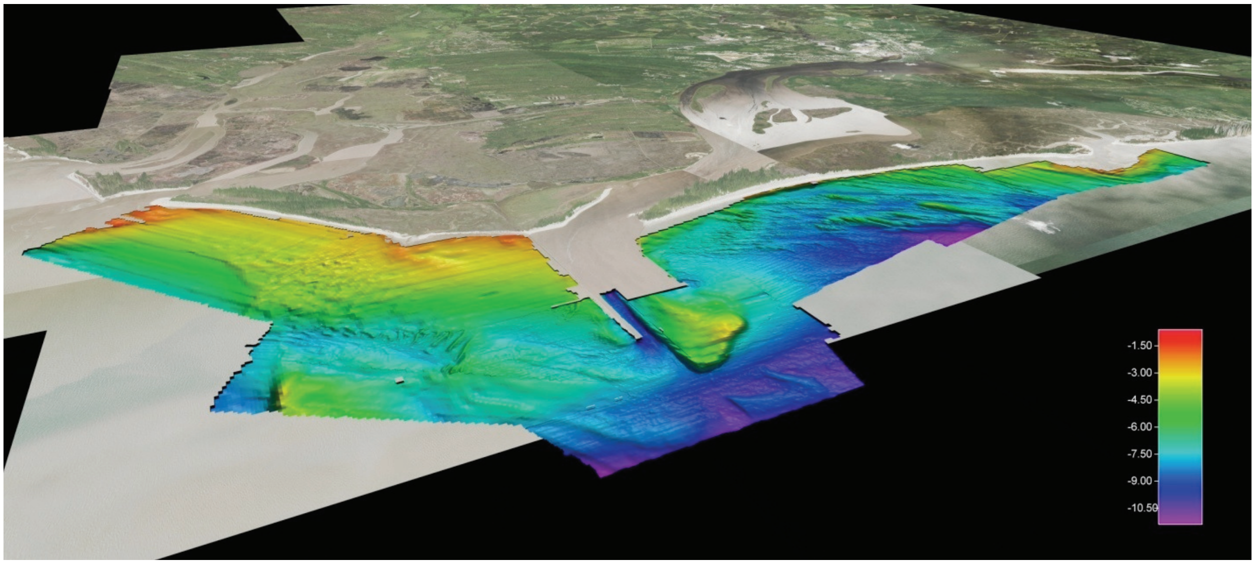
Regional Sediment Management: Charleston and Georgetown Harbor Inlets, SC



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INTRODUCTION

The Center for Marine and Wetland Studies (CMWS) at Coastal Carolina University (CCU) conducted hydrographic surveys for the major tidal inlet features of Charleston Harbor Inlet in Charleston County and Georgetown Harbor Inlet in Georgetown County (Figure 3, Figure 4). The objective of the study was to collect bathymetric data at a sufficient density to develop accurate digital elevation models. The resulting models will be used to delineate major inlet features, evaluate sediment volumetric change, and serve as input for numerical model grids. In addition, beach profiles and surficial sediment sampling and analysis were conducted to characterize the active beach systems adjacent to the Winyah Bay entrance. The project was conducted in three phases. Phases 1 and 2 were at Georgetown Harbor Inlet and Phase 3 was at Charleston Harbor Inlet.

METHODS

Bathymetric, topographic, and sediment data was collected at Charleston Harbor Inlet and Georgetown Harbor Inlet from Aug 2009-Aug 2010 to assess the major tidal features of the inlets. Daily work activities associated with the project are provided in the Appendix 1. All data provided to USACE is in UTM meters (NAD83, Zone 17N). Beach profile figures within the report (Appendix 2) are displayed in ft.

Single beam, multibeam and beach profile surveys were conducted with a Real-Time Kinematic Global Positioning System (RTK-GPS). An Ashtech Z-Xtreme receiver with an Airlink modem (Charleston Harbor) or Pac Crest UHF modem (Georgetown Harbor) was used as a base station to broadcast real-time corrected GPS data to the roving unit collecting single beam, multibeam, or beach profile data. A base station was set-up on established benchmarks or temporary benchmarks (TBMs) and positional accuracy was determined by comparisonof established benchmark values versus collected data. A list of all benchmarks used during the project is provided in Appendix 3. Hard copy records of all pre-survey calibrations are provided with this report. All hydrographic data collection requirements listed in the Scope of Work (SOW) were met.

Single beam surveys were conducted in nearshore and shoal areas generally < 15 ft water depth. Line spacing for the single beam surveys were 200 ft shore parallel. Single beam zones for Georgetown Harbor were N1-1, N1-2, N2, N3-1, Entrance North, Sand Island-1, East Bank, and N. Santee (Figure 3) and single beam zones for Charleston Harbor were Breach Inlet, Sullivans 1, Sullivans 1M, Morris 1, Morris 2, and Morris 3 (Figure 4).

Multibeam surveys were conducted in areas generally > 15 ft water depth with 100% coverage and 10% overlap for multibeam survey zones. Multibeam zones for Georgetown Harbor were WB1, WB2, WB3, WB4, WB5, and WB6 (Figure 3) and multibeam zones for Charleston Harbor were CH1, CH2, CH3, and CH4 (Figure 4).

Multibeam

Data Acquisition

Swath bathymetry data were collected using a Kongsberg EM3002 dual head multibeam echosounder system. Tracklines for each polygon were first established with HYPACK software and run at 30-50 m line spacing to achieve a minimum of 10% overlap between adjacent passes. The acquisition software used was the Seafloor Information System (SIS), which allowed for real-time monitoring of the multibeam sonar data via multiple numerical and visual data displays. The multibeam data were checked in real-time for quality, most notably for minor refraction errors that were readily corrected by suspending data collection and performing an updated cast of the sound velocity profile in the area. At the beginning and conclusion of each survey day a sound velocity profile (SVP) was obtained using an AML Oceanographic Smart SV&P probe and input into the multibeam acquisition software to account for refraction of the sound waves through the water column. Additional sound velocity casts were taken when needed as water column characteristics changed throughout the day primarily as a result of solar heating and the survey’s shifting proximity to the freshwater discharge plume. During data acquisition, the EM3002 system also integrated heave, pitch and roll data collected at 100 Hz from a Seatex Seapath 200 RTK vessel reference unit (MRU-5), which was centered approximately 15 cm above the bow-mounted sonar heads in a waterproof subsea bottle. Further, two L1/L2 GPS antennas mounted along the vessel centerline provided both accurate heading and RTK-GPS positions that were collected at a 25 Hz sampling rate and referenced to an accompanying base station located less than 8 km from the survey site. A workflow diagram for multibeam data acquisition is provided in Figure 5. At the conclusion of a survey day, the raw Simrad EM3002 data files were imported into CARIS HIPS and SIPS software (v. 7.0) for postprocessing. This included minor data cleaning (flaggin of outliers) and the application of a geoid file for tide correction referenced to the NAVD 88 vertical datum.

Data Processing

Bathymetric data were post-processed using CARIS HIPS ver. 7.0 hydrographic data processing software. Post-survey data cleaning, as well as Bathymetry Associated with Statistical Error (BASE) Surface creation using swath angle algorithm, were applied in CARIS HIPS. Soundings (xyz) were exported from a BASE Surface as xyz text file with 1m spatial resolution. The xyz were imported into Fledermaus Dmagic ver. 7.1 to grid. In Dmagic, the 1m decimated xyz text files were interpolated into 1m digital elevation model (DEM) grids. The 1m Fledermaus grids were exported as ArcInfo ASCII raster files (.asc), which were converted into 1m bathymetry ArcInfo grids in ArcGIS. Final x,y,z soundings, surface models, and derived products are relative to the NAVD88 vertical datum.

Single Beam

Data Acquisition

Single beam data acquisition was conducted aboard an 18 ft rigid hull inflatable boat and a 20 ft Carolina Skiff. Each single beam survey boat was outfitted with a Knudsen Mini-Sounder (210 kHz) , TSS DMS-05 motion reference unit, Ashtech Z-Xtreme GPS receiver, and dual frequency GPS antenna. Sound velocity profiles conducted at the beginning and end of surveying each day were used to determine sound velocity. All instrument and water level offsets were measured and entered into HYPACK. HYPACK software was used for navigation and data acquisition. A diagram illustrating single beam data acquisition and processing workflow is provided in Figure 6.

Data Procesing

Raw depth and position data were merged, heave/pitch/roll and tide corrections were applied, and data were processed to produce a corrected, RTK-positioned depth with HYPACK software. Initial outlier points were removed using the HYPACK Single Beam editor and exported as a text file. Final filtering and smoothing was performed with a customized MATLAB script.

Beach Profiles

Beach profiles extending from the crest of the primary dune to a distance 3000 ft offshore were collected at North Island (NI) and South Island (SI) every 1000 ft along shore to a distance of 10,000 ft north and south of the Winyah Bay Entrance and every 2500 ft from there to North Inlet and the N. Santee Delta (Figure 3). Subaerial beach data were collected with a roving RTK-GPS unit attached to a backpack system and subaqueous data were collected aboard a single beam survey boat. A total of 22 profiles were collected on North Island and 15 beach profiles were collected on South Island.

Sediment Analysis

Surficial sediment samples were collected in Aug 2009 at every other beach profile in the Winyah Bay study area (Figure 7) at the crest of the primary dune (DC), base of the primary dune (DB), berm (B), beach face (BF), surf zone (S), and -15 ft or 3000 ft seaward of the dune crest (O), whichever was crossed first (see Appendix 4 for sediment sampling locations). Beach sediment samples were collected during beach profile data collection and the -15 ft or 3000 ft offshore samples were collected by a swimmer in conjunction with collecting marine portions of beach profiles. Samples were collected by hand and stored in sealed quart bags until sediment analysis in the laboratory.

Once in the laboratory, sediment samples were washed using a 63 mm sieve and placed into labeled beakers. Samples were dried for 2 to 5 days in a Fisher Scientific Isotemp oven at 30°C. After drying, 50 g of each sample were weighed for sieving. Samples were sieved using a set of U.S. standard sieves, ranging from -2 phi to 3 phi. Samples were shaken for five minutes on a RX-86, W.S. Tyler shaker, removed from individual sieves, and weighed recording individual weight per sieve and cumulative weight.

A pipette method based on Stokes' Law was used for mud samples. The law states that denser particles sink farther than less dense particles when suspended in a liquid. The pipette method measures the actual percent by weight of each particle size class. Fifty grams of each sample was washed using a 63 mm sieve and allowed to settle in a 1000 mL graduated cylinder. After, 20 mL of 0.5% calgon (sodium hexametaphosphate) solution was added to the graduated cylinder for de-flocculation. The graduated cylinder was then filled with water to the 1000 mL level and stirred (avoiding bubbles during mixing). Next, a stop watch was started. At the indicated time and withdrawal depth, 10 mL of solution was removed using a pipette and placed into a beaker. The size fraction, time, and beaker number was recorded. 10 mL of water was then removed using a pipette and rinsed into the beaker. This process was repeated for the remaining size fractions and other mud samples. Samples were dried for 2 to 5 days in a Fisher Scientific Isotemp Oven set at 30^{o}C and were subsequently weighed in order to compute the weight in each mud fraction.

RESULTS

Multibeam and Single Beam Data

Multibeam and single beam data products are provided on external hard drives accompanying this report and can also be acquired through the eCoastal database available on-line through Coastal Carolina University. Multibeam data are provided as ESRI ArcGIS grids with accompanying raw and processed data and single beam data are provided as a feature class titled “spot_elevation_point”.

Beach Profiles and Sediments

Beach profile data are provided as ASCII files with appropriate descriptive headers on the external hard-drives accompanying this report and are available through the eCoastal database. All beach profiles and photographs at each profile are provided in the Appendices 2 and 5. Please note the vertical scale on NI profiles -25 ft to 20 ft (NAVD88) and the vertical scale on SI profiles is -15 ft to 12 ft (NAVD88). Sediment data including sampling coordinates are provided as an ASCII file on an external hard drive and are described in this report. Table 1 provides mean phi size, standard deviation, and grain size and sorting based on the Udden-Wentworth grain size scale. A description of general morphology and sediment dynamics of North and South Island is provided below.

North Island

North Island is approximately 13 km in length from North Inlet to the Winyah Bay entrance (Figure 3). The northern two-thirds of the island is generally characterized by a thin beach and dune system backed by salt marshes associated with the North Inlet and Winyah Bay estuarine systems (Figure 8). The southern third of the island is generally characterized by a thin beach and extensive dune system backed by a maritime forest. Historical shoreline data (provided by SC Department of Health and Environmental Control-DHEC) indicates North Inlet has migrated south approximately 1 km since the 1870s and the northern half of the island has been eroding over the same time period (Figure 9). The southern end of the island prograded approximately 1 km from 1872-73 to 1962-64, but has been net erosional since the 1960s.

The northern end of North Island is influenced by sediments associated with the North Inlet ebb tidal delta. The shoreline in this area is dynamic as a result of proximity to North Inlet and shoal-attachment processes (Figure 10). At low tide, subaerial exposure of ebb tidal delta sediments and the intertidal beach is extensive.   While unable to measure the marine portion of beach profiles within the ebb tidal delta region, nearshore depths out to 3000 ft offshore were generally < -15 ft (NAVD88) (NI1-NI6).

The mid-section of North Island is characterized by a thin, erosional beach (Figure 11). An escarpment was present at the dune base at profiles NI5-8 and a narrow berm was documented at profiles NI9-14. Palm trees were noted on the berm and primary dune as well as remnants of palm trees in the intertidal zone at profiles NI5-8. The dune system at the southern end is the most extensive on the island (Figure 12) while the beach is generally erosional. An escarpment at the dune base at profiles NI15-21 and numerous uprooted trees on the beachface and berm at the southern-most area of the island indicate the area is erosional (Figure 13).

Surficial sediments on North Island generally consisted of fine to medium sands moderately to well sorted at the dune crest and dune base (Table 1, Figure 14). The berm consisted of medium sand moderately to moderately well sorted and the beachface consisted of primarily poorly sorted medium sand. The surf zone and offshore sediment samples were more variable than other sampling locations ranging from fine silt to gravel. Overall, the coarsest sediments were located in the surf zone.

South Island

South Island is approximately 8 km in length from the entrance of Winyah Bay to the North Santee delta (Figure 15). An small tidal inlet bisects Sand Island to the north and South Island to the south. Historical shoreline data indicates Sand Island and the current barrier island beach associated with South Island were not present prior to construction of the Georgetown jetties in the late 1800s (Figure 16). After jetty construction, sediments associated with the ebb tidal deltas of Winyah Bay and Santee formed narrow barrier island beaches by the 1920s and have since migrated landward to their current locations. Sand Island has accreted significantly north of the southern Winyah Bay jetty and the back barrier marsh system that was previously open to the ocean has been filling in with sediment and vegetation over the past 100 years.

Sand Island is a narrow and low-lying island approximately 2 km from the southern jetty to the tidal inlet (Figure 17). Numerous overwash fans are located on Sand Island and spit development suggests southerly migration of the tidal inlet. Sand Island is devoid of any significant dune features and consists of a narrow berm that increases in width to the south. The beach face is gently sloping and depths up to 3000 ft offshore rarely exceed -10 ft (NAVD88). The presence of organic rich deposits in the surf zone in addition to overwash deposits suggest landward migration of Sand Island over the marsh surface (Figure 17).

The beach at South Island is narrow with a small berm along most of the island. The dune system is more prominent than at Sand Island and a small maritime forest is present between the dunes and the back barrier system (Figure 15). Beach profiles and photographs on South Island also suggest a gently sloping beachface and shallow nearshore environment with depths at 3000 ft offshore around -10 ft depth (NAVD88) (see Appendix 2, 5).

Sediment samples collected on Sand and South Islands were generally finer than sediments collected on North Island and are likely a function of proximity to Winyah Bay and Santee deltas and the small inlet located between the islands (Table 1, Figure 17). Coarser sediments are generally trapped within the estuary. Dune crest and dune base sediments were primarily well to moderately well sorted fine sand. Berm samples were moderately to moderately well sorted medium sand and beachface samples were fine sand to gravel. Surf zone samples were quite variable with fine silt, fine sand, and medium sand located on Sand Island and fine to medium sand documented on South Island. Finer sediments associated with the surf zone on Sand Island are a function of the shoreline migrating landward over the marsh surface (Figure 17). Offshore sediment samples were primarily moderately well sorted fine sand with medium sand located at SI7 and coarse sand at SI13.

TABLES

Table 1. Mean phi size, standard deviation, grain size, and sorting of surficial sediment samples collected along transects on North and South Islands. Grain sizes based on the Udden-Wentworth grain size scale.

Zone	Profile	Mean Phi Size	Standard Deviation	Grain Size	Sorting
Dune Crest	NI-1	2.464	0.286	Fine Sand	Very Well
	NI-3	2.054	0.497	Fine Sand	Well
	NI-5	1.938	0.573	Medium Sand	Moderately Well
	NI-7	2.164	0.557	Fine Sand	Moderately Well
	NI-9	2.012	0.539	Fine Sand	Moderately Well
	NI-11	2.096	0.525	Fine Sand	Moderately Well
	NI-13	1.968	0.618	Medium Sand	Moderately Well
	NI-15	1.889	0.642	Medium Sand	Moderately Well
	NI-17	1.752	0.643	Medium Sand	Moderately Well
	NI-19	1.690	0.600	Medium Sand	Moderately Well
	NI-21	1.801	0.539	Medium Sand	Moderately Well
	SI-1	1.982	0.641	Medium Sand	Moderately Well
	SI-3	2.294	0.513	Fine Sand	Moderately Well
	SI-5*	N/A	N/A	N/A	N/A
	SI-7*	N/A	N/A	N/A	N/A
	SI-9	2.448	0.280	Fine Sand	Very Well
	SI-11	2.272	0.460	Fine Sand	Well
	SI-13	2.361	0.377	Fine Sand	Well
Dune Base	NI-1	2.450	0.413	Fine Sand	Well
	NI-3	1.292	0.872	Medium Sand	Moderately
	NI-5	2.129	0.557	Fine Sand	Moderately Well
	NI-7	2.150	0.766	Fine Sand	Moderately
	NI-9	1.811	0.549	Medium Sand	Moderately Well
	NI-11	2.008	0.661	Fine Sand	Moderately Well
	NI-13	1.693	0.768	Medium Sand	Moderately
	NI-15	1.461	0.663	Medium Sand	Moderately Well
	NI-17	1.518	0.708	Medium Sand	Moderately Well
	NI-19	1.443	0.789	Medium Sand	Moderately
	NI-21	1.677	0.558	Medium Sand	Moderately Well
	SI-1	1.877	0.732	Medium Sand	Moderately
	SI-3	1.201	0.935	Medium Sand	Moderately
	SI-5*	N/A	N/A	N/A	N/A
	SI-7*	N/A	N/A	N/A	N/A
	SI-9	2.002	0.544	Fine Sand	Moderately Well
	SI-11	2.151	0.536	Fine Sand	Moderately Well
	SI-13	2.400	0.360	Fine Sand	Well
Berm	NI-1	2.395	0.375	Fine Sand	Well
	NI-3	1.956	0.600	Medium Sand	Moderately Well
	NI-5	1.883	0.522	Medium Sand	Moderately Well
	NI-7	1.822	0.710	Medium Sand	Moderately
	NI-9	1.716	0.533	Medium Sand	Moderately Well
	NI-11	1.778	0.692	Medium Sand	Moderately Well
	NI-13	1.697	0.751	Medium Sand	Moderately
	NI-15	1.522	0.766	Medium Sand	Moderately
	NI-17	1.839	0.533	Medium Sand	Moderately Well
	NI-19	1.662	0.546	Medium Sand	Moderately Well
	NI-21	1.562	0.511	Medium Sand	Moderately Well
	SI-1	1.972	0.624	Medium Sand	Moderately Well
	SI-3	1.110	0.720	Medium Sand	Moderately
	SI-5	1.047	0.703	Medium Sand	Moderately Well
	SI-7*	N/A	N/A	N/A	N/A
	SI-9	1.953	0.674	Medium Sand	Moderately Well
	SI-11	1.861	0.692	Medium Sand	Moderately Well
	SI-13	1.400	0.882	Medium Sand	Moderately

