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The 1997 Category II Capping Project at the New York Mud Dump Site: Results From the April 1998 Postcap Subbottom Profiling Survey

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ACKNOWLEDGMENT

This report presents results from the postcap subbottom profile survey for the 1997 Category II Capping Project at the New York Mud Dump Site. This survey was conducted by Science Applications International Corporation (SAIC) of Newport, RI, under Delivery Order 10 of SAIC's Indefinite Quantity Contract No. DACW51-97-D-0014 with the U.S. Army Corps of Engineers - New York District (NYD). Mr. Brian May is the manager of technical activities under the NYD contract; Dr. Scott McDowell is SAIC's program manager. Mr. Ed DeAngelo was the Project Leader for Delivery Order 10.

Logistical and planning support for the survey were provided by Mr. Brian May of NYD with assistance from Mr. Tim LaFontaine.

Mr. Ed DeAngelo, Mr. Steve Pace and Ms. Kate Pickle were responsible for mobilizing the field equipment and conducting the survey operations aboard the Corps vessel M/V *Gelberman*. The crew of the M/V *Gelberman* should be commended for their skill in vessel handling while running the subbottom survey lines, as well as their dedication during long hours of operations at the Mud Dump Site.

Ms. Pickle and Mr. DeAngelo processed the subbottom profile data, produced the graphic data products and prepared the report. Dr. McDowell provided technical review of the report, while Ms. Ellen Bellagamba Bliss was responsible for report production.

1.0 INTRODUCTION

1.1 Background

Material dredged from the Port of New York and New Jersey is placed in an ocean disposal site in the New York Bight known as the Mud Dump Site (MDS). The site is located six miles off the coast of northern New Jersey and is a 2.2 square mile rectangular area in approximately 12-27 m of water (Figure 1-1). In a July 24, 1996 letter to several U.S. Congressional Representatives from New Jersey, EPA Administrator Carol Browner, Secretary of Transportation Frederico Pena, and Secretary of the Army Togo West, Jr. announced that the MDS would close by September 1, 1997. The "3 Party Letter" further states that simultaneous with the closure of the MDS, the site and surrounding areas which have been used historically for disposal of material with trace levels of contaminants, will be re-designated as the Historic Area Remediation Site (HARS). On August 26, 1997, the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers finalized the rule providing for simultaneous closure of the MDS and designation of the HARS.

The planned closure of the MDS on September 1, 1997, left the Port of New York and New Jersey with a limited period of time to dispose a finite volume of contaminated (i.e., Category II) dredged sediments at the site and place a layer of clean (i.e., Category I) sediment over it. Through the collaborative efforts of the Corps of Engineers' Waterway Experiment Station (WES), Science Applications International Corporation (SAIC), and the Corps of Engineers' New York District (NYD), a plan was developed in early 1997 to address dredging, ocean disposal and subsequent capping of the Category II material at the MDS prior to the September 1 closure. The project is referred to as the 1997 Category II Capping Project.

As part of the initial phase of the project, the NYD directed SAIC to perform a series of baseline oceanographic studies to assess the predisposal conditions in a region of the MDS which had been selected for the disposal of the Category II material (Figure 1-2). These studies, which were designed to characterize the biological, chemical, geological and physical conditions of the region, involved seafloor video imaging, collection of surface sediment and biological tissue samples, sediment coring, precision bathymetry, and REMOTS® sediment-profile imaging.

1.2 Disposal of Category II Dredged Material

The 1997 Category II Capping Project was located in the southeastern quadrant of the MDS (Figure 1-1). During the summer of 1997, approximately 690,000 yd^3 Category II dredged material were disposed within the base mound area under the close scrutiny of the NYD site managers. Actual disposal operations were conducted in cells measuring 200 ft × 300 ft within the base mound area, and the amount of dredged and cap material deposited in each cell was monitored continuously.

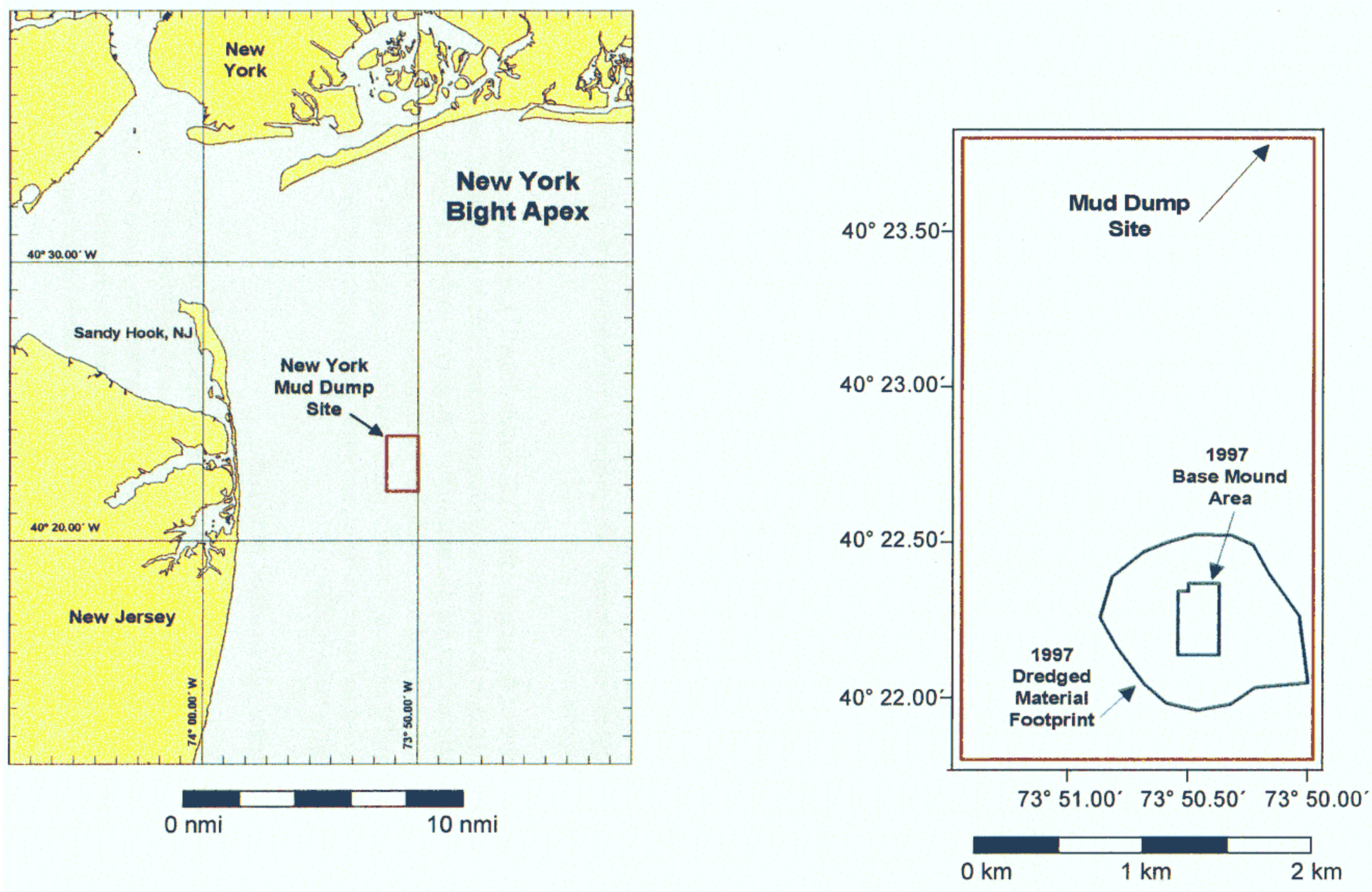

Figure 1-1. The location of the Mud Dump Site in the New York Bight. The location of the 1997 Category II Project Area in the southeastern portion of the Mud Dump Site is also shown.

While the Category II material was being placed during the summer of 1997, the SAIC-operated New York Disposal Surveillance System (NYDISS) units installed aboard the disposal scows (SAIC 1997a) recorded the disposal points. SAIC also performed a series of precision bathymetric surveys to monitor the mound as it was being created on the seafloor (Figure 1-2). Following the completion of disposal operations, another round of environmental surveys was conducted to serve as a baseline for future monitoring. This included a REMOTS® sediment-profile imaging survey which was used to delineate the dredged material footprint (SAIC 1997b).

