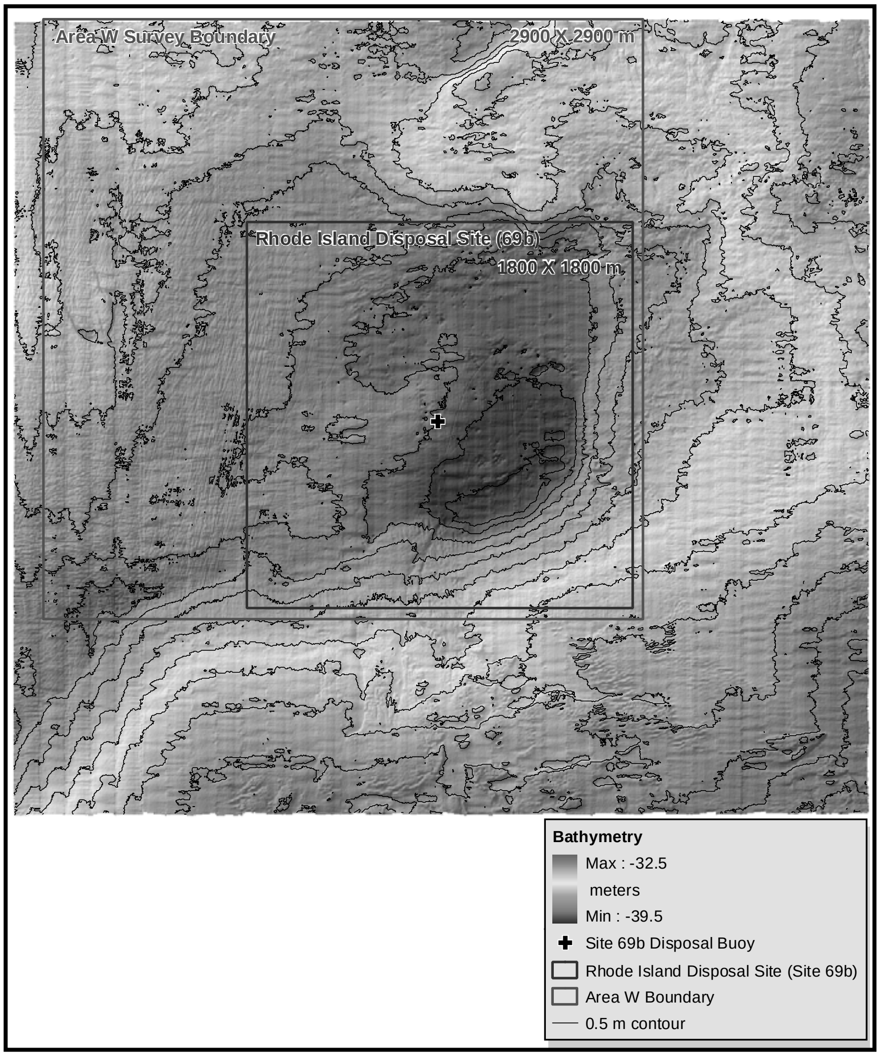
Monitoring Surveys of the Rhode Island Sound Disposal Site Summer 2003

Disposal Area Monitoring System DAMOS



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13. ABSTRACT

The Rhode Island Sound Disposal Site (RIDS) was monitored by Science Applications International Corporation (SAIC) several times in 2003 as part of the Disposal Area Monitoring System (DAMOS) Program. RIDS is a 3.42 km^2 dredged material disposal site, which lies approximately 21 km south of the entrance to Narragansett Bay, Rhode Island. Selected specifically for use as part of the Providence River and Harbor Maintenance Dredging Project, an anticipated 3.3 million cubic meters of dredged material will be placed at RIDS over the course of the project. A series of surveys were performed between February and October 2003 to document the changes in seafloor topography and surficial sediment composition resulting from dredged material deposition.

Sequential bathymetric surveys performed in February, July, and September 2003 successfully tracked the development of an artificial containment cell within the confines of RIDS. During the first five months of the maintenance project (April to September 2003), an estimated barge volume of 706,000 m^3 of coarse-grained, glacial till was strategically placed at eleven predetermined disposal points parallel to the western disposal site boundary. The purpose of this bathymetric ridge was to construct an artificial containment cell that will eventually be used to limit the lateral spread of an estimated 2.1 million cubic meters of unconsolidated, estuarine silts to be placed at RIDS during future phases of the dredging project. It is anticipated that upon completion, the final capacity of the artificial containment cell will meet or exceed the volume of unconsolidated material to be disposed. In September 2003, a side-scan sonar survey was completed over a 2900 × 2900 m area known as Area W to evaluate the distribution of dredged material in the area surrounding RIDS. The side-scan sonar data displayed several areas of interest, including apparent trails of recently deposited dredged material outside the disposal site boundaries. A follow-up study performed in October 2003 using sediment-profile photography and underwater video concluded that despite a change in surface sediment composition, the deposition of dredged material outside the disposal site boundaries resulted in minimal to non-existent impacts to the resident benthic community.

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EXECUTIVE SUMMARY

The Rhode Island Sound Disposal Site (RIDS) was monitored by Science Applications International Corporation (SAIC) several times in 2003 as part of the Disposal Area Monitoring System (DAMOS) Program. RIDS is a 3.42 km^2 dredged material disposal site, which lies approximately 21 km south of the entrance to Narragansett Bay, Rhode Island. Selected specifically for use as part of the Providence River and Harbor Maintenance Dredging Project, an anticipated 3.3 million cubic meters of dredged material will be placed at RIDS over the next several months. The initial environmental monitoring operations performed over RIDS in 2003 consisted of multibeam and single-beam bathymetry, side-scan sonar, REMOTS® sediment-profile imaging, as well as underwater video. The survey objectives were to document the changes in seafloor topography and surficial sediment composition resulting from dredged material deposition.

Sequential bathymetric surveys performed in February, July, and September 2003 successfully tracked the development of an artificial containment cell within the confines of RIDS. During the first five months of the maintenance project, an estimated barge volume of 706,000 m^3 of coarse-grained, glacial till was strategically placed at eleven predetermined disposal points parallel to the western disposal site boundary. This mix of sand, gravel, and cohesive clay was excavated as part of the construction of several Confined Aquatic Disposal (CAD) cells within the Fox Point Reach of Providence River and used to develop a continuous ridge of sediment along the western boundary of RIDS. The purpose of this bathymetric ridge was to construct an artificial containment cell, enhancing the 500,000 m^3 capacity of a natural bottom depression located in the southwestern quadrant of the disposal site. This containment feature will eventually be used to limit the lateral spread of an estimated 2.1 million cubic meters of unconsolidated, estuarine silts to be placed at RIDS during future phases of the dredging project. As of September 2003, the artificial containment cell at RIDS offered a dredged material capacity of 1.44 million cubic meters. However, the capacity of this feature is expected to increase over the next several months as additional sediment is placed at predefined disposal points along the western boundary of RIDS. It is anticipated that the final capacity of the artificial containment cell will meet or exceed the volume of unconsolidated material to be disposed.

Monitoring surveys performed over RIDS and the surrounding area of the disposal site in July 2003 as part of another program detected a variety of features on the seafloor both inside and outside the disposal site boundaries that prompted further evaluation. In September 2003, a side-scan sonar survey was completed over a 2900 × 2900 m area known as Area W to evaluate the distribution of dredged material in the area surrounding RIDS. The side-scan sonar data displayed several areas of interest, including disposal trails and the bathymetric ridge constructed within RIDS; areas of concentrated trawl scars (recent and relic) to the west of the disposal site; a naturally occurring ridge of coarse sediment to the north of RIDS; and apparent trails of recently deposited dredged material outside the disposal site boundaries.

Underwater video and REMOTS® sediment-profile imaging performed in October 2003 confirmed that the majority of the features and seafloor composition detected outside the disposal site boundary were the product of ambient conditions in Rhode Island Sound. However, both past and ongoing fishing activity adjacent to RIDS appeared to be the basis for a number of linear trawl scar features that existed in the ambient sediment to the west of RIDS. The depth of the furrows created by the dragging doors of a trawl net and the silty sand comprising the seafloor in this area likely allowed the scars on the seafloor to persist for a substantial length of time after the disturbance and remain detectable in the side-scan sonar record.

In addition, the seafloor imagery also confirmed the presence of dredged material outside the disposal site boundaries in the form of continuous narrow, low-relief trails of deposited sediment. Similar disposal trail features were also detected within the confines of RIDS, suggesting these deposits were the product of residual dredged material being washed from open split-hull disposal barges as they began a return transit to Narragansett Bay following a disposal event. The presence of disposal trails outside the boundary was the result of barges continuing their course after the load was placed at one of the eleven predetermined disposal points established along the western disposal site boundary. The observations in July resulted in an immediate change in disposal practices that required the barges to be closed before leaving the site boundaries.

The most prominent disposal trail was found approximately 450 m outside the disposal site boundary and determined to be approximately 1,100 m in overall length, with widths ranging from 12 to 35 m. The sediment detected in the October 2003 survey was comprised of a mix of coarser-grained material (sand, gravel, and cobble) and clumps of cohesive clay. Based on its composition and contrast to the ambient sediments, it appears this disposal trail represents a deposit of material removed from the Fox Point Reach of the Providence River during CAD cell construction. Despite a change in surface sediment composition at some stations within the survey grid, the impacts to the resident benthic community were minimal to non-existent. As a result, it can be inferred that the seafloor immediately surrounding this disposal trail, as well as those of lesser consequence elsewhere in the region, readily recovered from any highly localized benthic disturbances.

1.0 INTRODUCTION

This report presents the results of a series of environmental surveys performed in an area over Rhode Island Sound encompassing the Rhode Island Sound Disposal Site (RIDS), also known as Site 69b. The information acquired from this survey will be used to identify and characterize areas of recent sediment accumulation and will assist in the management of dredged material placement as a result of the Providence River and Harbor Maintenance Dredging Project.

1.1 Background

Dredging activity along the New England coast is overseen by the U.S. Army Corps of Engineers, New England District (NAE). Monitoring of the impacts associated with the subaqueous disposal of sediments dredged from harbors, inlets, and bays in the New England region has been overseen by the Disposal Area Monitoring System (DAMOS) Program. Established in 1977, the goals of DAMOS pertain to detailed investigation of dredging and dredged material disposal practices to minimize any adverse physical, chemical, and biological impacts. The activity sponsored by DAMOS helps to ensure that the effects of sediment deposition on the marine environment within pre-defined areas of seafloor are local and temporary. A flexible, tiered management protocol is applied in the long-term monitoring of sediment disposal at open-water dredged material disposal sites along the coast of New England (Germano et al. 1994).

Major dredging activity in Rhode Island waters has not occurred in approximately 25 years, when the Providence River and Harbor Navigation Project was completed in 1976. Prior to dredging activities in 1976, the last significant dredging (2,060,000 m^3 total volume) occurred in 1971 in the Federal Navigation Channel, and resulted in a deepening of the channel from 35 ft Mean Lower Low Water (MLLW) to 40 ft MLLW (ACOE 2001). Over the past 20 years, there has been significant shoaling of the Providence River shipping channel (ranging from 1 to 4 m) as a result of sedimentation, thus creating hazardous navigation conditions, restricting access for large vessels in route to the Port of Providence, and reducing the economic value of the port.

1.2 Providence River Federal Navigation Project

The Providence River comprises the headwaters of Narragansett Bay and is formed by the confluence of the Woonasquatucket and Moshassuck Rivers emanating from northern Rhode Island. Providence River flows through downtown Providence, joining the Seekonk River and emptying into Narragansett Bay. The East Passage of the bay serves as an integral shipping channel for Rhode Island, with the Providence River and Harbor representing the principal commercial port in Rhode Island. Deep-draft vessel traffic in Providence River and Harbor includes tankers, barges, and general cargo vessels. In particular, the harbor is an unloading point for the region's supply of refined petroleum products, and oil tankers must maintain access to Providence to ensure a steady energy supply for the state (ACOE 2001). Furthermore, there are numerous marine terminal facilities within the Port of Providence that serve the commercial fishing and industrial transport fleet.

The Federal Navigation Channel is 16.8 miles long and runs from Providence Harbor following the Providence River south to the deeper waters near Prudence Island (ACOE 2001; Figure 1-1). Although the channel has an authorized depth of 40 ft and width of 600 ft, shoaling of the channel has resulted in depths as shallow as 30 ft. Shallower depths have forced restrictions on vessel traffic, which could result in environmental and economic problems. The Providence River dredging project's fundamental purpose is to restore the depth and width of the channel to meet existing economic and safety needs. To fully restore the channel to its authorized dimensions and restore safe navigation requires the removal of approximately 3.3 million cubic meters of sediment and disposing the material at various subaqueous disposal sites (ACOE 2001). Until recently, there was no available ocean disposal site in Rhode Island waters capable of accepting large volumes of dredged material that are determined to be suitable for unconfined open water disposal.

The current Providence River and Harbor Maintenance Dredging Project involves the dredging of approximately 2.1 million cubic meters of suitable maintenance material (material that meets the ocean disposal testing requirements) to be placed in an open water disposal site. In conjunction with the federal maintenance project, a small group of private facilities, marine terminals and other facilities have been permitted to use the active disposal site for additional non-federal maintenance and improvement dredging projects (ACOE 2001). An estimated 380,000 m^3 of sediment is expected to be dredged from these smaller projects and deposited at an open water disposal site. In addition, because of industrialization around Providence Harbor, roughly 920,000 m^3 of material is considered unsuitable for unconfined open water disposal. As a result, this material will be placed into a series of Confined Aquatic Disposal (CAD) cells located in the upper portion of the river (Fox Point Reach) in order to isolate the contaminants from the marine environment. To create the CAD cells, an estimated 1.5 million cubic meters of sediment was dredged within Fox Point Reach and deposited at the open water disposal site.

1.3 Rhode Island Sound Disposal Site

The Rhode Island Sound Disposal Site (RIDS) has been selected for the unconfined disposal of dredged sediments from the Providence River and Harbor Maintenance Dredging Project. The disposal site is centered at 41° 13.850´ N, 71° 22.817´ W (NAD 83). The offshore disposal site occupies an 1800 × 1800 m area of seafloor, and located in Rhode Island Sound approximately 31 nmi (58 km) from Providence Harbor and 11 nmi (21 km) south of the entrance of Narragansett Bay (Figure 1-2). RIDS is positioned within the

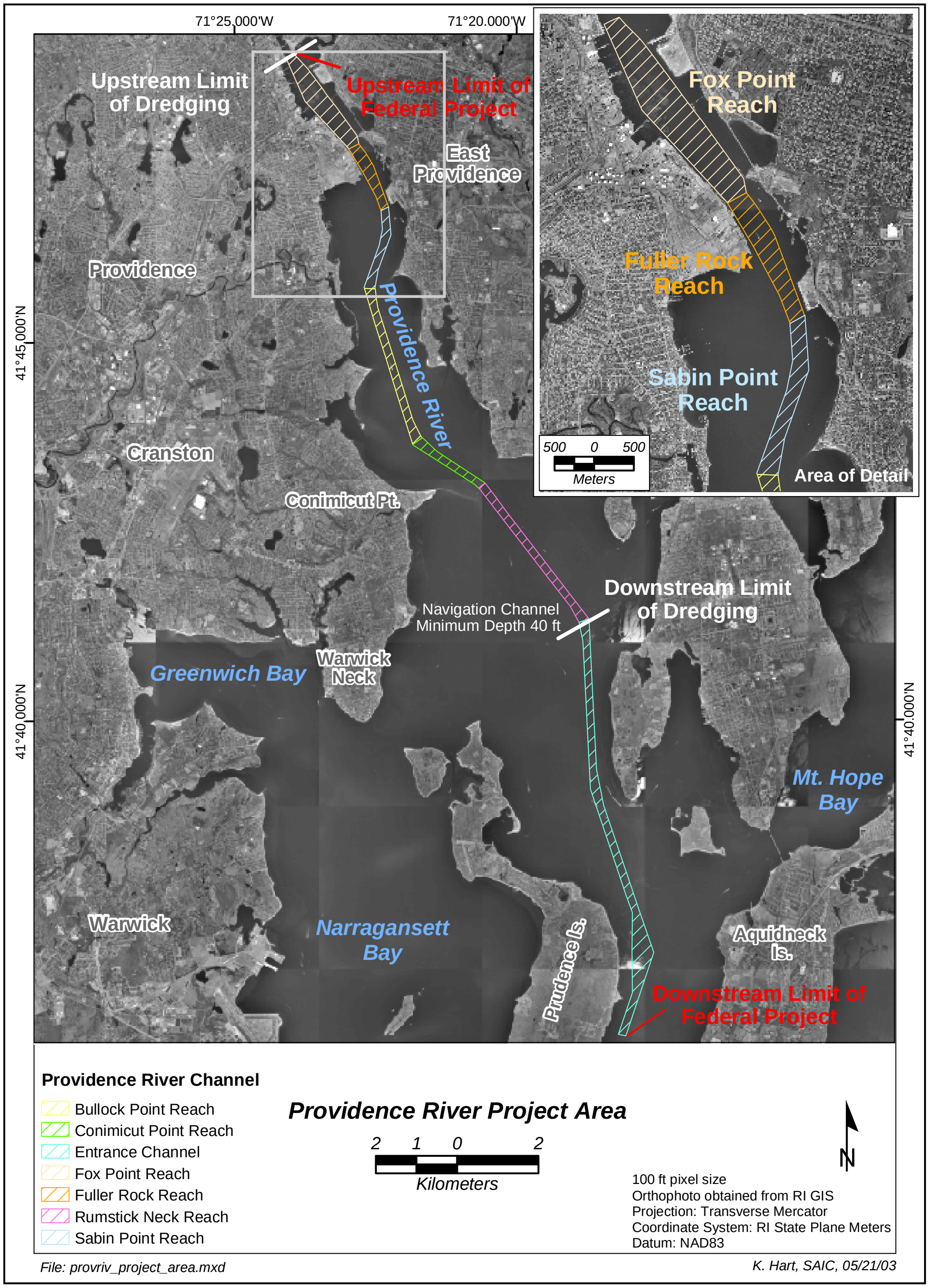


Figure 1-1. Providence River maintenance dredging project area and associated project limits

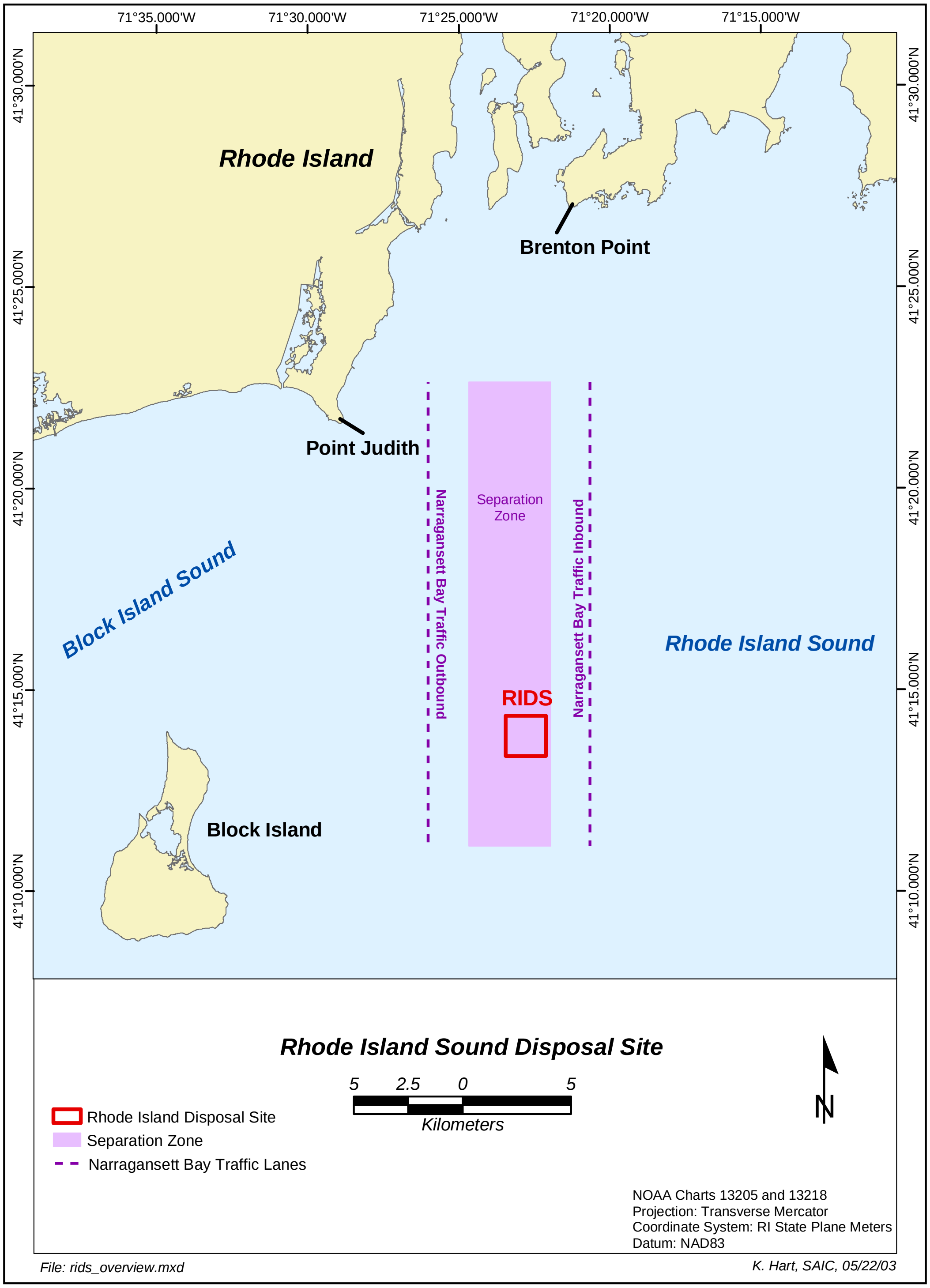


Figure 1-2. Location of the Rhode Island Disposal Site within Rhode Island Sound relative to the coast of southern Rhode Island

Separation Zone for the Narragansett Bay Inbound and Outbound Traffic Lanes. A detailed, baseline multibeam bathymetric survey encompassing a 4000 × 3800 m area was completed in February 2003. Results of the survey confirmed that the disposal site is located in a topographic depression, with water depths within the disposal site ranging from 36 to 39 m. From 13 April 2003 through 26 September 2003, a total estimated volume of 844,000 m^3 of dredged material has been placed within RIDS (Table 1-1). The disposal of material generated from both the federal and non-federal maintenance projects will result in a total estimated volume of 3.6 million cubic meters of sediment deposited at RIDS (ACOE 2001).

1.4 Management Strategy

Dredging in New England waters typically involve the use of a clamshell bucket to extract rock, sand, gravel, mud and clay from the bottom of waterways and transfer the material to barges or on-shore facilities for disposal. The majority of material intended for disposal at RIDS is fine-grained estuarine sediments (silts) derived from dredging within the lower reaches of the navigation channel. However, a percentage of the material has been removed from the upper region of the river (Fox Point Reach) to create the CAD cells (Table 1-1). These sediments consist of basement material which underlies the estuarine deposit and is composed of a mixture gravel, sand, and clay (glacial till). All sediment excavated as part of the Providence River project was removed by clamshell bucket and transferred to disposal barges with capacities ranging from approximately 3,000 to 4,600 m^3. The material deemed suitable for unconfined open water disposal generated from dredging operations has been transported to RIDS by the disposal barges and deposited at various pre-determined placement locations within the disposal site.

Due to various environmental concerns within the Providence River and Narragansett Bay, the dredging project is subject to a strict schedule, or sequencing, of excavation operations to minimize the overall impact to various biological resources that utilize Narragansett Bay. As a result, the majority of the dredging that has occurred to date has been restricted to areas within the Fox Point Reach of the Providence River. A percentage of the sediments located in this area are classified as unsuitable for open water disposal and require the specialized handling techniques for proper disposal, prompting continued excavation and filling of CAD cells.

Over the past ten years, the use of artificial and natural containment features on the seafloor has become quite common to constrain the areal size of a dredged material mound or sediment deposit within a disposal site. Several disposal sites in New England offer natural containment features as part of the existing seafloor such as strong bathymetric ridges, deep troughs, or shear bedrock ridges (i.e., Western Long Island Sound Disposal Site, Portland Disposal Site, Cape Arundel Disposal Site) that can be used to limit the lateral spread of a disposal mound. Dredged material disposal sites established over a featureless or

Table 1-1.

Summary of Providence River Dredging Project Material Placed at RIDS

Type of Material	Time Period		
	13 April - 16 July volume	**17 July - 26 September volume**	**total volume per material type**
CAD Cell Material	213,000 m^3	493,000 m^3	706,000 m^3
Maintenance Material	138,000 m^3	________	138,000 m^3
total volume per disposal season	351,000 m^3	493,000 m^3	844,000 m^3

gently sloping seafloor (i.e., Central Long Island Sound Disposal Site, New London Disposal Site, Massachusetts Bay Disposal Site) require the construction of artificial containment features to constrain a large unconsolidated sediment deposit (Morris 1996).

Applying the knowledge gained from close monitoring and management of other open water disposal sites in the New England region, it was decided that the volumes of glacial till from the construction of CAD cells could have a beneficial use at RIDS. Because of its physical composition, the mix of glacial till, clay, and sand removed from the river as part of the CAD cell construction process was strategically placed at a series of disposal points (Targets 1-11) in an effort to form a continuous ridge of sediment along the western boundary of RIDS (Figure 1-3). The development of an artificial containment structure along the western boundary of the disposal site would enhance the containment properties of the open water disposal site and minimize the lateral spread of unconsolidated sediments to be deposited at RIDS during future stages of the project. A naturally occurring ridge surrounding a depression located in the southeast corner of the disposal site will be used to contain the fine-grained dredged material within the southeast corner of the disposal site. The February 2003 baseline bathymetric survey indicated this natural containment feature would be capable of containing large volumes of dredged material before filling the depression to the elevation of the surrounding seafloor.

As the Providence River maintenance dredging project progresses, the placement of fine-grained estuarine sediments removed from the southern reaches of the Providence River navigation channel will be directed to additional target disposal locations within RIDS. Future disposal of unconsolidated sediments will target appropriate disposal locations (e.g., Targets A-G) within the disposal site. The actual usage of these points is dependent upon the stage of the tide and likely transport of the sediment plume in the water column (Figure 1-3). On a flood tide (northwesterly flow), sediment will be deposited in the southeast corner of the disposal site at the designated disposal focus points to allow for transport of the plume in the northwesterly direction and maximize sediment particle settlement within the disposal site boundaries. Alternatively, when the tide is ebbing (southeasterly direction), disposal will occur in the northwestern corner of the disposal site to ensure the majority of the entrained sediment in the water column settles within the confines of the site.

1.5 Survey Objectives and Predictions

As part of the monitoring activities sponsored under DAMOS, SAIC has completed three environmental surveys over RIDS. A baseline multibeam bathymetry survey was completed in February 2003 to closely examine seafloor topography in an area encompassing RIDS prior to the deposition of dredged material. Additional surveys were performed in July and September 2003 to evaluate changes in seafloor topography and examine the distribution of sediments. The objectives of the July and September 2003 survey over RIDS were to:

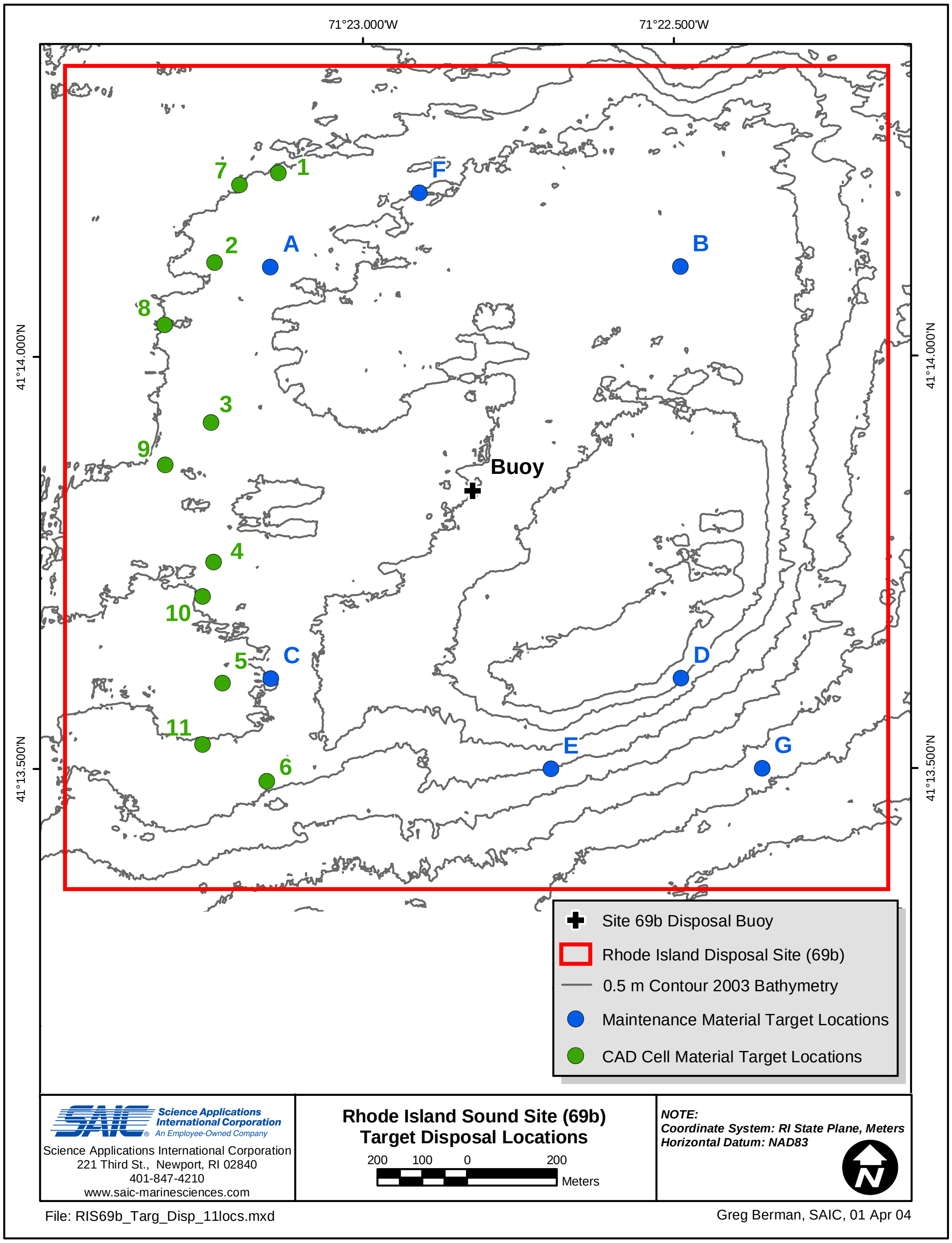


Figure 1-3. Location of the target disposal locations for maintenance material (blue) and CAD cell material (green) relative to the boundaries of RIDS

1) monitor the development of a bathymetric ridge within the western portion of the disposal site as a result of recent dredging operations from the Providence River;

2) determine topography and composition of various bottom features (disposal trails and trawl scars) and assess the distribution of recently disposed sediment; and

3) determine sediment composition in areas of seafloor where disposal trails and deposits have been observed in the side-scan sonar surveys of the area west of RIDS and to determine the lateral extent and thickness of these features.

2.0 METHODS

The following section will provide an overview of the monitoring activities within RIDS and the surrounding area (Area West) in support of the Providence River and Harbor Maintenance Dredging Project. Field efforts for RIDS included a baseline multibeam survey (February 2003) along with two follow-up monitoring efforts in July and September 2003 utilizing single-beam bathymetry, side-scan sonar, sediment-profile imaging and towed video (Table 2-1).

Two separate monitoring surveys employing both bathymetry and side-scan sonar were conducted in July (primary monitoring event) and September 2003 (secondary monitoring event) following dredged material placement at RIDS during various phases of the Providence River and Harbor Maintenance Dredging Project. The results of the July and September bathymetric surveys were compared to those of the February 2003 baseline (i.e., predisposal) multibeam bathymetric survey.

Sediment-profile imaging and towed video survey operations were completed in October 2003 after completion and review of the side-scan sonar survey data to characterize sediment types in areas of the seafloor where dredged material disposal trails and deposits have been observed in the previous side-scan sonar surveys. Target station locations and video transects were carefully selected to document changes in surface sediment characteristics along features identified in the side-scan sonar.

The duration of all field operations including the baseline bathymetry survey extended from 19 February 2003 through 9 October 2003 (Table 2-1). With the exception of the baseline multibeam survey that was conducted on the R/V *Ocean Explorer*, all survey operations were conducted aboard the M/V *Beavertail* out of its homeport in Jamestown, Rhode Island. A detailed description of the field data acquisition and processing techniques for each of the main survey elements is presented in the sections below.

2.1 Navigation and Survey Control

During field operations conducted in July and September 2003, a Trimble DSM212L Differential Global Positioning System (DGPS) receiver provided precise navigation data. Because of its proximity to the survey area, the U.S. Coast Guard differential beacon broadcasting from Moriches, NY (293 kHz) was used for generating the real-time differential corrections. During survey operations the DGPS system output positions data at a rate of once per second to an accuracy of ±3 m in the horizontal control of North American Datum of 1983 (NAD 83). Prior to departure from the dock on each field survey day, the proper operation of the navigation system was confirmed by comparing the output DGPS position with the known position of a point on the dock.

Table 2-1.