Zone	Profile	Mean Phi Size	Standard Deviation	Grain Size	Sorting
Beach Face	NI-1	2.375	0.570	Fine Sand	Moderately Well
	NI-3	1.563	1.563	Medium Sand	Poorly
	NI-5	1.753	1.090	Medium Sand	Poorly
	NI-7	0.940	1.881	Coarse Sand	Poorly
	NI-9	1.174	1.324	Medium Sand	Poorly
	NI-11	1.894	1.062	Medium Sand	Poorly
	NI-13	1.602	1.306	Medium Sand	Poorly
	NI-15	1.973	0.812	Medium Sand	Moderately
	NI-17	2.268	0.519	Fine Sand	Moderately Well
	NI-19	2.362	0.439	Fine Sand	Well
	NI-21	1.695	1.231	Medium Sand	Poorly
	SI-1	1.970	1.007	Medium Sand	Poorly
	SI-3	2.049	0.870	Fine Sand	Moderately
	SI-5	2.138	0.633	Fine Sand	Moderately Well
	SI-7*	N/A	N/A	N/A	N/A
	SI-9	1.612	1.056	Medium Sand	Poorly
	SI-11	2.390	0.551	Fine Sand	Moderately Well
	SI-13	1.634	1.155	Medium Sand	Poorly
Surf zone	NI-1	1.332	1.484	Medium Sand	Poorly
	NI-3	-1.962	1.358	Gravel	Poorly
	NI-5	0.527	2.047	Coarse Sand	Very Poorly
	NI-7	-0.266	2.127	Very Coarse Sand	Very Poorly
	NI-9	1.520	1.735	Medium Sand	Poorly
	NI-11	1.309	1.560	Medium Sand	Poorly
	NI-13	2.361	0.779	Fine Sand	Moderately
	NI-15	0.429	1.947	Coarse Sand	Poorly
	NI-17	1.422	1.380	Medium Sand	Poorly
	NI-19	1.784	0.866	Medium Sand	Moderately
	NI-21	1.591	1.031	Medium Sand	Poorly
	SI-1	6.317	1.110	Medium Silt	Poorly
	SI-3	7.050	1.080	Fine Silt	Poorly
	SI-5	2.234	0.681	Fine Sand	Moderately Well
	SI-7*	N/A	N/A	N/A	N/A
	SI-9	1.510	0.930	Medium Sand	Moderately
	SI-11	2.247	0.718	Fine Sand	Moderately
	SI-13	1.549	1.573	Medium Sand	Poorly
Offshore	NI-1*	N/A	N/A	N/A	N/A
	NI-3*	N/A	N/A	N/A	N/A
	NI-5	2.235	0.696	Fine Sand	Moderately Well
	NI-7	2.284	0.834	Fine Sand	Moderately
	NI-9	0.863	2.086	Coarse Sand	Very Poorly
	NI-11	2.676	0.470	Fine Sand	Well
	NI-13	2.506	0.398	Fine Sand	Well
	NI-15	1.530	1.164	Medium Sand	Poorly
	NI-17	0.570	1.326	Coarse Sand	Poorly
	NI-19	1.001	1.154	Medium Sand	Poorly
	NI-21	1.962	0.795	Medium Sand	Moderately
	SI-1	2.145	0.608	Fine Sand	Moderately Well
	SI-3	2.287	0.511	Fine Sand	Moderately Well
	SI-5	2.219	0.545	Fine Sand	Moderately Well
	SI-7	1.441	0.812	Medium Sand	Moderately
	SI-9	2.188	0.609	Fine Sand	Moderately Well
	SI-11	2.494	0.450	Fine Sand	Well
	SI-13	0.746	0.926	Coarse Sand	Moderately

*Feature (e.g. dune crest, berm) was not present at transect location.

Table 2. Udden-Wentworth Grain Size Scale.

	Millimeters	µm	Phi (φ)	Wentworth size class	
			-20		Gravel
	4096		-12	Boulder (-8 to -12φ)	
	1024		-10		
	256		-8	Pebble (-6 to -8φ)	
	64		-6		
	16		-4	Pebble (-2 to -6φ)	
	4		-2		
	3.36		-1.75		
	2.83		-1.50	Gravel	
	2.38		-1.25		
	2.00		-1.00		Sand
	1.68		-0.75		
	1.41		-0.50	Very coarse sand	
	1.19		-0.25		
	1.00		-0.00		
	0.84		0.25		
	0.71		0.50	Coarse sand	
	0.59		0.75		
1/2	0.50	500	1.00		
	0.42	420	1.25		
	0.35	350	1.50	Medium sand	
	0.30	300	1.75		
1/4	0.25	250	2.00		
	0.210	210	2.25		
	0.177	177	2.50	Fine sand	
	0.149	149	2.75		
1/8	0.125	125	3.00		
	0.105	105	3.25		
	0.088	88	3.50	Very fine sand	
	0.074	74	3.75		
1/16	0.0625	63	4.00		Mud
	0.0530	53	4.25		
	0.0440	44	4.50	Coarse silt	
	0.0370	37	4.75		
1/32	0.0310	31	5	Medium silt	
1/64	0.0156	15.6	6	Fine silt	
1/128	0.0078	7.8	7	Very fine silt	
1/256	0.0039	3.9	8		
	0.0020	2.0	9		
	0.00098	0.98	10		
	0.00049	0.49	11	Clay	
	0.00024	0.24	12		
	0.00012	0.12	13		
	0.00006	0.06	14		

FIGURES

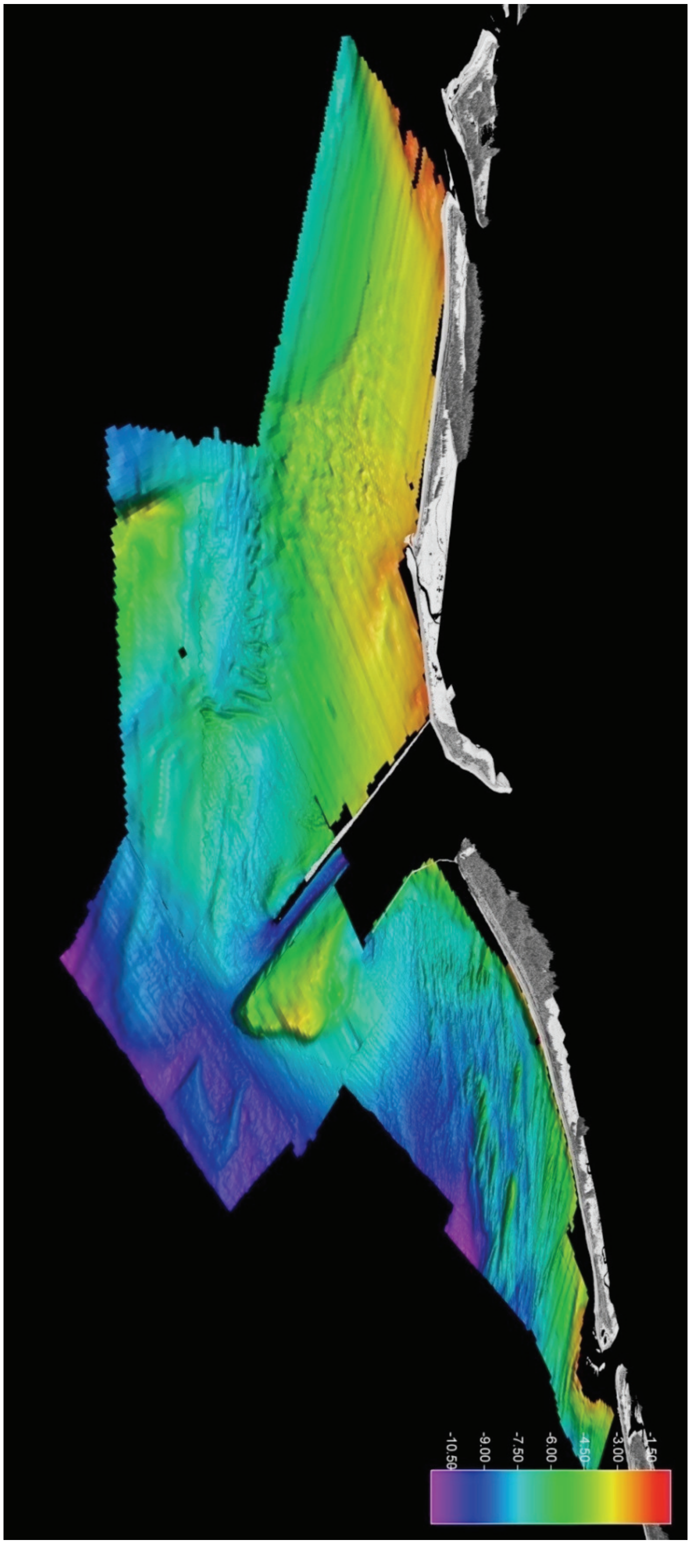


Figure 1. Composite image of multibeam and single beam bathymetry collected adjacent to the Winyah Bay entrance.

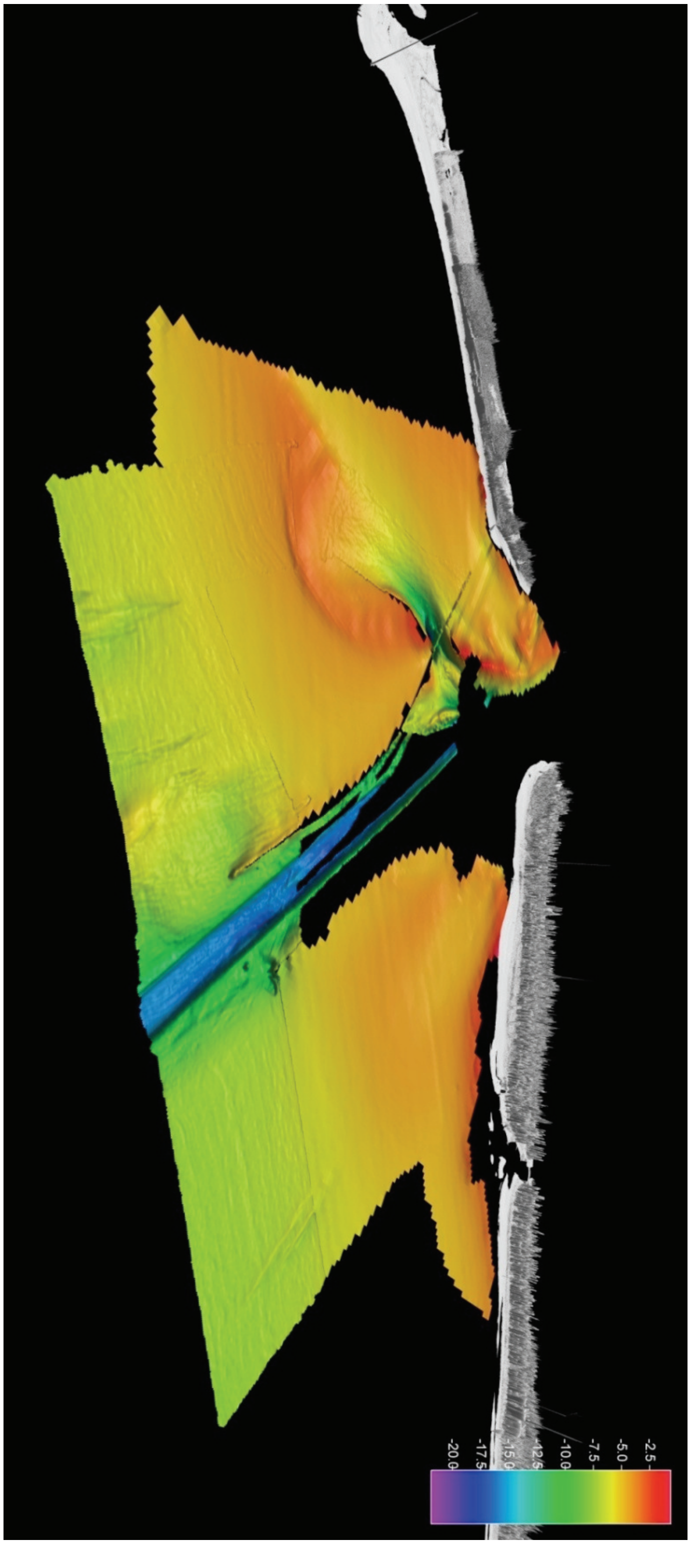
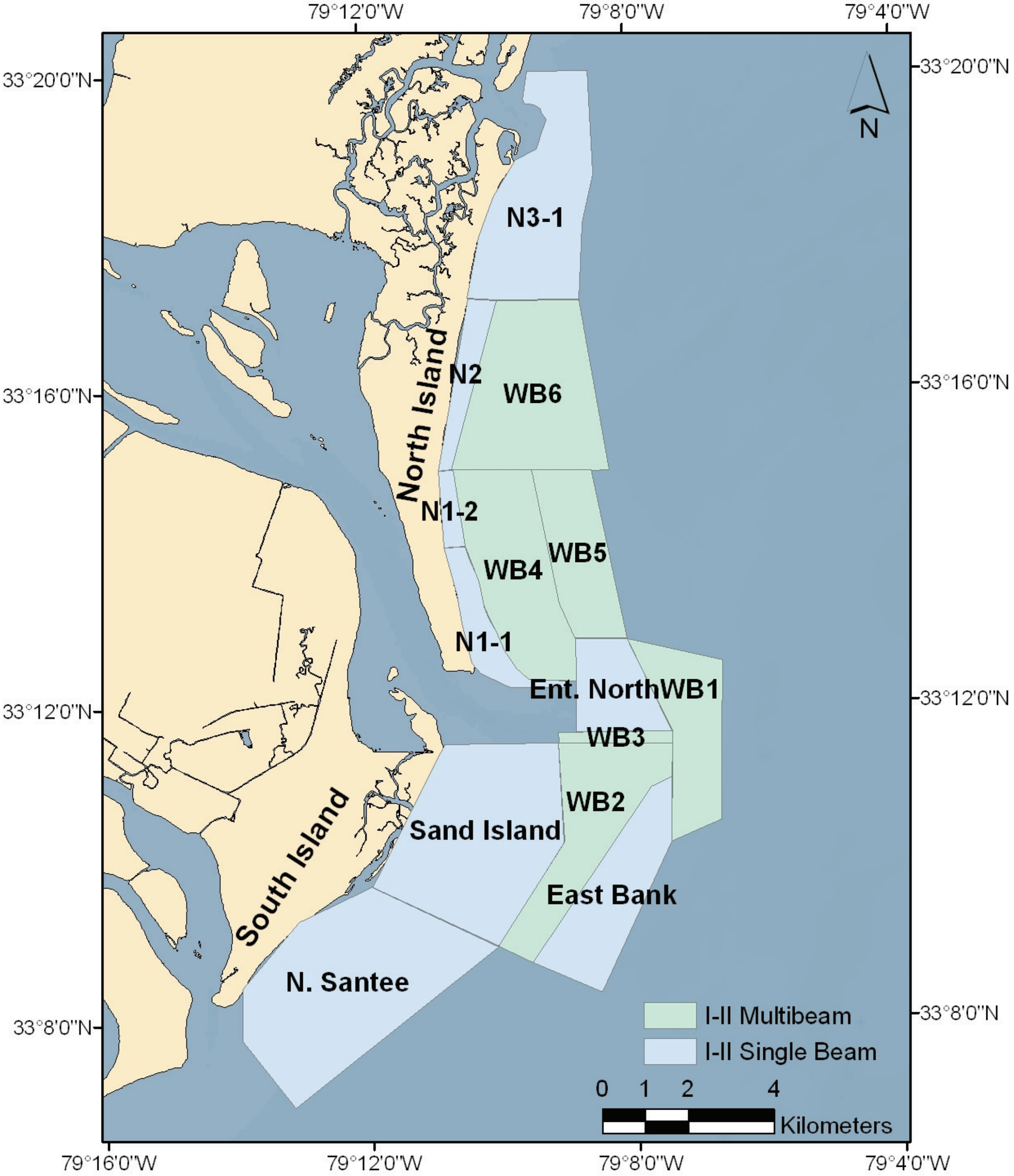


Figure 2. Composite image of multibeam and single beam bathymetry collected adjacent to the Charleston Harbor entrance.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79°8'0"W
79°4'0"W
33°20'0"N
33°16'0"N
33°12'0"N
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N
N3-1
N2
WB6
North Island
N1-2
WB5
WB4
N1-1
Ent. North
WB1
WB3
WB2
South Island
Sand Island
East Bank
N. Santee
🟩 I-II Multibeam
🟦 I-II Single Beam
0
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4
Kilometers

Figure 3. Map of Georgetown Harbor Inlet (Phase I and II) indicating single beam and multibeam data collection polygons.

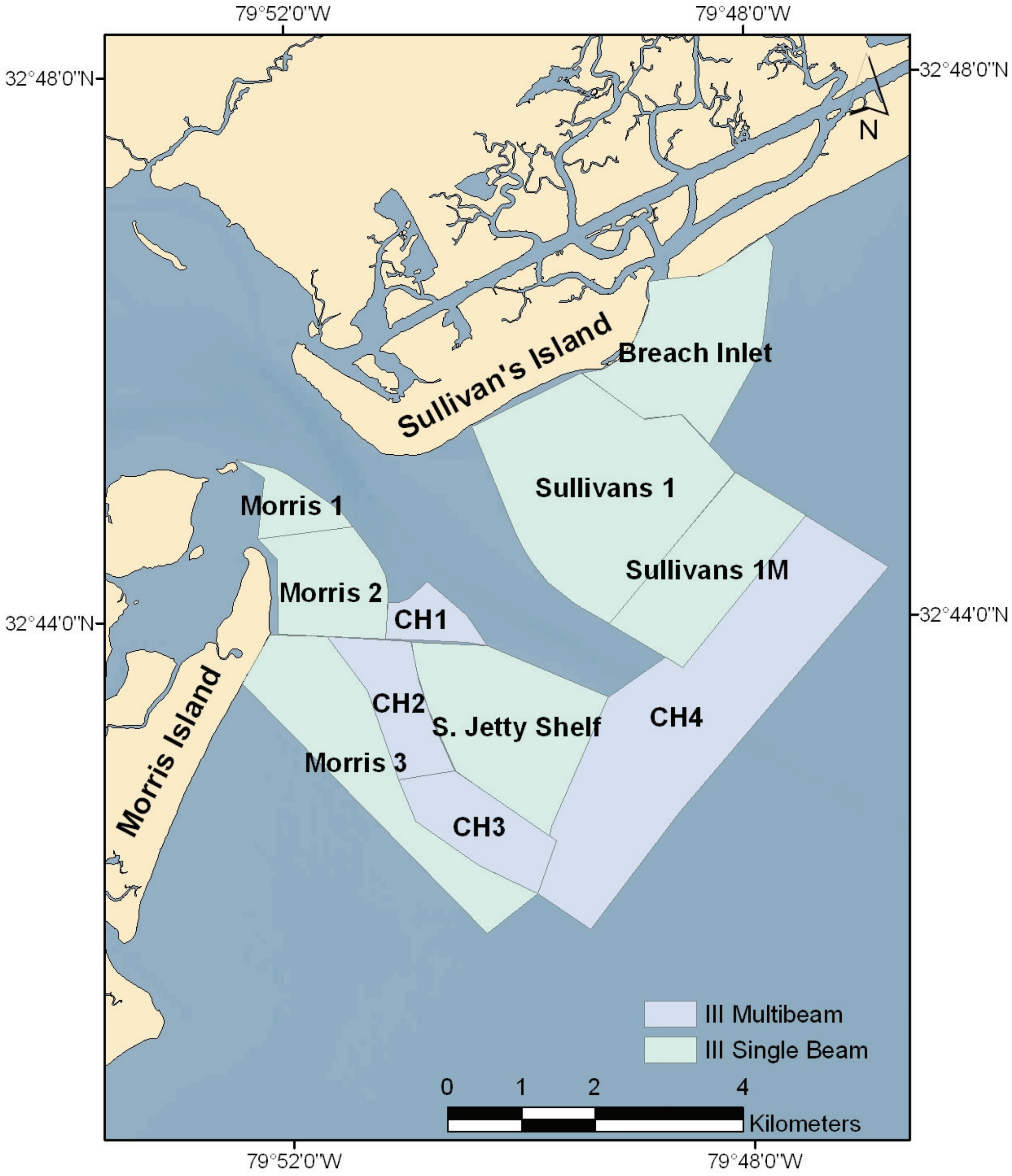


Figure 4. Map of Charleston Harbor Inlet (Phase III) indicating single beam and multibeam data collection polygons.