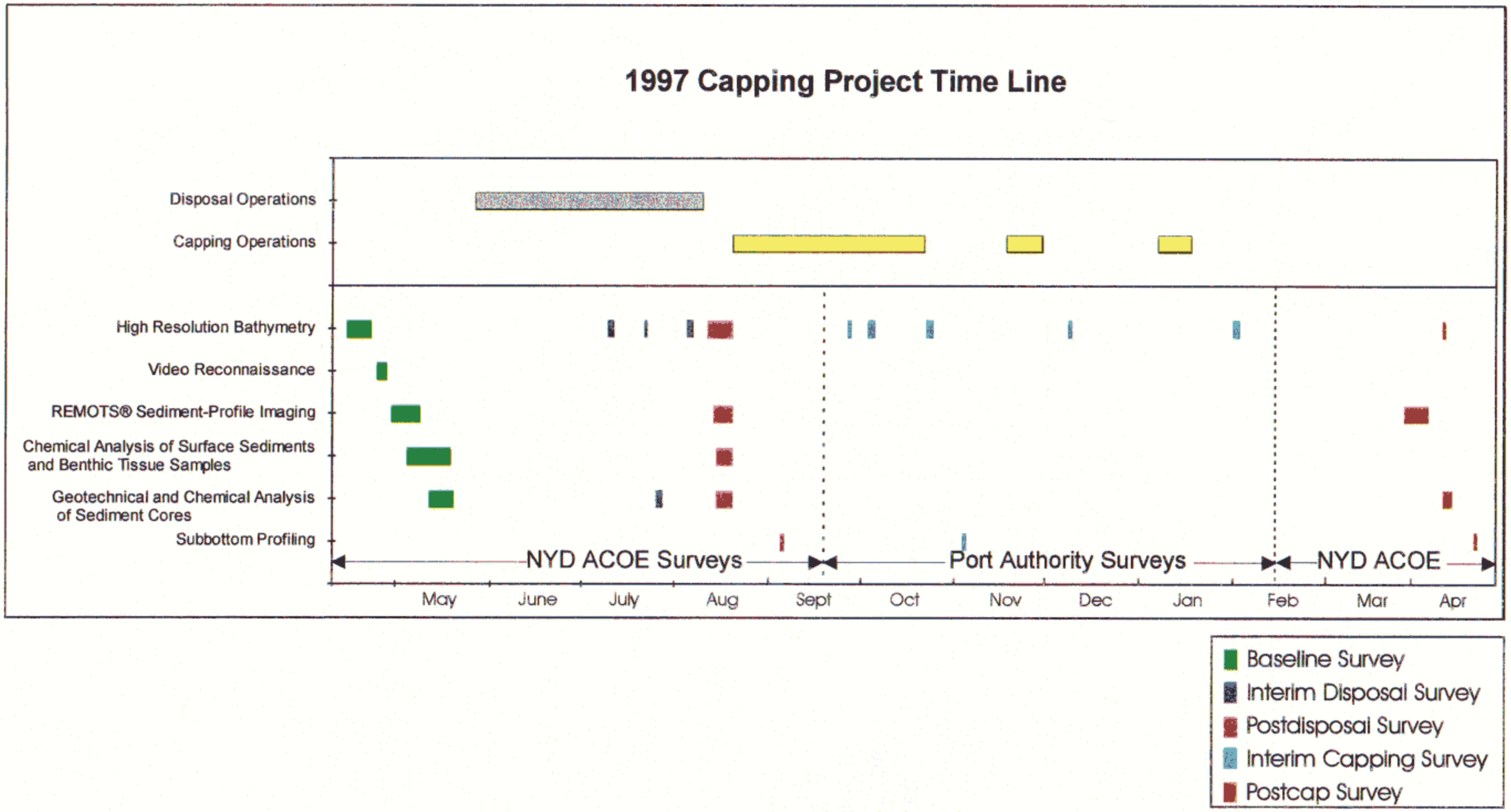

Figure 1-2. 1997 Category II Capping Project time line

1.3 Capping Operations

Under the dredging permit, the Port Authority of NY/NJ (PA) was responsible for placing a 1-m thick sand cap over the entire Category II dredged material footprint. The dredged material footprint was divided into a grid of rows and columns spaced 100 ft apart (Figure 1-3). The rows and columns served as track lines and provided guidance for hopper dredges during sand dispersal operations. Sand dispersal activities were closely monitored by the PA and the NYD to ensure that sand was evenly distributed over the entire footprint. Figure 1-3 shows track locations of the sand hopper dredges during sand cap disposal events. These sand cap disposal tracts were recorded by NYDISS units installed aboard the hopper dredges. During the capping period of August 1997 to January 1998, the Port Authority of New York/New Jersey (PA) placed over 2 million yd^3 of sand from Ambrose Channel over the entire Category II material footprint

1.4 Survey Objectives

The objective of the survey reported here was to map the location and thickness of the sand cap and underlying Category II dredged material with an acoustic subbottom profile system. To meet this objective, an Edgetech XStar™ Model 216S Full Spectrum Digital Subbottom Profiler was used to survey the same area of the Mud Dump Site where three successive bathymetric surveys had been conducted during the disposal and capping phases of the 1997 Category II Project. The subbottom results were compared to results from successive bathymetric depth difference analyses in order to ground truth the bathymetric techniques. This report presents the results for the 1997 Category II Project Mound postcap subbottom profile survey performed in April 1998.

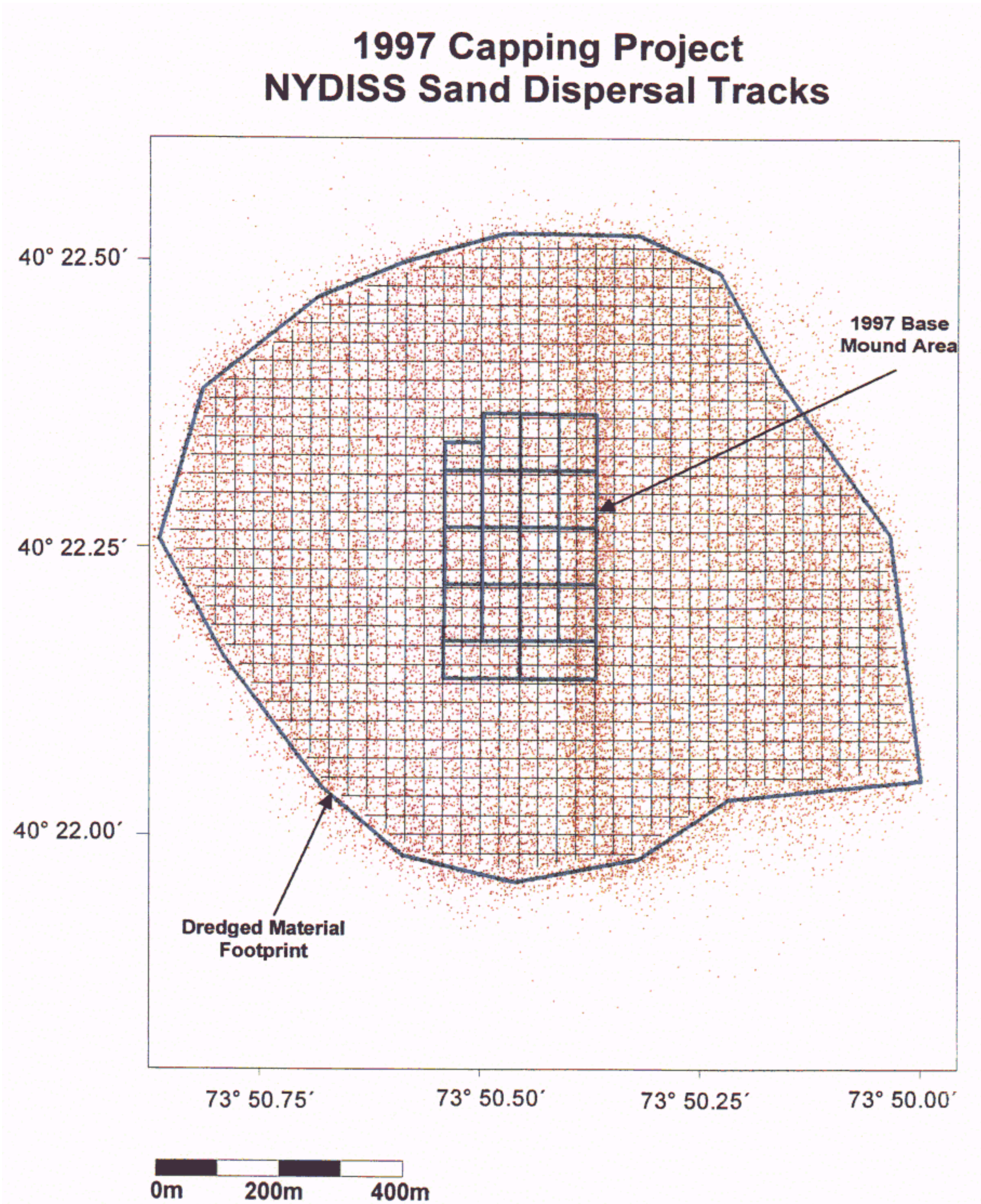

Figure 1-3. Location of sand dispersal ship tracks, as recorded with SAIC's NYDISS system.