Summary of 2003 Field Operations in Rhode Island Sound

SURVEY	DATE	SURVEY TECHNIQUE
Baseline	2/19/2003 - 2/20/2003	Multibeam Bathymetry over 15.2 km^2 survey area
Primary Monitoring	7/18/2003 - 7/30/2003	Single-beam Bathymetry over RIDS
Secondary Monitoring	9/26/2003 - 10/9/2003	Single-beam Bathymetry over RIDS Side-Scan Sonar over Area W & RIDS REMOTS® over Area W & RIDS Towed Video over Area W & RIDS

Coastal Oceanographic's HYPACK® Max survey and data acquisition software was used to provide the real-time data display and logging of the vessel position and depth sounding data. Prior to field operations, HYPACK® Max was used to define a State Plane grid (Rhode Island State Plane Coordinates) around the survey area and to establish the planned bathymetric and side-scan survey lines as well as the video lines. During the survey operations, the incoming navigation data were translated into state plane coordinates, time-tagged, and stored within HYPACK® Max. Depending on the type of field operations being conducted, the real-time navigation information was displayed in a variety of user-defined modes within HYPACK® Max.

2.2 Multibeam Bathymetry

Since its inception in 1977, the DAMOS Program has utilized single-beam bathymetry as a primary monitoring tool to document changes in seafloor topography resulting from the deposition of dredged sediments. Using one acoustic transducer, depth measurements are collected along a series of tightly spaced (25 meters), parallel survey lines to yield multiple depth profiles within a survey area. Because single-beam bathymetry typically covers only a small percentage of the total seafloor area (less than 5%), a large degree of interpolation between survey lines is required to generate a representation of the seafloor. As a result, single-beam bathymetry products (e.g., 3-D surface models and contour plots) have the potential to distort smaller features that may have only been detected by a few data points along a single track-line. Additionally, any small features that happen to fall entirely between survey lines will not be detected at all.

In 1998, multibeam bathymetry was introduced to the DAMOS Program for use at disposal sites with rocky and irregular bottom topography (i.e., Portland Disposal Site and Cape Arundel Disposal Site) in order to obtain a more accurate representation of the seafloor. Multibeam bathymetric survey systems employ a specialized transducer array comprised of multiple, narrow acoustic beams that are capable of completely ensonifying an area that is up to seven times the surrounding water depths. For example, in water depths of 20 m, a multibeam survey line can provide full bottom coverage over a swath of up to 140 m. The swath coverage provided by the multibeam systems allows higher resolution surveys to be completed in a shorter amount of time. A detailed explanation pertaining to multibeam bathymetry and the configuration of the survey system employed at RIDS during the February 2003 survey is presented in Appendix A.

2.2.1 Survey Area

Multibeam, bathymetric data were acquired within a 4000 × 3800 m grid (15.2 km^2 area) established over Rhode Island Sound and centered on RIDS (Figure 2-1). Depth soundings were collected along 34 main scheme survey lanes spaced at 120 m intervals and oriented along a north/south direction. In addition, a series of three cross-lanes were also

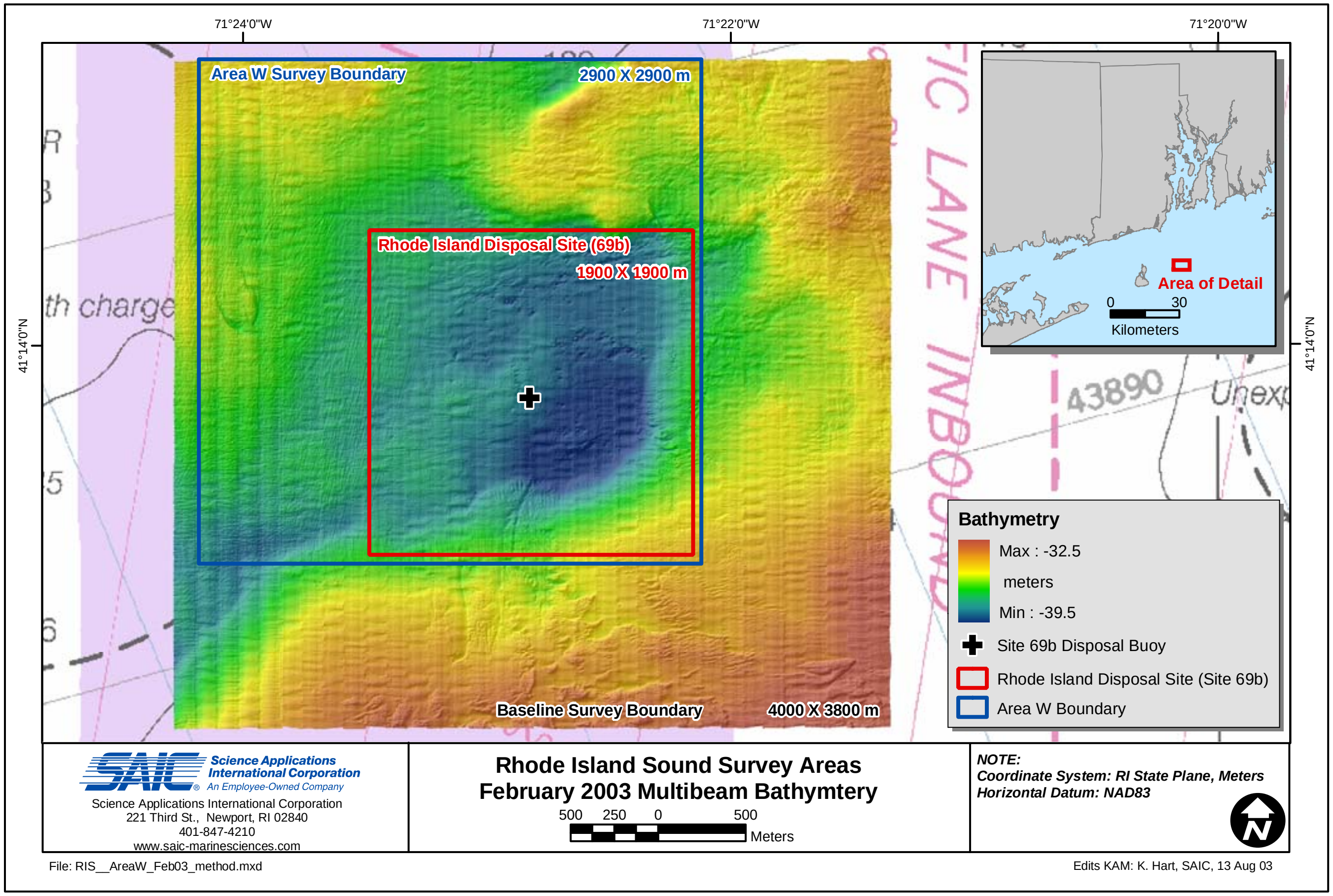


Figure 2-1. Location of the 2003 survey areas in Rhode Island Sound over February baseline multibeam bathymetry

established perpendicular to the main survey lines to serve as reference checks to the processed multibeam data. These data were used to evaluate the consistency of the bathymetric data.

2.2.2 Survey Vessel Positioning

The R/V *Ocean Explorer* was used as the survey platform for multibeam bathymetry survey operations conducted at Rhode Island Sound. This specialized survey vessel is specifically designed and outfitted for high speed (~11 knots) swath bathymetry data collection. The main cabin of the vessel serves as the data collection and first-order-processing center. Upon completion of the survey, all data were delivered to the Data Processing Center for post-processing. Table A-1 within Appendix A provides a list of characteristics for the R/V *Ocean Explorer*. Precision navigation, helmsman display, and data integration from the multitude of sensors aboard the survey vessel were accomplished with the use of SAIC's Integrated Survey System 2000 (ISS-2000). Real-time navigation, data time tagging, and data logging were controlled by the ISS-2000 in a Windows NT 4.0 environment.

Positioning information was recorded from multiple independent Global Positioning System (GPS) receiver networks in the North American Datum of 1983 (NAD 83). Two, linked GPS receivers embedded within a TSS POS/MV 320, 3-axis Inertial Motion compensation Unit (IMU) were used as the primary source for vessel position and attitude correctors applied to the multibeam data. The POS/MV IMU was interfaced with a Trimble Probeacon Differential Beacon Receiver to improve the positioning data to an accuracy of ±3 m. Correctors to the satellite information broadcast from the U.S. Coast Guard differential station at Moriches, NY (293 kHz) were applied to the satellite data. The ISS-2000 monitored horizontal dilution of precision (HDOP; quality of the signal); number of satellites, elevation of satellites, and age of correctors to ensure the resulting bathymetric positioning errors did not exceed five meters at the 95% confidence level.

2.2.3 Multibeam System Configuration

A RESON 8101 shallow water, multibeam system was employed for the acquisition of sounding data over the RIDS survey area. The RESON 8101 was mounted on the keel of the survey vessel, and utilizes 101 individual narrow beam (1.5°) transducers capable of yielding total swath coverage of 150° (75° per side). The actual width of coverage is adjustable through range scale settings with a maximum equivalent to 7.4 times the water depth. The RESON 8101 transducer can transmit up to 12 high frequency (240 kHz) sound pulses, or pings, per second, though that number may be reduced in deeper water where sound travel times are greater. This rapid ping rate provides dense along-track data coverage and allows the survey boat to be operated at higher speeds. During the Rhode Island Sound survey, vessel speed was controlled to yield average along-track coverage of 2.5 pings per square meter of seafloor. Acoustic returns from the seafloor are detected by the transducer array and raw depth values are transmitted to the RESON 6042 topside control unit. The RESON 6042 then applies a series of real-time corrections (i.e., sound velocity, attitude, predicted tides, draft, squat, etc.) to the raw soundings before transmitting them to the ISS-2000 for position stamps and data storage.

The quality and accuracy of the multibeam data (particularly in the outer beams) is highly dependent upon the precise measurement of the position, motion, and attitude of the survey vessel (e.g., heading, heave, pitch, and roll). Real-time heading and attitude compensation were accomplished in the multibeam system based on the data output by the POS/MV GPS-aided inertial navigation system. The POS/MV heading, heave, pitch, and roll data were transferred to the RESON 6042, which applied corrections to the raw soundings before they were transmitted to the ISS-2000 and stored for post processing.

Density profiles were obtained at approximately two-hour intervals during the RIDS survey in order to document changing water column characteristics. A Brooke Ocean Technology Ltd., Moving Vessel Profiler-30 (MVP) sound velocity profiling system was used to determine water column speed of sound. After examining the records, the data are sent to the RESON 6042 topside control unit. Within the RESON 6042, a beam refraction model was computed from the speed of sound data, and beam angle correctors are applied to the raw multibeam sounding data received from the RESON 8101 transducer.

Raw soundings collected by the RESON 8101 multibeam system reference depth values to the transducer mounted on the underside of the survey vessel. At the beginning and end of each survey day, static draft measurements were made on the port and starboard sides of the survey vessel. Static draft values were applied to the raw soundings as well as correctors based on settlement and squat of the survey vessel will in motion.

2.2.4 Tidal Corrections

Tidal height corrections for the Rhode Island Sound survey were obtained via the National Oceanographic and Atmospheric Administration (NOAA). Both predicted and observed tide information was based on the NOAA tide station at Newport, RI (8452660) corrected to the appropriate local tide zone. The local tide zone correctors applied to the Newport tide data were zero minutes for time difference and 89% for height.

Predicted tides were applied in the RESON 6042 topside control unit in real-time during the survey operations. Verified, observed tidal data downloaded from the NOAA CO-OPS web page were applied during the post-processing effort. Tide-corrector files for each tide zone were created from actual tide data using the ISS-2000 “TID2HMPS” routine.

These corrector files were then applied to the multibeam data using the "APPCORS" program within the ISS2000 Survey Analysis software.

2.3 Single-Beam Bathymetry

2.3.1 Bathymetric Data Acquisition

Single-beam, bathymetric data, meeting the USACE Class I survey standards (USACE 2002), were acquired during two separate monitoring events (July and September 2003) over a 3.6 km^2 area centered over RIDS for the purpose of determining sediment accumulation and topography of bottom features (Figure 2-1). The surveys were conducted on an "as needed" basis, with timing corresponding to progress of the Providence River maintenance dredging project. Depth soundings were acquired along 76 main scheme survey lanes spaced at 25 m intervals and oriented along a north-south direction for both the July and September 2003 surveys.

In addition, a series of cross-lanes were also established perpendicular to the main survey lines to provide a cross-check comparison only. This data was used to evaluate the consistency of the bathymetric data. Bathymetric data obtained from the summer and fall 2003 surveys were compared to the February 2003 baseline survey to determine sediment accumulation within RIDS as a result of recent disposal activity.

During the bathymetric survey operations, the HYPACK® Max survey software was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS. The Hydrotrac® used a narrow-beam (3°), 208-kHz transducer, to produce a continuous analog record of the bottom, and transmitted approximately five digital depth values per second to HYPACK® Max. Within HYPACK® Max, the time-tagged position and depth data were merged to create continuous depth records along the actual survey track. These records were viewed in real-time to ensure adequate coverage of the survey area.

The echosounder transducer was attached to an over-the-side pole mount that was deployed along the starboard side of the M/V *Beavertail*. Though the vessel draft changed slightly during the course of the survey operations due to changes in vessel loading (primarily fuel levels), the transducer draft was maintained at one-meter throughout the survey by routinely monitoring the height of the pole prior to departure from the dock. The draft correction was applied directly to the raw echosounder data within the Hydrotrac® topside recorder and no further draft corrections were applied within HYPACK® Max. Based on settlement and squat tests conducted aboard the M/V *Beavertail* prior to the survey operations, the dynamic draft impacts at standard survey speeds (generally below six knots) were negligible.

2.3.2 Bathymetric Data Processing

The bathymetric data were fully edited and processed using the HYPACK® Max single-beam data processing modules. Raw position and sounding data were edited as necessary to remove or correct questionable data, sound velocity and draft corrections were applied, and the sounding data was reduced to Mean Lower Low Water (MLLW) using observed tides obtained from NOAA.

During bathymetric survey data acquisition, an assumed and constant water column sound velocity of 1500 $m \cdot s^{-1}$ was entered into the Odom echosounder. In order to account for the variable speed of sound through the water column, CTD profile data were used to calculate vertical profiles of the water column sound velocity at the beginning and end of each survey day. Each CTD cast was processed to produce a one-meter bin-averaged sound velocity profile from the sea surface down to the depth of the cast. The digital CTD cast data were grouped by day and stored within a master spreadsheet file for additional analysis and eventual export into HYPACK® Max.

A Seabird Electronics SBE-19® conductivity-temperature-depth (CTD) profiler was used to calculate vertical profiles of the water column sound velocity at the beginning and end of each survey day. These casts were taken in the deeper waters of each survey area to account for the sound velocity over the full range of depths encountered during the survey. This CTD sound velocity data was used to correct the raw echosounder data that was acquired using a constant assumed sound velocity of 1500 $m \cdot s^{-1}$.

After the daily sound velocity processing and analysis was completed, the data were used to generate a daily sound velocity profile table within HYPACK® Max. This average sound velocity table was based on a composite of each of the casts obtained on a particular day and extended well beyond the deepest depth encountered on the survey. Based on the assumed sound velocity entered into the echosounder during data acquisition and the observed sound velocity reflected in the daily sound velocity profile table, HYPACK® Max computed and applied the required sound velocity corrections to all of the sounding records.

Observed water level data from the NOAA primary tide station at Newport, RI (8452660) were obtained through NOAA's Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network (http://www.co-ops.nos.noaa.gov/). The six-minute Newport tide data were downloaded from the OLLD web site and the appropriate range and phase offsets were applied to transfer this data out to the Rhode Island Sound survey areas. Based on conventions established during prior surveys in this area, a zero time offset and an 89% height correction offset were applied to the observed Newport tidal height data. The corrected Newport water level data was then used to create daily tidal corrector files within HYPACK® Max that were then used to reduce all of the sounding data to the MLLW vertical datum.

After the bathymetric data were fully edited and reduced to MLLW, cross-check comparisons on overlapping data were performed in order to verify the proper application of the correctors and to evaluate the overall consistency of the entire data set. Because of the survey pattern used for acquiring the bathymetric survey data, a reasonable number of cross-check comparison points were created at the intersections between survey lines oriented perpendicular to each other. Using the HYPACK® Max Statistics routine it was possible to systematically compute the differences between all points from different survey lines that fell within a user-specified distance of each other. For these datasets, the cross-check comparisons were based on a search radius of 10 m.

After the data were verified through the cross-check comparisons, they were then run through the HYPACK® Max Mapper routine in order to reduce the size of the full data set in a systematic way. Because of the rapid rate at which a survey echosounder can generate data (approximately five depths per second during this survey), the along-track data density for a single-beam survey tends to be very high (multiple soundings per meter). In most cases, these data sets contain many redundant data points that can be eliminated without any effect on the overall quality of the data. The Mapper routine examines the full data set along each survey line and averages all data points that fall within a user-specified grid cell to produce a single average value for each cell. The output from this routine is a merged, ASCII-xyz file that may contain anywhere from 2 to 10% of the original data set. These greatly reduced, but still representative, data sets are far more efficient to use in the subsequent modeling and analysis routines. In addition, the averaging algorithm helps to filter out the impacts of the sea action that was prevalent during most of the survey operations. For this survey, the data were mapped to an interval of both 5 and 10 m for use in all subsequent analyses.

2.3.3 Bathymetric Data Analysis and Presentation

The primary intent of this analysis was to evaluate the seafloor surface defined by the bathymetric data in an attempt to characterize the topography and to identify any unique seafloor features. Because single-beam bathymetric survey data typically covers only a small percentage of the total seafloor area (approximately 5%), these analysis tools rely on a large degree of interpolation between the discrete survey data points in order to generate a three-dimensional seafloor surface model. This interpolation usually works well in flat or gently-sloping areas, but in steep and irregular areas the interpolation of the surface can be very dependent upon the orientation of the survey lines and the density of the data around the area.

The reduced 10 m averaged trackline data was imported to ArcGIS 8.2 for gridding to a continuous raster surface. The Spatial Analyst extension for ArcGIS was used to explore the variance of the bathymetric trackline data and determine the optimal gridding parameters. Several gridding routines were investigated before final interpolation using Kriging; the

Kriging method produced a variance grid along with the calculated surface. This variance grid provided a good indication of how well the chosen Kriging parameters calculated the surface. Using the optimal Kriging parameters, the resulting gridded dataset was used for all subsequent analysis and graphics production.

2.4 Side-Scan Sonar

2.4.1 Side-Scan Sonar Data Collection

Side-scan sonar data were acquired in a 2900 × 2900 m survey grid over Area W encompassing RIDS to develop a high resolution acoustic return of the seafloor (Figure 2-1). Data obtained from the September 2003 survey were used to compare seafloor features (bedforms, sediment types, and sediment disposal trails) to those observed as part of a different study conducted in the July 2003 and to document changes within RIDS resulting from disposal operations. A total of 17 lanes, oriented in an east/west direction and spaced at 180 m were completed during the September 2003 survey.

Side-scan sonar systems provide an acoustic image of the seafloor by detecting the strength of the backscatter returns from signals emitted from a towed side-scan sonar transducer array. The side-scan transducers operate similar to a conventional depth-sounding transducer except that the towfish has a pair of opposing transducers aimed perpendicular to and directed on either side of the vessel track. Side-scan sonar data can reveal general seafloor characteristics and also provide the size and location of distinct objects. Dense objects (e.g., metal, rocks, and hard sand seafloor areas) will reflect strong signals and appear as dark areas in the records presented in this report. Conversely, areas characterized by soft features (e.g., silt or mud sediments), which absorb sonar energy, appear as light areas in the sample records.

The side-scan sonar data were acquired with an Edgetech DF-1000® digital side-scan sonar system operating at a frequency of 100 kHz to provide wide area coverage. The side-scan sonar fish was towed behind the survey vessel by an armored signal cable that provided power to the towfish and two-way communication with the topside Triton-Elics ISIS® data acquisition system. Typically between 80-100 m of cable was deployed to maintain the towfish at the proper altitude above the seafloor. The layback between the navigation system and the towfish was computed based on the amount of cable deployed and the depth of the towfish; this layback value was applied during the data processing phase. The topside data acquisition system recorded acoustic data from the towfish and position information from the navigation system, and displayed real-time side-scan sonar imagery on a PC monitor. The side-scan sonar range scale was set to provide 100 m of coverage on either side of the towfish along each lane. By collecting swath data along lanes spaced at 180 m intervals, the resulting data provided approximately 110% coverage of the seafloor within the survey area.

2.4.2 Side-Scan Sonar Data Processing and Analysis

During data acquisition, each survey line was saved into a separate file to facilitate post-processing. During post-processing, each line was individually reviewed using Chesapeake Technologies SonarWeb® image processing software. Within SonarWeb®, towfish layback was applied to the navigation data, water column and time varied gain (TVG) adjustments were made to the acoustic data, and then the data were merged together using the SonarWeb® mosaic utility. After the mosaic was completed, it was saved and exported as a geo-referenced TIFF (Tagged Image File Format) file. These TIFF files were then used for a variety of subsequent analysis techniques. Ultimately, fully geo-referenced TIFF image mosaics were created for both survey areas and individual high-resolution screen grabs were created for particular features of interest. Based on the imagery mosaics, geographic positions for areas of differing seafloor composition were delineated and defined to help focus the subsequent sediment-profile imaging stations.

2.5 REMOTS® Sediment-Profile Imaging

REMOTS® (Remote Ecological Monitoring of the Seafloor) sediment-profile imaging is a benthic sampling technique used to detect and map the distribution of thin (<20 cm) dredged material layers, delineate benthic disturbance gradients, and monitor the process of benthic recolonization following physical seafloor disturbance. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics. The DAMOS Program has used this technique for routine disposal site monitoring for over 20 years.

The REMOTS® hardware consists of a Benthos Model 3731 sediment-profile camera designed to obtain undisturbed, vertical cross-section photographs (in situ profiles) of the upper 15 to 20 cm of the seafloor (Figure 2-2). Computer-aided analysis of each REMOTS® image yields a suite of standard measured parameters, including sediment grain size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (RPD, a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (OSI, a summary parameter reflecting overall benthic habitat quality). REMOTS® image acquisition and analysis methods are fully described in Rhodes and Germano (1982; 1986) and in DAMOS Contribution 128 (SAIC 2001) and therefore not repeated here.

The October 2003 REMOTS® survey performed over RIDS and surrounding Area W was employed primarily to assess surface sediment composition in particular areas of interest. The survey also examined the conditions of the seafloor where sediment disposal trails and additional deposits have been observed, aiding in determining the thickness and lateral extent of each feature. REMOTS® sampling locations over the 2900 × 2900 m survey

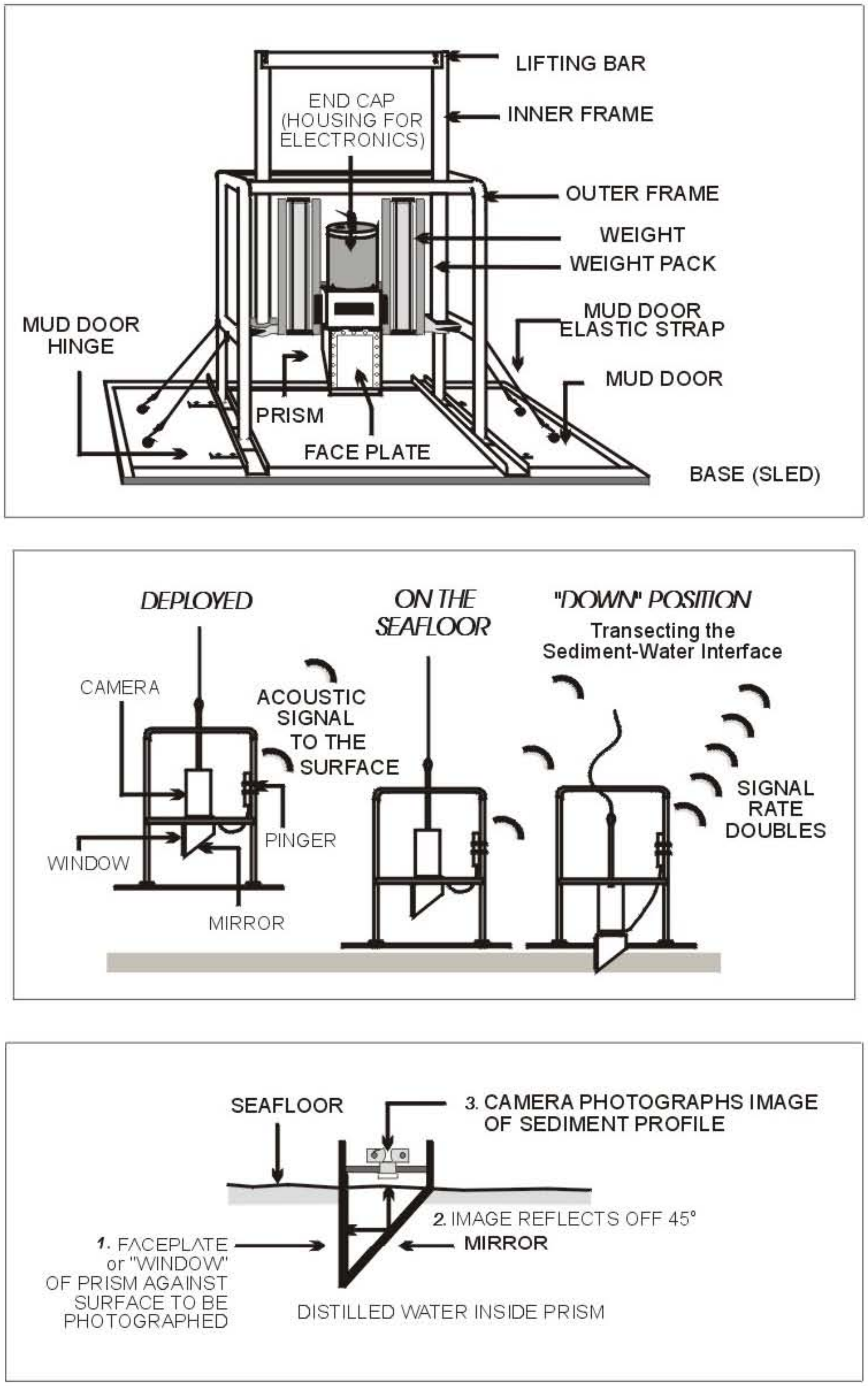


Figure 2-2. Schematic diagram of the Benthos Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

area consisted of a total of 34 stations, with 11 stations located within the 1800 × 1800 m RIDS boundary and 23 stations located outside the disposal site within Area W (Table 2-2; Figure 2-3).

The REMOTS® stations targeted areas of recent sediment accumulation, as well as other bottom features visible in the side-scan sonar mosaic reviewed prior to the October REMOTS® survey (i.e., disposal trail, trawl scars, etc.). Each station was chosen to document sediment characteristics along a defined feature in correlation with the side-scan mosaic, as well as a towed video survey. Twelve stations were placed to the west of the RIDS boundary transecting the most prominent disposal trail displayed on the side-scan mosaic (Table 2-2; Figure 2-3). Six stations were placed outside the northwest corner of RIDS to detect trawl scars made by fishing gear (Table 2-2; Figure 2-3). In addition, two transects of REMOTS® stations were occupied within RIDS; a series of five stations overlaying a ridge feature were selected along the western edge of the survey boundary, with an additional six stations selected in a northwest/southeast transect extending from the center of the disposal site out to the survey boundary (Table 2-2; Figure 2-3). These stations were chosen to verify bottom features believed to be accumulations of recent dredged material. Five stations trending northwest to southeast were also selected north of the disposal site within Area W to examine a sediment transition area with areas of coarser material on either side of an existing seafloor depression (Table 2-2; Figure 2-3). At each of the REMOTS® stations occupied in the October 2003 survey, the camera was lowered into the seafloor multiple times to obtain at least three replicate images of suitable quality for subsequent analysis. Stations that showed little to no penetration on the camera were subjected to additional surveying.

The majority of the 34 stations established over survey area were successfully sampled during the October 2003 survey. Some of the selected stations consisted of hard bottom conditions (rocks, gravel, and/or coarse sand) preventing full penetration of the camera. A best possible effort was made to obtain at least one analyzable image for those stations, however after multiple attempts, data was unattainable at Stations 17, 20, and 32, indicative of hard bottom conditions.

2.6 Towed Video

2.6.1 Data Collection

A towed video system was used to conduct a sediment characterization survey within RIDS and surrounding Area W. Data obtained from the video was used to assess conditions around areas of the seafloor where sediment trails and deposits have been observed in previous side-scan sonar surveys. A Photoseas 1000 video camera, contained within specialized pressure housing, was outfitted so that it could be mounted onto a large sediment sampler frame. A 100 m long composite video coaxial cable connected the camera to a topside VCR/Monitor unit located in the vessel wheelhouse. The live video image was recorded to the topside unit in conjunction with a Sea-Tracks GPS video overlay box from Seaviewer Camera Inc.

Table 2-2.

October 2003 Rhode Island Sound REMOTS® Sediment-Profile Imaging Station Locations

Area	Station	Latitude	Longitude
		NAD 83	
Disposal Trail (Area W)	1	41° 13.664´ N	71° 23.876´ W
	2	41° 13.664´ N	71° 23.810´ W
	3	41° 13.664´ N	71° 23.798´ W
	4	41° 13.664´ N	71° 23.743´ W
	5	41° 13.732´ N	71° 23.878´ W
	6	41° 13.731´ N	71° 23.813´ W
	7	41° 13.731´ N	71° 23.800´ W
	8	41° 13.731´ N	71° 23.744´ W
	9	41° 13.826´ N	71° 23.879´ W
	10	41° 13.826´ N	71° 23.811´ W
	11	41° 13.826´ N	71° 23.795´ W
	12	41° 13.826´ N	71° 23.741´ W
Sediment Transition Area (Area W)	13	41° 14.699´ N	71° 23.491´ W
	14	41° 14.635´ N	71° 23.366´ W
	15	41° 14.579´ N	71° 23.262´ W
	16	41° 14.534´ N	71° 23.177´ W
	17	41° 14.477´ N	71° 23.063´ W
RIDS	18	41° 13.750´ N	71° 22.800´ W
	19	41° 13.709´ N	71° 22.739´ W
	20	41° 13.670´ N	71° 22.686´ W
	21	41° 13.626´ N	71° 22.620´ W
	22	41° 13.580´ N	71° 22.552´ W
	23	41° 13.525´ N	71° 22.469´ W
	24	41° 14.089´ N	71° 23.300´ W
	25	41° 13.940´ N	71° 23.302´ W
	26	41° 13.788´ N	71° 23.301´ W
	27	41° 13.656´ N	71° 23.304´ W
	28	41° 13.515´ N	71° 23.300´ W
Trawl Scar (Area W)	29	41° 14.328´ N	71° 23.702´ W
	30	41° 14.349´ N	71° 23.655´ W
	31	41° 14.378´ N	71° 23.589´ W
	32	41° 14.491´ N	71° 23.883´ W
	33	41° 14.496´ N	71° 23.788´ W
	34	41° 14.497´ N	71° 23.699´ W

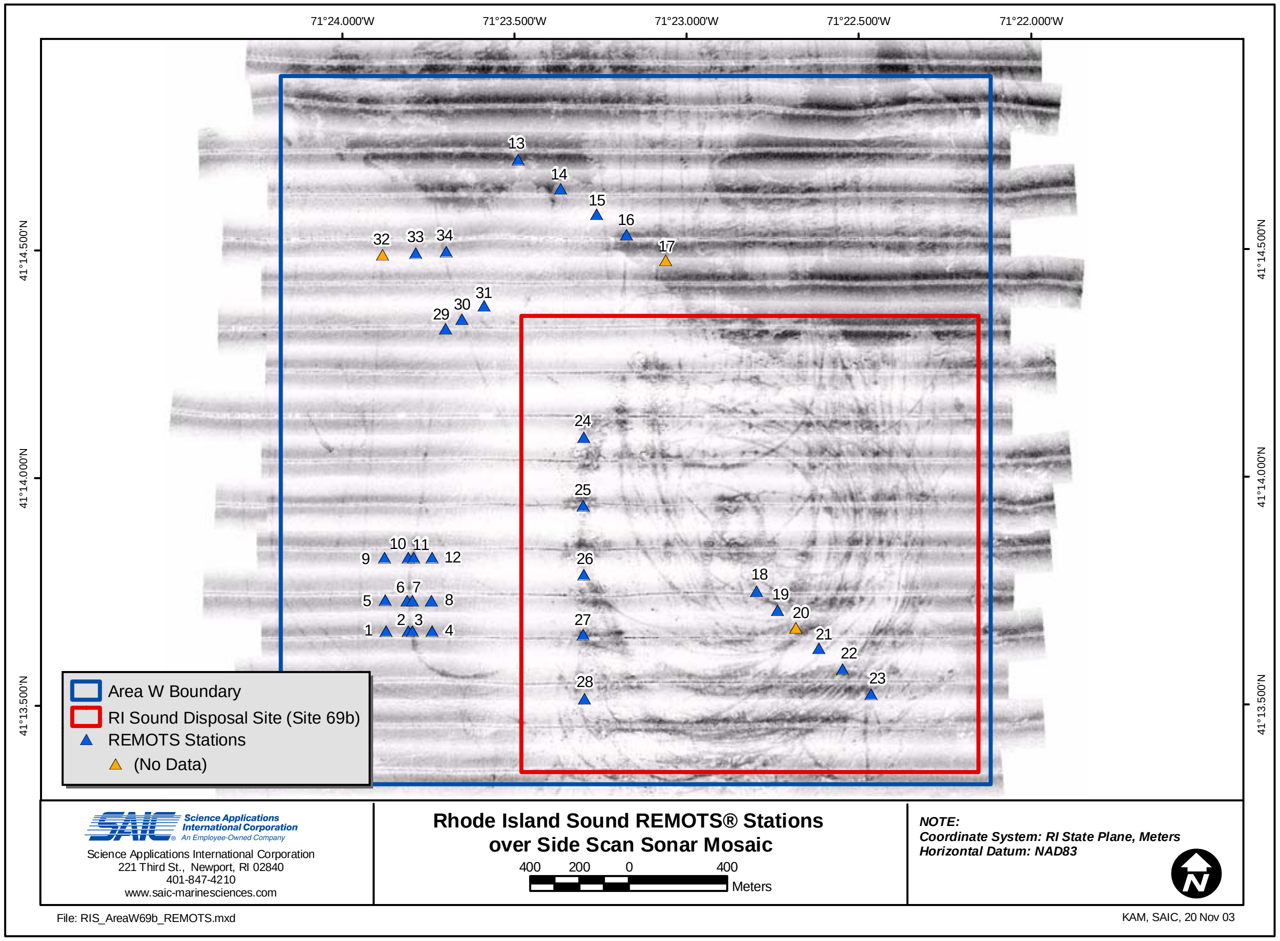


Figure 2-3. Map showing the October 2003 REMOTS® stations within various sampling areas occupied at Area W over the September 2003 side-scan sonar mosaic

The overlay box was used to capture the navigation information directly onto the image being recorded. The video system was attached to the boat winch allowing vertical maneuverability of the camera.

