RESULTS OF THE SUMMER 2002 SEDIMENT TOXICITY AND REMOTS SEDIMENT-PROFILE IMAGING SURVEY AT THE HISTORIC AREA REMEDIATION SITE

FINAL REPORT

May 2003

SAIC Project No. 01-0440-04-4425-001

SAIC Report No. 635

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ACKNOWLEDGEMENTS

This report presents the results of the summer 2002 survey to evaluate sediment toxicity within and around the Historic Area Remediation Site (HARS). This survey was conducted by Science Applications International Corporation (SAIC) of Newport, RI, under contract to the U.S. Army Corps of Engineers—New York District (NYD). Dr. Stephen Knowles was the NYD's manager of technical activities; Mr. Raymond Valente was SAIC's project manager. Dr. Knowles provided logistical and planning support for the survey, with assistance from Mr. Tim LaFontaine of the NYD's Caven Point facility.

REMOTS sediment-profile/plan view imaging and sediment toxicity sampling operations were conducted aboard the NYD's M/V *Gelberman*. The crew of the M/V *Gelberman* is commended for their skill in vessel handling while conducting all survey operations, as well as their dedication during long hours of operation at the HARS.

The following SAIC staff participated in the field operations: Natasha Pinckard, Greg Tufts, and Raymond Valente. Brian Andrews and Christine Seidel of SAIC were responsible for data tracking and management.

Applied Marine Sciences of League City, Texas, was responsible for the geotechnical analyses of the sediment grab samples. Aqua Survey, Inc. (ASI) of Flemington, NJ conducted the toxicity testing on the sediment grab samples.

Karen Hart and Ray Valente prepared this report in conjunction with Natasha Pinckard and Pamela Walter. Michelle San Antonio and Megan Thomas were responsible for report production.

EXECUTIVE SUMMARY

Since the closure of the Mud Dump Site in September 1997 and its re-designation as the Historic Area Remediation Site (HARS), placement of remediation material in HARS Priority Remediation Areas (PRAs) 1, 2, 3, and 4 has been ongoing. Under the HARS Site Management and Monitoring Plan (SMMP), monitoring of sediment toxicity is conducted periodically to verify that placement of remediation material has significantly reduced the elevated levels of chemical contamination and associated toxicity observed in pre-HARS studies sponsored by EPA Region 2.

Specifically, surface sediments collected in an EPA-sponsored survey of October 1994 were found to be significantly toxic at numerous stations located within and in the area surrounding the former MDS (based on the standard 10-day toxicity test with the amphipod *Ampelisca abdita*). A second sediment toxicity monitoring survey, sponsored by the Corps of Engineers New York District (NYD) and conducted in October 2000, revealed a surprising lack of significant sediment toxicity within and around the HARS, even at the same sampling locations where sediments were determined to be toxic in the previous EPA-sponsored survey of October 1994. Based on this discrepancy between the two sets of results (October 1994 versus October 2000), additional toxicity testing of surface sediment in and around the HARS and former MDS was deemed necessary.

This report presents the results of a third HARS sediment toxicity survey conducted in July 2002. This survey involved re-sampling of the EPA October 1994 stations, as well as sampling at additional stations located in PRAs 1, 2, 3, and 4. In additional, REMOTS sediment-profile images and sediment plan view images were obtained at each station to evaluate benthic recolonization status and overall benthic habitat quality, both in areas of the HARS that have received remediation material and those that have not.

Consistent with past surveys, the REMOTS and plan view images showed a wide variety of surface sediment types within and in the area surrounding the HARS. Surface sediments consisting of fine-grained remediation dredged material placed since September 1997 occurred over much of the area of PRAs 1, 2, and 3, while older (i.e., relic) fine-grained dredged material was observed in unremediated areas (e.g., PRAs 5, 6, 7, 9, and a few stations within PRAs 1 and 4). Rippled fine sand was the dominant sediment type observed at stations surrounding the HARS.

Due to the variety of substrates observed within the surveyed area and the varying lengths of time that the remediation material has been in place on the seafloor, a variety of infaunal successional stages were observed in the REMOTS images. Surface-dwelling infauna (i.e., Stage I) was the dominant successional stage over the surveyed area, particularly at stations with surface sediments comprised of sand. In both the remediated and unremediated portions of the HARS (PRAs 2–7, and 9), where fine-grained, organic-rich remediation and relic dredged material was observed, the benthic infaunal community consisted of a mixture of surface-dwellers (Stages I and II) and larger-bodied, deeper-dwelling, deposit-feeders (Stage III).

EXECUTIVE SUMMARY (CONTINUED)

Benthic habitat quality, as reflected in the REMOTS Organism-Sediment Index (OSI) values, was considered to be largely undisturbed, or non-degraded, over most of the surveyed area (OSI values greater than +6.0). A few stations exhibited disturbed benthic habitat quality (OSI values <+3.0), attributed to high apparent inventories of organic matter in the deposited dredged material and resultant high apparent sediment oxygen demand. It is anticipated that as this organic matter is consumed by infauna or decomposes through microbial action, there will be a gradual progression towards an advanced Stage III infaunal community, and sediment aeration will be further enhanced through bioturbation.

None of the surface sediment samples collected at the 60 stations visited in the July 2002 survey were found to have significant toxicity in the 10-day amphipod test. These results are consistent with those of the October 2000 survey but are again at odds with those of the original October 1994 survey. Three possible reasons are cited herein for these results: 1) the remediation dredged material that has been placed within PRAs 1, 2, 3, and 4 has in fact served to eliminate the significant sediment toxicity that was observed previously, 2) the results of the original October 1994 survey may reflect sediment toxicity due to elevated levels of ammonia rather than elevated contaminant levels. Ammonia was not purged from the sediment prior to the October 1994 testing, but was purged in the October 2000 and July 2002 surveys, in accordance with EPA-recommended testing protocol, and 3) natural physical and biological processes (e.g., sediment erosion and deposition, bioturbation, microbial decomposition) have led to a significant reduction in toxicity over time.

LIST OF ACRONYMS

ANOVA	analysis of variance
ASTM	American Standard Test Method
DAMOS	Disposal Area Monitoring System
DGPS	Differentially-corrected Global Positioning System
Eh	electro-chemical potential
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HARS	Historic Area Remediation Site
kHz	kilohertz
m^2	square meters
MDS	Mud Dump Site
mm	millimeter
m/sec	meters per second
M/V	Merchant Vessel
NAD 83	North American Datum of 1983
NYD	New York District
OSI	Organism-Sediment Index
ppt	parts per thousand
PRA	priority remediation area
QAPP	Quality Assurance Project Plan
QC	Quality Control
REMOTS	Remote Ecological Monitoring of the Seafloor
RPD	Redox Potential Discontinuity
USACE	U.S. Army Corps of Engineers
SAIC	Science Applications International Corporation
SMMP	Site Management and Monitoring Plan
SRT	standard reference toxicant
USCS	Unified Soil Classification System
UTC	Universal Time Coordinate

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1.0 INTRODUCTION

1.1 Background

Prior to September 1997, sediments dredged from New York Harbor were deposited at the Mud Dump Site (MDS), located in the New York Bight about six nautical miles east of Sandy Hook, New Jersey. Based on an agreement among the Environmental Protection Agency (EPA), the Department of the Army, and the Department of Transportation, the MDS and some surrounding historical dredged material disposal areas were re-designated as the Historic Area Remediation Site (HARS; Figure 1.1-1) beginning in September 1997. The HARS is divided into nine priority remediation areas (PRAs), where remediation material is to be placed (Figure 1.1-2). A Buffer Zone surrounds the PRAs, and the No Discharge Zone is an area outside the PRAs where no further disposal is permitted (Figure 1.1-2).

Region 2 of the Environmental Protection Agency (EPA) and the New York District (NYD) of the U.S. Army Corps of Engineers (USACE) are jointly responsible for managing the HARS, primarily in an effort to reduce the elevated contamination and toxicity of surface sediments to acceptable levels. The two agencies have prepared a Site Management and Monitoring Plan (SMMP) for the HARS that identifies a number of actions, provisions, and practices to manage remediation activities and monitoring tasks. The main objective of the HARS SMMP is to ensure that placement of the remediation dredged material does not result in any significant adverse environmental impacts but does result in sufficient modification (i.e., remediation) of currently unacceptable sediment chemistry and toxicity characteristics. To verify that such remediation is occurring, the SMMP includes a tiered environmental monitoring program designed to focus both on the entire HARS and on each of the nine individual remediation areas in the PRA.

Following designation of the HARS in September 1997, remediation has been taking place in PRAs 1, 2, 3, and 4, beginning with disposal of material from the Passenger Ship Terminal (PST) dredging project in March 1998. As part of the tiered environmental monitoring program, the SMMP requires that sediment toxicity monitoring be undertaken at regular intervals to verify that placement of remediation material has significantly reduced the elevated levels of chemical contamination and associated toxicity, observed previously in the EPA Region 2 survey of October 1994 (Figure 1.1-3).

A sediment toxicity monitoring survey sponsored by the NYD in October 2000 involved sampling at stations located primarily in and around PRA 1 (Figure 1.1-4). This survey involved collection and testing of surface sediments both from areas within the HARS that had already received remediation material, as well as from areas in and around the HARS and former MDS that had not yet been remediated. The results of this survey revealed a surprising lack of significant sediment toxicity, particularly at sampling locations that had not yet received remediation material and that were found to have toxic sediments in the previous October 1994 survey sponsored by EPA Region 2 (Battelle 1996). Due to this significant difference between the two sets of results (October 1994 versus October 2000), additional toxicity testing of surface sediments in and around the HARS and former MDS was conducted (this report). An additional goal of the study reported here was to document the status of benthic communities at the HARS and compare results between remediated and unremediated areas.

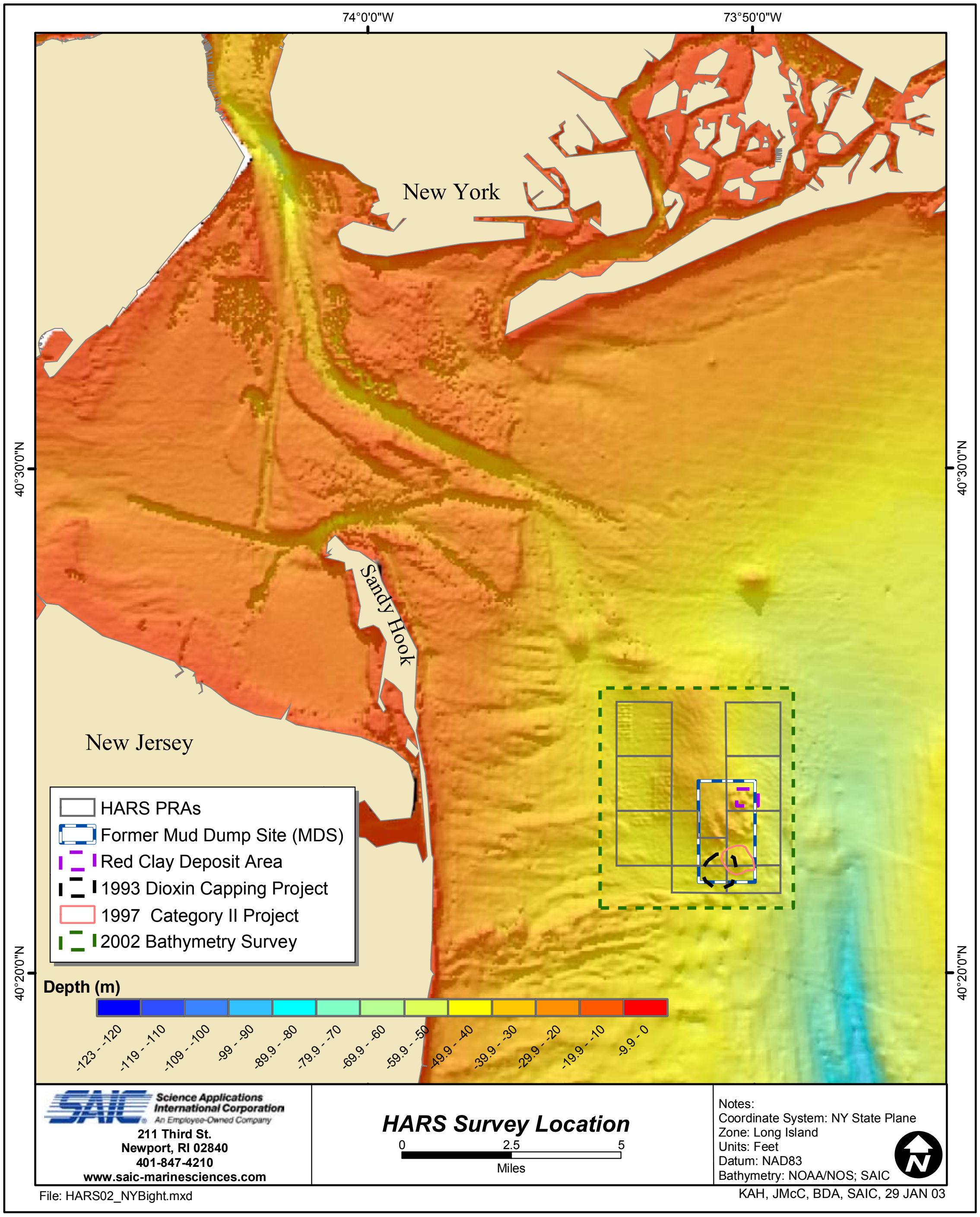


Figure 1.1-1. Map showing the locations of the former Mud Dump Site (MDS) and the Historic Area Remediation Site (HARS) in the New York Bight. The color-coded bathymetric data throughout the wide area surrounding the HARS are from the National Oceanic and Atmospheric Administration (NOAA) Coastal Relief Model Volume 1. The bathymetry at the HARS is from an SAIC survey conducted during summer 2002.

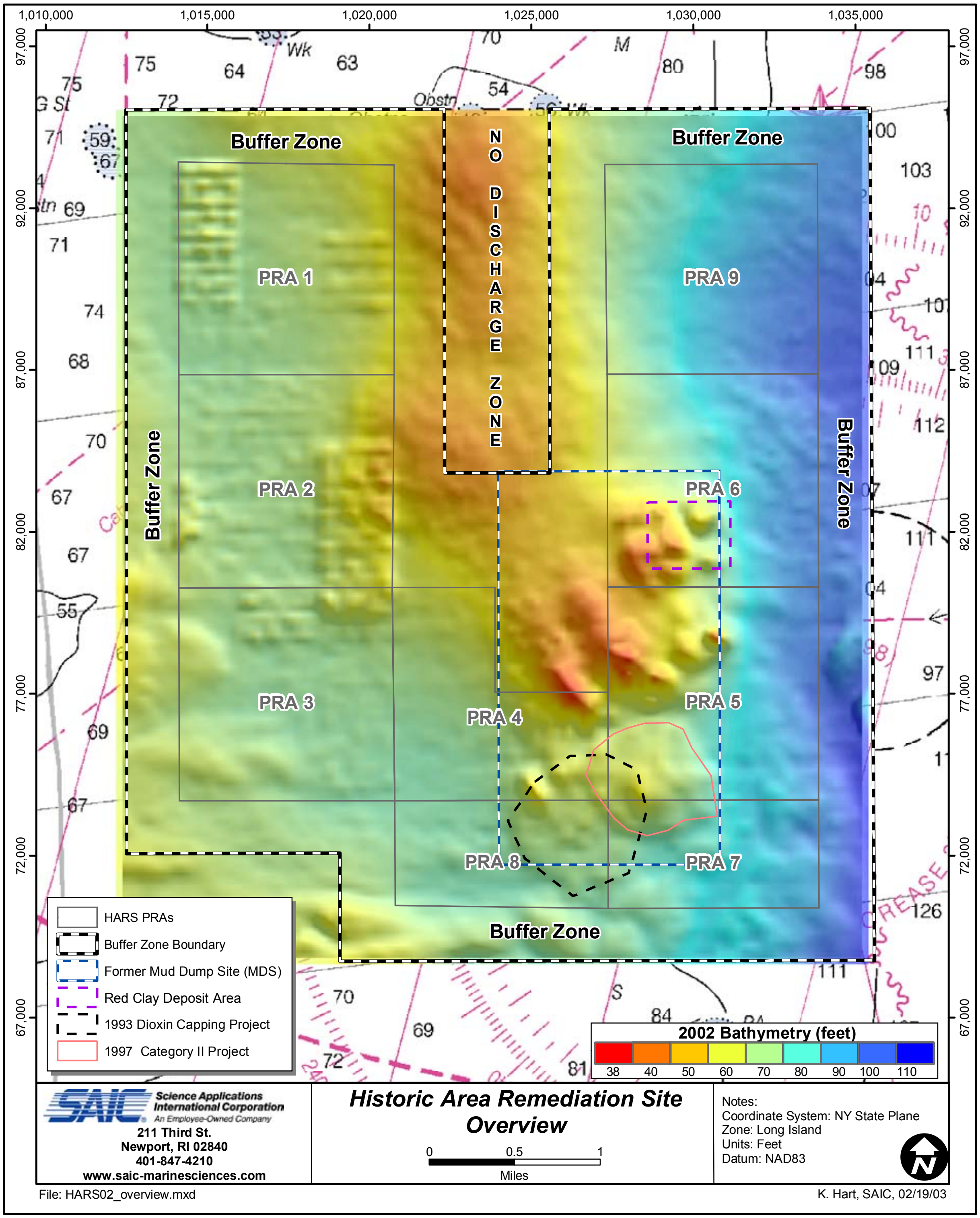


Figure 1.1-2. Map of the HARS PRAs, Buffer Zone, and No Discharge Zone relative to 2002 survey bathymetry

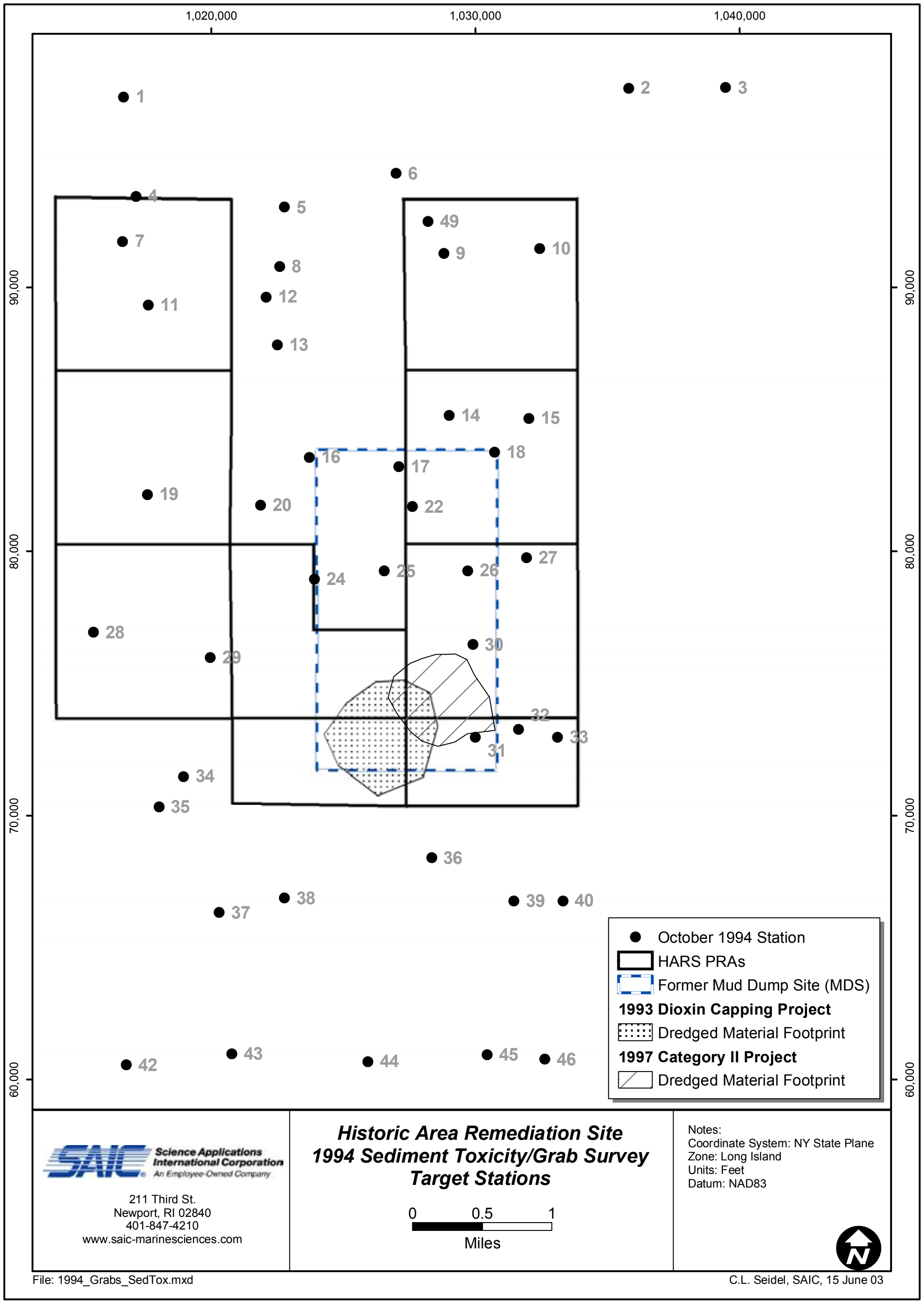


Figure 1.1-3. Locations of stations where sediment toxicity samples were collected in the EPA Region 2 survey of October 1994

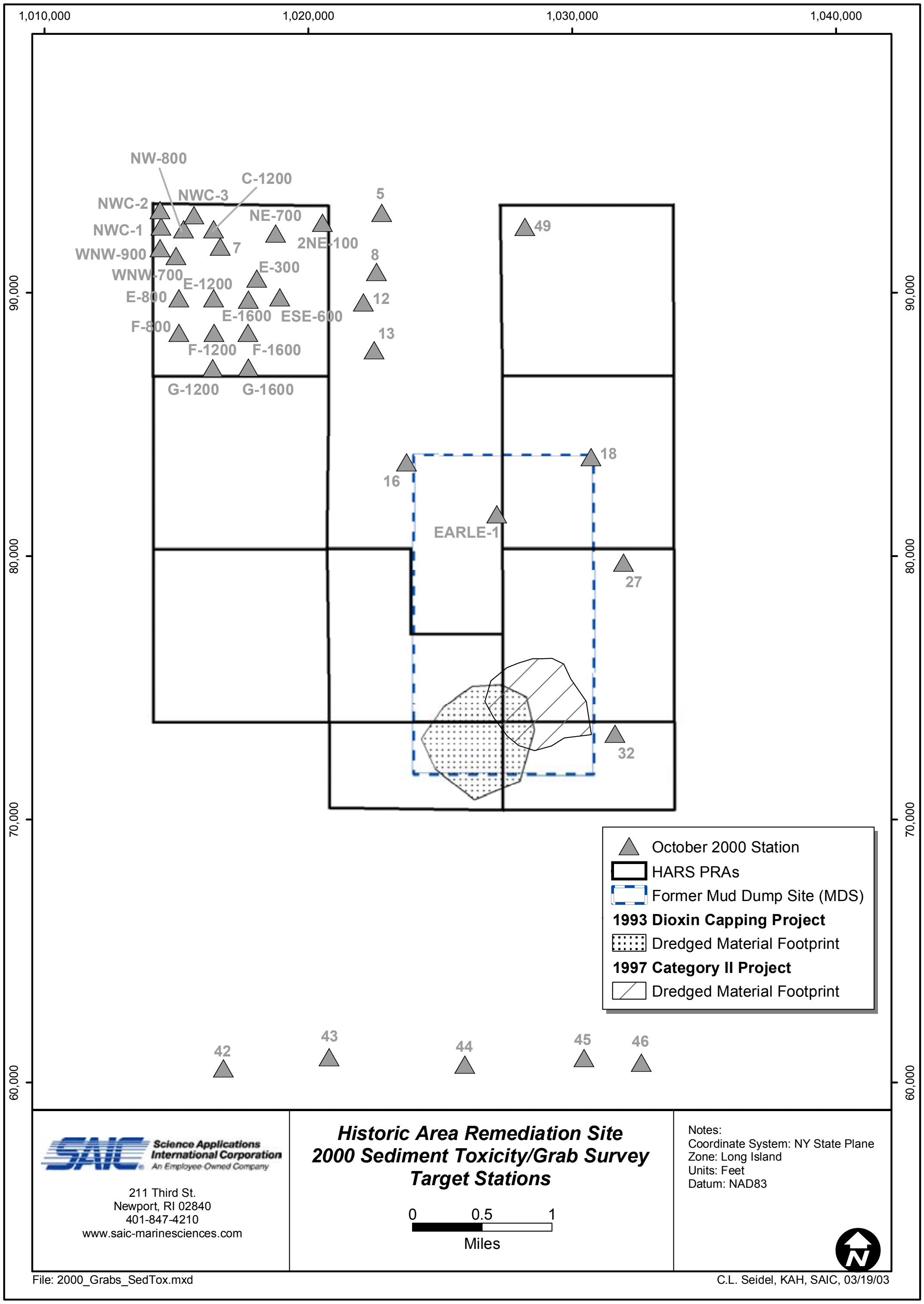


Figure 1.1-4. Locations of stations where sediment toxicity samples were collected in the NYD survey of October 2000

1.2 2002 Survey Objectives

During the summer of 2002, a sediment toxicity survey and a REMOTS/plan view survey were conducted over remediated and unremediated areas within and outside the HARS to evaluate temporal differences in sediment toxicity and characterize the current benthic recolonization status over areas where remediation material has been placed. Specifically, the 2002 survey efforts involved the following techniques and objectives:

- Sediment grabs were collected to determine the toxicity of surface sediments at 44 stations sampled previously in the EPA Region 2 survey of October 1994 and to provide additional comparisons of present-day results with those from the past.

- Sediment grabs were collected at an additional 16 stations located randomly within PRAs 1, 2, 3, and 4 to determine the toxicity of surface sediments and the efficacy of ongoing remediation efforts in these areas.

- Additional grabs were collected in a tight radius around a single station to evaluate small-scale variability in sediment toxicity.

- REMOTS sediment-profile images and sediment planview photographs were collected at each of the 60 toxicity stations to evaluate sediment physical and biological conditions, particularly with respect to infaunal successional status and overall benthic habitat quality.

2.0 METHODS

2.1 Field Operations and Sampling Design

The summer 2002 sediment toxicity and REMOTS sediment-profile imaging survey took place between June 24 and July 13, 2002. The M/V *Gelberman,* operated by the USACE NYD, was used for all field operations. The survey work was conducted in two phases: REMOTS sediment-profile and plan view images were collected on June 24, 25, and 26, while surface sediments for subsequent toxicity testing were collected using a grab sampler on July 10, 11, and 12.

The sampling was conducted at a total of 60 "primary" stations (Table 2.1-1 and Figure 2.1-1). Of these 60 stations, 44 were previously sampled in the EPA Region 2 study of October 1994. These stations are identified in Table 2.1-1 using non-consecutive numbers between 1 and 49; this numbering and the station coordinates are identical to those used in the 1994 EPA Region 2 study (Battelle 1996). Sampling was also conducted at an additional 16 stations, identified with letter prefixes in Table 2.1-1 and Figure 2.1-1. These stations were located in areas of Priority Remediation Areas 1, 2, 3, and 4 that had both received and not yet received remediation material at the time of the summer 2002 field operations.

Of the 60 primary stations listed in Table 2.1-1, Station 18 was selected for a special investigation designed to address the following two questions:

1) Can significant differences in sediment toxicity be found across relatively short distances on the seafloor at the HARS?

2) Can any consistent difference in toxicity be found between the near-surface, oxidized layer of sediment versus the underlying, anoxic sediment?

Station 18 was selected for this special investigation because it met the following criteria: 1) the sediment at this station was known to be composed of fine-grained, historic dredged material, 2) it was originally sampled in the EPA Region 2 study of 1994 and found to have significant toxicity, and 3) it was located in an area (northeast corner of the former Mud Dump Site) that had not yet received remediation material at the time of the summer 2002 sampling. The investigation of small-scale spatial variability involved collecting sediment for toxicity testing at three additional stations (Stations 18W, 18N, and 18E), that were located, respectively, at a distance of 25 m to the west, north and east of Station 18 (Table 2.1-2 and Figure 2.1-2). Additional details regarding this sampling are provided in Section 2.3.1 below. Also provided below are the detailed methods for vessel navigation and positioning, collection and testing of the sediment toxicity samples, and collection and analysis of both the REMOTS sediment-profile and sediment plan view images.

2.2 Navigation and Positioning

Differentially-corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software were used to provide real-time vessel navigation to an accuracy of ±3 m for each survey effort. A Trimble DSMPro GPS

Table 2.1-1.
Coordinates of the 60 Primary Stations Sampled
During the 2002 REMOTS and Sediment Toxicity Survey at the HARS.
Stations numbered between 1 and 49 correspond to the Battelle October 1994 sampling locations; the remainder are 16 stations located in selected areas of PRAs 1, 2, 3, and 4.

Station	Latitude NAD83	Longitude NAD83
1	40.4335	-73.8835
2	40.4343	-73.8148
3	40.4343	-73.8017
4	40.4232	-73.8818
5	40.4220	-73.8617
6	40.4255	-73.8465
7	40.4185	-73.8837
8	40.4158	-73.8623
9	40.4172	-73.8400
10	40.4177	-73.8270
11	40.4118	-73.8802
12	40.4127	-73.8642
13	40.4077	-73.8627
14	40.4003	-73.8393
15	40.4000	-73.8285
16	40.3960	-73.8583
17	40.3950	-73.8462
18	40.3965	-73.8332
19	40.3922	-73.8803
20	40.3910	-73.8650
22	40.3908	-73.8443
24	40.3833	-73.8577
25	40.3842	-73.8482
26	40.3842	-73.8368
27	40.3855	-73.8288
28	40.3778	-73.8877
29	40.3752	-73.8718
30	40.3765	-73.8362
31	40.3668	-73.8358
32	40.3677	-73.8300
33	40.3668	-73.8247
34	40.3628	-73.8755
35	40.3597	-73.8788
36	40.3543	-73.8418
37	40.3487	-73.8707
38	40.3502	-73.8618
39	40.3498	-73.8307
40	40.3498	-73.8240
42	40.3328	-73.8833
43	40.3340	-73.8690
44	40.3332	-73.8505
45	40.3338	-73.8343
46	40.3333	-73.8265
49	40.4205	-73.8422
E0800	40.4131	-73.8892
G1200	40.4059	-73.8846
H2000	40.4023	-73.8752
I1200	40.3987	-73.8846
K0800	40.3915	-73.8892
L1200	40.3879	-73.8846
L1600	40.3879	-73.8799
L2400	40.3879	-73.8705
M1200	40.3843	-73.8846
M2800	40.3843	-73.8658
N2000	40.3807	-73.8752
N3200	40.3806	-73.8611
P2800	40.3735	-73.8658
P3200	40.3734	-73.8610
Q1600	40.3699	-73.8799
Q2400	40.3699	-73.8705

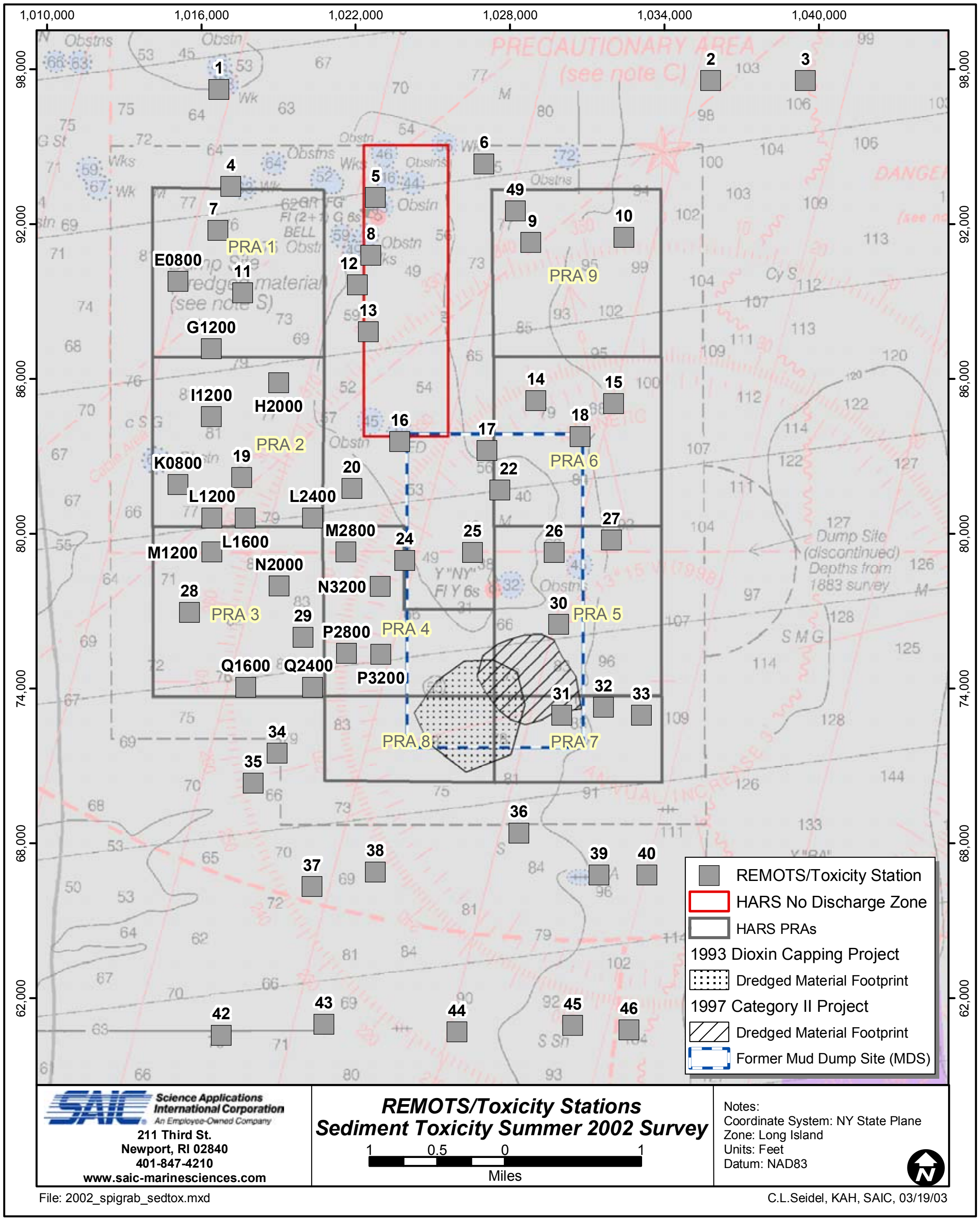


Figure 2.1-1. Map showing the locations of the 60 primary stations where sediment toxicity samples, as well as REMOTS and plan view images, were obtained during the summer 2002 survey. Stations 1 through 49 (excluding Stations 21, 23, 41, 47, and 48) are identical to the 44 stations originally sampled for sediment toxicity in the EPA Region 2 study of October 1994 (as shown in Figure 1.1-3).