2.0 METHODS

2.1 Subbottom Survey Operations

Survey operations were conducted aboard the New York District's M/V *Gelberman* on April 26-27, 1998. The survey area measured 1500 m (north-south) by 1300 m (east-west) and extended to the eastern and southern boundaries of the Mud Dump Site (Figure 2-1). The center of the survey region corresponded with the target location for the disposal mound of the 1997 Category II Capping Project. Subbottom profile data were collected along 26 north-south oriented survey lanes spaced 50 m apart. The survey plan occupied every other lane of the cap monitoring bathymetry survey performed by SAIC (SAIC 1998a). In order to reduce any horizontal positioning artifacts when comparing subbottom profile data to bathymetric data, the survey lanes were designed to coincide with even numbered lanes surveyed during bathymetric interim-disposal and cap monitoring surveys (SAIC 1997c-f, SAIC 1998a).

Vessel positioning and data integration were achieved with SAIC's Portable Integrated Navigation Survey System (PINSS). This PC-based system provides real-time navigation, and collection of position, time, and depth soundings for subsequent analysis. Vessel positioning was determined using a Trimble GPS receiver. One-to-five meter positioning accuracy was achieved by applying differential corrections to the GPS signals that were acquired from the U.S. Coast Guard differential GPS (DGPS) beacon located at Sandy Hook NJ.

During field operations, the PINSS provided the navigator and vessel operator with range and bearing to selected targets (i.e., beginning and end of survey lines), signal quality, time of day, and selected data from environmental sensors such as the depth sounder. PINSS computed towfish position using a cable layback calculated and provided this position to the subbottom profile system.

High resolution subbottom profile data were acquired with an Edgetech XStar™ Model 216S Full Spectrum Digital Subbottom Profiler. Subbottom seismic profiling is a standard technique for determining changes in acoustic impedance below the sediment/water interface. Acoustic impedance is a function of the density of a layer and speed of sound within that layer. The depth of penetration and the degree of resolution depends on the frequency and pulse width of the seismic signal, and the characteristics of the penetrated material. The acoustic transducers of the XStar system were mounted in a towfish and lowered using the winch and crane aboard the *Gelberman.* The electronic signal cable from the towfish was mated to the mechanical tow cable with brass clips.

The XStar system generated a frequency-modulated pulse that was swept over an acoustic range of 2 to 10 kHz during the subbottom survey. The pulse rate was set to 8 pulses per second for optimum performance of the output devices. At 8 pulses per second, traveling at an average vessel speed of 4 to 5 knots, a subbottom measurement was acquired every

34 to 43 cm along the vessel track. Every sonar return was recorded digitally and stored with a geodetic positional fix. This sampling capability allowed high resolution digital analysis of dredged material thickness across the disposal mound.

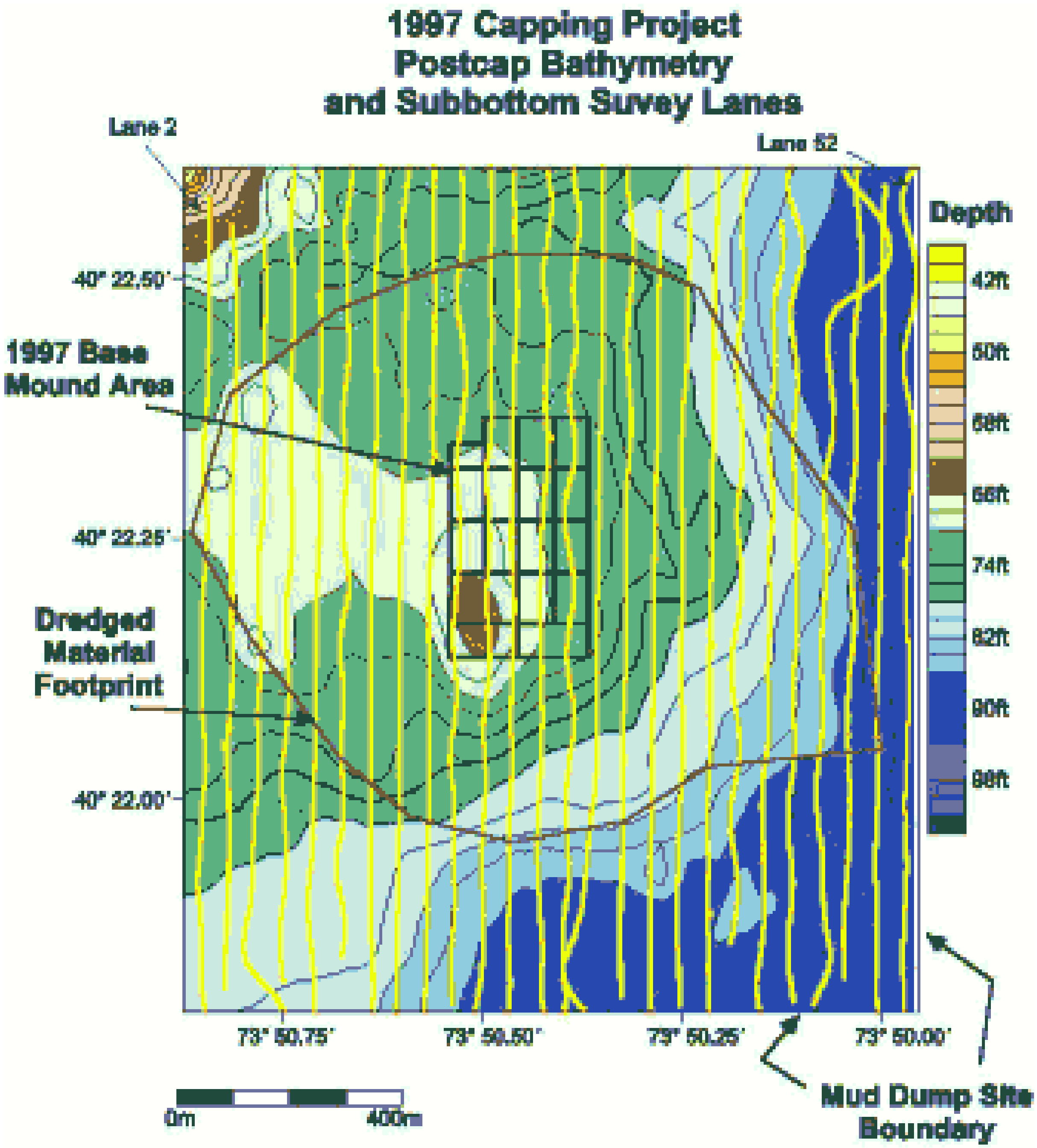

Figure 2-1. Track plot of the 26 serveys lanes where subbottom profile data were collected on April 27, 1998. In addition, the 1997 Base Mound Area, Dredged Material Footprint from REMOTS® analysis, and Mud Dump Site boundary have been plotted.

The XStar profiler generated a narrow acoustic beam (13°) which translated to a 5-m wide bottom swath along each survey lane in an average water depth of 75 ft (23 m) at the Mud Dump Site. The swath width will vary proportionally with water depth and the depth at which the fish is towed. The towing depth was approximately 5 meters. With a lane spacing of 50 meters, approximately 10% bottom coverage was obtained for the survey area.

The amplified return signal of the XStar transducers was sent through an A/D converter to an on-board Sun Sparc II Workstation for data display and archive. The XStar data acquisition system consists of computer components for automatic data storage, real-time color data display and hard copy printouts of profile data. Continuous sonar data were stored digitally on 8mm magnetic tape and printed to an EPC thermal printer in real-time.

2.2 Subbottom Data Analysis

Following the survey, subbottom profile data stored on 8mm tape were read and analyzed using an SAIC PC-based C-complied program. The subbottom data were displayed on the PC monitor as both a continuous profile, duplicating the shipboard display, as well as individual pulses. The depth to the first arrival (the sediment-water interface) was automatically tracked and subbottom layers were manually digitized by tracing subsurface reflectors with the computer's mouse. As many as three separate layers can be tracked simultaneously. The digitized data were stored in files containing the geodetic position and the vertical distance (depth) from the first return (sediment-water interface) to the subsurface layer for each sonar ping. The measurement was based on the assumption that the average sound velocity in the sediment layer was 1500 m/s.

The digitized data files were imported into SAIC's Hydrographic Data Analysis System (HDAS), where the data were edited for outliers and corrected for sound velocity values derived from geotechnical analysis of sediments samples (Section 2.3). Following the application of sound velocity correctors, the layer thickness values were spatially averaged to produce a matrix of cells each having dimensions of 25 m by 25 m. The gridded data were used to produce the various isopach maps included in this report, and will be incorporated into the GIS database of the Disposal Analysis Network for the New York District (DAN-NY), which resides at the NYD. Additionally, the gridded data were used to estimate the volume of material associated with each digitized layer. Finally, subbottom dredged material thickness and volume results were compared to time-series bathymetric results. All graphics for this report have been plotted in NAD83 latitude/longitude coordinates, unless otherwise noted.