A total of eight video transects were occupied to assess the seafloor composition of selected areas within and around RIDS (Table 2-3; Figure 2-4). Each lane was planned in HYPACK® Max prior to survey commencement and was labeled with a letter (A-H). Transect positions were based upon features detected in the prior side-scan sonar mosaic. Transects A through C were oriented east/west and placed outside the western boundary of RIDS (Figure 2-4). These three transects were designed to examine the most prominent disposal feature (disposal trail) located outside of the disposal site. Transect D, located north of RIDS, was oriented northwest to southeast and was designed to evaluate alternating areas of hard, compact substrate and softer material in a valley between two natural bathymetric ridges (Figure 2-4). In addition, Transects E and F were located within the disposal site boundary and were designed to identify areas of disposal trails and dredged material accumulation. Transect E extended in a northwest/southeast direction from the center of the disposal site out towards the disposal site boundary (Figure 2-4). Transect F, oriented north to south, corresponded to a ridge-like feature along the western side of the disposal site (Figure 2-4). Video Transects G and H were placed northwest of the disposal site in a region with faint bottom features believed to be trawl scars resulting from fishing activity that were detected in the side-scan mosaic.

The video cable was secured directly to the winch wire allowing for a nearly vertical positioning of the video unit relative to the GPS antenna. Logging and recording was simultaneously initiated within HYPACK® Max and the topside video unit when the survey vessel was in position at the start of each lane. Because slow vessel speed was necessary to collect quality data, no headway speed was initiated; vessel speed was based upon the drift of the survey vessel, with steerage of the vessel maintained relative to the direction of the wind. Most transects were run in a west to east direction, with the exception of Transects E, F, and D which were run either north to south or northwest to southeast.

2.6.2 Data Analysis

Analysis of the towed video data included classifying the major sediment types, as well as documenting noteworthy objects or bottom features. A written log was kept during the review of the video, noting any significant changes in sediment type and geographic location. If a sediment type was present for an extended period it was noted in the log, but minor changes or patchiness lasting less than five seconds were not included in the classification. The substrate classification results were ported to a Geographic Information System (GIS) for display. The primary viewing revealed some biological activity within RIDS. However, observational rather than quantitative data on biota were recorded, as the primary focus of the analysis was on the surface sediments characterization and the presence or absence of dredged material.

Table 2-3.

October 2003 Rhode Island Sound Towed Video Transect Coordinates

Lane	Orientation	Latitude	Longitude
		NAD 83	
A	E/W	41° 13.664´ N	71° 23.979´ W
A'		41° 13.664´ N	71° 23.657´ W
B	E/W	41° 13.731´ N	71° 23.979´ W
B'		41° 13.731´ N	71° 23.657´ W
C	E/W	41° 13.826´ N	71° 23.979´ W
C'		41° 13.826´ N	71° 23.656´ W
D	NW/SE	41° 14.746´ N	71° 23.581´ W
D'		41° 14.437´ N	71° 22.991´ W
E	NW/SE	41° 13.791´ N	71° 22.862´ W
E'		41° 13.496´ N	71° 22.428´ W
F	N/S	41° 14.169´ N	71° 23.301´ W
F'		41° 13.479´ N	71° 23.302´ W
G	NE/SW	41° 14.310´ N	71° 23.744´ W
G'		41° 14.405´ N	71° 23.530´ W
H	ENE/WSW	41° 14.490´ N	71° 23.931´ W
H'		41° 14.499´ N	71° 23.650´ W

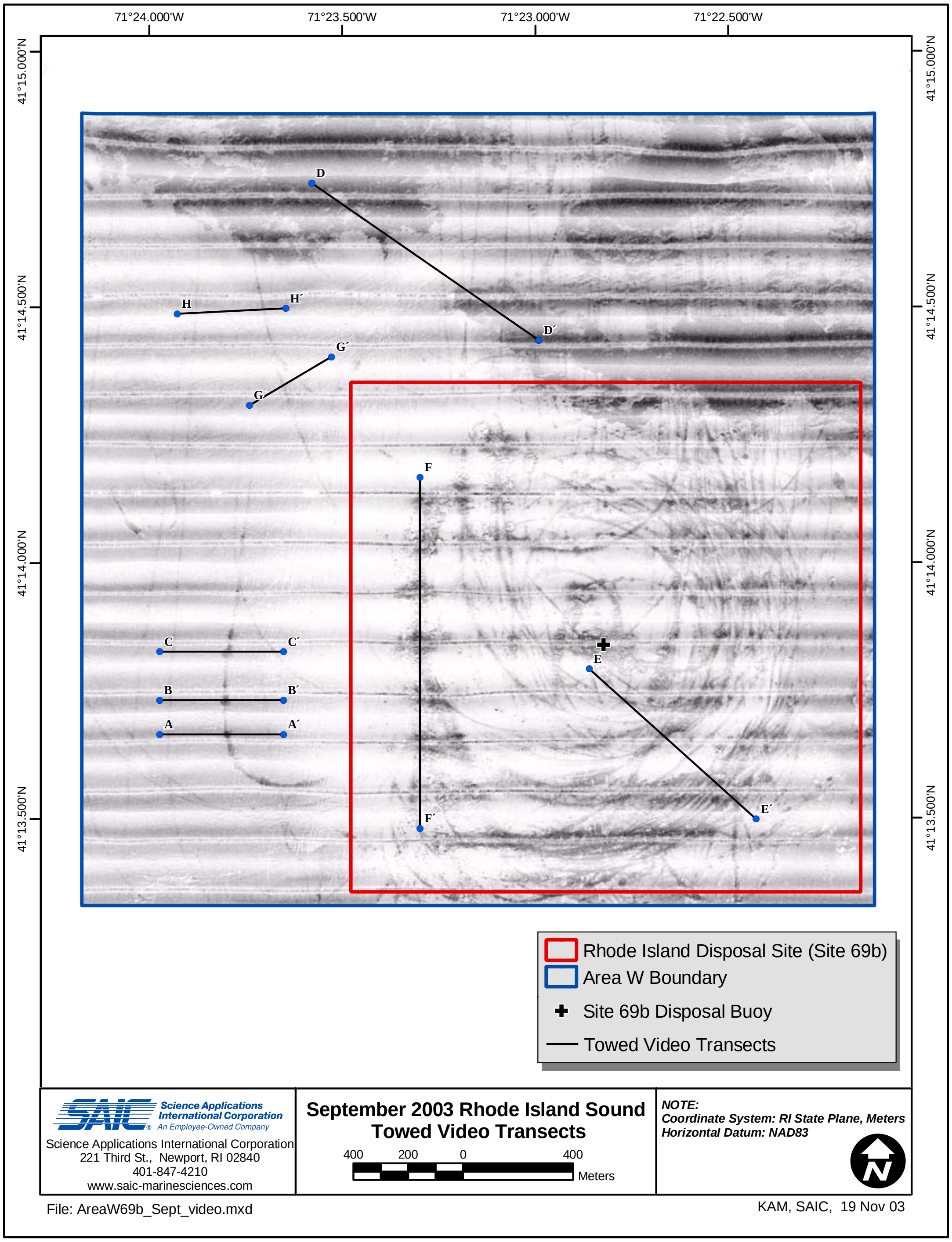


Figure 2-4. Map showing the October 2003 towed video transects within Area W over the September 2003 side-scan sonar mosaic

3.0 RESULTS

3.1 Bathymetry

A series of precision bathymetric surveys were performed over RIDS to determine seafloor topography and assess the distribution of recently disposed sediment. The February 2003 baseline survey utilized multibeam bathymetry over a 15.2 km^2 area encompassing RIDS, and was performed prior to disposal operations. The July and September 2003 single-beam bathymetric surveys were performed over a 3.6 km^2 area encompassing RIDS following the deposition of approximately 844,000 m^3 of dredged material.

3.1.1 Baseline Survey

The February 2003 multibeam bathymetric baseline survey encompassed a 4000 × 3800 m area to gain a comprehensive and detailed perspective of the disposal site (RIDS) and surrounding areas of interest (Area West; Figure 3-1). The results of the baseline survey produced a high-resolution (2 m grid cell) depiction of the seafloor within the surveyed area. The baseline survey produced a detailed representation of the disposal site prior to sediment disposal and indicated that RIDS was located in a general bathymetric depression that was bordered by a slight ridge to the north and east, as well as a more prominent ridge to the southeast corner of Area W (Figure 3-1). The water depth values for the entire 15.2 km^2 area surveyed in February ranged from a minimum of 32.5 m southeast of Area W to a maximum of 39.5 m in a depression southeast of the disposal site center (Figure 3-1). Volume calculations from the February 2003 baseline bathymetric survey indicated the bottom depression within the disposal site has the capacity of containing approximately 500,000 m^3 of dredged material. The areas of topographic highs (natural ridges) surrounding Area W to the southeast provide some shelter to the disposal site from storm-generated ocean swells from the southeast. The western portion of RIDS is a relatively flat area with little bottom topography or change in depth.

3.1.2 First Post-Disposal Monitoring Survey

In July 2003, the first single-beam bathymetric monitoring survey was performed over RIDS and provided an accurate indication of the bottom topography. Depth values within the 1900 × 1900 m survey area ranged from a minimum of 35.5 m occurring along a natural bathymetric ridge in the southeast corner of the disposal site center to a maximum depth of 39.5 m within a depression located northwest of the bathymetric ridge (Figure 3-2). As a result of recent disposal activity, five new bottom features were detected within the western portion of the disposal site in the July 2003 survey.

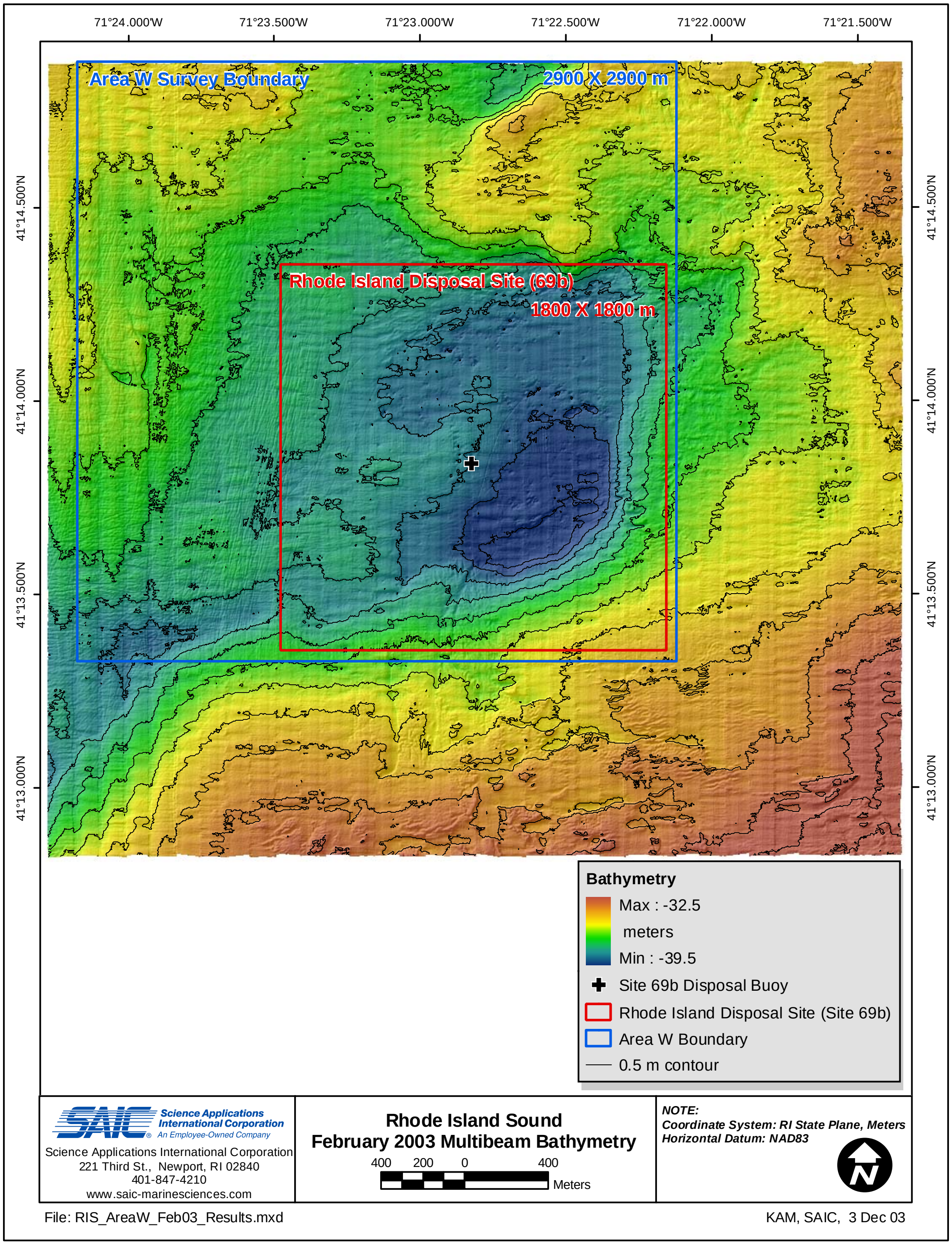


Figure 3-1. Bathymetric chart of the February 2003 baseline multibeam survey over the 15.2 km^2 survey area, 0.5 m contour interval

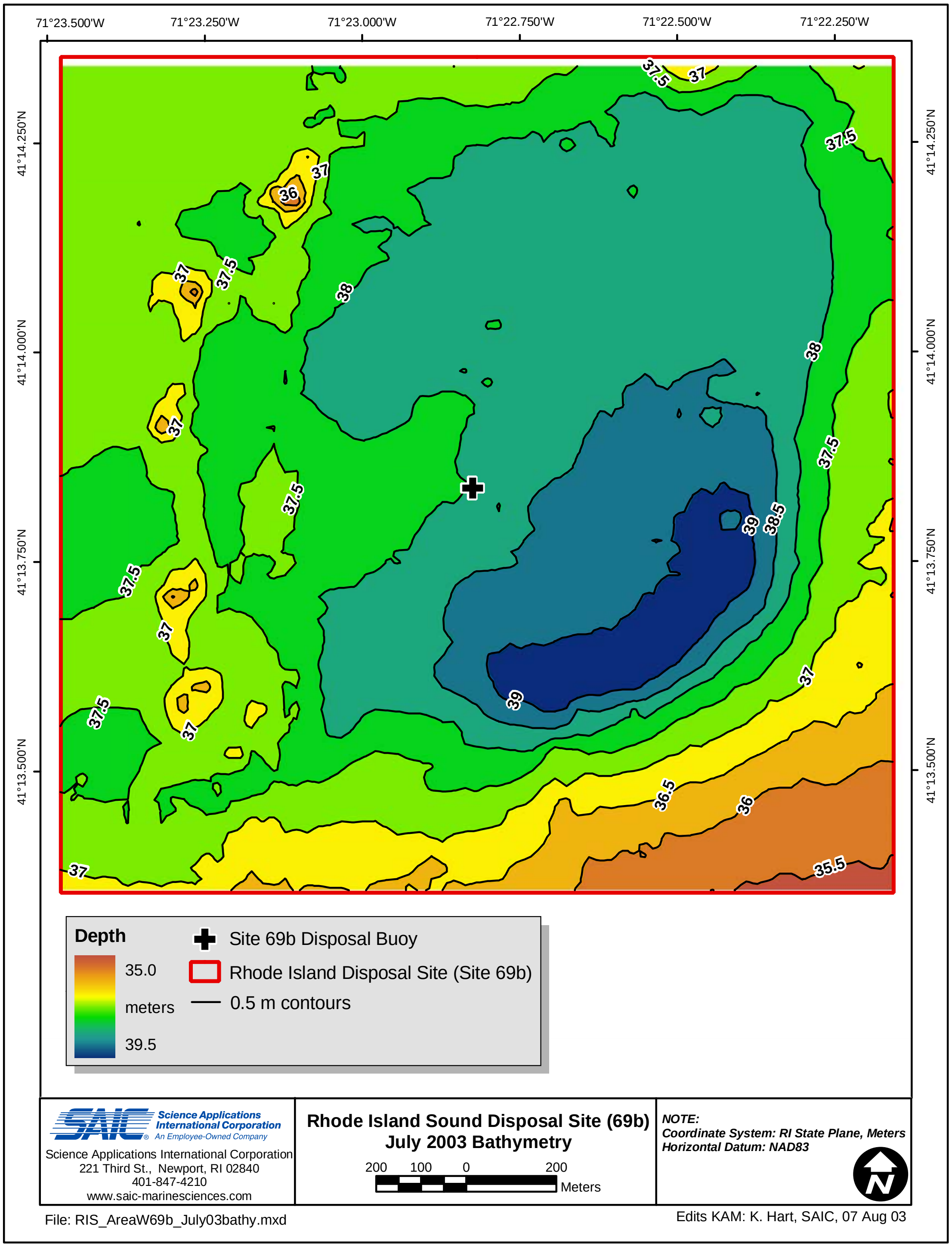


Figure 3-2. Bathymetric chart of the July 2003 survey area over RIDS, 0.5 m contour interval

Bathymetric depth difference comparisons were performed only over RIDS as bathymetry data were not collected in the surrounding Area W during the July and September 2003 surveys. A depth difference comparison of the baseline survey and the July 2003 monitoring survey revealed a minimum difference of 0.25 m and a maximum difference of 2 m (Figure 3-3). Disposal locations were designated throughout the site to facilitate the settling of plume sediments within the boundary of RIDS following disposal. As part of the RIDS management strategy, specific disposal points (Targets 1- 6) were targeted during the early phases of the Providence River dredging project. The first formations of the bathymetric ridge are shown in the depth difference comparison (Figure 3-3). Several small, interconnecting disposal mounds were observed in the western portion of RIDS and reflected recent disposal activity associated with the on-going Providence River dredging project (Figure 3-3). Disposal events occurred at Targets 1-5, with minimal accumulation detected at Target 6.

The apron of the features created around the CAD cell disposal targets ranged from approximately 80 m in diameter for Targets 3 and 6 to 200 m for the northern-most features (Targets 1 and 2). The highest apex occurs over the northern-most feature, with a height of 2 m above natural seafloor depth, while other features display topographic highs approximately 1 m above ambient seafloor (Figure 3-3). Future disposal of unconsolidated sediments (from the maintenance project) will be deposited in the depression located within the deepest part of the site, at the lettered locations (Targets A – G; Figures 1-3 and 3-3). The depth difference also shows recent disposal activity near Target E, as a deposit with a maximum diameter of 250 m was noted (Figure 3-3).

3.1.3 Second Post-Disposal Monitoring Survey

In September 2003, a second single-beam bathymetry monitoring survey was performed to document further disposal activity from the Providence River dredging project. This survey mirrored the first post-disposal monitoring effort covering the same 1900 × 1900 m area over RIDS. Similar to the July 2003 monitoring survey, the minimum and maximum depths in September ranged from 35 to 39.5 m, respectively in the same regions as the July survey (Figure 3-4). However, the September 2003 survey revealed an increase in the overall size of the containment ridge in the western portion of the disposal site.

As anticipated, a depth difference comparison of the September 2003 survey and the February 2003 baseline survey showed both a horizontal and vertical increase in the morphology of the containment ridge; the apron of the containment ridge had extended in all directions connecting the previous topographic features (Figure 3-5). The minimum depth difference for the September survey was 0.25 m, while the maximum depth difference was 2.5 m. The apex of the bathymetric ridge, located in the center of the feature, increased from 2 m above natural depth to 2.5 m.

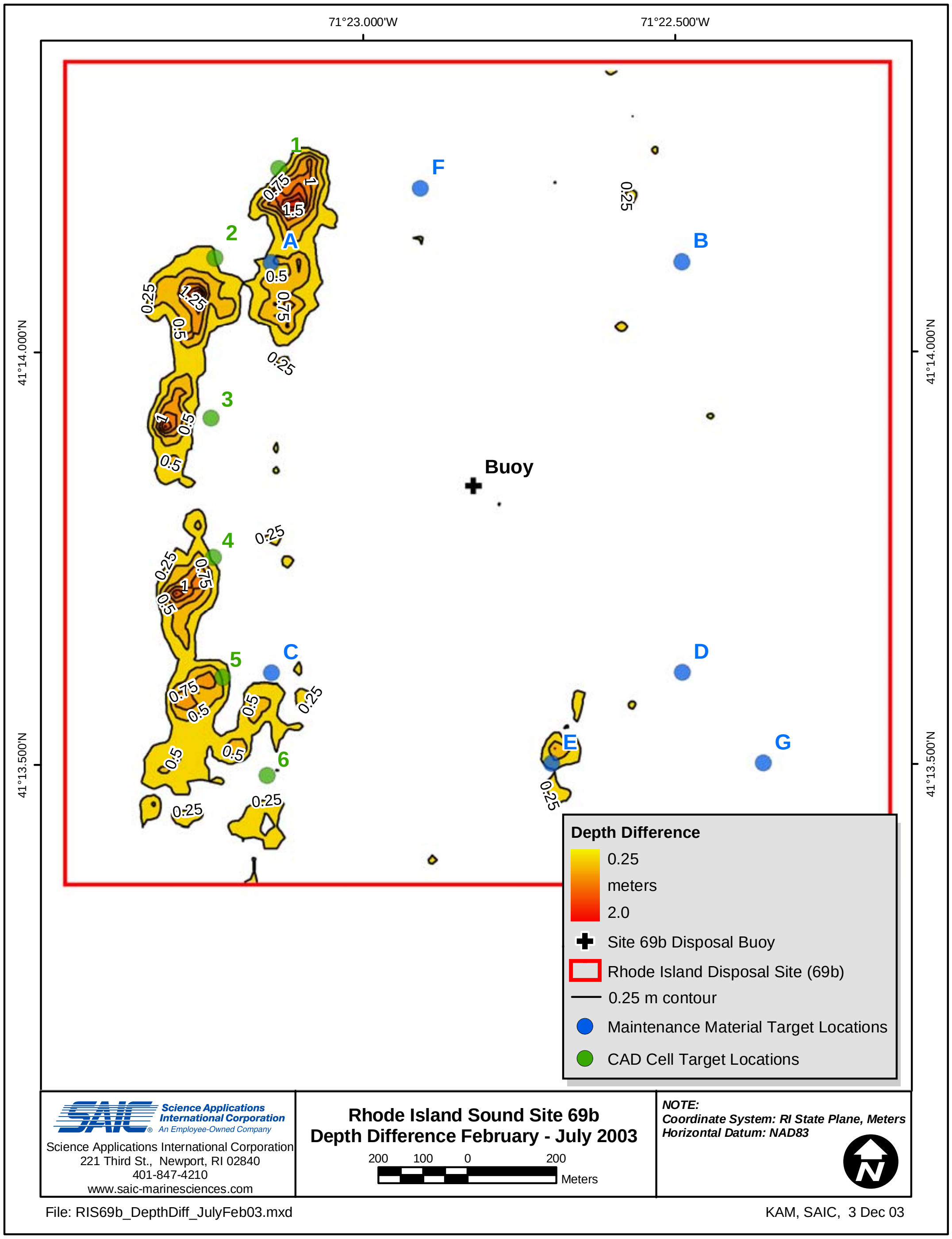


Figure 3-3. Chart showing the results of the depth difference comparison between the February 2003 baseline and July 2003 bathymetric data over RIDS, 0.25 m contour interval

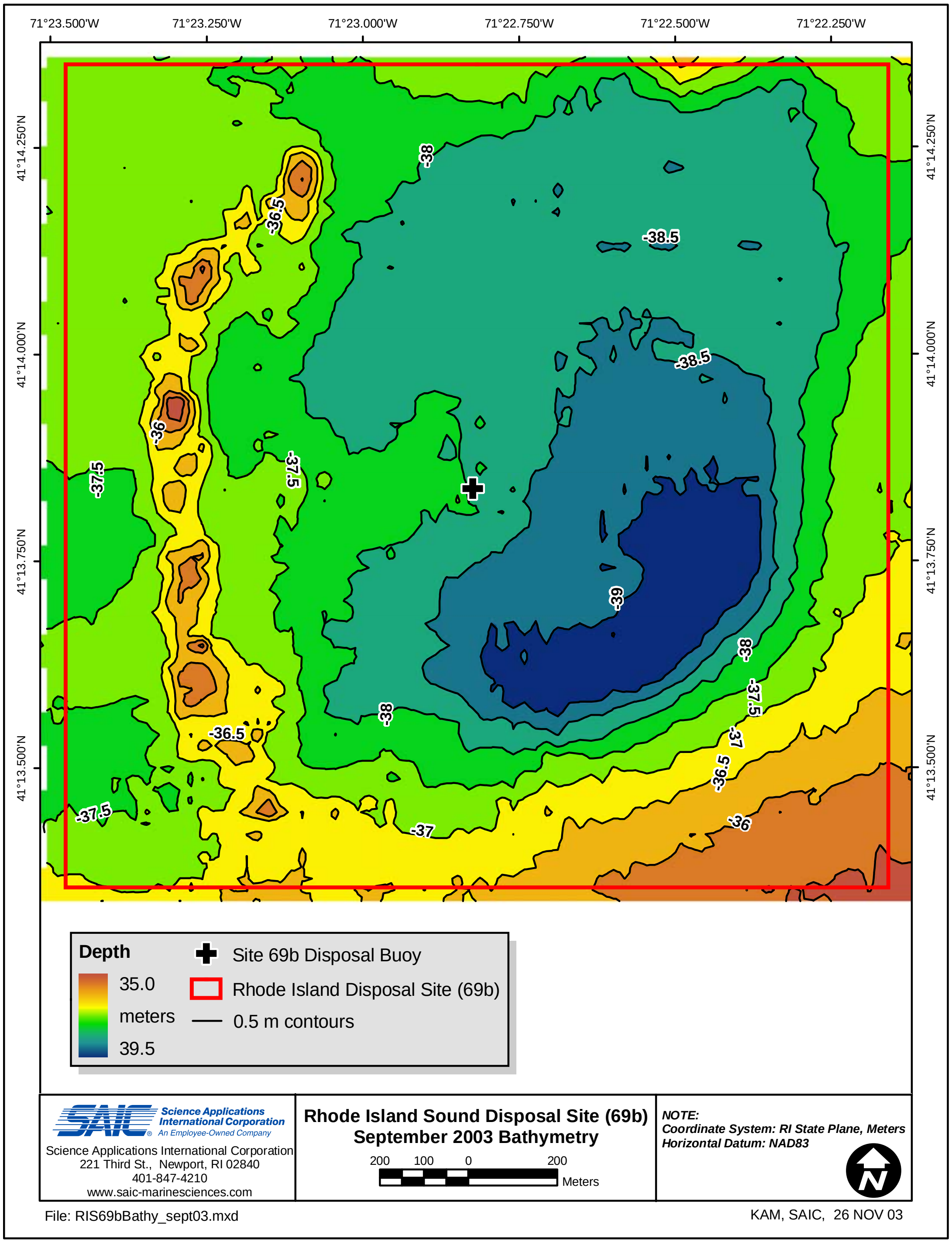


Figure 3-4. Bathymetric chart of the September 2003 survey area over RIDS, 0.5 m contour interval

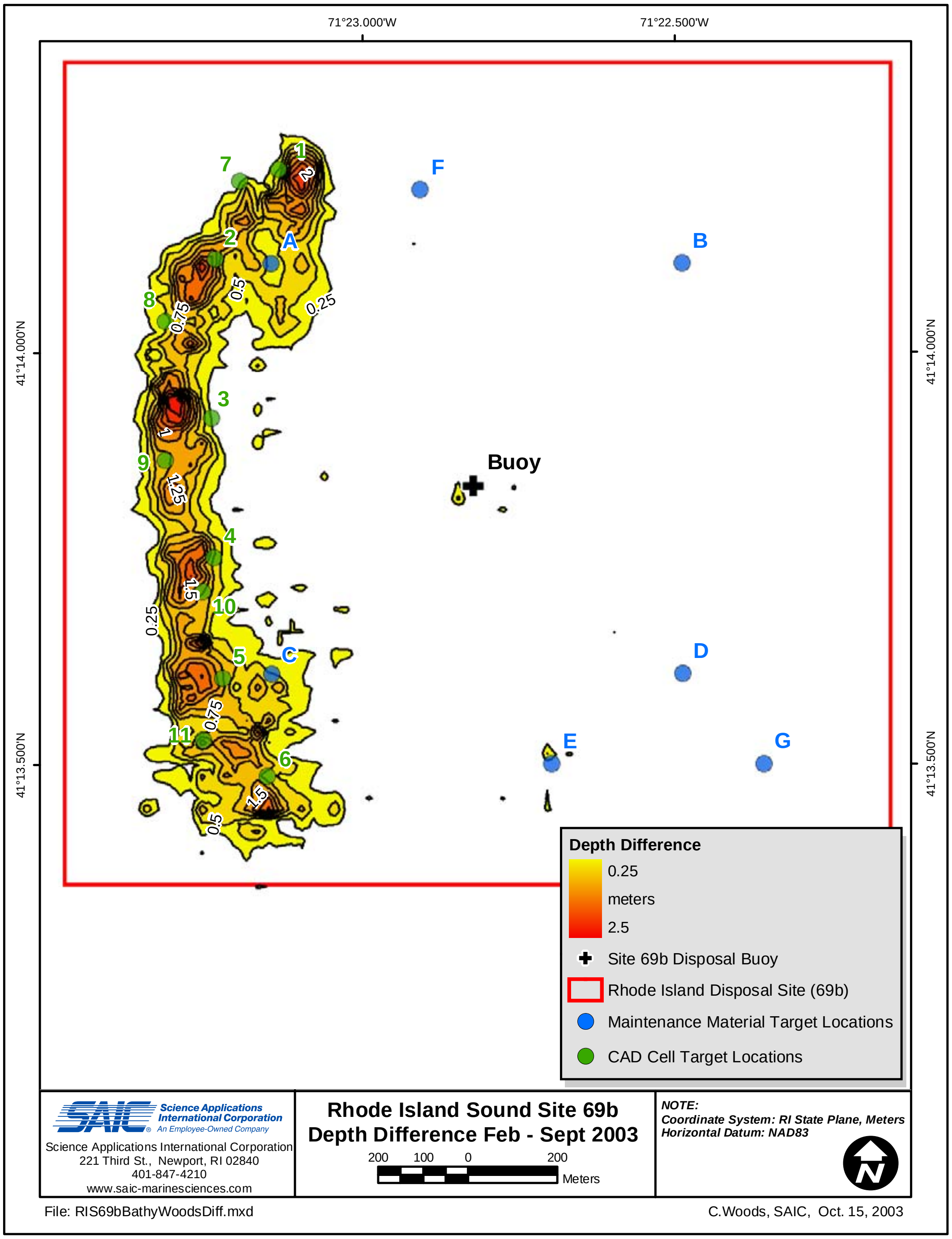


Figure 3-5. Chart showing the results of the depth difference comparison between the February 2003 baseline and September 2003 bathymetric data over RIDS, 0.25 m contour interval

Between the July and September surveys an additional five disposal points were selected for the deposition of material generated by the construction of CAD cells. As a result of recent, controlled dredged material placement at all eleven disposal points a continuous ridge with a maximum width of approximately 400 m has been formed. It also appears that disposal activity has been directed to Target 6, causing an extension of the containment ridge farther to the south (Figure 3-5). Volume calculations indicated the development of a continuous ridge along the western boundary of RIDS has resulted in the formation of an artificial containment cell with an overall capacity of 1.44 million cubic meters, if filled to the 37.5 m contour.

Apart from the containment ridge, additional small areas of sediment accumulation were observed in other regions of the disposal site. A recent small accumulation of sediment at the disposal buoy, located in the center of RIDS, has resulted in a slight increase in height in this area (Figure 3-5). The small deposit formed around Target E had displayed a small degree of consolidation since the July survey, with thickness values decreasing slightly.

3.2 Side-Scan Sonar

The data obtained from the September 2003 side-scan sonar survey over Rhode Island Sound Area W including RIDS were used to develop a high resolution, acoustic map of the seafloor displaying various seafloor features (sediment types, disposal trails and bedforms; Figure 3-6). The September survey provided at least 110% coverage of the seafloor and illustrated distinctive features within the survey area.

The September 2003 survey clearly displayed areas of sediment accumulation within RIDS trending north/south along the western edge of the disposal site. As a result of recent disposal events, multiple small, interconnecting disposal mounds forming a containment ridge were evident in the western region of the disposal site (Figure 3-6). RIDS was dominated by lower-reflectance acoustic returns, however the disposal mounds exhibited darker material (strong acoustic returns) and reflect widespread areas of sediment accumulation (dredged material). The newly formed portion of the containment ridge along with the natural topographic relief within RIDS have resulted in the formation of a circular shaped containment feature.

Side-scan sonar showed agreement with the bathymetry collected within RIDS as areas of dredged material accumulation detected in the September bathymetry survey corresponded with the dredged material identified in the side-scan sonar (Figure 3-7). In addition, these disposal mounds displayed numerous barge disposal trails leading away in a circular pattern from the western side of the disposal site with some extending outside the northern, western, and southern boundaries of RIDS (Figure 3-6). These trails were narrow, low relief features that were undetectable in the single-beam bathymetry data, and are associated with small amounts of dredged material falling from the barge as it departs from the main disposal point.