Table 2.1-2.
Coordinates of the Stations Sampled to Evaluate Small-Scale
Spatial Variability During the 2002 Sediment Toxicity Survey at the HARS

Station	Latitude NAD83	Longitude NAD83
18*	40.3965	-73.8332
18E	40.3965	-73.8329
18N	40.3967	-73.8332
18W	40.3965	-73.8335

*Station 18 is also a primary station.

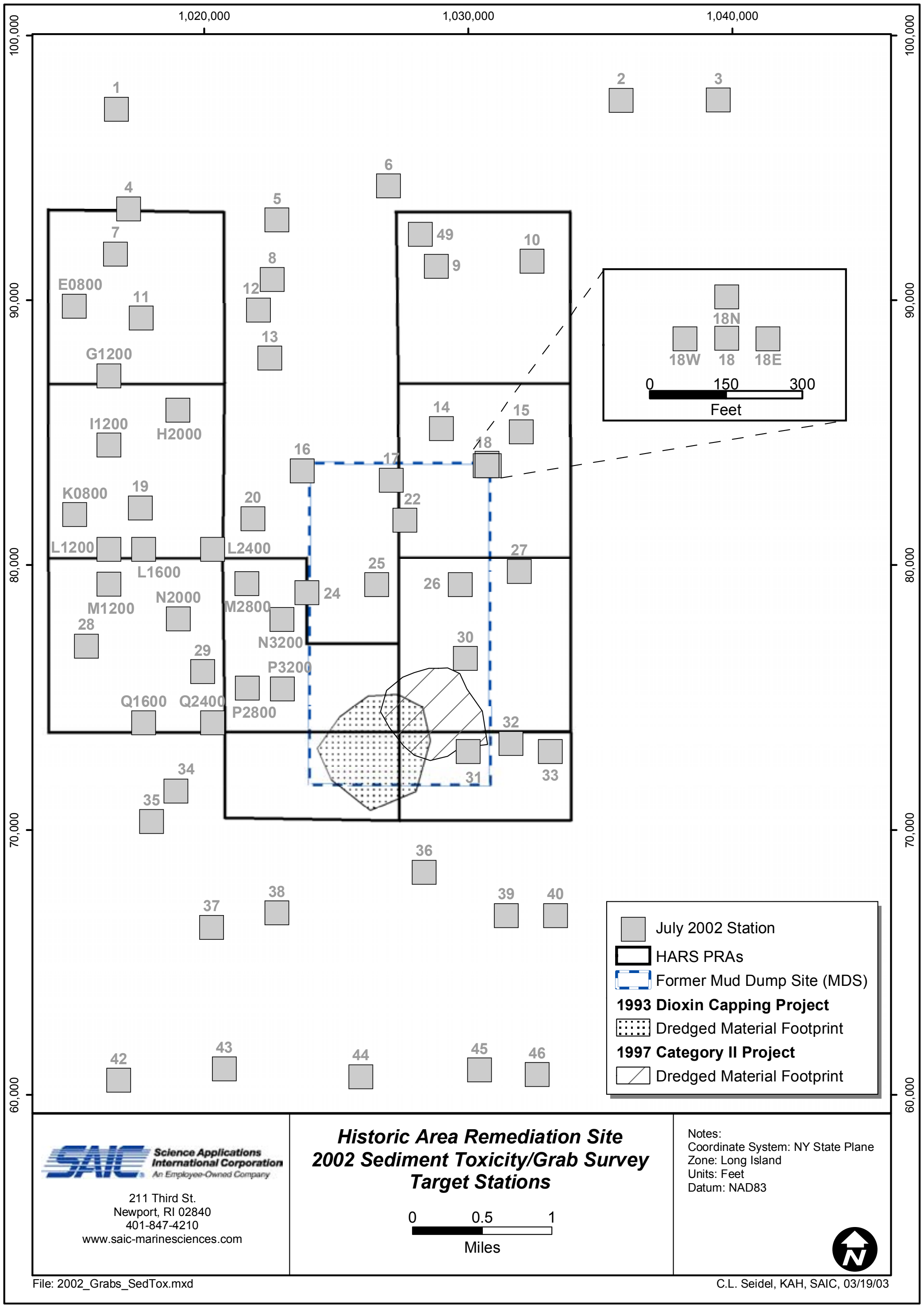


Figure 2.1-2. Map of the 60 primary stations for the summer 2002 sediment toxicity and REMOTS survey, with inset showing the distribution of the additional stations for evaluating small-scale spatial variability in sediment toxicity around Station 18

receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The DSMPro GPS unit also contains an integrated differential beacon receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Sandy Hook, NJ was utilized for real-time satellite corrections due to its geographic position relative to HARS.

The DGPS data were ported to HYPACK® data acquisition software for position logging and helm display. The target stations were determined prior to the commencement of survey operations and stored in a project database. Throughout the survey, individual stations were selected and displayed to position the survey vessel at the correct geographic location for sampling. The position of each sample was logged with a time stamp in Universal Time Coordinate (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database for display use. Vessel positioning was continuously logged during these surveys. DGPS navigation data were received, logged, and displayed in the NAD 83 geographic coordinate system.

2.3 Sediment Toxicity Sample Collection and Analysis

2.3.1 Sample Collection

Samples of surface sediment for subsequent toxicity testing were collected at each of the 60 primary stations shown in Figure 2.1-1 using a stainless steel, 0.1 m^2 Van Veen grab sampler. Upon arrival at the target station, the grab sampler was set in an open position and lowered to the seafloor on a stainless steel winch wire. Upon reaching the bottom, a trigger device caused the bucket to close and retain a surface sediment sample. The grab sampler was raised on the winch wire and placed on a stand secured to the deck of the survey vessel. The grab was deployed one or more times at each station within a 5 m radius of the target coordinates listed in Table 2.1-1.

After retrieving the grab sampler, the sediment sample was determined to be acceptable or not. A grab was considered acceptable if the bucket was at least half full and the sediment surface in the bucket appeared to be intact, with no evidence of disturbance or washout. Grabs showing disturbance of the sediment surface or those containing an insufficient volume of sediment were determined to be unacceptable and rejected, resulting in re-deployment of the sampler at the station until an acceptable sample was obtained. The time of collection and geographic position of the sample were recorded both in the field logbook and by the navigation system.

If the grab was deemed acceptable, its entire content was placed into a large mixing bowl. Deployment of the grab continued at each station until a sufficient volume of sediment had been collected in the mixing bowl. The sediment in the bowl (typically representing the content of only a single grab, or at most two grabs, at most of the stations) was then mixed (homogenized) and aliquots placed into separate containers for the following laboratory analyses: 1) grain size, and 2) sediment toxicity.

As previously indicated, Station 18 was selected for use in testing small-scale spatial variability (both horizontal and vertical) in sediment toxicity. Three substations (Stations 18E, 18W, and 18N) were located at a distance of 25 m to the west, north, and east of primary Station 18 (Figure

2.1-2), and three sediment toxicity samples and corresponding grain size samples were collected at Station 18, as well as at each of its three substations (Table 2.1-2). One set of samples at each station consisted of the entire content of the grab sampler ("FG" = full grab), identical to what was done at the other 59 stations. A second set of samples at each station consisted of a composite of the top layer of sediment in the grab (upper 2 to 4 cm = "GT" = grab top), while the third set of samples consisted of a composite of the bottom layer in the grab (below about 4 cm = "GB" = grab bottom).

In total, 71 samples were collected in this survey for toxicity testing and grain size analysis. This total includes the full grab ("FG") samples collected at 59 of the 60 primary stations listed in Table 2.1-1, as well as the 12 additional FG, GT, and GB samples collected at Stations 18, 18W, 18N, and 18E (Table 2.1-2).

Immediately following collection, the various samples were placed within a refrigerator on board the *Gelberman*. SAIC personnel delivered the samples for toxicity testing to the Aqua Survey, Inc. facility in Flemington, NJ immediately following their collection during each of the three days. Samples for grain size analysis were sent in an ice-filled cooler by overnight courier to Applied Marine Sciences in League City, TX.

2.3.2 Laboratory Methods for Sediment Grain Size Analysis

Sediment grain size was determined by Applied Marine Sciences, Inc. of League City, TX using the procedures in ASTM Method D-422 (sieve and hydrometer analysis). Sieve sizes for sand fraction analyses included US standard sieve sizes 10, 20, 40, 60, 100, and 200, to provide coarse (1–0 phi), medium (2–1 phi), fine (3–2 phi), and very fine (4–3 phi) sand fractions, respectively. Clay and silt fractions were measured using a hydrometer (ASTM Method D-422). Size classifications were based on the Wentworth scale (Table 2.3-1). Sediment was also classified based on the Unified Soil Classification System (ASTM Method D-2487; Table 2.3-2).

2.3.3 Laboratory Methods for Sediment Toxicity Testing

Aqua Survey, Inc. (ASI) of Flemington, NJ conducted the toxicity testing on the sediment grab samples between 16 July and 23 August 2002. The methods employed for this study by ASI followed guidelines described in EPA/600/R-94/025 (Methods for assessing the toxicity of sediment-associated contaminants with estuarine and marine amphipods; USEPA 1994). Additional guidance was provided by the USEPA/USACE document, Evaluation of Dredged Material Proposed for Ocean Disposal – Testing Manual (aka, "the Green Book") and by the Regional Testing Manual prepared by the U.S. Army Corps of Engineers New York District and Region 2 of the US EPA.

Upon arrival at ASI, all samples were logged in and assigned unique sample numbers. Sediment toxicity was evaluated using the standard 10-day amphipod test with *Ampelisca abdita*, a representative benthic species. Prior to testing, all the samples were mixed by hand until homogenized and then pressed-sieved through a 1-mm sieve, because large marine worms (polychaetes) were seen in several of the sediments. Total ammonia in the pore water of these sediments was measured, and those sediments that had total ammonia concentrations above the EPA-specified threshold of 20 mg/L were purged to bring the pore water ammonia down below this level. Sediments with pore water ammonia below this threshold were set up and run as static tests.

Table 2.3-1.
Grain Size Scales for Sediments

ASTM (Unified) Classification [1]	U.S. Std. Mesh [2]	Size in mm	PHI Size	Wentworth Classification [3]
Boulder		4096.	-12.0	
		1024.	-10.0	Boulder
	12 in (300 mm)	256.	-8.0	Large Cobble
		128.	-7.0	
Cobble		107.64	-6.75	
		90.51	-6.5	Small Cobble
	3 in. (75 mm)	76.11	-6.25	
		64.00	-6.0	
		53.82	-5.75	
		45.26	-5.5	Very Large Pebble
Coarse Gravel		38.05	-5.25	
		32.00	-5.0	
		26.91	-4.75	
		22.63	-4.5	Large Pebble
	3/4 in (19 mm)	19.03	-4.25	
		16.00	-4.0	
		13.45	-3.75	
		11.31	-3.5	Medium Pebble
Fine Gravel		9.51	-3.25	
	2.5	8.00	-3.0	
	3	6.73	-2.75	
	3.5	5.66	-2.5	Small Pebble
	4	4.76	-2.25	
	5	4.00	-2.0	
Coarse Sand	6	3.36	-1.75	
	7	2.83	-1.5	Granule
	8	2.38	-1.25	
	10	2.00	-1.0	
	12	1.68	-0.75	
	14	1.41	-0.5	Very Coarse Sand
	16	1.19	-0.25	
Medium Sand	18	1.00	0.0	
	20	0.84	0.25	
	25	0.71	0.5	Coarse Sand
	30	0.59	0.75	
	35	0.50	1.0	
	40	0.420	1.25	
	45	0.354	1.5	Medium Sand
	50	0.297	1.75	
	60	0.250	2.0	
	70	0.210	2.25	
Fine Sand	80	0.177	2.5	Fine Sand
	100	0.149	2.75	
	120	0.125	3.0	
	140	0.105	3.25	
	170	0.088	3.5	Very Fine Sand
	200	0.074	3.75	
	230	0.0625	4.0	
Fine-grained Soil:	270	0.0526	4.25	
	325	0.0442	4.5	Coarse Silt
Clay if PI $\geq$ 4	400	0.0372	4.75	
Silt if PI < 4		0.0312	5.0	Medium Silt
		0.0156	6.0	Fine Silt
		0.0078	7.0	Very Fine Silt
		0.0039	8.0	Coarse Clay
		0.00195	9.0	Medium Clay
		0.00098	10.0	Fine Clay
		0.00049	11.0	
		0.00024	12.0	
		0.00012	13.0	
		0.000061	14.0	

1. ASTM Standard D 2487-92. This is the ASTM version of the Unified Soil Classification System. Both systems are similar (from ASTM (1993)).
2. Note that British Standard, French, and German DIN mesh sizes and classifications are different.
3. Wentworth sizes (in inches) cited in Krumbein and Sloss (1963).

Source: U.S. Army Corps of Engineers. (1995). Engineering and Design Coastal Geology, "Engineer Manual 1110-2-1810, Washington, D.C.

Table 2.3-2.
Unified Soil Classification System (USCS) Modified from ASTM D-2487

PRIMARY DIVISIONS			GROUP SYMBOL	DESCRIPTION
COARSE GRAINED SOILS: Sands and Gravels (Over 50% retained on #200 sieve)	GRAVELS (Over 50% of coarse material retained on #4 sieve)	CLEAN GRAVEL (Less than 5% passing #200 sieve)	GW	Well graded gravel, many different particle sizes, little or no fines
			GP	Poorly graded, few different particle sizes, little or no fines
		GRAVEL WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	SAND (Over 50% of coarse material passed #4 sieve)	CLEAN SANDS (Less than 5% passing #200 sieve)	SW	Well graded gravel, many different particle sizes, little or no fines
			SP	Poorly graded, few different particle sizes, little or no fines
		SAND WITH FINES	SM	Silty gravels, gravel-sand-silt mixtures
			SC	Clayey gravels, gravel-sand-clay mixtures
FINE GRAINED SOILS: Silts and Clays (Over 50% passing the #200 sieve)	SILTS AND CLAYS (Liquid limit is less than 50%)		ML	Inorganic silts, slight to no plasticity
			CL	Inorganic clays, low to moderate plasticity
			OL	Organic silts and clays of low plasticity
	SILTS AND CLAYS (Liquid limit is more than 50%)		MH	Inorganic silts, moderate to high plasticity
			CH	Inorganic clays, high plasticity, fat clays
			OH	Organic silts and clays of high plasticity

The initial pore water ammonia concentration of each sample is given in Appendix A, Table A-1. A minimum of two extra test chambers were set up for each test sample. These were used to measure the pore water ammonia at test initiation and termination. All samples with an initial pore water ammonia of greater than 20 mg/L had extra dummy chambers set up to monitor the reduction in pore water ammonia during the purging process, which consisted of manual renewals occurring at a rate of two complete exchanges per day. Once the pore water ammonia had dropped to below 20 mg/L, the test was initiated and subsequently conducted as static renewals.

Due to both the number of samples and the need to purge eight of the samples, a series of nine tests were run, each with their own control. The control sediment was obtained from the site of organism collection, Atlantic Highlands, Sandy Hook, New Jersey. This sediment was also sieved prior to testing.

Whole sediment toxicity was assessed through a 10-day exposure with the amphipod, *Ampelisca abdita*. Five replicate exposure chambers for each sample were set up containing 175 ml of sediment and 800 ml of overlay water. The overlay water was collected from the Manasquan Inlet, New Jersey and had a salinity of 28±2 ppt. The exposure chambers were then aerated gently and allowed to settle overnight before introduction of 20 organisms to each of the replicate chambers the next day.

The *A. abdita* used in testing were field collected from Atlantic Highlands, Sandy Hook, New Jersey. The organisms were 2–4 mm in length and were acclimated to the test overlay water and test temperature. Daily water quality and physical parameters were monitored. The photoperiod for the duration of the test was continuous light, using wide-spectrum fluorescent lights for illumination, giving 500–1000 lux.

A standard reference toxicant test was performed on each new set of organisms, and the data were entered into a program based on currently accepted methods for calculating an LC_{50}. The initial standard reference toxicant (SRT) run on one set of organisms was unacceptable because no single concentration had greater than 50 percent survival. A second SRT was run, but the holding time of the organisms was greater than the seven days required in the scope of work. The second SRT did have an LC_{50} within the control chart confidence limits, however.

2.3.4 Sediment Toxicity Data Analysis

In order to standardize the results from three different surveys (1994, 2000, and 2002) and compare them, all survival rates were normalized based on the reported control value associated with each sample. To calculate the normalized values the following equation was used:

Normalized % survival = [(% survival of sample)/(% survival in control sediment)] * 100

In the 1994 study conducted by EPA Region 2, the collected samples were split into two groups and tested at two different facilities: the EPA Region 2 laboratory in Edison, NJ and the Battelle Ocean Sciences facility in Sequim, WA (Battelle 1996). In the testing of samples at the Battelle facility, a single control sample was employed, and a mean organism survival of 90.7% for this sample was used to normalize the results for the test samples. In the testing performed at the

EPA facility, the mean survival rate for the single control sample that was utilized was 100% (Battelle 1996). The SAIC 2000 and 2002 sediment samples were tested at Aqua Survey, Inc. in smaller groupings, with one control for each group. The normalized results for each group were calculated to the appropriate control.

Once all samples were normalized to their respective control, toxicity (yes or no) was determined based on two criteria. A sediment sample was considered toxic if: 1) its mean survival was <80% of the mean control survival, and 2) its mean survival was significantly different from the mean control survival (based on a t-test at the 0.05 significance level; Thursby et al. 1997; USEPA 1994). For the 1994 data compiled by Battelle and the EPA, statistical analysis was completed using the analysis of variance (ANOVA) with Dunnett's Test (α=0.05) method and ANOVA with Bonferroni/Dunn's test (α=0.05) method (Battelle 1996). Samples from 1994 were considered toxic if there was <80% survival.

2.4 REMOTS Sediment-Profile and Sediment Plan View Imaging

During the REMOTS survey operations, at least two replicate sediment-profile images and one plan view image were collected at each of the 60 primary stations (Table 2.1-1; Figure 2.1-1). Color slide film was used and developed at the end of each field day using a small, portable color film processor to verify proper equipment operation and image acquisition.

2.4.1 REMOTS Sediment-Profile Image Acquisition

REMOTS sediment-profile imaging is a formal and standardized technique for sediment-profile imaging and analysis (Rhoads and Germano 1982; 1986). A Benthos Model 3731 Sediment-Profile Camera (Benthos, Inc., North Falmouth, MA) was used in this study (Figure 2.4-1). The camera is designed to obtain in situ profile images of the top (20 cm) of seafloor sediment. Functioning like an inverted periscope, the camera consists of a wedge-shaped prism with a front face-plate and a back mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface facing the camera. The prism is filled with distilled water, the assembly contains an internal strobe used to illuminate the images, and a 35-mm camera is mounted horizontally on top of the prism. The prism assembly is moved up and down into the sediments by producing tension or slack on the winch wire. Tension on the wire keeps the prism in the up position, out of the sediment.

The camera frame is lowered to the seafloor at a rate of approximately 1 m/sec (Figure 2.4-1). When the frame settles onto the seafloor, slack on the winch wire allows the prism to penetrate the seafloor vertically. A passive hydraulic piston ensures that the prism enters the bottom slowly (approximately 6 cm/sec) and does not disturb the sediment-water interface. As the prism starts to penetrate the seafloor, a trigger activates a 13-second time delay on the shutter release to allow maximum penetration before a photo is taken.

A Benthos Model 2216 Deep Sea Pinger is normally attached to the camera to output a 12 kHz signal once per second; upon discharge of the camera strobe, the ping rate doubles for a period of 10 seconds. By monitoring the pinger's repetition rate from the surface vessel, one can confirm that a successful image was obtained. Because the sediment photographed is directly against the face plate, turbidity of the ambient seawater does not affect image quality. When the camera is

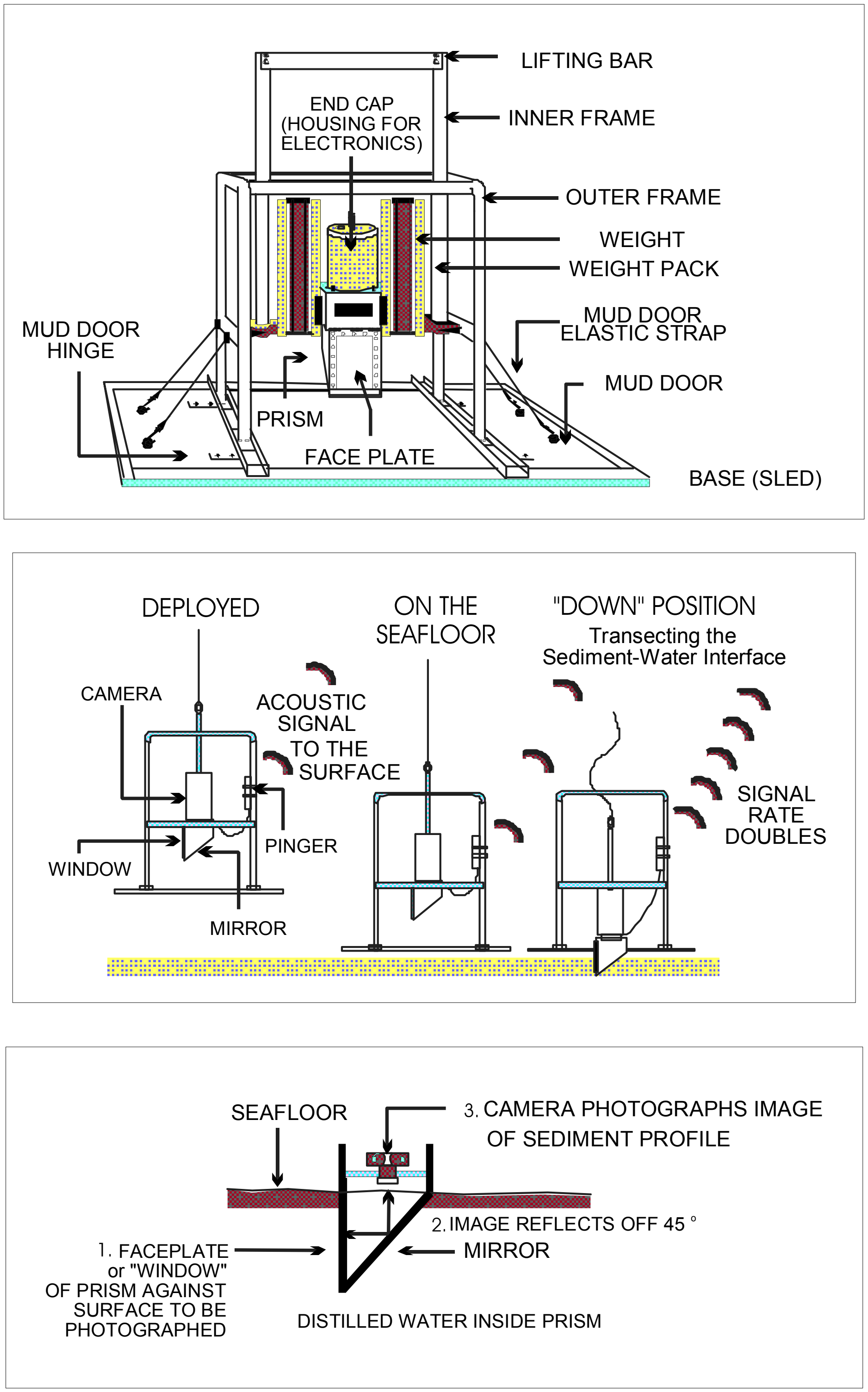


Figure 2.4-1. Schematic diagram of Benthos, Inc. Model 3731 REMOTS sediment-profile camera and sequence of operation on deployment

raised, a wiper blade cleans off the faceplate, the film is advanced by a motor drive, the strobe is recharged, and the camera can be lowered for another image. At least two replicate sediment-profile images were obtained at each station using color slide film (Kodak Ektachrome).

2.4.2 REMOTS Sediment-Profile Image Analysis

A computerized image analysis system was used to analyze the images. The original sediment-profile images (35-mm slides) were scanned and imported digitally into the image analysis system for measurement of a suite of standard biological and physical parameters. The data for each image were stored automatically in a centralized database and exported in various formats (data tables and reports) to be compared statistically and mapped using Arcview GIS. All measurements were reviewed (quality assurance check) before being approved for final data synthesis, statistical analyses, and interpretation. Summaries of the standard REMOTS measurement parameters presented in this report are presented below.

2.4.2.1 Sediment Type Determination

The sediment grain-size major mode and range are estimated visually from the photographs by overlaying a grain size comparator of the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the REMOTS sediment-profile camera. Seven grain size classes are on this comparator: >4 phi, 4 to 3 phi, 3 to 2 phi, 2 to 1 phi, 1 to 0 phi, 0 to –1 phi, and <-1 phi. Table 2.3-1 is provided to allow conversion of phi units to other commonly used grain size scales. The lower limit of optical resolution of the photographic system is about 62 microns (4 phi), allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing REMOTS sediment-profile image estimates with grain size statistics determined from laboratory sieve analyses.

The major modal grain size that is assigned to an image is the dominant grain size as estimated by area within the imaged sediment column. In those images that show layering of sand and mud, the dominant major mode that is assigned depends on how much area of the image is represented by sand versus mud. These textural assignments may or may not correspond to traditional sieve analyses depending on how closely the vertical sampling intervals are matched between the grab or core sample and the depth of the imaged sediment. Layering is noted as a comment accompanying the REMOTS sediment-profile image data file.

2.4.2.2 Benthic Habitat Classification

Based on extensive past REMOTS sediment-profile survey experience in coastal New England, five basic benthic habitat types have been found to exist in shallow-water estuarine and open-water near shore environments: AM = Ampelisca mat, SH = shell bed, SA = hard sand bottom, HR = hard rock/gravel bottom, and UN = unconsolidated soft bottom (Table 2.4-1). Several sub-habitat types exist within these major categories (Table 2.4-1). Each of the REMOTS sediment-profile images obtained in the present study was assigned one of the habitat categories listed in Table 2.4-1.

Table 2.4-1.
Benthic Habitat Categories Assigned to Sediment-Profile Images Obtained in this Study

Habitat AM: *Ampelisca* Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (*Ampelisca* spp.) tube mats at the sediment-water interface.
Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: **SH.SI: Shell Bed over silty sediment** - shell layer overlying sediments ranging from fine sands to silts to silt-clay. **SH.SA: Shell Bed over sandy sediment** - shell layer overlying sediments ranging from fine to coarse sand.
Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments, do not appear to be bioturbated, bedforms common, successional stage mostly indeterminate because of low prism penetration. **SA.F: Fine sand** - uniform fine sand sediments (grain size: 4 to 3 phi). **SA.M: Medium sand** - uniform medium sand sediments (grain size: 3 to 2 phi). **SA.G: Medium sand with gravel** - predominately medium to coarse sand with a minor gravel fraction.
Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty-sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates).
Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (I, II and III). Biogenic features were common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: **UN.SS: Fine Sand/Silty** - very fine sand mixed with silt (grain size range from 4 to 2 phi), with little or no shell hash. **UN.SI: Silty** - homogeneous soft silty sediments (grain size range from >4 to 3 phi), with little or no shell hash. Generally deep prism penetration. **UN.SF: Very Soft Mud** - very soft muddy sediments (>4 phi) of high apparent water content, methane gas bubbles present in some images, deep prism penetration.

2.4.2.3 Mud Clasts

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in REMOTS sediment-profile images. During image analysis, the number of clasts are counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. Also, once at the sediment-water interface, these sediment clumps are subject to bottom-water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6–12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g., angular versus rounded, are also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

2.4.2.4 Sedimentary Methane

At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in REMOTS sediment-profile images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total areal coverage of all methane pockets are measured.

2.4.2.5 Measurement of Dredged Material and Cap Layers

The recognition of dredged material from REMOTS sediment-profile images is usually based on the presence of anomalous sedimentary materials within an area of ambient sediment. The ability to distinguish between ambient sediment and dredged or cap material demands that the survey extend well beyond the margins of a disposal site so that an accurate characterization of the ambient bottom is obtained. The distributional anomalies may be manifested in topographic roughness, differences in grain size, sorting, shell content, optical reflectance, fabric, or sediment compaction (i.e., camera prism penetration depth). Second-order anomalies may also provide information about the effects of dredged material on the benthos and benthic processes such as bioturbation (see following sections).

2.4.2.6 Boundary Roughness

Small-scale boundary roughness is measured from an image with the computer image analysis system. This vertical measurement is from the highest point at the sediment-water interface to the lowest point. This measurement of vertical relief is made within a horizontal distance of 15 cm (the total width of the optical window). Because the optical window is 20 cm high, the greatest possible roughness value is 20 cm. The source of the roughness is described if known. In most cases this is either biogenic (mounds and depressions formed by bioturbation or foraging activity) or relief formed by physical processes (ripples, scour depressions, rip-ups, mud clasts, etc.).

2.4.2.7 Optical Prism Penetration Depth

The optical prism of the REMOTS sediment-profile camera penetrates the bottom under a static driving force imparted by its weight. The penetration depth into the bottom depends on the force exerted by the optical prism and the bearing strength of the sediment. If the weight of the camera prism is held constant, the change in penetration depth over a surveyed region will reflect horizontal variability in geotechnical properties of the seafloor. In this sense, the camera prism acts as a static-load penetrometer. The depth of penetration of the optical prism into the bottom can be a useful parameter, because dredged and capped materials often have different shear strengths and bearing capacities.

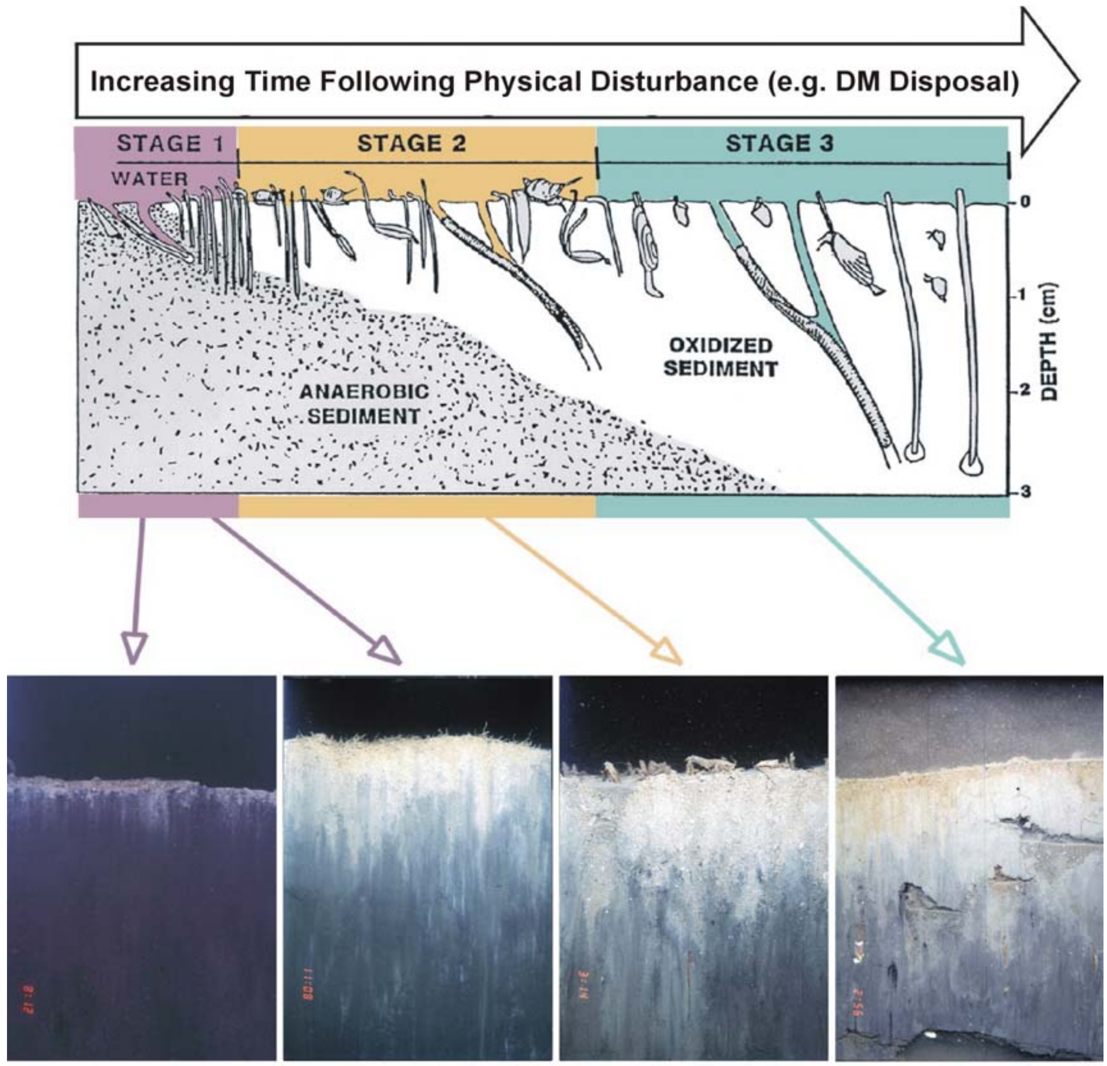
2.4.2.8 Infaunal Successional Stage

Determination of the infaunal successional stage applies only to soft-bottom habitats, where the REMOTS camera is able to penetrate into the sediment. In hard bottom environments (i.e., rocky substrates), camera penetration is prevented and the standard suite of REMOTS measurements cannot be made. In such instances, the infaunal successional stage is considered to be “indeterminate.” Hard bottom areas can support abundant and diverse epibenthic communities and therefore may represent habitat which is biologically productive or otherwise is of value as refuge or living space for organisms. However, the value of hard bottom habitats is not reflected in the REMOTS successional stage designation.

The mapping of infaunal successional stages is based on the theory that organism-sediment interactions in marine soft-bottom habitats follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, disturbance by bottom trawlers, dredged material deposition, hypoxia). The theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is formally developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

Benthic disturbance can result from natural processes, such as seafloor erosion, changes in seafloor chemistry, and predator foraging, as well as from human activities like dredged material or sewage sludge disposal, thermal effluent from power plants, bottom trawling, pollution from industrial discharge, and excessive organic loading. Evaluation of successional stages involves deducing dynamics from structure, a technique pioneered by R. G. Johnson (1972) for marine soft-bottom habitats. The application of this approach to benthic monitoring requires *in situ* measurements of salient structural features of organism-sediment relationships as imaged through REMOTS technology.

Pioneering assemblages (Stage I assemblages) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes (Figure 2.4-2); alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary; and bioturbation depths are shallow, particularly in the earliest stages of colonization (Figure 2.4-2). In the absence of further disturbance, these early successional assemblages are eventually replaced by infaunal deposit feeders; the start of this "infaunalization" process is designated



A B C D

Figure 2.4-2. The drawing at the top illustrates the development of infaunal successional stages over time following a physical disturbance. The REMOTS images below the drawing provide examples of the different successional stages. Image A shows highly reduced sediment with a very shallow redox layer (contrast between light colored surface sediments and dark underlying sediments) and little evidence of infauna. Numerous small polychaete tubes are visible at the sediment surface in image B (Stage I), and the redox depth is deeper than in image A. A mixture of polychaete and amphipod tubes occurs at the sediment surface in image C (Stage II). Image D shows numerous burrow openings and feeding pockets (voids) at depth within the sediment; these are evidence of deposit-feeding, Stage III infauna. Note the aRPD is relatively deep in this image, as bioturbation by the Stage III organisms has resulted in increased sediment aeration, causing the redox horizon to be located several centimeters below the sediment-water interface.

arbitrarily as Stage II. Typical Stage II species are shallow dwelling bivalves or, as is common in New England waters, tubicolous amphipods. In studies of hypoxia-induced benthic defaunation events in Tampa Bay, Florida, Ampeliscid amphipods appeared as the second temporal dominant in two of the four recolonization cycles (Santos and Simon 1980a, 1980b).

