	12.03	-3.99	18.37
	89	1082+69	-0.35	5.18	-0.89	6.24	0.88	4.78	-0.46	7.84	-0.98	15.98
	90	1093+69	-4.35	8.22	-4.13	18.30	-8.13	21.62	-7.78	28.13	-7.38	36.29
	91	1102+82	-3.93	9.01	-2.85	15.45	-7.18	26.37	-8.57	33.23	-10.91	40.58
	92	1112+81	-3.82	8.73	-1.89	11.85	-7.24	25.81	-8.18	31.77	-9.56	37.13
	93	1122+81	-4.44	6.93	-2.45	10.17	-9.92	11.06	-12.39	13.44	-14.83	16.14
	94	1131+73	1.10	5.22	1.86	8.53	3.78	7.04	1.68	6.06	-1.82	7.48
	95	1141+97	2.54	4.25	4.13	8.50	2.89	13.33	2.36	15.83	0.09	22.39
	96	1151+92	-2.21	4.88	1.98	11.82	-1.54	15.65	-2.18	13.91	-5.51	16.27
	97	1161+91	-1.15	4.81	2.59	14.29	-3.05	12.23	-4.38	12.52	-7.90	16.49
	98	1171+91	-4.86	15.50	0.63	40.50	-13.49	36.28	-14.16	37.33	-17.96	47.68
	99	1182+17	-4.12	19.29	2.08	45.56	-9.11	48.12	-9.71	50.15	-15.36	58.13
	100	1191+90	-2.98	9.52	3.92	31.49	-8.53	23.49	-8.66	24.40	-10.72	27.94
	101	1201+93	-2.88	5.00	3.32	17.16	-9.03	11.71	-10.09	14.29	-16.32	30.58
	102	1211+94	-2.93	6.80	3.27	19.13	-7.59	20.61	-9.03	22.17	-12.14	32.34

Table E-1. Summary of Average Annual Volume Change Statistics Along Bogue Banks (2008 to 2015) Cont.

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Fort Macon	103	1222+11	-4.89	6.98	-2.03	14.60	-14.77	16.31	-19.07	23.57	-26.12	47.73
	104	1231+86	-2.38	7.41	1.68	23.27	-13.40	26.42	-14.57	27.63	-16.62	33.87
	105	1241+79	-4.85	13.60	-1.75	39.14	-12.92	49.56	-9.62	54.65	-11.00	55.42
	106	1251+79	-6.46	10.12	-5.66	32.41	-23.02	30.07	-19.12	29.03	-20.56	36.42
	107	1257+09	-6.83	10.11	-4.52	18.46	-19.54	32.92	-11.52	26.76	-12.38	27.23
	108	1261+80	-1.67	5.83	1.20	20.41	-2.35	28.03	4.59	41.60	5.46	40.89
	109	1267+13	-2.22	7.89	-0.30	12.03	-5.40	18.90	-0.26	33.38	-0.29	33.07
	110	1271+73	-2.62	11.48	-1.30	18.16	-6.43	32.47	-5.42	47.13	-5.35	47.95
	111	1278+93	-0.81	7.70	3.22	24.34	1.93	30.82	25.85	76.94	42.55	63.36
	112	1283+93	1.61	4.06	7.10	24.27	6.20	25.19	40.32	99.98	41.97	102.75

Table E-2. Summary of Average Annual Volume Change Statistics Along Bear Island (2008 to 2015)

Average Annual Volume Change (2008-2015)												
Reach	Transect Number	Station	Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
			Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Bear Island	1	0+00	-2.78	12.92	-6.59	35.56	-4.90	93.44	17.38	153.03	18.38	158.10
	2	10+00	0.50	4.84	-0.13	20.79	11.45	71.07	36.66	88.67	38.76	93.88
	3	20+00	1.03	6.58	2.12	16.27	7.45	30.85	17.48	39.16	19.38	42.01
	4	30+00	0.04	4.71	1.06	12.15	0.17	12.62	0.87	13.13	0.07	13.69
	5	40+00	-2.51	4.97	-2.92	11.89	-2.95	12.94	-5.87	14.38	-6.55	19.70
	6	50+00	-2.09	5.95	-1.40	10.23	-0.47	17.40	-3.34	19.16	-4.20	23.39
	7	60+00	-5.59	12.49	-5.63	11.37	-6.78	10.11	-9.63	20.65	-10.56	29.72
	8	70+00	0.27	4.08	-1.62	3.80	-1.28	7.44	-4.28	10.69	-5.88	19.39
	9	80+00	-0.79	3.88	-1.24	6.08	-1.98	10.45	-5.37	7.95	-6.46	14.01
	10	90+00	-1.24	3.32	-1.23	11.82	-2.33	16.35	-6.66	13.72	-8.68	18.68
	11	100+00	-0.90	4.43	-1.09	9.12	-3.60	11.76	-7.94	6.96	-10.22	8.16
	12	110+00	0.02	4.63	0.65	7.06	-0.60	5.85	-5.34	8.60	-9.18	14.19
	13	120+00	-2.09	5.47	-1.89	9.82	-2.92	11.74	-8.20	9.14	-12.71	16.81
	14	130+00	-1.64	5.54	-1.44	11.26	-1.66	18.31	-6.42	19.23	-11.00	23.89
	15	140+00	-2.01	4.40	-2.17	6.66	-3.59	9.90	-8.62	9.49	-14.32	13.69
	16	150+00	-1.82	9.05	-2.81	20.54	-4.19	29.68	-7.22	38.15	-11.84	46.84
	17	160+00	-0.08	7.59	-0.83	19.78	-1.77	39.59	-8.29	37.10	-14.07	36.23
	18	170+00	-	-	-	-	-	-	-	-	-	-