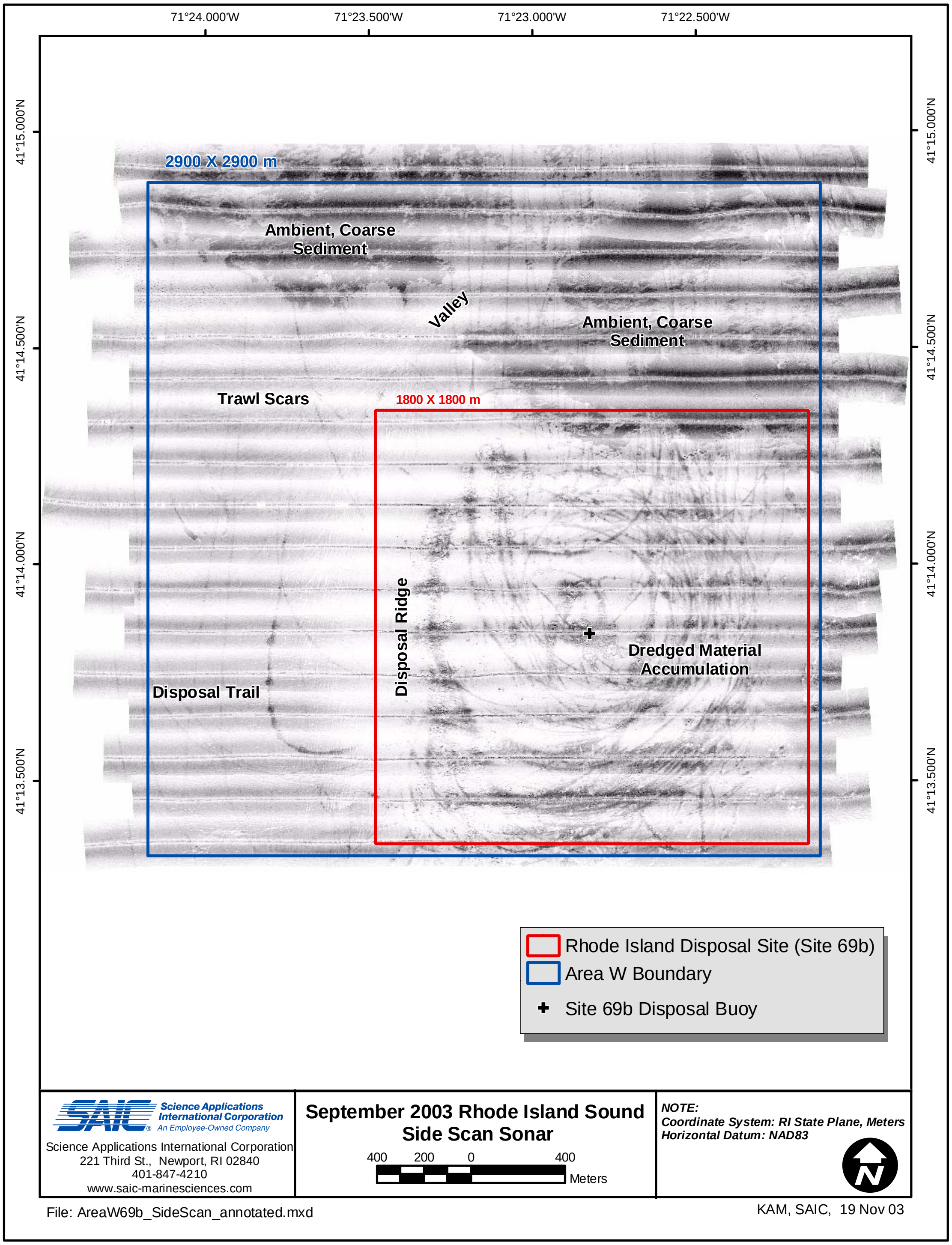


Figure 3-6. Map showing the side-scan sonar mosaic (100 kHz) over the September 2003 Area W survey area

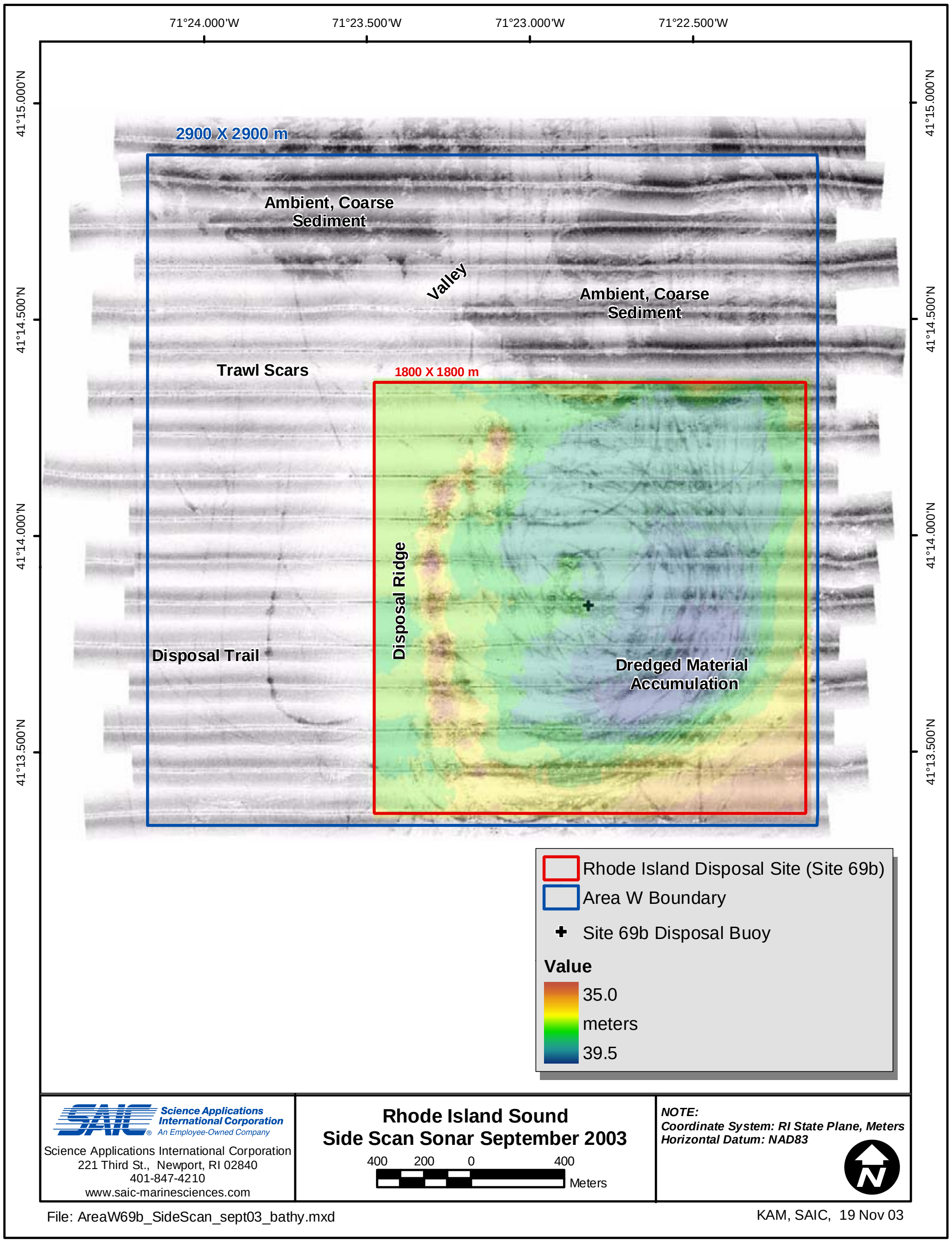


Figure 3-7. Composite graphic displaying the September 2003 side-scan sonar mosaic overlain by bathymetry data showing the relationship between seafloor topography and seafloor composition within RIDS, 0.5 m color gradient

The disposal trail features in the side-scan sonar contrast with the lower-reflectance acoustic returns of the ambient sediments in this region of Rhode Island Sound. The bottom depression that is visible in the bathymetry in the southeastern regions of RIDS, appears as an area of lower sonar return in the side-scan mosaic, suggesting soft ambient sediments continue to dominate the seafloor despite the presence of multiple disposal trails and individual deposits.

The full mosaic of Area W revealed that the area was comprised of varying sediment types, ranging from glacially derived sediment to recently deposited dredged material. The sediment overlying the northern portion of Area W (a natural bathymetric ridge) had a very hard acoustic return and appeared to be comprised largely of coarse-grained glacial sediment (coarse sand, gravel, and till); this area was adjacent to areas of softer sediment types with lower reflectance (Figure 3-6). Sediment grab samples taken from the northern region of Area W (grab Stations West_01 and West_02) during the July 2003 survey in support of the Rhode Island Sound Region Long-Term Dredged Material Disposal Site Evaluation Project confirmed the presence of gravel, till, and coarse sand (Battelle 2003; Figure 3-8). Unconsolidated sediment (sand and silt) was detected in areas of low-reflectance acoustic return in the southern portion of survey area (Figure 3-6). Sediment grabs taken from the southern region (grab Station West_03 and West_04) were composed of softer silt and sand confirming the presence of these sediment types in the side-scan mosaic (Battelle 2003; Figure 3-8).

The most prominent of the disposal trails detected in the side-scan sonar survey was clearly visible in the southwest corner of Area W approximately 450 m outside the RIDS disposal site boundary. Trending north-south, the accumulations of recently deposited dredged material produced stronger acoustic returns in the mosaic relative to the ambient silt and fine sand (Figure 3-6). The L-shaped disposal trial covered a relatively small area within Area W, with an overall length of approximately 1,100 m and widths ranging from 12 to 35 m. The strength of the acoustic return indicated that the disposal trail consisted of newly deposited material, most likely originating from the small volume of dredged material remaining in the barge after disposal operations at RIDS. Three distinct sediment deposits were visible within this disposal trail and prompted the placement of REMOTS® sampling stations over these features for a cross-check comparison (see Figure 2-3). Other than numerous disposal-related features (e.g., disposal mounds and trails), no obvious man-made artifacts were detected in the September 2003 imagery data (Figure 3-6). However, the side-scan data captured a cluster of indistinct scar-like features in the northwest region of Area W, as well as several linear trawl scars surrounding the disposal trail in the southwest corner of Area W (Figure 3-6). With a closer inspection of the side-scan sonar, these scar-like features can be inferred as trawl scars (fishing-related seafloor disturbance).

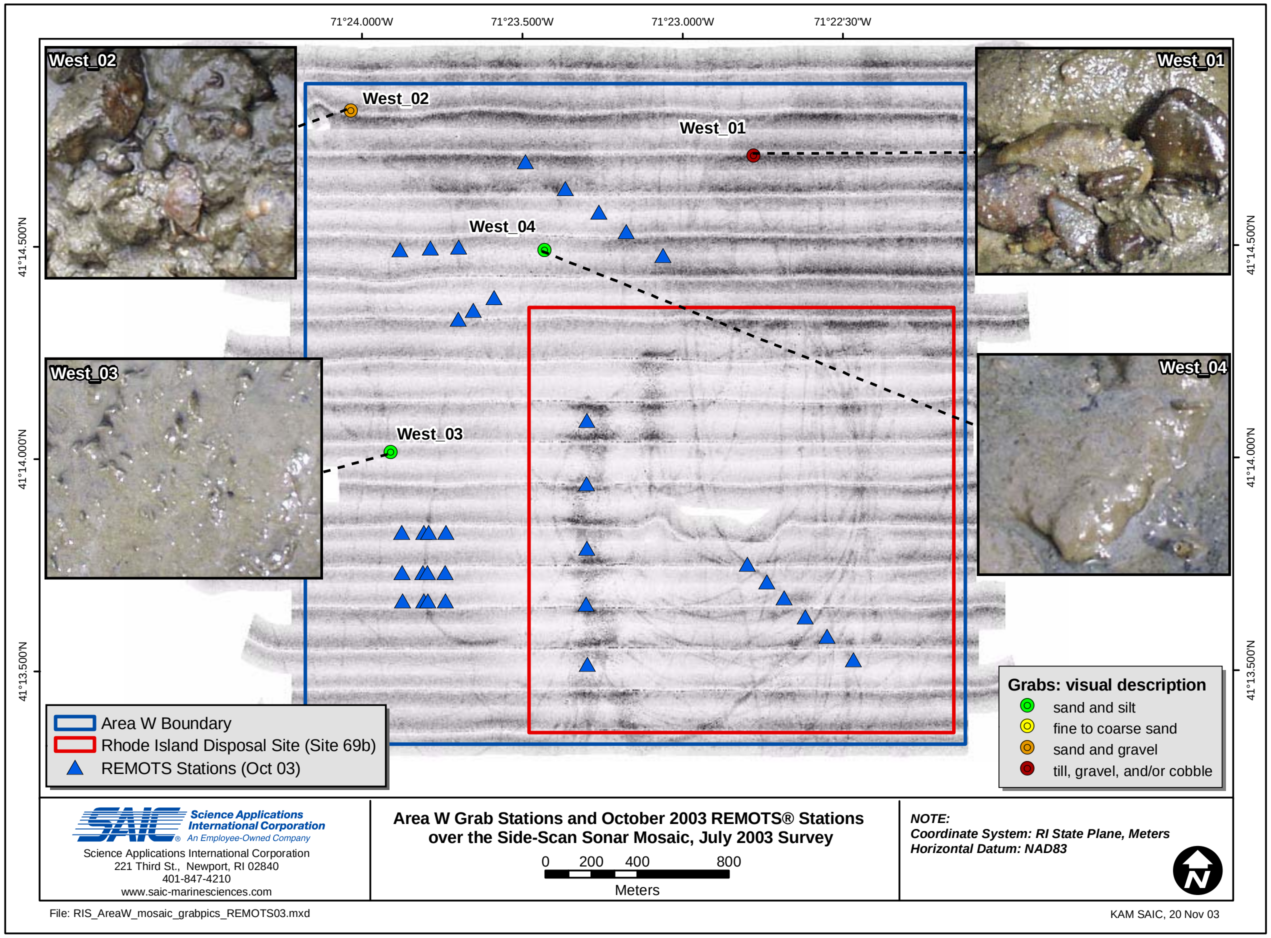


Figure 3-8. Photos from selected grab sample locations relative to REMOTS® station locations shown over the July 2003 side-scan sonar mosaic of Area W collected as part of an earlier study funded by NAE

3.3 REMOTS® Sediment-Profile Imaging

The REMOTS® results were primarily used to assess surface sediment composition within RIDS and the surrounding survey area (Area West), determine the distribution of dredged material, and examine the conditions of the seafloor in areas with potential disposal trails, deposits, and trawl scars. The biological parameters were also examined for the disposal trail survey area to assess the impacts of the deposition of dredged material and evaluate the process of benthic community recovery. The complete set of REMOTS® image analysis results is provided in Appendix B; these results are summarized in Tables 3-1 through 3-4.

3.3.1 Disposal Trail

Dredged material was evident in the REMOTS® images at 5 of the 12 stations (Stations 2, 7, 8, 10, and 11) and coincided with the position of the disposal trail features detected in the side-scan sonar mosaic in the southwestern portion of the survey area (Table 3-1 and Figure 3-9). Dredged material was detected in only one replicate image of all these stations, with the exception of Station 11, which displayed dredged material in two replicate images. Because sampling stations were established directly over the larger sediment deposit areas detected in the side-scan mosaic, dredged material layers were thicker than initially anticipated. When present, dredged material layers exceeded the penetration depth of the REMOTS® camera (i.e., dredged material layer thickness greater than prism penetration) in all but the one replicate image from Station 8. At this station, a discrete layer of deposited sediment was detected over ambient sediment (Table 3-1 and Figure 3-10A). With the exception of Station 8, results of the REMOTS® survey indicated that the disposal trail was relatively narrow, with a lateral extent of approximately 12 to 35 m. The dredged material detected at the Disposal Trail stations was predominately fine-grained, composed of tan and gray fine-grained silty sand mottled with white clay, with a grain size major mode of 4 to 3 phi (Table 3-1; Figure 3-10B).

Ambient sediment (i.e., unaffected by dredged material disposal) consisting of tan and gray silty sand was evident at the remaining stations surrounding the disposal trail (Table 3-1 and Figures 3-9 and 3-11). A major modal grain size of 4 to 3 phi was detected at most of the stations displaying ambient sediment (Table 3-1). Results from the side-scan sonar and sediment grab survey conducted in July 2003 revealed soft sediment (sand and silt) in the region just north of the disposal trail stations (Battelle 2003; Figure 3-8). Side-scan returns (lower-reflectance) in this area (grab Station West_03) were similar to those observed over the majority of the ambient stations within the disposal trail sample area and supported the results of the REMOTS® analysis (Figure 3-8).

Table 3-1.

Summary of REMOTS® Sediment-Profile Imaging Results over Disposal Trail Stations, October 2003 Survey

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Grain Size Major Mode (# replicates)	Successional Stages Present	Highest Stage Present	RPD Mean (cm)	OSI Mean	OSI Median
1	7.26	0.00	0	1.63	4 to 3 phi (2)	I,III	ST III	1.26	5.0	5.0
2	8.35	2.41	1	1.28	4 to 3 phi (3)	I,III	ST I on III	2.05	5.7	5.0
3	9.77	0.00	0	0.92	4 to 3 phi (2)	I,III	ST I on III	1.90	6.0	6.0
4	9.41	0.00	0	1.28	4 to 3 phi (3)	I,III	ST I on III	2.02	5.3	4.0
5	7.83	0.00	0	1.07	4 to 3 phi (2)	I,III	ST I on III	3.11	8.0	8.0
6	9.82	0.00	0	1.66	4 to 3 phi (2)	I,III	ST I on III	2.23	6.5	6.5
7	12.80	8.54	1	0.95	4 to 3 phi (2)	I,II,III	ST I on III	2.74	8.0	8.0
8	12.27	2.99	1	1.11	3 to 2 phi (1), 4 to 3 phi (2)	I,III	ST I on III	2.26	5.7	6.0
9	8.90	0.00	0	0.74	4 to 3 phi (2)	I,III	ST I on III	1.90	6.0	6.0
10	7.85	3.08	1	1.87	4 to 3 phi (3)	I,III	ST I on III	1.80	5.3	4.0
11	11.70	> 8.26	2	2.08	4 to 3 phi (3)	I,II	ST II	2.01	5.7	6.0
12	10.79	0.00	0	1.02	4 to 3 phi (3)	I,III	ST I on III	1.32	6.0	7.0
AVG	9.73	2.11	0.5	1.30				2.05	6.1	6.0
MAX	12.80	> 8.26	2	2.08				3.11	8.0	8.0
MIN	7.26	0.00	0	0.74				1.26	5.0	4.0

Table 3-2.

Summary of REMOTS® Sediment-Profile Imaging Results over Trawl Scar Stations, October 2003 Survey

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Grain Size Major Mode (# replicates)	Successional Stages Present	Highest Stage Present	RPD Mean (cm)	OSI Mean	OSI Median
29	7.45	0.00	0	2.69	4 to 3 phi (2)	I,II,III	ST II on III	2.24	6.5	6.5
30	7.62	0.00	0	1.52	> 4 phi (1), 4 to 3 phi (2)	I,III	ST I on III	2.12	5.7	5.0
31	12.39	0.00	0	0.81	3 to 2 phi (2)	I,II,III	ST II on III	4.19	9.0	9.0
32	5.91	0.00	0	1.34	3 to 2 phi (1), 4 to 3 phi (2)	I,II,III,INDET	ST II on III	1.86	8.0	8.0
33	3.79	0.00	0	0.57	< -1 phi (1), 4 to 3 phi (1)	I,III,INDET	ST I on III	4.48	11.0	11.0
34	8.43	0.00	0	1.20	3 to 2 phi (1), 4 to 3 phi (3)	I,III	ST I on III	3.17	7.0	6.0
AVG	7.60	0.00	0	1.36				3.01	7.9	7.6
MAX	12.39	0.00	0	2.69				4.48	11.0	11.0
MIN	3.79	0.00	0	0.57				1.86	5.7	5.0

Table 3-3.

Summary of RIDS REMOTS® Sediment-Profile Imaging Results, October 2003 Survey

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Grain Size Major Mode (# replicates)	Successional Stages Present	Highest Stage Present	RPD Mean (cm)	OSI Mean	OSI Median
18	14.25	> 14.25	8	1.41	> 4 phi (5), 4 to 3 phi (3)	I,III,INDET	ST III	2.76	6.3	6.0
19	11.16	> 11.16	4	1.92	> 4 phi (2), 3 to 2 phi (1), 4 to 3 phi (1)	I,III	ST III	3.36	6.8	6.0
21	20.61	> 20.61	4	0.12	> 4 phi (4)	INDET	INDET	INDET	INDET	INDET
22	12.40	> 12.40	4	1.39	> 4 phi (1), 4 to 3 phi (3)	I,III	ST III	3.84	8.5	8.5
23	8.73	> 8.73	3	1.37	4 to 3 phi (3)	I	ST I	3.47	6.0	7.0
24	9.90	> 9.90	4	2.16	> 4 phi (2), 2 to 1 phi (1), 4 to 3 phi (1)	I,INDET	ST I	0.44	2.0	2.0
25	5.02	> 5.02	3	1.04	3 to 2 phi (2), 4 to 3 phi (1)	I,INDET	ST I	3.15	5.5	5.5
26	6.85	> 6.85	2	0.85	4 to 3 phi (2)	I,INDET	ST I	0.99	3.0	3.0
27	9.78	> 9.78	4	1.29	> 4 phi (1), 4 to 3 phi (3)	I,III	ST I on III	1.77	4.8	4.5
28	10.04	> 10.04	3	1.74	> 4 phi (1), 4 to 3 phi (2)	I,INDET	ST I	2.54	5.0	5.0
AVG	10.87	10.87	3.9	1.33				2.48	5.3	5.3
MAX	20.61	20.61	8	2.16				3.84	8.5	8.5
MIN	5.02	4.79	2	0.12				0.44	2.0	2.0

Table 3-4.

Summary of REMOTS® Sediment-Profile Imaging Results over the Sediment Transition Area (Area W), October 2003 Survey

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Grain Size Major Mode (# replicates)	Successional Stages Present	Highest Stage Present	RPD Mean (cm)	OSI Mean	OSI Median
13	3.60	0.00	0	1.70	4 to 3 phi (3)	I	ST I	1.88	4.0	4.0
14	8.94	0.00	0	2.59	3 to 2 phi (1), 4 to 3 phi (2)	I,III	ST I on III	1.88	5.3	4.0
15	6.33	0.00	0	0.75	> 4 phi (1), 4 to 3 phi (1)	I	ST I	2.54	5.0	5.0
16	8.29	0.00	0	1.22	4 to 3 phi (3)	I,III	ST I on III	3.08	7.0	6.0
AVG	6.79	0.00	0	1.56				2.34	5.3	4.8
MAX	8.94	0.00	0	2.59				3.08	7.0	4.0
MIN	3.60	0.00	0	0.75				1.88	4.0	6.0

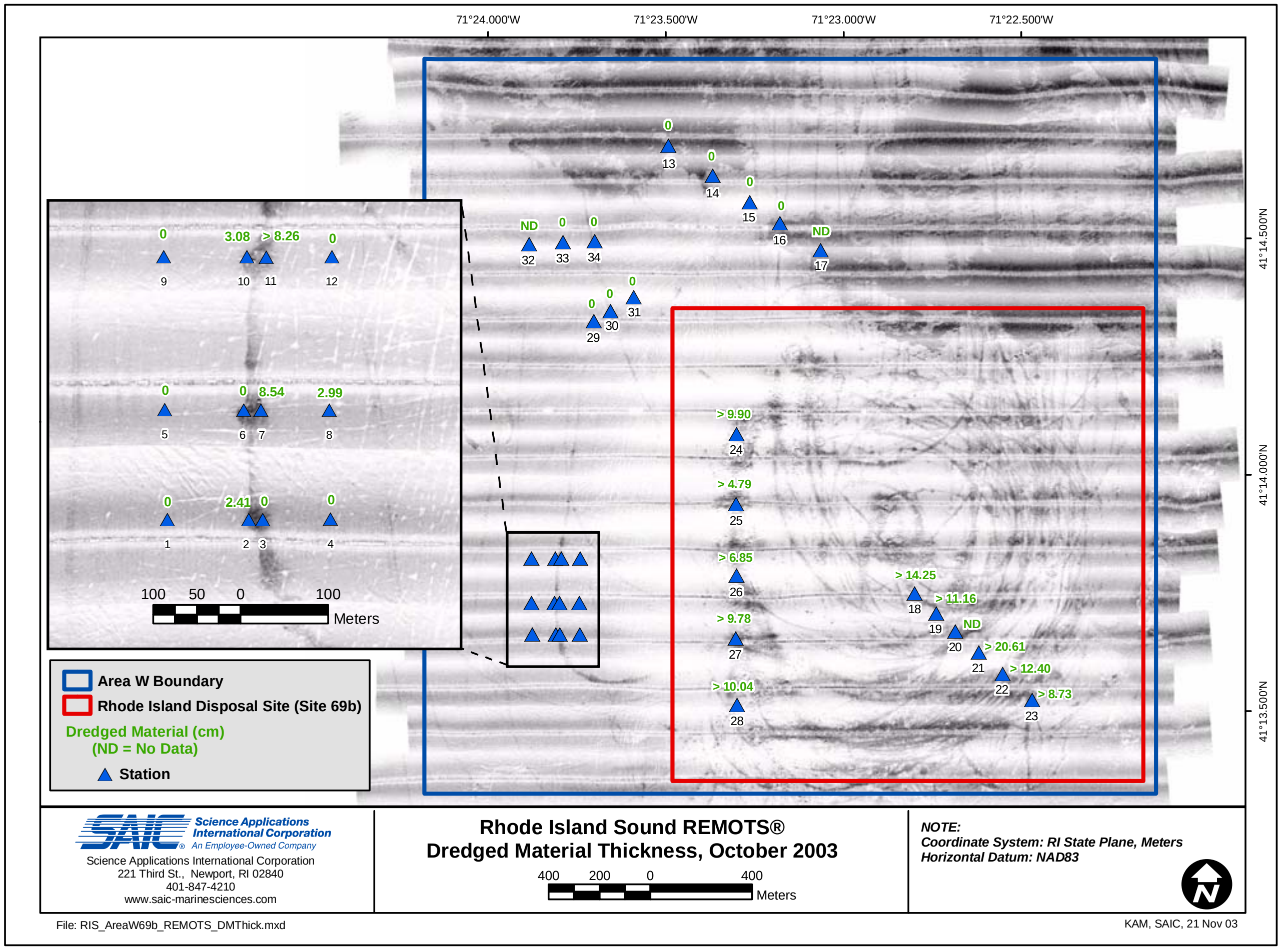
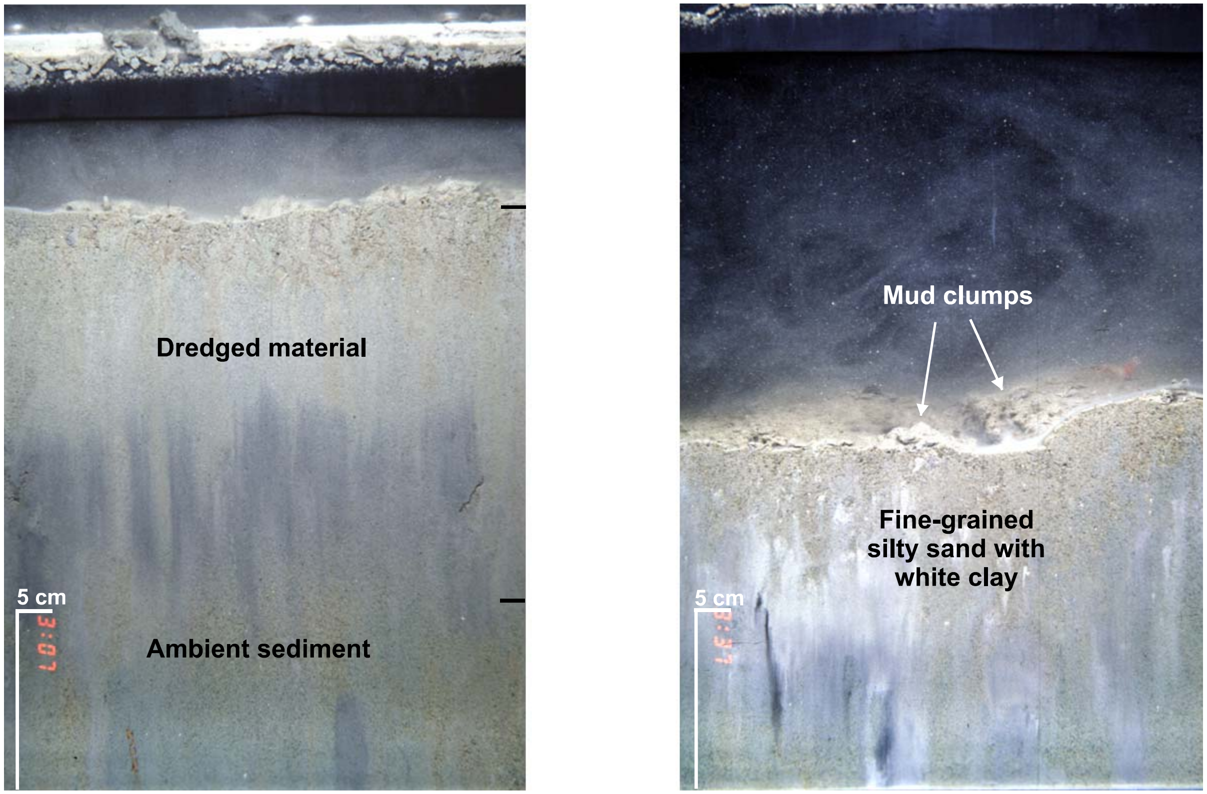


Figure 3-9. Map of mean dredged material thickness (cm) for the October 2003 REMOTS® stations over the September 2003 side-scan sonar mosaic



A B

Figure 3-10. REMOTS® images obtained from Disposal Trail Stations 8 (A) and 10 (B) during the October 2003 survey illustrating fine-grained dredged material (grain size major mode of 4 to 3 phi) composed of silty sand and white clay. Image A shows a discrete dredged material layer (9.0 cm) over ambient sediment, while Image B shows a dredged material layer that exceeded the penetration depth of the REMOTS® camera (>9.3 cm). Mud clumps were visible at the sediment surface of image B and reflect recent physical disturbance likely due to the placement of dredged material at this station.

Figure 3-11. REMOTS® image from Disposal Trail Station 4 located outside the disposal trail showing ambient fine grained sediment (silty sand)

The penetration depth of the sediment-profile camera prism typically serves as a relative measure of sediment density or compaction. Mean camera penetration measurements for the disposal trail stations ranged from 7.3 cm at Station 1 to 12.8 cm at Station 7 (Table 3-1). The overall average of 9.7 cm indicates relatively firm sediment likely due to a significant sand component.

Replicate-averaged small-scale boundary roughness values for the disposal trail stations ranged from 0.7 cm at Station 9 to 2.1 cm at Station 11, with an overall average of 1.3 cm indicative of a small amount of small-scale surface relief due primarily to physical processes (Table 3-1). Surface roughness was attributed to physical factors in all but two replicate images. Bedforms (sand ripples) were present at the sediment-water interface in several images suggesting this area is subject to some degree of bedload transport, occurring as a result of wave-induced bottom scour during high-energy storm events (Figure 3-12A). Furthermore, mud clasts/clumps were visible at the sediment surface of several images and indicate recent physical disturbance from dredged material disposal (Figure 3-10B). A dense assemblage of amphipod tubes (*Ampelisca* sp.) were detected at the sediment surface of one replicate image of Station 11 and resulted in biogenic surface roughness for this replicate image (Figure 3-12B).

The benthic community appeared quite stable within the disposal trail survey region, with an advanced biological assemblage present at each station sampled. Stage I surface dwelling polychaetes were often detected at the sediment-water interface, with evidence of Stage III deposit feeders common at depth in the replicate images (Table 3-1). Stage II organisms (*Ampelisca sp.*) represented the most advanced successional stage detected at Station 11, which displayed the most significant accumulation of dredged material.

Replicate-averaged RPD depths ranged from 1.3 to 3.1 cm, with an overall mean of 2.1 cm, indicating moderate to well aerated surficial sediments. It is also noteworthy that the stations with layers dredged material present (Stations 2, 7, 8, 10, and 11) displayed the deeper RPD depths. This trend may be the result of elevated levels of bioturbation within the benthos as resident infauna preferentially exploit the deposited sediment as a food source due to the higher organic material content relative to the ambient fine sands in the region.

Due to the presence of advanced successional stages and relatively deep RPDs, median OSI values ranged +5 to +8, indicating the area was recovering quite well from the highly localized benthic disturbances. OSI values of +6 and above are indicative of a stable, non-degraded benthic habitat conditions and were calculated for the majority of the stations sampled in disposal trail survey area (Table 3-1).