2.3 Calibration of Subbottom Data

During a postcap vibra-coring survey conducted a week prior to the subbottom survey, core samples of the upper 8 to 10 feet of surficial sediments were collected from the project sand cap (SAIC 1998b). Table 2-1 summarizes the results from the geotechnical analysis of 14 core samples. An average speed of sound in the cap layer was estimated from these data for calibration of the subbottom data.

Results of the grain size analyses indicated that the sand cap material consisted of varying percentages of coarse, medium, and fine sand (Table 2-1a). The bulk density of the sand cap portion of the core samples ranged from 1.81 - 2.07 g/cc. Typical speeds of sound through sand on the continental shelf have been summarized by Hamilton (1971; Table 2-2); these data were used to estimate a speed of sound for the 1997 Category II Project sand cap. The speed of sound through fine to coarse sand ranges from 1711 to 1836 m/s; for calibration purposes, a speed of 1711 m/s was used as a conservative estimate of the speed of sound in the cap material.

Table 2-1. Summary of Physical Properties of the Sand Cap and Dredged Material Based on Analyses of Postcap Sediment Cores Collected from the 1997 Project Mound (SAIC 1998b)

	Sand Cap Material					
	Average	Std. Dev.	Coefficient of Variation	Min	Max	Sample Count
Water Content (%)	20.8	1.6	7.7	17.1	26.3	68
Bulk Density (g/cc)	1.96	0.05	2.55	1.81	2.07	68
> Coarse (%)	6.1	5.1	83.6	1.0	19.5	29
Sand (%)	90.1	4.6	5.1	78.5	95.5	29
Coarse (%)	19.6	7.1	36.2	7.0	30.0	29
Medium (%)	44.3	5.8	13.1	35.0	55.5	29
Fine (%)	25.7	10.9	42.4	10.0	47.0	29
Very Fine (%)	2.5	2.0	80.0	0.0	7.0	29
Silt & Clay (%)	3.7	2.2	59.5	1.0	10.0	29
Liquid Limit (%)	---	---	---	---	---	---
Plasticity Index (%	---	---	---	---	---	---
Specific Gravity	---	---	---	---	---	---
Void Ratio	0.71	0.3	40.9	0.5	2.1	68
USCS Symbol(s)*	SP					28

	Dredged Material					
	Average	Std. Dev.	Coefficient of Variation	Min	Max	Sample Count
Water Content (%)	59.7	13.1	21.9	21.5	85.3	98
Bulk Density (g/cc)	1.67	0.10	6.0	1.51	2.05	96
> Coarse (%)	1.8	2.4	133.33	0.0	14.0	44
Sand (%)	16.4	9.5	57.9	3.0	42.5	44
Coarse (%)	2.6	1.9	73.1	0.5	9.5	44
Medium (%)	5.7	3.5	61.4	0.5	14.5	44
Fine (%)	6.8	4.8	70.6	1.5	25.0	44
Very Fine (%)	9.0	3.0	33.3	2.5	15.0	44
Silt (%)	62.4	8.5	13.6	37.0	78.0	44
Clay (%)	19.4	4.5	23.2	12.0	32.0	44
Liquid Limit (%)	65.0	11.1	17.1	34.5	82.5	31
Plasticity Index (%	40.0	9.0	22.5	16.8	59.1	31
Specific Gravity	2.64	0.05	1.9	2.52	2.73	31
Void Ratio	1.56	0.31	19.9	0.59	2.21	96
USCS Symbol(s)*	CH (27), CL (3), SC (1)					31

Table 2-2. Sediment Properties, Continental Terrace Shelf and Slope Environment (Hamilton 1971).

Sediment Type	No. Samples	Sand (%)	Silt (%)	Clay (%)	Density (g/cc)		Velocity (m/sec)		R	
					Avg.	SE	Avg.	SE	Avg.	SE
Sand										
Coarse	2	100.0	...	...	2.03	...	1836	...	0.4098	...
Medium	12	99.8	0.2	...	2.01	0.009	1749	6	0.3835	0.002
Fine	9	88.1	6.3	7.1	1.98	0.024	1742	10	0.3749	0.005
Very fine	3	83.9	13.0	2.9	1.91	...	1711	...	0.3517	...
Silty sand	11	65.0	21.6	13.4	1.83	0.025	1677	9	0.3228	0.008
Sandy silt	6	34.5	51.2	14.3	1.56	...	1552	...	0.2136	...
Sand-silt-clay	17	32.6	41.2	26.1	1.58	0.030	1578	9	0.2504	0.010
Clayey silt	40	6.1	59.2	34.8	1.43	0.016	1535	3	0.1767	0.012
Silty clay	17	5.3	41.5	53.6	1.42	0.013	1519	3	0.1586	0.005

SE Standard error of the mean.

R Rayleigh reflection coefficient at normal incidence = $\frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1}$

3.0 RESULTS

A. Subbottom Measurement of the Sand Cap Layer

The sand cap appeared as a distinct layer located below the sediment-water interface in the subbottom profiles (Figure 3-1). The example subbottom profile shown in Figure 3-1 is from lane 26 located in the center of the survey area. Three acoustic density discontinuities have been identified in Figure 3-1: 1) the seawater-sediment interface, 2) the sand cap-Category II dredged material interface, and 3) the Category II dredged material-“ambient” seafloor interface. The transition between each layer is marked by a gradient in return color or a dark return band at the interface.

Figure 3-1 includes a close up view of the sonar records showing the layers in the top 5 m of the sediment in greater detail. The top layer of sand in Figure 3-1 appears as a light gray interval directly below the sharp, dark return of the seawater-sediment interface. The sand layer varied in thickness from a few centimeters (the limit of the analyst’s ability to trace the interface) on the flanks of the cap region up to 2 m in some locations.

A matrix of digitized cap thickness measurements from the 26 survey transects was created by spatially averaging the data into a grid of regularly spaced 25 m square cells. The gridded data were then used to generate isopach contour maps of the digitized sand cap thickness. Figure 3-2 is a two dimensional color filled contour isopach map. Isopach thickness values are displayed in 0.25 m intervals, with the 0.8 m and 0.9 m contour included to provided greater resolution near the permitted 1 m minimum. The dredged material disposal base mound and the final dredged material footprint, as determined by REMOTS® sediment profile imaging, have been included for reference.

Figure 3-2 indicates that in general sand was distributed evenly over the entire Category II dredged material footprint. Analysis of the subbottom profile data identified thicker sand deposits, in excess of 2 m, in the eastern portion of the project area compared to the western portion. The thicker deposits on the eastern side of the base mound area are consistent with a greater density of dispersal events in this area as shown in Figure 1-3. Throughout the project area, small patches with 0.8 m – 0.9 m of sand were observed. However, these areas with less than the required 1-m thick layer of sand are small and well within the measurement limits of the subbottom system, as discussed later in Section 4.1.

Along the most western boundary of the dredged material footprint, there appears to be no sand cap (Figure 3-2). This portion of the 1997 Category II Project area overlaps the sand cap placed during the 1993 Dioxin Capping Project as demonstrated in Figure 3-2. In this region it was difficult to differentiate between sand placed during the 1997 Project from sand placed during the 1993 Project (SAIC 1994) and therefore no measurements were made.