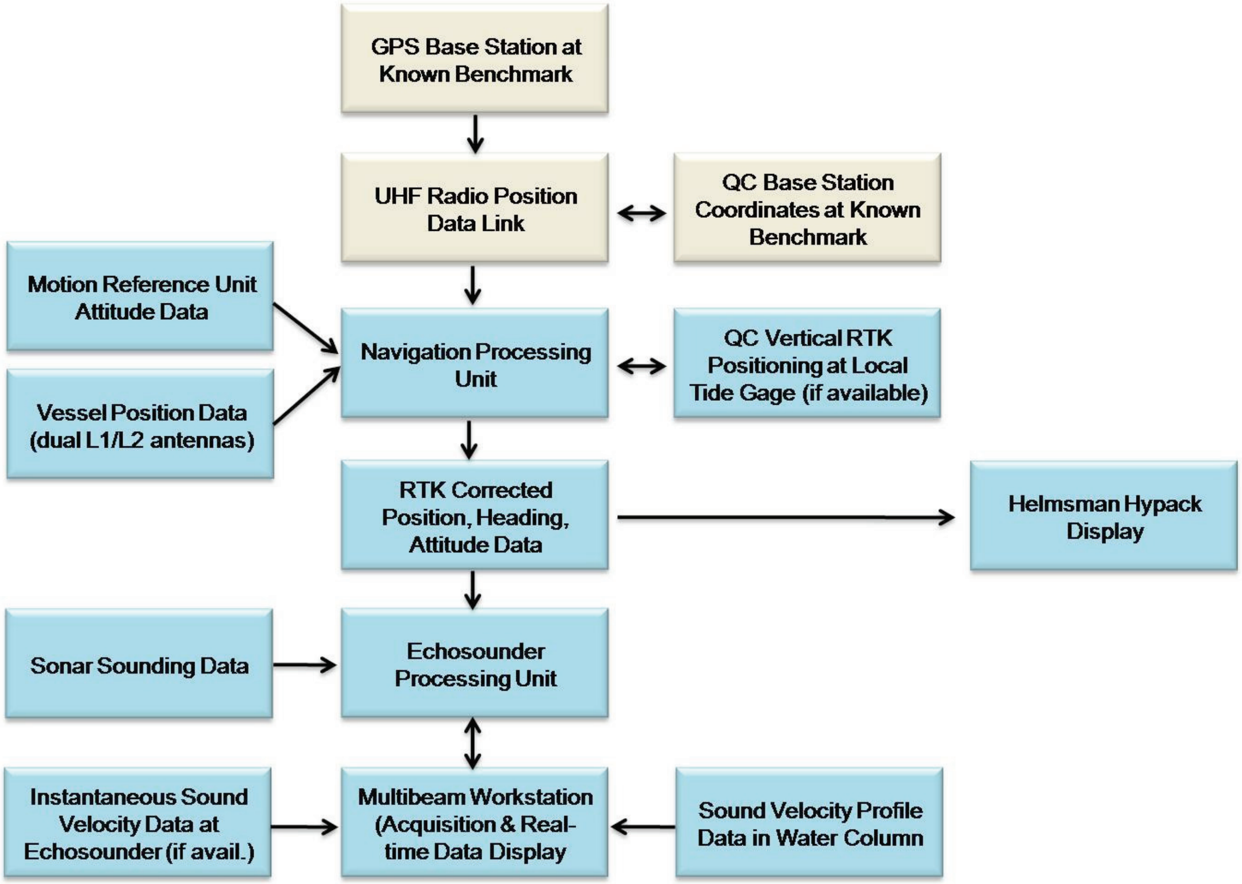


Figure 5. Multibeam bathymetry work flow diagram.

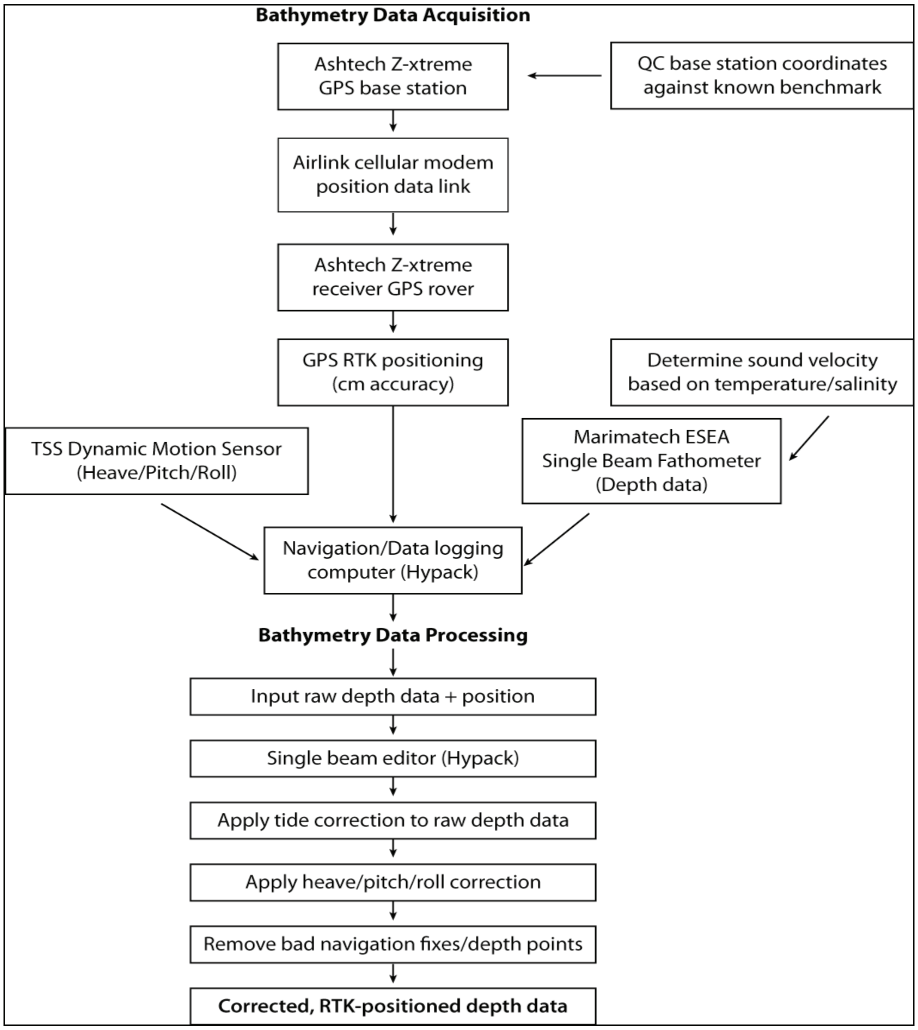
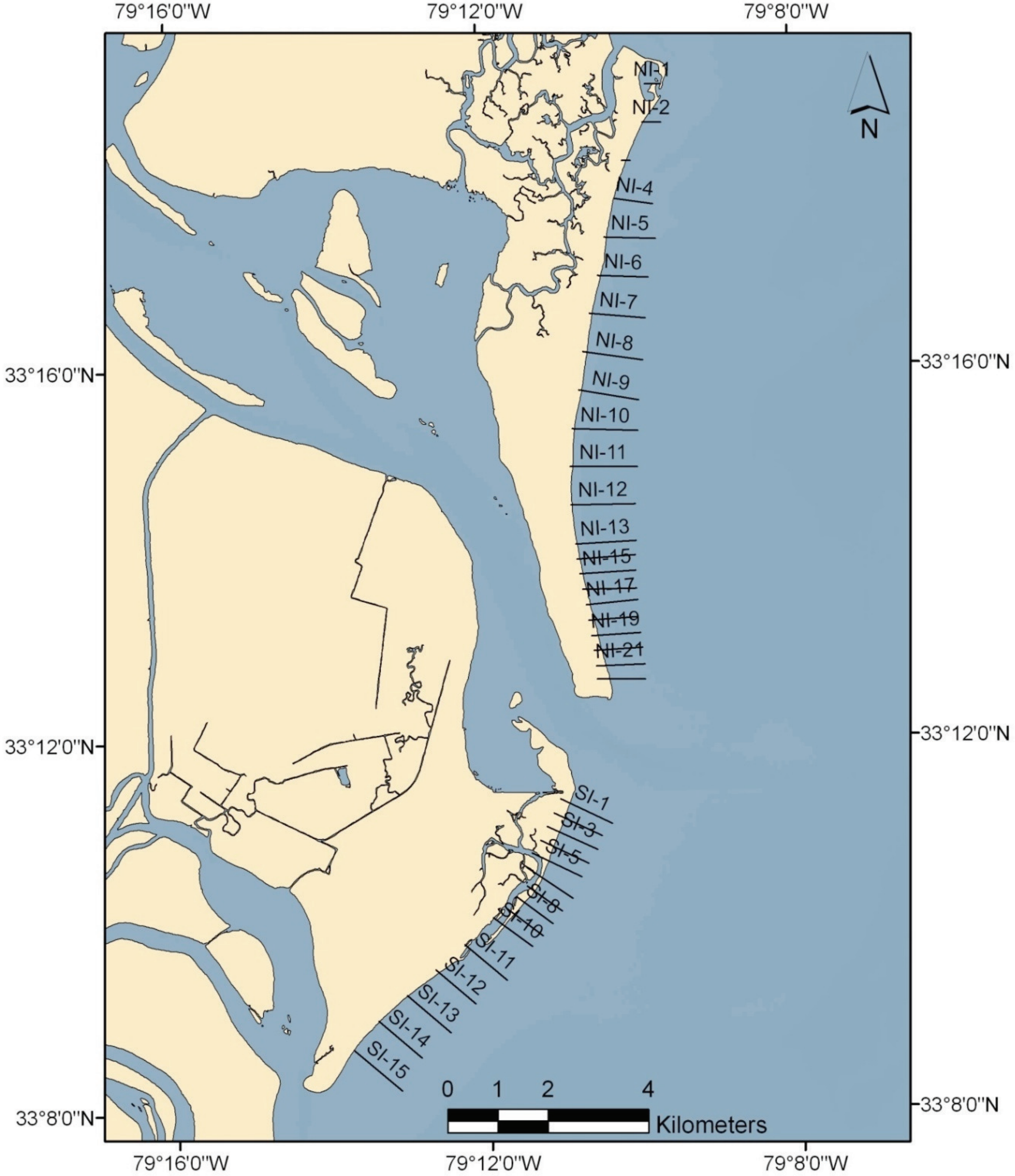


Figure 6. Single beam data acquisition and processing workflow diagram.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79°12'0"W
79°8'0"W
33°16'0"N
33°12'0"N
33°8'0"N
N
NI-1
NI-2
NI-4
NI-5
NI-6
NI-7
NI-8
NI-9
NI-10
NI-11
NI-12
NI-13
NI-15
NI-17
NI-19
NI-21
SI-1
SI-3
SI-5
SI-8
SI-10
SI-11
SI-12
SI-13
SI-14
SI-15
0
1
2
4
Kilometers

Figure 7. Map of North and South Islands adjacent to Winyah Bay indicating locations of beach profiles. Sediment samples were collected at all odd numbered profiles. NI=North Island, SI=South Island.

Figure 8. Aerial photographs of North Island taken from North Inlet facing south. The mouth of Winyah Bay is in the upper left corner. Photograph: Aug 2009.

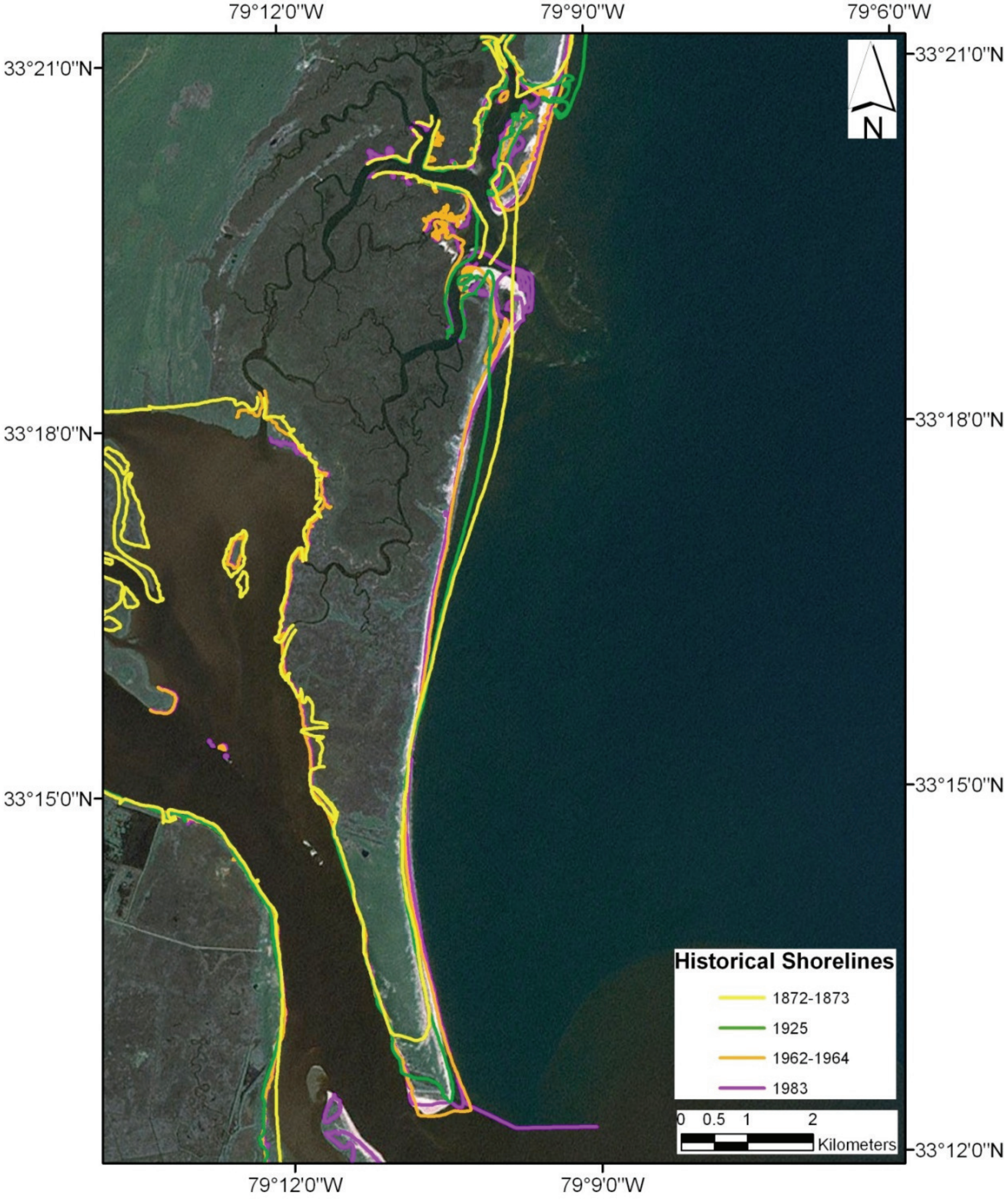


Figure 9. Historical shoreline locations at North Island illustrating the southerly migration of North Inlet, erosion of the beach along the northern half of the island, and progradation of the spit to the south. Shoreline data provided by DHEC.

Figure 10. Photograph of a shoal attaching to the northern end of North Island. The beach along this section of North Island is generally gently sloping with a well developed dune system. The northern most section of the island consists of a small tidal pond fed by a narrow creek that discharges into Jones creek (back barrier marsh). Photograph: Aug 2009.

Figure 11. The central section of North Island consists of a narrow beach with a small dune system immediately adjacent to salt marsh vegetation (top). Historical shorelines (see Figure 9), remnants of trees in the intertidal zone, presence of trees on the berm, and erosion of the primary dune indicate this section of North Island is net erosional. Photographs: Aug 2009.

Figure 12. The southern section of North Island is characterized by a steeper beachface, narrow berm, well developed dune system, and a maritime forest. Photograph: Aug 2009.

Figure 13. Photograph of the southern end of North Island (top). The area is highly erosional with no berm or dune system and numerous uprooted trees are present on the berm and beachface (bottom). Photographs: Aug 2009.

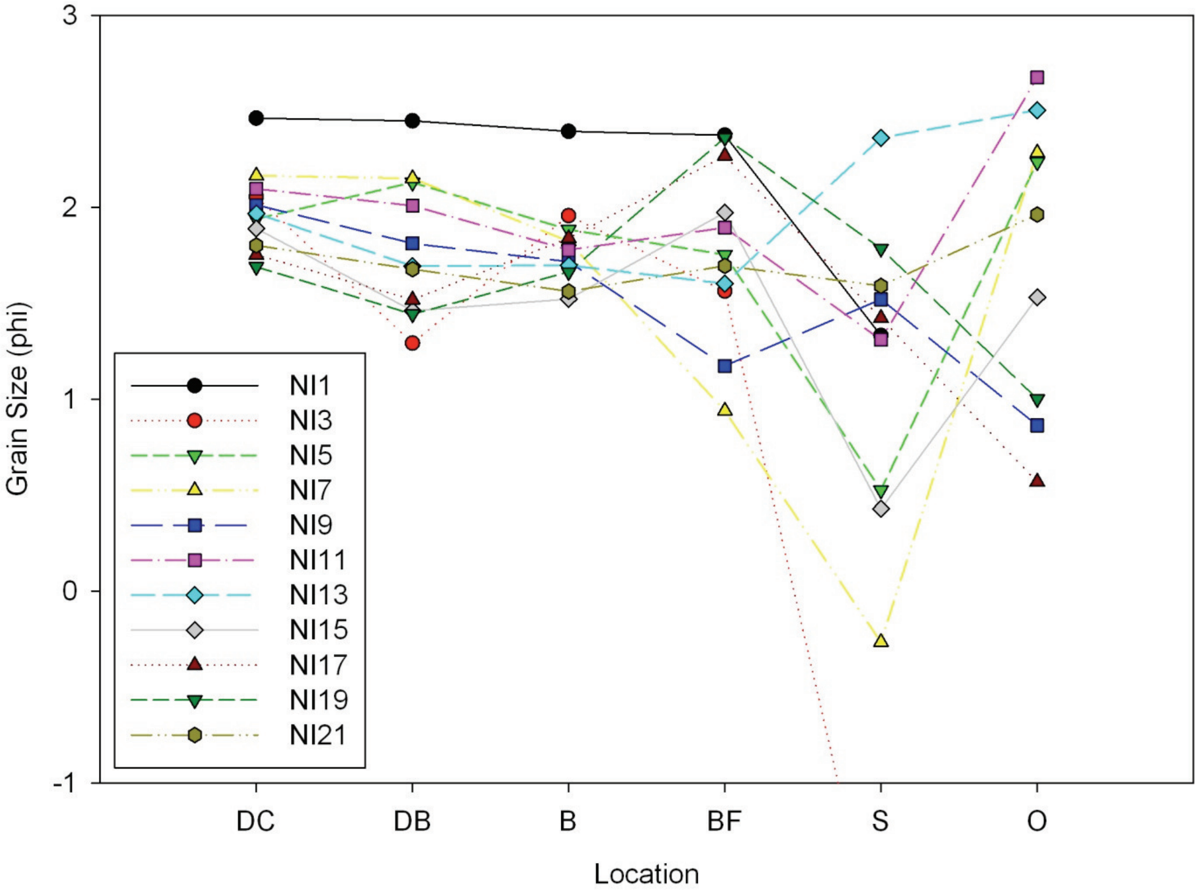


Figure 14. Grain size distribution of surficial sediment samples collected on North Island.