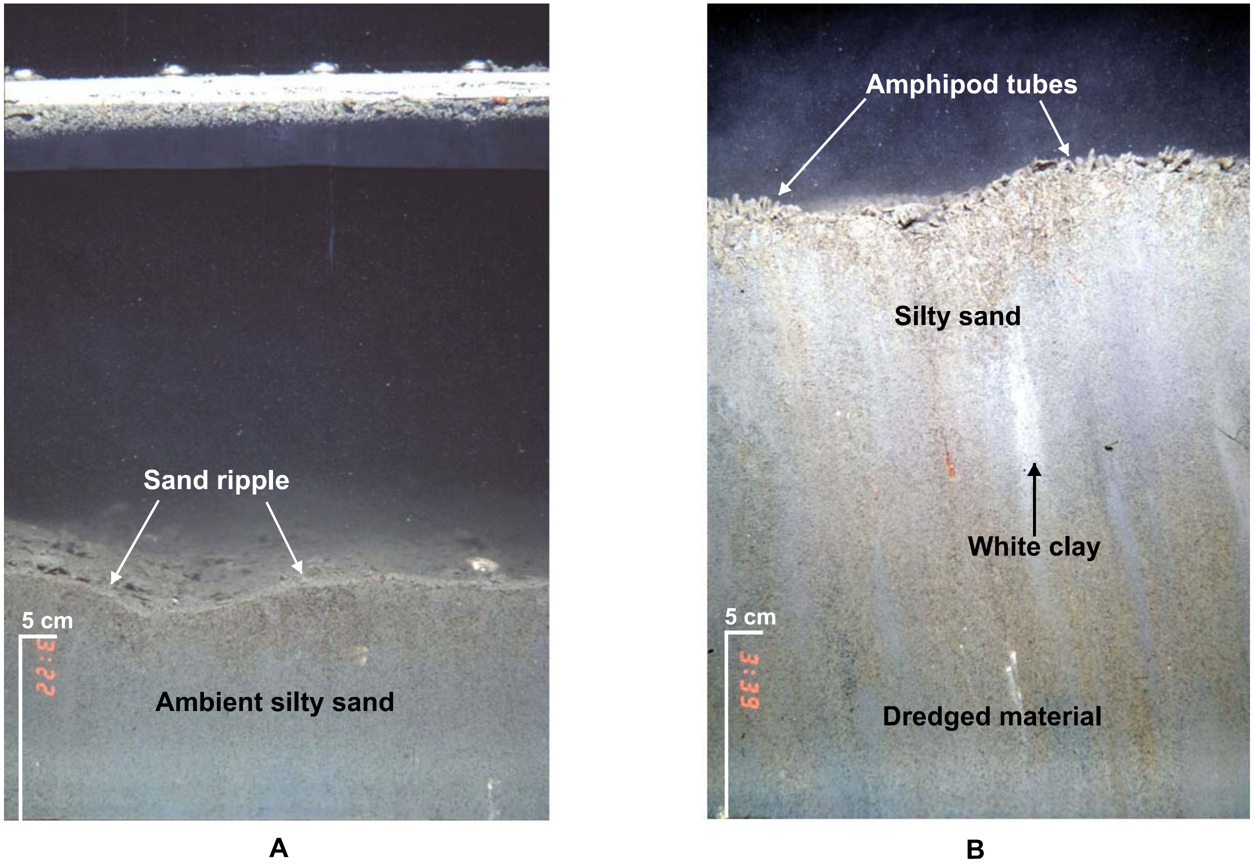


Figure 3-12. REMOTS® images collected from Disposal Trail Station 5 (A) and Station 11 (B) displaying surface roughness in ambient sediment (A) and dredged material (B). Image A illustrates physical surface roughness as a result of bedforms (sand ripples) at the sediment-water interface. Image B shows biogenic surface roughness due to a dense assemblage of juvenile amphipod tubes (*Ampelisca*) at the sediment-water interface.

3.3.2 Trawl Scars

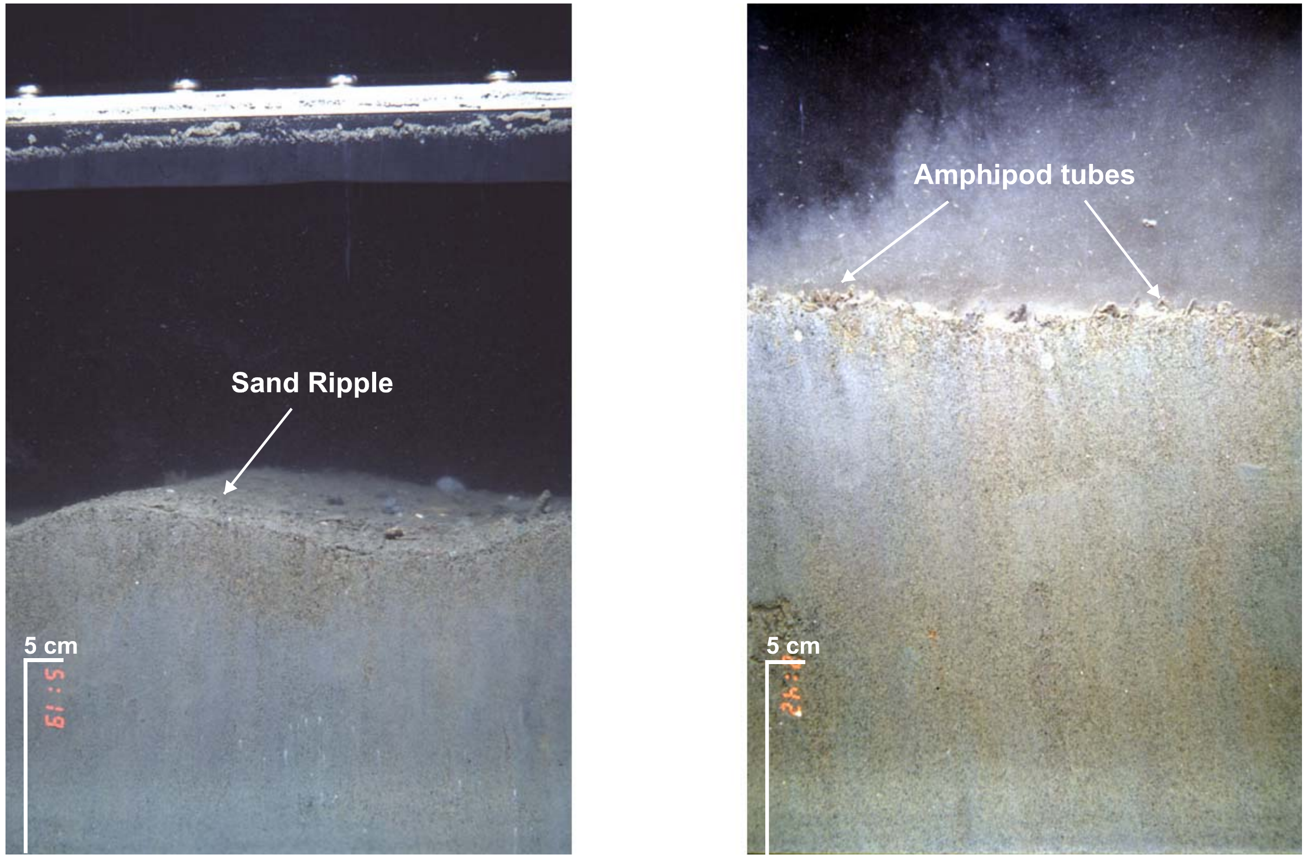
Ambient tan and gray fine-grained silty sand was observed at all six stations over the trawl scar area located northwest of RIDS (Table 3-2; Figure 3-9). The grain size major mode of the trawl scar stations was primarily 4 to 3 phi, however three stations had at least one replicate image showing a slightly coarser sand component that ranged from 3 to 2 phi. The July 2003 Area W grab station positioned within an area of lower reflectance in the side-scan sonar mosaic (Station West_04) also showed material composed primarily of sand and silt (Figure 3-8).

Mean camera penetration measurements varied from a shallow 3.8 cm at Station 33 to 12.4 cm at Station 31 (average of 7.6 cm; Table 3-2). These relatively low camera prism measurements reflect the presence of more compact material (fine sand) that tended to resist deep penetration of the sediment-profile camera. Underpenentration of the REMOTS® camera occurred in two replicate images obtained in this area during the October 2003 survey.

The northwest region of Area W has traditionally been used for the trawling of ground fish (i.e., flounder). Although previous side-scan sonar surveys have revealed faint features that appeared to be trawl scars from fishing gear, no obvious evidence of recent trawling activity was evident in the REMOTS® images (see Figure 3-6). Small-scale boundary roughness values for stations within the trawl scar area ranged from 0.6 cm at Station 33 to 2.7 cm at Station 29, with an overall average of 1.4 cm (Table 3-1). Values in this range reflect relatively low boundary roughness (small amount of small-scale surface relief). Surface roughness was attributed to physical factors at most stations as a result of mud clasts and bedforms (sand ripples) at the sediment surface (Figure 3-13A). The presence of bedforms suggests this area is subject to some degree of bedload transport. Two replicate images exhibited biogenic surface roughness due to dense assemblages of amphipod tubes (*Ampelisca* sp.) at the sediment-water interface (Figure 3-13B).

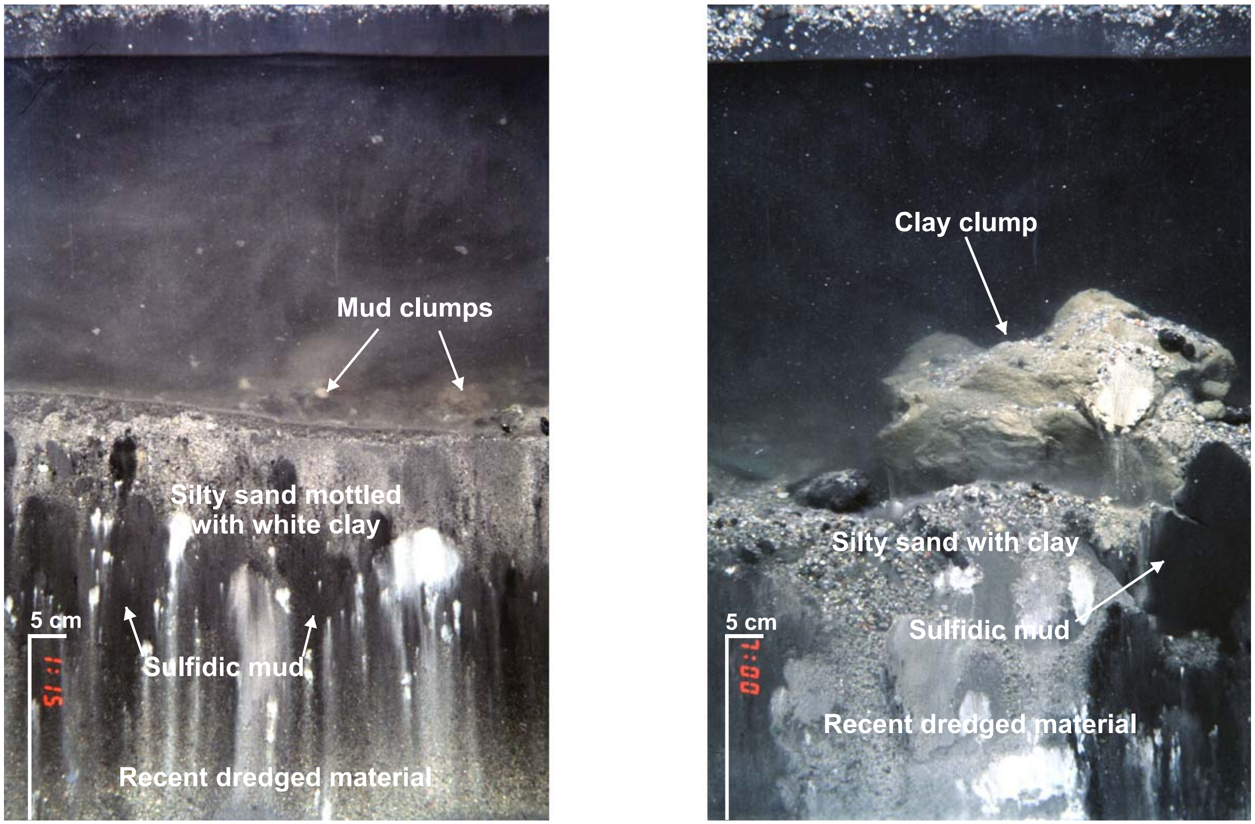
3.3.3 RIDS

Recent dredged material deposits were widespread over the surveyed area of RIDS. REMOTS® results were in agreement with the side-scan mosaic and showed that dredged material was evident over the entire site (Figure 3-9). The sediment observed in the REMOTS® images at all 10 stations positioned over sediment deposit features was considered to be relatively recent dredged material removed from the CAD cells in the upper Providence River (Fox Point Reach) as part of the first phase of the dredging project. The dredged material occurred in layers that exceeded the penetration depth of the REMOTS® camera at all stations (Table 3-3). The dredged material was generally fine-grained, composed mainly of tan and gray silty sand mottled with cohesive white clay and black sulfidic mud (Figure 3-14). Because dredged material disposal will be ongoing for the next 12 months, benthic recolonization of the areas affected by dredged material placement will appear to be disturbed,



A B

Figure 3-13. REMOTS® images collected from Trawl Scar Station 30 (A) and Station 31 (B) displaying surface roughness in ambient sediment. Image A illustrates physical surface roughness as a result of bedforms (sand ripples) at the sediment-water interface. Biogenic surface roughness was detected in image B, with a dense assemblage of juvenile amphipod tubes (*Ampelisca*) at the sediment-water interface.



A B

Figure 3-14. REMOTS® images obtained from Stations 26 (A) and 24 (B) within RIDS illustrating the overall appearance of recent dredged material. Fine-grained silty sand mottled with cohesive white clay and patches of black sulfidic sediment was detected in both images. Small mud clumps (evidence of physical disturbance) are visible at the sediment surface of image A, while larger clay clumps are visible at the sediment surface of image B.

alternating between early stages of recolonization consisting of surface-dwelling organisms (Stage I pioneering, tubicolous polychaetes) and more advanced burrowing infauna (Stage II and Stage III taxa) depending on the length of time between disposal events and the composition of material deposited.

Many images collected over RIDS displayed a relatively thick depositional layer of fine sand (approximately 3 cm) on the sediment surface over the underlying dredged material (Figure 3-15). This sand layer, which is more mobile than fine-grained cohesive sediments, is likely due to the transport and subsequent settling of ambient sediment (fine sand) during the passage of a high-energy storm event in early fall (Hurricane Isabel) that occurred prior to the October survey.

The grain size major mode of the dredged material was somewhat variable, with grain sizes of >4 phi (silt-clay), 4 to 3 phi (silty sand), and 3 to 2 phi (fine sand; Table 3-3). One replicate image of Station 24 displayed medium sand and pebbles (2 to 1 phi). Due to the wide range of grain sizes observed over RIDS stations, mean camera penetration measurements also varied from a shallow 5 cm at Station 25 to a deep 20.6 cm (average of 10.9 cm; Table 3-3). Higher mean camera penetration depths generally corresponded to stations with softer sediment (>4 phi). Overpenetration of the REMOTS® camera occurred in five replicate images obtained from RIDS in the October 2003 survey.

Replicate-averaged small-scale boundary roughness values for RIDS REMOTS® stations ranged from 0.1 cm at Station 21 to 2.2 cm at Station 24, with an average of 1.3 cm (Table 3-3). These relatively low boundary roughness values reflect a small amount of small-scale surface relief. At all of the stations, the surface roughness was predominately due physical factors as a result of cohesive clay clumps, mud clasts (indicator of dredged material disposal), and bedforms at the sediment-water interface (Figure 3-16).

3.3.4 Sediment Transition Area within Area W

Ambient sediment consisting of tan and gray silty sand was detected at all stations sampled over the sediment transition area within Area W (Table 3-4). A major modal grain size of 4 to 3 phi (silty sand) was detected at most stations. However, a higher sand component promoted a larger grain size classification in one replicate of Station 14 (3 to 2 phi) located in a region classified by coarser material, while a higher input of silt-clay produced a smaller grain size classification of >4 phi in one replicate of Station 15 located within the valley feature detected in the side-scan mosaic (Table 3-4; Figures 3-9 and 3-17A).

Mean camera penetration measurements for the sediment transition area stations were shallow, ranging from 3.6 cm at Station 13 to 8.9 cm at Station 14, with an overall average of 6.8 cm indicating firm sediment due to an increased sand content (Table 3-4). Stations

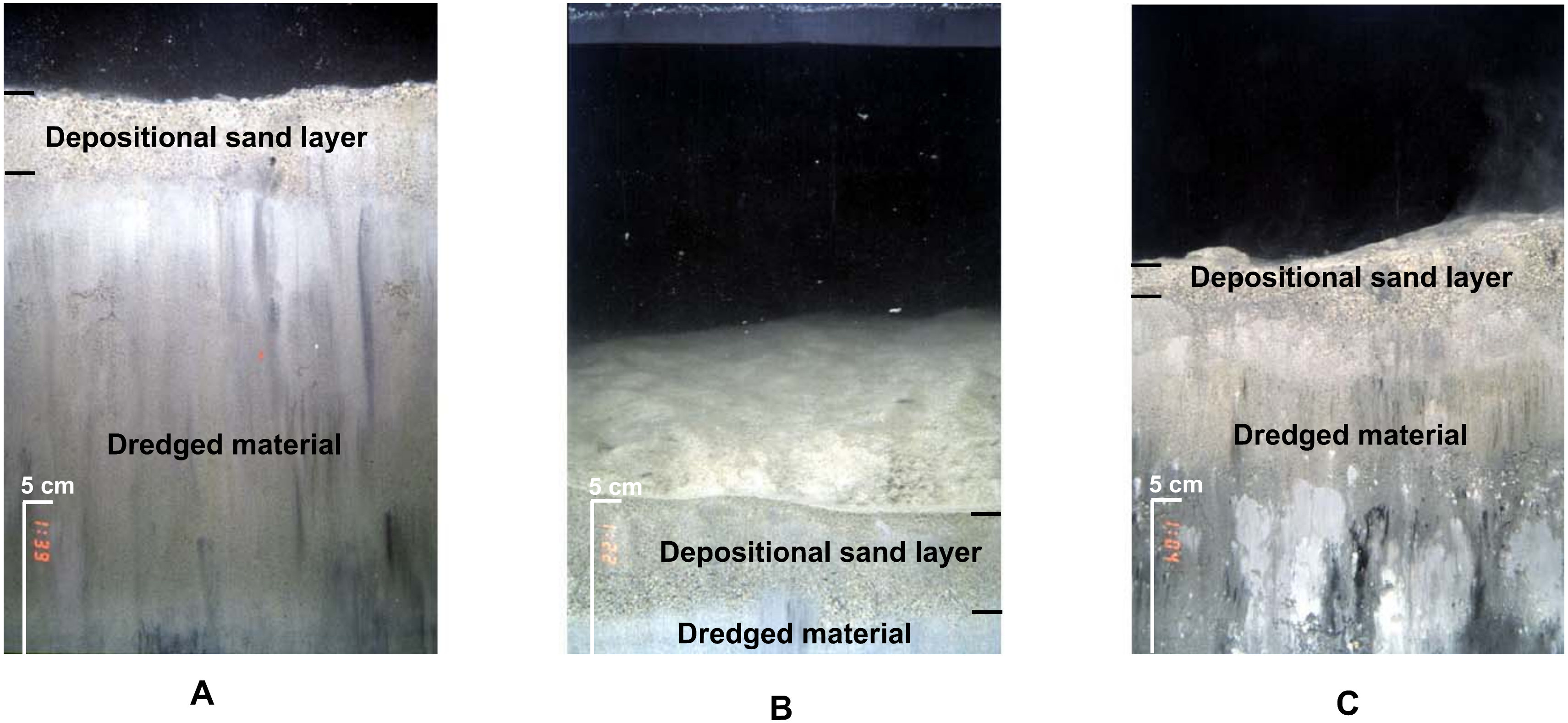
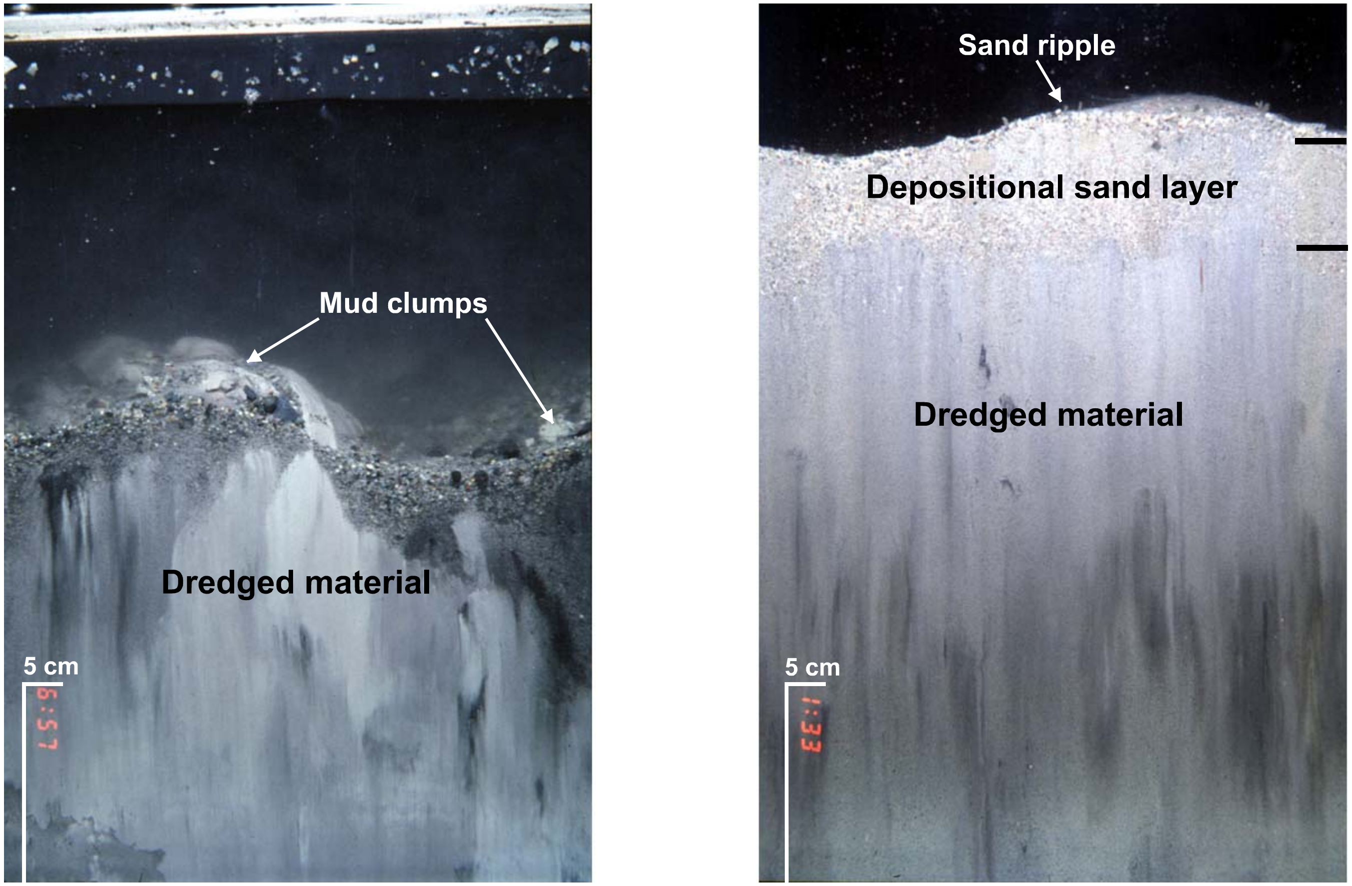


Figure 3-15. Series of REMOTS® images from RIDS Stations 19 (A), 25 (B), and 27 (C) displaying a depositional sand layer over dredged material stratigraphy.



A

B

Figure 3-16. REMOTS® images obtained from Stations 24 (A) and 18 (B) within RIDS showing physical surface roughness due to dredged material placement evidenced by mud clumps (A) and sand ripples (B) at the sediment-water interface. A depositional layer of fine sand is visible over the fine-grained dredged material in image B.

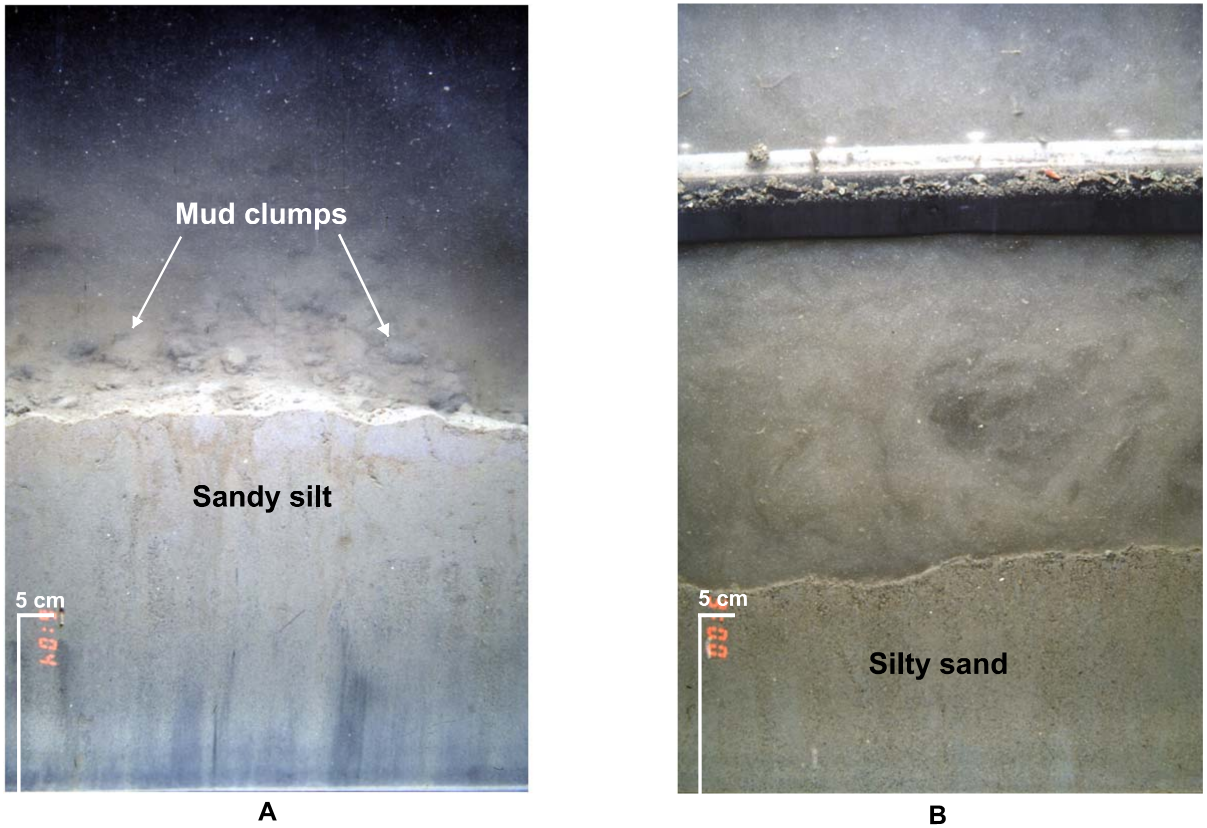


Figure 3-17. REMOTS® images obtained from Station 15 (A), located in a natural depression and Station 13 (B), located over a natural bathymetric ridge within the Sediment Transition Area illustrating variability in grain size major modes and camera penetration values. Image A displays softer sediment (grain size major mode of > 4 phi) and a deeper camera penetration measurement of 9.5 cm, while Image B displays a grain size major mode of 4 to 3 phi (silty sand) resulting in fairly shallow camera penetration (mean of 5.4 cm). Mud clumps are visible at the sediment-water interface of image A.

displaying low or no camera penetration (Stations 13 and 17) corresponded to areas of naturally occurring coarser sediment accumulation (sand or rock) as detected in the side-scan (Figure 3-17B). Alternatively, stations with slightly deeper camera penetration measurements (Stations 14, 15, and 16) generally correlated with areas of softer sediment (silt-clay or silty sand) observed within the valley featured in the side-scan mosaic (Figure 3-17A).

Numerous attempts were made to collect data at Station 17, positioned over the area of coarser sediment (bathymetric ridge) west of the valley; however no camera penetration was obtained at this station due to hard bottom conditions preventing penetration of the sediment-profile camera. Hard bottom conditions had been previously detected in the region west of the valley through sediment grab sampling (grab Station West_01) as part of the July 2003 side-scan sonar survey (Figure 3-8; Battelle 2003). Furthermore, the classification of unconsolidated sediments (sand and silt) for REMOTS® stations located within the topographic valley (Stations 14, 15, and 16) was in agreement with a grab sample collected in an area of lower-reflectance side-scan sonar return (grab Station West_04; Figure 3-8).

Replicate-averaged small-scale boundary roughness values for the stations within the sediment-transition area ranged from 0.8 cm at Station 15 to 2.6 cm at Station 14 (Table 3-4). The overall average of 1.6 cm indicates small to moderate amounts of small-scale surface relief. Surface roughness was attributed to physical factors at the sediment-water interface at all stations as a result of shell fragments and mud clasts/clumps at the sediment surface (Figure 3-17A).

3.4 Towed Video

The video data collected during the October 2003 field operation indicated that the seafloor across the video transects in Area W consisted primarily of sand overlain by a layer of fine silt with isolated areas of coarser material (Figure 3-18). Shells and/or shell fragments (*Mercenaria*) as well as sea stars were abundant in all transects. The amount of analyzable data from the video was limited somewhat by sea state conditions and sediment type. As the camera passed over the seafloor it often impacted the bottom, stirring up softer sediment and reducing visibility.

Transects A through C were designed to investigate the features along a disposal trail located outside of the western boundary of the disposal site. All three of these transects displayed similar sediment characteristics, with a predominant sediment classification of fine silt over firm sand. Overall, there appeared to be less sediment drape and more visibility over these transects compared to transects occupied in other regions of the survey area. Detailed inspections of the video data were performed where the transects intersected the disposal trail.

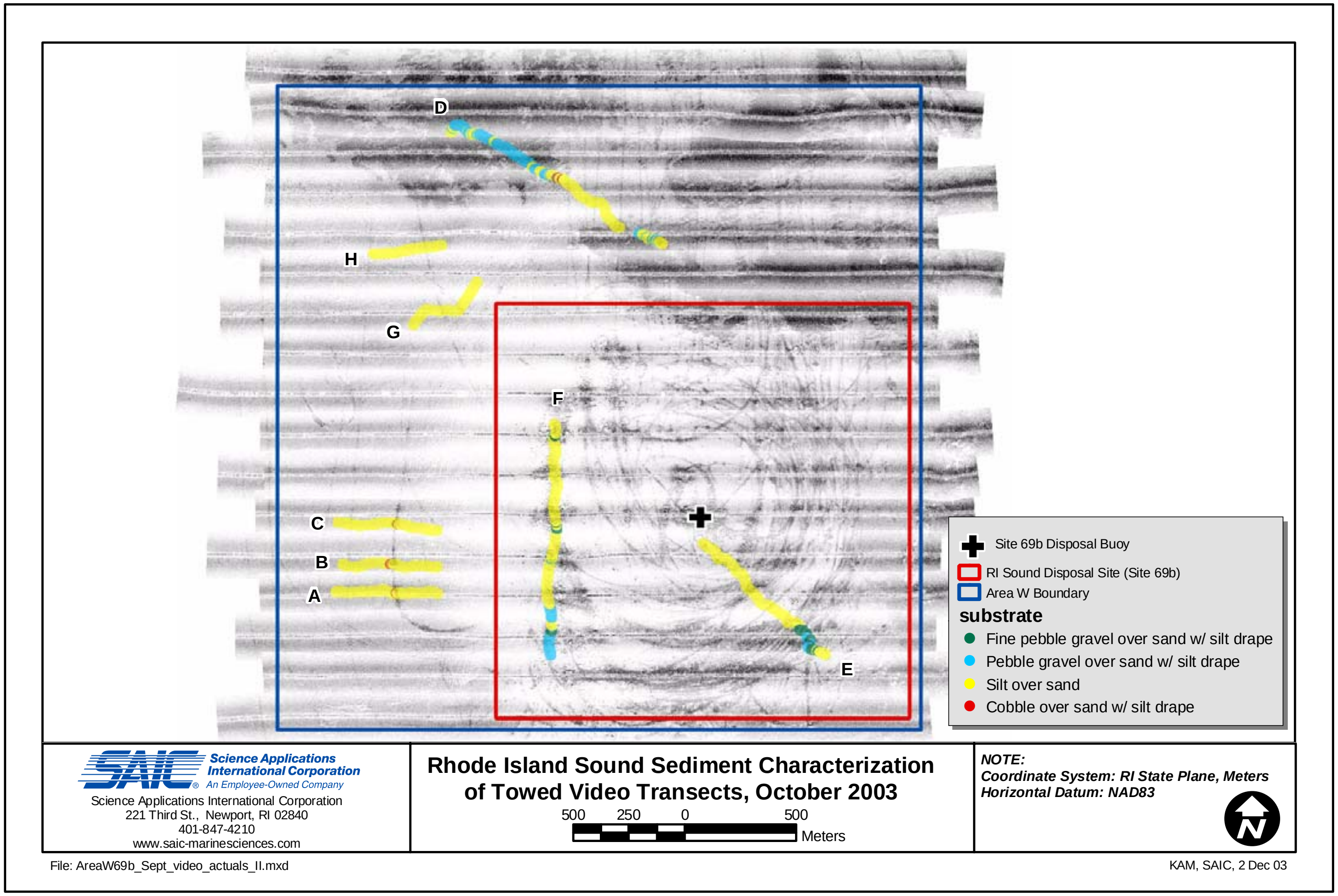


Figure 3-18. Color-coded video transects occupied over Area W showing various sediment types encountered during the October 2003 video survey, over the September 2003 side-scan sonar mosaic

The seafloor within Transect A was classified by predominantly ambient silt over sand with shells and/or shell fragments and sea stars (Figures 3-19 and 3-20). Some loose (drifting) eelgrass plants were also observed. While visibility was obscured by suspended sediment for much of the area of interest, there were two instances where glacial till (rocks and gravel) was detected.

Similar to Transect A, Transect B also displayed silt over sand with shells and shell fragments (Figure 3-21A). The video data revealed an area of seafloor with hard cobble and pebble gravel over the disposal trail feature in one section of the transect (Figure 3-21B). These deposits were relatively free of sediment drape compared to ambient gravel observed in other transects within Area W and are likely the trail of dredged material comprised of glacial till removed from the CAD cell. The extent of coarse material generally corresponded to areas of high acoustic return in the side scan, while the remainder of the seafloor within Transect B appeared to be composed of ambient silty sand.

Comparisons of the REMOTS® images and video over Transect B showed some disagreement in seafloor sediment type. REMOTS® images positioned within Transect B over the apparent disposal trail displayed white and gray clay (dredged material) within a silty sand matrix (see Figure 3-10B), while video data suggested the presence of glacial till. Discrepancies in sediment type may be attributed to the patchy distribution of dredged material and the limitations of each survey technique with regards to spatial coverage.