Stage III taxa, in turn, represent high-order successional stages typically found in low-disturbance regimes. These invertebrates are infaunal, and many feed at depth in a head-down orientation. The localized feeding activity results in distinctive excavations called feeding voids (Figure 2.4-2). Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. This granulometric change is caused by the accumulation of coarse particles that are rejected by the animals feeding selectively on fine-grained material. Other subsurface structures, such as burrows or methane gas bubbles, do not exhibit these characteristics and therefore are quite distinguishable from these distinctive feeding structures. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment. In the retrograde transition of Stage III to Stage I, it is sometimes possible to recognize the presence of relict (i.e., collapsed and inactive) feeding voids.

The end-member stages (Stages I and III) are easily recognized in REMOTS images by the presence of dense assemblages of near-surface polychaetes (Stage I) or the presence of subsurface feeding voids (Stage III; Figure 2.4-2). The presence of tubicolous amphipods at the sediment surface is indicative of Stage II. It is possible for Stage I polychaetes or Stage II tubicolous amphipods to be present at the sediment surface, while at the same time, Stage III organisms are present at depth within the sediment. In such instances, where two types of assemblages are visible in a REMOTS image, the image is designated as having either a Stage I on Stage III (I–III) or Stage II on Stage III (II–III) successional stage. Additional information on REMOTS image interpretation can be found in Rhoads and Germano (1982, 1986).

2.4.2.9 Apparent RPD Depth

Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying anoxic sediments. Sand also has higher optical reflectance than mud. These differences in optical reflectance are readily apparent in REMOTS sediment-profile images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black. The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent redox potential discontinuity (RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) which separates the positive Eh region (oxidized) from the underlying negative Eh region (reduced) can only be determined accurately with microelectrodes. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD, and it is mapped as a mean value.

The depression of the apparent RPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore, this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the apparent RPD is also slow (Germano 1983). Measurable changes in the apparent RPD depth using the REMOTS sediment-profile image optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients), which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. In sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS (Disposal Area Monitoring System) Program for the USACE, New England Division, SAIC repeatedly has documented a drastic reduction in apparent RPD depths at disposal sites immediately after dredged material disposal, followed by a progressive postdisposal apparent RPD deepening (barring further physical disturbance). Consequently, time-series RPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean apparent RPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette et al. 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly reduced (lower reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

2.4.2.10 Organism-Sediment Index (OSI)

The multi-parameter REMOTS Organism-Sediment Index (OSI) has been constructed to characterize benthic habitat quality. Benthic habitat quality is defined relative to two end-member standards. The lowest value is given to those bottoms which have low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment (see Rhoads and Germano 1982, 1986, for REMOTS criteria for these conditions). The OSI for such a condition is –10 (highly disturbed or degraded benthic habitat quality). At the other end of the scale, an aerobic bottom with a deeply depressed RPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have an OSI value of +11 (unstressed or undisturbed benthic habitat quality).

The OSI is a sum of the subset indices shown in Table 2.4-2. The OSI is calculated automatically by SAIC software after completion of all measurements from each REMOTS photographic negative. The index has proven to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance (Germano and Rhoads 1984, Revelas et al. 1987, Valente et al. 1992).

The OSI may be subject to seasonal changes because the mean apparent RPD depths vary as a result of temperature-controlled changes of bioturbation rates and sediment oxygen demand. Furthermore, the successional status of a station may change over the course of a season related to recruitment and mortality patterns or the disturbance history of the bottom. The sub-annual change in successional status is generally limited to Stage I (polychaete-dominated) and Stage II (amphipod-dominated) seres. Stage III seres tend to be maintained over periods of several years unless they are eliminated by increasing organic loading, extended periods of hypoxia, or burial by thick layers of dredged material. The recovery of Stage III seres following abatement of such events may take several years (Rhoads and Germano 1982). Stations that have low or moderate OSI values (< +6) are indicative of recently disturbed areas and tend to have greater temporal and spatial variation in benthic habitat quality than stations with higher OSI values (> +6).

2.4.3 Sediment Plan View Image Acquisition

Plan view (i.e., "downward-looking" or horizontal sediment surface plane) photographs of approximately 0.3 m^2 of the seafloor surface were obtained in conjunction with the REMOTS sediment-profile images at each station (Figure 2.1-1). The photographs were acquired with a PhotoSea 1000a 35 mm Underwater Camera System and a PhotoSea 1500s Strobe Light attached to the REMOTS sediment-profile camera frame. The plan view images were acquired immediately prior to the landing of the REMOTS sediment-profile camera frame on the seafloor, providing an undisturbed record of the surface sediments before penetration of the REMOTS sediment-profile prism. Once the camera frame was lifted above the sediments, the plan view camera system automatically cycled the film and recharges the strobe in preparation for the next image. In this manner, a corresponding plan view image was usually obtained for each REMOTS sediment-profile image acquired.

Table 2.4-2.
Calculation of REMOTS Organism-Sediment Index Value

A. CHOOSE ONE VALUE:		
	Mean aRPD Depth	Index Value
	0.00 cm	0
	> 0 - 0.75 cm	1
	0.75 - 1.50 cm	2
	1.51 - 2.25 cm	3
	2.26 - 3.00 cm	4
	3.01 - 3.75 cm	5
	> 3.75 cm	6
B. CHOOSE ONE VALUE:		
	Successional Stage	Index Value
	Azoic	-4
	Stage I	1
	Stage I to II	2
	Stage II	3
	Stage II to III	4
	Stage III	5
	Stage I on III	5
	Stage II on III	5
C. CHOOSE ONE OR BOTH IF APPROPRIATE:		
	Chemical Parameters	Index Value
	Methane Present	-2
	No/Low Dissolved Oxygen**	-4
REMOTS ORGANISM-SEDIMENT INDEX =	Total of above subset indices (A+B+C)	
	RANGE: -10 - +11	

** Note: This is not based on a Winkler or polarigraphic electrode measurement. It is based on the imaged evidence of reduced, low reflectance (i.e., high oxygen demand) sediment at the sediment-water interface.

2.4.4 Sediment Plan View Image Analysis

The purpose of the plan view image analysis was to supplement the more detailed and comprehensive REMOTS characterization of the seafloor. Analysis of the plan view images included screening all the replicate images acquired at each station to select one representative image for analysis. Poor water clarity, lack of contrast or water shots taken prematurely due to the camera system trigger sensitivity (sediment surface not within the focal length of the system when activated) eliminated some of the images from further consideration.

The plan view image analysis consisted of qualitative descriptions of key sediment characteristics (e.g., sediment type, bedforms and biological features) based on careful scrutiny of each chosen replicate image. Sediment descriptions were based on visual observations and therefore only the obvious presence of boulders, cobble, rock, gravel, sand and/or fines (clay and silt) were noted. Bedforms were described as being either rippled (i.e., presence of sand waves) or smooth (i.e., absence or very little evidence of sand waves) to provide an indication of physical processes (i.e., currents). Any evidence of epifaunal or infaunal organisms (i.e., fish, starfish, tubes, burrow openings, fecal mounds etc.) was also recorded.

3.0 RESULTS

3.1 Sediment Toxicity

3.1.1 Toxicity Survey

The sediment toxicity testing was conducted in nine sample groups, each with its own control sample. The number of samples per control varied by group. Control organism survival ranged from 90% to 98%. No control sample had a mean survival less than 80%, meeting the requirement for an acceptable test. The raw laboratory results, including the percent survival data for each sediment sample, are provided in Appendix A, Table A-2.

Initial pore water ammonia concentrations at eight stations (Stations 19, 22, 29, 33, H2000, I1200, M2800, and N2000) were found to be above the threshold of 20 mg/L. Concentrations ranged from 20.4 mg/L (Station 33) to 86.8 mg/L (Station N2000) at these stations (Appendix A, Table A-1). The sediment was purged to reduce the concentration of ammonia until it was below the threshold. At the other stations, initial pore water ammonia concentrations ranged from <0.08 mg/L to 19.5 mg/L.

Final pore water ammonia concentrations from all stations were well below the threshold and ranged from <0.08 mg/L to 12.6 mg/L. At the eight stations that were purged, final pore water ammonia concentrations ranged from 1.29 mg/L (Station 29) to 12.6 mg/L (Station H2000). At Station N2000, which had an initial ammonia concentration (86.8 mg/L) well above the other seven stations that were purged, the final pore water ammonia was 2.92 mg/L.

The sediment toxicity testing results for the 2002 survey indicated that sediment at each of the 60 primary stations was non-toxic (Table 3.1-1; Figure 3.1-1). Overall, all of the primary stations showed greater than 80% normalized organism survival. Only three of the stations (Stations 46, M1200, and P2800) had normalized survival percentages less than or equal to 85%, and only one other station (Station 17) had a percentage less than 90%. Of these four primary stations, Station M1200 was the only one that had a "raw" mean percent survival (not normalized to the control) less than 80%. Since its normalized value was above 80%, a statistical analysis was not necessary.

A review of the ammonia data from all the samples indicated that there was very little correlation between initial or final pore water ammonia and percent survival. Stations that had between 80% and 90% normalized survival (Stations 17, 46, M1200, and P2800) all had initial pore water ammonia values less than the 20 mg/L threshold limit (Appendix A, Table A-1). Initial pore water ammonia concentrations for these stations ranged from <0.08 mg/L (Station 17) to 16.3 mg/L (Station P2800), and final pore water concentrations were between 0.83 mg/L (Station 17) and 5.88 mg/L (Station M1200). Stations with initial pore water ammonia levels greater than 20 mg/L all showed greater than 95% normalized organism survival. In addition, primary stations with final ammonia concentrations greater than 6.00 mg/L all showed between 90% and 103% normalized survival.

Table 3.1-1.
Percent Organism Survival at the 60 Primary Stations
Sampled During the 2002 REMOTS and Sediment Toxicity Survey at the HARS

Station[1]	Mean % Survival	Normalized % Survival[2]
1	93	97
2	93	97
3	94	98
4	97	104
5	93	100
6	91	95
7	91	98
8	93	97
9	87	96
10	99	103
11	94	101
12	95	99
13	92	96
14	87	94
15	91	98
16	87	96
17	85	89
18	93	100
19	98	100
20	85	93
22	86	96
24	96	101
25	94	98
26	91	99
27	93	100
28	82	90
29	89	99
30	91	99
31	95	103
32	93	101
33	94	104
34	96	104
35	93	101
36	86	95
37	94	102
38	84	92
39	86	95
40	98	107
42	91	100
43	92	99
44	87	96
45	93	97
46	81	85
49	95	99
E0800	93	100
G1200	90	95
H2000	99	101
I1200	93	103
K0800	88	93
L1200	90	99
L1600	86	91
L2400	98	107
M1200	75	82
M2800	93	103
N2000	95	97
N3200	89	98
P2800	81	85
P3200	96	103
Q1600	92	96
Q2400	90	98

[1]Stations numbered between 1 and 49 correspond to the Battelle October 1994 sampling locations; the remainder are 16 stations located in selected areas of PRAs 1, 2, 3, and 4.
[2]Normalized % survival = mean % survival normalized to respective control survival (Appendix A)

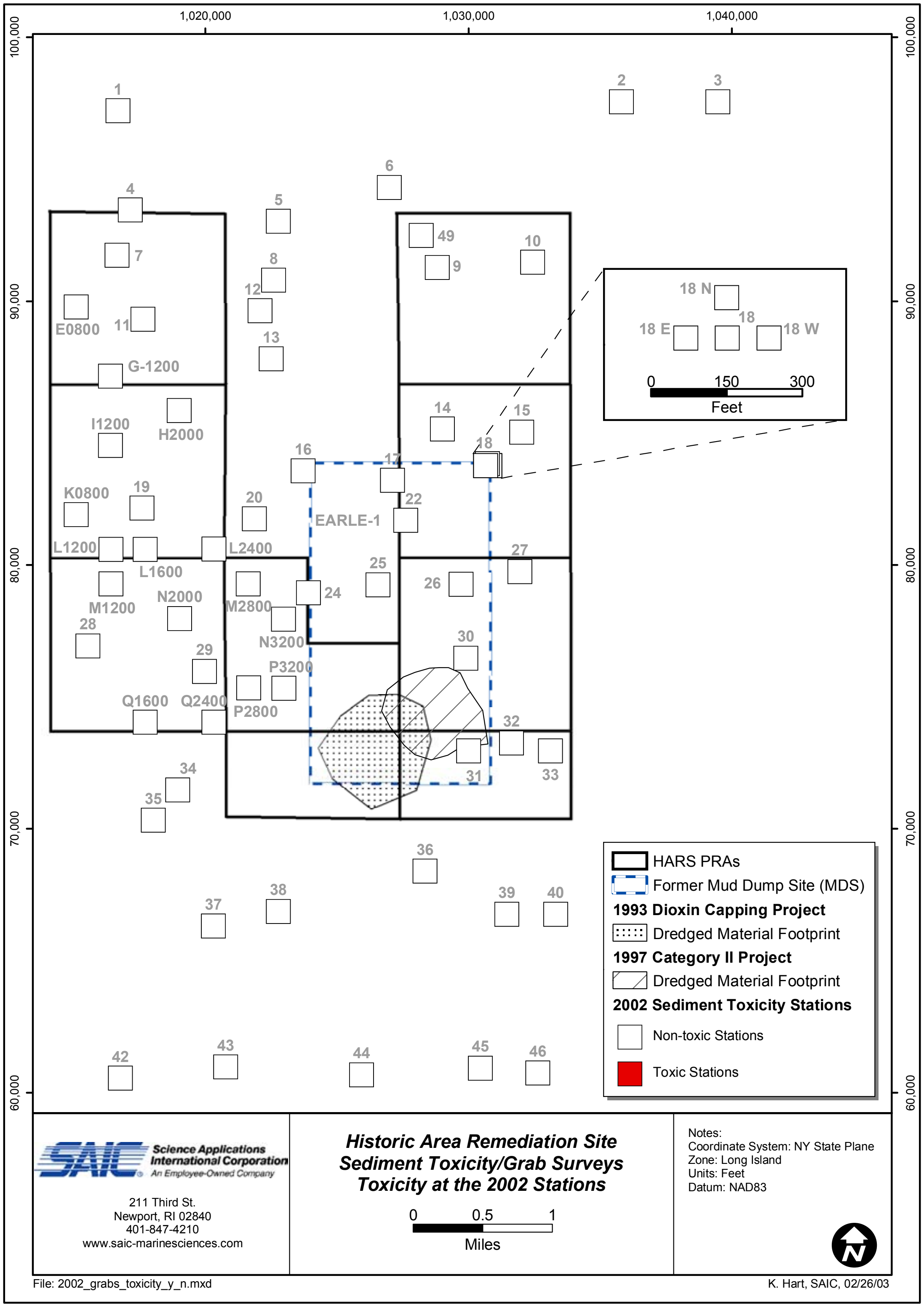


Figure 3.1-1. Map of toxicity at the 2002 sediment toxicity grab stations over the HARS

3.1.2 Evaluation of Small-Scale Spatial Variability

As previously indicated, Station 18 was selected for the 25-m assessment of small-scale vertical and spatial variability in sediment toxicity because 1) it was originally sampled in the EPA Region 2 study of 1994 and found to have significant toxicity, 2) the sediment was composed of fine-grained, historic dredged material, and 3) it was located in an area (northeast corner of the former Mud Dump Site) that has not yet received remediation material. Samples of the full grab (FG), grab top (GT), and grab bottom (GB) were taken from Stations 18, 18E, 18N, and 18W.

The sediment samples at each station and at each depth were non-toxic (Table 3.1-2; Figure 3.1-1). All samples had a normalized percent survival greater than 90%, except for sample 18E FG. The mean percent survival (not normalized to the control) for sample 18E FG was 76%. The sample was not considered toxic because its normalized percent survival was 80%.

3.1.3 Comparison to Previous Surveys

Stations within and around the HARS were sampled for sediment toxicity in October 1994 by Battelle (under contract to EPA Region 2) and in October 2000 by SAIC. Results from these previous surveys are briefly summarized here for a comparison to the 2002 survey data. All of the stations sampled in 1994 were sampled again in 2002 (Figure 3.1-2). Some of the 2000 stations were also sampled in 2002, and some of the 2000 stations were sampled in both 1994 and 2002 (Figure 3.1-2).

The 1994 sediment toxicity survey sponsored by EPA Region 2 yielded results showing widespread toxicity over the HARS (Table 3.1-3; Figure 3.1-3). Normalized organism survival ranged from 0% to 104% for that data set (Table 3.1-3). Twenty-six (26) out of 44 stations were considered toxic (<80% survival). Twenty-two (22) stations showed less than 70% normalized organism survival. All eight samples collected within the former MDS were toxic.

SAIC sampled 33 stations in October 2000 for sediment toxicity. Most stations were located in HARS PRA 1, while some were scattered within other areas of the HARS and others were south of the HARS (Figure 3.1-3). Normalized organism survival percentages ranged from 59% to 103% for the 2000 data set (Table 3.1-4). Only two samples (WNW-700 and WNW-900) from the 2000 survey were considered toxic (Table 3.1-4; Figure 3.1-3). All other samples were non-toxic. Station WNW-700 had a normalized percent survival of 63%, while WNW-900 had 59% survival. These were both significantly different from the mean control survival (t-test at 0.05 significance level). These two toxic stations were located less than 200 m apart in PRA 1 (Figure 3.1-3).

Fifteen (15) of the 33 stations sampled in 2000 had been sampled in the 1994 survey (Figure 3.1-3). Two stations sampled in 2000 (Stations E1600 and EARLE-1) were also located in close proximity to two 1994 stations (Stations 11 and 22, respectively). All 2000 samples corresponding to 1994 stations were non-toxic (Table 3.1-4; Figure 3.1-3). Six of the 15 corresponding stations were toxic in 1994 but not in 2000. In addition, Stations E1600 and

Table 3.1-2.
Percent Organism Survival at Station 18, Sampled for Spatial Variability During the 2002 REMOTS and Sediment Toxicity Survey at the HARS

Station	Mean % Survival	Normalized % Survival[1]
18 FG*	93	100
18 GT	97	101
18 GB	93	97
18E FG	76	80
18 E GT	91	95
18 E GB	90	94
18 N FG	94	98
18 N GT	97	101
18 N GB	94	98
18 W FG	93	97
18 W GT	98	102
18 W GB	95	99

*Same as Station 18 in table 3.1-1

[1]Normalized % survival = mean % survival normalized to respective control survival (Appendix A)

FG= full grab (0 cm to bottom)

GT= grab top (0-4 cm)

GB= grab bottom (4 cm to bottom)

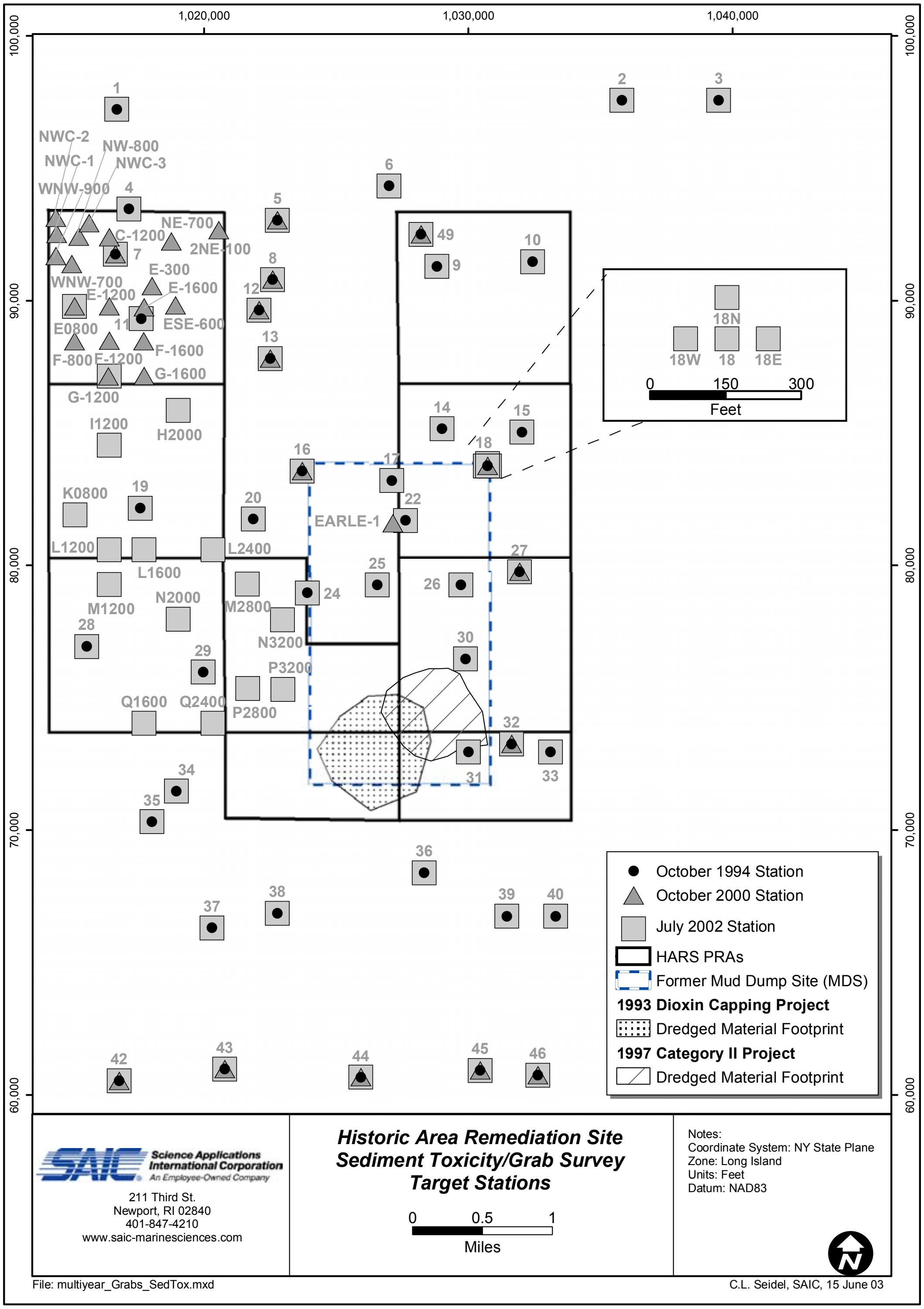


Figure 3.1-2. Map of target sediment toxicity grab stations for the 1994, 2000, and 2002 surveys in and around the HARS

Table 3.1-3.
Percent Organism Survival at the 44 Grab Stations Sampled
in October 1994 in the Study Sponsored by EPA Region 2.
Shaded rows indicate significant sediment toxicity at the respective station.

Station	Latitude NAD83	Longitude NAD83	Mean % Survival	Normalized % Survival[1]
1	40.4335	-73.8835	94	104
2	40.4343	-73.8148	78	86
3	40.4343	-73.8017	43	47
4	40.4232	-73.8818	90	99
5	40.4220	-73.8617	81	89
6	40.4255	-73.8465	49	54
7	40.4185	-73.8837	0	0
8	40.4158	-73.8623	89	98
9	40.4172	-73.8400	77	85
10	40.4177	-73.8270	81	89
11	40.4118	-73.8802	4	4
12	40.4127	-73.8642	65	72
13	40.4077	-73.8627	22	24
14	40.4003	-73.8393	5	6
15	40.4000	-73.8285	0	0
16	40.3960	-73.8583	56	62
17	40.3950	-73.8462	3	3
18	40.3965	-73.8332	1	1
19	40.3922	-73.8803	0	0
20	40.3910	-73.8650	22	24
22	40.3908	-73.8443	3	3
24	40.3833	-73.8577	71	78
25	40.3842	-73.8482	70	77
26	40.3842	-73.8368	1	1
27	40.3855	-73.8288	10	11
28	40.3778	-73.8877	1	1
29	40.3752	-73.8718	0	0
30	40.3765	-73.8362	54	60
31	40.3668	-73.8358	32	35
32	40.3677	-73.8300	37	41
33	40.3668	-73.8247	39	43
34	40.3628	-73.8755	83	92
35	40.3597	-73.8788	71	78
36	40.3543	-73.8418	-	50
37	40.3487	-73.8707	-	94
38	40.3502	-73.8618	-	89
39	40.3498	-73.8307	-	93
40	40.3498	-73.8240	-	94
42	40.3328	-73.8833	-	97
43	40.3340	-73.8690	-	95
44	40.3332	-73.8505	-	87
45	40.3338	-73.8343	-	99
46	40.3333	-73.8265	-	99
49	40.4205	-73.8422	74	82

[1]Normalized % survival = mean % survival normalized to respective control survival

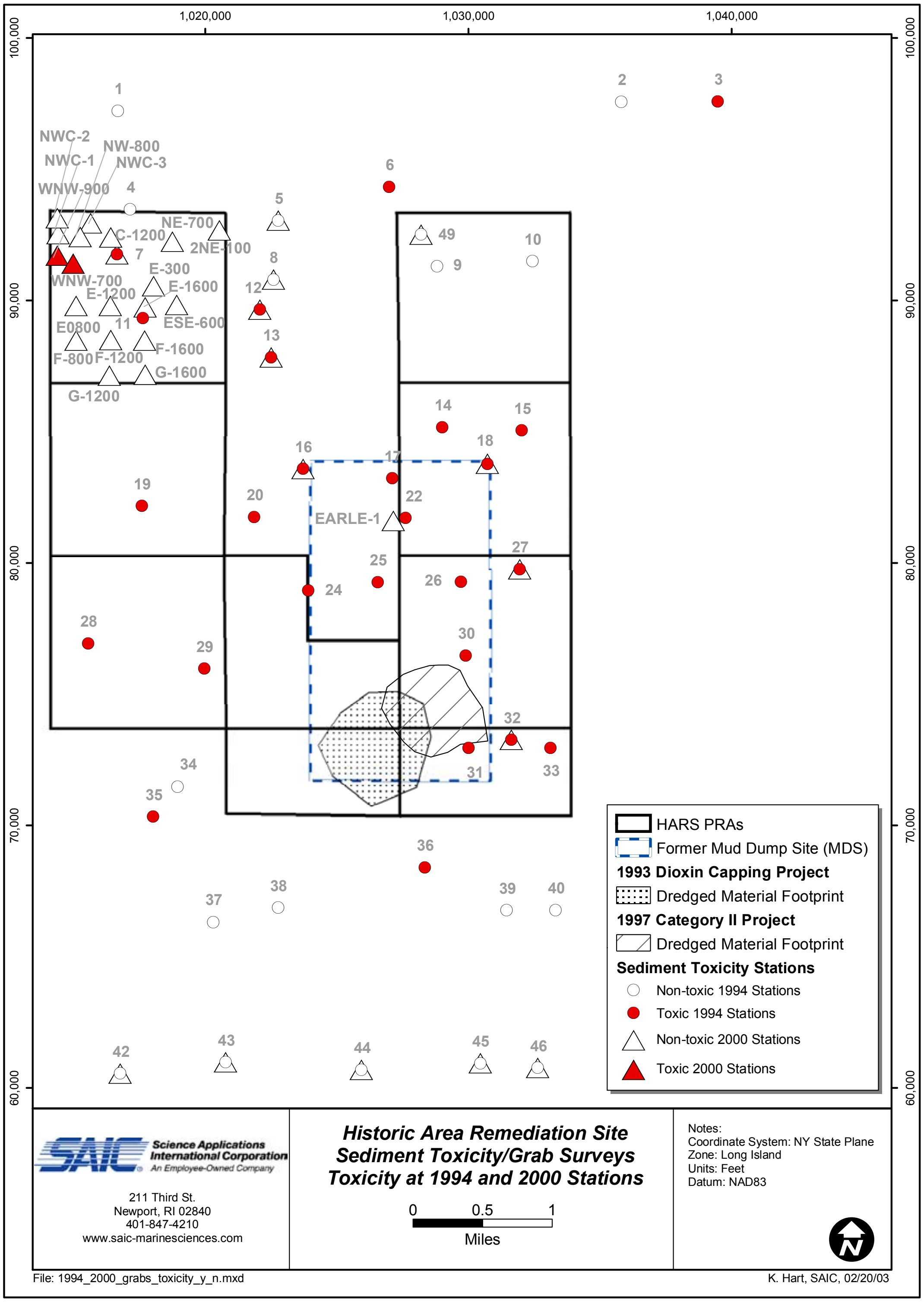


Figure 3.1-3. Map of toxicity at the 1994 and 2000 sediment toxicity grab stations over the HARS

Table 3.1-4.
Percent Organism Survival at the Stations Sampled
in the October 2000 Sediment Toxicity Survey at the HARS.
Shaded rows indicate significant sediment toxicity at the respective station.

Station[1]	Latitude NAD83[2]	Longitude NAD83[2]	Mean % Survival	Normalized % Survival[3]
5	40.4220	-73.8617	91	94
7	40.4185	-73.8837	89	92
8	40.4158	-73.8623	99	102
12	40.4127	-73.8642	94	97
13	40.4077	-73.8627	99	102
16	40.3960	-73.8583	100	103
18	40.3965	-73.8332	89	89
27	40.3855	-73.8288	94	94
32	40.3677	-73.8300	94	94
42	40.3328	-73.8833	97	100
43	40.3340	-73.8690	92	95
44	40.3332	-73.8505	96	99
45	40.3338	-73.8343	96	96
46	40.3333	-73.8265	90	93
49	40.4205	-73.8422	93	96
C-1200	40.4203	-73.8845	94	97
E-1200	40.4131	-73.8846	94	97
E-1600	40.4130	-73.8798	99	100
E-300	40.4152	-73.8787	97	98
Earle-1	40.3905	-73.8461	98	99
ESE-600	40.4132	-73.8756	98	99
F-1200	40.4095	-73.8845	96	96
F-800	40.4095	-73.8893	99	100
G-1200	40.4058	-73.8847	99	102
G-1600	40.4059	-73.8798	96	99
2NE-100	40.4210	-73.8697	94	97
NE-700	40.4198	-73.8761	98	101
NW-800	40.4203	-73.8886	89	92
NWC-1	40.4206	-73.8917	79	81
NWC-2	40.4223	-73.8918	80	82
NWC-3	40.4217	-73.8872	96	99
WNW-700	40.4175	-73.8897	61	63
WNW-900	40.4183	-73.8918	57	59

[1]Stations 5-49 were previously sampled in the EPA Region 2 study (Battelle 1996)
[2]Target coordinates are presented
[3]Normalized % survival = mean % survival normalized to respective control survival

EARLE-1, sampled in 2000 were non-toxic, while nearby 1994 Stations 11 and 22 were toxic. The lack of toxicity shown by the 2000 survey results (in contrast to the 1994 survey results) prompted the resampling of all of the 1994 stations in the summer 2002 survey.

As stated previously, all of the sediment samples collected in 2002 by SAIC were found to be non-toxic. Twenty-nine (29) of these samples corresponded to 1994 stations, two samples corresponded to 2000 stations, and 15 samples corresponded to both 1994 and 2000 stations (Figures 3.1-2 and 3.1-4). The two stations found to be toxic in 2000 were not resampled in 2002 by SAIC. All 26 stations that were considered toxic in 1994 had greater than 80% organism survival in 2002 (Figure 3.1-4).

3.2 Sediment Grain Size

The laboratory analysis of the subsamples taken from each sediment toxicity grab sample showed that grain size was highly variable over the study area. Grain size at the 60 primary stations ranged from silty clay to gravelly sand, and some samples had a mixture of all sediment types (Table 3.2-1). Gravel was generally sparse in the samples. Stations that contained the most gravel (>10%) included Stations 6 (23.7%), 17 (10.4%), 25 (18.9%), 33 (39.9%), and E0800 (13.3%). Otherwise, the majority of the samples were made up of sand, silt, and clay in varying proportions. Applied Marine Sciences (AMS) classified each station based on the percentage of gravel, coarse sand, medium sand, fine sand, silt, and clay in the sample and the plasticity of the sample (Table 3.2-1). This classification was based on the Unified Soil Classification Standard (USCS, modified from ASTM D-2487), and the grain size major mode was the most important factor in the assignment of the abbreviation pertaining to each sample (Table 2.3-2). Figure 3.2-1 graphically represents the classification of each station.

Sandy sediment was found outside the PRAs to the south (Stations 34–46), to the north (Stations 1–6), and within the No Discharge Zone (Stations 8, 12, 13, 16, and 20; Figure 3.2-1). Within the PRAs, sediment type ranged from clay to gravelly sand (Figure 3.2-1). PRAs 1, 2, 3, 4, and 6 contained mostly clay and silt. Also within PRAs 2 and 3 was a mixture of sand and gravel. Therefore, based on the grain size data, the remediation material within PRAs 1–4 was primarily composed of silt and clay with some gravel and sand. Relict dredged material within PRAs 2 and 3 was composed of sand and gravel. Generally, unremediated areas of the HARS include portions of PRAs 5–9. Stations in PRA 7 were comprised primarily of sand with some gravel, silt, and clay (Figure 3.2-1). PRAs 5 and 9 contained stations with silt, clay, or sand, with no spatial correlation (Figure 3.2-1).

At Station 18, sampled to determine the degree of small-scale spatial variability (both vertical and horizontal), silt was the dominant grain size fraction in all of the samples, with a secondary component of clay and some sand (Table 3.2-2). The sediment samples collected at Stations 18, 18W, 18N, and 18E did not vary a great deal with respect to grain size, either horizontally or vertically. Two samples from the grab bottom, 18E GB and 18N GB, did show higher sediment plasticity. They were designated inorganic silt with moderate to high plasticity (MH), while most other samples were inorganic silt with slight or no plasticity (ML; Table 3.2-2).