Figure 15. Aerial photograph of South Island taken near the Santee Delta facing north. A tidal inlet bisects Sand Island (to the north) and South Island (to the south). The mouth of Winyah Bay is in the upper right corner of the photograph. Photograph: Aug 2009.

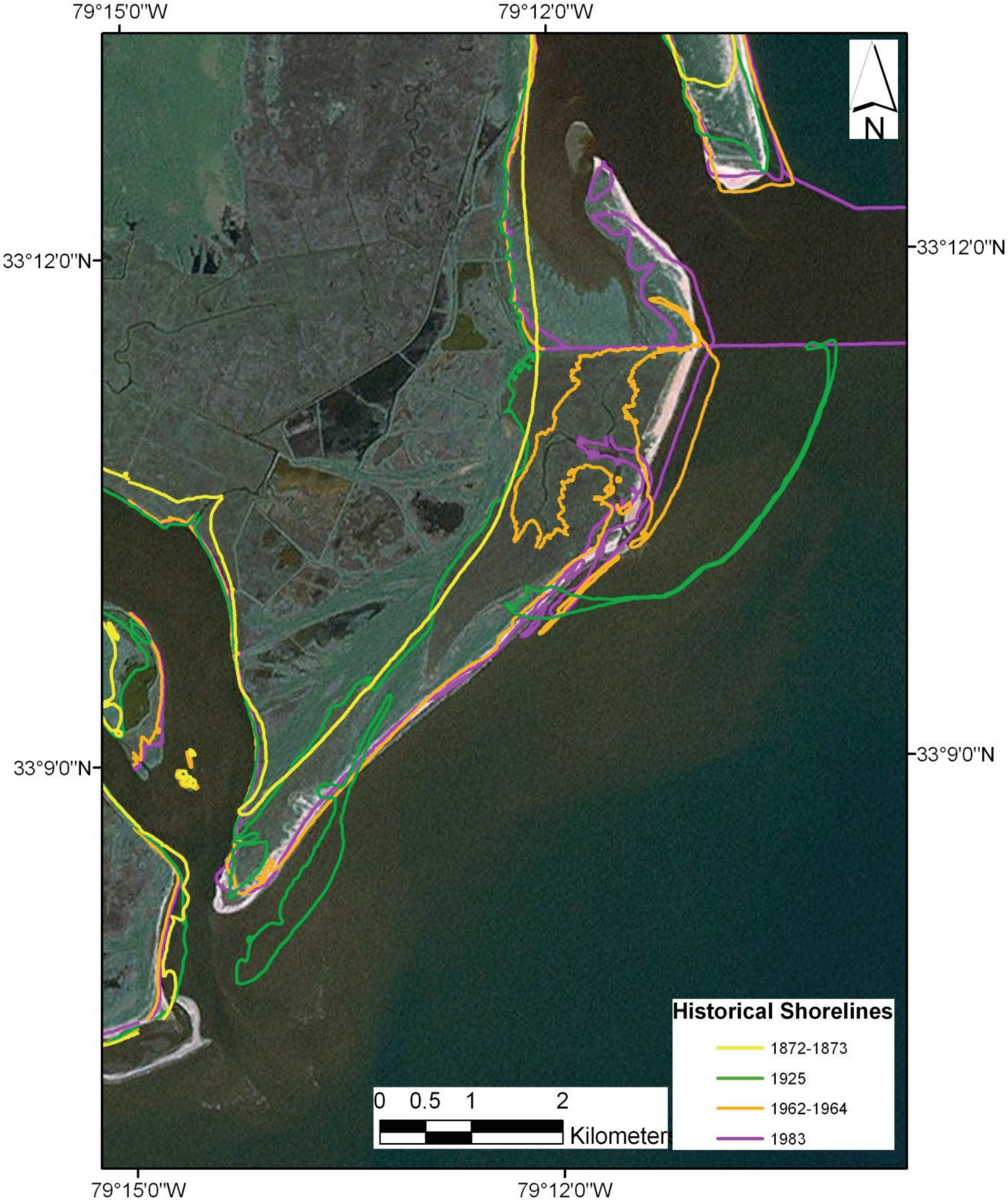

79°15'0"W
79°12'0"W
33°12'0"N
33°9'0"N
N
Historical Shorelines
1872-1873
1925
1962-1964
1983
0 0.5 1 2
Kilometers

Figure 16. Historical shoreline locations at South Island. Shoreline data provided by DHEC. Note: barrier island beaches were not formed until after installation of the Georgetown jetties in the late 1800s.

Figure 17. Aerial photograph of Sand Island illustrating migration of beach and inlet between Sand and South Islands (top). Overwash fans in the marsh adjacent to the beach and exposure of marsh sediments in the surf zone (top, bottom left, bottom right) on the northern half of the island indicate landward migration of the beach system. Photographs: Aug 2009.

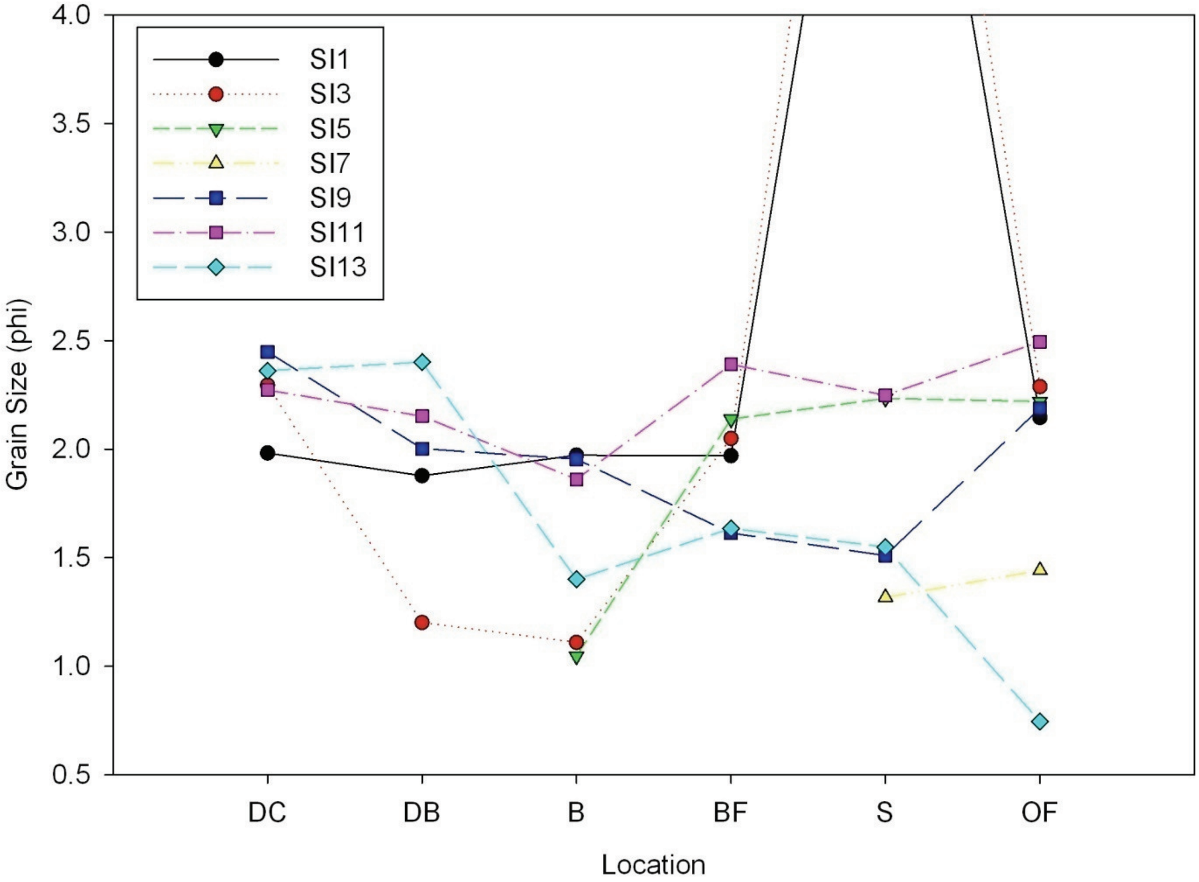


Figure 18. Grain size distribution of surficial sediment samples collected on South Island.

APPENDICES

Appendix 1: Date, Location, and Field Work Conducted for CCU RSM Project

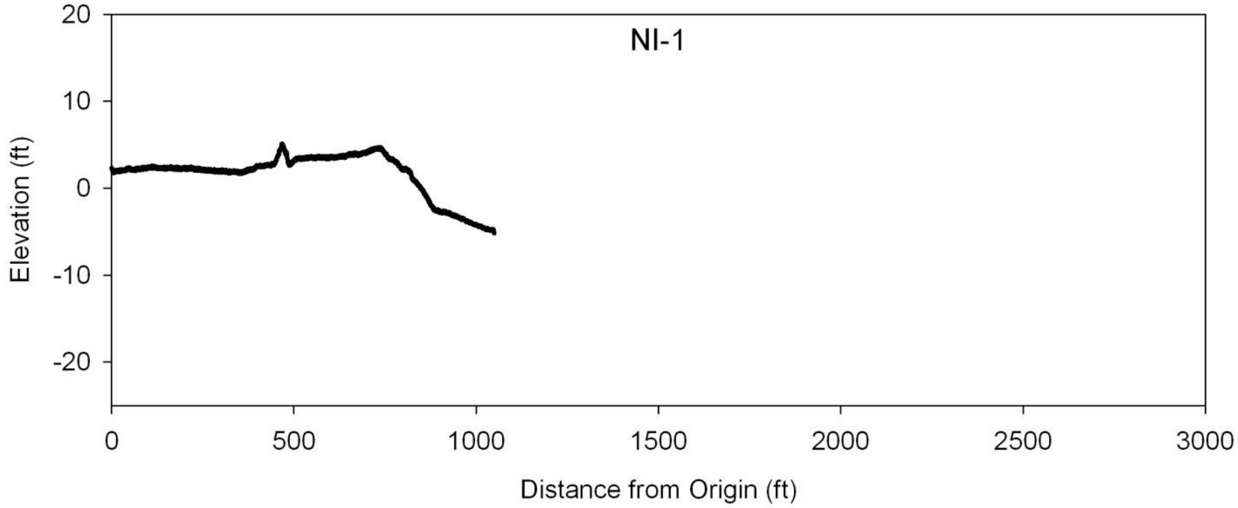
Date	Location(s)	Work Conducted	Comments	Personnel
7-22-09	Baruch/GT Lighthouse	Establish TBMs	2 TBM @ lighthouse	McCoy, Marshall
8-3-09	North Island	Beach profiles, beach sediment sampling	Completed NI1-11	McCoy, Howe, Martin, Young, Ledoux
8-4-09	North Island, South Island	Beach profiles, beach sediment sampling	Completed NI12-22, SI1-6	McCoy, Howe, Martin, Young, Ledoux
8-5-09	Winyah	Multibeam		Phillips, Marshall, Donahue
8-6-09	Winyah	Multibeam		Phillips, Marshall, Donahue
8-7-09	South Island	Beach profiles, beach sediment sampling	Completed SI7-14	McCoy, Howe
8-8-09	North Island	Marine profiles, marine sediment sampling	Completed NI4-22	McCoy, Ledoux
8-17-09	Winyah	Multibeam		Phillips, Marshall, Donahue
8-18-09	Winyah	Multibeam		Phillips, Marshall, Donahue
8-19-09	Winyah	Multibeam		Phillips, Marshall, Donahue
8-21-09	Winyah	Multibeam		Phillips, Marshall, Donahue
10-19-09	Winyah	Multibeam	Win South	Phillips, Marshall
10-20-09	Winyah	Multibeam Single beam	Win South All SI offshore profiles completed	Phillips, Marshall McCoy, Bender
10-21-09	Winyah	Multibeam Single beam	Win South N1	Phillips, Marshall McCoy, Bender
*10-22-09	Winyah	Multibeam	Win South	Phillips, Marshall
11-03-09	Winyah	Multibeam Single Beam	Win South Profiles, N1	Phillips, Marshall McCoy, Johnson
11-05-09	Winyah	Multibeam	Win South	Phillips, Marshall
3-30-10	Winyah	Single Beam	N1	Johnson, Rowell
3-31-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win Entrance Entrance North Entrance North	Phillips, Marshall Johnson Rowell, Stankiewicz
4-1-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win Entrance Sand Island Sand Island	Phillips, Viso, Okano Johnson Rowell, Stankiewicz
4-2-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win Entrance Sand Island Sand Island	Phillips, Okano, Stankiewicz McCoy Rowell
4-5-10	Winyah	Multibeam	N1-M-3, Win Entrance	Phillips, Marshall

		Single Beam (1) Single Beam (2)	N1 N1	Johnson Rowell, Stankiewicz
4-6-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	N1-M-3, Win Entrance Sand Island Sand Island	Phillips, Marshall Johnson Rowell, Stankiewicz
4-12-10	Winyah	Multibeam	N1-M-3	Phillips, Marshall
4-16-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	N1-M-3	Phillips, Marshall Johnson Rowell, Stankiewicz
4-20-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	N1-M-1, N1-M-2, N1-M-3 East Bank East Bank	Phillips, Marshall Johnson Rowell, Stankiewicz
4-22-10	Winyah	Single Beam (1) Single Beam (2)	East Bank East Bank	Johnson Rowell, Stankiewicz
4-29-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	N1-M-1, NI-M-2 North Santee North Santee	Phillips, Marshall Johnson Rowell
5-05-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win Entrance, Win South North Santee North Santee	Phillips, Marshall Johnson Rowell
5-15-10	Winyah	Multibeam	N1-M-1, NI-M-3	Johnson, Marshall
5-18-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win South North Santee North Santee	Phillips, Marshall Johnson Rowell
5-27-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win South North Santee Sand Island	Phillips, Okano Johnson Rowell
5-28-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win South North Santee North Santee	Phillips, Okano Johnson Rowell
5-29-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	Win South North Santee North Santee	McCoy, Viso Johnson Rowell
6-02-10	Winyah	Multibeam	WinSouth	Phillips, Marshall
6-08-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	WinSouth North Santee North Santee	Phillips, Marshall Johnson Rowell
6-11-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	WinSouth North Santee North Santee	Phillips, Marshall Johnson Rowell
6-12-10	Winyah	Multibeam Single Beam (1)	N2-M-1 North Santee	McCoy, Marshall Johnson
6-15-10	Winyah	Multibeam Single Beam (1) Single Beam (2)	N2-M-1 North Santee North Santee	Phillips, Marshall Johnson Rowell
6-17-10	Winyah	Multibeam	N2-M-1	Phillips, Marshall
6-18-10	Winyah	Multibeam	N2-M-1	Phillips, Marshall

6-21-10	Winyah	Multibeam	N2-M-1	Phillips, Marshall
6-22-10	Winyah	Multibeam	N2-M-1	Phillips, Marshall
7-12-10	Charleston	Multibeam	Patch test	Phillips, Marshall, Johnson
7-13-10	Charleston	Multibeam Single Beam (1)	S. Channel Cut, S. Channel Morris 1	Phillips, Marshall Johnson
7-14-10	Charleston	Multibeam Single Beam (1)	S. Channel Cut, S. Channel Morris 2	Phillips, Marshall Johnson
7-15-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf, S. Channel Sullivans 1	Phillips, Marshall Johnson
7-18-10	Charleston	Single Beam (1)	Sullivans 1	Johnson
7-21-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf, S. Channel Sullivans 1	Phillips, Marshall Johnson
7-22-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf, S. Channel Sullivans 1	Phillips, Marshall Johnson
7-23-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf Sullivans 1	Phillips, Marshall Johnson
7-24-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf Sullivans 1	Phillips, Marshall Johnson
7-25-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf Sullivans 1	Phillips, Marshall Johnson
7-27-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf Sullivans 1	Phillips, Marshall Johnson
7-28-10	Charleston	Multibeam Single Beam (1)	South Shelf Entrance Shelf South Channel Morris 3 South Shelf	Phillips, Marshall Johnson
7-29-10	Charleston	Multibeam Single Beam (1)	Entrance Shelf South Shelf South Channel South Channel Cut Morris 3	Phillips, Marshall Johnson
7-30-10	Charleston	Single Beam (1)	Morris 3	Johnson
8-16-10	Winyah	Single Beam (1)	North Inlet	Johnson
8-17-10	Winyah	Single Beam (1)	North Inlet	Johnson
8-18-10	Winyah	Single Beam (1)	North Inlet	Johnson

*Note 10-22-09 has been added to the table as of Mar. 31, 2010.