Transect C was also classified as silt over sand with shells, shell fragments, and sea stars (Figure 3-22). Similar to Transect A, there were two data points along the apparent disposal trail where cobble and rocks were detected (Figure 3-19).

Transect D, located north of RIDS, was designed to examine alternating areas of hard, compact substrate and softer material in a valley between two natural bathymetric ridges. As the video system crossed this feature, the sediment type over Transect D alternated between areas of silt over sand and areas of pebble/gravel over sand. (Figure 3-19 and 3-23A). It was often difficult to definitively distinguish between pebble/gravel with a heavy sediment drape in this transect from eroded clay clasts. However, the October 2003 REMOTS® results and sediment grabs obtained earlier within Area W in July 2003 revealed areas of ambient silty sand and coarser material over this transect area. The sediment drape likely accumulates on the rock surfaces between ocean storm events. Several red anemones were also observed at the sediment surface along this transect (Figure 3-23B).

Transects E and F were located within the disposal site boundary and were designed to identify areas of possible disposal trails and recent dredged material accumulation. Visibility at these transects was reduced compared to prior transects, possibly as a result of recent disposal events. Transect E displayed areas of silt over sand and pebble/gravel over

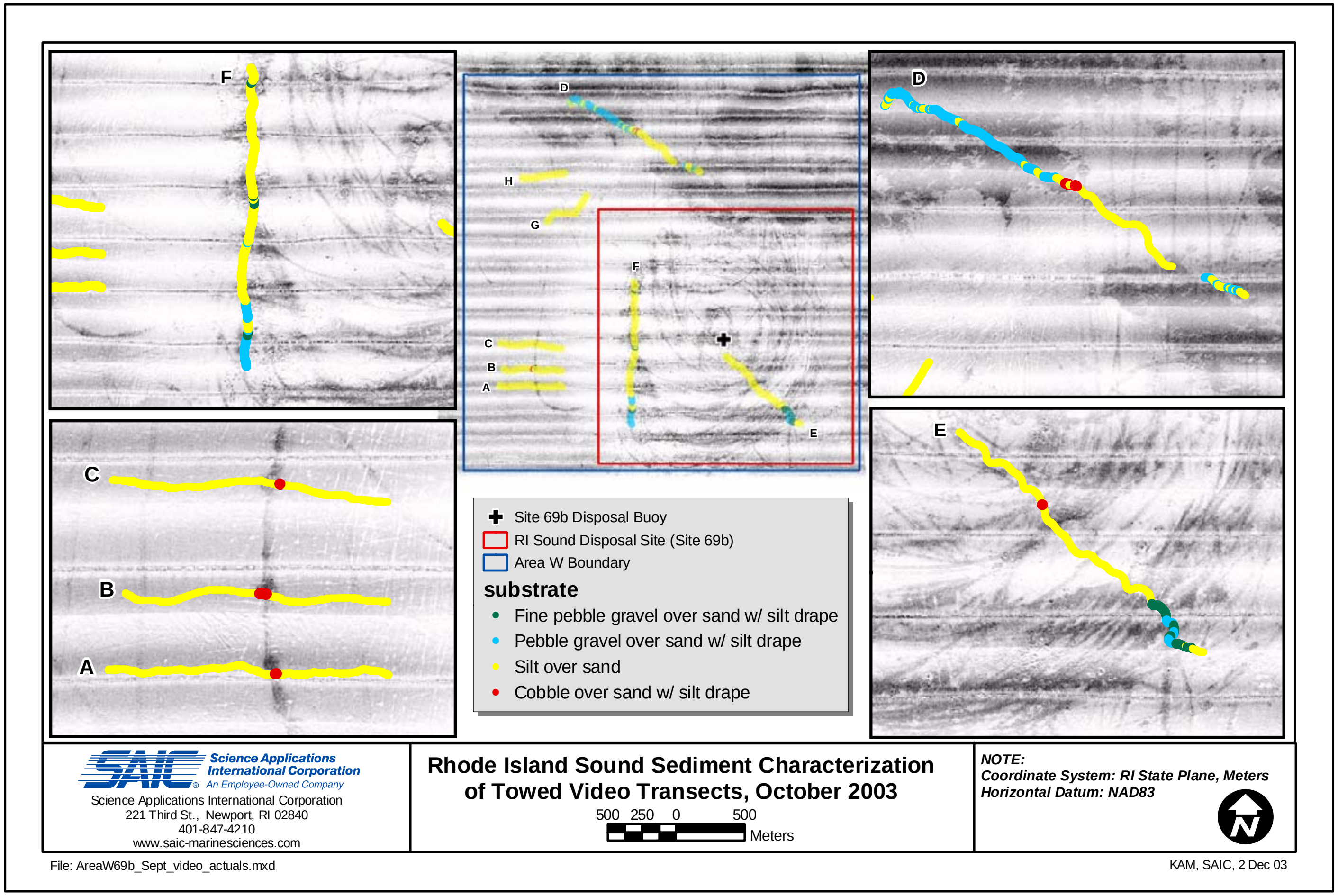


Figure 3-19. Enlarged color-coded video transects occupied within Area W showing various sediment types encountered during the October 2003 video survey, over the September 2003 side-scan sonar mosaic

DISPOSAL TRAIL
TRANSECT A

Figure 3-20. A video image obtained from Transect A collected over the disposal trail area displaying ambient silt over sand with shell fragments and sea stars

DISPOSAL TRAIL
TRANSECT B

A

B

Figure 3-21. Example images obtained from the towed video footage collected within Transect B showing the various sediment types observed within the disposal trail sample area. Image A depicts ambient silt over sand with shell, while image B positioned over the disposal trail displays silty sand overlain by cobbles and rocks (glacial till).

DISPOSAL TRAIL
TRANSECT C

Figure 3-22. Video image obtained from Transect C within the disposal trail area showing silt over sand with shell fragments.

TRANSECT D

A

B

Figure 3-23. Example images obtained from the towed video footage of Transect D showing sand overlain by varying degrees of pebble, gravel, and rock detected on the seafloor within the sediment transition area of Area W. A red anemone is visible in the top portion of image B.

silty sand (Figure 3-19). Raised bottom features resembling bedforms (sand ripples) were present within Transect E (Figure 3-24A). Some clay clasts (indicative of dredged material disposal) and cobbles were also found along Transect E (Figure 3-24B). Furthermore, a sea cucumber was observed next to cobble in Transect E.

Transect F transected a ridge-like feature (containment ridge) along the western side of the disposal site. Sediment types over Transect F were similar to Transect E, with mostly silt over sand with areas of cobble and pebble gravel (Figures 3-19 and 3-25). Clay clasts may have been present along this transect, however it was difficult to distinguish them from silt-draped pebble. Cohesive clay clumps were detected in the REMOTS® images within RIDS at many stations. Sand ripples also appeared to be present along Transect F. Transects E and F were the only transects to display obvious sand ripples at the sediment surface; sand ripples were also visible in several REMOTS® images within RIDS.

Video Transects G and H were placed northwest of the disposal site in a region with bottom features presumed to be relic trawl scars detected in the side scan mosaic. The sediment type along Transect G was relatively uniform, with silt over sand overlain by shell fragments (Figures 3-18 and 3-26). No obvious features resembling trawl scars could be distinguished from the video data. No areas of cobble or gravel (glacial till) were detected along this transect. Transect H was similar to Transect G and likewise classified as silt over sand with shells (Figures 3-18 and 3-26). The shells are most likely *Mercenaria* sp., indigenous to the site and are not an indication of dredged material disposal.

TRANSECT E

A

B

Figure 3-24. Example images obtained from Transect E within RIDS displaying various seafloor features. Image A shows a sand ripple at the surface of silty sand with pebble and gravel. The sediment in image B is comprised of sand overlain by silt-draped pebble and gravel, with possible clay clasts at the surface. A sea cucumber is visible in the center of the image near a rock (B).

RIDS
TRANSECT F

A

B

Figure 3-25. Video images from Transect F within RIDS showing pebble and gravel over sand with a silt drape. Clay clasts may be present at the surface in image A.

TRAWL SCAR
TRANSECT G

TRAWL SCAR
TRANSECT H

Figure 3-26. Example images obtained from Transect G and Transect H within the trawl scar area showing the predominate sediment type observed within the area (silt over sand). Several shells are visible at the sediment surface in the image from Transect H.

4.0 DISCUSSION

4.1 Seafloor Topography within RIDS

Since its inception in 1977, the primary goal of DAMOS has been to minimize adverse physical, chemical, and biological impacts associated with the subaqueous disposal of dredged material on the benthic environment. As a result, the management strategy employed at many of the regional dredged material disposal sites in New England waters has focused on limiting the lateral spread of dredged material on the seafloor. The process of concentrating disposal activity and controlling the formation of a sediment deposit on the seafloor tends to reduce the area of ambient bottom impacted by dredged material placement activity and often fosters both rapid and measurable benthic habitat recovery.

The Rhode Island Sound Disposal Site was established over a 3.24 km^2 area of seafloor that offers a relatively large topographic depression in the southeast quadrant for the controlled placement of dredged material (Figure 3-1). Volume calculations based upon the baseline bathymetric survey performed in February 2003 indicated this natural containment feature would be sufficient to contain approximately 500,000 m^3 of dredged material before filling the depression to the elevation of the surrounding seafloor. However, the total volume of sediment suitable for unconfined open water disposal generated by Providence River and Harbor Maintenance Dredging Project is expected to be in excess of 3.6 million cubic meters, approximately seven times the capacity of the natural bottom depression (USACE 2001). Furthermore, a substantial percentage (58%) of the total estimated project volume was expected to consist of unconsolidated estuarine silts, which will spread to a greater extent on the seafloor than more consolidated sediments to form a wide apron around the margins of the disposal mound.

The remaining 42% of the total volume of suitable material would consist of coarse-grained basement material (glacial till) removed from the Fox Point Reach to create a series of CAD cells. In an effort to enhance the overall capacity of the basin feature and minimize the lateral spread of the unconsolidated sediment to be deposited as part of the dredging project, an artificial containment feature is currently being developed within the confines of RIDS. The 1.5 million cubic meters of glacial till that is expected to be dredged during the CAD cell construction process will be strategically placed at a series of predetermined disposal points established inside the western disposal site boundary (Figure 1-3). Dredged material disposal will be tightly controlled such that a continuous ridge is formed to the west of the seafloor depression, augmenting the natural bottom feature to increase its overall capacity.

One of the objectives of the July and September 2003 post-disposal surveys over the RIDS was to monitor the development of this bathymetric ridge. The July 2003 bathymetric survey was conducted three months after the start of the dredging project, with approximately 213,000 m^3 of CAD cell material directed to Points 1 through 6. Depth difference comparisons between the July 2003 and February 2003 baseline surveys revealed the basic formation of a containment ridge in the western portion of RIDS. Several small, interconnecting disposal mounds were detected at five individual disposal targets (1 through 5), with a minimal amount of material detected in close proximity to Point 6 (Figure 3-3). In addition, an estimated barge volume of 138,000 m^3 of estuarine silts was deposited at disposal points A through G within RIDS between April and the July 2003. The depth difference comparisons also documented the accumulation of dredged material and sediment deposits in excess of 0.25 m high at Points A and E.

The results of the September 2003 bathymetric survey documented changes in the morphology of the containment ridge developing in the western portion of the disposal site. After reviewing the results of the July bathymetric survey, five additional disposal points (7 through 11) were targeted for sediment disposal in order to facilitate the development of a continuous berm along the western portion of the disposal site rather than promoting the formation of independent disposal mounds (Figure 1-3). Disposal logs indicate that approximately 493,000 m^3 of additional CAD cell material was directed to Points 1-11, substantially increasing the height and width of the bottom feature. Depth difference comparisons between the February baseline and September 2003 bathymetric data revealed the strategic placement of 706,000 m^3 of coarse-grained dredged material has resulted in the formation of individual deposits as high as 2.5 m above the ambient seafloor with interconnecting aprons forming a continuous ridge approximately 400 m wide parallel to the western disposal site boundary. In addition, the ridge extends farther to the south resulting in a continuous ridge that essentially closes the artificial containment cell (Figure 4-1). This containment structure will continue to be developed as the Providence River dredging project progresses, and along with a naturally occurring ridge surrounding the depression in the southeast corner of the disposal site, will ultimately result in an enclosed containment ring that would minimize the lateral spread of unconsolidated sediments to be deposited at RIDS during future stages of the project. As of the September 2003 survey, the artificial contaminant cell offers a capacity of 1.44 million cubic meters.

4.2 Sediment Composition

The full mosaic of Area W displaying the September 2003 side-scan sonar data revealed that the survey area was comprised of varying sediment types, ranging from ambient, coarse-grained, glacially derived sediment to recently deposited, fine-grained dredged material. In addition to the many disposal trails that were visible within the confines of RIDS, a single, relatively narrow disposal trail was also detected outside the western disposal site boundary. Although this seafloor feature was clearly visible in a side-scan sonar survey of Area W conducted in July 2003 in support of another program, the survey was repeated in September 2003 to fully examine the disposal trail, as well as to document changes in sediment composition within the disposal site resulting from dredged material distribution (Battelle 2003). REMOTS® sediment-profile imaging and underwater video were also used to collect

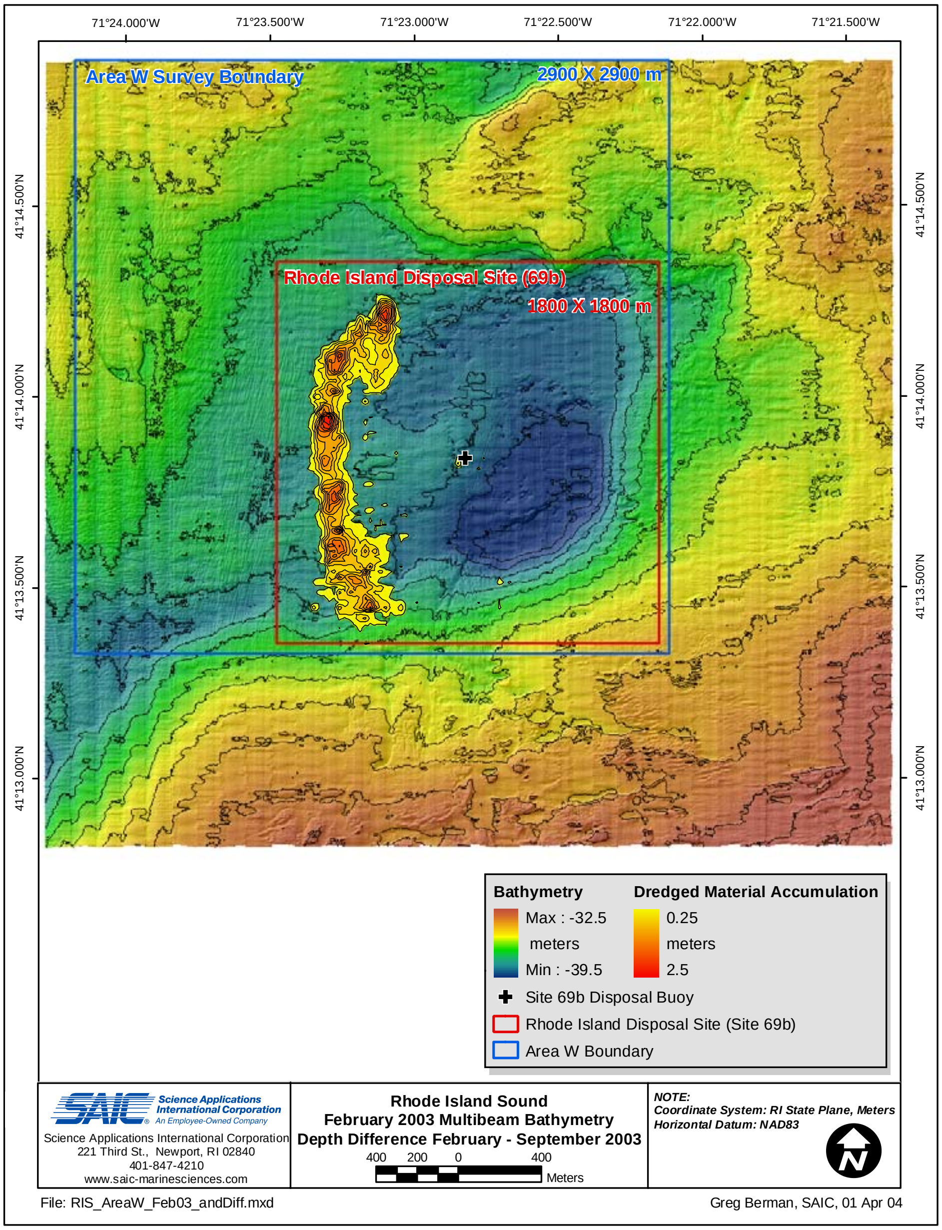


Figure 4-1. Composite graphic showing the accumulation of dredged material resulting from CAD cell construction at Points 1 through 11 as of September 2003 over the initial baseline bathymetry survey (February 2003). The dredged material deposits have coalesced to form a continuous ridge paralleling the western boundary of the disposal site to enhance containment of large volumes of unconsolidated sediments to be deposited in the near future.

visual information pertaining to surficial sediment composition, lateral extent, and thickness of the disposal trail feature. In addition, several other areas of interest within Area W were examined with sediment-profile imagery and video to further groundtruth the findings of the side-scan sonar survey.

4.2.1 Disposal Trails

Bathymetric results of the 2003 surveys indicate that the dredged material resulting from the Providence River maintenance dredging project was generally contained within the confines of the disposal site. However, additional features visible within the side-scan sonar data collected over the entire Area W suggested that small volumes of dredged material were also deposited outside the western boundary of the disposal site. Multiple narrow, low-relief trails of dredged material were detected in the side-scan sonar surveys performed in both July and September 2003.

When first detected in the July 2003 survey, the trails existing both inside and outside the disposal site boundary were determined to be the remaining sediments washed from open split-hull barges after disposal operations occurred at RIDS. A typical 6,000 yd^3 (4,600 m^3) capacity split-hull, disposal barge utilized for the transport of sediment dredged as part of the Providence River dredging project has a reported overall beam (width) of 20 m. The lateral size of the disposal trail features (approximately 15 to 20 m) detected in the July 2003 side-scan sonar mosaic was consistent with the barge dimensions, suggesting that the features are likely the result of post-disposal operations of the barge as it departed from the designated disposal point.

The pattern of disposal trails on the seafloor suggests the course navigated by tug boats and loaded disposal barges into RIDS was commonly to approach a target disposal point inside the site from the north, followed by a turn to the east after placement, then to north to begin the return transit. Although much of the sediments remaining in the individual barge loads after the initial disposal event was washed out and deposited within the confines of RIDS, a number of these trails were detectable outside the northern site boundary, indicating the disposal barges were not completely closed prior to leaving the site. Once discovered in July 2003, this practice was reportedly discontinued to prevent any further deposition of dredged material outside RIDS.

An L-shaped disposal trail trending north-south was visible outside the western boundary of RIDS, in the southwest corner of Area W. This feature represented the most prominent of these disposal trails detected in the side-scan, with distinct accumulations of recent dredged material producing higher acoustic returns in the mosaic. Although existing outside the disposal site, the disposal trail represented a relatively small feature, with an overall length of 1,100 m and lateral extents ranging from 12 to 35 m (Figure 4-2). The disposal trail exhibited several areas of strong, circular acoustic returns indicative of

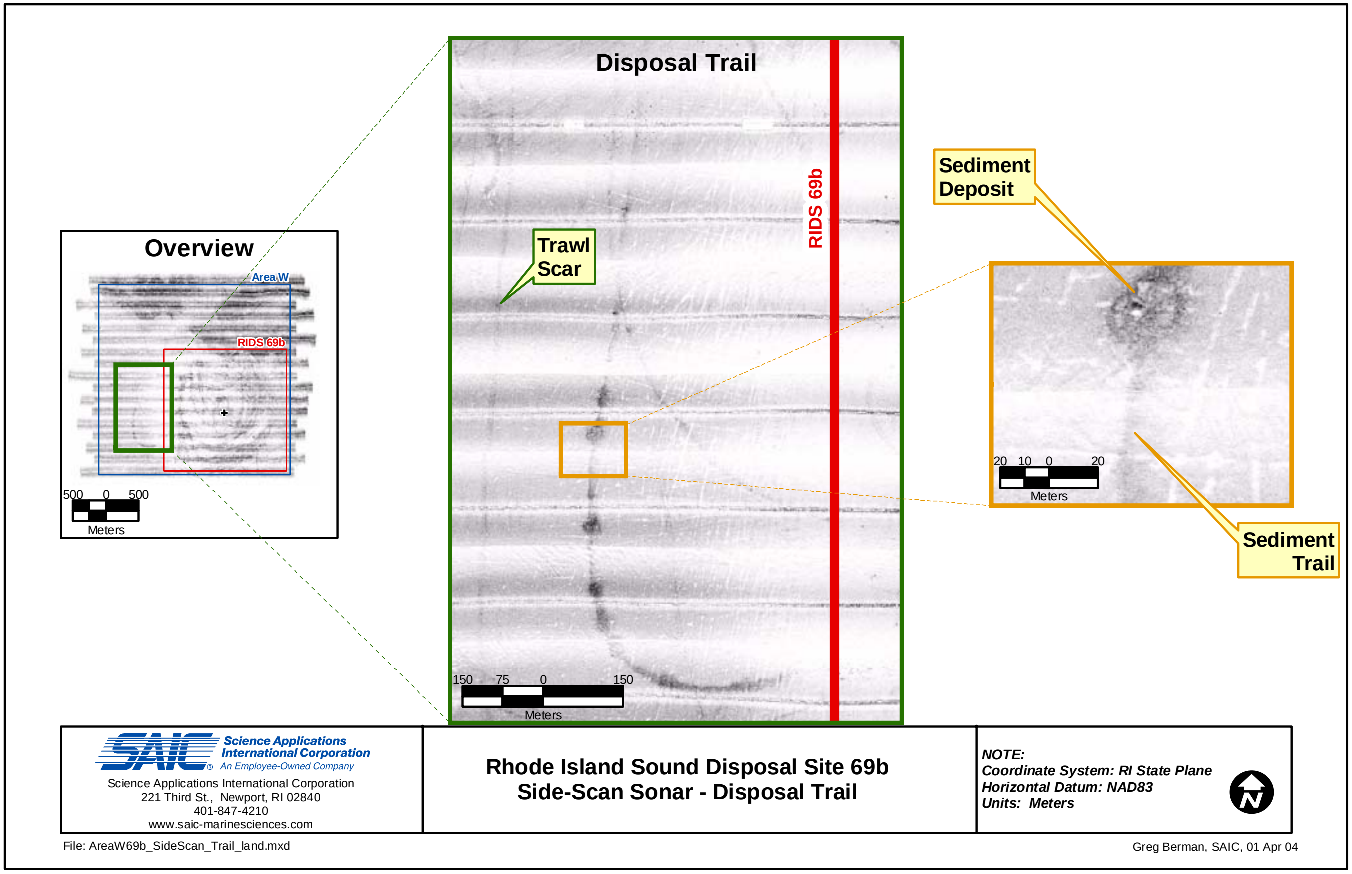


Figure 4-2. Enlarged view of the disposal trail feature detected in the September 2003 side-scan sonar mosaic showing larger, circular sediment deposits (high acoustic return) in between linear sediment trails (faint acoustic return). A trawl scar is also visible near the disposal trail, suggesting the presence of fishing activity (i.e., trawling) in this region of Area W.

individual deposits of dredged material interconnected by faint linear acoustic returns representing sediment trails. Similar disposal trail features were also detected within the confines of RIDS. These features appeared in the side-scan sonar as long semi-circles originating from the disposal ridge formed along the western boundary of the site, continuing south and east of the disposal buoy position, and terminating near the northern disposal site boundary.

The formation of this disposal trail was likely the result of a single errant turn of a tug and disposal barge to the west after a disposal event. Sediments washed from the open disposal barge simply accumulated on the seafloor mimicking the path of the barge, as it turned west following a disposal event and then north during the return transit. The larger circular features detected along this disposal trail appear to be larger individual deposits or clumps of sediment that fell to the seafloor as they were washed from the hull (Figure 4-2). Given the overall size and prominence of this disposal trail, the information gathered over this area of seafloor could be used to infer that the impacts to other areas outside the RIDS boundaries subjected to much smaller scale dredged material deposition would be substantially less. As a result, the seafloor to the west of RIDS was subjected to further investigation to evaluate the effects of dredged material accumulation.

Closer inspection of the side-scan sonar mosaic in the vicinity of the disposal trail also showed numerous trawl scars, which appeared as lighter, linear features that ran parallel to the disposal trail (north-south). These scars indicate the presence of fishing activity in this region of Area W as a result fishing gear (heavy doors and ground chains) dragged over the ambient seafloor, and do not represent disposal features.

The October 2003 REMOTS® results over the disposal trail sample area were used to examine the conditions of the seafloor where sediment disposal trails had been observed, aiding in determining the thickness and lateral extent of each feature. Both side-scan sonar and video imagery agreed with REMOTS® results, indicating that the majority of the disposal trail sampling area was comprised of ambient silty sand, with coarser material (or recent sediment accumulation) observed over narrow sections of the survey area. The areal dimension of the disposal trail measured from the side-scan mosaic was similar to those measured by REMOTS® and video. With the exception of REMOTS® Station 8 (located about 90 m east of the main disposal trail feature), which displayed a thin layer of recent dredged material over ambient sediment (9.0 cm), results of both the REMOTS® and video data suggest that the disposal trail was limited in lateral extent to approximately 12 to 35 m (see Figures 3-9 and 3-10).

REMOTS® results suggest that the extent of the disposal trail was limited, with only 5 of the 12 REMOTS® stations displaying evidence of dredged material. Recent dredged material (fine-grained silty sand mottled with white clay) was present generally at stations positioned directly over the disposal trail, correlating with the stronger acoustic returns from the side-scan sonar mosaic. When present, the thickness of the dredged material layer exceeded the penetration depth of the REMOTS® camera in all but one replicate from Station 8. However, this was likely the direct result of the intentional placement of REMOTS® stations over larger sediment deposit areas detected in the side-scan sonar mosaic. In contrast, video imagery of the seafloor in the disposal trail survey area detected patches of coarse-grained sediment (sand and gravel), as well as several cobble-sized rocks on the seabed. The mix of sediment types detected over the disposal trail suggests this sediment emanated from the CAD cell excavation activity in the Fox Point Reach of Providence River.

Despite the changes in surficial sediment composition detected in some areas within the survey area, benthic habitat conditions do not appear to be affected by the deposition of dredged material along the disposal trail. An advanced, successional stage, deep RPDs, and correspondingly high OSI values were detected at most stations occupied over the disposal trail survey area, suggesting the impacts were minimal to non-existent or the resident benthic community readily recovered from the small-scale benthic disturbance. Based on these findings, it can be inferred that the benthic community and habitat quality of the seafloor immediately surrounding this disposal trail, as well as those of lesser consequence elsewhere in the region, was not affected over the long-term by the highly localized benthic disturbances.

Furthermore, the newly deposited sediments may have offered some benefit to the resident benthos within the areas of seafloor displaying evidence of disposal trails. The deeper RPD values calculated as part of the October 2003 REMOTS® survey within the disposal trail area generally correlated to stations exhibiting dredged material in the surficial sediment layers. This suggests that the deeper RPDs may be the result of increased bioturbation by resident infauna as they exploit the organic content of the dredged material deposits. The ambient fine sands within this region of Rhode Island Sound are relatively devoid of organic material and therefore provide a less concentrated source of food source for deposit feeding organisms. When deposited as a distinct layer (<10 cm thick) over ambient sediments, larger-bodied, motile species would likely migrate up to the new sediment-water interface to re-establish a source of oxygenated bottom water then reside within the fresh sediment deposit. Sediments originating from inland waters generally carry an increased organic load relative to those comprising the seafloor in Rhode Island Sound and would support higher population densities of deposit feeding organisms. The end result would be increased foraging by deposit feeding invertebrates (bioturbation) within the surface sediments and incorporation of larger volumes of oxygen-rich bottom waters into the sediment column.

4.2.2 Rhode Island Sound Disposal Site

As mentioned in the subsections above, disposal features within RIDS including disposal mounds and trails were visible in the bathymetry/side-scan mosaic overlay. Side-scan sonar showed agreement with the bathymetry collected within RIDS, displaying evidence of recent dredged material deposition concentrated around disposal Points 1 through 11 along the western region of the disposal site. In addition, a multitude of low relief disposal features including barge disposal trails were also visible in the side-scan mosaic, representing small amounts of material that were washed from an open disposal barges as they departed from a particular disposal point (Figure 3-19).

In general, the information extracted from the REMOTS® sediment-profile images was in agreement with side-scan sonar, suggesting that recent dredged material deposits (silty sand mottled with white clay) were widespread over RIDS. A depositional layer of fine sand was visible over the underlying dredged material in many REMOTS® images. Bedforms (sand ripples) of this sand layer were visible in both the REMOTS® and video images. Sand layers often appeared rippled, which was likely due to the bedload transport of ambient fine sand during a high-energy storm event that occurred prior to the October survey.

4.2.3 Sediment Transition Area within Area W

The region north of the disposal site within Area W was surveyed in order to examine a sediment transition area encompassing areas of coarser material on either side of an existing seafloor depression. The northern portion of Area W displayed areas of ambient coarse-grained glacial sediment with high acoustic return (coarse sand, gravel, and till) adjacent to areas of softer ambient sediment types with lower reflectance. Data obtained from the REMOTS® and video surveys also revealed a variety of sediment types over the transition area in Area W. An area of fine-grained sediment was detected in the valley feature located between the natural bathymetric ridges displaying coarser material (pebble/gravel). Sediment grab samples obtained in this region of Area W during the July 2003 survey displayed similar results, with variable sediment types of gravel, till, and coarse sand, as well as softer silt and sand.

Figure 4-3 represents an overlay of the February 2003 baseline bathymetry and the September 2003 side-scan sonar surveys. The strong sonar returns are representative of glacially deposited sediment, which generally correlated to areas of seafloor displaying water depths shallower than 36.5 m (MLLW). The deeper valley feature that bisects the glacial deposit and the remainder of the survey area displayed either ambient fine sand or silt at the sediment-water interface. This finding suggests that the wave climate and/or current regime in this portion of Rhode Island Sound may minimize the accumulation of fine-grained sediments in areas of seafloor with overlying water depths less than 36.5 m. However, a more detailed measurement program focusing on the wave climate and resuspension in the area surrounding RIDS would be necessary to provide more definitive information.

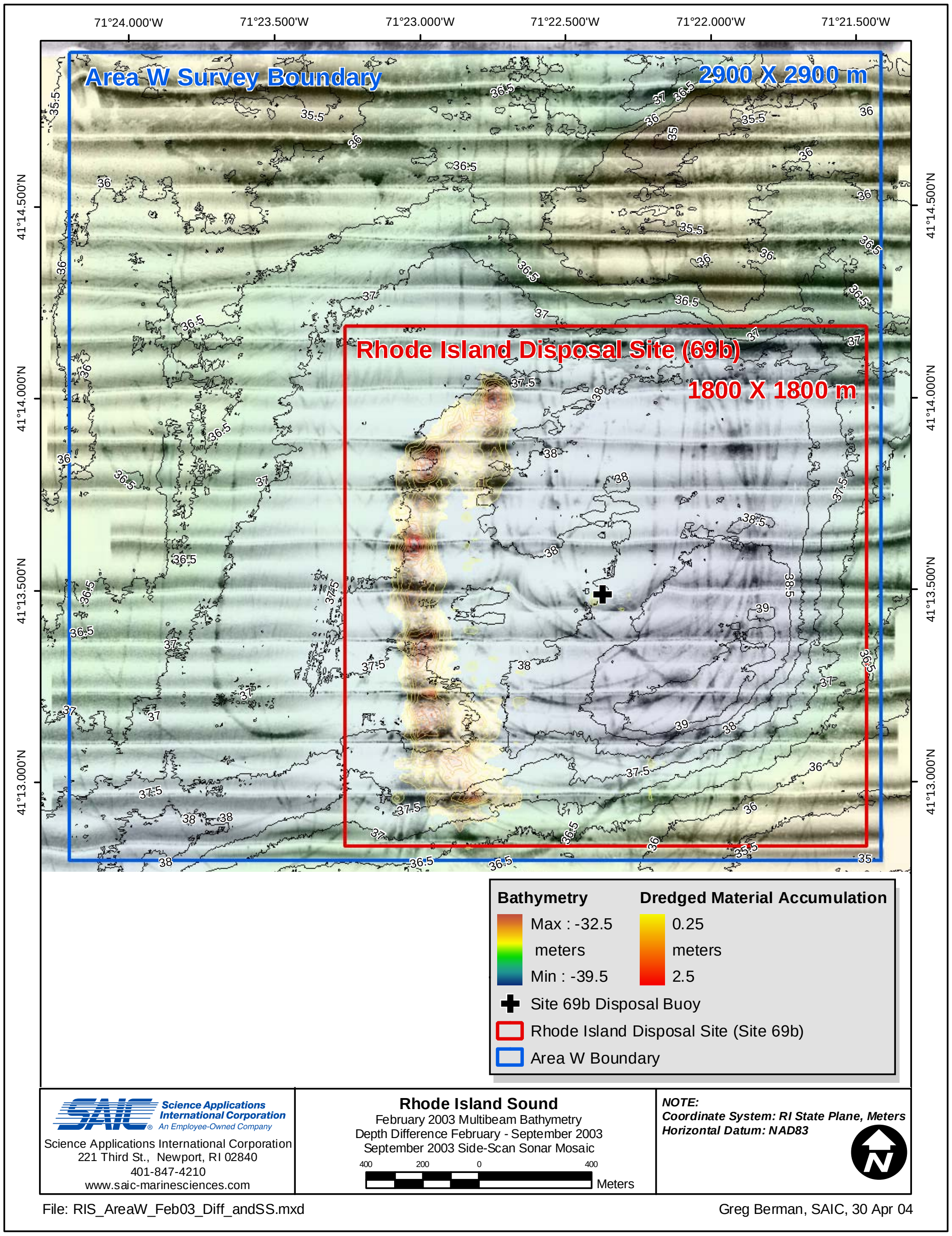


Figure 4-3. Composite graphic showing the relationship between water depth and sediment type in the area surrounding RIDS. Coarser grained, glacially deposited ambient sediments yielding strong sonar returns tended to be present at water depths shallower than 36.5 m.