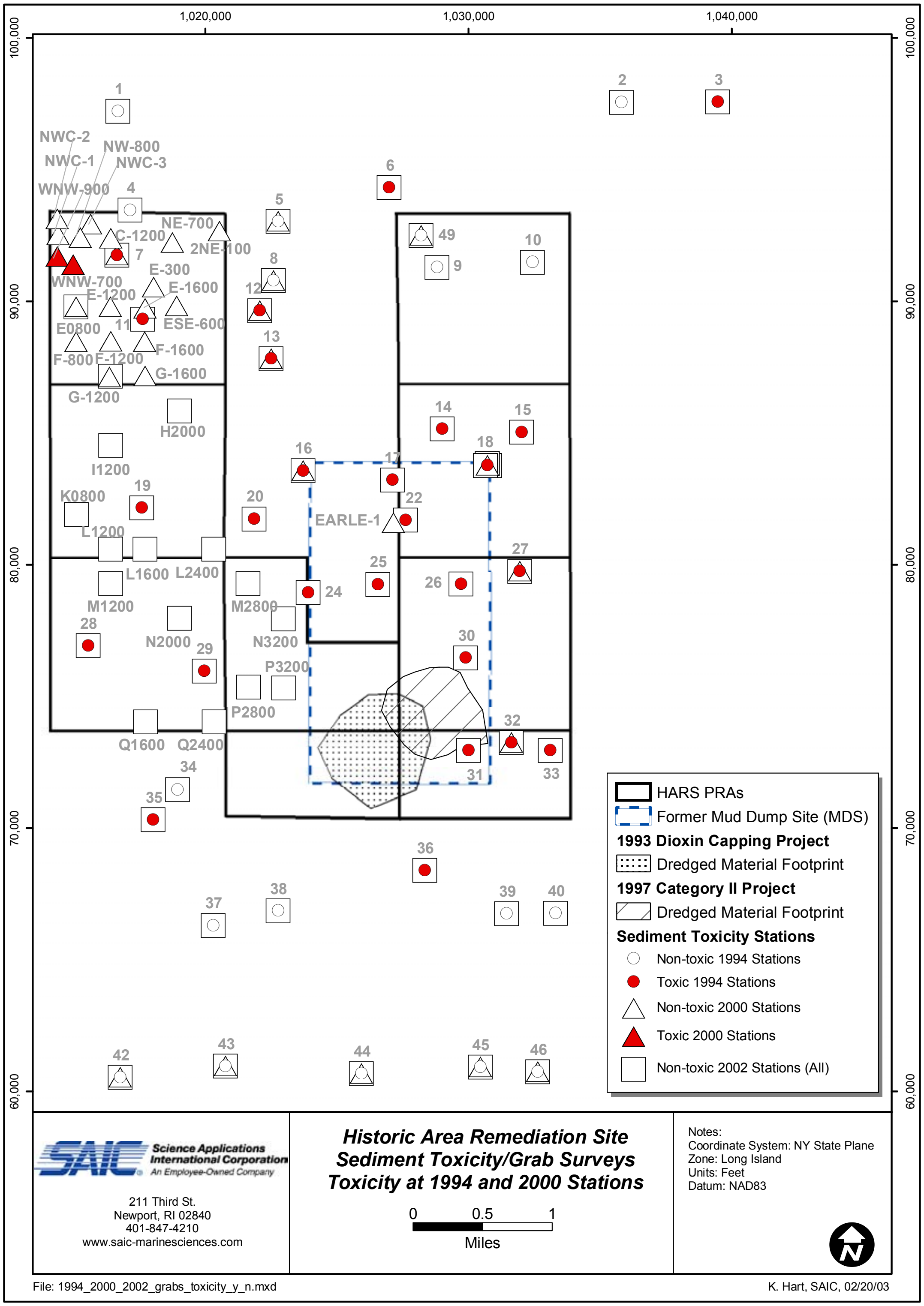


Figure 3.1-4. Map of toxicity at the 1994, 2000, and 2002 sediment toxicity grab stations in and around the HARS

Table 3.2-1.
Grain Size Results for the 60 Primary Sediment Toxicity Stations Sampled in the 2002 Survey

Sample ID	Gravel (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	USCS Classification[1]
Sieve Number or Particle Size	#4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm	
1	5.64	14.70	30.17	44.40	1.99	3.10	SP-SC
2	3.61	1.13	4.37	75.44	7.24	8.20	SC-SM
3	1.10	0.18	1.89	63.70	17.13	16.00	SC-SM
4	0.00	0.34	8.69	80.47	5.15	5.35	SP-SC
5	0.00	0.24	7.78	88.63	0.60	2.75	SP
6	23.75	8.27	39.69	25.07	1.11	2.10	SP
7	0.00	0.28	1.95	15.45	45.82	36.50	ML
8	0.00	0.09	14.68	82.86	0.06	2.31	SP
9	0.18	0.50	4.16	66.58	13.58	15.00	SC-SM
10	0.00	0.86	4.12	35.79	33.23	26.00	ML
11	0.29	0.26	0.52	9.56	46.37	43.00	MH
12	0.14	0.11	5.62	90.64	0.26	3.23	SP
13	0.00	0.09	4.36	92.62	0.23	2.71	SP
14	0.21	0.70	1.43	9.47	50.20	38.00	MH
15	2.18	1.55	4.16	52.12	24.00	16.00	SM
16	0.03	0.13	7.36	90.12	0.21	2.14	SP
17	10.40	3.96	11.17	64.76	2.71	7.00	SP-SC
18	0.00	0.63	0.63	9.07	49.17	40.50	MH
19	0.00	0.00	0.66	4.09	48.75	46.50	MH
20	0.10	0.08	6.50	88.63	0.90	3.79	SP
22	0.00	0.24	1.45	10.57	31.73	56.00	CH
24	3.05	13.43	35.30	17.66	12.06	18.50	SC
25	18.99	15.14	22.27	40.78	0.29	2.52	SP
26	0.06	0.17	10.74	50.31	8.98	29.75	SC
27	0.51	0.44	0.50	6.48	42.07	50.00	CH
28	1.25	0.72	2.35	47.20	23.49	25.00	SC-SM
29	0.00	0.58	1.01	8.32	38.60	51.50	CH
30	0.00	0.58	2.93	43.88	26.61	26.00	ML
31	0.00	0.07	9.26	84.99	1.36	4.32	SP-SC
32	2.71	1.05	9.01	65.45	11.78	10.00	SC-SM
33	39.93	14.33	17.67	16.60	5.72	5.75	SW-SC
34	1.01	2.55	58.51	35.53	0.41	2.00	SP
35	0.21	1.91	64.34	31.56	0.28	1.70	SP
36	0.18	0.30	53.25	43.44	0.12	2.70	SP
37	2.04	4.32	59.98	31.80	0.21	1.65	SP
38	1.42	30.55	42.21	23.55	0.62	1.65	SP
39	0.54	0.68	4.95	91.09	0.39	2.35	SP
40	0.00	0.13	7.85	70.48	10.29	11.25	SC-SM
42	0.32	0.76	5.32	89.19	0.92	3.50	SP
43	0.87	1.55	49.69	45.10	0.19	2.60	SP
44	0.00	0.09	24.99	71.97	0.51	2.45	SP
45	0.00	0.41	39.94	52.20	2.20	5.25	SP-SC
46	2.73	18.66	29.43	22.90	11.78	14.50	SC-SM
49	0.07	0.83	4.55	60.05	22.50	12.00	SM
E0800	13.33	8.98	12.03	10.19	25.98	29.50	CL
G1200	0.00	0.16	0.80	20.28	48.26	30.50	ML
H2000	0.00	0.02	0.87	27.55	47.06	24.50	ML
I1200	0.14	1.03	4.36	2.89	36.58	55.00	CH
K0800	2.09	2.12	7.17	53.55	17.56	17.50	SC-SM
L1200	0.00	0.40	6.28	77.94	7.88	7.50	SC-SM
L1600	0.00	0.13	2.40	6.47	45.51	45.50	MH
L2400	9.32	8.48	44.41	22.42	7.87	7.50	SC-SM
M1200	0.29	2.18	5.32	37.17	30.30	24.75	ML
M2800	0.00	0.13	0.48	3.25	38.13	58.00	CH
N2000	0.88	0.69	2.05	10.16	42.21	44.00	CL
N3200	0.00	1.24	3.38	44.26	31.07	20.05	ML
P2800	3.30	2.91	8.75	31.34	32.21	21.50	ML
P3200	0.00	0.43	1.15	48.55	32.12	17.75	SM
Q1600	0.00	0.51	37.40	55.64	2.96	3.50	SP-SC
Q2400	0.38	0.37	1.60	10.88	38.77	48.00	CL

[1]USCS = Unified Soil Classification Standard (modified from ASTM D-2487)

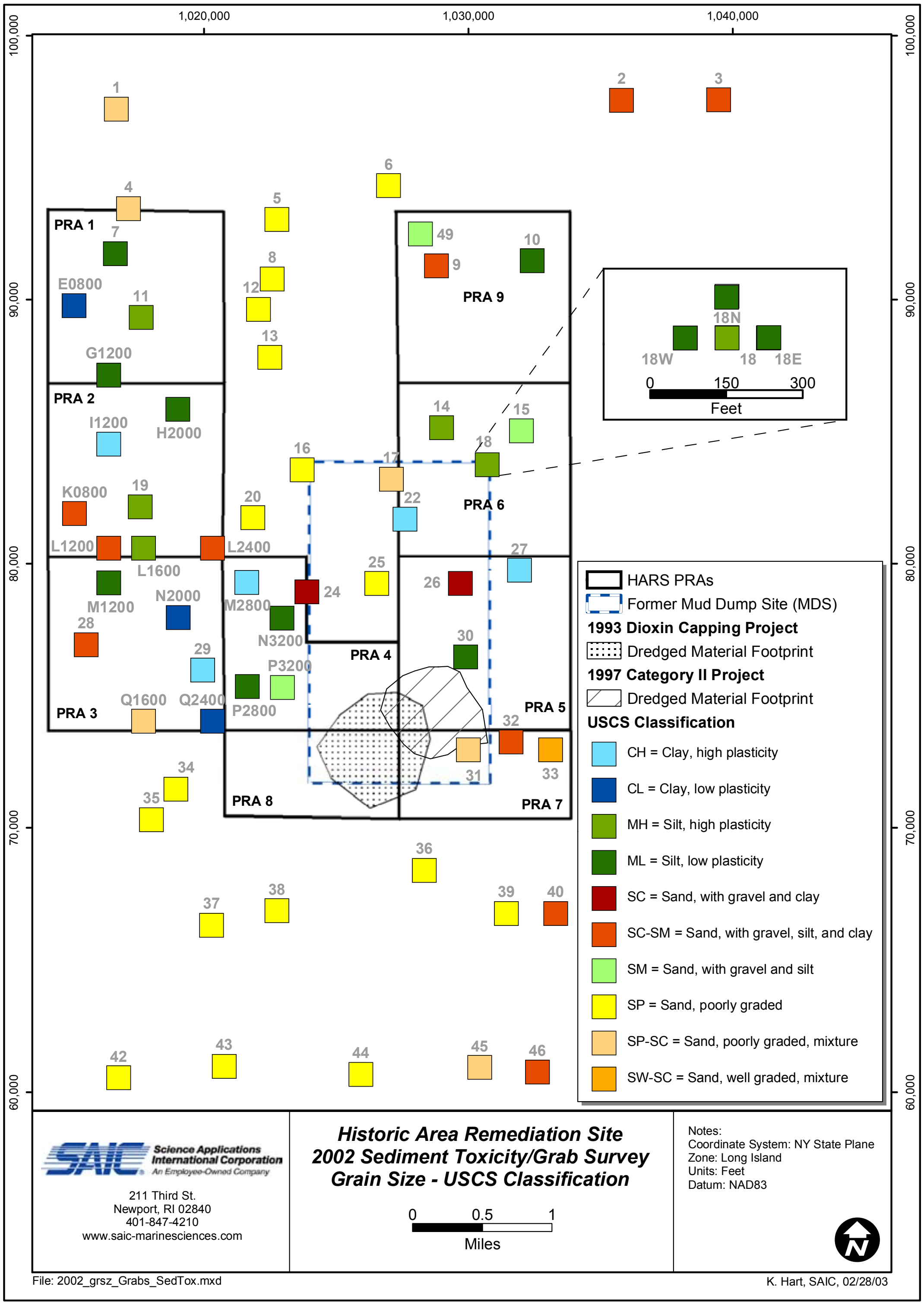


Figure 3.2-1. Map of USCS Classification based on sediment grain size analysis at each of the 2002 sediment toxicity grab stations

Table 3.2-2.
Grain Size Results for Station 18, Sampled for Spatial Variability in the 2002 Survey

Sample ID	Gravel (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	USCS Classification[1]
Sieve Number or Particle Size	#4	#10	#20-#40	#60-#200	0.074-0.005 mm	<0.005 mm	
18 FG*	0.00	0.63	0.63	9.07	49.17	40.50	MH
18 GT	0.00	1.34	1.38	17.66	44.62	35.00	ML
18 GB	0.00	0.11	0.64	12.83	46.42	40.00	ML
18E FG	0.00	0.66	0.89	12.82	49.63	36.00	ML
18E GT	0.00	1.52	1.57	13.78	47.63	35.50	ML
18E GB	0.00	0.00	0.40	7.41	50.19	42.00	MH
18N FG	0.00	0.85	1.18	14.37	48.09	35.50	ML
18N GT	0.00	1.51	0.98	11.41	48.60	37.50	ML
18N GB	0.00	0.02	0.23	7.72	51.02	41.00	MH
18W FG	0.00	1.14	1.42	21.12	43.82	32.50	ML
18W GT	0.00	1.12	1.50	21.47	42.41	33.50	ML
18W GB	0.00	0.16	0.84	16.01	45.99	37.00	ML

*Same as Station 18 in Table 3.2-1

FG= full grab (0 cm to bottom)

GT= grab top (0-4 cm)

GB= grab bottom (4 cm to bottom)

[1]USCS = Unified Soil Classification Standard (modified from ASTM D-2487)

3.3 REMOTS Sediment-Profile and Plan View Imaging Survey

REMOTS sediment-profile and plan view imaging results from the June 2002 survey at the sediment toxicity stations in and around the HARS are presented below. A complete set of REMOTS image analysis results for the surveyed area is provided in Appendix B; these results are summarized in Table 3.3-1.

3.3.1 Dredged Material Distribution and Physical Sediment Characteristics

Analysis of the REMOTS images from the 2002 survey indicated that surface sediments within and surrounding the HARS were very variable in composition, composed of fine-grained historic (i.e., relic) dredged material, fine-grained recent dredged material, ambient sand, or sand over fine-grained relic dredged material. Placement of remediation material in PRAs 1, 2, 3, and 4 has been ongoing since designation of the HARS in September 1997; this material is therefore considered to be "recent" dredged material. Remediation material composed of tan over gray silt was present at the majority of stations within PRAs 1, 2, and 3, and at two stations located in PRA 4 (Figures 3.3-1 and 3.3-2). The thickness of the surface layer of remediation material exceeded the camera prism penetration depth (i.e., imaging depth) at these stations (i.e., denoted by a greater than symbol in Table 3.3-1). Coarser grained remediation material (rocks, cobble, and pebbles) was present at 3 stations (Stations K0800, L1200, and L2400) located primarily in the southern portion of PRA2; this material is likely dredged material from the KVK channel deepening dredging project (Figure 3.3-3).

Fine-grained, older (i.e., relic) dredged material resulting from disposal activities prior to HARS designation in September 1997 was present at 20 of the 63 stations, located primarily in the eastern portion of the HARS in PRAs 5, 6, 7, and 9 (Figure 3.3-1). In addition, relic dredged material was also detected at various stations in PRAs 3 and 4 and at three stations located south of the HARS (Figure 3.3-1). The thickness of the relic dredged material layers exceeded the camera prism penetration depth at these stations.

A layer of fine or coarse sand was present over the underlying relic dredged material at 5 stations (Figure 3.3-4). This sand-over-dredged material stratigraphy is commonly detected within the former MDS and other areas in and around the HARS and is generally presumed to be the result of ambient sand being transported by bottom currents over deposited dredged material. Furthermore, cap sand from the 1997 Category II Capping Project was observed at Station 31; this clean fine sand is assumed to be the cap sand from Ambrose Channel placed within the capping boundary. Lastly, ambient fine sand, often rippled, was observed at a number of stations located primarily in the No Discharge Zone and areas north and south of the HARS, as well as in various replicate images of stations within PRAs 2, 3, and 5 (Figure 3.3-1).

Consistent with the variability in sediment types, a wide range of grain size major modes was observed among the REMOTS stations, ranging from > 4 phi (silt-clay) to < -1 phi (cobble). However, the REMOTS stations were characterized mainly by fine grained sediments (grain size major modes of > 4 and 4 to 3 phi; Table 3.3-1 and Figures 3.3-2 and 3.3-5). Stations characterized by remediation or relic dredged material within PRAs 1, 2, 3, 4, 6, 7, and 9 generally displayed fine-grained sediment (> 4 phi or 4 to 3 phi). Alternatively, sediments

Table 3.3-1.
Summary of REMOTS Sediment-Profile Imaging Results for the Sediment Toxicity Stations, June 2002 Survey

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
1	2 to 1 phi (2)	4.6	0.0	0	0.6	SA.M (2)	ST I (2)	3.9	6.5
10	> 4 phi (2)	14.8	> 14.8	2	0.5	UN.SF (2)	ST I (1), ST II (1)	2.8	6.0
11	> 4 phi (2)	14.6	> 14.6	2	0.6	UN.SF (2)	ST I (2)	2.5	4.0
12	3 to 2 phi (2)	3.2	0.0	0	1.6	SA.F (2)	INDET (1), ST I (1)	6.3	7.0
13	3 to 2 phi (2)	6.1	1.7	1	1.0	SA.F (2)	ST I (2)	4.2	7.0
14	> 4 phi (2)	13.0	> 13.0	2	0.7	UN.SF (2)	ST II on III (1), ST II to III (1)	2.2	8.0
15	> 4 phi (1), 1 to 0 phi (1)	4.2	> 4.2	2	2.2	HR (1), UN.SI (1)	INDET (1), ST I (1)	3.2	6.0
16	3 to 2 phi (2)	2.3	0.0	0	2.4	SA.F (2)	INDET (1), ST I (1)	> 2.3	6.0
17	> 4 phi (2)	11.4	10.3	2	1.5	UN.SI (2)	ST I (1), ST II (1)	1.6	5.0
18	> 4 phi (2)	13.0	> 13.0	2	0.8	UN.SF (2)	ST II (2)	1.7	6.0
19	> 4 phi (2)	19.9	> 19.9	2	0.4	UN.SF (2)	INDET (1), ST I on III (1)	5.3	11.0
2	< -1 phi (1), 4 to 3 phi (1)	1.5	0.0	0	1.6	HR (1), SA.F (1)	INDET (2)	1.3	INDET
20	3 to 2 phi (2)	3.7	0.0	0	1.7	SA.F (2)	ST I (2)	> 3.7	6.5
22	1 to 0 phi (2)	10.4	7.0	2	1.1	SA.G (2)	ST I (2)	4.4	6.0
24	> 4 phi (2)	16.6	> 16.6	2	0.9	UN.SF (2)	ST I (2)	0.5	2.0
25	1 to 0 phi (2)	7.5	> 7.5	2	0.6	SA.G (2)	ST I (2)	5.4	7.0
26	3 to 2 phi (2)	2.7	> 2.7	2	2.6	SA.F (2)	ST I (2)	2.3	5.0
27	> 4 phi (2)	14.2	> 14.2	2	1.0	UN.SF (2)	ST II (1), ST II on III (1)	1.2	6.5
28	4 to 3 phi (1)	5.2	> 5.2	1	0.2	UN.SI (1)	ST I (1)	1.5	3.0
29	> 4 phi (2)	16.3	> 16.3	2	0.4	UN.SF (2)	INDET (1), ST I on III (1)	1.3	7.0
3	> 4 phi (1)	8.1	0.0	0	0.7	UN.SI (1)	ST II (1)	2.7	7.0
30	> 4 phi (1), 3 to 2 phi (1)	4.7	3.2	1	1.1	SA.F (1), UN.SS (1)	ST I on III (1), ST II (1)	2.3	7.5
31	3 to 2 phi (2)	4.8	0.0	0	1.7	SA.F (2)	ST I (2)	> 4.8	7.0
32	4 to 3 phi (2)	7.5	> 7.5	2	1.4	SA.F (1), UN.SS (1)	ST II (2)	3.1	7.5
33	> 4 phi (2)	12.6	> 12.6	2	1.0	UN.SF (2)	ST I (1), ST I on III (1)	1.2	5.5
34	2 to 1 phi (2)	4.5	0.0	0	1.9	SA.M (2)	ST I (2)	> 4.5	7.0
35	2 to 1 phi (2)	5.0	0.0	0	0.8	SA.M (2)	ST I (2)	> 5.0	7.0
36	> 4 phi (1), 4 to 3 phi (1)	6.6	> 4.5	1	0.5	UN.SI (1), UN.SS (1)	ST I (1), ST I on III (1)	2.2	6.5
37	2 to 1 phi (2)	4.8	0.0	0	1.8	SA.M (2)	ST I (2)	> 4.8	7.0
38	1 to 0 phi (2)	5.9	0.0	0	0.6	SA.G (2)	ST I (2)	> 5.9	7.0
39	3 to 2 phi (2)	4.5	0.0	0	1.1	SA.F (2)	ST I (1), ST II (1)	> 4.5	8.0

Table 3.3-1. (continued)

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
4	3 to 2 phi (2)	3.3	0.0	0	1.5	SA.F (2)	ST I (1), ST II (1)	2.0	5.0
40	> 4 phi (1), 4 to 3 phi (1)	8.4	> 8.4	2	1.5	UN.SI (2)	ST II (1), ST II on III (1)	3.1	8.5
42	3 to 2 phi (2)	4.3	0.0	0	1.2	SA.F (2)	ST I (2)	> 4.3	7.0
43	3 to 2 phi (2)	5.7	0.0	0	0.7	SA.F (2)	ST I (2)	4.2	6.5
44	3 to 2 phi (2)	3.2	0.0	0	1.3	SA.F (2)	ST I (2)	2.8	5.5
45	4 to 3 phi (2)	11.6	3.2	2	0.7	UN.SS (2)	ST II (2)	3.0	8.0
46	> 4 phi (2)	13.0	> 13.0	2	0.6	UN.SI (2)	ST I (1), ST II on III (1)	1.8	6.0
49	> 4 phi (1), 4 to 3 phi (1)	7.1	> 7.1	2	1.1	UN.SI (1), UN.SS (1)	ST I (1), ST I on III (1)	1.9	6.5
5	3 to 2 phi (2)	4.7	0.0	0	2.3	SA.F (2)	ST I (2)	> 4.7	7.0
6	3 to 2 phi (2)	7.8	1.6	1	1.5	SA.F (2)	ST I (2)	4.6	7.0
7	> 4 phi (2)	9.4	> 9.4	2	0.3	UN.SI (2)	ST II (2)	2.3	6.5
8	2 to 1 phi (1), 3 to 2 phi (1)	5.5	0.0	0	1.9	SA.F (1), SA.M (1)	ST I (2)	> 5.5	7.0
9	> 4 phi (2)	10.5	> 10.5	2	0.5	UN.SI (2)	ST II (1), ST II to III (1)	2.0	6.5
E0800	> 4 phi (2)	16.4	> 16.4	2	0.5	UN.SF (2)	ST I (2)	2.7	5.0
G1200	> 4 phi (2)	13.8	> 13.8	2	0.6	UN.SF (2)	ST I (2)	2.1	4.5
H2000	> 4 phi (2)	14.3	> 14.3	2	0.4	UN.SF (2)	ST I on III (2)	3.3	10.0
I1200	> 4 phi (2)	20.6	> 20.3	2	0.1	UN.SF (2)	INDET (2)	INDET	INDET
K0800	1 to 0 phi (1), 4 to 3 phi (1)	0.5	> 0.5	2	1.4	HR (1), UN.SS (1)	INDET (2)	INDET	INDET
L1200	< -1 phi (2)	1.0	0.0	0	2.2	HR (2)	INDET (2)	INDET	INDET
L1600	> 4 phi (2)	15.3	> 15.3	2	0.8	UN.SF (2)	ST I on III (1), ST II (1)	4.0	9.5
L2400	< -1 phi (1), 1 to 0 phi (1)	3.1	> 0.0	1	0.3	HR (1), SA.G (1)	INDET (1), ST I (1)	6.2	7.0
M1200	1 to 0 phi (1), 4 to 3 phi (1)	1.9	> 1.92	2	2.6	HR (1), SA.F (1)	INDET (1), ST I (1)	1.8	4.0
M2800	> 4 phi (2)	20.2	> 20.2	2	0.3	UN.SF (2)	INDET (2)	INDET	INDET
N2000	> 4 phi (2)	17.8	> 17.8	2	0.8	UN.SF (2)	ST I (1), ST III (1)	0.7	2.0
N3200	> 4 phi (2)	10.1	> 10.1	2	0.7	UN.SI (2)	ST I (2)	3.9	6.5
P2800	> 4 phi (2)	12.7	> 12.7	2	0.4	UN.SF (2)	ST I (1), ST I on III (1)	1.9	6.0
P3200	> 4 phi (2)	10.1	> 10.1	2	0.2	UN.SI (2)	ST I (2)	2.9	5.5
Q1600	2 to 1 phi (2)	4.6	2.4	1	0.6	SA.F (1), UN.SS (1)	ST I (2)	3.6	6.0
Q2400	> 4 phi (2)	16.7	> 16.7	2	0.4	UN.SF (2)	ST I (1), ST I on III (1)	1.7	6.0
AVG		8.8	6.9	1.3	1.0			3.1	6.4
MAX		20.6	> 20.3	2	2.6			6.3	11.0
MIN		0.5	0.0	0	0.1			0.5	2.0

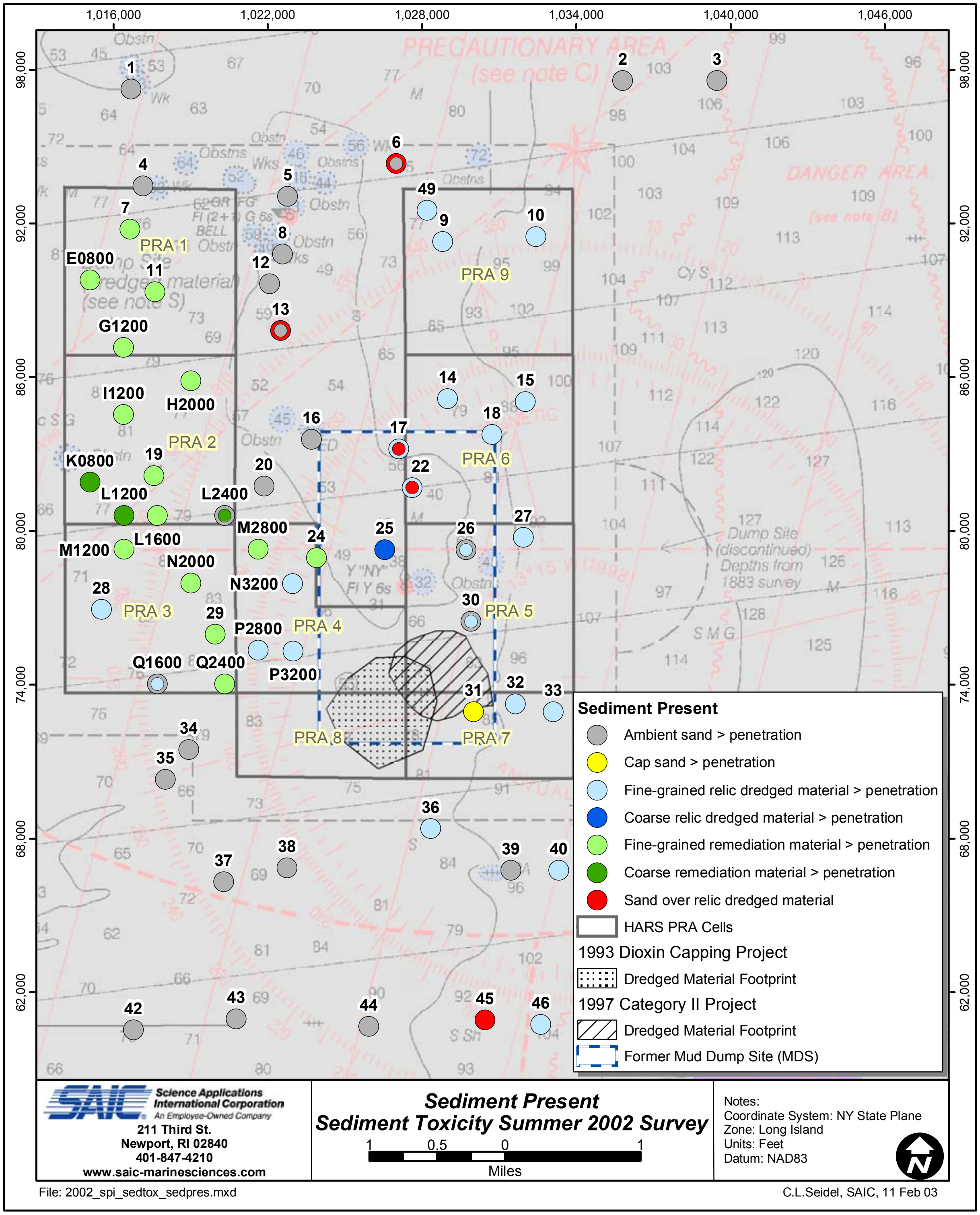


Figure 3.3-1. Map of sediment types observed in the REMOTS images at the 2002 sediment toxicity stations

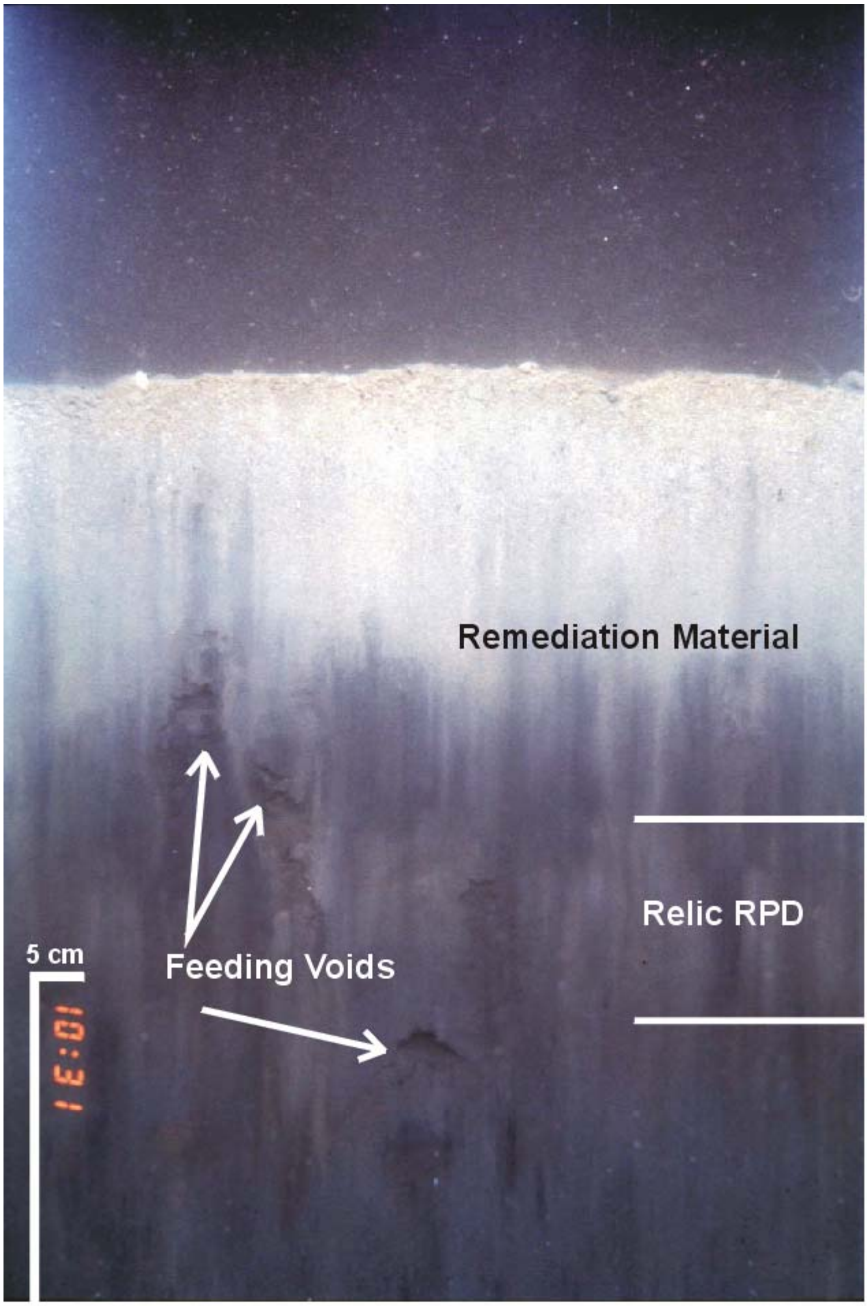


Figure 3.3-2. REMOTS image from Station H2000 in PRA2 showing fine-grained, remediation material extending from the sediment surface to below the imaging depth (i.e., thickness of the remediation material layer is greater than the camera penetration depth). A relic RPD indicative of dredged material layering is visible at depth. A grain size major mode of > 4 phi characterized the majority of stations with remediation or relic dredged material. This is an example of habitat type UN.SF (unconsolidated, soft mud). Active sub-surface feeding voids are also visible in this image.