Appendix 2: Beach Profiles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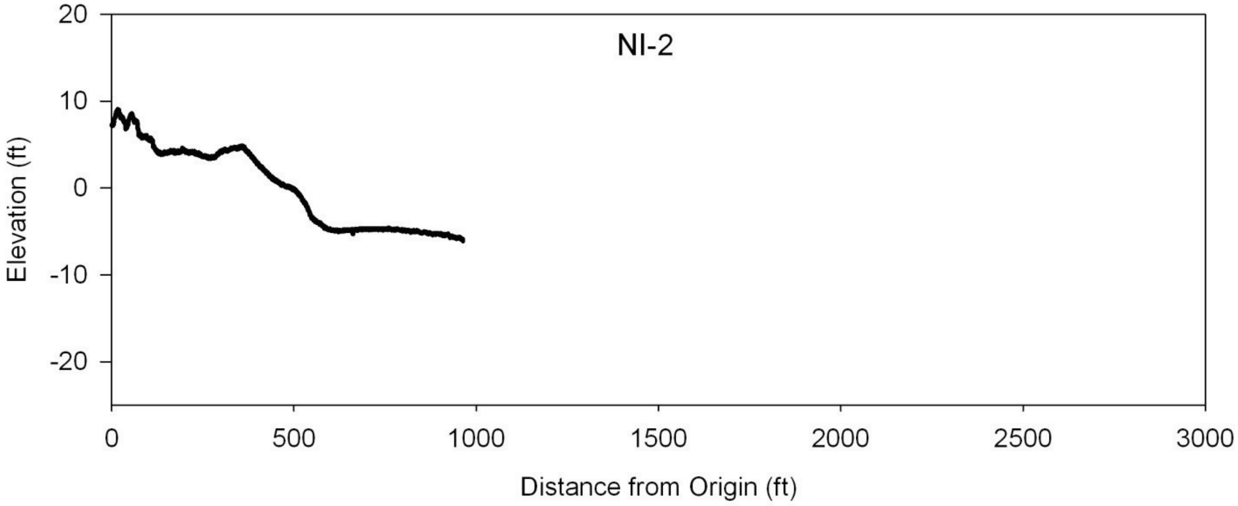
2500
3000
Distance from Origin (ft)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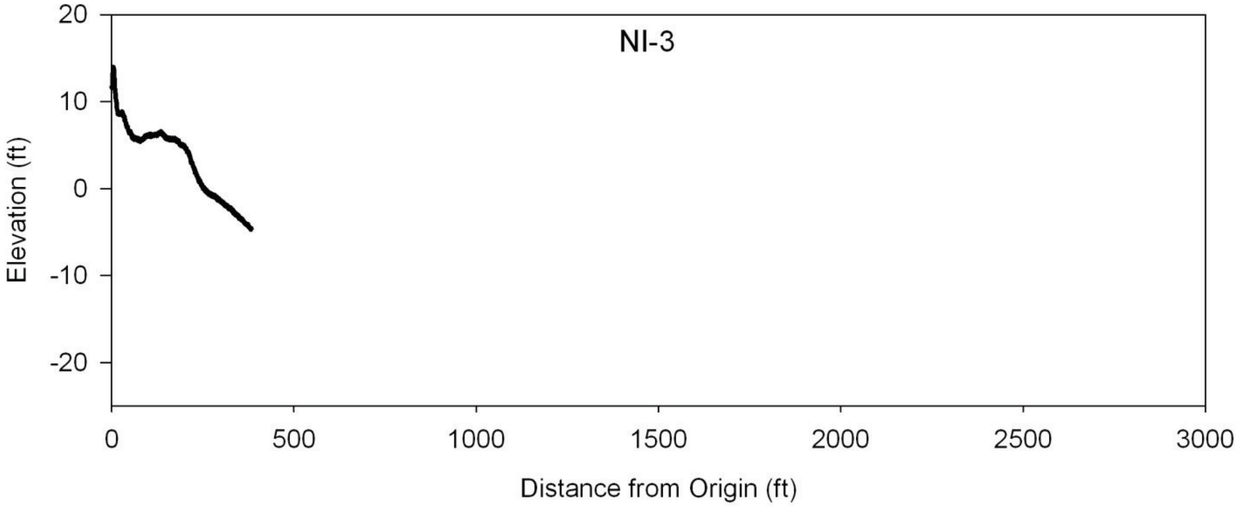
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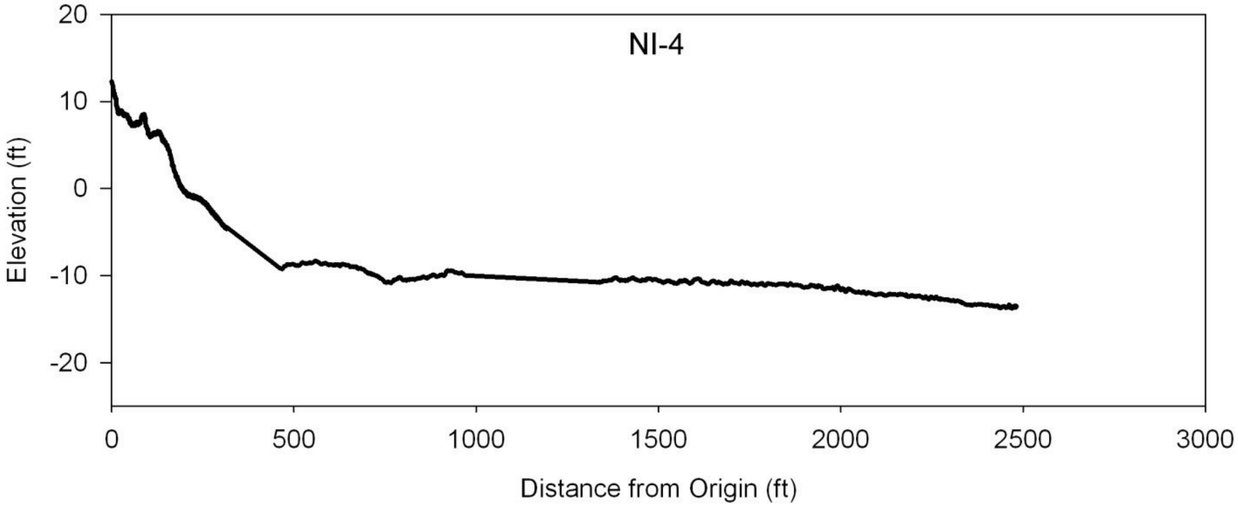
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-20
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2000
2500
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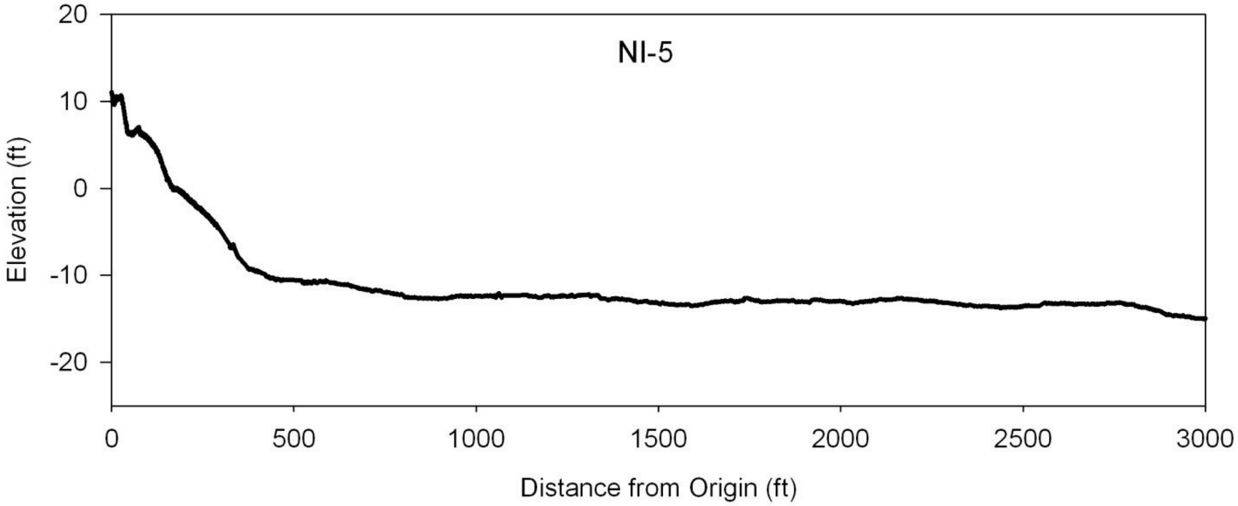
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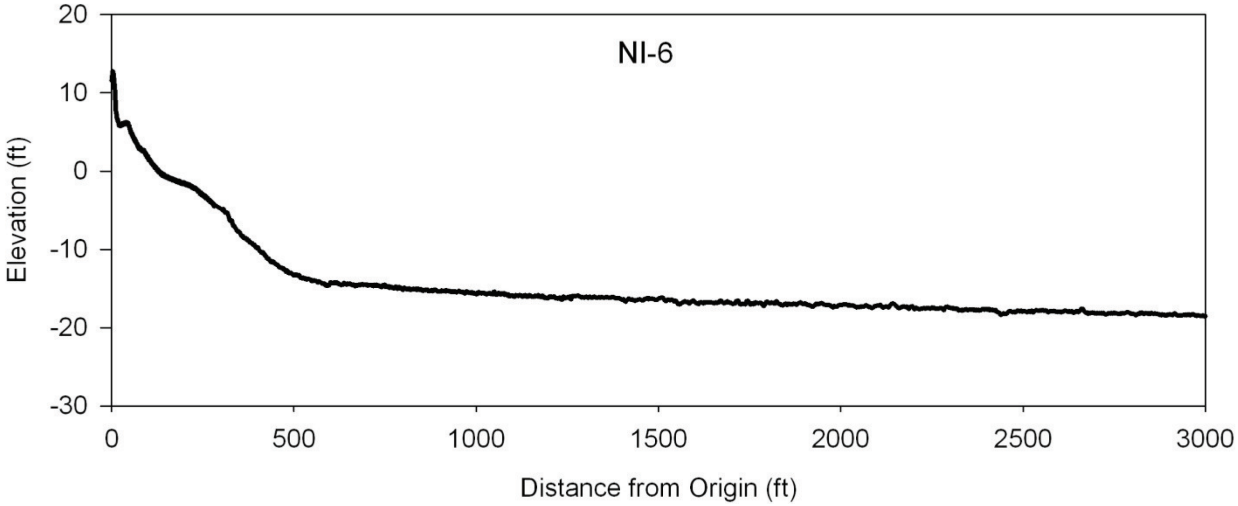
Distance from Origin (ft)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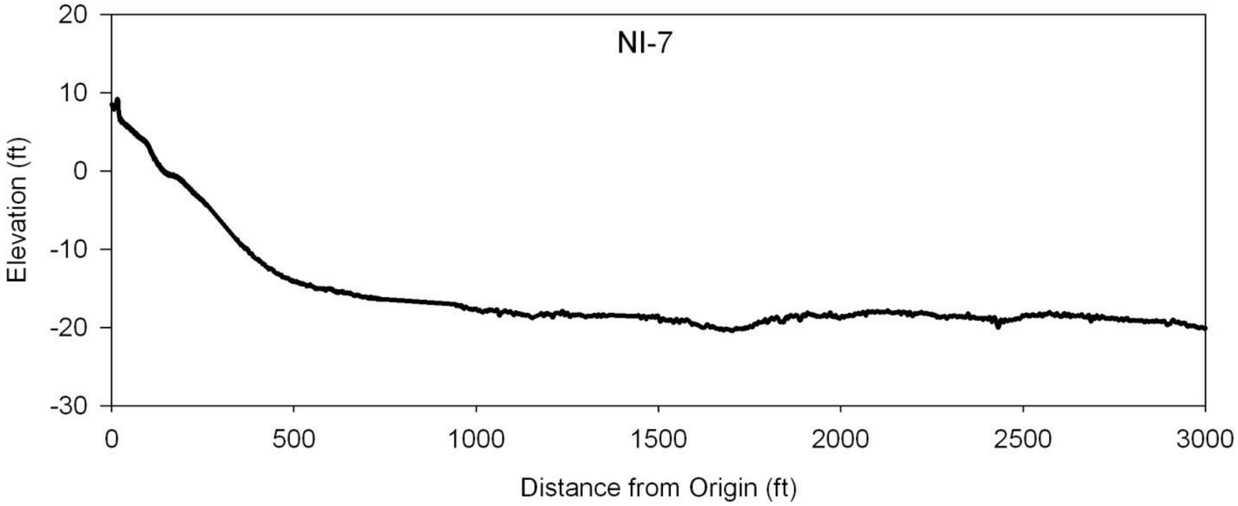
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3000
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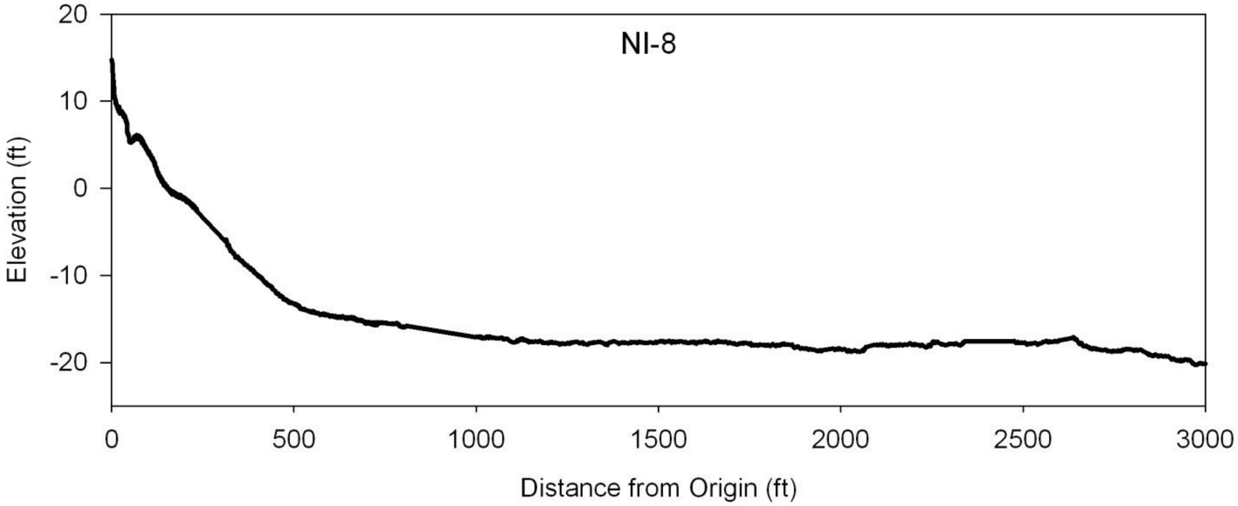
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2500
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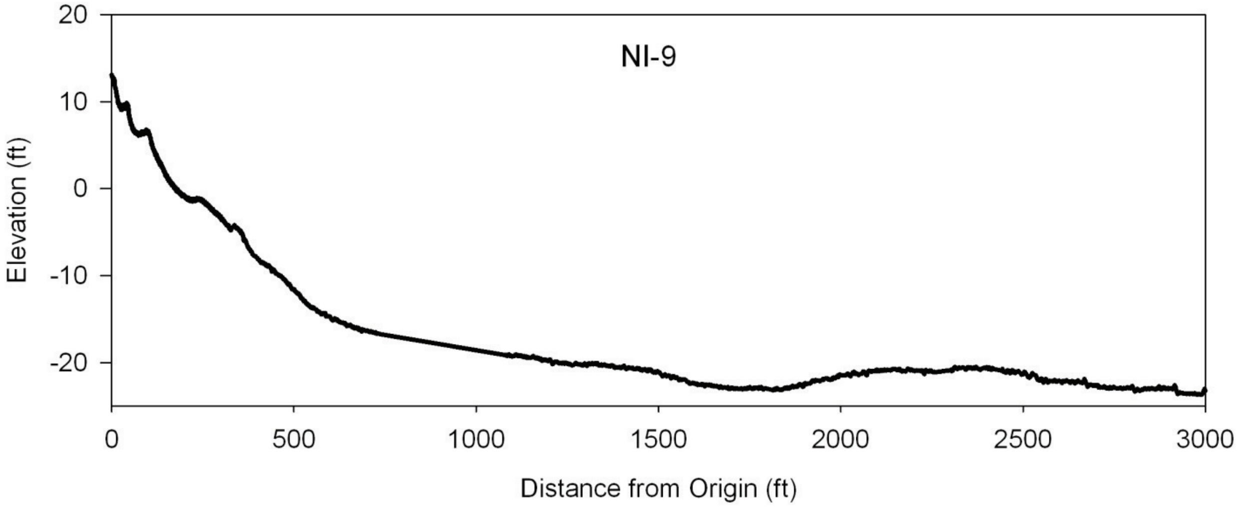
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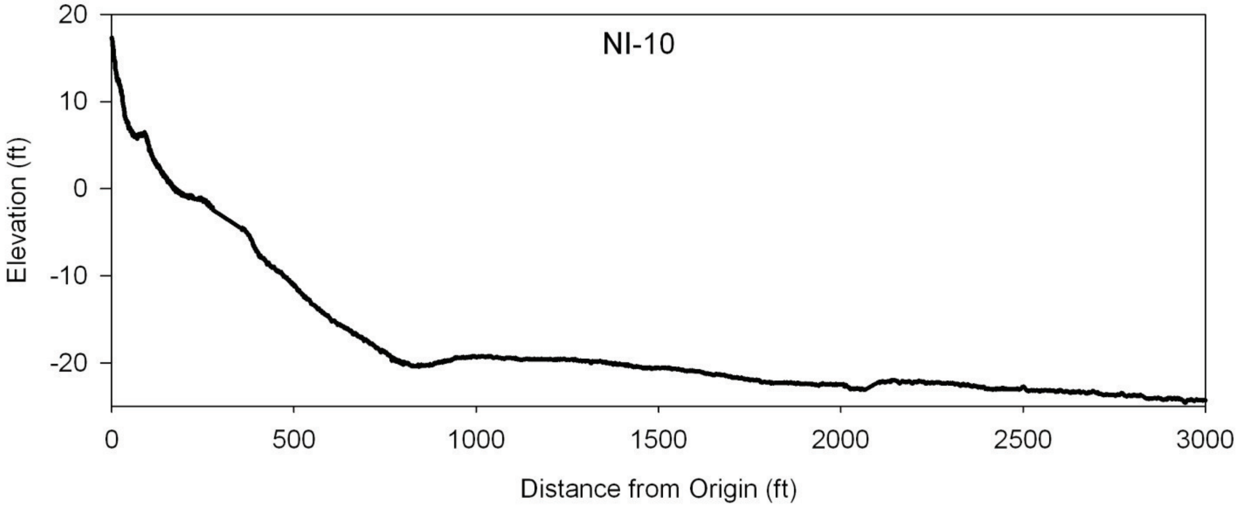
Distance from Origin (ft)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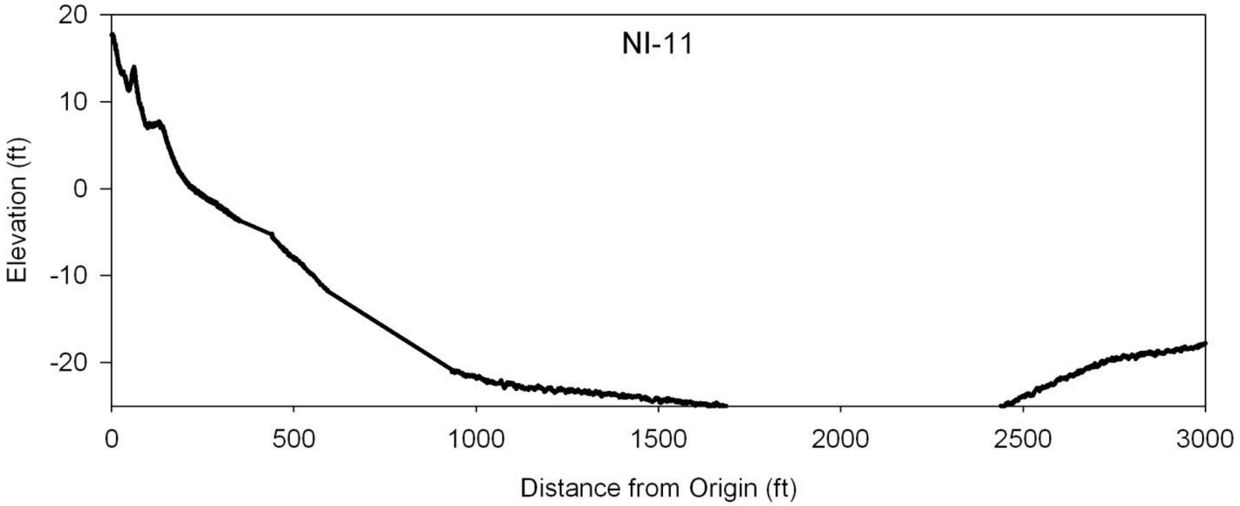
Distance from Origin (ft)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2500
3000
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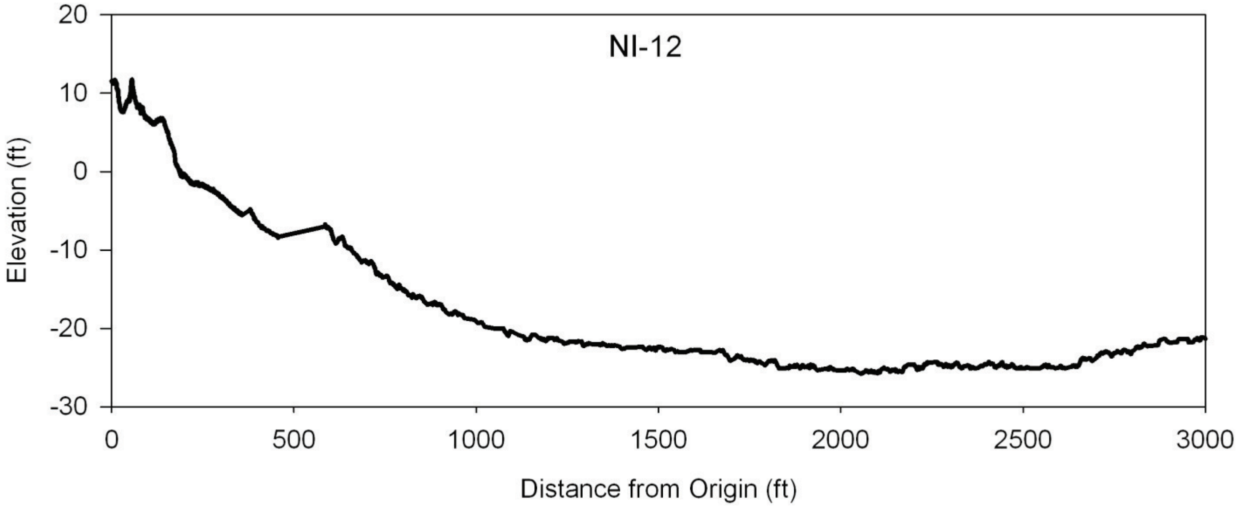
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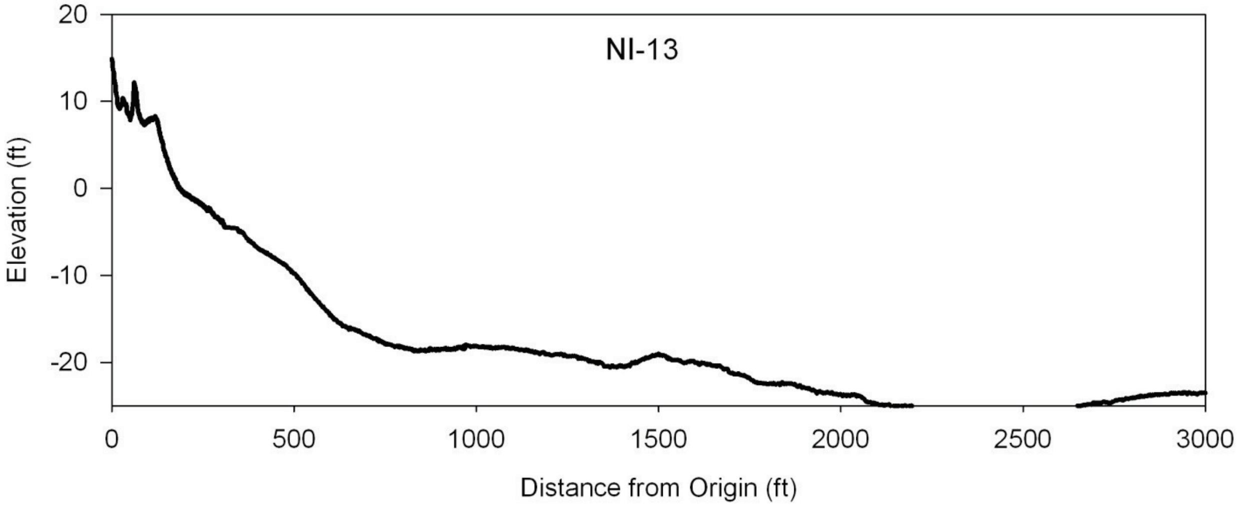
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2500
3000
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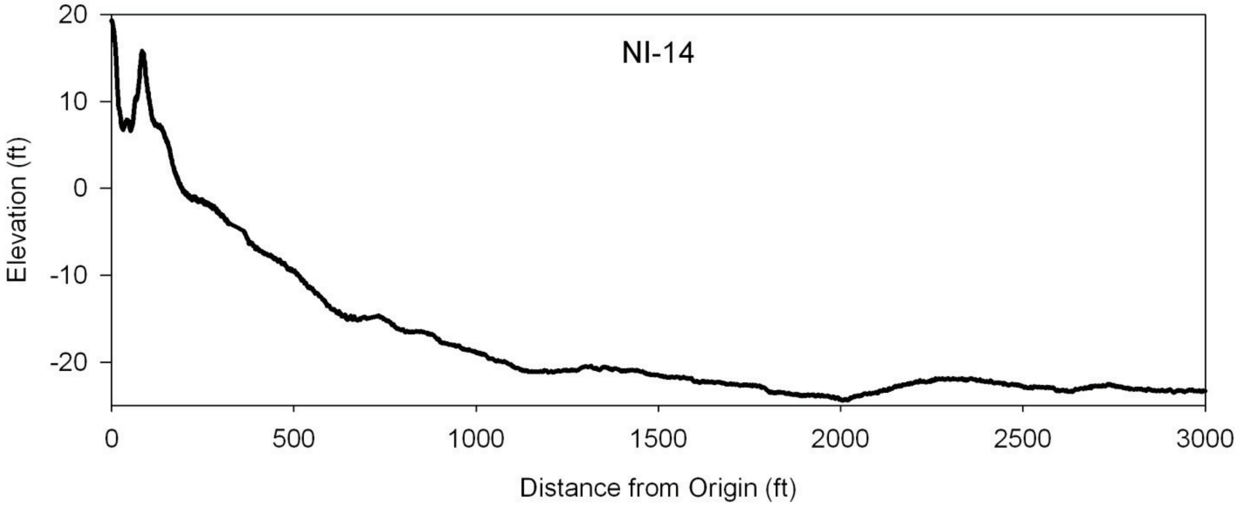
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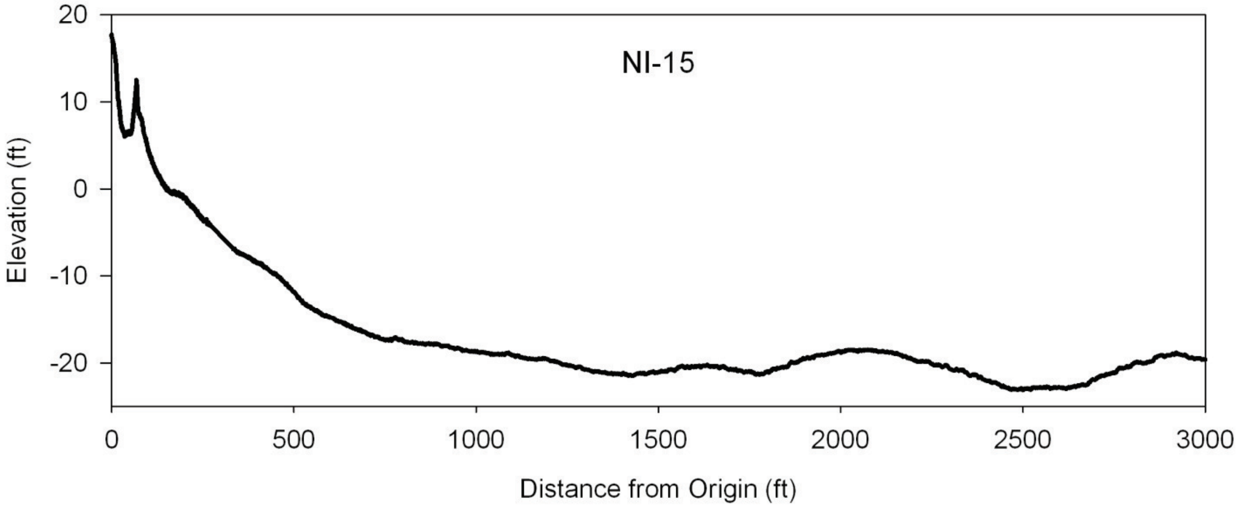
2000
2500
3000