4.2.4 Trawl Scar Area

Based on the seafloor imagery produced by the February 2003 multibeam bathymetry and the side-scan sonar data, it appears fishing activity (trawling of ground fish) has generally been focused within the area west of RIDS (Figures 3-1 and 3-6). A number of linear trawl scar features, running predominantly north-south, were noted in both data sets. These features represent fishing-related disturbance of the ambient seafloor as trawling gear (heavy doors and ground chain) is dragged along the bottom, and are not linked to sediment deposition. Each trawl door creates a small trench or furrow 5 to 15 cm in relief on the seafloor, which appeared in the side-scan and multibeam bathymetry data as tightly spaced parallel lines that mimicked the beam (width) of the fishing vessel towing the net (nominally 10 m).

The relatively smooth bottom topography and uniform sediment type in this portion of Area W allowed the trawl scars in the ambient sediments to persist for an extended period of time. The darker trawl scars displayed in Figures 3-6 and 4-2 represented recently formed trawl scars that contrast with the lighter sonar returns of undisturbed ambient sediments. In addition, a multitude of faint trawl scar marks with a white appearance were also detected in the side-scan sonar mosaic in an area outside the disposal site and represent disturbances caused by past fishing activity, likely predating the use of RIDS for dredged material placement.

Both REMOTS® sediment-profile and video imagery showed that the seafloor within the Trawl Scar area was composed of ambient silty sand that does not display any obvious evidence of sediment placement (Figures 3-9 and 3-13). No other man-made features were detected in the trawl scar sample area.

5.0 CONCLUSIONS AND RECOMMENDATIONS

- Following the disposal of dredged material from the Providence River and Harbor Maintenance Dredging Project during the first half of 2003, the July 2003 bathymetric survey indicated the formation of several small interconnecting disposal mounds around disposal Targets 1-5. Depth difference comparisons between the February baseline and July 2003 bathymetric data revealed the initial formation of a containment ridge in the western portion of RIDS. Additional dredged material deposits (greater than 0.25 m high) were detected at disposal points A through G.

- The September 2003 bathymetric survey documented an increase in the overall size of the containment ridge within RIDS. The bathymetric depth range for the September 2003 survey was similar to the July 2003 survey, with minimum and maximum depths of 35.0 m and 39.5 m, respectively. Depth difference comparisons between the February baseline and September 2003 bathymetric data revealed the formation of a continuous ridge of deposited sediment with a maximum height of 2.5 m above the ambient seafloor. The development of this topographic feature along the western boundary, in conjunction to pre-existing features in the ambient seafloor, have resulted in the formation of an artificial containment cell at RIDS.

- The full side-scan sonar mosaic of Area W revealed that the survey area was comprised of varying sediment types, ranging from ambient, glacially derived sediment to recently deposited dredged material. The northern portion of Area W displayed areas of coarse-grained glacial sediment with strong acoustic return (coarse sand, gravel, and till) adjacent to areas of softer sediment types with lower reflectance. Recent and past trawl scar marks were detected in an area outside the northwest corner of the disposal site and confirm the area immediately west of RIDS is subject to fishing activity.

- Side-scan sonar showed agreement with the bathymetry collected within RIDS, displaying disposal events over disposal Targets 1-11 in the western region of the disposal site. Additional low relief disposal features including barge disposal trails were also visible in the side-scan sonar mosaic. The side-scan sonar mosaic also corresponded relatively well with REMOTS® results, showing widespread accumulations of recently deposited dredged material (silty sand mottled with white clay) within the disposal site. Clay clasts (indicators of dredged material placement) were also visible in portions of the video transects over RIDS. A depositional layer of fine sand was visible over the underlying dredged material in many REMOTS® images. Bedforms within this sand layer, likely due to sediment transport processes during a prior high-energy storm event, were present in both the REMOTS® and video images.

- The side-scan sonar mosaic also displayed evidence of multiple, linear sediment deposits located outside the northern, southern, and western boundaries of RIDS. Based on evidence collected as part of an earlier survey, it was determined that these features were disposal trails resulting from split hull disposal barges leaving the disposal sit in an open position. The narrow, low relief deposits represented the small-scale accumulation of dredged material at the sediment-water interface. These features were detectable by side-scan sonar due to the localized changes in sediment composition, but were believed to be of little ecological consequence.

- An L-shaped disposal trail trending north-south and lying outside the western boundary of the disposal site was the most prominent of the disposal trails detected. The lateral extent of the disposal trail and larger, circular sediment deposits were consistent with the reported beam dimensions of the barges (20 m) currently operating during the Providence River and Harbor Maintenance Dredging Project and suggest that the sediment deposits are the result of post-disposal operations as the barge departed the disposal site. This feature was subjected to detailed investigations to evaluate the impacts this deposit and provide information that could be extrapolated to characterize the effects of the smaller-scale disposal trails present in the region. Results of the side-scan sonar, REMOTS® sediment-profile imagery, and video surveys indicated the disposal trail was relatively narrow, with widths ranging from 12 to 35 m. The sediment appeared to be comprised of recently deposited sand, gravel, silt, and clay dredged from the Fox Point reach of Providence River during CAD cell construction. Despite a change in surface sediment composition at some stations within the survey grid, the impacts to the resident benthic community were minimal to non-existent. As a result, it can be inferred that the seafloor immediately surrounding this disposal trail, as well as those of lesser consequence elsewhere in the region, readily recovered from any highly localized benthic disturbances.

- Data obtained from the side-scan sonar, REMOTS®, and video surveys indicated a variety of sediment types and bottom features existed outside the boundary of RIDS. A sediment transition area is present to the north of RIDS, with areas of fine-grained sediment (fine sand and silt) adjacent to coarser material (pebble/gravel) over the natural bathymetric ridge.

- Both REMOTS® and video results showed that the seafloor within the Trawl Scar survey area was composed of ambient silty sand that does not display any evidence of sediment deposition. The linear features detected in the side-scan mosaic represented the seafloor disturbance associated with the dragging of heavy doors, nets, and ground chain along the bottom. The relatively smooth bottom topography and uniform sediment type in this portion of Area W allow the trawl scars in the ambient sediments to persist for an extended period of time, with some scars likely predating the beginning of disposal activity at RIDS.

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Appendix A
Multibeam System Configuration

MULTIBEAM SYSTEM CONFIGURATION

Background

Single-beam bathymetric survey techniques entail using one acoustic transducer to collect depth measurements along a series of tightly spaced (25 meters), parallel survey lines to yield multiple depth profiles within a survey area. The depth profiles are edited and reduced to MLLW and then merged together during post-processing. A grid system is then defined over the survey area of interest, typically based on the track-line spacing for the survey. For track-lines spaced at 25 m intervals, a grid cell size of 12.5 m (along-track) by 25 m (cross-track) would be used to ensure sufficient data coverage to fill each cell. After the individual data points are corrected for tidal variation and water column sound velocity, a gridding routine averages all of the single-beam data points that fall within each cell, to generate a single depth value for each cell. The end result of this process is a matrix of depth values that define a three-dimensional surface model of the survey area.

Because the single-beam bathymetry typically covers only a small percentage of the total seafloor area (less than 5%), a large cross-track cell size must be specified in order to ensure that actual data points fall within each defined cell. As a result of the large cell size requirement, single-beam bathymetry products (e.g., 3-D surface models and contour plots) tend to distort smaller features that may have only been detected by a few data points along a single track-line. Additionally, any small features that happen to fall entirely between survey lines will not be detected at all. The only way to improve the resolution (or reduce the cell size) of the single-beam data models is to use much tighter line spacing over a grid-type survey pattern.

Multibeam sounding systems employ a specialized transducer array comprised of multiple, narrow acoustic beams that are capable of ensonifying an area that is up to seven times the surrounding water depths. For example, in water depths of 20 m, a multibeam survey line can provide full bottom coverage over a swath of up to 140 m. The swath coverage provided by the multibeam systems allows full bottom coverage surveys to be completed in a shorter amount of time, relative to single-beam surveys that provide less than five percent bottom coverage. The higher density of the multibeam data sets enables the generation of 3-D surface models that are based on grid cells that are as small as 1 × 1 m. Even at this small cell size, the multibeam systems will provide redundant data points in each cell, thereby enabling data quality comparisons to be made. Relative to a single-beam survey, a multibeam survey will provide a far more complete and much higher resolution representation of the seafloor topography. Multibeam bathymetry was first introduced to the DAMOS Program in 1998 as a means to better characterize the rocky, irregular seafloor topography within the Portland and Cape Arundel Disposal sites in waters of southern Maine.

Survey Area

Multibeam, bathymetric data, meeting the USACE Class I survey standards (USACE 2002), were acquired within a 4000 × 3800 m grid established over Rhode Island Sound and centered on Site 69b (see Figure 2-1). Depth soundings were collected along 34 main scheme survey lanes spaced at 120 m intervals and oriented along a north-south direction. In addition, a series of three cross-lanes were also established perpendicular to the main survey lines to provide a cross-check comparison only. This data was used to evaluate the consistency of the bathymetric data.

Survey Vessel Positioning

The R/V *Ocean Explorer* was used as the survey platform for multibeam bathymetry survey operations conducted at Rhode Island Sound. This specialized survey vessel is specifically designed and outfitted for high speed (~11 knots) swath bathymetry data collection. The main cabin of the vessel serves as the data collection and first-order-processing center. Upon completion of the survey, all data were delivered to the Data Processing Center for post-processing. Table A-1 provides a list of characteristics for the R/V *Ocean Explorer*. Precision navigation, helmsman display, and data integration from the multitude of sensors aboard the survey vessel were accomplished with the use of SAIC's Integrated Survey System 2000 (ISS-2000). Real-time navigation, data time tagging, and data logging were controlled by the ISS-2000 in a Windows NT 4.0 environment.

Positioning information was recorded from multiple independent Global Positioning System (GPS) receiver networks in the North American Datum of 1983 (NAD 83). Two, linked GPS receivers embedded within a TSS POS/MV 320, 3-axis Inertial Motion compensation Unit (IMU) were used as the primary source for vessel position and attitude correctors applied to the multibeam data. The POS/MV IMU was interfaced with a Trimble Probeacon Differential Beacon Receiver to improve the positioning data to an accuracy of ± 3 m. Correctors to the satellite information broadcast from the U.S. Coast Guard differential station at Moriches, NY (293 kHz) were applied to the satellite data. The ISS-2000 monitored horizontal dilution of precision (HDOP; quality of the signal); number of satellites, elevation of satellites, and age of correctors to ensure the resulting bathymetric positioning errors did not exceed five meters at the 95% confidence level.

The second GPS system served as a source of position confidence checks and a real-time monitor to verify the navigation information provided by the POS/MV IMU. The secondary system consisted of a Trimble 7400 RSi GPS receiver interfaced with a Leica MX41R Differential Beacon Receiver. Differential correctors broadcast from the U.S. Coast Guard station in Sandy Hook, NJ (286 kHz) were applied to the satellite data. The real-time monitor within ISS-2000 raised an alarm when the two DGPS positions differed by more than 10 m horizontally. All positioning confidence checks were well within the allowable inverse distance of 5 m.

Multibeam System Configuration

Because of the swath acoustic coverage provided by multibeam systems, there are several external data sensors that must be incorporated into any multibeam survey. In addition to the position, depth, and water column sound velocity typically required for a single-beam survey, multibeam surveys must also have sensors to accurately measure vessel heading, heave, pitch, and roll. The sensor configuration on R/V *Ocean Explorer* during the Rhode Island Sound survey is depicted in Figure A-1 and the sensor offsets relative to top centerline of the POS/MV IMU are shown in Table A-2.

Depth Soundings

A RESON 8101 shallow water, multibeam system was employed for the acquisition of sounding data over the Rhode Island Sound survey area (Table A-3). The RESON 8101 was mounted on the keel of the survey vessel, and utilizes 101 individual narrow beam (1.5°) transducers capable of yielding a total swath coverage of 150° (75° per side). The actual width of coverage is adjustable through range scale settings with a maximum equivalent to 7.4 times the water depth. The RESON 8101 transducer can transmit up to 12 high frequency (240 kHz) sound pulses, or pings, per second, though that number may be reduced in deeper water where sound travel times are greater. This rapid ping rate provides dense along-track data coverage and allows the survey boat to be operated at higher speeds. During the Rhode Island Sound survey, vessel speed was controlled to yield average along-track coverage of 2.5 pings per square meter of seafloor.

Acoustic returns from the seafloor are detected by the transducer array and raw depth values are transmitted to the RESON 6042 topside control unit. The RESON 6042 then applies a series of real-time corrections (i.e. sound velocity, attitude, predicted tides, draft, squat, etc.) to the raw soundings before transmitting them to the ISS-2000 for position stamps and data storage. An Odom DF 3200 single-beam Echotrac echosounder was also operated to provide a real-time quality check of the RESON 8101 data.

Attitude and Heading Compensation

A single multibeam swath extends a great distance perpendicular to the precise aspect of the transducer at the time of the transmit pulse. As a result, the quality and accuracy of the multibeam data (particularly in the outer beams) is highly dependent upon the precise measurement of the position, motion, and attitude of the survey vessel (e.g., heading, heave, pitch, and roll). Real-time heading and attitude compensation were accomplished in the multibeam system based on the data output by the POS/MV GPS-aided inertial navigation system (Table A-3). The primary positioning unit (POS/MV IMU) was mounted on the vessel centerline just forward and above the RESON 8101 transducer to minimize positional offsets. The POS/MV heading, heave, pitch, and roll data were transferred to the RESON 6042, which applied corrections to the raw soundings before they were transmitted to the ISS-2000 and stored for post processing.

With the vessel underway, the azimuth accuracy of the POS/MV system is ± 0.05 degree, one order of magnitude better than a gyrocompass. The accuracy of the system for heave was 5 percent of one meter or five centimeters, and ± 0.10° dynamic accuracy for roll and pitch (± 0.05° static accuracy for roll and pitch). Heading, roll, and pitch biases were determined in a series of patch tests performed in the Narragansett Bay during the Sea Acceptance Test. These biases are required to account for any minor misalignment between the mounting of the 8108 transducer and the POS/MV IMU.

Sound Velocity

Any acoustic echosounder (single or multibeam) computes a depth by precisely measuring the travel time of a sound pulse that originates from the transducer, reflects off of the seafloor, and returns back to the transducer. The acoustic travel time is multiplied by the speed of sound within the water column, and then divided in half to obtain a depth value. As a result, the accurate determination of the speed of sound within the water column is required for the correct calculation of depth during the survey operation.

Sound velocity in seawater is a function of density, a variable characteristic controlled by water temperature and salinity. A variety of tools exist for the determination of an average water column speed of sound that satisfies the requirements of a single beam system, where the acoustic signal is transmitted straight down through the water column. However, because multibeam systems generate numerous acoustic beams angled off of the vertical, strong water column density gradients, or pycnoclines, can have a greater impact on multibeam data (particularly in the outer beams). When the non-vertical multibeam pings encounter pycnoclines, they tend to be refracted by the change in speed, causing them to strike the seafloor at a different location relative to those traveling through a well-mixed water column. The effects of pycnoclines on multibeam data are corrected in real-time during multibeam surveys by generating refraction models that are based on periodic density profiles for the entire water column.

Density profiles were obtained at approximately two-hour intervals during the Rhode Island Sound survey in order to document changing water column characteristics. A Brooke Ocean Technology Ltd., Moving Vessel Profiler-30 (MVP) sound velocity profiling system was used to determine water column speed of sound (Table A-3). After examining the records, the data are sent to the RESON 6042 topside control unit. Within the RESON 6042, a beam refraction model was computed from the speed of sound data, and beam angle correctors are applied to the raw multibeam sounding data received from the RESON 8101 transducer.

Static Draft of the Survey Vessel

Raw soundings collected by the RESON 8101 multibeam system reference depth values to the transducer mounted on the underside of the survey vessel. In order to adjust the depth values to the water’s surface, a draft corrector was applied to the raw soundings in the

RESON 6042 topside control unit. Depth of the transducer below the vessel's main deck (3.07 m) was determined from measurements made during a dry dock period in May 2000. This measurement remains constant as both the deck and the keel are fixed structures on the survey vessel. However, daily draft measurements were made between the main deck and the still water level to compensate for changes in vessel draft due to fuel and water consumption (Figure A-2).

At the beginning and end of each survey day, static draft measurements were made on the port and starboard sides of the survey vessel. The height of the vessel's main deck above the still water level was subtracted from 3.07 m to yield actual draft of the transducer array. The draft measured for the Rhode Island Sound 2003 survey was 1.43 m, which in turn was added to the raw soundings.

Settlement and Squat

The configuration of the R/V *Ocean Explorer* allows the collection of high-quality swath bathymetry data at speeds approaching 11 knots. The displacement of water by the survey vessel's hull allows the boat to settle into the water slightly. The faster the hull moves through the water, the greater the volume of water displaced, promoting further settlement. In addition, higher speeds and the resulting increased shaft revolutions per minute (RPMs) also cause the bow of the survey vessel to rise higher in the water and the stern to dip further into the water. This apparent change in vessel's vertical position, relative to the water line, is capable of impacting the hydrographic data set unless settlement and squat correctors are applied. Measurements of settlement and squat for the R/V *Ocean Explorer* were conducted on 13 May 2000 (Julian day 134), in Narragansett Bay, RI over an area of seafloor 18 meters below the water's surface. As expected, the correction values increase proportionally with the vessel's speed over ground.

Tidal Corrections

Tidal height corrections for the Rhode Island Sound survey were obtained via the National Oceanographic and Atmospheric Administration (NOAA). Both predicted and observed tide information was based on the NOAA tide station at Newport, RI (8452660) corrected to the appropriate local tide zone. The local tide zone correctors applied to the Newport tide data was 89% for height.

Predicted tides were applied in the RESON 6042 topside control unit in real-time during the survey operations. Verified, observed tidal data downloaded from the NOAA CO-OPS web page were applied during the post-processing effort. Tide-corrector files for each tide zone were created from actual tide data using the ISS-2000 "TID2HMPS" routine. These corrector files were then applied to the multibeam data using the "APPCORS" program within the ISS2000 Survey Analysis software.

Data Acquisition

Multibeam depth data were collected by the RESON 8101/6042 system in the Generic Sensor Format (GSF). The GSF file format allows flags to be set as an indication of the validity of each ping or beam within the bathymetric data. These flags can be set either in real time during acquisition or later during post processing of the data. The GSF combined with history records inserted into the files in real time and during post processing provides complete tracking of all correctors and processing steps that were applied to the data. Thus, the original GSF file is continually updated without creating multiple redundant multibeam files; no data are deleted, they are only flagged and ignored in the final processing routines.

A real-time coverage monitor was used during data collection to ensure adequate coverage of multibeam data that meets or exceeds International Hydrographic Organization (IHO) standards. Multibeam backscatter imagery data, similar to side-scan sonar, were collected in eXtended Triton Format (XTF). These data were collected by the RESON 6042 and stored to the hard drive. The imagery data are useful for bottom-type classification.

Multibeam Data Processing

All data processing was conducted using the SAIC ISS2000 system. Initial navigation quality control was done on the vessel shortly after the data was collected. Where time allowed, multibeam data were edited onboard the vessel using the geoswath editor, which provides both plan and profile views of each beam in its true geographic position and depth. At the end of each day, both the raw and processed data were backed up onto 4 mm tape and shipped to the Data Processing Center in Newport, RI.

In the processing center, manual data editing was completed and reviewed by an ACSM-certified Hydrographer. Verified tide data from the Newport, RI (8452660) station were applied to the multibeam data during this phase of the post-processing. The data collected along the three cross lines were compared to soundings obtained from the same locations along the mainscheme survey lines as a quality control tool. Any questionable data were noted and later evaluated by the lead Hydrographer.

Once the data were fully processed and reviewed, the depth data were gridded into 1 × 1 m cells then ported to an ASCII XYZ file. Each cell contained a single depth value derived from averaging all of soundings that fell within that cell. When large differences were detected between soundings within the same cell, the edited multibeam files were re-examined and re-edited as needed. The resulting XYZ file can be manipulated in GIS through gridding to provide seafloor representations of various resolutions. The gridded data sets were used to evaluate coverage and quality, and to facilitate comparison with future single beam bathymetric data sets.

Table A-1.

Survey Vessel Characteristics

Vessel Name	LOA (Ft)	Beam (Ft)	Draft (Ft)	Gross Tonnage	Power (Hp)	Registration Number
R/V *Ocean Explorer*	61’	16’4”	3’3”	56	1100	US905425

Table A-2.

R/V *Ocean Explorer* Antenna and Transducer Locations Relative to the POS/MV IMU Vessel Reference Point, Measurements in Meters

Sensor	Offset in ISS2000		POS/MV IMU	
Multibeam RESON 8101 Transducer Hull Mount			X	-1.63
			Y	0.00
			Z	0.70
ODOM Single-beam Transducer	X	-2.04		
	Y	-.018		
	Z	0.80		
Trimble 7400 Antenna	X	-5.70		
	Y	0.00		
	Z	-7.43		
POS/MV GPS Master Antenna			X	-5.70
			Y	-1.00
			Z	-7.44

Table A-3.

The R/V *Ocean Explorer* System Components

Subsystem	Components
Positioning	TSS-POS/MV Model 320 Position and Orientation System (Dual GPS receivers and IMU)
Vessel Position Quality Monitoring	Trimble 7400 GPS Receiver (Quality Monitoring) Trimble DGPS Beacon Receiver
Integrated Navigation System	SAIC ISS2000
Survey Autopilot	Robertson AP9 Mk II
Multibeam Sonar	RESON 8101 240 kHz Multibeam Depth Sounder
Motion Sensor	TSS-POS/MV Model 320 Position and Orientation System
Data Acquisition and Display	Windows NT Computer running ISS2000 Integrated Survey System Software
Sound Velocity Profiler	Brooke Ocean Technology MVP 30, Moving Vessel Profiler (SVP System)

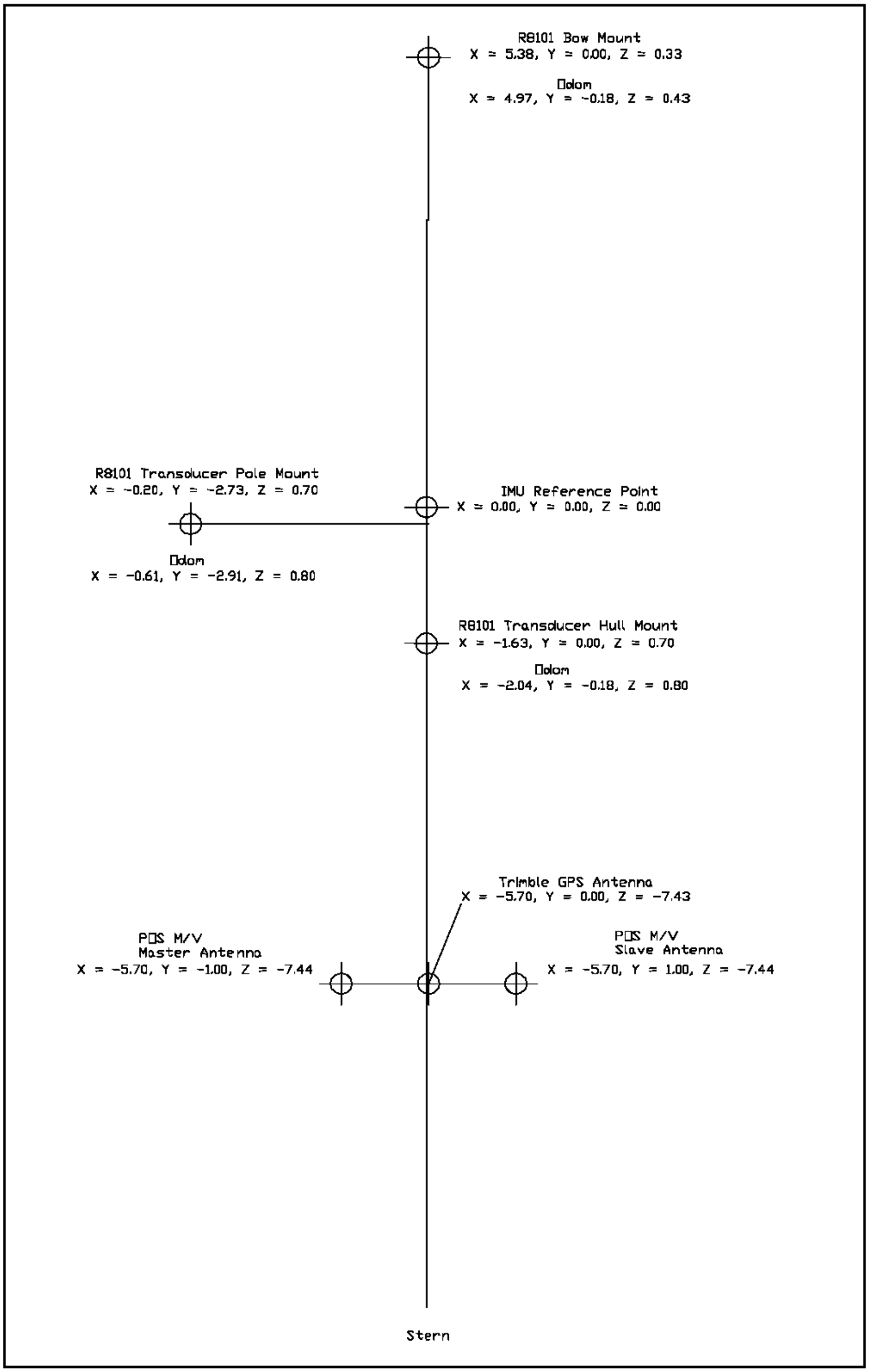

Figure A-1. Configuration of R/V *Ocean Explorer* during survey operations

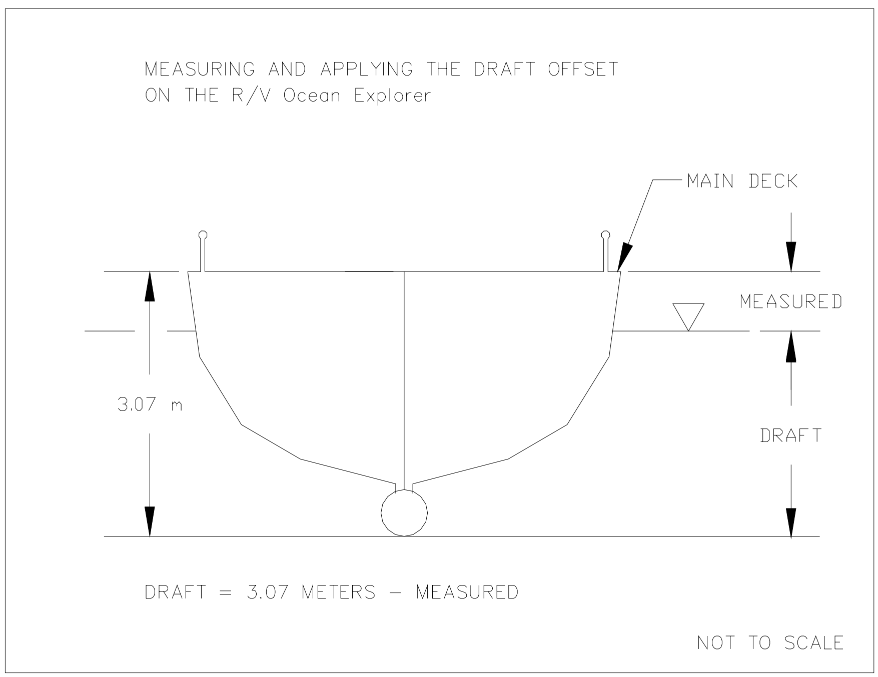

Figure A-2. R/V *Ocean Explorer* and draft determination

Appendix B
2003 REMOTS® Survey Results

Appendix B1

Disposal Trail REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi) Min	Grain Size (phi) Max	Grain Size (phi) Maj Mode	Benthic Habitat	Mud Clasts Present	Mud Clasts Avg. Diam
1	a	10/7/2003	14:29:00	ST III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
1	b	10/7/2003	14:29:00	ST I	> 4 phi	3 phi	4 to 3 phi	UN.SS	FALSE	0
2	a	10/7/2003	14:35:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SI	TRUE	0
2	b	10/7/2003	14:38:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SI	TRUE	0
2	c	10/7/2003	14:39:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
3	a	10/7/2003	14:39:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
3	e	10/7/2003	14:50:00	ST I	> 4 phi	2 phi	4 to 3 phi	SA.F	FALSE	0
4	a	10/9/2003	14:57:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
4	b	10/7/2003	14:58:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
4	c	10/7/2003	14:59:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
5	b	10/7/2003	15:22:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
5	c	10/7/2003	15:22:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
6	a	10/7/2003	15:12:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SI	TRUE	0
6	d	10/7/2003	15:15:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
7	b	10/7/2003	15:10:00	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
7	c	10/7/2003	15:11:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
8	a	10/7/2003	15:05:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
8	b	10/7/2003	15:06:00	ST I on III	> 4 phi	2 phi	3 to 2 phi	UN.SS	FALSE	0
8	c	10/7/2003	15:06:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
9	b	10/7/2003	15:29:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
9	d	10/7/2003	15:31:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
10	a	10/7/2003	15:36:00	ST I	> 4 phi	3 phi	4 to 3 phi	UN.SS	TRUE	0
10	b	10/7/2003	15:36:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
10	c	10/7/2003	15:37:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SI	FALSE	0
11	a	10/7/2003	15:38:00	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
11	b	10/7/2003	15:39:00	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SI	TRUE	0
11	c	10/7/2003	15:39:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
12	a	10/7/2003	15:56:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
12	b	10/7/2003	15:57:00	ST I on III	> 4 phi	4 phi	4 to 3 phi	UN.SS	FALSE	0
12	c	10/7/2003	15:58:00	ST I on III	> 4 phi	4 phi	4 to 3 phi	UN.SI	FALSE	0

Appendix B1

Disposal Trail REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)		
			Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean
1	a	10/7/2003	6.60	8.84	2.24	7.72	0	0	0	0	0	0
1	b	10/7/2003	6.29	7.30	1.01	6.80	0	0	0	0	0	0
2	a	10/7/2003	9.11	10.43	1.32	9.77	0	0	0	0	0	0
2	b	10/7/2003	7.81	8.32	0.51	8.06	0	0	0	0	0	0
2	c	10/7/2003	6.22	8.22	2.00	7.22	> 6.22	> 8.22	> 7.22	0	0	0
3	a	10/7/2003	9.82	10.58	0.76	10.20	0	0	0	0	0	0
3	e	10/7/2003	8.82	9.89	1.07	9.35	0	0	0	0	0	0
4	a	10/9/2003	9.11	10.24	1.13	9.67	0	0	0	0	0	0
4	b	10/7/2003	8.18	9.23	1.05	8.70	0	0	0	0	0	0
4	c	10/7/2003	9.01	10.68	1.67	9.85	0	0	0	0	0	0
5	b	10/7/2003	4.64	5.87	1.23	5.26	0	0	0	0	0	0
5	c	10/7/2003	9.94	10.84	0.90	10.39	0	0	0	0	0	0
6	a	10/7/2003	7.22	9.48	2.26	8.35	0	0	0	0	0	0
6	d	10/7/2003	10.75	11.81	1.06	11.28	0	0	0	0	0	0
7	b	10/7/2003	16.51	17.64	1.13	17.08	> 16.51	> 17.64	> 17.08	0	0	0
7	c	10/7/2003	8.13	8.91	0.78	8.52	0	0	0	0	0	0
8	a	10/7/2003	9.80	10.92	1.12	10.36	0	0	0	0	0	0
8	b	10/7/2003	10.67	11.75	1.08	11.21	0	0	0	0	0	0
8	c	10/7/2003	14.67	15.80	1.13	15.24	0	0	8.97	0	0	0
9	b	10/7/2003	10.06	10.55	0.49	10.31	0	0	0	0	0	0
9	d	10/7/2003	7.00	7.98	0.98	7.49	0	0	0	0	0	0
10	a	10/7/2003	5.70	8.25	2.55	6.97	0	0	0	0	0	0
10	b	10/7/2003	8.44	10.06	1.62	9.25	> 8.44	> 10.06	> 9.25	0	0	0
10	c	10/7/2003	6.61	8.05	1.44	7.33	0	0	0	0	0	0
11	a	10/7/2003	14.77	16.43	1.66	15.60	> 14.77	> 16.43	> 15.6	0	0	0
11	b	10/7/2003	9.70	10.92	1.22	10.31	0	0	0	0	0	0
11	c	10/7/2003	7.51	10.87	3.36	9.19	> 7.51	> 10.87	> 9.19	0	0	0
12	a	10/7/2003	12.07	13.08	1.01	12.57	0	0	0	0	0	0
12	b	10/7/2003	10.67	11.71	1.04	11.19	0	0	0	0	0	0
12	c	10/7/2003	8.10	9.11	1.01	8.60	0	0	0	0	0	0