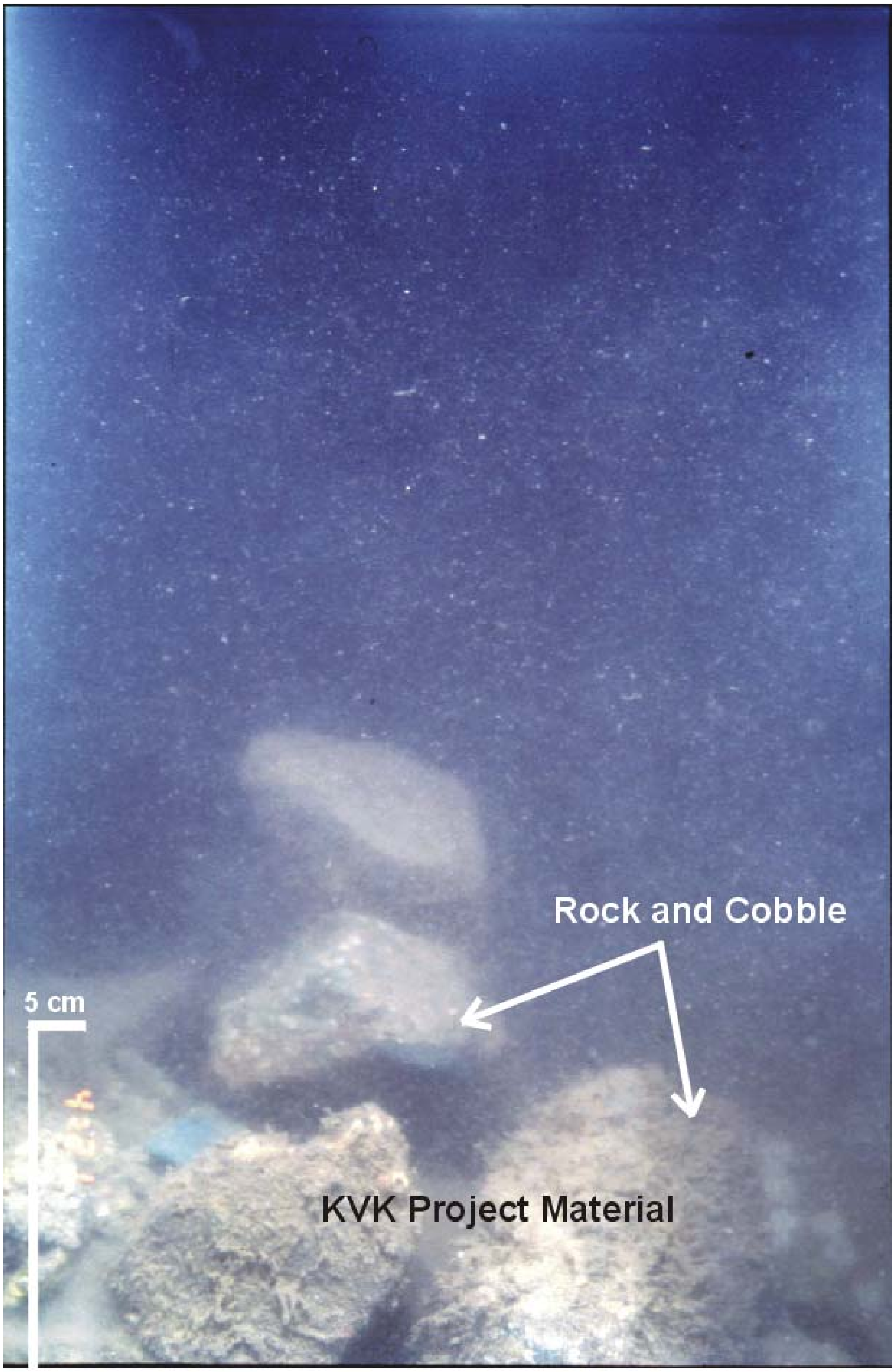
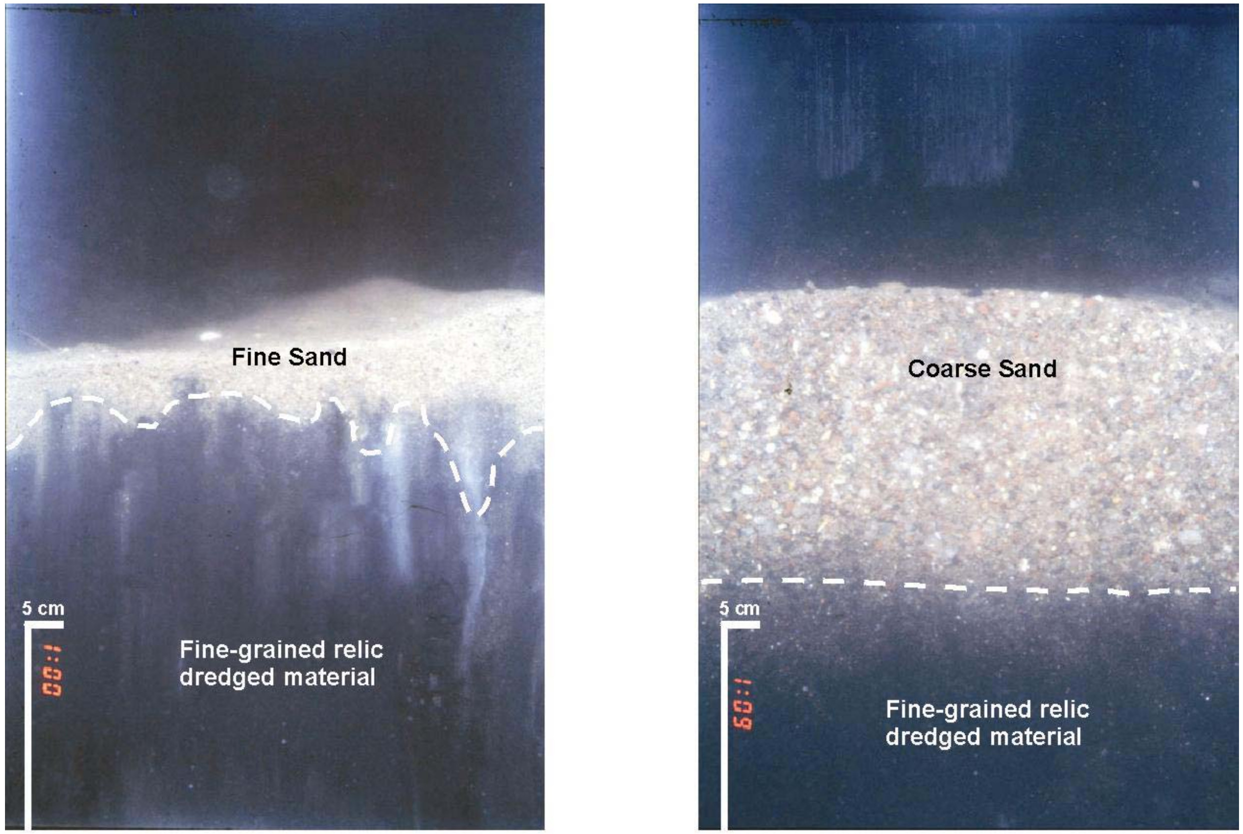


Figure 3.3-3. REMOTS image obtained from Station L1200 located in PRA2 illustrating hard bottom conditions (benthic habitat HR and grain size major mode of < -1phi) resulting from deposition of rock and cobble from the KVK dredging project



A B

Figure 3.3-4. REMOTS images from Stations 17 (A) and 22 (B) illustrating the distinct stratigraphy in which a surface layer of sand overlies black, fine-grained relic dredged material at depth. A thin veneer of light-colored, fine sand is present at the sediment-water interface, overlying the black dredged material in image A, while a layer of coarse sand over fine-grained relic dredged material is present in image B. The dashed line in each image defines the interface between the two layers. This interface is more distinct in the original REMOTS slide but appears somewhat indistinct in these reproduced prints.

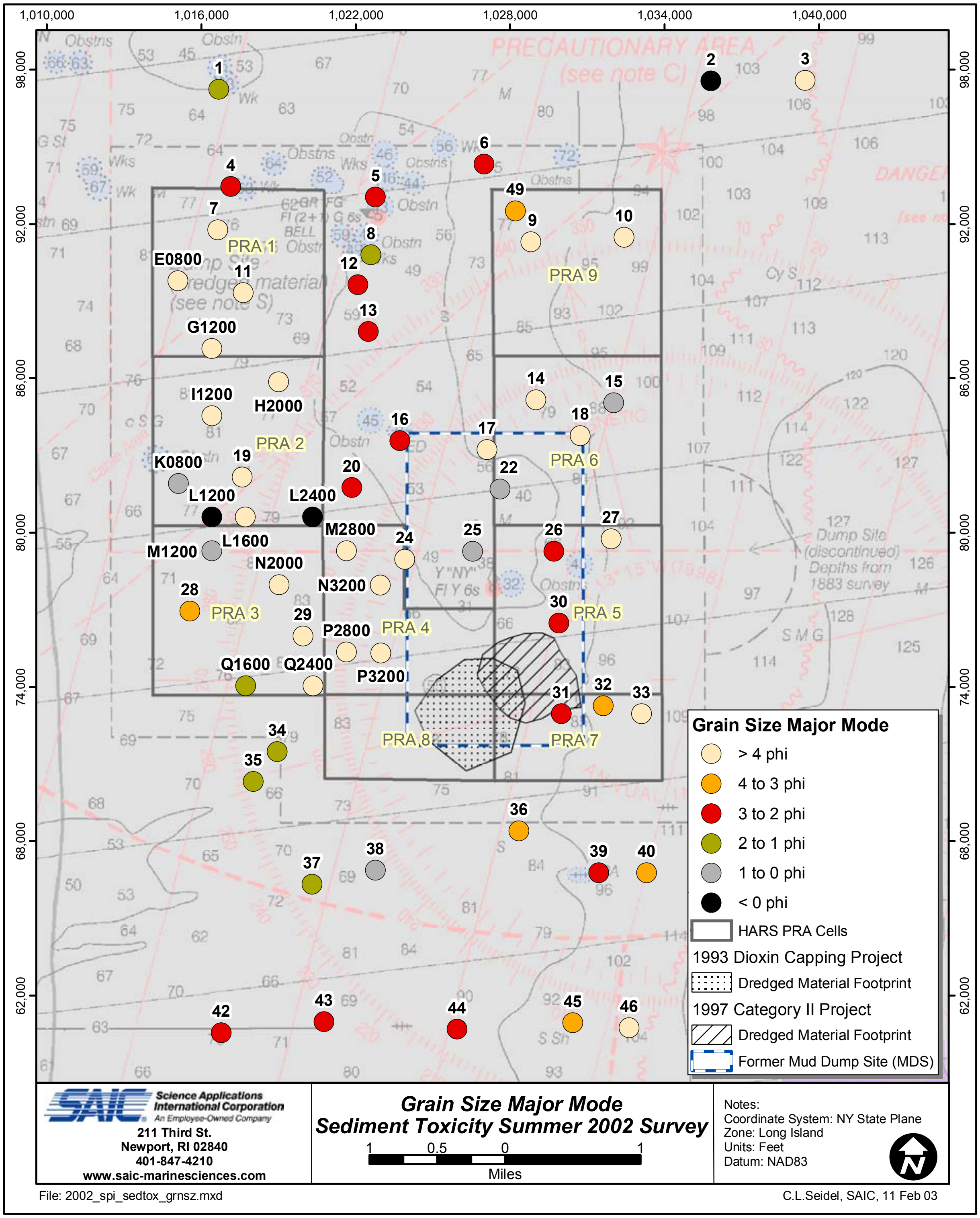


Figure 3.3-5. Map showing the grain size major mode (in phi units) of surface sediments at the sediment toxicity stations over the HARS

composed of rock and cobble (1 to 0 phi and < 0 phi) were found primarily at stations in the southern portion of PRA 2 and the in the northern half of the former MDS (Figure 3.3-5). Fine to medium sand (grain size major modes of 3 to 2 or 2 to 1 phi) were observed predominately at stations with ambient sediment located in the No Discharge Zone, areas north and south of the HARS, and at three stations (Stations 26, 30, and 31) within the eastern portion of the former MDS (Figure 3.3-5).

In general, there was good agreement between the REMOTS grain size results and the grain size analysis of the grab subsamples (Table 3.3-2). Sixty-seven percent (40 of the 60 primary stations) of the results interpreted by REMOTS analysis agreed with the laboratory analytical results from the grab subsamples. Of the 33% that did not agree (20 of the primary stations), only 7 stations differed by more than one phi class. Visually distinguishing between two adjacent phi classes, as performed in the REMOTS image analysis, can be difficult, especially with small grain sizes (i.e., fine sand, silt, or clay). Furthermore, the grab composite subsamples could have sampled layers of sediment with more than one distinctive grain size major mode. A small percentage of REMOTS sediment-profile images showed sand-over-mud stratigraphy, causing difficulty in choosing a single grain size major mode (Table 3.3-2). Finally, the differing grain size results could also be a result of spatial variability on the seafloor. Since variability in grain size was sometimes noted among replicate images from the same REMOTS station, it is likely that such spatial variability could also exist between the grab samples and REMOTS images at a station.

A variety of different benthic habitat types were observed within the surveyed area, however, the primary benthic habitat classifications were very soft mud (habitat type UN.SF) and fine sand (habitat type SA.F), occurring in 31% and 27% of the replicate images, respectively (Table 3.3-1 and Figures 3.3-2, 3.3-6, and 3.3-7). Benthic habitat type UN.SF generally corresponded to stations with either fine-grained relic dredged material or remediation material located within the PRAs, while benthic habitat type SA.F corresponded to stations with ambient sand located primarily outside the HARS boundary. Coarser sand and gravel (benthic habitat type SA.G) or hard rock/gravel bottom conditions (benthic habitat type HR) were mainly detected at stations located in the southern region of PRA2, where KVK project remediation material was deposited, as well as at stations within the former MDS (Figures 3.3-3 and 3.3-6).

The depth of penetration of the REMOTS camera prism can be used to map gradients in the bearing strength (hardness) of the sediment. The penetration depth values have a possible range of 0 to 21 cm (i.e., no penetration to full penetration of the sediment-profile camera prism into the sediment). Freshly deposited, fine-grained sediments or older, highly bioturbated sediments tend to be soft and allow relatively deep penetration, while compacted sands are hard and resist camera prism penetration.

Mean camera prism penetration depth measurements ranged from 0.5 cm at Station K0800 to 20.6 cm at Station I1200, with an overall average of 8.8 cm (Table 3.3-1 and Figure 3.3-8). The wide range of values reflects the wide variety of sediment types found across the surveyed area. Low camera penetration measurements reflect the presence of compact sand or hard bottom

Table 3.3-2.
Comparison of Grain Size Results from REMOTS Visual Analysis
Versus Laboratory Analysis of Grab Subsamples at Stations Sampled in the 2002 Survey

Station	Grain size (phi) observed by REMOTS	Grain size (phi) determined by ASTM Method D-422	Agreement in grain size results	Grain size difference > 1 phi class
1	2 to 1 phi	4 to 2 phi	NO	NO
2	**4 to 3 phi***	4 to 2 phi	YES	NO
3	> 4 phi	4 to 2 phi	NO	NO
4	3 to 2 phi	4 to 2 phi	YES	NO
5	3 to 2 phi	4 to 2 phi	YES	NO
6	3 to 2 phi	2 to 1 phi	NO	NO
7	> 4 phi	> 4 phi	YES	NO
8	3 to 2 phi	4 to 2 phi	YES	NO
9	> 4 phi	4 to 2 phi	NO	NO
10	> 4 phi	4 to 2 phi	NO	NO
11	> 4 phi	> 4 phi	YES	NO
12	3 to 2 phi	4 to 2 phi	YES	NO
13	3 to 2 phi	4 to 2 phi	YES	NO
14	> 4 phi	> 4 phi	YES	NO
15	**> 4 phi***	4 to 2 phi	NO	NO
16	3 to 2 phi	4 to 2 phi	YES	NO
17	> 4 phi	4 to 2 phi	NO	NO
18	> 4 phi	> 4 phi	YES	NO
19	> 4 phi	> 4 phi	YES	NO
20	3 to 2 phi	4 to 2 phi	YES	NO
22	1 to 0 phi	> 4 phi	NO	YES
24	> 4 phi	2 to 1 phi	NO	YES
25	1 to 0 phi	4 to 2 phi	NO	YES
26	3 to 2 phi	4 to 2 phi	YES	NO
27	> 4 phi	> 4 phi	YES	NO
28	4 to 3 phi	4 to 2 phi	YES	NO
29	> 4 phi	> 4 phi	YES	NO
30	3 to 2 phi	4 to 2 phi	YES	NO
31	3 to 2 phi	4 to 2 phi	YES	NO
32	4 to 3 phi	4 to 2 phi	YES	NO
33	> 4 phi	> -1 phi	NO	YES
34	2 to 1 phi	2 to 1 phi	YES	NO
35	2 to 1 phi	2 to 1 phi	YES	NO
36	4 to 3 phi	2 to 1 phi	NO	YES
37	2 to 1 phi	2 to 1 phi	YES	NO
38	1 to 0 phi	2 to 1 phi	NO	NO
39	3 to 2 phi	4 to 2 phi	YES	NO
40	4 to 3 phi	4 to 2 phi	YES	NO
42	3 to 2 phi	4 to 2 phi	YES	NO
43	3 to 2 phi	2 to 1 phi	NO	NO
44	3 to 2 phi	4 to 2 phi	YES	NO
45	4 to 3 phi	4 to 2 phi	YES	NO
46	> 4 phi	2 to 1 phi	NO	YES
49	4 to 3 phi	4 to 2 phi	YES	NO
E0800	> 4 phi	> 4 phi	YES	NO
G1200	> 4 phi	> 4 phi	YES	NO
H2000	> 4 phi	> 4 phi	YES	NO
I1200	> 4 phi	> 4 phi	YES	NO
K0800	**4 to 3 phi***	4 to 2 phi	YES	NO
L1200	< -1 phi	4 to 2 phi	NO	YES
L1600	> 4 phi	> 4 phi	YES	NO
L2400	1 to 0 phi	2 to 1 phi	NO	NO
M1200	**4 to 3 phi***	4 to 2 phi	YES	NO
M2800	> 4 phi	> 4 phi	YES	NO
N2000	> 4 phi	> 4 phi	YES	NO
N3200	> 4 phi	4 to 2 phi	NO	NO
P2800	> 4 phi	> 4 phi	YES	NO
P3200	> 4 phi	4 to 2 phi	NO	NO
Q1600	2 to 1 phi	4 to 2 phi	NO	NO
Q2400	> 4 phi	> 4 phi	YES	NO

***** Station displayed variable grain sizes; other replicate image of the station displayed a very different grain size major mode
Shaded stations indicate stations with a sand over mud stratigraphy

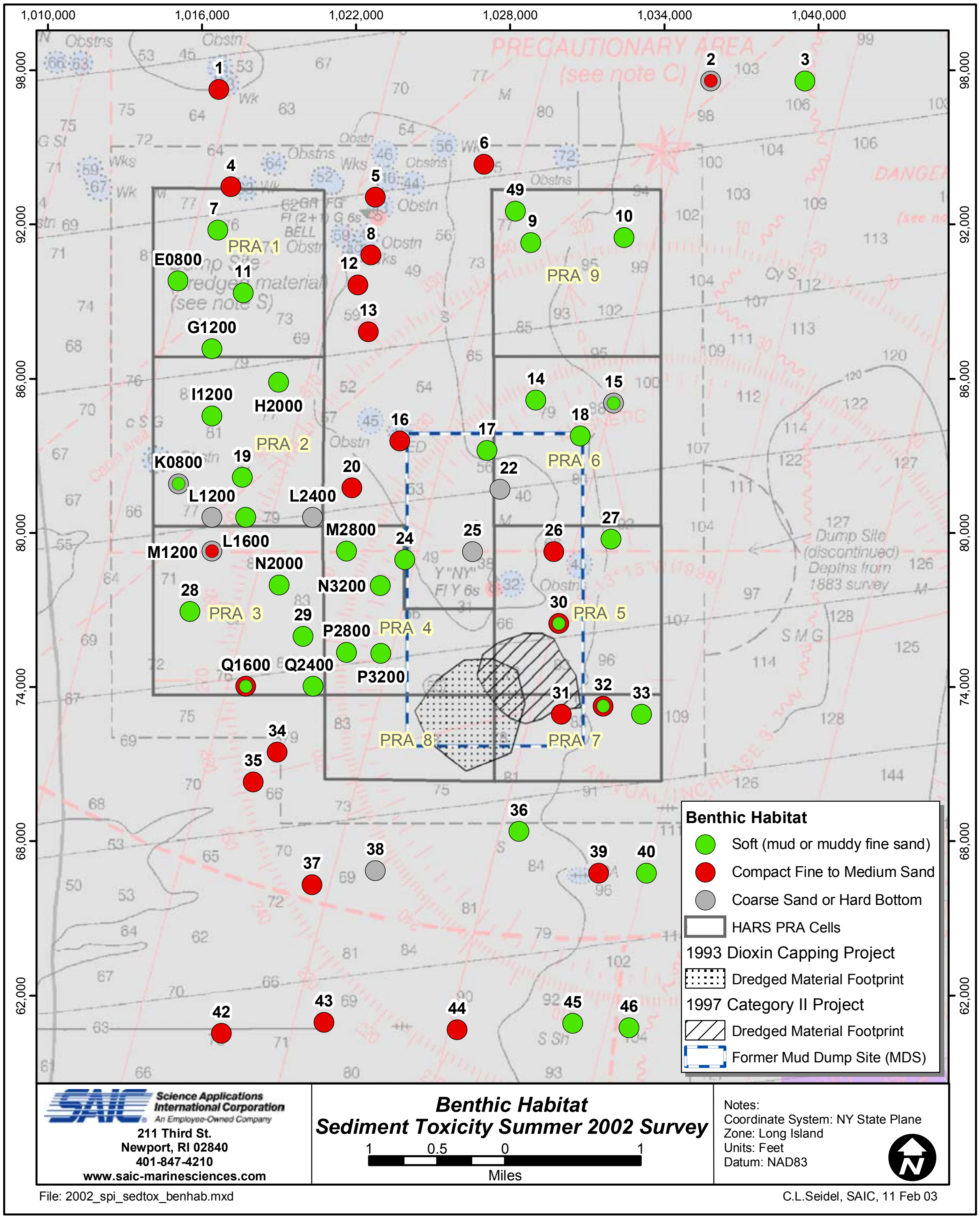
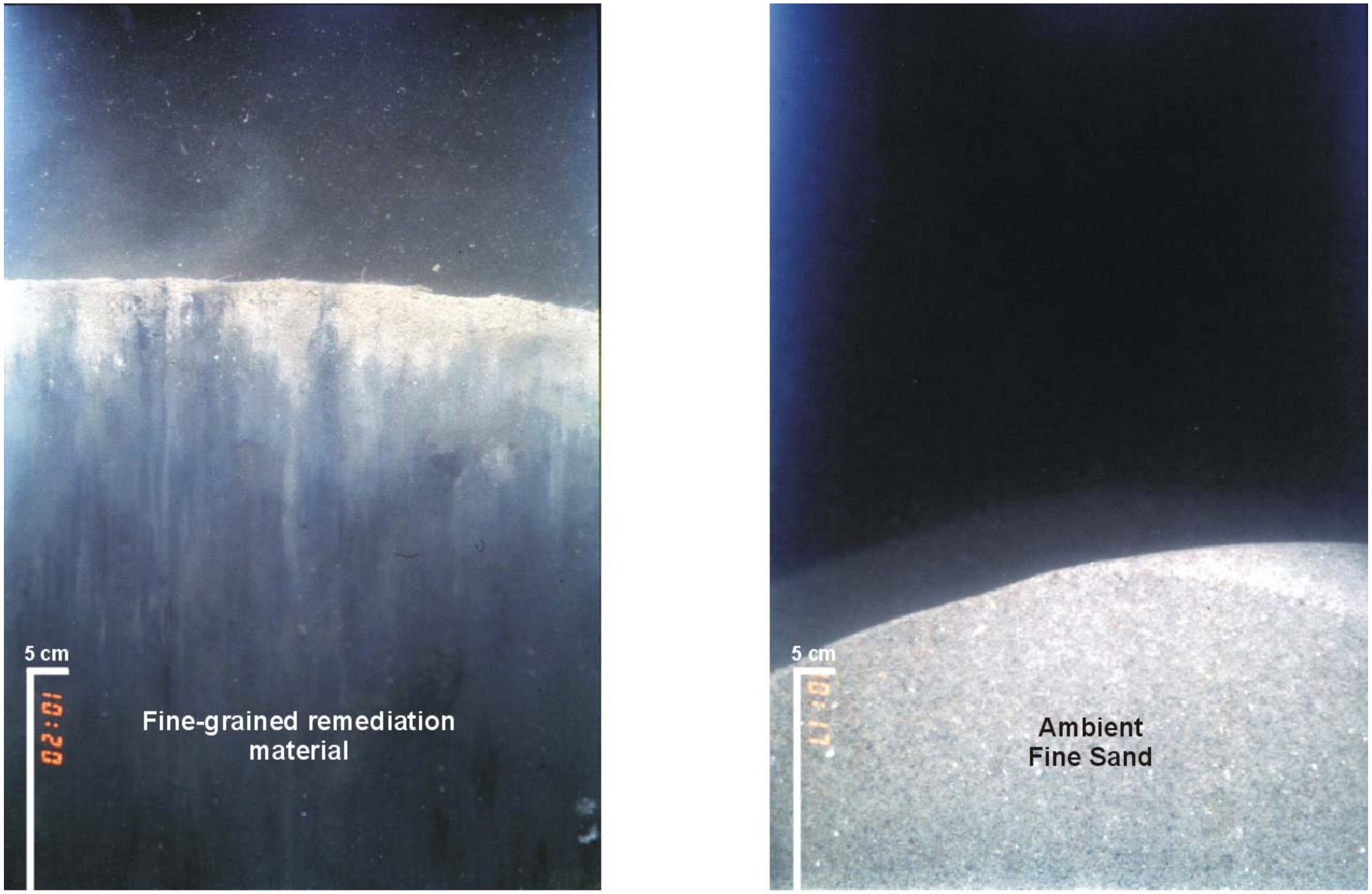


Figure 3.3-6. Map of benthic habitat types observed in the REMOTS images at the sediment toxicity stations. Two colors at a station indicate different habitat types observed in each of the two replicate images.



A B

Figure 3.3-7. REMOTS images collected from Stations G1200 (A) and 12 (B) illustrating the two primary benthic habitat types observed within the surveyed area. Benthic habitat type UN.SF (very soft mud) was observed at Station G1200 characterized by fine-grained remediation material, while benthic habitat type SA.F (fine sand) was observed at Station 12 composed of rippled, homogenous ambient fine sand. The RPD depth extends below the camera's penetration depth in image B (> 6.3 cm).

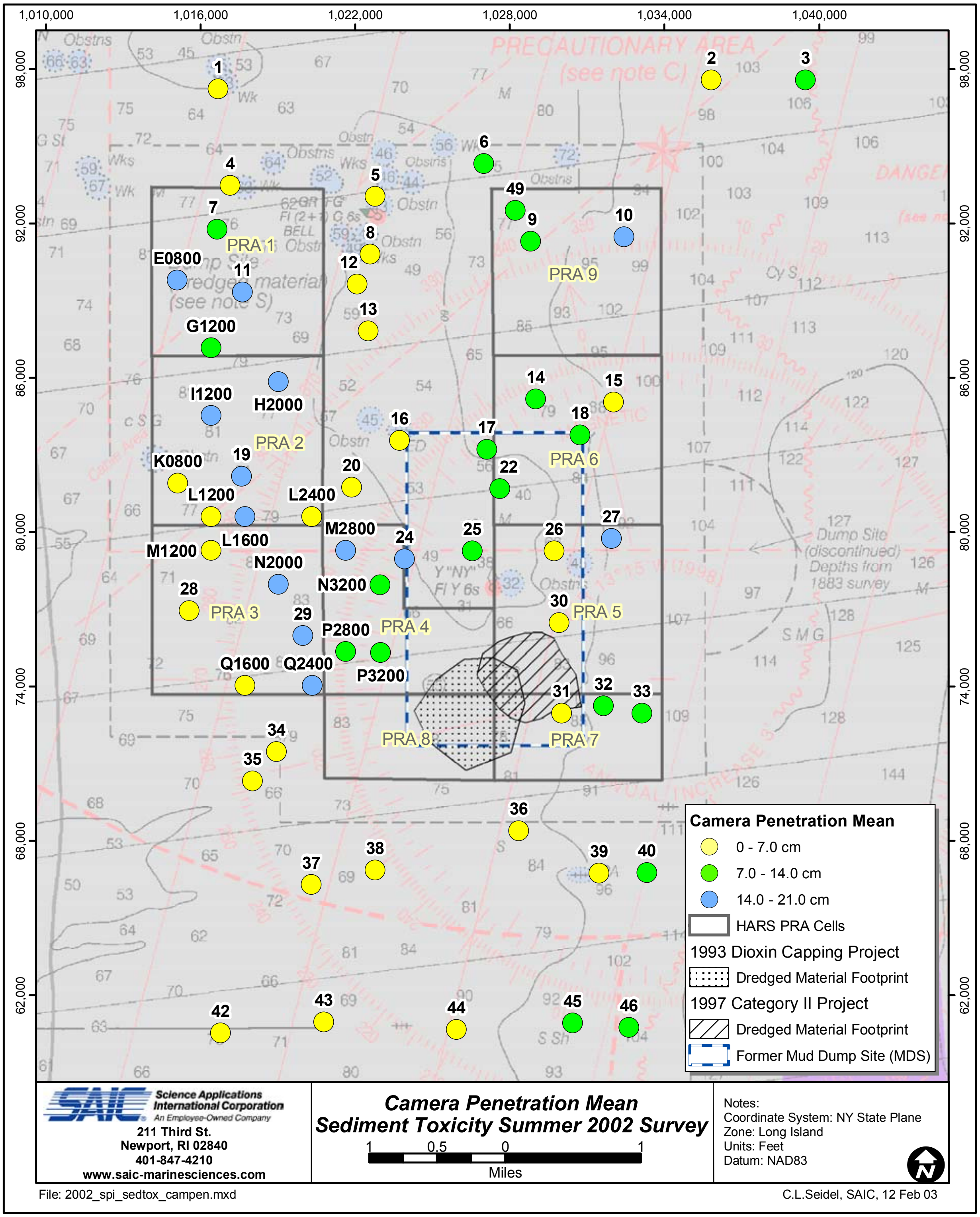


Figure 3.3-8. Map showing the average prism penetration depth at each of the 2002 sediment toxicity REMOTS stations

conditions at various stations that tended to resist deep penetration of the sediment-profile camera. Alternatively, deeper camera penetration measurements generally corresponded to stations displaying either older, softer and/or bioturbated fine-grained dredged material or recent fine-grained remediation material (> 4 phi). Apparent hard bottom conditions (cobble, rock, or compact sand) or very soft unconsolidated sediment (silt-clay) at several stations resulted in under- or over-penetration of the camera prism and prevented the analysis of key parameters (e.g., RPD, successional status, and OSI) in certain replicate images from these stations.

Small-scale boundary roughness values ranged from 0.1 cm at Station I1200 to 2.6 cm at Stations 26 and M1200, with an overall average of 1.0 cm (Table 3.3-1 and Figure 3.3-9). Values in this range reflect minor small-scale surface relief due primarily to physical processes. Surface roughness was attributed to physical factors in 83% of the replicate images (98 of the total 118 images), partly due to bedforms (sand ripples) at the sediment-water interface at several stations (Figure 3.3-10A). The presence of ripples in the well-sorted fine sand of many stations suggests that these sands are subjected to bed-load transport, possibly due to the existing bottom current regime or as a result of elevated waves and currents during periodic high-energy storm events. A small percentage of the replicate images displayed biogenic surface roughness due to the presence of dense polychaetes and amphipod stalks (i.e., "stick amphipods" of the Family Podoceridae), as well as biological surface reworking by burrowing infauna at the sediment-water interface (Figure 3.3-10B). Shell fragments were observed at a number of stations over the surveyed area.

The sediment plan view images supported the results of the REMOTS analysis, showing a combination of sediment types including silts, fine sand, and hard bottom conditions over the surveyed area. Four stations (Stations 1, 16, 29, and 33) did not have an analyzable plan view image due to poor image quality. Sediment plan view images revealed that stations within PRAs 1 through 7 and 9 were dominated by fine-grained sediment. Plan view images from stations within the No Discharge Zone and outside the HARS also showed relatively good agreement with the REMOTS images and confirmed the presence of fine sand or relic dredged material (Figure 3.3-11). In addition, plan view images from stations within the southern portion of PRA 2 and at various stations within the former MDS and outside the HARS also confirmed the presence of hard bottom conditions that were detected within the REMOTS images (Figures 3.3-12, 3.3-13, and 3.3-14). Furthermore, a significant amount of shell material was detected in the plan view images throughout the surveyed area.

Small-scale spatial variability was detected at various stations with respect to grain size and benthic habitat. In particular, the REMOTS image from Station L1200 showed a hard cobble and rock bottom, while the sediment plan view image revealed a relatively soft bottom (silt; Figure 3.3-15). This discrepancy indicates small-scale spatial variability in the sediment in the southern portion of PRA 2, with sediment characterized by both fine and coarse remediation material due to recent (i.e., since September 1997) placement activities.

A number of biological features were detected within the sediment plan view images including starfish, crabs, infaunal burrows, tracks, sand dollars, anemones, polychaete and amphipod tubes, and hydroids (Figures 3.3-15B and 3.3-16). These organisms sometimes appeared in the corresponding REMOTS images (Figures 3.3-11 and 3.3-13).

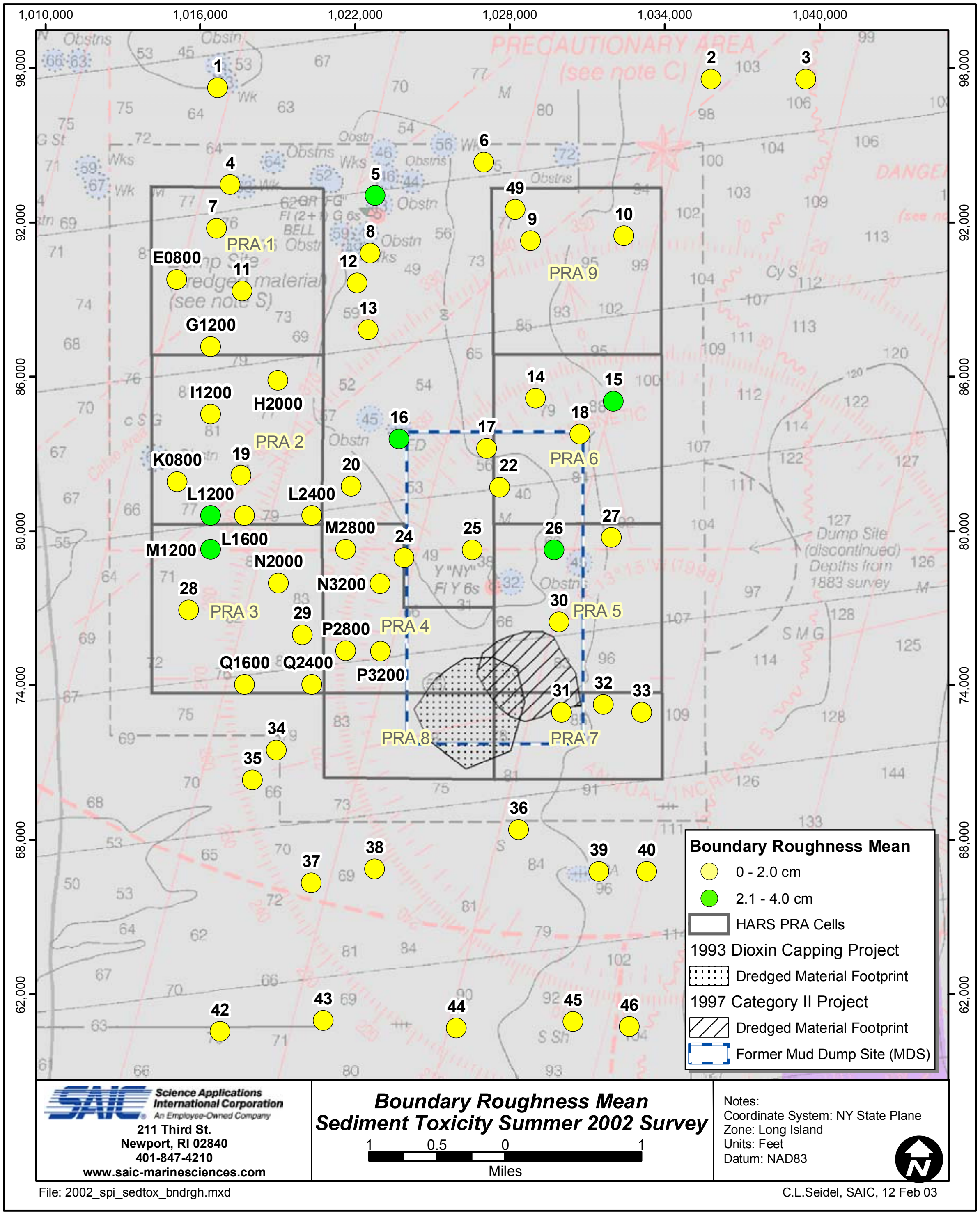
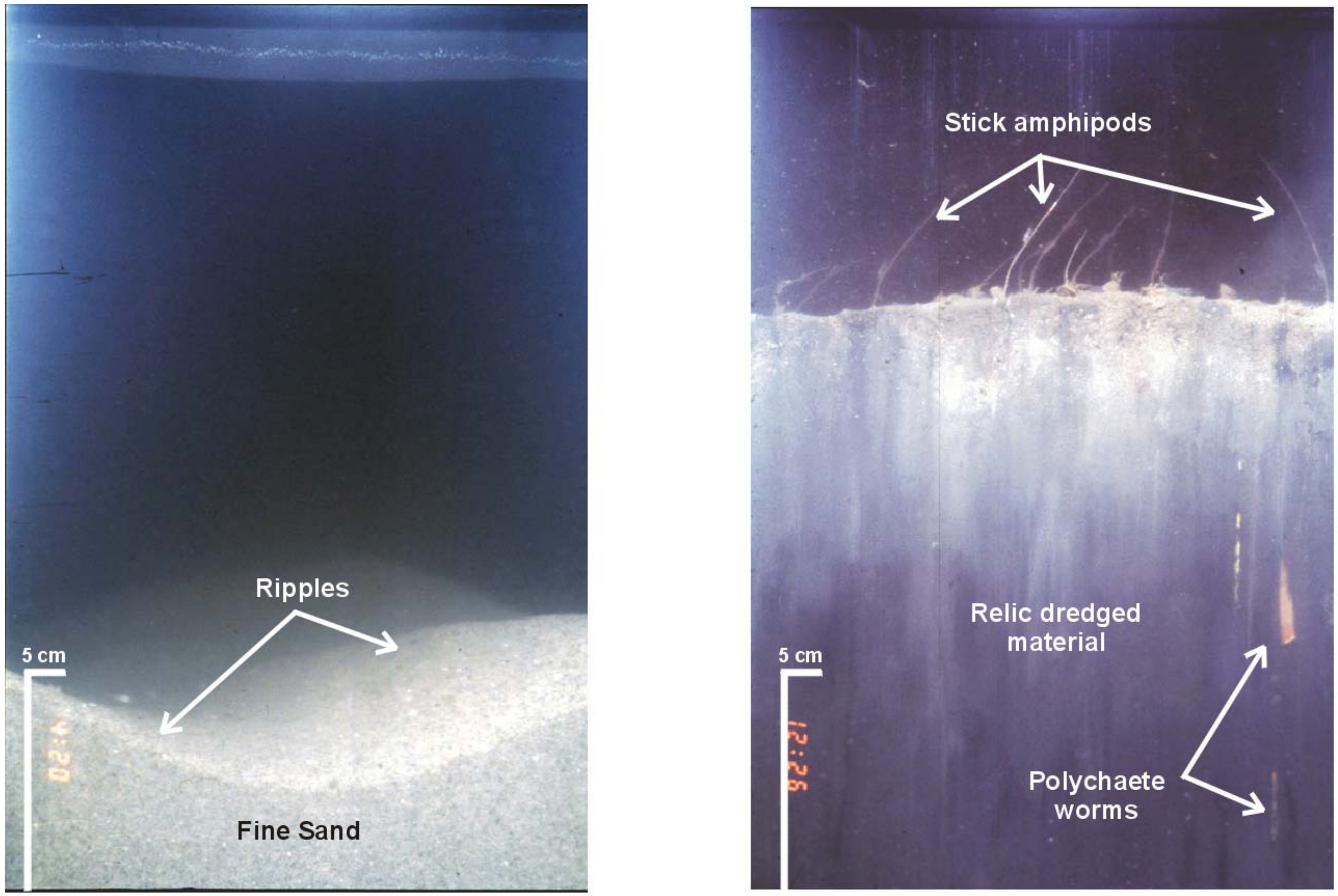


Figure 3.3-9. Map of average small-scale surface boundary roughness values at each of the 2002 sediment toxicity REMOTS stations



A B

Figure 3.3-10. REMOTS images from Stations 16 (A) and 14 (B) illustrating physical and biogenic surface roughness. Image A shows physical surface roughness due to compact, rippled fine sand. Biogenic surface roughness due to the presence of dense stick amphipods (Family Podoceridae) at the sediment-water interface is illustrated in image B. Burrowing polychaete worms are visible at depth in this image.