Distance from Origin (ft)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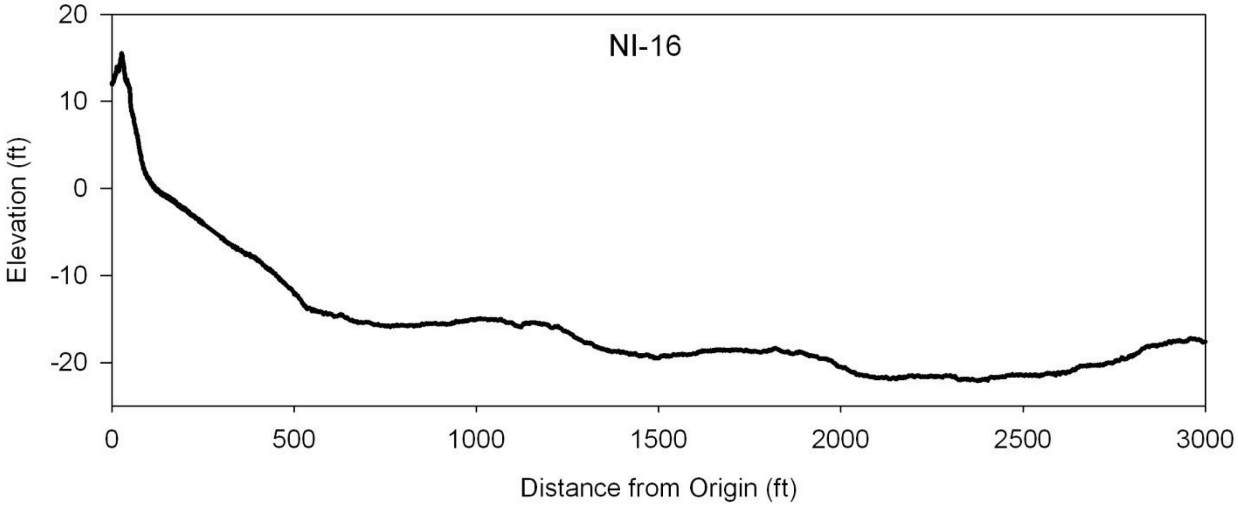
Distance from Origin (ft)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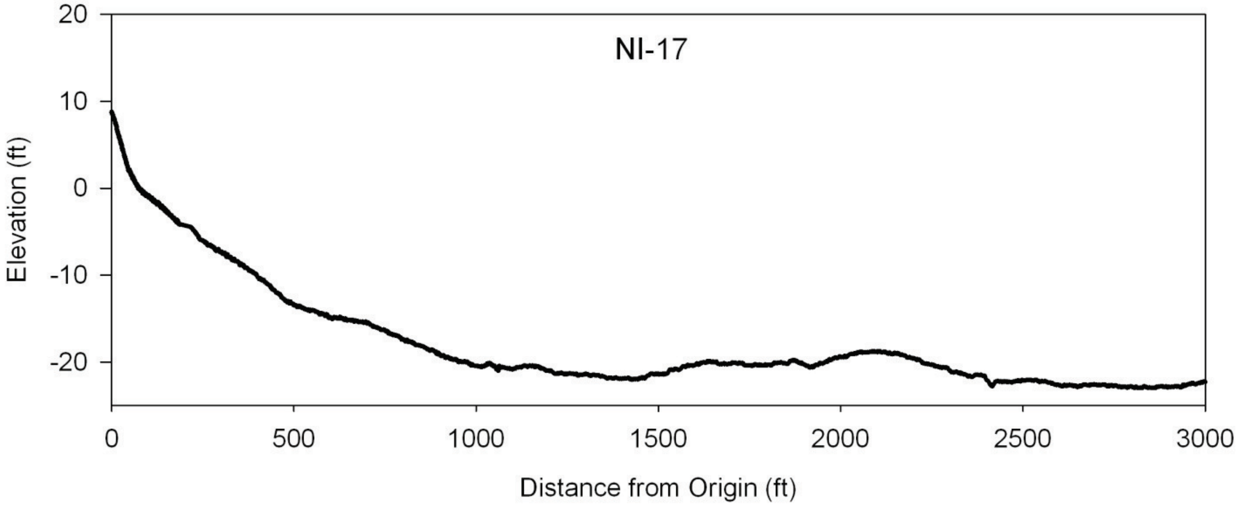
Distance from Origin (ft)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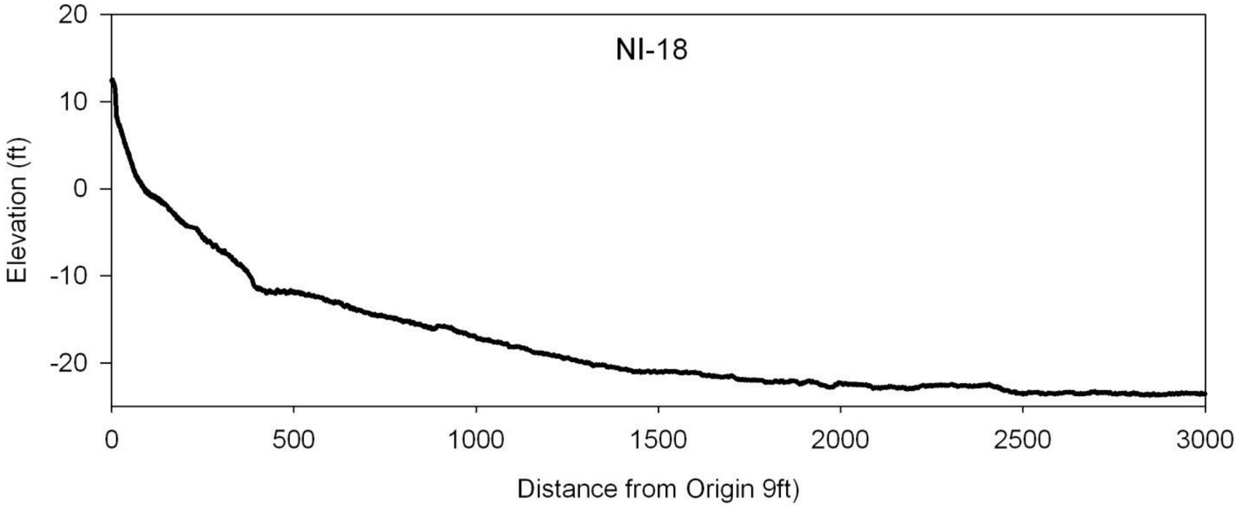
Distance from Origin (ft)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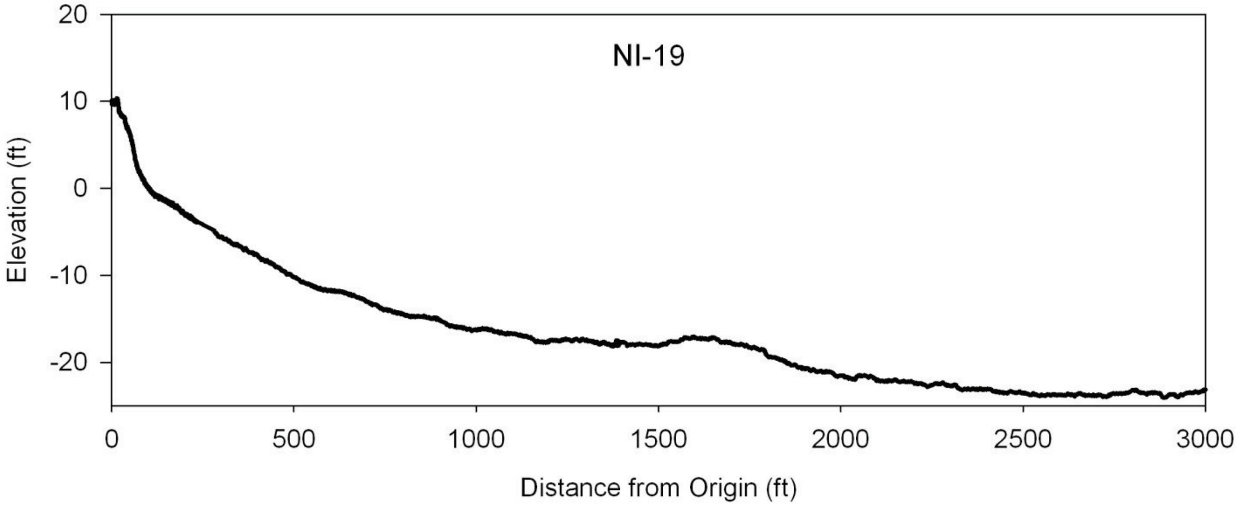
2500
3000
Distance from Origin 9ft)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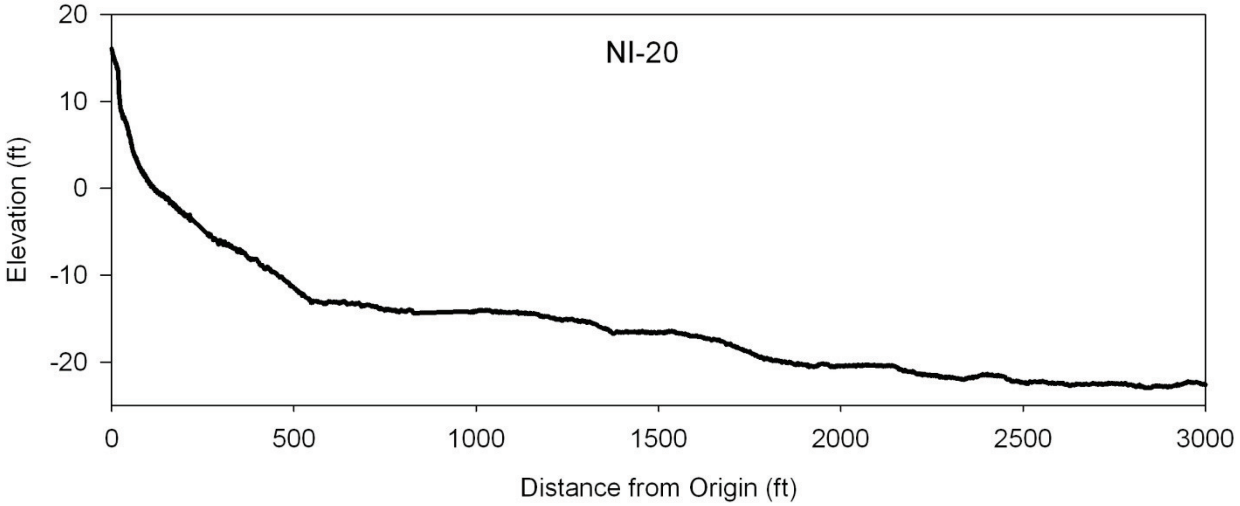
1500
2000
2500
3000
Distance from Origin (ft)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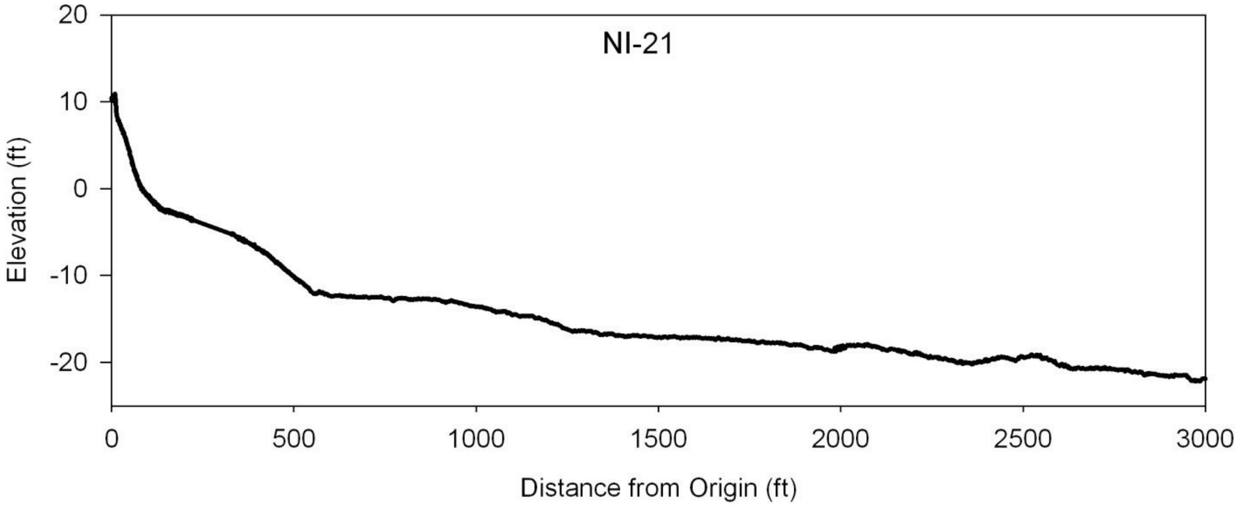
3000
Distance from Origin (ft)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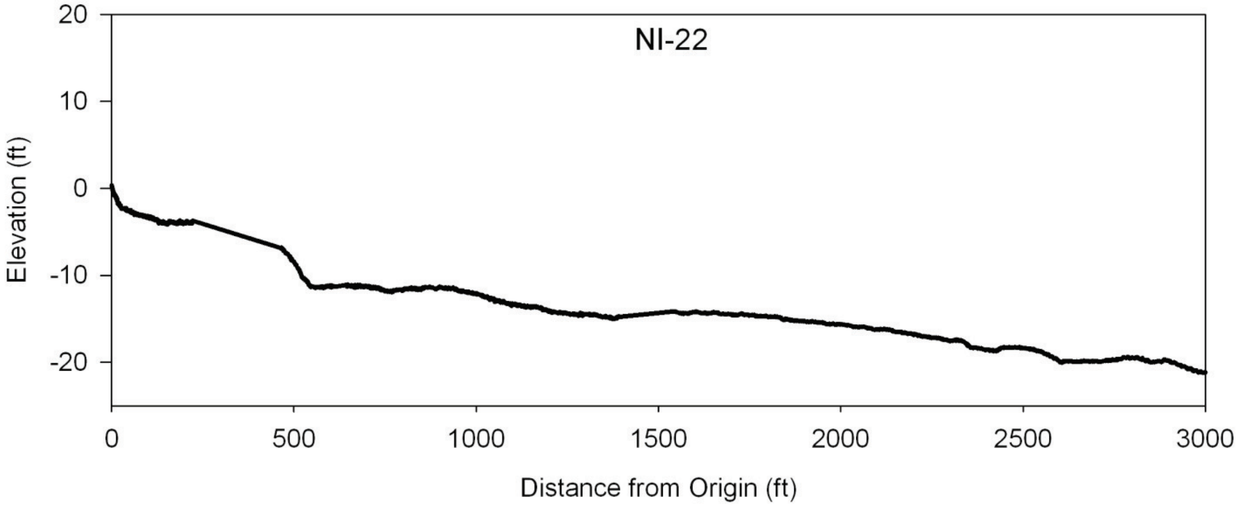
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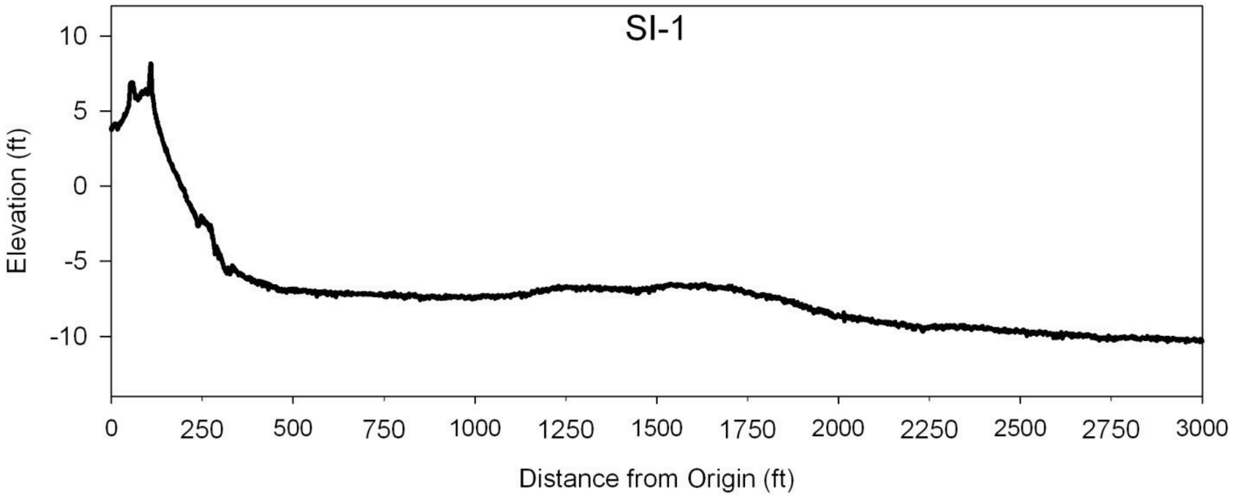
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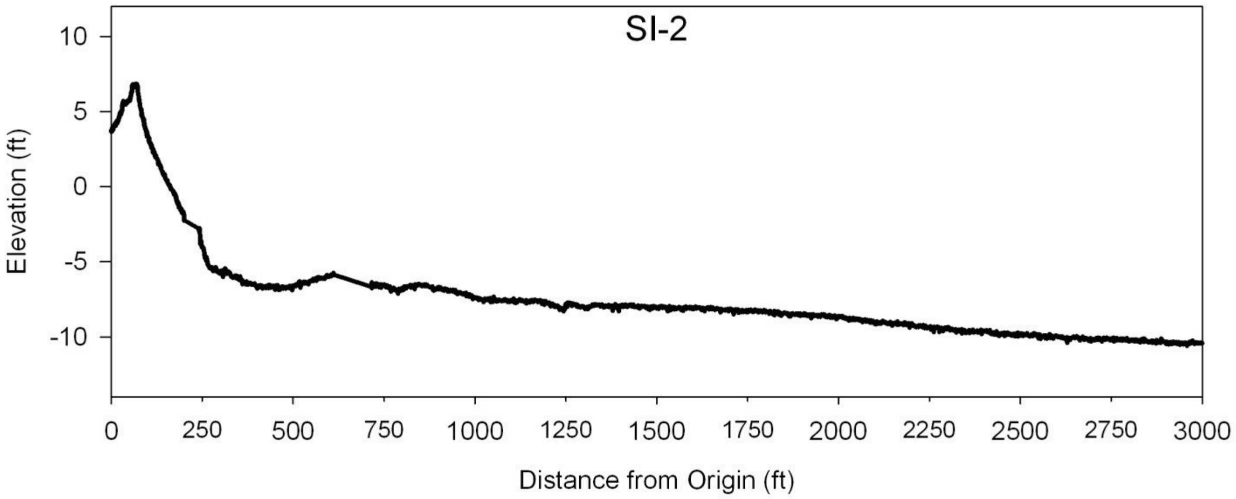
Distance from Origin (ft)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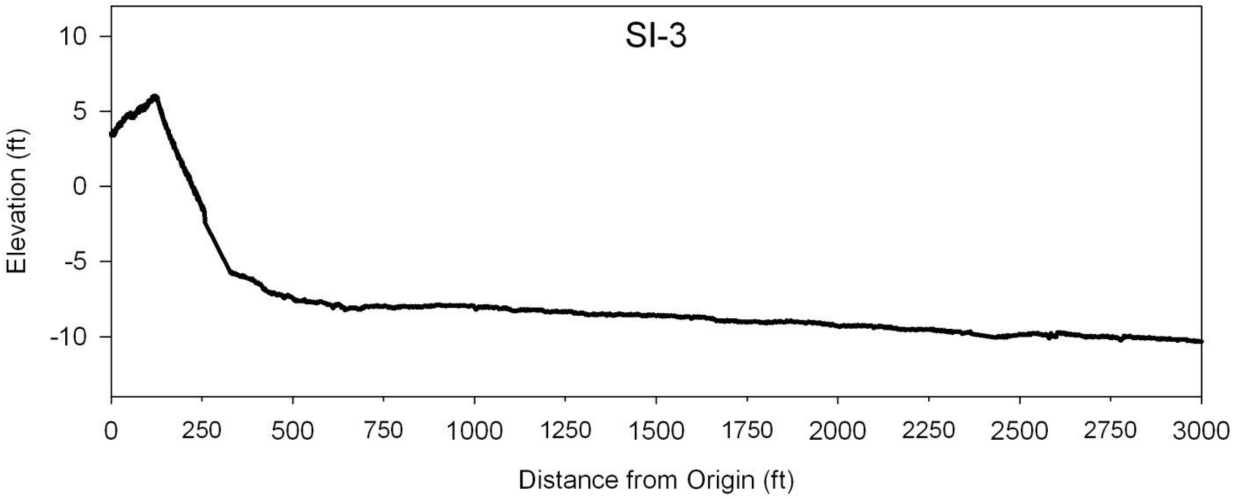
3000
Distance from Origin (ft)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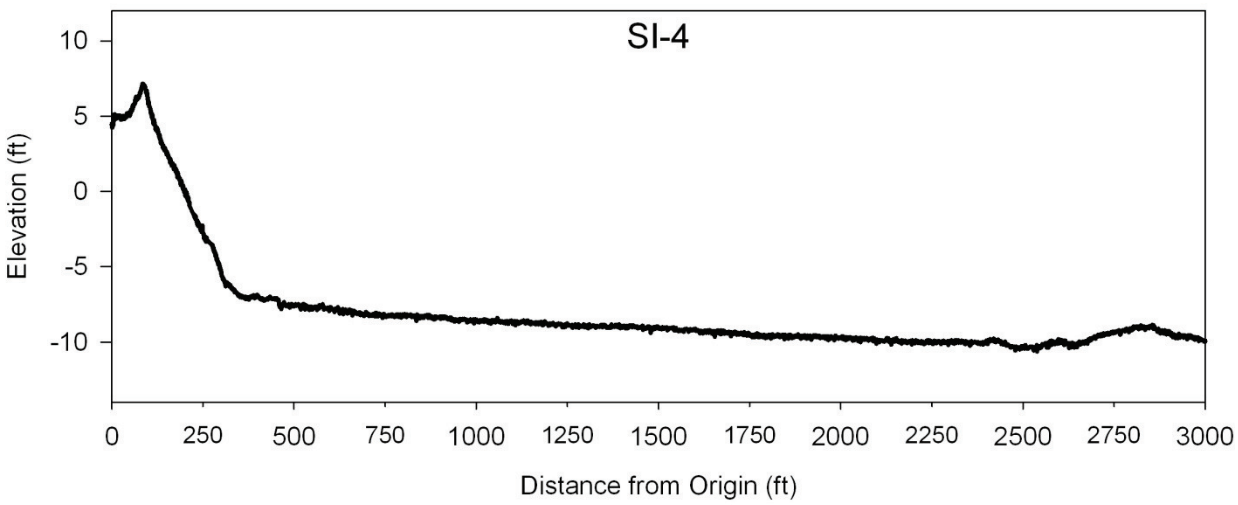
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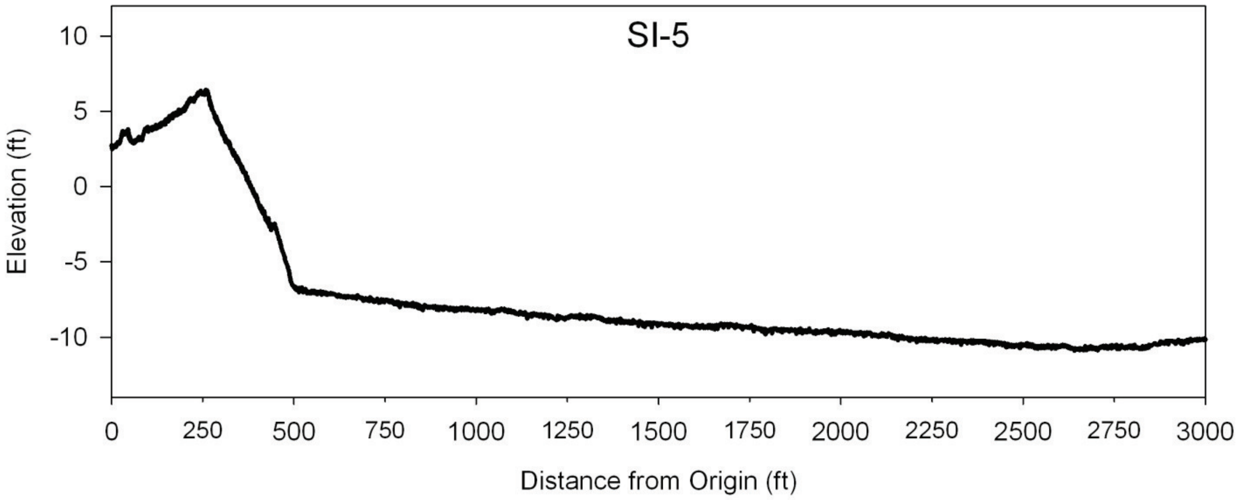
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-5
Elevation (ft)
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-10
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250
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750
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1250
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1750
2000
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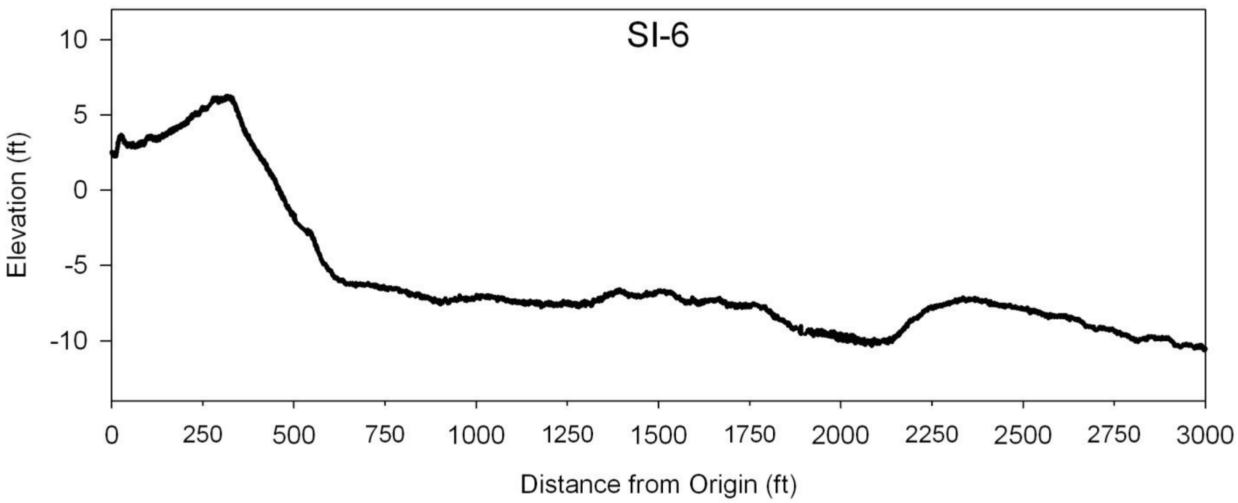
2750
3000
Distance from Origin (ft)