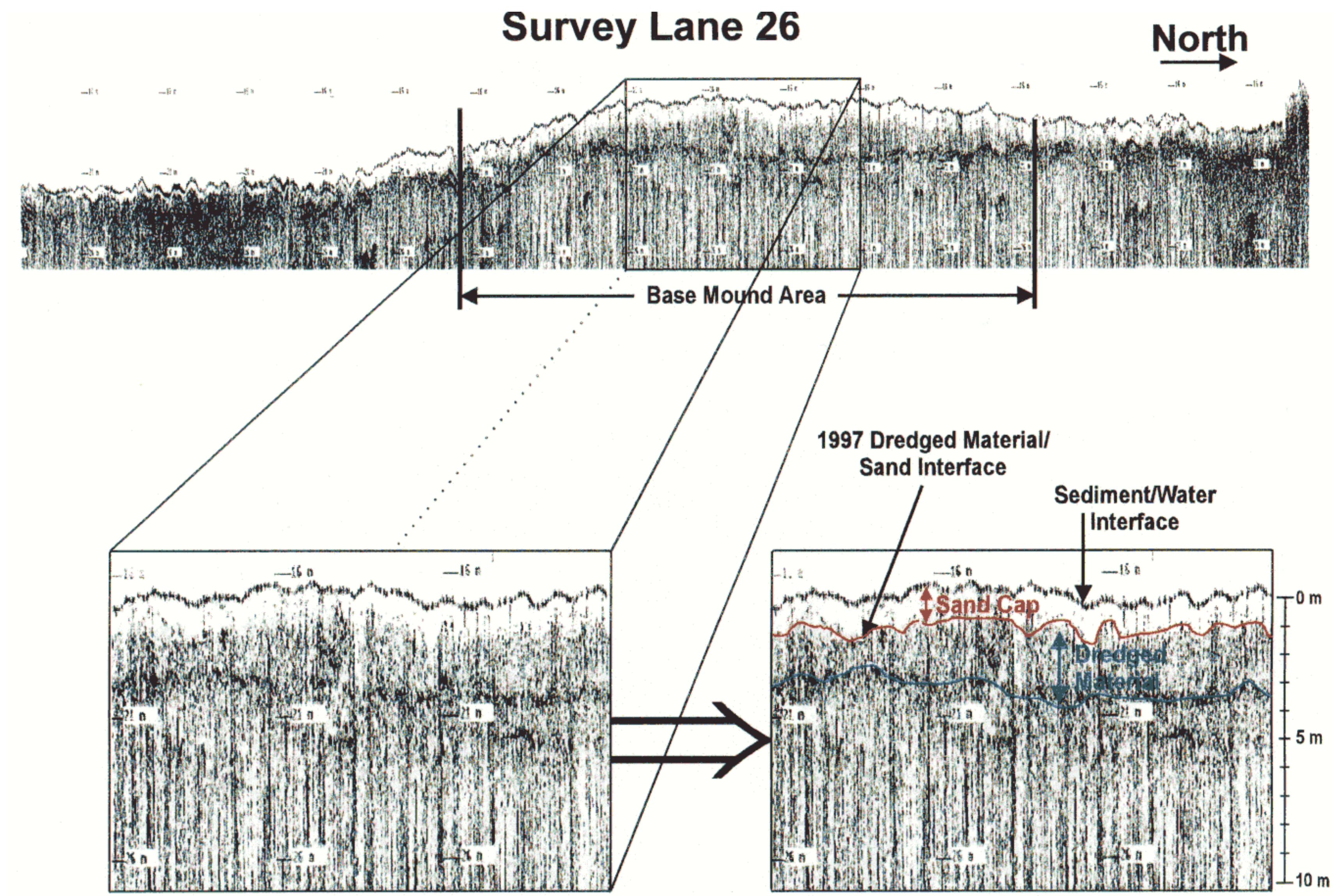

Figure 3-1. X-Star Subbottom acoustic profile imagery data collected from survey lane 26.

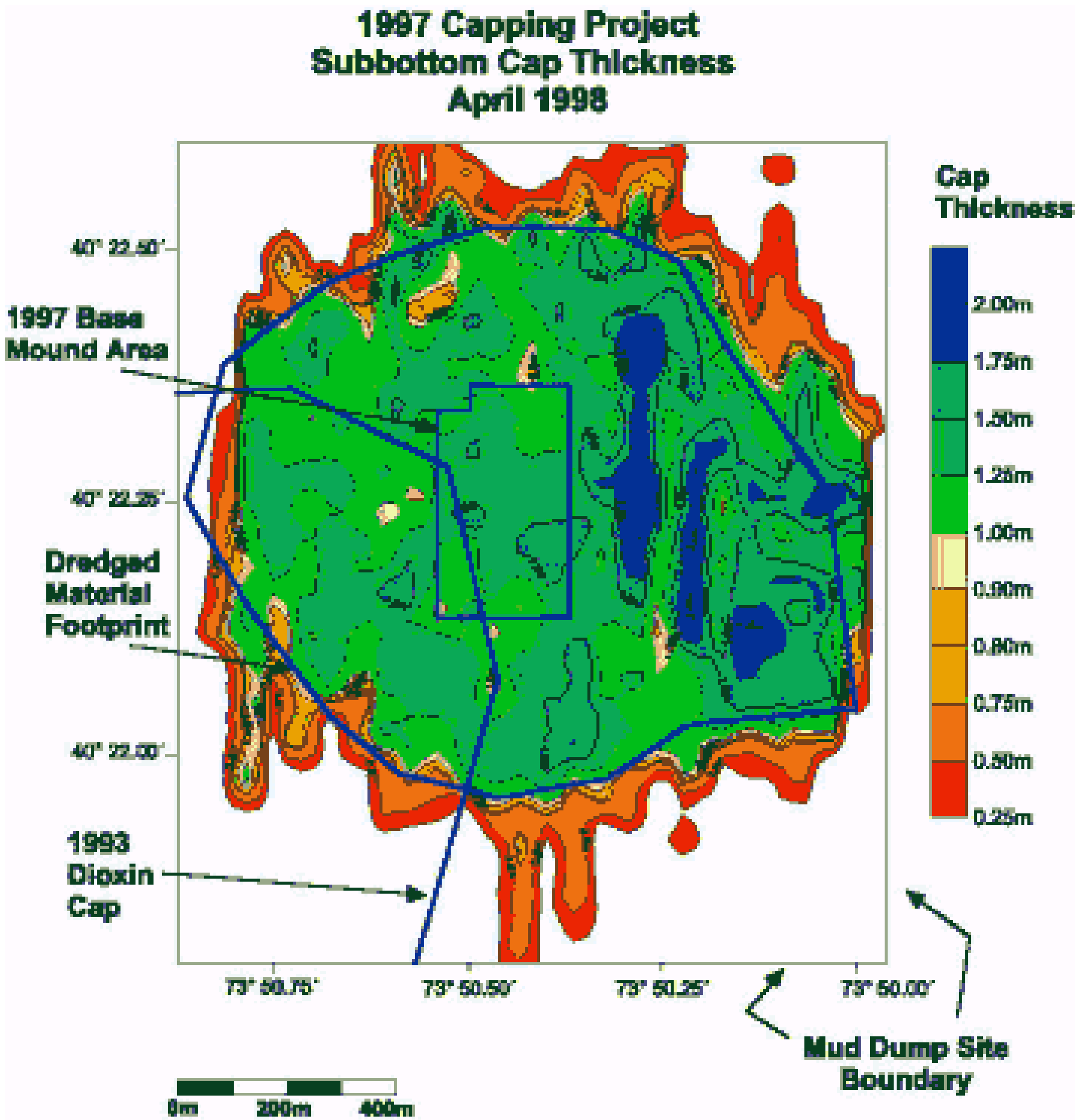

Figure 3-2. Two-dimensional isopach map of cap thickness values. In addition, the 1997 Base Mound Area, Dredged Material Footprint from REMOTS® analysis, 1993 Dioxin Cap boundary, and Mud Dump Site boundary have been plotted.

Volumetric analysis was conducted on the subbottom cap measurements to calculate the amount of sand dispersed in the project area. The subbottom results show that following the completion of capping operations, 2,002,900 yd^3 of sand had been placed at the project area.

Figure 3-3 is a frequency distribution plot of cap thickness for each cell within the dredged material footprint area. The red bars indicate cells with thickness values less than one meter and green indicates cells with a value of one or more meters. The blue line represents the cumulative percentage of cell thickness values. The subbottom results show that at least 91% of cells had at least one meter of cap. Note, however, that these statistics include the cells on the western side of the footprint where 1997 sand could not be differentiated from 1993 sand and therefore, overestimate the number cells that have not been completely capped.

3.2 Subbottom Measurement of the Subsurface Dredged Material Layer

In the swept-frequency sonar subbottom records, it was possible to identify the interface between the bottom of the 1997 sand cap layer and the underlying dredged material. However, signal attenuation (loss of return signal) in the sand cap layer hindered the system's ability to detect thin layers (< 0.5 ft) of underlying dredged material. The dredged material highlighted in Figure 3-1 appears as a gray layer below the sand cap. The interface between the sand and the Category II dredged material was characterized by a transition in return shading from light to dark. The base of the Category II project material layer was marked by a high-amplitude reflector, resulting from the acoustic impedance between the fine-grained dredged material (SAIC 1998c) and the underlying coarse-grained basement material (SAIC 1992, 1997g).

Figure 3-4 is a two dimensional color filled contour isopach map of the subbottom dredged material measurements. The dredged material isopach contours have been plotted at 0.5 ft intervals for comparison with data published in the postdisposal subbottom survey report (SAIC 1998c). The greatest thickness of dredged material was oriented north-south on the eastern side of the base mound area, with one large peak having a maximum thickness of 9.7 ft, and a smaller peak with a maximum thickness of 8.6 ft just to the south.

Volumetric analysis was conducted on the subsurface dredged material layer measurements to calculate the amount of dredged material in the project area. The subbottom results show that following the completion of capping operations, 637,400 yd^3 of dredged material could be detected beneath the sand layer.