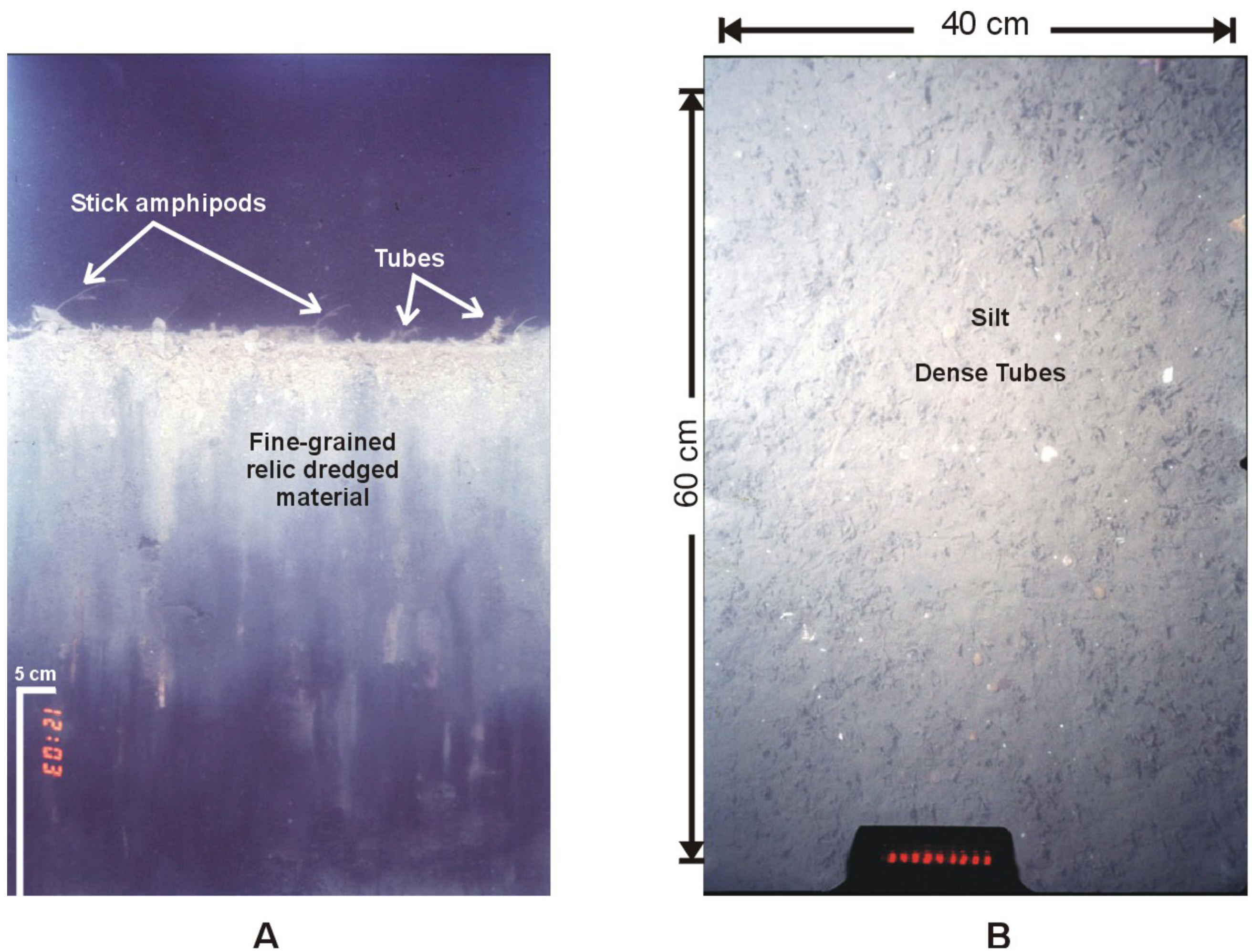
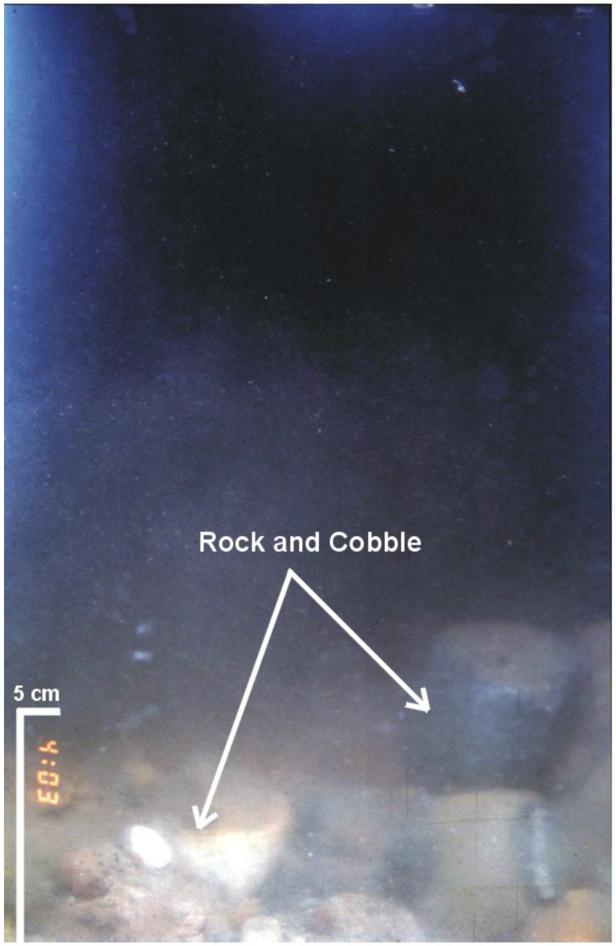
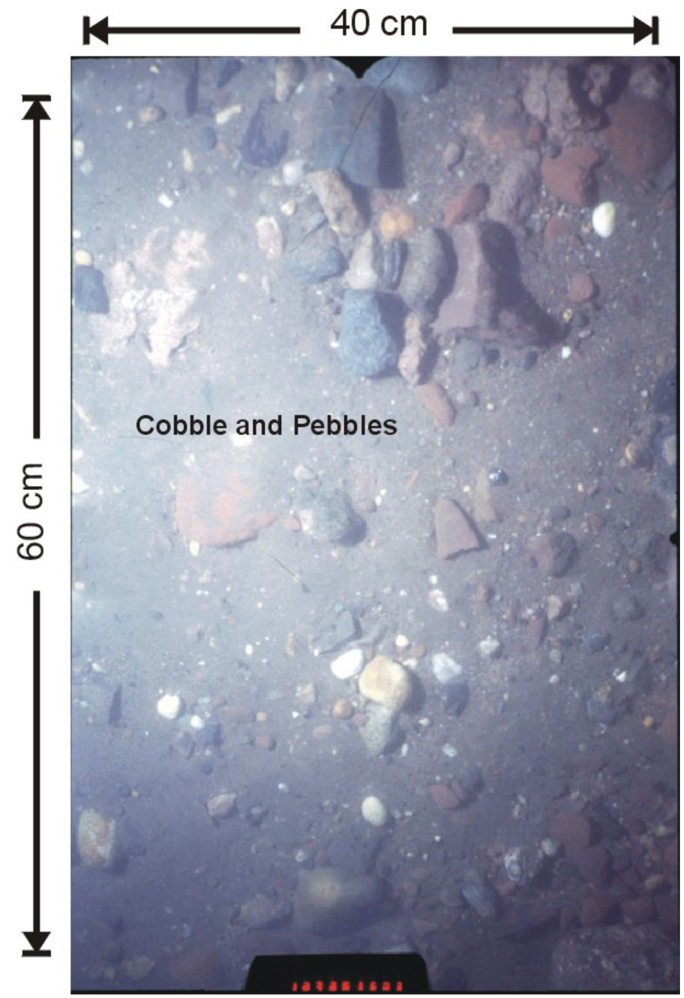


Figure 3.3-11. REMOTS image (A) and corresponding plan view photograph (B) from Station 46 showing agreement in sediment composition. The REMOTS image shows fine-grained relic, black dredged material with surface tubes. A silty bottom with dense tubes is also visible in the plan view photograph.

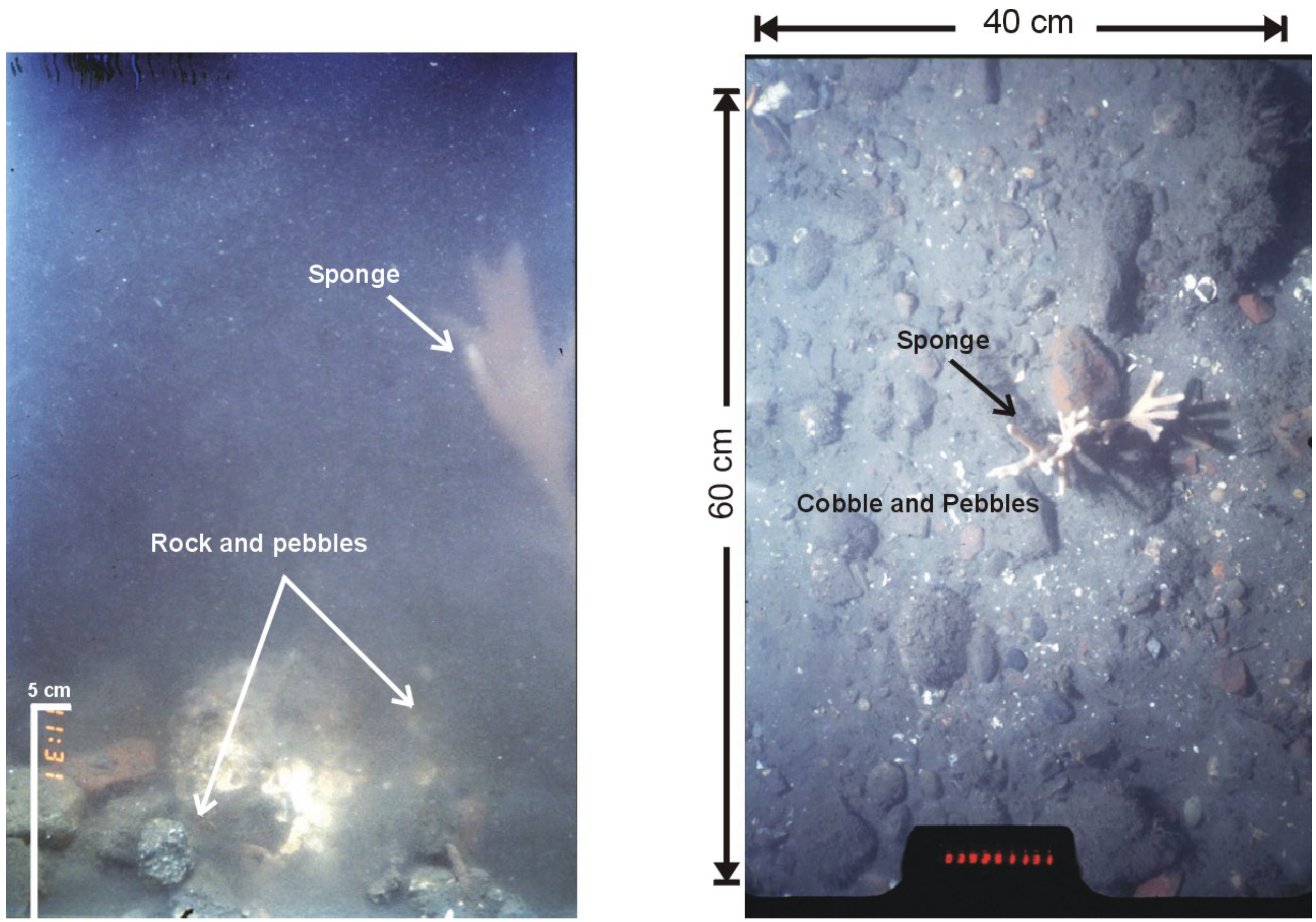


A



B

Figure 3.3-12. REMOTS image (A) and corresponding plan view photograph (B) from Station L2400 located in PRA 2 displaying hard bottom conditions consisting of rock, cobble, and pebble at this station.



A B

Figure 3.3-13. REMOTS image (A) and corresponding plan view photograph (B) from Station 2 located north of the HARS illustrating agreement in sediment composition and biological features. Cobble and pebble in a silty matrix is visible in both images. A sponge (*Alcyonium* sp?) and encrusting epifauna are also detected in both the REMOTS and sediment plan view image.

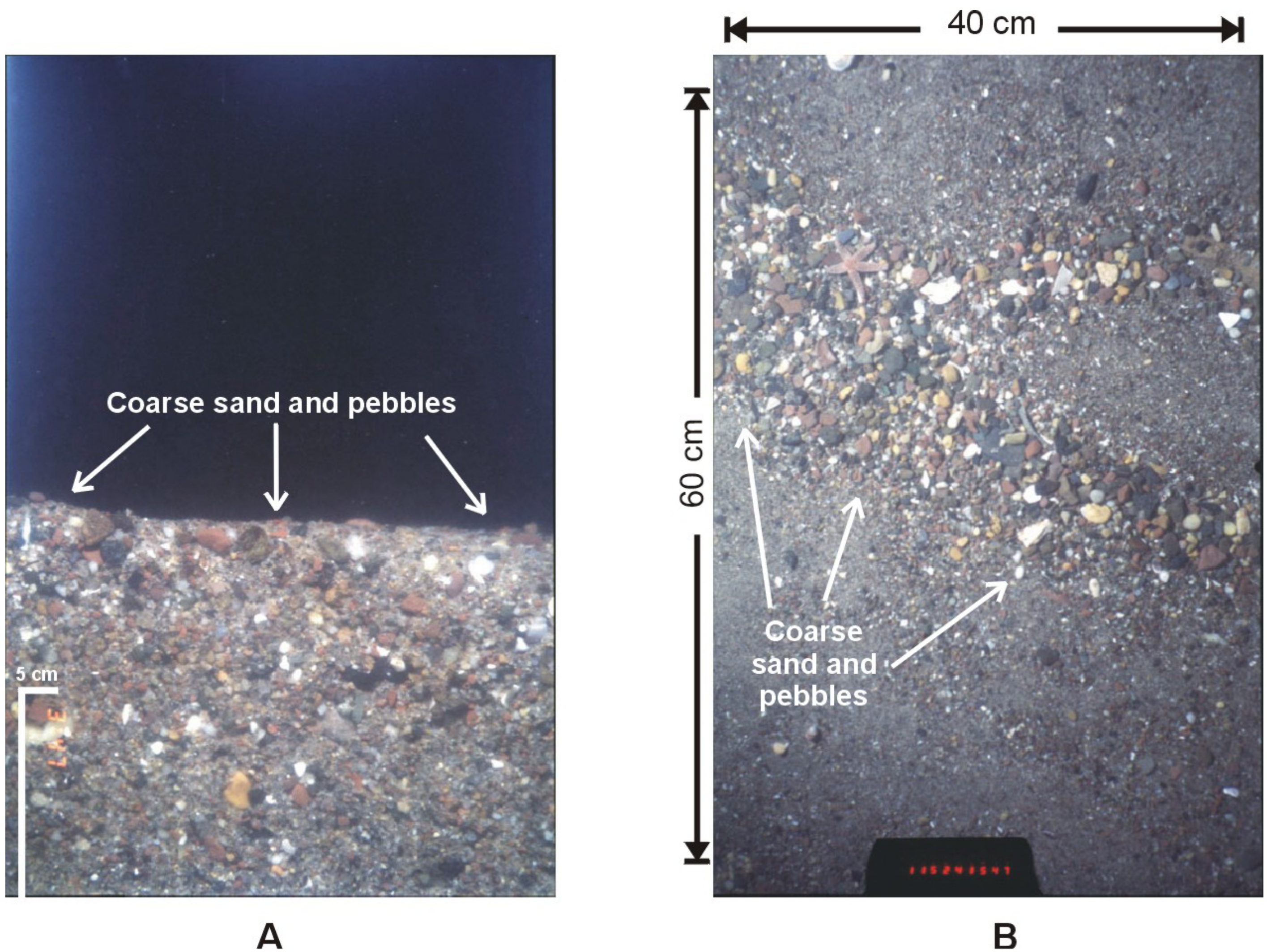


Figure 3.3-14. REMOTS image (A) and corresponding plan view photograph (B) from Station 25 located in the former MDS showing coarse sand and pebbles

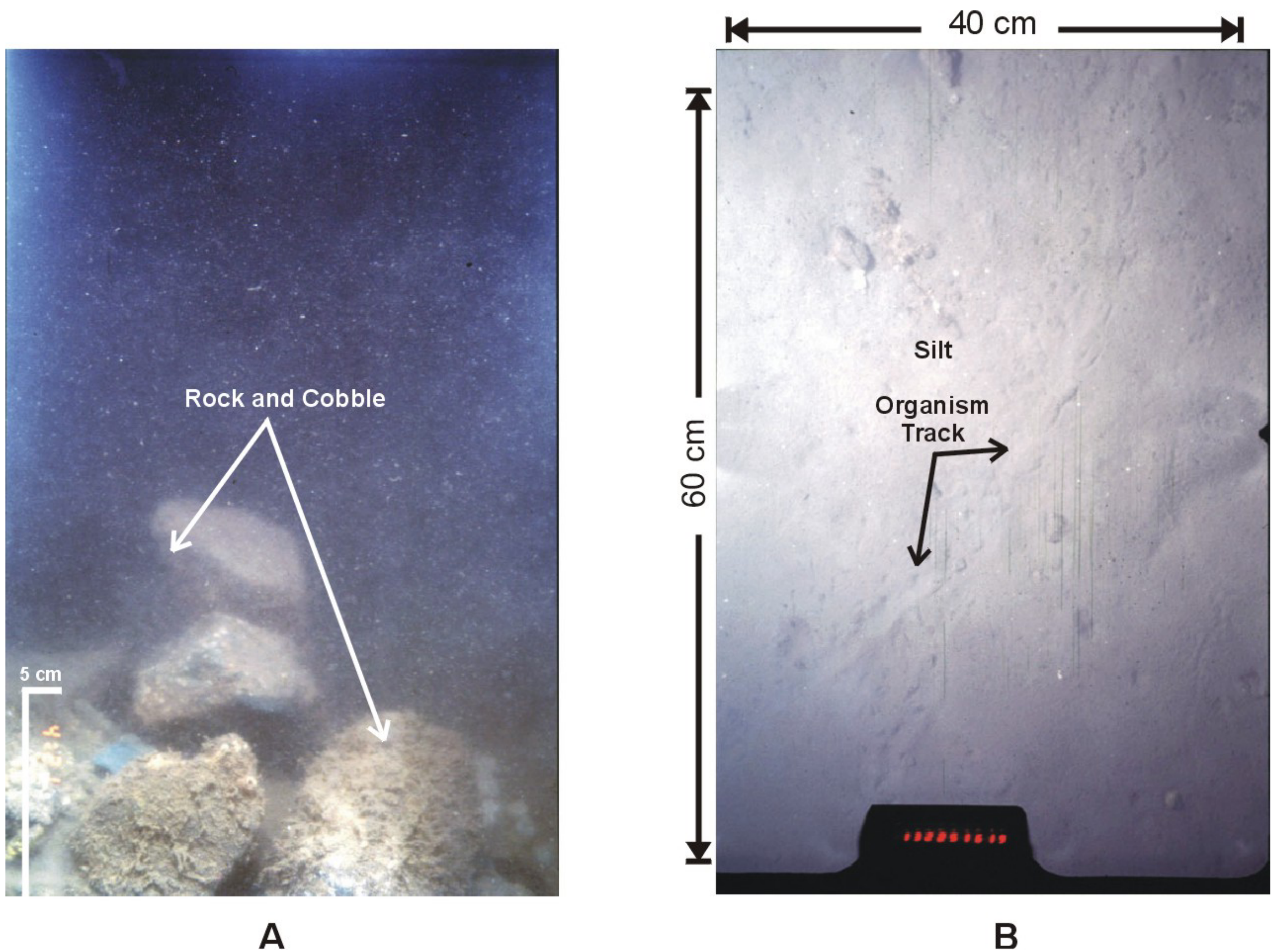


Figure 3.3-15. REMOTS image (A) and corresponding plan view photograph (B) from Station L1200 illustrating within-station variability in sediment types. A hard rock and cobble bottom is present in image A while a soft, silt bottom is detected in image B. An organism track likely from a gastropod is visible at the sediment surface in image B.

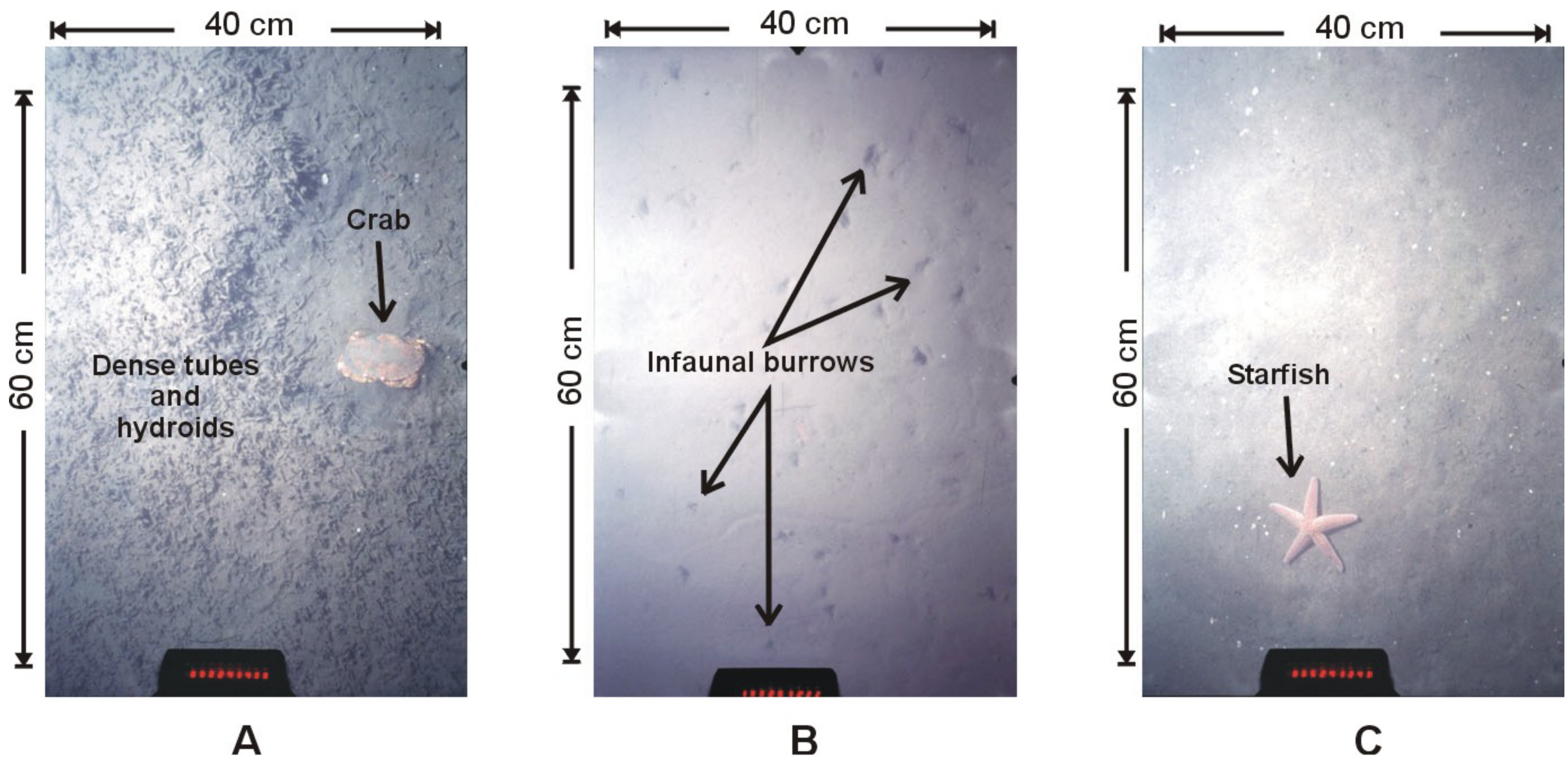


Figure 3.3-16. Three sediment plan view photographs showing a variety of biological features at the sediment surface. Image A shows a crab, a surface tubemat, and encrusting epifauna (hydroids). A number of infaunal burrows are visible in image B, while a starfish is present in image C.

3.3.2 Benthic Recolonization Status and Benthic Habitat Quality

Three REMOTS parameters were used to assess benthic recolonization status and overall benthic habitat quality within the surveyed area: apparent RPD depth, infaunal successional status, and OSI.

A wide variety of different successional stages were observed at the stations over the surveyed area, including Stage I surface-dwelling organisms, Stage II infaunal amphipods, and Stage III head-down, deposit-feeding infauna (Table 3.3-1 and Figure 3.3-17). Stage I pioneering, tubicolous polychaetes occurred alone in 55% of the replicate images (65 of the total 118 images), and represented the highest successional stage present at a number of stations (Figure 3.3-17). Stage I organisms generally occurred at stations characterized by sandy sediments. The dominance of sand and the absence of organic-rich, fine-grained sediment at these stations precludes the establishment of a Stage III community consisting of subsurface deposit feeders. However, a Stage II community consisting of infaunal stick amphipods (Family Podoceridae) was detected at 9 stations (Figures 3.3-17 and 3.3-18). In addition, Stage II shallow-dwelling bivalves (*Nucula* sp.) may have been present at some stations; it was often difficult to distinguish shell fragments from these small bivalves at the sediment-water interface.

Evidence of Stage III head-down, deposit-feeding infauna (active feeding voids in the subsurface sediments) was detected in 15% of the replicate images (Figure 3.3-2). Larger bodied Stage III infauna were observed predominately at stations displaying organic-rich, fine-grained remediation or relic dredged material in PRAs 2 through 7, PRA 9, and at various stations located south of the HARS. When present, Stage III organisms were generally accompanied by either Stage I polychaetes or Stage II stick amphipods at the sediment-water interface (Stage I on III and Stage II on III successional status, respectively; Figure 3.3-19). Five stations were given an indeterminate successional status designation due to hard bottom conditions. Overall, the low frequency of Stage III larger-bodied infauna likely reflects the wide variety of substrates unable to support advanced Stage III taxa (hard sand/gravel bottoms). However, the absence of Stage III organisms in finer grained sediment suggests the successional status was in a continuing process of recovery following past dredged material placement.

The RPD depth provides a measure of the apparent depth of oxygen penetration into the surface sediments and the degree of biogenic sediment mixing. The mean apparent RPD depths at sediment toxicity stations within and surrounding the HARS ranged from 0.5 cm at Station 24 to 6.3 cm at Station 12, with an overall average of 3.1 cm (Table 3.3-1 and Figure 3.3-20). Overall, these are relatively deep RPD depths, which are indicative of well-oxygenated surface sediments. At the sandy stations located outside the remediation areas of the HARS (ambient stations), this oxidation is attributed to physical mixing of the uppermost sediment layer related to periodic bedload movement of the sand. The deepest mean apparent RPD depths occurred at these stations characterized by high reflectance sand and therefore, the RPD depths were often a function of the camera prism penetration depth (i.e., RPD greater than penetration; Figure 3.3-7B). At stations characterized by fine-grained recent and relic dredged material, aeration of the sediment and corresponding increases in the RPD depth are attributed to bioturbation activities of infaunal organisms (Figure 3.3-19).