SI-6
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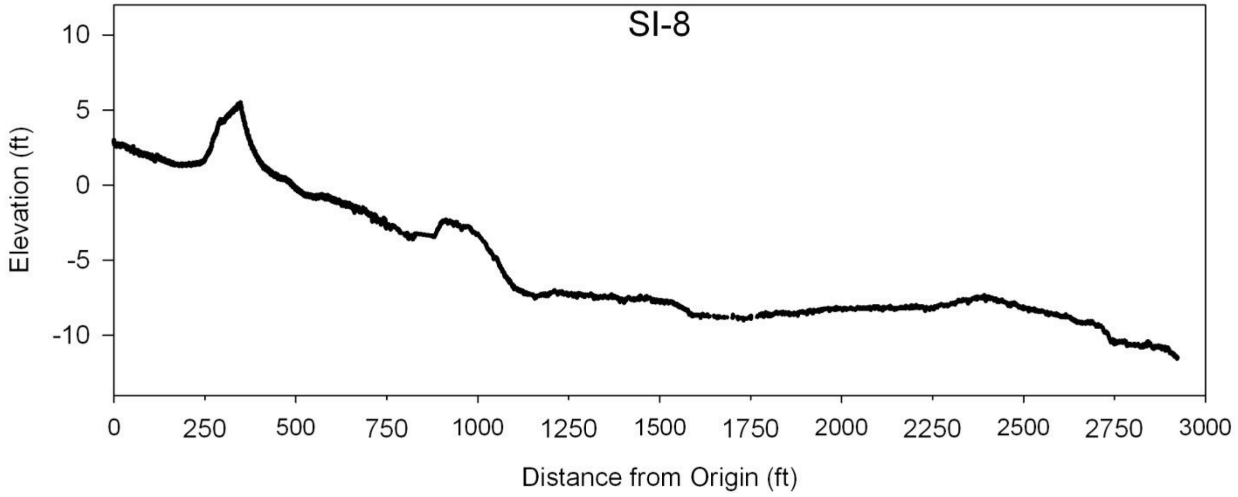
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-8
Elevation (ft)
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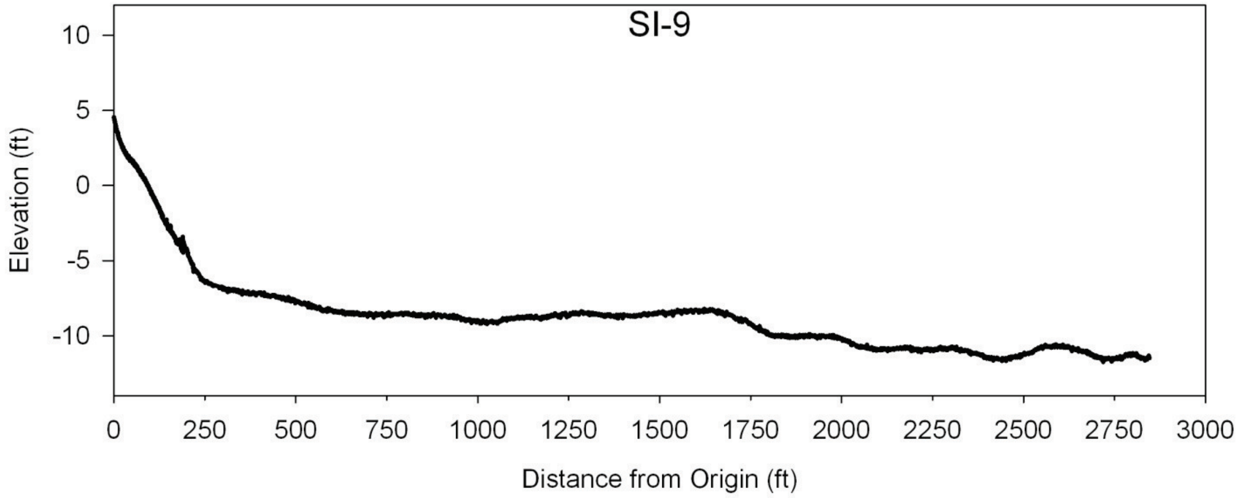
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-9
Elevation (ft)
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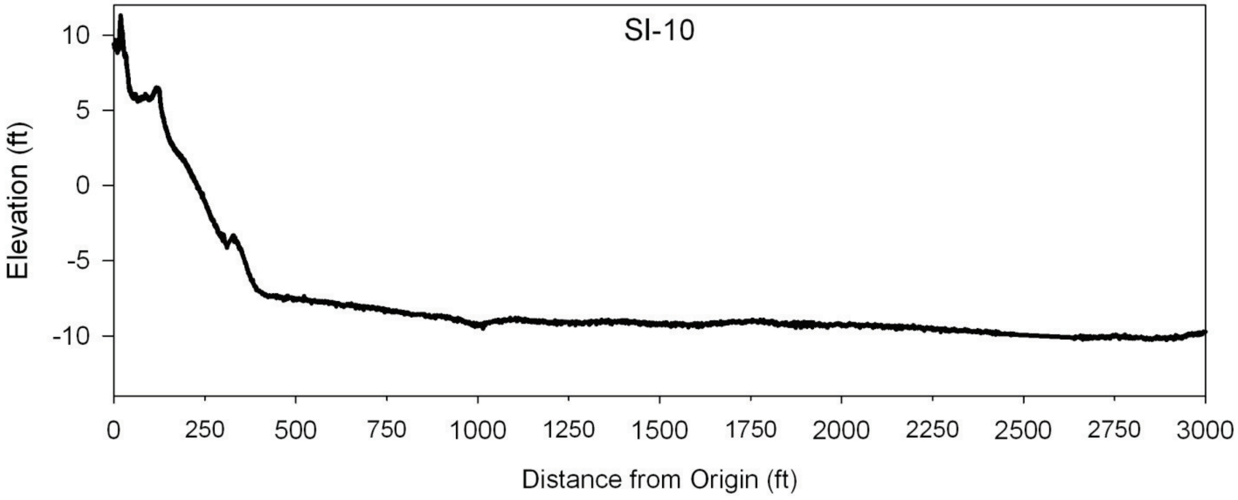
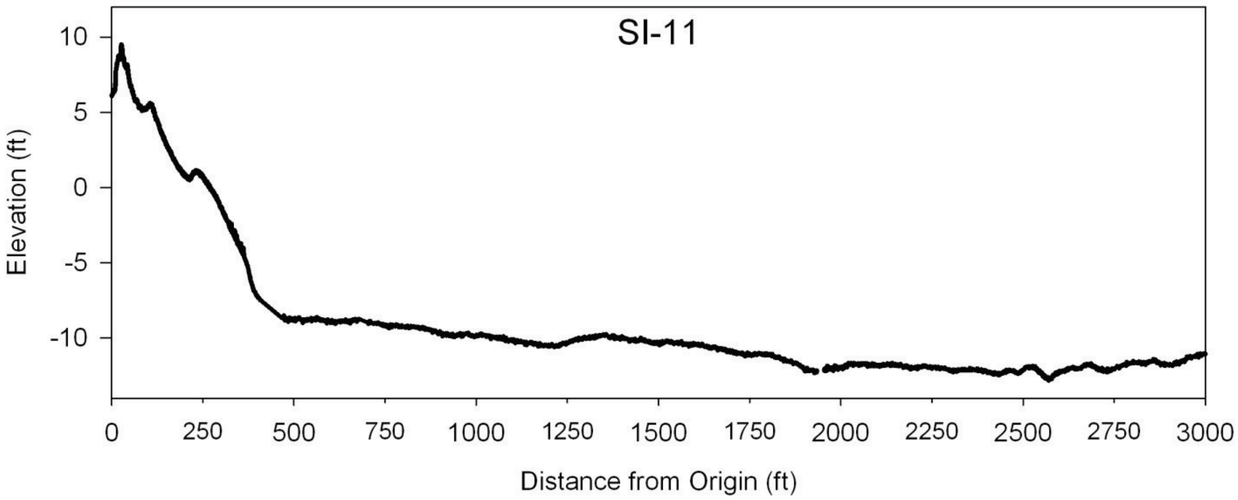
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-10
Elevation (ft)
10
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-11
Elevation (ft)
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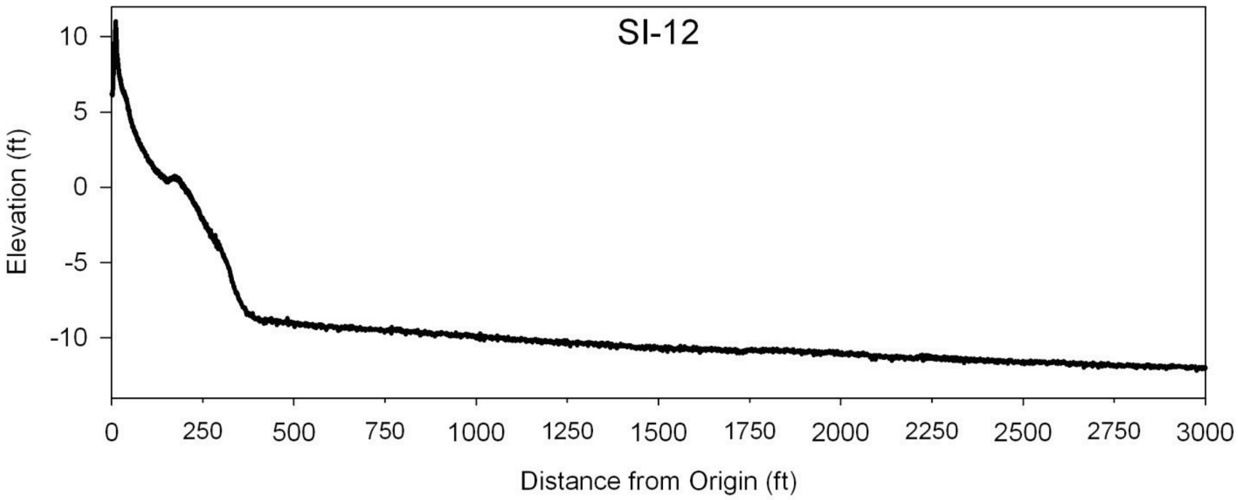
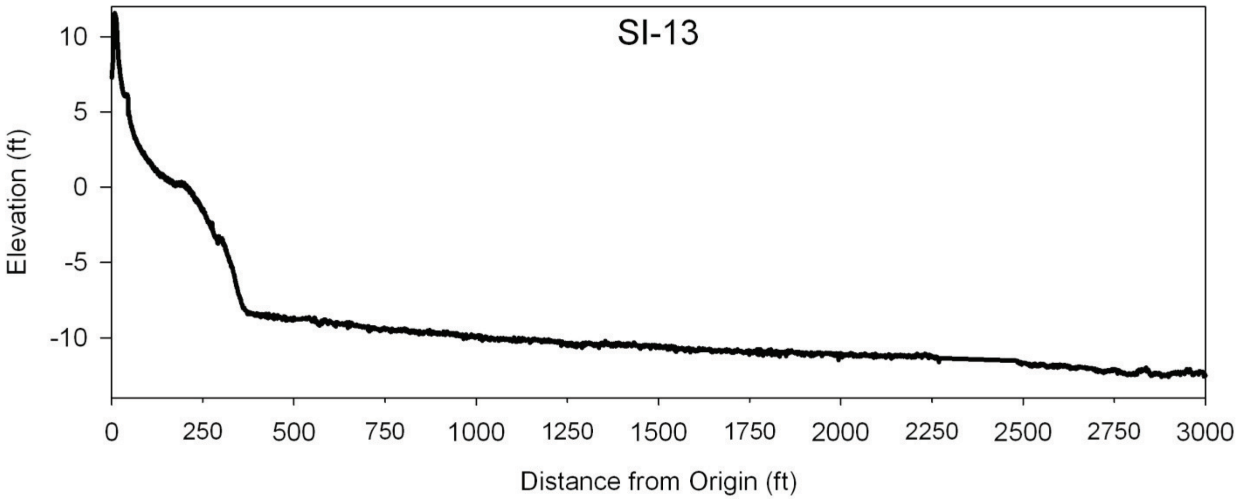
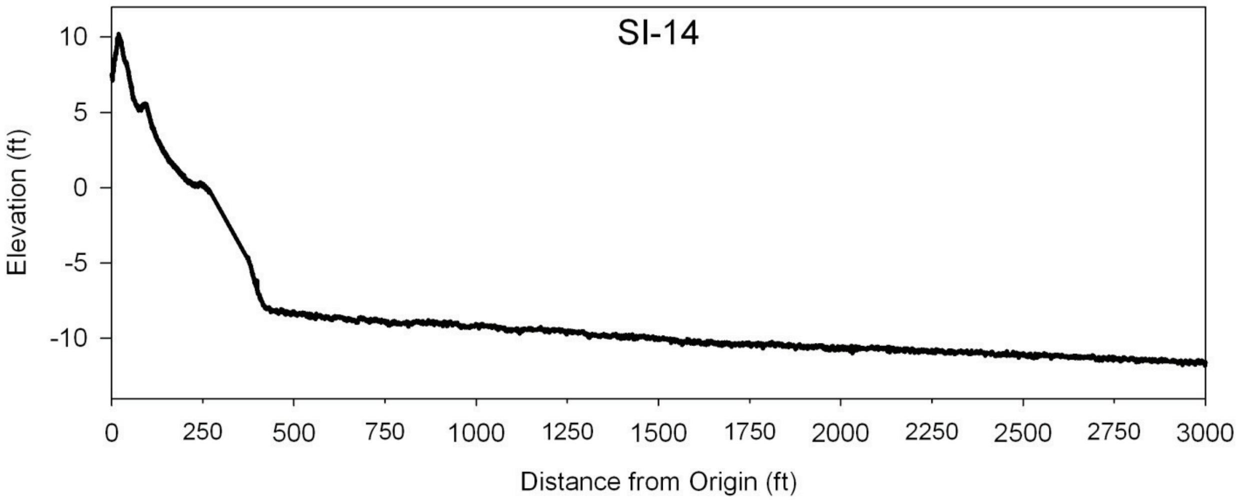
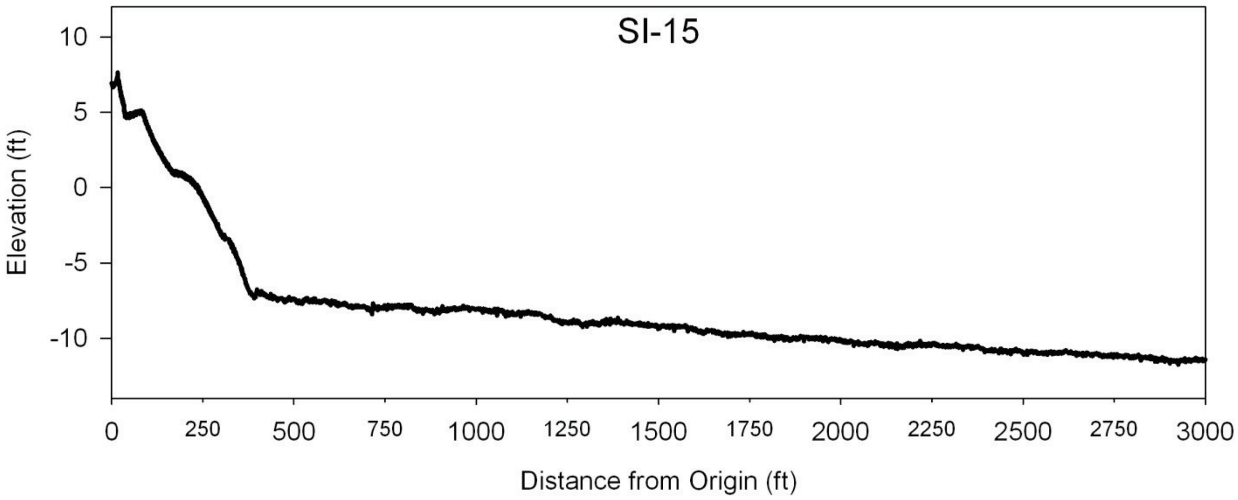
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-12
Elevation (ft)
10
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-13
Elevation (ft)
10
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-14
Elevation (ft)
10
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)