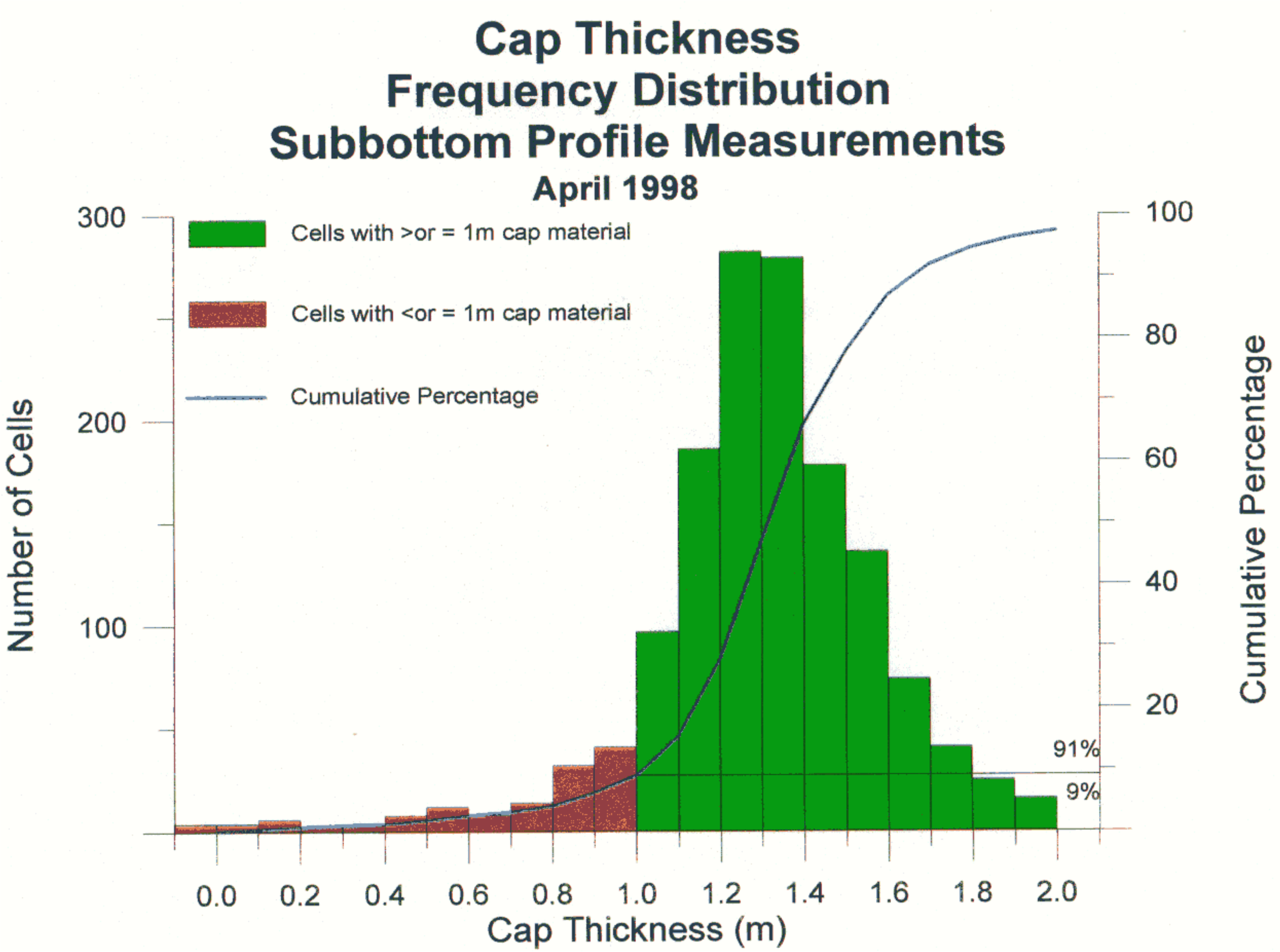

Figure 3-3. Cumulative frequency distribution of cap thickness values from the postcap subbottom cap thickness grid. The distribution is based on a total of 1,487 25-m cells located within the dredged material footprint.

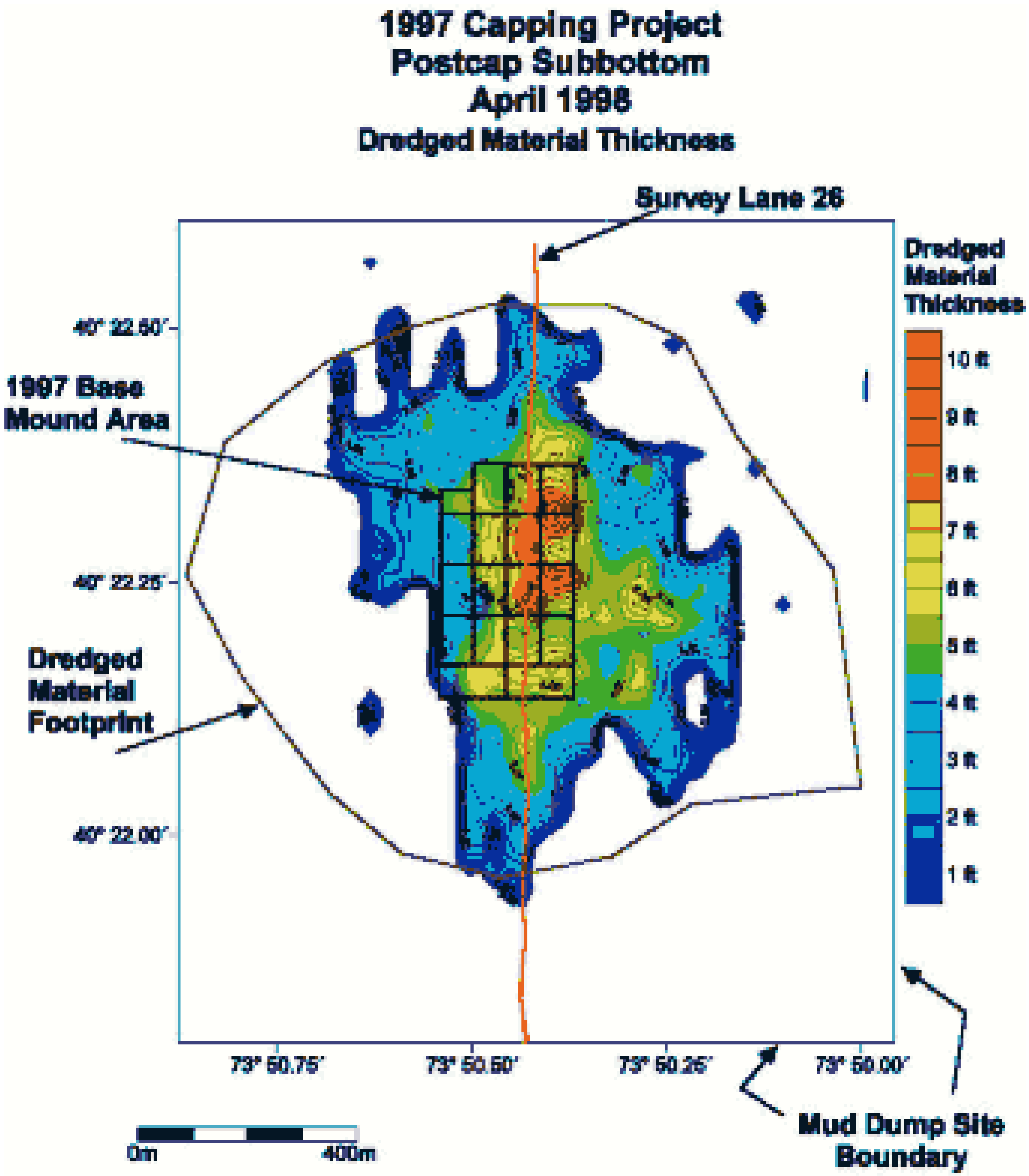

Figure 3-4. Two-dimensional isopach map of dredged material thickness values derived from subbottom profile data. In the figure, the ship track for survey lane 26 has been plotted, as well as the 1997 Base Mound Area, Dredged Material Footprint from REMOTS® analysis, and Mud Dump Site boundary.

4.0 DISCUSSION

4.1 Associated Measurement Errors

During the 1997 Category II Capping Project, two independent technologies, precision bathymetry and acoustic swept-frequency subbottom profiling, were used to map the thickness and areal coverage of sand cap and partially contaminated dredged material on the seafloor. Because each method relies on different assumptions and is subject to different limitations, each has different limitations in its ability to detect sediment layers. Prior to assessing the physical reasons for the difference in the two monitoring methods, an analysis of the errors associated with each type of measurement must be conducted.

The bathymetric measurement technique for the determination of dredged material has an approximate uncertainty of ±0.5 to 1.0 ft for each survey dataset. The resolution of the subbottom data is dependent on the system frequency, speed of sound estimates and, following the survey, the ability of the analyst to resolve and digitize individual subbottom reflectors. Although this error is less constrained than the error associated with bathymetry, it is estimated to be within the same range (±0.5 to 1.0 ft). Over the area of seafloor covered with at least 0.5 ft of Category II dredged material this vertical measurement error would correspond with a volumetric error of approximately
100,000 yd^3 or 15%. Therefore, the differences in dredged material thickness and distribution noted between bathymetry and subbottom data are greater than can be explained by measurement error.