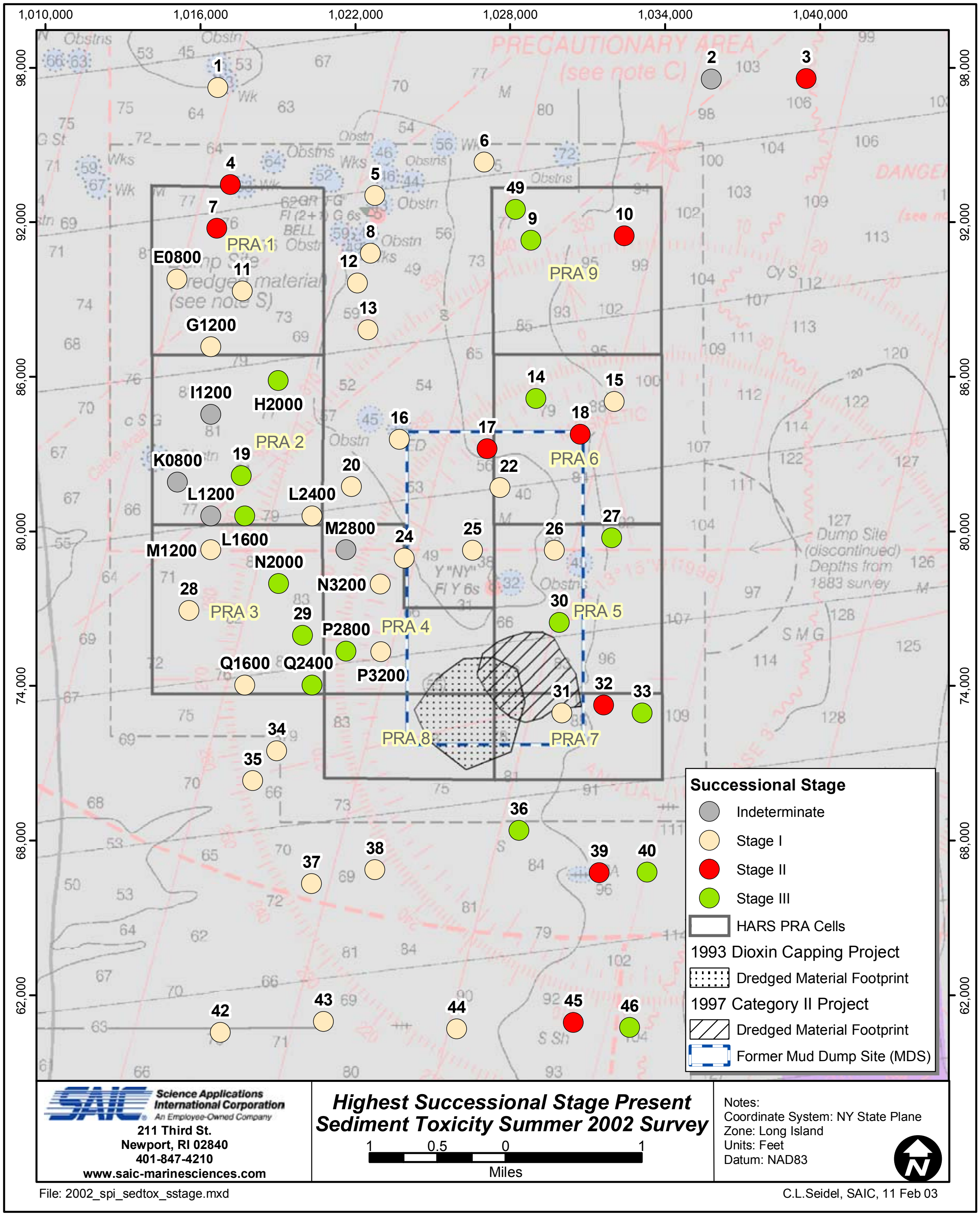


Figure 3.3-17. Map showing the highest successional stage observed for the two replicate images collected at each of the 2002 sediment toxicity REMOTS stations

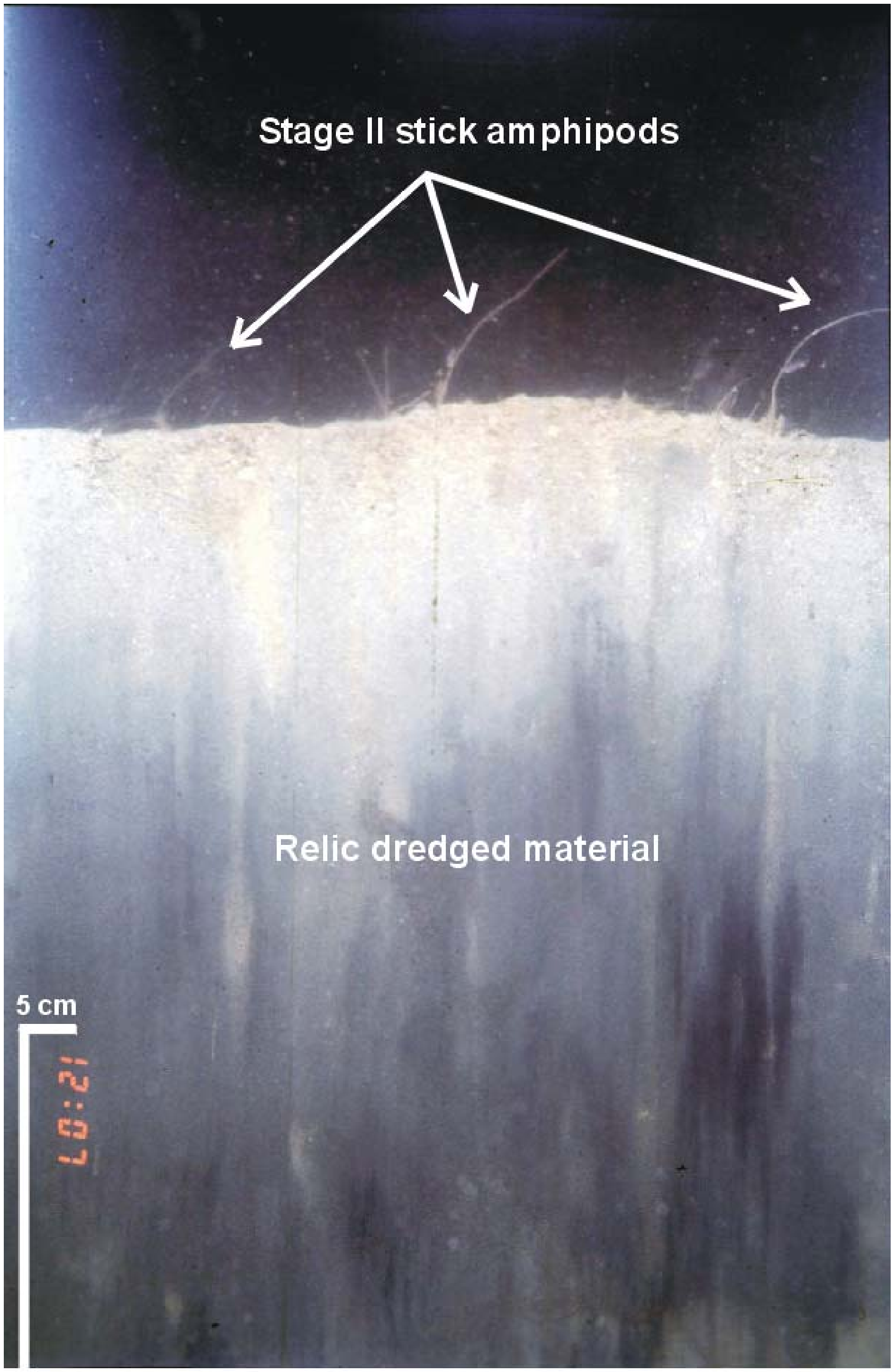
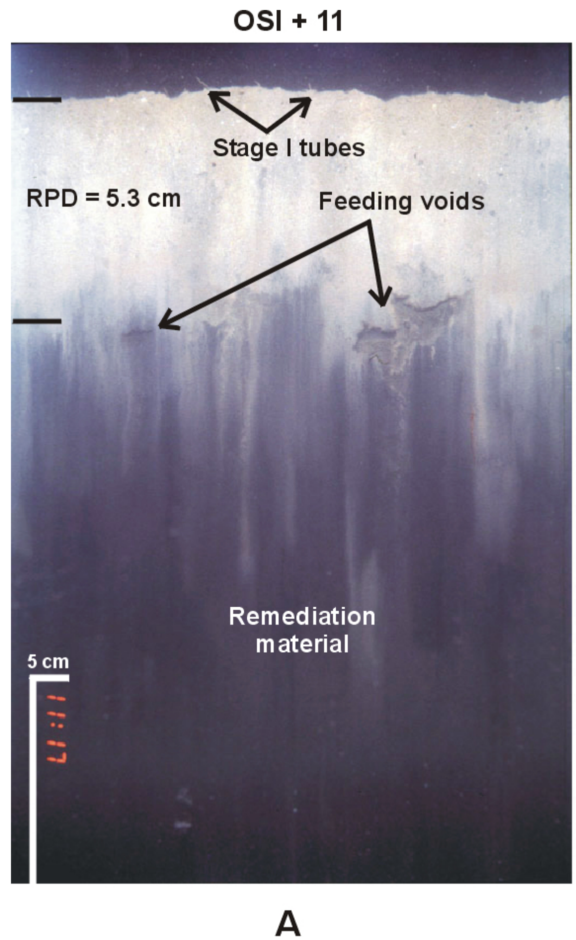


Figure 3.3-18. REMOTS image obtained from Station 10 illustrating a Stage II successional status designation as a result of numerous Stage II stick amphipods (Family Podoceridae) at the sediment-water interface.



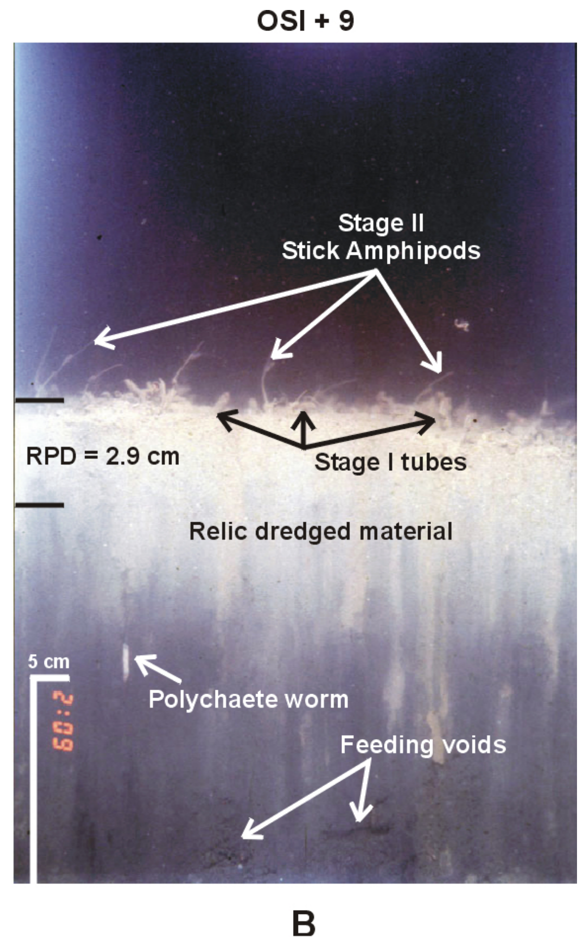


Figure 3.3-19. REMOTS images from Station 19 (A) and 40 (B) illustrating Stage I on III and Stage II on III, respectively. Stage I polychaetes at the sediment-water interface are present over Stage III feeding voids at depth of the remediation material (image A). Numerous Stage II stick amphipods (Family Podoceridae) are visible at the sediment surface, while several small Stage III feeding voids occur at depth within relic dredged material in image B. The presence of these advanced successional stages and well-developed RPD depths resulted in OSI values of +11 and +9 (undisturbed benthic habitat quality) for Stations 19 and 40, respectively.

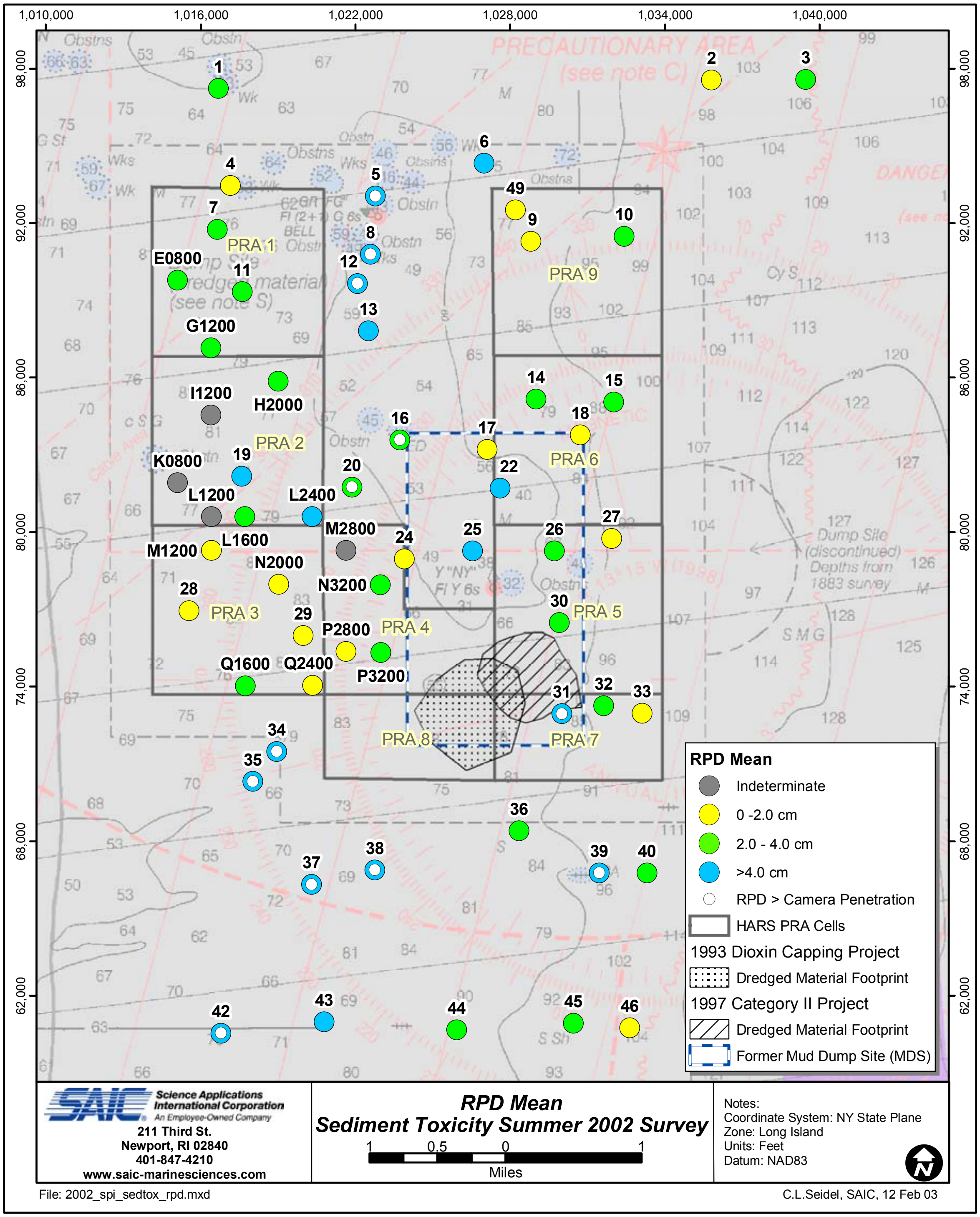


Figure 3.3-20. Map of mean apparent RPD depths at the 2002 sediment toxicity REMOTS stations

Although no evidence of redox rebound intervals was noted in the surficial sediment, a relic RPD (an indicator of sediment layering) was detected at Station H2000 (Figure 3.3-2). Relic RPDs usually occur when a relatively thin layer of dredged material is placed over an older deposit or ambient sediments, and represent the depth of oxygenation in the underlying material prior to being covered by the fresh deposit. A new RPD will be formed at the sediment surface as oxygen is incorporated into the surficial sediments via the bioturbational activity of the benthic infauna.

Although no evidence of low sediment dissolved oxygen conditions was detected in any of the REMOTS images obtained in the June 2002 survey, methane was detected within the sediment at Station 11 located within PRA 1 (Figure 3.3-21). Methane gas bubbles (a product of anaerobic decomposition of organic matter) were observed migrating up to the sediment surface from the underlying sulfidic mud at this station. The presence of very black, sulfidic mud (low reflectance) at depth suggests that the dredged material (recent remediation material) in this area was anoxic at the time of placement, with a high organic matter content.

Mean OSI values for the sediment toxicity stations ranged from +2.0 at Stations 24 and N2000 to +11.0 at Station 19 (Table 3.3-1 and Figure 3.3-22). The overall average of +6.4 is generally indicative of undisturbed or non-degraded benthic habitat quality. Of the 60 stations, 33 stations (55%) displayed mean OSI values > +6.0 (highly colonized or undisturbed). Despite the minimal presence of Stage III organisms, high OSI values were generally found among the sandy stations, due in part to deep mean RPD depths determined in the sand at these stations. However, a number of stations within PRAs 2, 5, 7, and 9 also exhibited high OSI values as a result of advanced Stage III activity and relatively deep RPD depths within the recent or relic dredged material (Figure 3.3-19). In contrast, OSI values indicative of disturbed benthic habitat quality were detected at Stations 24, 28, and N2000 (Figure 3.3-22). Values on the lower end of the scale (≤ +3) occurred at stations with very shallow RPD depths, presence of methane bubbles, and/or no advanced successional stages (Figure 3.3-21). OSI calculations were not possible at five stations due to indeterminate RPD depths and/or successional status.

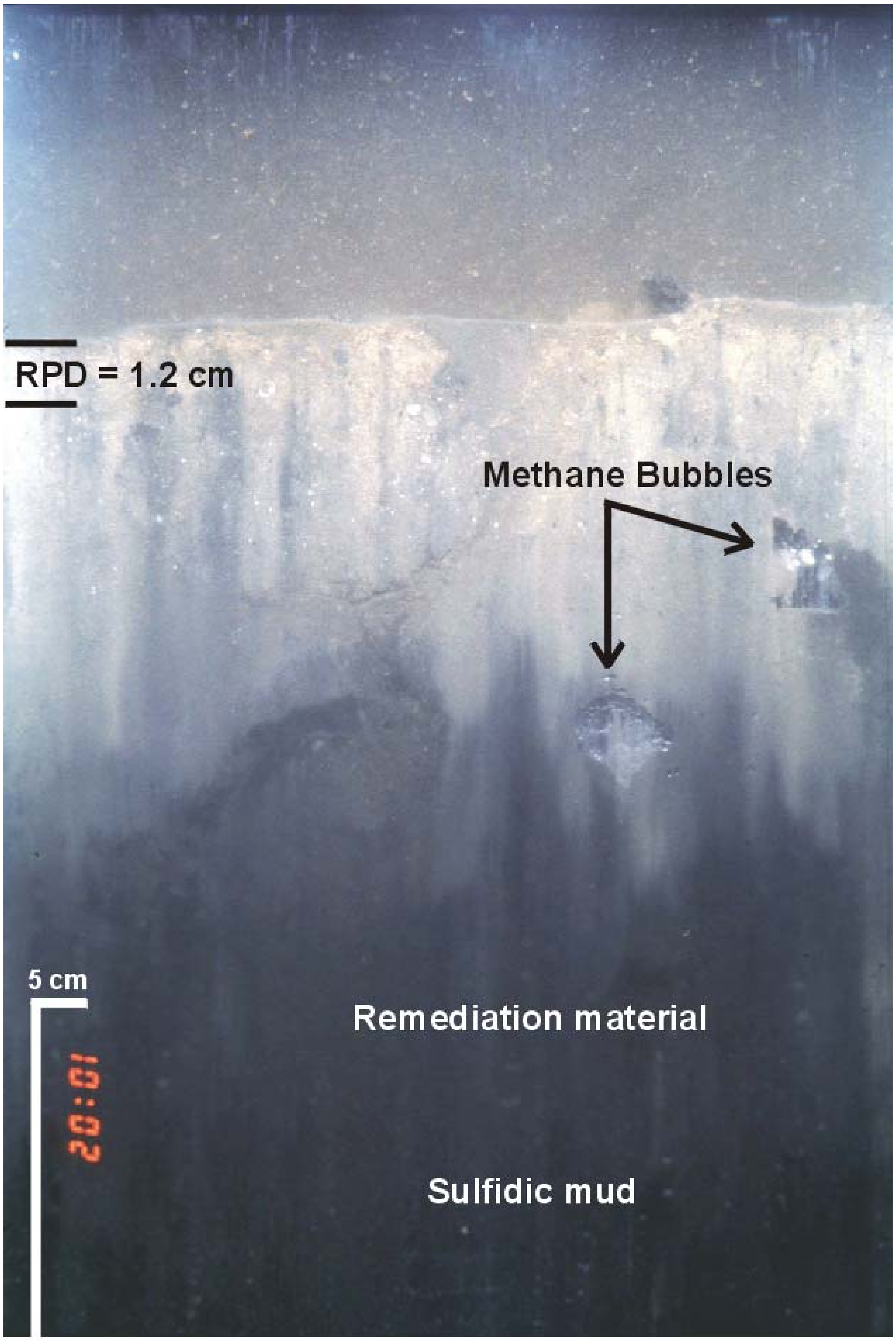


Figure 3.3-21. REMOTS image from Station 11 located within PRA 1 illustrating methane gas bubbles entrained within the remediation material at depth. Black, sulfidic mud is visible at sediment depth. The presence of methane, a shallow RPD, and a Stage I successional status resulted in an OSI value of + 2 (disturbed benthic habitat quality) for this replicate image.

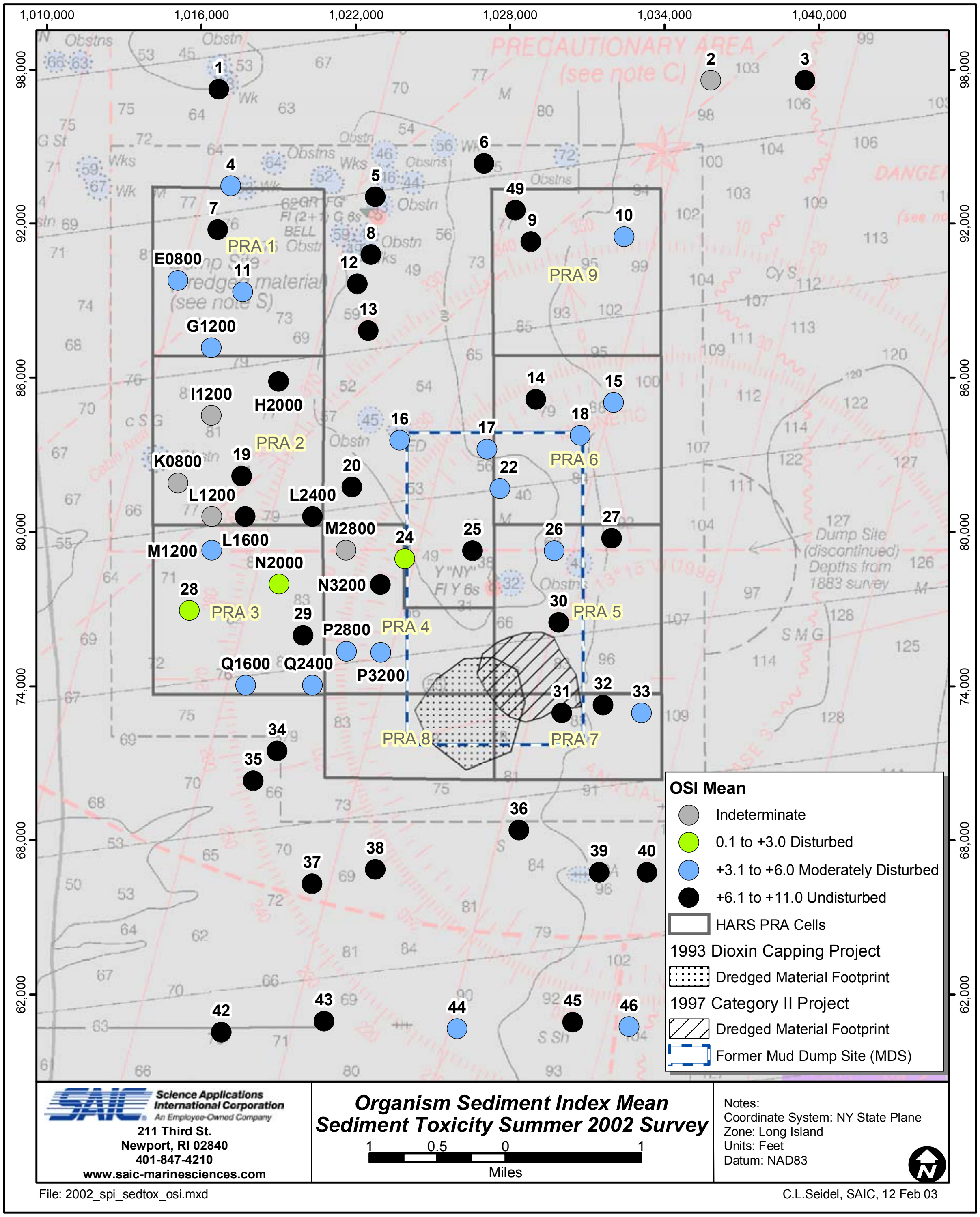


Figure 3.3-22. Map of mean OSI values at the 2002 sediment toxicity REMOTS stations

4.0 DISCUSSION

As the primary objective of this study, a detailed sediment toxicity survey and toxicity analysis was completed over the HARS. A secondary objective of this study was to evaluate sediment physical and biological conditions, particularly with respect to infaunal successional status and overall benthic habitat quality. Discussion of this secondary objective is presented first, followed by a discussion of the sediment toxicity testing results.

4.1 Physical and Biological Sediment Conditions

The June 2002 REMOTS survey represented the first REMOTS survey over the sediment toxicity stations in and around the HARS and proved to be a useful tool in providing a general characterization of sediment physical conditions as well as current benthic recolonization status over areas where remediation material has been placed.

4.1.1 Physical Characteristics

The June 2002 REMOTS and sediment plan view imaging surveys revealed that a wide variety of surface sediment types exist within the HARS, as a result of the wide variety of materials disposed at the site over the years.

Dredged material considered to be relatively recent (fine-grained remediation material) characterized the majority of the sediment at the REMOTS stations within PRAs 1, 2, and 3. The distribution of remediation material on the seafloor agreed well with the locations of disposal events over PRAs 1, 2, 3, and 4 (Figure 4.1-1). According to disposal logs, there was no placement of remediation material in the southwestern and western portions of PRAs 3 and 4, respectively (Figure 4.1-1). The REMOTS images obtained at Stations 28, Q1600, N3200, P2800, and P3200 located within these cells also did not reveal remediation material, but rather showed relic dredged material or ambient sediment. A grain size major mode of > 4 characterized much of the stations displaying remediation material. In addition, benthic habitat type UN.SF (very soft mud) generally corresponded to stations with fine-grained remediation material. However, coarser grained remediation material (cobble, and pebble) emanating from the KVK channel deepening dredging project was present at 3 stations in PRA 2.

Relatively thick (greater than the REMOTS camera prism penetration depth) layers of fine-grained relic dredged material (silt) were observed primarily in the unremediated portion of the HARS in PRAs 5, 6, 7, and 9 and in various stations within PRAs 1 and 4. Much of this material represents historic dredged material deposited over many years of disposal within and in the area surrounding the former MDS. Similar to stations with fine-grained remediation material, grain size major modes of > 4 and 4 to 3 phi and benthic habitat UN.SF (very soft mud) were noted at stations with relic dredged material. The relic dredged material detected at stations positioned to the southeast of the HARS likely represents dredged material that has accumulated over many years in areas located downslope, away from the disposal points within the former MDS. Coarser sediment comprising the relic dredged material at Station 25 located in the former MDS may represent a lag deposit remaining after fines were winnowed away from previously disposed dredged material (e.g., Figure 3.3-14).

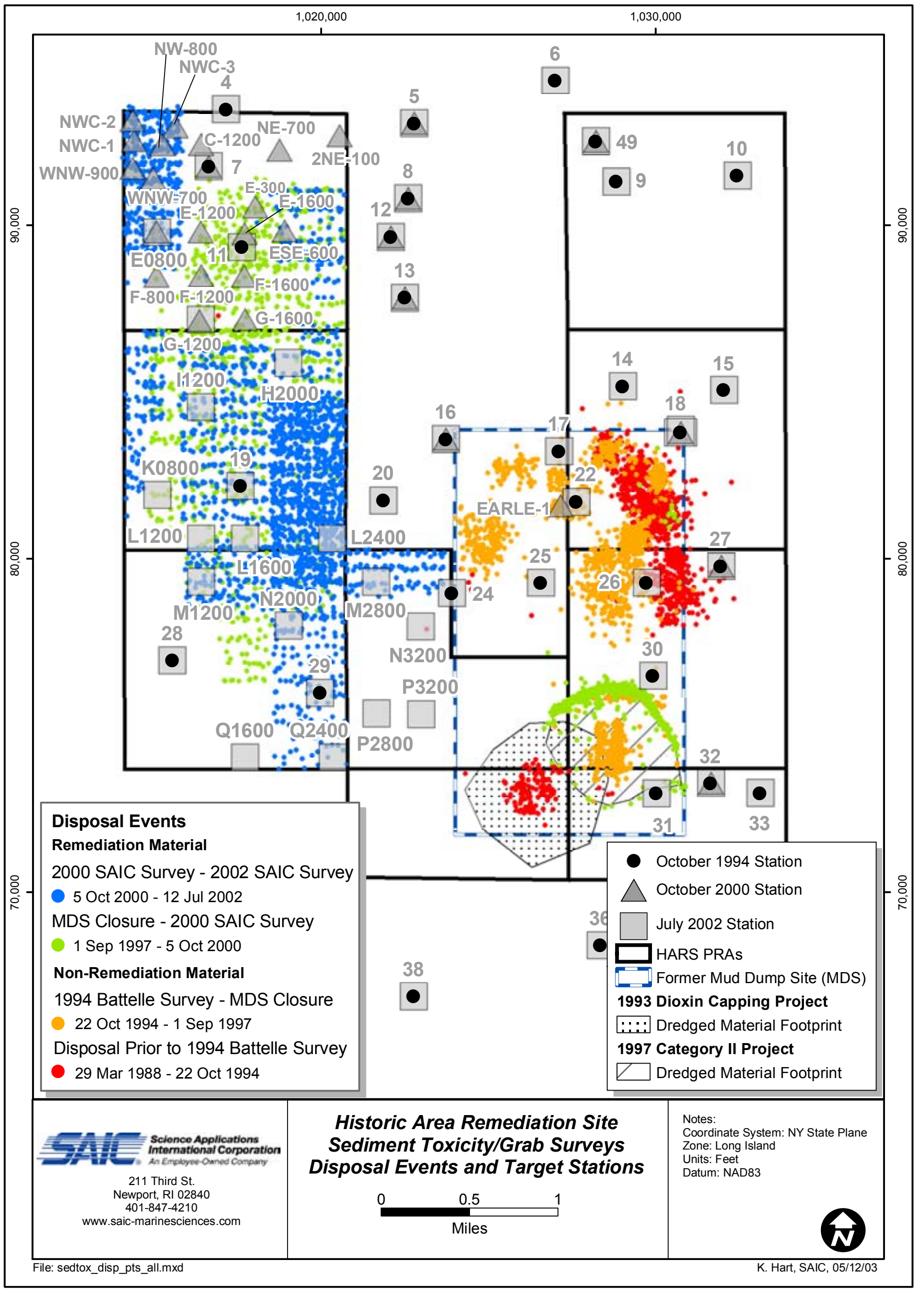


Figure 4.1-1. Map showing locations of the 1994, 2000, and 2002 sediment toxicity stations within and immediately outside the HARS in relation to dredged material placement events over the period March 1988 to July 2002. The period from March 1988 to September 1, 1997 (the day of official closure of the MDS) includes the disposal events that occurred prior to the original October 1994 sediment toxicity survey. This disposal occurred primarily in the northern half of the former MDS. From September 1, 1997 to July 12, 2002 (i.e., prior to both the October 2000 and July 2002 sediment toxicity surveys), the placement of remediation material was concentrated in PRAs 1, 2, and 3 of the HARS.

The images from the June 2002 survey also indicated that a surface layer of fine or coarse sand was present over the underlying relic dredged material at five stations (e.g., Figure 3.3-4). Presumably, over the years, fine-grained relic dredged material resulting from past disposal has been covered by migrating sand, resulting in a distinct sand-over-mud stratigraphy. The surface layer of sand serves to isolate the underlying fine-grained material and protect it from further erosion. However, it also prevents the material from being colonized by organisms and becoming aerated, which explains the highly-reduced (i.e., black) appearance of the underlying sediment in the images (e.g., Figure 3.3-4).

Sand was observed at Station 31 and was assumed to be clean cap sand from Ambrose Channel placed within the capping boundary of the 1997 Category II Capping Project. Stations located in the No Discharge Zone and in areas to the north and south of the HARS displayed ambient sediment generally consisting of fine to medium sand (benthic habitat type SA.F), with occasional ripples. The ripples suggest that the sand experiences periodic bedload transport, most likely from elevated bottom currents or wave action during the passage of large storms. Larger grain size major modes of 3 to 2 phi or 2 to 1 phi generally characterized these sandy stations.

Grain size results from REMOTS analysis correlated well with results from the sediment grab samples (Figures 3.2-1 and 3.3-5; Table 3.2-2). Results indicated coarser-grained material (sand and gravel) was present outside the HARS PRAs (to the north and south and within the No Discharge Zone). Fine-grained sediment (silt and clay) was present in remediated areas of PRAs 1-4, while sediment was coarser (sand and gravel) in the southwest areas of PRAs 2 and 3 where relic dredged material was present. Consistent with numerous past REMOTS monitoring surveys in and around the former Mud Dump Site, grain size was found to be variable throughout PRAs 5–9.

4.1.2 Biological Conditions and Benthic Recolonization Status

Due to the variety of substrates observed within the surveyed area and the variable timing of past dredged material placement, a wide variety of successional stages was observed. The sediment-profile and plan view images both indicated that the surveyed area had been colonized by diverse infaunal communities consisting of both surface-dwelling (i.e., Stages I and II) and deeper burrowing (i.e., Stage III) organisms at the time of the summer 2002 survey. However, Stage I was the dominant successional stage, representing the highest successional stage present in 55% of the images. Stage I taxa generally occurred at stations with sandy sediments. The physical instability of the sand surface favors the long-term dominance of surface-dwelling, opportunistic organisms. In addition, large-bodied, Stage III deposit-feeders require soft, organic-rich sediments; Stage III communities have difficulty becoming established on rippled sand bottoms and were generally found in finer-grained sediments at stations displaying organic-rich remediation or relic dredged material.

Many of the stations located in PRAs 2 through 7, as well as PRA 9, where fine-grained, organic-rich dredged material was present, displayed a Stage I on III or II on III successional status. Overall, advanced Stage III activity was present in 15% of the replicate images obtained during the summer 2002 survey. The REMOTS results indicate that a relatively diverse infaunal community comprised of Stage I polychaetes and Stage II amphipods at the sediment surface, and larger-boded Stage III infauna, existed across the surveyed area during the summer 2002 survey.

Both the sediment-profile and plan view images indicated that the surface of both the remediation and relic dredged material was inhabited by a benthic community consisting of both epifaunal and infaunal organisms at the time of the June 2002 survey. Epifaunal organisms visible in the plan view images included starfish, crabs, sand dollars, and hydroids. Stations with fine-grained sediment generally displayed a higher abundance of benthic infauna including burrowing anemones, polychaete tubes, and amphipod tubes, as well as evidence of infaunal burrows; these organisms often appeared in the corresponding REMOTS images. At several of the 2002 stations, the REMOTS images revealed stick-dwelling or stalked amphipods of the Family Podoceridae at the sediment surface (e.g., Figure 3.3-18). These Stage II Podocerid amphipods were fairly widespread across the surveyed area, as evidenced by the distinctive thin stalks constructed by these organisms to raise themselves a few centimeters above the seafloor to facilitate suspension-feeding (e.g., Figure 3.3-18).

RPD depths were relatively deep, particularly at the sandy stations, and reflected well-oxygenated surface sediments. The detection of methane at Station 11 in PRA 1 indicates that the remediation material placed in this area was relatively organic-rich at the time of placement, with subsequent microbial decomposition of the organic matter under anaerobic conditions at depth, resulting in production of methane (e.g., Figure 3.3-21). The sediment at this station was classified as toxic in the EPA study of 1994, but was found to be non-toxic in the following 2000 and 2002 surveys. The initial pore water ammonia concentration at this station, measured prior to initiation of the 2002 toxicity testing, was 19.5 mg/L. This concentration level was near the threshold of 20 mg/L established by the EPA. The presence of elevated ammonia is a further indicator of increased organic carbon and anaerobic decomposition in the sediments at this station. The relatively high organic matter content within the remediation material has contributed to the compromised benthic habitat conditions determined by REMOTS sampling at Station 11.

In general, the overall OSI value calculated for the surveyed area (+6.4) is indicative of undisturbed benthic habitat quality. However, because placement of remediation material within PRAs 1, 2, and 3 has been on going for a number of years, benthic recolonization within these areas is in various stages, depending on when remediation material was placed. OSI values indicative of disturbed benthic habitat quality (< +3.0) were detected at Stations 28, N2000, and 24. Sediment was determined to be toxic at Stations 28 and 24 in the EPA study of 1994, however, neither station displayed significant sediment toxicity in 2000 or 2002, suggesting some additional source of disturbance to the benthic community at these stations. Pore water ammonia measurements revealed concentrations below threshold levels for Stations 24 and 28. However, the initial pore water ammonia level for Station N2000 surpassed the threshold, with a concentration of 86.8 mg/L indicating a significantly high concentration of ammonia. Elevated levels of reduced end products like ammonia and sulfide, which result from anaerobic decomposition of organic matter, produce unfavorable benthic habitat conditions and were reflected in a REMOTS OSI of +2.

A broad comparison of the REMOTS stations located within the areas of the HARS that have received remediation material (PRAs 1, 2, and 3) versus unremediated areas displaying uncapped relic dredged material indicates similar benthic habitat quality exists within both areas. However, due to the relatively recent placement of organic-rich remediation material in PRAs 1, 2, and 3, it is anticipated that as the levels of sediment organic matter gradually decrease over time due to natural decomposition, the infaunal successional process will result in an increase in the abundance of Stage III organisms and a subsequent increase in RPD depths (bioturbation) in the coming years in this region of the HARS.

4.2 Sediment Toxicity

The two primary objectives of this study were developed to assess the sediment toxicity at the HARS. These objectives were: 1) to determine the toxicity of surface sediments at 44 stations sampled previously in the EPA October 1994 study and provide additional comparisons of present-day results with those from the past, and 2) to collect samples at an additional 16 stations located within PRAs 1, 2, 3 and 4 to determine the toxicity of surface sediments and the efficacy of ongoing remediation efforts in these areas. The results of the collection and analysis of the July 2002 samples indicated an overall absence of sediment toxicity relative to the October 1994 survey. Results from the October 2000 survey also had shown highly improved conditions at corresponding 1994 stations.