SI-15
Elevation (ft)
10
5
0
-5
-10
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
Distance from Origin (ft)

Appendix 3: Benchmark Information used for RSM Phases, 1, 2, and 3

Georgetown Harbor Inlet

TBM: Clambank Dock Causeway at Baruch Field Lab
Directions: http://links.baruch.sc.edu/BWBIMCSservices.htm
Northing: 551173.215 ift SC SPC
Easting: 2551490.83 ift SC SPC
Elevation: 4.95 ft NAVD ‘88
Latitude: 33°20’05.9487”N decimal minutes
Longitude: 79°11’38.4395”W decimal minutes
Ground Ellipsoid: -33.152m

TBM: RedRock at G-Town Light, Winyah Bay, SC
Directions: left at the Y in the walkway as approaching the lighthouse - look for distinct triangle shaped red shale colored rock imbedded in second sidewalk pad.
Northing: 510338.941 ift SC SPC
Easting: 2554735.363 ift SC SPC
Elevation: 4.53 ft NAVD ‘88
Latitude: 33°13’21.3814”N decimal minutes
Longitude: 79°11’08.6474”W decimal minutes
Ground Ellipsoid: -33.181m

TBM: BlackRock at G-Town Light, Winyah Bay, SC
Directions: left at the Y in the walkway as approaching the lighthouse - look for distinct triangle shaped black rock imbedded in first sidewalk pad.
Northing: 510337.324 ift SC SPC
Easting: 2554729.300 ift SC SPC
Elevation: 4.32 ft NAVD ’88
Latitude: 33°13’21.3665”N decimal minutes
Longitude: 79°11’08.7191”W decimal minutes
Ground Ellipsoid: -33.245m

TBM: Lighthouse Dock “Washer” at G-Town Light, Winyah Bay, SC
Directions: When docking the boat at G-Town Lighthouse, a washer was placed in center of boardwalk. Confidence is low in the accuracy of this point due to poor RTK fix when being marked.
Northing: 510260.56 ift SC SPC
Easting: 2554381.28 ift SC SPC
Elevation: 6.53 ft NAVD ‘88
Latitude: 33°13’20.6674”
Longitude: 79°11’12.8316”
Ground Ellipsoid: -32.569m

TBM: Lighthouse Deck at G-Town Light, Winyah Bay, SC
Directions: Exit lighthouse at the summit. The railing post immediately to your port is where the antenna affixed to the QC pole are mounted vertically.
Northing: 510350.82 ift SC SPC
Easting: 2554951.08 ift SC SPC
Elevation: 77.90 ift NAVD ’88 (23.7442ft)
Latitude: 33°13’21.4614”
Longitude: 79°11’06.1056”
Ground Ellipsoid:-10.818m

TBM: Observation Tower at Baruch Field Lab
Directions: Antenna placed vertically at eastern corner of observation tower.
Northing: 3689874.35 UTM (zone 17N)
Easting: 668033.33 UTM (zone 17N)
Elevation: 18.45m NAVD ’88
Latitude: 33˚20’05.7753”N Decimal Minutes
Longitude: 79˚11’40.1964”W Decimal Minutes

Charleston Harbor Inlet

Tidal Bench Mark: Johnson RM 3 (PID# CJ0398)
Directions: Located at Fort Johnson SC Department of Natural Resources Marine Division facility on James Island. Adjacent to north side of civil war brick structure.
Northing: 335910.19 ift SC SPC
Easting: 2338799.18 ift SC SPC
Elevation: 6.83 ft NAVD ‘88
Latitude: 32°45’05.67206”N decimal minutes
Longitude: 79°53’52.68336”W decimal minutes
Ground Ellipsoid: -31.165m

No image available

Tidal Bench Mark: Ft Johnson 8 (PID# CJ0400)
Directions: Located at Fort Johnson SC Department of Natural Resources Marine Division facility on James Island. Embedded in concrete seawall along the edge of DNR dock.
Northing: 336518.83 ift SC SPC
Easting: 2338482.83 ift SC SPC
Elevation: 6.06 ft NAVD ‘88
Latitude: 32°45’11.72762”N decimal minutes
Longitude: 79°53’56.31161”W decimal minutes
Ground Ellipsoid: -31.410m
Vertical Order – First Class II

TBM: Fort Johnson Seawall
Directions: Southeast corner of concrete slab adjacent to seawall at Fort Johnson SC Department of Natural Resources Marine Division facility. Adjacent to “No Fishing” sign.
Northing: 336540.97 ift SC SPC
Easting: 2338486.79 ift SC SPC
Elevation: 6.43 ft NAVD ‘88
Latitude: 32°45’11.9463”N decimal minutes
Longitude: 79°53’56.2625”W decimal minutes
Ground Ellipsoid: -31.287m

Appendix 4: Sediment Sampling Coordinates (UTM meters, Zone 17N)

Profile	Location	Northing	Easting
NI1	DC	3687966	671066
NI1	DB	3687964	671069
NI1	B	3687964	671153
NI1	BF	3687960	671174
NI1	S	3687965	671190
NI3	DC	3686435	670516
NI3	DB	3686435	670518
NI3	B	3686436	670571
NI3	BF	3686437	670586
NI3	S	3686437	670608
NI5	DC	3684915	670128
NI5	DB	3684912	670144
NI5	B	3684913	670163
NI5	BF	3684911	670175
NI5	S	3684914	670200
NI5	O	3684917	671121
NI7	DC	3683399	669843
NI7	DB	3683395	669844
NI7	B	3683397	669857
NI7	BF	3683399	669877
NI7	S	3683400	669901
NI7	O	3683405	670057
NI9	DC	3681867	669630
NI9	DB	3681868	669636
NI9	B	3681864	669664
NI9	BF	3681865	669676
NI9	S	3681865	669708
NI9	O	3681861	669837
NI11	DC	3680348	669454
NI11	DB	3680348	669460
NI11	B	3680348	669498
NI11	BF	3680347	669510
NI11	S	3680348	669535
NI11	O	3680345	669664
NI13	DC	3678811	669563
NI13	DB	3678812	669567
NI13	B	3678811	669606
NI13	BF	3678807	669614
NI13	S	3678809	669637
NI13	O	3678817	669756
NI15	DC	3678215	669648
NI15	DB	3678216	669654
NI15	B	3678215	669678
NI15	BF	3678214	669687
NI15	S	3678215	669715
NI15	O	3678213	669850
NI17	DC	3677600	669777
NI17	DB	3677603	669781
NI17	B	3677601	669785
NI17	BF	3677598	669794
NI17	S	3677599	669813
NI17	O	3677597	669966
NI19	DC	3676983	669879
NI19	DB	3676987	669884
NI19	B	3676986	669897
NI19	BF	3676986	669903
NI19	S	3676986	669926
NI19	O	3676979	670168
NI21	DC	3676384	669984
NI21	DB	3676384	669986
NI21	B	3676386	669994
NI21	BF	3676387	670001
NI21	S	3676385	670015
NI21	O	3676376	670349

Profile	Location	Northing	Easting
SI1	DC	3673723	669285
SI1	DB	3673721	669291
SI1	B	3673719	669295
SI1	BF	3673716	669300
SI1	S	3673707	669318
SI1	O	3673244	670262
SI3	DC	3673172	669009
SI3	DB	3673167	669017
SI3	B	3673164	669023
SI3	BF	3673161	669029
SI3	S	3673153	669047
SI3	O	3672714	669990
SI5	B	3672607	668787
SI5	BF	3672602	668798
SI5	S	3672594	668859
SI5	O	3672192	669685
SI7	O	3671500	669283
SI9	DC	3671529	668213
SI9	DB	3671527	668215
SI9	B	3671527	668216
SI9	BF	3671522	668223
SI9	S	3671506	668245
SI9	O	3671008	668905
SI11	DC	3670825	667364
SI11	DB	3670807	667387
SI11	B	3670803	667391
SI11	BF	3670796	667399
SI11	S	3670770	667430
SI11	O	3670124	668195
SI13	DC	3669801	666219
SI13	DB	3669796	666226
SI13	B	3669791	666230
SI13	BF	3669781	666243
SI13	S	3669754	666276
SI13	O	3669091	667063

Appendix 5: Pictures at Beach Profiles

Profile NI1

Profile NI1

Profile NI2

Profile NI2

Profile NI3

Profile NI4

Profile NI5

Profile NI6

Profile NI7

Profile NI8

Profile NI9

Profile NI9

Profile NI10

Profile NI11

Profile NI11

Profile NI13

Profile NI14

Profile NI15

Profile NI16

Profile NI17

Profile NI18

Profile NI19

Profile NI20

Profile NI20

Profile NI21

Profile NI22


Profile SI1

Profile SI1 (cont.)

Profile SI2

Profile SI2 (cont.)

Profile SI3

Profile SI3

Profile SI4

Profile SI5

Profile SI5

Profile SI6

Profile SI8

Profile SI9

Profile SI10

Profile SI11

Profile SI12

Profile SI12

Profile SI13

Profile SI14