Table D-3. Summary of Average Annual Volume Change Statistics Along Shackleford Banks (2008 to 2015)

Average Annual Volume Change (2008-2015)												
			Above +1.1 ft NAVD		Above -5 ft NAVD		Above -12 ft NAVD		Above -20 ft NAVD		Above -30 ft NAVD	
Reach	Transect Number	Station	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation	Mean Volume Change (cy/ft)	Standard Deviation
Shackleford Banks	1	0+00	-0.74	0.97	7.36	22.32	14.15	27.12	14.11	28.15	21.08	30.62
	2	20+51	1.09	1.62	3.37	5.19	-1.79	9.83	-7.38	13.76	-9.10	26.01
	3	40+80	3.74	3.82	7.17	7.35	9.45	8.49	9.69	9.79	1.20	17.96
	4	58+81	1.83	2.81	3.89	2.65	7.83	3.34	7.97	4.73	14.57	21.30
	5	77+99	-0.88	2.63	-2.43	4.79	-4.71	8.50	-9.34	17.57	-20.63	18.46
	6	96+76	-0.88	2.79	-2.04	6.47	-2.61	16.91	-6.89	20.15	-6.20	22.21
	7	113+28	-0.78	3.22	-0.61	6.39	-3.00	15.60	-7.25	16.32	-11.28	17.75
	8	130+01	0.12	2.76	0.06	5.27	-1.20	6.78	-5.24	4.12	-11.69	19.13
	9	152+46	-0.08	4.43	-1.43	5.57	-4.81	14.60	-6.24	20.87	-9.48	27.31
	10	170+79	-0.70	3.25	-2.34	6.62	-2.53	11.12	-5.39	12.65	-5.09	18.99
	11	190+43	-1.66	3.13	-2.31	10.20	-3.63	17.50	-6.40	22.33	-8.55	30.08
	12	210+07	-4.00	11.16	-4.29	14.28	-6.22	21.55	-9.48	19.03	-13.86	26.93
	13	229+21	-1.50	6.75	-2.06	10.22	-3.23	14.31	-4.64	19.24	-6.27	25.38
	14	248+63	-1.82	7.70	-4.04	8.85	-5.54	16.46	-8.70	20.06	-11.27	24.72
	15	272+15	0.13	5.33	-0.87	7.70	0.37	4.65	-1.25	8.54	-0.91	9.71
	16	293+38	-0.75	4.91	-2.36	10.32	-1.31	17.41	-5.15	15.68	-4.28	21.40
	17	322+18	-0.22	4.52	-0.66	7.44	-0.60	11.52	-4.42	15.17	-8.49	23.36
	18	343+08	-1.35	6.04	-0.80	11.31	-2.07	22.78	-6.88	18.89	-8.11	21.97
	19	363+54	-3.61	10.48	-3.37	16.03	-2.31	29.09	-5.85	22.48	-12.86	26.01
	20	383+92	-6.55	8.91	-10.93	10.62	-11.16	25.76	-16.08	18.21	-22.72	16.57
	21	405+26	-9.71	10.95	-20.20	22.72	-28.99	27.80	-42.26	35.24	-41.63	45.38
	22	423+85	-14.66	16.54	-34.03	37.69	-45.75	57.72	-72.36	101.84	-82.54	177.47
	23	444+92	-18.82	14.38	-77.20	85.58	-118.41	128.30	-131.83	144.34	-135.62	153.13
	24	460+01	-23.50	26.13	-55.19	43.83	-100.00	74.10	-108.55	92.16	-91.31	104.36

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