The error associated with estimating the speed of sound within a sediment layer can have a significant impact on the accuracy of subbottom measurements. For example, swept-frequency subbottom profile measurements were used to measure the sand cap thickness during the 1993 Dioxin Capping Project at the Mud Dump Site. The sand cap volume was calculated twice, once from subbottom measurements based on the speed of sound in seawater (1500 m/s), and once using a more realistic value for continental shelf sand, 1711 m/s (Table 2-2). Volume calculations using the 1500 m/s value were 12% lower than the calculated volume using 1711 m/s (SAIC 1994). Sand cap material for both the 1993 Dioxin Capping Project and the 1997 Category II Project was mined from the Ambrose Channel and both caps have similar acoustic properties. Therefore, similar results are expected for this survey.

A. 1997 Category II Project Sand Cap

In the past the NYD has monitored dredged material placement and sand cap construction with standard bathymetric depth differencing techniques to measure changes in topography and to calculate the in-place volume of material. Bathymetric depth differencing relies on the assumption that the only process affecting topographic change is anthropogenic disposal activity. However, prior to the beginning of sand capping on the 1997 Category II Project dredged material mound, the dredged material experienced a postdisposal slope adjustment (SAIC 1998c). Material from the peak of the western portion of the mound slumped downslope toward the southern boundary of the dredged material footprint.

The slope adjustment presented the PA and NYD with an operational/management dilemma. Standard bathymetric differencing techniques alone could not be used to determine if a 1-m thick layer of sand had been placed on the western portion of the disposal mound. Figure 4-1 is a color contour plot of cap thickness generated from the depth difference analysis between the August 1997, postdisposal and the April 1998, postcap bathymetric surveys. Because of the slope adjustment, there appears to be a hole in the sand cap with negative difference values. The usefulness of bathymetric depth differencing in determining the cap thickness relies on the assumption that the only measurable change in topography between two consecutive surveys is related to the anthropogenic dispersal of sand. The slope adjustment of the disposal mound, which altered the topography by as much as one meter, added a second source of change that could not be accounted for with depth differencing methods.

Unlike bathymetric depth differencing, acoustic subbottom profiling relies on differences in the acoustic properties of sediment layers to differentiate between them. Sand from Ambrose Channel which was used as the capping material has different geotechnical and acoustic properties than the fine-grained dredged material (Table 2-1). The density gradient between the silty Category II dredged material and coarse-grained sand cap created an acoustic reflector that permitted SAIC scientists to measure accurately the thickness of the sand layer. The subbottom measurements shown in Figure 3-2 clearly demonstrate that all of the dredged material, particularly the material in the area of the slope adjustment, was covered with a layer of sand at least one meter thick.

Table 4-1. Various Volume Estimates for the 1997 Category II Project Sand Cap and Dredged Material Layers

	Volume Estimates (yd³)	
	Sand	**Dredged Material**
PA/NYD	2,038,000	690,000
Bathymetry		
Postdisposal	---	696,000
Postcap	1,749,000	---
Subbottom		
Postdisposal		941,000*
Postcap	2,003,000	751,000
*Volume reflects a combination of dredged material and sand cap. See text.		

The subbottom profile data results were used to calculate the volumes of both the sand cap and underlying dredged material at the Category II project. The calculated volumes

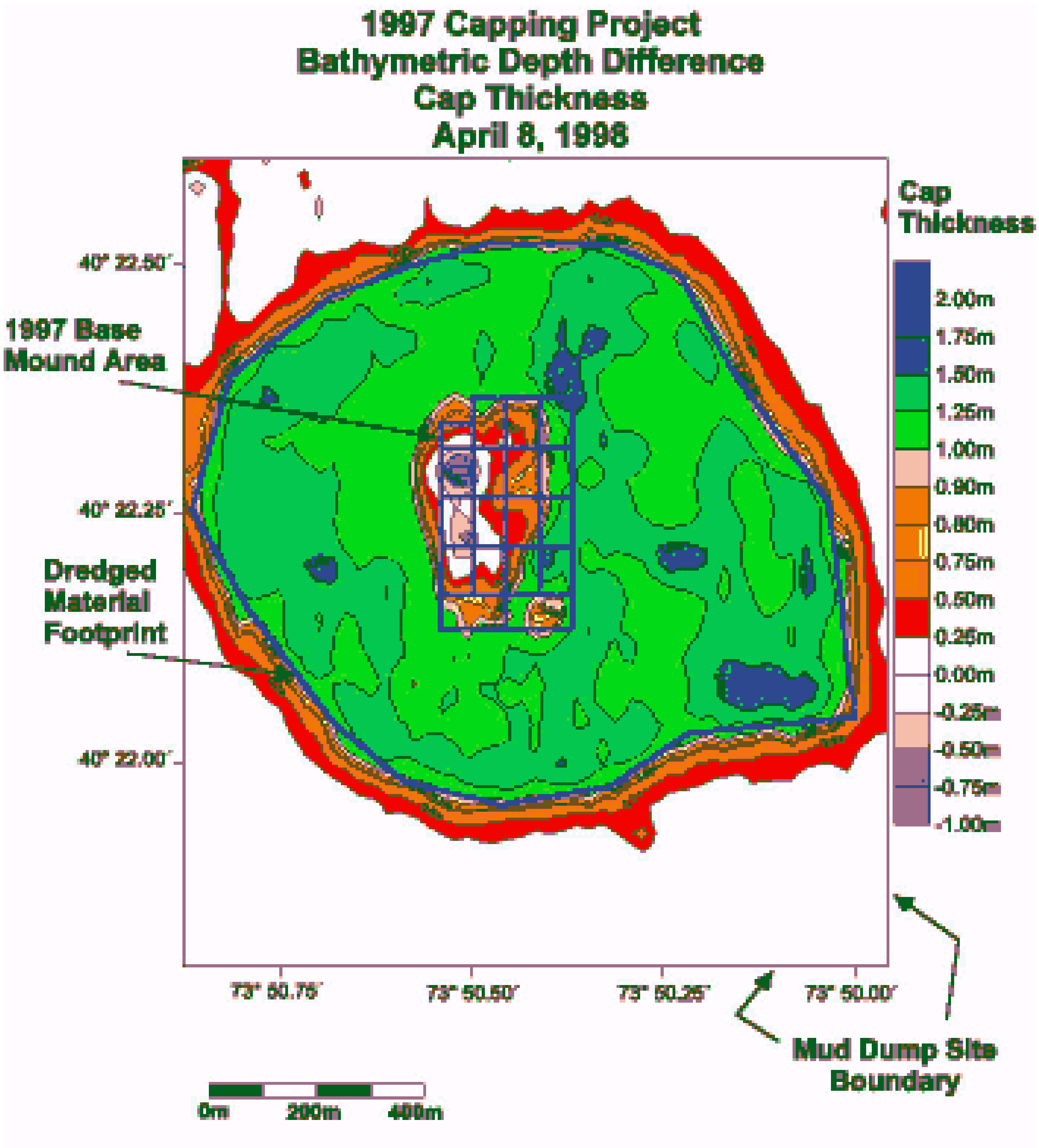

Figure 4-1. Two-dimensional isopach map of cap thickness values estimated from depth difference analysis. In addition, the 1997 Base Mound Area, Dredged Material Footprint from REMOTS® analysis, and Mud Dump Site boundary have been plotted.