Appendix B1

Disposal Trail REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low
			Min	Max	Mean	Count	Depth	Diam.		Roughness	DO
1	a	10/7/2003	0.93	2.26	1.39	0	0	0	7	Physical	NO
1	b	10/7/2003	0.27	2.13	1.14	0	0	0	3	Physical	NO
2	a	10/7/2003	0.40	5.00	2.30	0	0	0	9	Physical	NO
2	b	10/7/2003	0.26	4.10	1.34	0	0	0	3	Physical	NO
2	c	10/7/2003	0.46	5.82	2.50	0	0	0	5	Physical	NO
3	a	10/7/2003	0.33	3.93	1.64	0	0	0	8	Physical	NO
3	e	10/7/2003	0.79	4.24	2.16	0	0	0	4	Physical	NO
4	a	10/9/2003	1.06	2.91	1.78	0	0	0	4	Biogenic	NO
4	b	10/7/2003	0.53	7.02	2.12	0	0	0	8	Physical	NO
4	c	10/7/2003	0.73	4.04	2.16	0	0	0	4	Physical	NO
5	b	10/7/2003	0.33	3.33	2.38	0	0	0	5	Physical	NO
5	c	10/7/2003	1.44	5.48	3.83	0	0	0	11	Physical	NO
6	a	10/7/2003	0.13	3.64	2.08	0	0	0	4	Physical	NO
6	d	10/7/2003	0.65	3.78	2.38	0	0	0	9	Physical	NO
7	b	10/7/2003	1.06	4.70	3.54	0	0	0	8	Physical	NO
7	c	10/7/2003	0.13	3.57	1.94	0	0	0	8	Physical	NO
8	a	10/7/2003	0.33	2.32	1.42	0	0	0	3	Physical	NO
8	b	10/7/2003	0.86	3.44	1.70	0	0	0	8	Physical	NO
8	c	10/7/2003	0.66	4.77	3.65	0	0	0	6	Physical	NO
9	b	10/7/2003	0.98	6.92	1.90	0	0	0	8	Physical	NO
9	d	10/7/2003	0.26	4.11	1.90	0	0	0	4	Physical	NO
10	a	10/7/2003	0.39	4.11	1.66	0	0	0	4	Physical	NO
10	b	10/7/2003	0.52	3.52	2.05	0	0	0	4	Physical	NO
10	c	10/7/2003	1.04	2.48	1.68	0	0	0	8	Physical	NO
11	a	10/7/2003	0.26	4.18	1.78	0	0	0	6	Biogenic	NO
11	b	10/7/2003	0.98	2.15	1.60	0	0	0	6	Physical	NO
11	c	10/7/2003	0.98	3.65	2.64	0	0	0	5	Physical	NO
12	a	10/7/2003	0.78	4.70	1.62	0	0	0	4	Physical	NO
12	b	10/7/2003	0.20	1.89	1.12	0	0	0	7	Physical	NO
12	c	10/7/2003	0.26	1.89	1.21	0	0	0	7	Physical	NO

Appendix B1

Disposal Trail REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Comments
1	a	10/7/2003	Ambient tan & gry muddy fine sand, recently trawled, void, shell frag, polychaete @z, m clumps-far, starfish-wiper blade
1	b	10/7/2003	Ambient tan & gry muddy fine sand, tubes, sm worms @z, starfish-wiper blade
2	a	10/7/2003	Ambient tan & gry muddy fine sand, tubes, voids, rock & shells @ surf, surf reworking, burrow opening
2	b	10/7/2003	Ambient tan & gry sandy m, sm tubes, ox clasts, m clump or rock-far, relic RPD?
2	c	10/7/2003	DM>pen, tan sand/gry & blk mottled sandy m, red sed @z, red clasts, polychaetes @z, rocks-far, tubes
3	a	10/7/2003	Ambient tan & gry muddy fine sand, DM residual from previous station, ox clast, sm voids?, relic RPD?
3	e	10/7/2003	Ambient tan & gry muddy fine sand, polychaetes @z, tubes, relic RPD?
4	a	10/9/2003	Ambient tan & gry muddy fine sand, shell @ surf, starfish @ surf, tubes, polychaete @z, red clast
4	b	10/7/2003	Ambient tan & gry muddy fine sand, red clasts, tubes, sm void, polychaetes @z
4	c	10/7/2003	Ambient tan & gry muddy fine sand, tubes, ox clasts, decayed amp tubes?
5	b	10/7/2003	Ambient tan & gry mudddy fine sand, bedforms, tubes
5	c	10/7/2003	Ambient tan & gry muddy fine sand, tubes, ox clasts, burrow, void, shell frags, sm worms @z
6	a	10/7/2003	Ambient tan & gry muddy fine sand, tubes, red clast, crab @ surf, relic RPD?
6	d	10/7/2003	Ambient tan & gry muddy fine sand, tubes, shell frags, void, ox & red clasts
7	b	10/7/2003	DM>pen, tan & gry muddy fine sand, abandoned amp tubes, tubes, polychaete @z, wht clay @z, burrow
7	c	10/7/2003	Ambient tan & gry sandy m, tubes, sm voids, relic RPD?
8	a	10/7/2003	Ambient tan & gry muddy fine sand, relic RPD?, tubes, sm void?, m clumps-far, ox & red clasts
8	b	10/7/2003	Ambient tan & gry muddy fine sand, relic RPD?, lg polychaetes @z, sm void, tubes, m clasts-far
8	c	10/7/2003	DM (8.97cm)/ambient, sed layering, tan/gry sandy m/tan muddy fine sand, tubes, polychaete @z, relic RPD, surf rework
9	b	10/7/2003	Ambient tan & gry muddy fine sand, tubes, void, burrow, worms @z
9	d	10/7/2003	Ambient tan & gry muddy fine sand, polychaetes @z, tubes
10	a	10/7/2003	Ambient tan & gry muddy fine sand, sediment, bedforms-sand ripple, polychaetes @z, red clast, tubes
10	b	10/7/2003	DM>pen, tan sand mottled w/ wht & gry clay, bedforms, ox clasts, shrimp-far, m clumps-far
10	c	10/7/2003	Ambient tan & gry sandy m, DM residual from previous rep, shells @ surf, rock?, sm voids, sm tubes, polychaete @z
11	a	10/7/2003	DM>pen, tan & gry muddy fine sand w/ wht clay, dense amphipod tube mat (disposed w/dm?), polychaetes @z
11	b	10/7/2003	Ambient tan & gry sandy m, decayed amp tubes (residual prev rep-disposed w/dm?), shell frags, polychaete @z
11	c	10/7/2003	DM>pen, tan muddy fine sand/gry sandy m, wht clay @z, tubes, ox clast, polychaete @z, sloping topo?
12	a	10/7/2003	Ambient tan & gry muddy fine sand, possible wht clay?, tubes, polychaetes @z
12	b	10/7/2003	Ambient tan & gry muddy fine sand, DM residual from previous rep, tubes, sm void
12	c	10/7/2003	Ambient tan & gry sandy m, m clumps-far, wiper clasts, void, tubes

Appendix B2

Trawl Scar Station REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi) Min	Grain Size (phi) Max	Grain Size (phi) Maj Mode	Benthic Habitat	Mud Clasts Present	Mud Clasts Avg. Diam
29	c	10/7/2003	17:28:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
29	d	10/7/2003	17:29:00	ST II on III	> 4 phi	2 phi	4 to 3 phi	UN.SI	FALSE	0
30	a	10/7/2003	17:18:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SI	FALSE	0
30	b	10/7/2003	17:19:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
30	c	10/7/2003	17:20:00	ST I on III	> 4 phi	3 phi	> 4 phi	UN.SI	TRUE	0
31	b	10/7/2003	17:05:00	ST I	> 4 phi	2 phi	3 to 2 phi	UN.SS	FALSE	0
31	g	10/9/2003	14:42:00	ST II on III	> 4 phi	2 phi	3 to 2 phi	UN.SS	FALSE	0
32	b	10/7/2003	16:08	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
32	c	10/7/2003	16:09	INDET	> 4 phi	< -1 phi	3 to 2 phi	HR	FALSE	0
32	d	10/7/2003	16:10	ST II on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
33	h	10/9/2003	14:51:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
33	i	10/9/2003	14:52:00	INDET	< -1 phi	< -1 phi	< -1 phi	HR	FALSE	0
34	b	10/9/2003	16:30:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
34	e	10/9/2003	16:56:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
34	f	10/9/2003	16:57:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
34	g	10/9/2003	16:58:00	ST I on III	> 4 phi	2 phi	3 to 2 phi	SA.F	TRUE	0

Appendix B2

Trawl Scar Station REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)		
			Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean
29	c	10/7/2003	2.07	5.04	2.97	3.55	0	0	0	0	0	0
29	d	10/7/2003	10.16	12.57	2.41	11.36	0	0	0	0	0	0
30	a	10/7/2003	6.90	8.05	1.15	7.48	0	0	0	0	0	0
30	b	10/7/2003	5.70	8.10	2.40	6.90	0	0	0	0	0	0
30	c	10/7/2003	7.98	8.99	1.01	8.48	0	0	0	0	0	0
31	b	10/7/2003	11.60	12.34	0.74	11.97	0	0	0	0	0	0
31	g	10/9/2003	12.36	13.25	0.89	12.81	0	0	0	0	0	0
32	b	10/7/2003	7.27	8.57	1.30	7.92	0	0	0	0	0	0
32	c	10/7/2003	0.00	1.70	1.70	0.85	0	0	0	0	0	0
32	d	10/7/2003	8.44	9.47	1.03	8.95	0	0	0	0	0	0
33	h	10/9/2003	7.00	8.15	1.15	7.57	0	0	0	0	0	0
33	i	10/9/2003	0.00	0.00	0.00	0.00	0	0	0	0	0	0
34	b	10/9/2003	8.03	8.42	0.39	8.23	0	0	0	0	0	0
34	e	10/9/2003	7.36	9.08	1.72	8.22	0	0	0	0	0	0
34	f	10/9/2003	5.41	7.51	2.10	6.46	0	0	0	0	0	0
34	g	10/9/2003	10.51	11.09	0.58	10.80	0	0	0	0	0	0

Appendix B2

Trawl Scar Station REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low
			Min	Max	Mean	Count	Depth	Diam.		Roughness	DO
29	c	10/7/2003	0.52	4.11	2.90	0	0	0	5	Physical	NO
29	d	10/7/2003	0.39	2.68	1.58	0	0	0	8	Biogenic	NO
30	a	10/7/2003	1.04	3.00	1.94	0	0	0	4	Physical	NO
30	b	10/7/2003	1.30	3.26	2.70	0	0	0	5	Physical	NO
30	c	10/7/2003	0.33	2.28	1.72	0	0	0	8	Physical	NO
31	b	10/7/2003	1.17	4.83	4.00	0	0	0	7	Physical	NO
31	g	10/9/2003	0.33	6.98	4.38	0	0	0	11	Physical	NO
32	b	10/7/2003	0.91	2.74	1.97	0	0	0	8	Physical	NO
32	c	10/7/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO
32	d	10/7/2003	0.65	2.74	1.74	0	0	0	8	Biogenic	NO
33	h	10/9/2003	3.13	5.68	4.48	0	0	0	11	Physical	NO
33	i	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
34	b	10/9/2003	0.85	3.52	2.46	0	0	0	5	Physical	NO
34	e	10/9/2003	0.85	4.37	2.32	0	0	0	5	Physical	NO
34	f	10/9/2003	0.26	5.55	3.80	0	0	0	7	Physical	NO
34	g	10/9/2003	0.65	6.59	4.12	0	0	0	11	Physical	NO

Appendix B2

Trawl Scar Station REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Comments
29	c	10/7/2003	Ambient tan & gry muddy fine sand, DM residual from previous station, ox & red clsts, starfish @surf, tubes
29	d	10/7/2003	Ambient tan & gry sandy m, abandoned amphipod tubes, void, burrow, tubes
30	a	10/7/2003	Ambient tan & gry sandy m, polychaetes @z, tubes, bedforms-sand ripple
30	b	10/7/2003	Ambient tan & gry muddy fine sand, bedforms?, sm tubes, red clast
30	c	10/7/2003	Ambient tan & gry sandy m, ox clasts, sm voids, tubes, surf rework
31	b	10/7/2003	Ambient tan & gry muddy fine sand, wht clay?,tubes, polychaetes @z
31	g	10/9/2003	Ambient tan & gry muddy fine sand, white clay?, amphipod tubes, void, polychaete @z, tubes
32	b	10/7/2003	Ambient tan & gry muddy fine sand, tubes, void, polychaetes @z
32	c	10/7/2003	Ambient, rocks/tan & gry muddy fine sand, underpen, shell frags
32	d	10/7/2003	Ambient tan & gry muddy fine sand, juvenile ampelisca, tubes, sm void
33	h	10/9/2003	Ambient tan & gry muddy fine sand, tubes, void or bisected burrow, polychaete @z
33	i	10/9/2003	No penetration, not able to analyze
34	b	10/9/2003	Ambient tan & gry muddy fine sand, tubes
34	e	10/9/2003	Ambient tan & gry muddy fine sand, tubes, ox & red clasts, surf rework
34	f	10/9/2003	Ambient tan & gry muddy fine sand, tubes, rock-far, burrow
34	g	10/9/2003	Ambient tan & gry muddy fine sand, tubes, ox clasts, void, polychaete @z

Appendix B3

RIDS REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic	Mud Clasts	
				Stage	Min	Max	Maj Mode	Habitat	Present	Avg. Diam
18	a	10/9/2003	13:32:00	INDET	> 4 phi	> 4 phi	> 4 phi	UN.SI	FALSE	0
18	b	10/9/2003	13:33:00	ST I	> 4 phi	1 phi	> 4 phi	UN.SI	TRUE	0
18	c	10/9/2003	13:33:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
18	d	10/9/2003	13:34:00	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
18	e	10/9/2003	13:45:00	ST III	> 4 phi	2 phi	4 to 3 phi	UN.SI	FALSE	0
18	f	10/9/2003	13:45:00	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	FALSE	0
18	g	10/9/2003	13:46:00	ST I	> 4 phi	< -1 phi	4 to 3 phi	UN.SS	FALSE	0
18	h	10/9/2003	13:47:00	ST I	> 4 phi	1 phi	4 to 3 phi	UN.SS	FALSE	0
19	a	10/9/2003	13:39:00	ST III	> 4 phi	2 phi	> 4 phi	UN.SI	TRUE	0
19	b	10/9/2003	13:39:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SI	FALSE	0
19	c	10/9/2003	13:40:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
19	e	10/9/2003	13:41:00	ST I	> 4 phi	1 phi	3 to 2 phi	UN.SS	TRUE	0
21	a	10/9/2003	14:27:00	INDET	> 4 phi	4 phi	> 4 phi	UN.SF	FALSE	0
21	b	10/9/2003	14:27:00	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	FALSE	0
21	c	10/9/2003	14:28:00	INDET	> 4 phi	2 phi	> 4 phi	UN.SF	FALSE	0
21	d	10/9/2003	14:29:00	INDET	> 4 phi	4 phi	> 4 phi	UN.SF	FALSE	0
22	a	10/9/2003	14:19:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
22	b	10/9/2003	14:20:00	ST III	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
22	c	10/9/2003	14:21:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
22	d	10/9/2003	14:22:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SI	TRUE	0
23	a	10/9/2003	14:11:00	ST I	> 4 phi	< -1 phi	4 to 3 phi	UN.SS	FALSE	0
23	b	10/9/2003	14:12:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0
23	c	10/9/2003	14:12:00	ST I	> 4 phi	< -1 phi	4 to 3 phi	UN.SS	FALSE	0
24	b	10/7/2003	18:55:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
24	c	10/7/2003	18:56:00	ST I	> 4 phi	1 phi	> 4 phi	UN.SI	TRUE	0
24	d	10/7/2003	18:59:00	ST I	> 4 phi	1 phi	2 to 1 phi	SA.M	TRUE	0
24	e	10/7/2003	19:00:00	INDET	> 4 phi	1 phi	4 to 3 phi	UN.SS	TRUE	0
25	b	10/9/2003	13:21:00	INDET	> 4 phi	3 phi	4 to 3 phi	SA.F	FALSE	0
25	c	10/9/2003	13:21:00	ST I	> 4 phi	2 phi	3 to 2 phi	SA.F	FALSE	0
25	d	10/9/2003	13:22:00	ST I	> 4 phi	2 phi	3 to 2 phi	UN.SS	FALSE	0
26	b	10/9/2003	13:07:00	INDET	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
26	d	10/9/2003	13:14:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
27	a	10/9/2003	13:03:00	ST I	> 4 phi	1 phi	4 to 3 phi	UN.SS	FALSE	0
27	b	10/9/2003	13:04:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
27	c	10/9/2003	13:05:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	FALSE	0
27	d	10/9/2003	13:06:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
28	a	10/9/2003	12:54:37	ST I	> 4 phi	3 phi	4 to 3 phi	UN.SI	FALSE	0
28	b	10/9/2003	12:55:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	TRUE	0
28	c	10/9/2003	12:56:00	INDET	> 4 phi	2 phi	4 to 3 phi	SA.F	FALSE	0

Appendix B3

RIDS REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)		
			Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean
18	a	10/9/2003	20.51	20.68	0.17	20.60	> 20.51	> 20.68	> 20.6	0	0	0
18	b	10/9/2003	19.48	20.70	1.22	20.09	> 19.48	> 20.7	> 20.09	0	0	0
18	c	10/9/2003	16.83	18.55	1.72	17.69	> 16.83	> 18.55	> 17.69	0	0	0
18	d	10/9/2003	12.96	14.40	1.44	13.68	> 12.96	> 14.4	> 13.68	0	0	0
18	e	10/9/2003	10.33	12.36	2.03	11.34	> 10.33	> 12.36	> 11.34	0	0	0
18	f	10/9/2003	12.85	14.13	1.28	13.49	> 12.85	> 14.13	> 13.49	0	0	0
18	g	10/9/2003	8.28	9.87	1.59	9.07	> 8.28	> 9.87	> 9.07	0	0	0
18	h	10/9/2003	7.07	8.94	1.87	8.01	> 7.07	> 8.94	> 8.01	0	0	0
19	a	10/9/2003	17.36	18.08	0.72	17.72	> 17.36	> 18.08	> 17.72	0	0	0
19	b	10/9/2003	7.79	10.55	2.76	9.17	> 7.79	> 10.55	> 9.17	0	0	0
19	c	10/9/2003	15.26	16.90	1.64	16.08	> 15.26	> 16.9	> 16.08	0	0	0
19	e	10/9/2003	0.38	2.96	2.58	1.67	> 0.38	> 2.96	> 1.67	0	0	0
21	a	10/9/2003	20.68	20.68	0.00	20.68	> 20.68	> 20.68	> 20.68	0	0	0
21	b	10/9/2003	20.21	20.70	0.49	20.45	>20.21	> 20.70	> 20.45	0	0	0
21	c	10/9/2003	20.68	20.68	0.00	20.68	> 20.68	> 20.68	> 20.68	0	0	0
21	d	10/9/2003	20.63	20.63	0.00	20.63	> 20.63	> 20.63	> 20.63	0	0	0
22	a	10/9/2003	12.86	14.20	1.34	13.53	> 12.86	> 14.2	> 13.53	0	0	0
22	b	10/9/2003	9.59	11.43	1.84	10.51	> 9.59	> 11.43	> 10.51	0	0	0
22	c	10/9/2003	11.85	13.05	1.20	12.45	> 11.85	> 13.05	> 12.45	0	0	0
22	d	10/9/2003	12.52	13.72	1.20	13.12	> 12.52	> 13.72	> 13.12	0	0	0
23	a	10/9/2003	5.01	6.48	1.47	5.74	> 5.01	> 6.48	> 5.74	0	0	0
23	b	10/9/2003	9.20	10.21	1.01	9.70	> 9.2	> 10.21	> 9.7	0	0	0
23	c	10/9/2003	9.92	11.56	1.64	10.74	> 9.92	> 11.56	> 10.74	0	0	0
24	b	10/7/2003	11.09	12.85	1.76	11.97	> 11.09	> 12.85	> 11.97	0	0	0
24	c	10/7/2003	9.25	11.19	1.94	10.22	> 9.25	> 11.19	> 10.22	0	0	0
24	d	10/7/2003	7.98	10.29	2.31	9.14	> 7.98	> 10.29	> 9.14	0	0	0
24	e	10/7/2003	6.95	9.59	2.64	8.27	> 6.95	> 9.59	> 8.27	0	0	0
25	b	10/9/2003	0.00	1.36	1.36	0.68	> 0.00	> 1.36	> 0.68	0	0	0
25	c	10/9/2003	3.91	4.87	0.96	4.39	> 3.91	> 4.87	> 4.39	0	0	0
25	d	10/9/2003	9.57	10.38	0.81	9.98	> 9.57	> 10.38	> 9.98	0	0	0
26	b	10/9/2003	3.32	3.91	0.59	3.62	> 3.32	> 3.91	> 3.62	0	0	0
26	d	10/9/2003	9.52	10.63	1.11	10.08	> 9.52	> 10.63	> 10.08	0	0	0
27	a	10/9/2003	10.97	11.78	0.81	11.38	> 10.97	> 11.78	> 11.38	0	0	0
27	b	10/9/2003	11.71	13.42	1.71	12.57	> 11.71	> 13.42	> 12.57	0	0	0
27	c	10/9/2003	7.41	8.03	0.62	7.72	> 7.41	> 8.03	> 7.72	0	0	0
27	d	10/9/2003	6.43	8.45	2.02	7.44	> 6.43	> 8.45	> 7.44	0	0	0
28	a	10/9/2003	11.09	12.79	1.70	11.94	> 11.09	> 12.79	> 11.94	0	0	0
28	b	10/9/2003	15.90	18.89	2.99	17.40	> 15.9	> 18.89	> 17.4	0	0	0
28	c	10/9/2003	0.51	1.04	0.53	0.77	> 0.51	> 1.04	> 0.77	0	0	0

Appendix B3

RIDS REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low
			Min	Max	Mean	Count	Depth	Diam.		Roughness	DO
18	a	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
18	b	10/9/2003	0.07	4.31	2.83	0	0	0	5	Physical	NO
18	c	10/9/2003	1.89	4.96	3.28	0	0	0	6	Physical	NO
18	d	10/9/2003	1.11	2.48	1.83	0	0	0	8	Physical	NO
18	e	10/9/2003	2.81	6.46	4.02	0	0	0	11	Physical	NO
18	f	10/9/2003	0.13	2.22	0.84	0	0	0	3	Physical	NO
18	g	10/9/2003	3.07	4.44	3.70	0	0	0	6	Physical	NO
18	h	10/9/2003	0.72	4.18	2.84	0	0	0	5	Physical	NO
19	a	10/9/2003	2.15	4.18	3.19	0	0	0	10	Physical	NO
19	b	10/9/2003	2.28	6.07	5.12	0	0	0	7	Physical	NO
19	c	10/9/2003	0.33	3.98	2.80	0	0	0	5	Physical	NO
19	e	10/9/2003	0.85	3.46	2.33	0	0	0	5	Physical	NO
21	a	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
21	b	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
21	c	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
21	d	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO
22	a	10/9/2003	0.26	6.79	4.47	0	0	0	7	Physical	NO
22	b	10/9/2003	0.39	5.94	3.25	0	0	0	10	Physical	NO
22	c	10/9/2003	3.59	4.89	4.14	0	0	0	7	Physical	NO
22	d	10/9/2003	0.46	4.89	3.49	0	0	0	10	Physical	NO
23	a	10/9/2003	0.65	3.46	1.85	0	0	0	4	Physical	NO
23	b	10/9/2003	2.48	5.29	3.78	0	0	0	7	Physical	NO
23	c	10/9/2003	2.22	5.81	4.78	0	0	0	7	Physical	NO
24	b	10/7/2003	0.13	0.59	0.29	0	0	0	2	Physical	NO
24	c	10/7/2003	0.07	1.24	0.58	0	0	0	2	Physical	NO
24	d	10/7/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO
24	e	10/7/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO
25	b	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO
25	c	10/9/2003	0.78	3.65	2.98	0	0	0	5	Physical	NO
25	d	10/9/2003	1.17	6.20	3.32	0	0	0	6	Physical	NO
26	b	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO
26	d	10/9/2003	0.07	1.76	0.99	0	0	0	3	Physical	NO
27	a	10/9/2003	1.83	3.72	2.72	0	0	0	5	Physical	NO
27	b	10/9/2003	0.39	2.28	1.24	0	0	0	7	Physical	NO
27	c	10/9/2003	0.33	1.44	0.92	0	0	0	3	Physical	NO
27	d	10/9/2003	0.98	3.72	2.18	0	0	0	4	Physical	NO
28	a	10/9/2003	0.72	4.24	2.34	0	0	0	5	Physical	NO
28	b	10/9/2003	0.26	6.98	2.74	0	0	0	5	Physical	NO
28	c	10/9/2003	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO

Appendix B3

RIDS REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Comments
18	a	10/9/2003	DM>pen, tan & gry sandy m, overpen, burrow, shell frag
18	b	10/9/2003	DM>pen, Tan sand/gry mottled sandy m w/wht clay, tubes, partially overpen, red sed @z, polychaetes @z
18	c	10/9/2003	DM>pen, tan sand/mottled gry sandy m, tubes, red sed @z, polychaetes @z, bedforms
18	d	10/9/2003	DM>pen, tan sand/mottled gry sandy m, tubes, sm polychaetes @z, sm void, red sed @z, wiper clast
18	e	10/9/2003	DM>pen, tan muddy fine sand mottled w/wht clay, burrow, polychaete @z, m clumps-far
18	f	10/9/2003	DM>pen, gry sandy m mottled w/wht clay, m clumps-far, red sed @ surf, patchy RPD
18	g	10/9/2003	DM>pen, tan sand w/ wht clay/gry sandy m, lg rock @ surf, sm tubes, wiper clast
18	h	10/9/2003	DM>pen, tan & gry sand mottled w/wht clay, red sed @z, dist surf
19	a	10/9/2003	DM>pen, tan sand/tan & gry mottled sandy m w/wht clay, polychaete @z, sm void, ox clasts
19	b	10/9/2003	DM>pen, tan/gry sandy m w/ wht clay, bedforms, m clumps-far
19	c	10/9/2003	DM>pen, tan sand/tan&gry mottled sandy m w/wht clay, red sed @z=wiper clst?, m clump @surf, worm @z, fecal/flock lyr,burrow opening?
19	e	10/9/2003	DM>pen, brn & gry fine sand, underpen, red clast
21	a	10/9/2003	DM>pen, over penetration
21	b	10/9/2003	DM>pen, tan & gry mottled sandy m, over penetration
21	c	10/9/2003	DM>pen, tan sand & gry mottled sandy m, red sed @z, burrowing anemone @z, over penetration
21	d	10/9/2003	DM>pen, tan & gry mottled sandy m, red sed @z, over penetration, burrowing anemone @z
22	a	10/9/2003	DM>pen, tan & gry muddy fine sand, wht clay, red sed band @z. ox clasts, sm worms @z, relic RPD?
22	b	10/9/2003	DM>pen, tan/gry & blk sandy m, polychaetes @z, v red sed @z, voids, burrow, surf rework
22	c	10/9/2003	DM>pen, tan & gry sandy m w/wht clay, red sed @z, ox clasts, tubes, worms @z, surf rework
22	d	10/9/2003	DM>pen, tan sandy m w/wht clay, red sed @z, voids, burrow, polychaetes @z, sm tubes, ox clasts
23	a	10/9/2003	DM>pen, tan & gry muddy fine sand w/pebbles, bedforms, red sed @z, rocks-far, starfish-far
23	b	10/9/2003	DM>pen, brn muddy fine sand/gry sandy m w/wht clay, red sed @z, rocks-far, red clasts
23	c	10/9/2003	DM>pen, tan sand/tan & blk sandy m, rocks @ surf, red sed @z
24	b	10/7/2003	DM>pen, recent deposit,thin sandy lyr/blk & gry mottled sandy m w/ wht clay, v sulfidic m, thin RPD, low DO?
24	c	10/7/2003	DM>pen, recent deposit, brn medium sand/gry clay, red sed @z, clay clumps @ surf, red clasts, thin RPD
24	d	10/7/2003	DM>pen, recent deposit, brn & gry medium sand/gry sandy m, red clasts, pebbles?
24	e	10/7/2003	DM>pen, recent deposit, gry sand mottlled w/wht clay, v red sed @z, lg clay clump @surf, red clasts, chaotic fabric
25	b	10/9/2003	DM>pen? & gry muddy fine sand, underpenetration, bedforms
25	c	10/9/2003	DM>pen, tan sand/gry muddy fine sand
25	d	10/9/2003	DM>pen, tan & gry muddy fine sand w/wht clay, burrows
26	b	10/9/2003	DM>pen, blk & gry muddy fine sand, disturbed surf, v red sed @ surf & @ z, low DO?, RPD blown away?
26	d	10/9/2003	DM>pen, recently deposited, tan sand/mottled tan & blk muddy fine sand w/wht clay, v red sed @z, flock layer, thin RPD, m clumps-far
27	a	10/9/2003	DM>pen, Gry sand/gry & blk mottled sandy m, red sed @z, wht clay @z
27	b	10/9/2003	DM>pen, tan sand/mottled wht & gry clay, tubes, void
27	c	10/9/2003	DM>pen, Gry sand/gry & blk mottled sandy m w/wht clay, red sed @z, relatively recently placed
27	d	10/9/2003	DM>pen, tan sand/tan & gry mottled sandy m, wht clay @z, tubes
28	a	10/9/2003	DM>pen, tan/gry sandy m w/wht clay, polychaete @z, sm tubes
28	b	10/9/2003	DM>pen,, recently deposited, tan & blk mottled sandy m w/wht clay, ox & red clasts, v red sed @z
28	c	10/9/2003	DM>pen, underpenetration, tan & gry mottled muddy fine sand w/wht clay

Appendix B4

Sediment-Transition Area (Area W) REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi) Min	Grain Size (phi) Max	Grain Size (phi) Maj Mode	Benthic Habitat	Mud Clasts Present	Mud Clasts Avg. Diam
13	e	10/9/2003	14:59:00	ST I	> 4 phi	1 phi	4 to 3 phi	UN.SS	FALSE	0
13	f	10/9/2003	15:00:00	ST I	> 4 phi	2 phi	4 to 3 phi	SA.F	FALSE	0
13	g	10/7/2003	15:01:00	ST I	> 4 phi	4 phi	4 to 3 phi	UN.SS	FALSE	0
14	a	10/7/2003	17:57:00	ST I	> 4 phi	4 phi	3 to 2 phi	UN.SS	TRUE	0
14	b	10/7/2003	17:58:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
14	c	10/7/2003	17:59:00	ST I on III	> 4 phi	3 phi	4 to 3 phi	UN.SS	FALSE	0
15	b	10/7/2003	18:04:00	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	FALSE	0
15	f	10/9/2003	15:07:00	ST I	> 4 phi	4 phi	4 to 3 phi	SA.F	FALSE	0
16	d	10/7/2003	18:32:00	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
16	e	10/7/2003	18:33:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	FALSE	0
16	f	10/7/2003	18:34:00	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	TRUE	0

Appendix B4

Sediment-Transition Area (Area W) REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)		
			Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean
13	e	10/9/2003	1.14	3.84	2.70	2.49	0	0	0	0	0	0
13	f	10/9/2003	4.80	6.07	1.27	5.44	0	0	0	0	0	0
13	g	10/7/2003	2.29	3.42	1.13	2.86	0	0	0	0	0	0
14	a	10/7/2003	7.00	9.97	2.97	8.49	0	0	0	0	0	0
14	b	10/7/2003	7.52	10.92	3.40	9.22	0	0	0	0	0	0
14	c	10/7/2003	8.42	9.82	1.40	9.12	0	0	0	0	0	0
15	b	10/7/2003	9.18	9.87	0.69	9.52	0	0	0	0	0	0
15	f	10/9/2003	2.74	3.55	0.81	3.14	0	0	0	0	0	0
16	d	10/7/2003	8.27	9.86	1.59	9.07	0	0	0	0	0	0
16	e	10/7/2003	6.76	7.93	1.17	7.35	0	0	0	0	0	0
16	f	10/7/2003	8.00	8.89	0.89	8.44	0	0	0	0	0	0

Appendix B4

Sediment-Transition Area (Area W) REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low
			Min	Max	Mean	Count	Depth	Diam.		Roughness	DO
13	e	10/9/2003	0.65	3.00	1.74	0	0	0	4	Physical	NO
13	f	10/9/2003	1.17	3.78	2.41	0	0	0	5	Physical	NO
13	g	10/7/2003	0.72	1.76	1.48	0	0	0	3	Physical	NO
14	a	10/7/2003	0.07	2.68	1.03	0	0	0	3	Physical	NO
14	b	10/7/2003	0.59	3.52	1.71	0	0	0	4	Physical	NO
14	c	10/7/2003	0.78	5.29	2.90	0	0	0	9	Physical	NO
15	b	10/7/2003	0.72	3.98	3.49	0	0	0	6	Physical	NO
15	f	10/9/2003	0.72	2.22	1.59	0	0	0	4	Physical	NO
16	d	10/7/2003	0.65	4.05	2.81	0	0	0	9	Physical	NO
16	e	10/7/2003	0.52	3.98	3.02	0	0	0	6	Physical	NO
16	f	10/7/2003	0.98	4.76	3.42	0	0	0	6	Physical	NO

Appendix B4

Sediment-Transition Area (Area W) REMOTS® Sediment-Profile Imaging Data, October 2003 Survey

Station	Replicate	Date	Comments
13	e	10/9/2003	Ambient tan & gry muddy fine sand w/shell, (hard bottom corresponds w/ side scan), underpen, tube
13	f	10/9/2003	Ambient tan & gry muddy fine sand, sm tubes
13	g	10/7/2003	Ambient tan & gry muddy fine sand, bedforms?
14	a	10/7/2003	Ambient tan & gry muddy fine sand, tubes, red clast, indistinct void?
14	b	10/7/2003	Ambient tan & gry muddy fine sand, tubes
14	c	10/7/2003	Ambient tan & gry muddy fine sand, void, tubes
15	b	10/7/2003	Ambient tan & gry sandy m w/ gry clay, m clumps-far, polychaete @z
15	f	10/9/2003	Ambient tan & gry muddy fine sand, developing artifact, underpen, sm tubes
16	d	10/7/2003	Ambient tan & gry muddy fine sand, shell fras @ surf, void, burrow, tubes, sm worm @z
16	e	10/7/2003	Ambient tan & gry muddy fine sand, tubes, polychaetes @z, shell bits
16	f	10/7/2003	Ambient tan & gry muddy fine sand, red clasts, tubes, shell frags, polychaete @z, m clumps or rocks-far