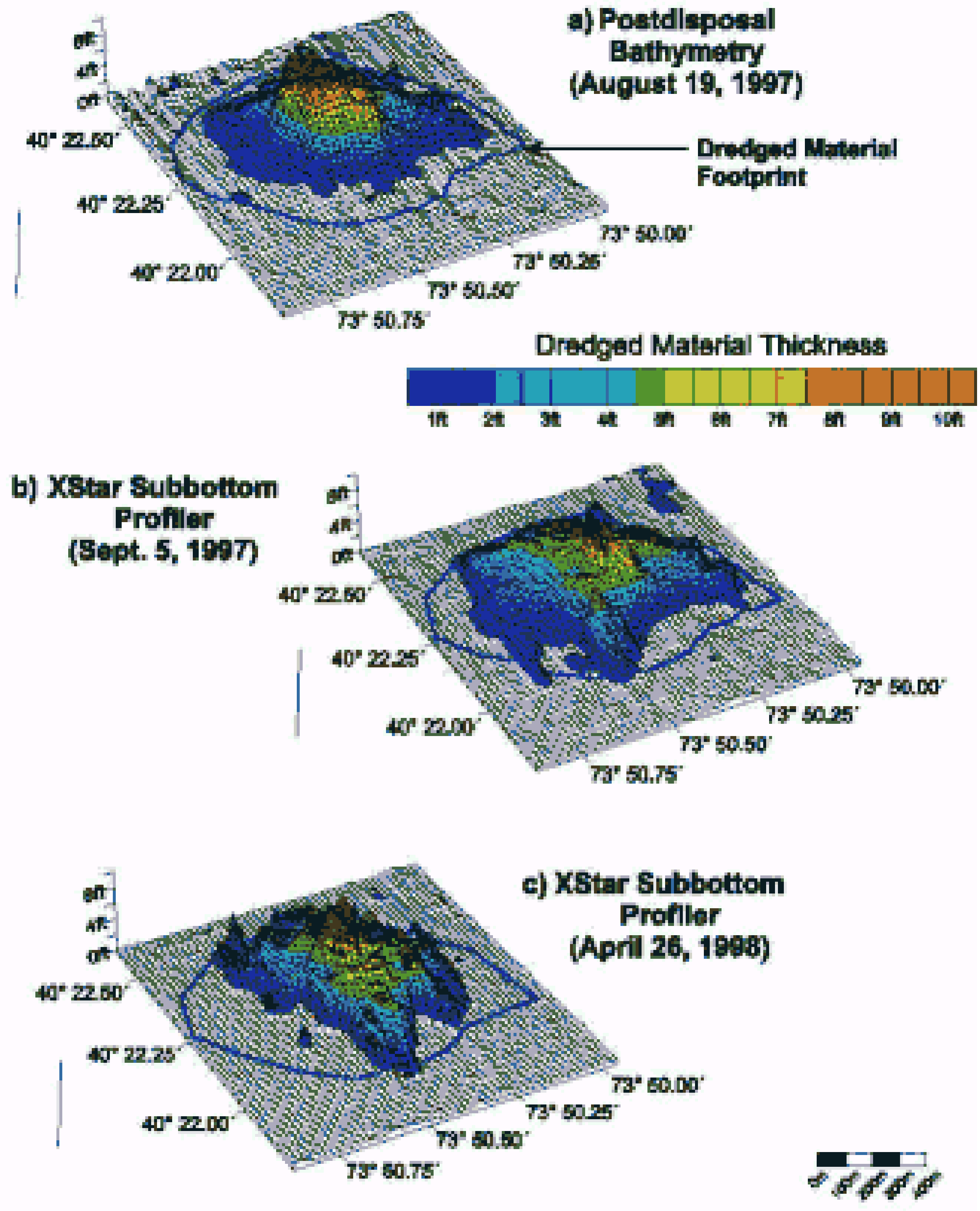

Figure 4-2. Three-dimensional plots of the dredged material (a) Bathymetric Depth Difference, August 1997, (b) Subbottom Profile, September 1997, and (c) Subbottom Profile, April 1998.

of material are shown in Table 4-1 along with volume estimates derived from previous surveys and independent analyses. The volume of sand dredged from Ambrose Channel and placed at the Category II Project site in the NYMD was estimated by the PA. By measuring the height of the sand in the bin of the hopper dredges, the PA estimated that a total of 2,038,000 yd^3 of sand had been dispersed over the Category II dredged material footprint.

The comparison of bathymetric survey results between the postdisposal survey (August 1997) and the postcap survey (April 1998) (Figure 4-1) show that standard bathymetric differencing techniques could only account for 1,749,000 yd^3 of sand, approximately 86% of the PA estimate. In contrast, the volume of sand calculated from the subbottom profile data was 2,003,000yd^3, 98% of the value reported by the PA. This result is not intended to represent a true mass balance, because several variables, including compaction of the underlying material, are not included in these estimates.

4.3 Measurement of 1997 Category II Project Dredged Material

In an independent analysis, the NYD estimated that 690,000 yd^3 (Table 4-1) of Category II dredged material had been removed from dredged sites within New York Harbor. This value was based on information from Great Lakes Dredge & Dock Company who conducted bathymetric progress surveys at the dredge sites in the harbor. Through a series of bathymetric surveys conducted at the project disposal area in the MDS (SAIC 1997c,d,e,f,h), SAIC estimated that 660,000 yd^3 (Table 4-1) had been deposited within the project area. However this estimate only included dredged material with a thickness equal to or greater than the 0.5 ft detection limit. Figure 4-2a is a three dimensional representation of the dredged material mound based on bathymetric depth difference analysis. Immediately following the disposal operations, the dredged material mound was relatively compact with the majority of material contained with the base disposal area and a circular footprint extending outward.

In September 1997, SAIC conducted a postdisposal subbottom profiling survey of the Category II Project Area to provide an alternative method of measuring and mapping the dredged material deposit on the seafloor (SAIC 1998c). Figure 4-2b is a three dimensional representation of the dredged material measurements results from September 1997, postdisposal subbottom survey. In general the footprint of dredged material was less constrained and the volume was 941,000 yd^3. The Category II mound slope adjustment which occurred just prior to the survey appeared as an extension of the dredged material toward the southern end of the dredged material footprint area.

The relatively large volume of dredged material measured during the September 1997 subbottom survey was an artifact created by the start of sand capping operations prior to the survey. Before the start of the survey approximately 330,000 yd^3 of sand cap material had been dispersed throughout the project area (SAIC 1998c). Dispersed over the project area, that volume of sand produced a layer too thin to be differentiated from the dredged material in the subbottom records and thus was included in the volume estimate of the dredged material. Finally, results from the April 1998 postcap subbottom survey provided a third estimate of the Category II dredged material mound configuration and volume. Figure 4-2c is a three dimensional representation of the dredged material layer measurements from the April 1998 postcap subbottom survey. The Category II dredged material configuration was similar to the results from the September 1997 survey, with the southerly extension from the slope adjustment. However, the volume of dredged material at least 0.5 ft thick was smaller than observed in September 1997, measuring 637,400 yd^3 (Table 4-1).

5.0 CONCLUSIONS

Results from the postcap subbottom survey of the 1997 Category II Project mound have shown that the swept-frequency technique is a useful tool for detecting and measuring sand cap material on the seafloor. Using the XStar subbottom profile system, SAIC scientists were able to:

- Measure and map the sand cap on top of the Category II material;
- Confirm that the area affected by the postdisposal slope adjustment had been covered with a layer of sand at least one meter thick.
- Measure and map the subsurface layer of partially contaminated Category II dredged material.

The results from the postcap subbottom profiling survey illustrate the importance of using a multi-faceted approach to monitor and verify the success of dredged material capping projects. In the case of the 1997 Category II Capping Project neither bathymetric differencing nor acoustic subbottom profile techniques alone could identify and confirm a complete cap over the entire dredged material footprint. Bathymetric depth differencing was limited by the postdisposal slope adjustment of the base disposal mound while the acoustic properties of the base sand layer from the 1993 Dioxin Capping made it difficult to detect a thin layer of dredged material sandwiched between it and the 1997 sand cap. It is only through the application of both technologies that we can say with confidence that the entire 1997 Category II dredged material mound has been capped with a layer of sand at least one meter thick.

6.0 REFERENCES

Hamilton, E.L. 1971. Prediction of *in situ* acoustic and elastic properties of marine sediments: Geophysics, v. 36, p. 266-284.

SAIC. 1992. Monitoring Cruise of the New York Mud Dump and Experimental Mud Dump Areas, September, 1991. USACE-CENAN, SAIC Report No. 270

SAIC. 1994. Analysis of Subbottom Profile Results from the New York Mud Dump Site: December 1993 - January 1994. Report #14 of Dioxin Capping Monitoring Program. USACE-CENAN, Contract DACW51-92-D-0045. SAIC Report No. 313.

SAIC. 1997a. Automated Surveillance of Disposal Operations During the 1997 Category II Project at the New York Mud Dump Site. Report #63 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-95-D-0027. SAIC Report No. 409.

SAIC. 1997b. The 1997 Category II Capping Project at the New York Mud Dump Site: Results of the August 1997 Postdisposal REMOTS® Survey. Report #66 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 414.

SAIC. 1997c. Results from the First Interim-Disposal Bathymetry Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #59 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 403.

SAIC. 1997d. Results from the Second Interim-Disposal Bathymetric Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #60 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 404 .

SAIC. 1997e. Results from the Third Interim-Disposal Bathymetric Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #61 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 406.

SAIC. 1997f. Results from the Post Disposal Bathymetric Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #62 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 408.

SAIC. 1997g. The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the May 1997 Baseline Coring Survey. Report #68 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-95-D-0027. SAIC Report No. 416.

SAIC. 1997h. Results from the April 1997 Baseline Bathymetry Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #56 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-95-D-0027. SAIC Report No. 398.

SAIC. 1998a. Summary of Cap Monitoring Survey Results for the 1997 Category II Capping Project. Task 8A of contract with Great Lakes Dredge and Dock Company. SAIC Report No. 432.

SAIC. 1998b. The 1997 Category II Capping Project at the New York Mud Dump Site: Summary of Geotechnical and Chemical Analyses from the April 1998 Postcap Vibracoring Survey. Report #85 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 440.

SAIC. 1998c. The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the September 1997 Post-Disposal Subbottom Profile Survey. Report #75 of the New York Mud Dump Site Studies. USACE-CENAN, Contract DACW51-97-D-0014. SAIC Report No. 424.