There are three potential reasons for the difference in toxicity results between the 1994 and the 2000/2002 surveys: 1) the remediation dredged material that has been deposited since the closure of the MDS in September 1997 has served to remediate some areas of the HARS and eliminated sediment toxicity, 2) sampling and analysis errors were prevalent during the 1994 survey, leading to erroneous sediment toxicity results, and 3) natural physical and biological processes have led to a reduction in toxicity over time. Each of these is discussed in the following sections.

4.2.1 Impact of Remediation Material

Following the official designation of the HARS on September 1, 1997, remediation activities technically began with placement of dredged material from the PST dredging project in March 1998. Only Category I material (sediment designated as clean and allowable for open-water disposal) can be used as remediation material. Material deposited prior to the closure of the MDS is considered unremediated or “relic” dredged material. Before the July 2002 survey operations began, most of the remediation dredged material deposited at the HARS had been placed in PRAs 1, 2, 3, and 4 (Figure 4.1-1). However, some red clay deposits were placed in the northeast corner of the former MDS (PRA 6) as part of ongoing disposal operations beginning prior to 1 September 1997. The type of remediation sediment deposited in PRAs 1–4 has varied widely in consistency and grain size.

Remediation material was present at several of the stations sampled in October 2000 (Figure 4.2-1) and at even more of the July 2002 stations (Figure 4.2-2). At the time of sediment collection for those surveys, stations that had received remediation material were expected to show little toxicity. Based on the results from 2000 and 2002, the remediation material that was sampled was indeed non-toxic. Placement of remediation material, therefore, could reasonably explain the change from toxic to non-toxic conditions observed between the October 1994 and 2000/2002 surveys at Stations 7, 11, 19, and 29 located in PRAs 1, 2, and 3 (Figures 3.1-4 and 4.1-1).

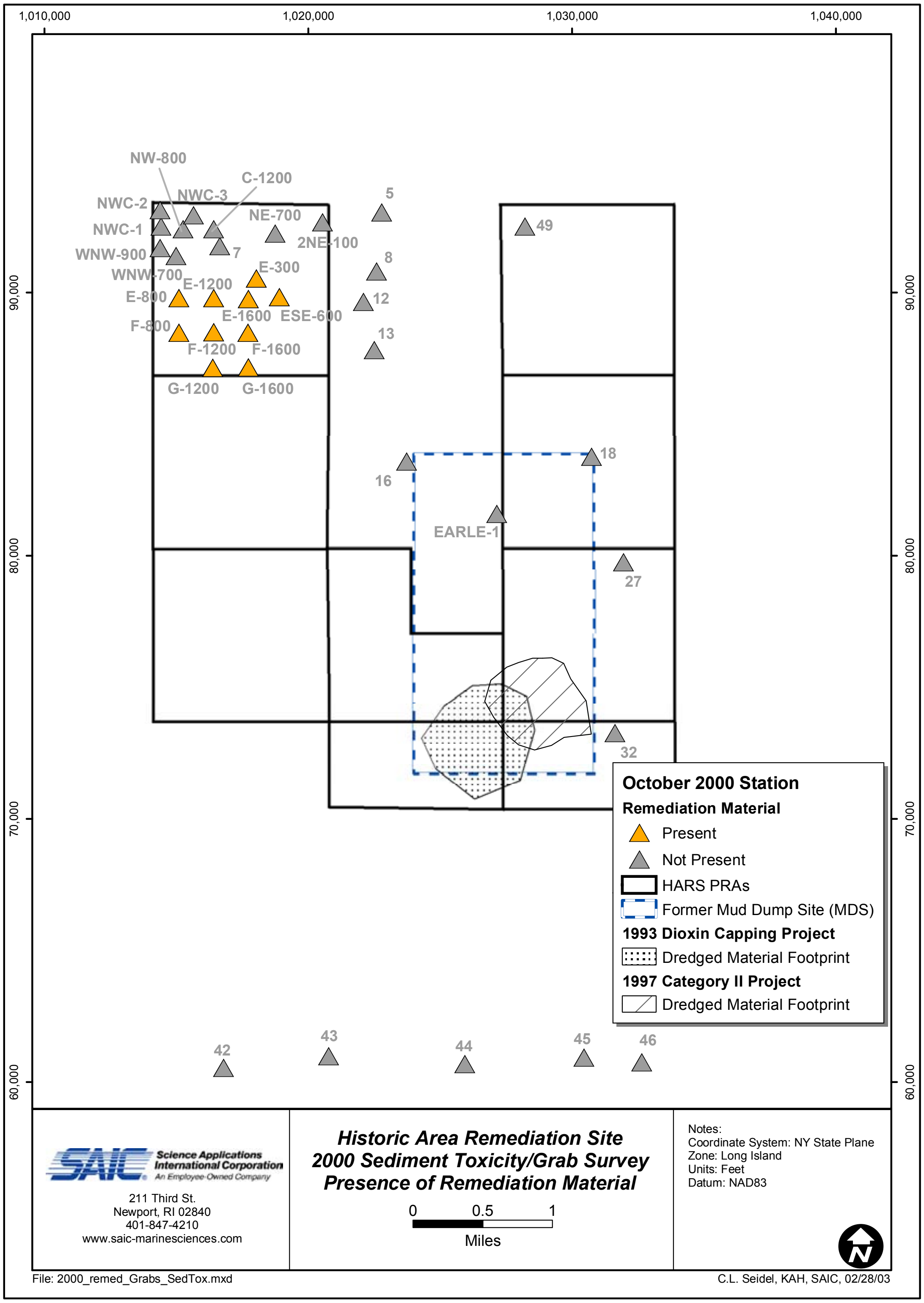


Figure 4.2-1. Map showing the stations where remediation material was known to be present at the time of the October 2000 sediment toxicity survey

Figure 4.2-2. Map showing the stations where remediation material was known to be present at the time of the 2002 sediment toxicity survey

Overall, the sediment samples collected by SAIC in October 2000 and July 2002 showed minimal toxicity. Only two stations sampled in October 2000 were significantly toxic (Stations WNW-700 and WNW-900 in PRA 1). At the time of the survey, these two stations had not yet received any remediation material (Figure 4.2-1). However, since the completion of the 2000 survey, remediation material was deposited over the locations of these two stations. Even though these stations were not sampled in 2002, it is likely that the remediation material placed in the area has lowered the toxicity levels at these stations, because sampling of remediation material at nearby Station E0800 in July 2002 yielded a non-toxic result.

Clay and silt were also deposited as remediation material in the northwest corner of the former MDS between the closure of the MDS (1 September 1997) and the October 2000 sediment toxicity survey (Figure 4.1-1). Sediment toxicity stations that may have sampled remediation material in these particular deposits include Station EARLE-1 (2000), Station 17 (2002), and Station 22 (2002). In October 2000, it was assumed that Station EARLE-1 had not yet received any remediation material, despite its proximity to disposal points (Figure 4.2-1). Station 22 was only 200 m northeast of the location of EARLE-1. But the July 2002 REMOTS results indicate that there was no remediation material present at either Station 17 or 22. This is evidence that these three stations were unremediated at the time of each survey, despite their close proximity to the disposal event locations (Figures 4.2-1 and 4.2-2). However, toxicity results showed that the sediment at Stations EARLE-1, 17, and 22 was non-toxic in the 2000 and 2002 surveys, even though the sediment at Stations 17 and 22 was found to be toxic in the previous 1994 survey.

4.2.2 Potential Sampling and Analysis Errors

Sample collection and analysis methods differed between the 1994 EPA Region 2 survey and the 2000 and 2002 surveys. The most significant difference involved the treatment of ammonia in the sediment samples prior to the testing. For both the October 2000 and July 2002 sediment toxicity samples, pore water ammonia was purged from the sediment if it was found to be above the EPA-specified threshold of 20 mg/L. This purging process was conducted in the samples (if levels exceeded the threshold) so that high ammonia concentrations could not potentially affect the mortality rate of the test amphipod, *A. abdita*.

Despite its potentially lethal effects on the test amphipod, ammonia apparently was not purged from the 1994 sediment samples (Battelle 1996). Static testing, as opposed to flow-through, was used in samples with high pore water ammonia (S. Knowles memorandum of February 5, 2002). Percent normalized survival of the amphipods was less than 5% when initial pore water ammonia levels exceeded 22 mg/L (Battelle 1996; Knowles 2002). These results suggest that significant ammonia toxicity and ammonia-enhanced toxicity may have occurred.

A second difference between the1994 EPA Region 2 survey and the 2000 and 2002 surveys involved the collection of sediment in the field. First, it was noted by Knowles (2002) that the methods of sediment collection used in the 1994 survey could have increased the effect of patchiness in the toxicity results. Patchiness in the 1994 study area was evidenced by infaunal abundance inconsistencies at single stations (Battelle 1996). This patchiness was in part associated with a potential navigation inaccuracy during field data collection (Knowles 2002). A Northstar Model-800 GPS/Loran navigation system (BOS GPS) with an absolute accuracy of 100 m was used for navigation and positioning, in place of an Anderson DGPS system, having an absolute accuracy of 10m, that was specified in the Quality Assurance Project Plan (QAPP; Battelle 1996). Second, all the 1994 samples were surface grab samples (Note: The full content of the grab was taken as the sample, similar to the 2000 and 2002 surveys), and therefore it was not possible to study potential variation of sediment characteristics as a function of burial depth (Knowles 2002; Battelle 1996).

Spatial variability (horizontal and vertical) was evaluated at Station 18 in the 2002 survey to address in part the suggestion of potential patchiness in sediment toxicity around stations sampled in all three surveys. Patchiness in sediment toxicity was not found in either the horizontal or vertical analyses. The sediment samples from Stations 18, 18E, 18N, and 18W were uniformly non-toxic. These results indicate an absence of variability in sediment toxicity across relatively short horizontal distances on the seafloor at Station 18, and also indicate an absence of any consistent differences related to the depth in the sediment column from which the sample was taken. The sampling associated with this evaluation of spatial variability was limited in scope to the area around a single station, and it cannot be stated conclusively that small-scale spatial variability in toxicity does not exist elsewhere at the HARS. However, based on these results, it is unlikely that small-scale spatial variability was a leading cause of the 1994 versus 2000/2002 differences in toxicity observed at many stations.

A third (and final) discrepancy with the 1994 survey is evident both in the sediment collection and in the laboratory analysis methods. The 1994 survey sponsored by EPA Region 2 was actually made up of two data sets, from two different years, 1994 and 1996 (Battelle 1996). These two toxicity sample sets were analyzed by two different laboratories. Battelle analyzed the majority of samples, collected in October 1994, while the EPA analyzed samples from Stations 37–40, and 42–46 collected in January 1996. It appears that there were no identical control or reference samples run by both labs to compare results obtained from the two sample/laboratory sets (Knowles 2002). The greater than one year difference in time of sampling, as well as potential differences in sample characteristics associated with different field crews, oceanographic conditions, etc., indicates that there may be problems in considering all of the samples to comprise a single set for analytical purposes (Knowles 2002). All ten of the samples collected and analyzed by the EPA in 1996 were found to be non-toxic, while 26 of the remaining 34 samples (>76%) collected in 1994 were toxic (<80% survival). However, the non-toxic result of the ten samples collected in 1996 is likely due to their station position, which is south of the current HARS PRAs, where unremediated material with potentially significant toxicity was assumed to be absent.

All samples collected in 2000 and 2002 were each analyzed in a single effort. The samples were also analyzed by the same laboratory (Aqua Survey, Inc.), which used control sediment from the same area (Atlantic Highlands, Sandy Hook, New Jersey) for both surveys.

4.2.3 Natural Toxicity Improvement over Time

Outside the HARS PRAs and within unremediated PRAs, sediment toxicity stations have shown apparent improvement in toxicity since 1994. Since remediation material has not been deposited in these areas, it is possible that the improvement in toxicity is due to either natural accumulation of cleaner sediment or biologically-mediated breakdown of the sediment contaminants responsible for the original toxicity. Vertical mixing of the surface sediment (by bioturbation or sediment transport by bottom currents) could cause a reduction in toxicity over time, as more toxic sediment is mixed with less toxic sediment. REMOTS sediment-profile imaging results indicated that a relatively active benthic community consisting of both epifaunal and infaunal organisms inhabited the sediment surface at several stations at the time of the 2002 survey. In addition, bottom currents over the HARS can potentially transport sediment and deposit it far from its source. It was noted in the REMOTS results that a layer of fine- to coarse-grained sand had been deposited over relic dredged material at five stations. These natural physical and biological factors could lead to the gradual improvement of toxicity over time at the HARS.

5.0 CONCLUSIONS

- The 2002 REMOTS and plan view imaging results indicated that a wide variety of surface sediment types exist within and surrounding the HARS. Fine-grained remediation material comprised the majority of the surface sediment of PRAs 1, 2, and 3, while fine-grained relic dredged material was observed in the unremediated portion of the HARS in PRAs 5, 6, 7, and 9 and in various stations within PRAs 1 and 4. A sand-over-mud stratigraphy (i.e., sand over underlying relic dredged material) was observed at 5 stations and reflects the bottom current regime in and around the HARS. Rippled, fine sand comprised the ambient surface sediments at stations surrounding the HARS.

- Grain size results from REMOTS analysis agreed well with the results from the sediment grab samples and indicated a variety of grain sizes present in and around the HARS. Fine-grained sediments (silt and clay) were present in PRAs 1–4 with variable grain sizes in PRAs 5–9.

- Due to the variety of substrates observed within the surveyed area and the various periods of dredged material placement, a wide variety of successional stages were observed. Surface-dwelling infauna (i.e., Stage I) was the dominant successional stage over the surveyed area, particularly in stations with surface sediments comprised of sand. In the remediated and unremediated portions of the HARS (PRAs 2–7, and 9), where fine-grained, organic-rich remediation and relic dredged material was observed, the benthic community consisted of a mixture of surface-dwellers (Stages I and II) and larger-bodied, deeper-dwelling deposit-feeders (Stage III).

- RPD depths were relatively deep and reflected well-oxygenated surface sediments. A high organic matter content at Station 11, a previously toxic station in 1994, is presumed to have produced anoxic conditions in the underlying sediments that resulted in the production of methane.

- Undisturbed benthic habitat quality (overall OSI value of +6.4) was observed across the surveyed area. Benthic recolonization of the sediments in PRAs 1–3 is in various stages due to the ongoing placement of remediation material since September 1997. Disturbed benthic habitat quality (OSI values <+3.0) was observed at Stations 28, N2000, and 24, of which Stations 24 and 28 had displayed toxic conditions in 1994 even though pore water ammonia measurements were below the threshold. Compromised benthic habitat quality at these stations in 2002 may be the result of additional sources of disturbance to the benthic community. Significantly high levels of ammonia detected at Station N2000 in 1994 due to an elevated organic carbon content, may have produced unfavorable benthic habitat conditions observed in 2002.

- Comparable benthic habitat quality exists within both the remediated and unremediated areas of the HARS. It is anticipated that as the relatively recent organic-rich remediation material in PRAs 1, 2, and 3 is recolonized, the benthic assemblage will progress towards an advanced Stage III community and produce deeper RPD depths in the coming years.

- Sediment toxicity results from the July 2002 survey indicated an overall absence of sediment toxicity relative to the October 1994 survey due to three possible reasons: 1) dredged material deposited after the closure of the MDS remediated some areas of the HARS and eliminated sediment toxicity, 2) sampling and analysis errors were prevalent during the 1994 survey, leading to erroneous sediment toxicity results, and 3) natural physical and biological processes led to the reduction in toxicity over time.

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APPENDIX A
SEDIMENT TOXICITY RAW DATA

Table A-1. Ammonia Testing

Round 1 Test Start Date 7/16/02 - Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 26	2021504	1.15	1.15
STA 31	2021467	3.09	1.00
STA 32	2012482	5.02	*
STA 34	2021484	0.63	*
STA 35	2021468	0.72	4.19
STA 37	2021483	0.10	<0.08
STA 40	2021473	6.17	4.94
STA L2400	2021498	3.68	3.82
STA 30	2021503	3.40	4.77
STA M1200	2021472	3.60	5.88
STA Q2400	2021477	5.57	2.87

* Technician error no final porewater ammonia reading done

Round 2 Test Start Date 7/19/02 - Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 43	2021471	4.08	<0.08
STA P3200	2021478	7.24	2.18
STA 27	2021505	4.88	2.62
STA 18	2021506	8.67	11.5
STA 15	2021507	6.11	3.26
STA 14	2021508	8.95	3.53
STA 11	2021518	19.5	6.63
STA E0800	2021519	5.79	2.61
STA 7	2021520	16.6	4.92
STA 4	2021521	3.16	<0.08
STA 5	2021522	0.14	0.10

Round 3 Test Start Date 7/26/02 - Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 3	2021535	7.47	5.24
STA 12	2021529	0.20	0.10
STA 10	2021536	9.90	6.65
STA 1	2021527	3.30	0.51
STA 2	2021534	9.90	3.75
STA 6	2021533	2.60	0.92
STA 8	2021528	0.12	<0.08
STA 13	2021530	0.10	<0.08
STA Q1600	2021476	3.25	0.66
STA 25	2021502	0.83	0.21
STA 45	2021481	1.92	0.18

Round 4 Test Start Date 7/30/02 - Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 44	2021465	1.73	0.16
STA 42	2021466	0.26	0.67
STA 39	2021469	0.81	1.36
STA 38	2021470	0.44	0.70
STA 36	2021475	0.09	0.91
STA 28	2021495	12.1	6.00
STA L1200	2021496	0.81	3.08
STA N3200	2021501	11.9	5.10
STA 16	2021511	0.09	0.21
STA 20	2021512	0.60	0.43
STA 9	2021531	9.18	4.51

Round 5 Test Start Date 8/2/02 - Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 49	2021532	8.98	2.60
STA 18 GT	2021537	9.93	2.77
STA 18 GB	2021538	13.0	3.88
STA 18 E GT	2021540	8.71	2.37
STA 18 E GB	2021541	10.1	2.31
STA 18 N FB	2021542	15.0	5.88
STA 18 N GT	2021543	7.46	1.96
STA 18 N GB	2021544	12.2	3.50
STA 18 W FG	2021545	11.3	2.99
STA 18 W GT	2021546	9.51	2.57
STA 18 W GB	2021547	15.9	3.18

Round 6 Test Start Date 8/6/02 – Static

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Final Porewater Ammonia mg/L
STA 46	2021485	9.79	5.00
STA P2800	2021464	16.3	5.80
STA 24	2021500	7.05	3.95
STA 17	2021509	<0.08	0.83
STA K0800	2021514	6.60	4.09
STA G1200	2021517	12.2	1.98
STA L1600	2021497	14.1	4.51
STA 18E FG	2021539	19.5	11.4

Round 7 Test Start Date 8/9/02 – Static Renewal

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Porewater Ammonia at Test Initiation Mg/L	Final Porewater Ammonia mg/L
STA 33	2021479	20.4	11.8	4.90
STA 29	2021480	23.7	14.0	1.29
STA M2800	2021499	24.0	17.3	2.31
STA I1200	2021515	20.5	10.33	2.22
STA 22	2021510	26.4	11.3	2.16

These five sediment samples purged for 3 days, at which time the porewater ammonia was below the 20 mg/L threshold, so the test was initiated.

Round 8 Test Start Date 8/13/02 – Static Renewal

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Porewater Ammonia at Test Initiation Mg/L	Final Porewater Ammonia mg/L
STA N2000	2021474	86.8	15.2	2.92

This sample purged for seven days, at which time the porewater ammonia was below 20 mg/L , so the test was initiated.

Round 9, Test Start Date 8/12/02 – Static Renewal

Sample ID	ASI #	Initial Porewater Ammonia mg/L	Porewater Ammonia at Test Initiation Mg/L	Final Porewater Ammonia mg/L
STA 19	2021513	31.4	18.9	4.62
STA H2000	2021516	30.4	18.2	12.6

These two samples purged for two days before the porewater ammonia was below the 20 mg/L threshold, at which time the test was initiated.

Table A-2
Raw Toxicity Testing Data

Table 68	10-Day Solid Phase Test Initial Live Count: 20	Static Renewal Round 9	Species: Job #:	*A. abdita* 22-303

Position #	ID#	Sample	Final Live Count	Percent Survival
9	0.1	Atlantic Highlands Control	20	
6	0.2	2021773	18	
5	0.3		20	
12	0.4		20	
11	0.5		20	98%
14	1.1	STA 19	19	
8	1.2	2021513	20	
2	1.3		19	
10	1.4		20	
1	1.5		20	98%
4	2.1	STA H2000	20	
15	2.1	2021516	20	
3	2.3		19	
7	2.4		20	
13	2.5		20	99%

Table A-2
Raw Toxicity Testing Data

Table 62	**10-Day Solid Phase Test**		**Static Renewal**	**Species:**	***A. abdita***
	Initial Live Count: 20		**Round 8**	**Job #:**	**22-303**
Position #	**ID#**	**Sample**	**Final Live Count**		**Percent Survival**
4	0.1	Atlantic Highlands Control	20		
1	0.2	2021773	19		
9	0.3		19		
3	0.4		20		
8	0.5		20		98%
6	1.1	STA N2000	20		
2	1.2	2021474	20		
10	1.3		18		
7	1.4		18		
5	1.5		19		95%

Table A-2
Raw Toxicity Testing Data

Table 56	**10-Day Solid Phase Test**		**Static Renewal**	**Species:**	***A. abdita***
	Initial Live Count: 20		**Round 7**	**Job #:**	**22-303**
Position #	**ID#**	**Sample**	**Final Live Count**		**Percent Survival**
9	0.1	Atlantic Highlands Control	18		
3	0.2	2021663	16		
28	0.3		18		
16	0.4		18		
8	0.5		20		90%
5	1.1	STA 33	17		
1	1.2	2021479	18		
10	1.3		19		
18	1.4		20		
21	1.5		20		94%
14	2.1	STA 29	16		
6	2.2	2021480	15		
22	2.3		20		
15	2.4		19		
26	2.5		19		89%
29	3.1	STA M2800	18		
30	3.2	2021499	20		
12	3.3		19		
27	3.4		19		
4	3.5		17		93%
2	4.1	STA I1200	18		
19	4.2	2021515	19		
25	4.3		19		
13	4.4		20		
7	4.5		17		93%
24	5.1	STA 22	17		
20	5.2	2021510	17		
17	5.3		17		
11	5.4		15		
23	5.5		20		86%

Table A-2
Raw Toxicity Testing Data

Table 50	**10-Day Solid Phase Test**	**Static**	**Species:**	***A. abdita***
	Initial Live Count: 20	**Round 6**	**Job #:**	**22-303**

Position #	ID#	Sample	Final Live Count	Percent Survival
29	0.1	Atlantic Highlands Control	19	
18	0.2	2021663	17	
16	0.3		20	
19	0.4		20	
39	0.5		19	95%
36	1.1	STA 46	14	
28	1.2	2021485	14	
31	1.3		20	
34	1.4		15	
8	1.5		18	81%
13	2.1	STA P2800	19	
23	2.2	2021464	19	
1	2.3		17	
30	2.4		9	
35	2.5		17	81%
41	3.1	STA 24	17	
7	3.2	2021500	20	
17	3.3		19	
37	3.4		20	
4	3.5		20	96%
43	4.1	STA 17	15	
5	4.2	2021509	15	
22	4.3		19	
14	4.4		18	
26	4.5		18	85%
11	5.1	STA KO800	18	
6	5.2	2021514	20	
32	5.3		17	
24	5.4		19	
40	5.5		14	88%
3	6.1	STA G1200	19	
42	6.2	2021517	15	
12	6.3		18	
38	6.4		19	
25	6.5		19	90%
2	7.1	STA L1600	18	
10	7.2	2021497	19	
45	7.3		19	
44	7.4		15	
9	7.5		15	86%
20	8.1	STA 18E-FG	10	
33	8.2	2021539	15	
21	8.3		14	
15	8.4		19	
27	8.5		18	76%

Table A-2
Raw Toxicity Testing Data

Table 38	**10-Day Solid Phase Test** **Initial Live Count: 20**	**Static** **Round 4**	**Species:** **Job #:**	***A. abdita*** **22-303**

Position #	ID#	Sample	Final Live Count	Percent Survival
51	0.1	Atlantic Highlands Control	20	
39	0.2	2021605	19	
9	0.3		17	
22	0.4		17	
47	0.5		18	91%
27	1.1	STA 44	20	
56	1.2	2021465	17	
19	1.3		17	
23	1.4		17	
32	1.5		16	87%
7	2.1	STA 42	14	
1	2.2	2021466	19	
26	2.3		20	
38	2.4		20	
60	2.5		18	91%
12	3.1	STA 39	18	
52	3.2	2021469	15	
57	3.3		19	
44	3.4		17	
41	3.5		17	86%
31	4.1	STA 38	20	
8	4.2	2021470	15	
3	4.3		18	
5	4.4		13	
45	4.5		18	84%
15	5.1	STA 36	12	
43	5.2	2021475	19	
34	5.3		20	
35	5.4		16	
53	5.5		19	86%
42	6.1	STA 28	20	
36	6.2	2021495	16	
10	6.3		16	
49	6.4		19	
28	6.5		11	82%
21	7.1	STA LI200	20	
16	7.2	2021496	18	
4	7.3		17	
25	7.4		18	
6	7.5		17	90%
18	8.1	STA N3200	17	
20	8.2	2021501	15	
59	8.3		18	
48	8.4		20	
24	8.5		19	89%
40	9.1	STA 16	20	
14	9.2	2021511	12	
54	9.3		18	
37	9.4		18	
2	9.5		19	87%
55	10.1	STA 20	20	
33	10.2	2021512	18	
17	10.3		14	
46	10.4		15	
50	10.5		18	85%

Table A-2
Raw Toxicity Testing Data

Table 32	**10-Day Solid Phase Test**	**Static**	**Species:**	***A. abdita***
	Initial Live Count: 20	**Round 3**	**Job #:**	**22-303**

Position #	**ID#**	**Sample**	**Final Live Count**	**Percent Survival**
22	0.1	Atlantic Highlands Control	19	
51	0.2	2021605	18	
17	0.3		20	
30	0.4		20	
1	0.5		19	96%
7	1.1	STA 3	17	
47	1.2	2021535	19	
43	1.3		20	
52	1.4		18	
59	1.5		20	94%
54	2.1	STA 12	19	
2	2.2	2021529	19	
6	2.3		18	
39	2.4		20	
24	2.5		19	95%
9	3.1	STA 10	20	
40	3.2	2021536	20	
41	3.3		19	
49	3.4		20	
32	3.5		20	99%
16	4.1	STA 1	18	
12	4.2	2021527	18	
21	4.3		19	
25	4.4		19	
34	4.5		17	91%
60	5.1	STA 2	20	
5	5.2	2021534	20	
42	5.3		17	
57	5.4		16	
8	5.5		20	93%
18	6.1	STA 6	19	
33	6.2	2021533	18	
56	6.3		18	
13	6.4		18	
20	6.5		18	91%
58	7.1	STA 8	20	
19	7.2	2021528	18	
11	7.3		18	
3	7.4		19	
36	7.5		18	93%
10	8.1	STA 13	17	
48	8.2	2021530	18	
37	8.3		19	
44	8.4		18	
14	8.5		20	92%
35	9.1	STA Q1600	18	
55	9.2	2021476	16	
27	9.3		19	
31	9.4		19	
15	9.5		20	92%
46	10.1	STA 25	20	
50	10.2	2021502	20	
23	10.3		20	
28	10.4		17	
45	10.5		17	94%
29	11.1	STA 45	17	
[illegible]	[illegible]	[illegible]	[illegible]	

Table A-2
Raw Toxicity Testing Data

Table 26	10-Day Solid Phase Test Initial Live Count: 20	Static Round 2	Species: Job #:	*A. abdita* 22-303
Position #	**ID#**	**Sample**	**Final Live Count**	**Percent Survival**
2	0.1	Atlantic Highlands	20	
36	0.2	Control	19	
16	0.3	2021523	19	
5	0.4		17	
28	0.5		18	93%
51	1.1	STA 43	19	
52	1.2	2021471	19	
42	1.3		19	
33	1.4		18	
55	1.5		17	92%
48	2.1	STA P3200	19	
45	2.2	2021478	18	
17	2.3		20	
27	2.4		20	
40	2.5		19	96%
43	3.1	STA 27	19	
9	3.2	2021505	18	
15	3.3		18	
3	3.4		20	
8	3.5		18	93%
4	4.1	STA 18	20	
14	4.2	2021506	18	
23	4.3		19	
39	4.4		17	
41	4.5		19	93%
30	5.1	STA 15	20	
58	5.2	2021507	16	
29	5.3		18	
47	5.4		18	
26	5.5		19	91%
13	6.1	STA 14	20	
21	6.2	2021508	20	
12	6.3		13	
11	6.4		14	
6	6.5		20	87%
37	7.1	STA 11	20	
49	7.2	2021518	18	
50	7.3		18	
56	7.4		18	
59	7.5		20	94%
57	8.1	STA E0800	19	
35	8.2	2021519	20	
25	8.3		17	
44	8.4		19	
7	8.5		18	93%
53	9.1	STA 7	20	
1	9.2	2021520	20	
20	9.3		17	
46	9.4		15	
10	9.5		19	91%
34	10.1	STA 4	20	
18	10.2	2021521	19	
31	10.3		20	
19	10.4		18	
38	10.5		20	97%
22	11.1	STA 5	18	

Table A-2
Raw Toxicity Testing Data

Table 20	**10-Day Solid Phase Test**		**Static**	**Species:** *A. abdita*
	Initial Live Count: 20		**Round 1**	**Job #: 22-303**
Position #	**ID#**	**Sample**	**Final Live Count**	**Percent Survival**
41	0.1	Atlantic Highlands	18	
29	0.2	Control	20	
45	0.3	2021523	17	
9	0.4		20	
4	0.5		17	92%
42	1.1	STA 26	20	
18	1.2	2021504	18	
11	1.3		15	
46	1.4		19	
47	1.5		19	91%
3	2.1	STA 31	18	
17	2.2	2021467	20	
59	2.3		19	
44	2.4		20	
57	2.5		18	95%
52	3.1	STA 32	18	
25	3.2	2021482	20	
34	3.3		20	
32	3.4		19	
58	3.5		16	93%
43	4.1	STA 34	20	
14	4.2	2021484	19	
27	4.3		19	
12	4.4		19	
16	4.5		19	96%
33	5.1	STA 35	17	
40	5.2	2021468	18	
6	5.3		20	
10	5.4		18	
13	5.5		20	93%
50	6.1	STA 37	19	
8	6.2	2021483	18	
28	6.3		20	
19	6.4		18	
35	6.5		19	94%
30	7.1	STA 40	20	
24	7.2	2021473	19	
38	7.3		19	
7	7.4		20	
51	7.5		20	98%
2	8.1	STA L2400	18	
22	8.2	2021498	20	
1	8.3		20	
20	8.4		20	
39	8.5		20	98%
49	9.1	STA 30	16	
36	9.2	2021503	19	
56	9.3		20	
53	9.4		19	
23	9.5		17	91%
15	10.1	STA M1200	18	
54	10.2	2021472	1	
21	10.3		20	
5	10.4		18	
37	10.5		18	75%
60	11.1	STA Q2400	20	
[illegible]	[illegible]	[illegible]	[illegible]	

Table A-2
Raw Toxicity Testing Data

Table 44 | **10-Day Solid Phase Test** | **Static** | **Species:** ***A. abdita***
Initial Live Count: 20 | **Round 5** | **Job #: 22-303**

Position #	ID#	Sample	Final Live Count	Percent Survival
56	0.1	Atlantic Highlands Control	20	
55	0.2	2021663	20	
9	0.3		18	
15	0.4		20	
33	0.5		18	96%
17	1.1	STA 49	20	
13	1.2	2021532	19	
44	1.3		20	
14	1.4		18	
42	1.5		18	95%
58	2.1	STA 18 GT	20	
31	2.2	2021537	20	
19	2.3		19	
60	2.4		19	
43	2.5		19	97%
54	3.1	STA 18 GB	18	
18	3.2	2021538	19	
37	3.3		19	
12	3.4		19	
1	3.5		18	93%
51	4.1	STA 18 E GT	20	
6	4.2	2021540	20	
49	4.3		16	
39	4.4		17	
21	4.5		18	91%
41	5.1	STA 18 E GB	19	
34	5.2	2021541	17	
8	5.3		20	
22	5.4		15	
27	5.5		19	90%
23	6.1	STA 18 N FB	20	
50	6.2	2021542	20	
59	6.3		20	
5	6.4		16	
26	6.5		18	94%
11	7.1	STA 18 N GT	18	
10	7.2	2021543	20	
46	7.3		20	
52	7.4		19	
3	7.5		20	97%
30	8.1	STA 18 N GB	18	
40	8.2	2021544	20	
16	8.3		18	
47	8.4		20	
4	8.5		18	94%
36	9.1	STA 18 W FG	17	
29	9.2	2021545	19	
20	9.3		20	
28	9.4		20	
38	9.5		17	93%
48	10.1	STA 18 W GT	20	
24	10.2	2021546	19	
57	10.3		20	
35	10.4		20	
25	10.5		19	98%
2	11.1	STA 18 W GB	18	

APPENDIX B
REMOTS IMAGE ANALYSIS RESULTS

Appendix B

REMOTS Sediment-Profile Imaging Data for the Sediment Toxicity Stations, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low	Comments
				Stage	Min	Max	Maj Mode	Habitat	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam		Roughness	DO	
1	A	6/25/2002	09:24	ST I	4 phi	1 phi	2 to 1 phi	SA.M	0	0	4.72	5.29	0.57	5.01	0	0	0	0	0	0	1.83	4.71	3.68	0	0	0	6	Physical	NO	Ambient brn medium sand, shell frags, debris @ surf?
1	B	6/25/2002	09:25	ST I	3 phi	0 phi	2 to 1 phi	SA.M	0	0	3.77	4.4	0.63	4.09	0	0	0	0	0	0	>3.77	>4.4	>4.09	0	0	0	7	Physical	NO	Ambient brn coarse sand, shell hash, tubes, RPD >pen
10	A	6/25/2002	12:07	ST II	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	13.99	14.57	0.58	14.28	> 13.99	> 14.57	> 14.28	0	0	0	0.35	4.65	2.82	0	0	0	7	Physical	NO	Relic DM>pen, tan/gry sandy m, stick amps, poly tubes: Print for report and add to Hall of Fame = stick amps
10	B	6/25/2002	12:08	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	10	0.24	15.16	15.65	0.49	15.4	> 15.16	> 15.65	> 15.4	0	0	0	0.14	6.28	2.68	0	0	0	5	Physical	NO	Relic DM>pen, tan/blk sandy m, ox & red clasts, wiper clasts, shell bits, sm worm @ z?
11	A	6/26/2002	10:01	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	2	0.27	13.57	13.9	0.33	13.73	> 13.57	> 13.9	> 13.73	0	0	0	0.76	4.60	3.28	0	0	0	6	Physical	NO	Recent DM>pen = remed material, tan sandy m/blk m, shell bits, tubes, vertical burrow, ox & red clasts, red sed@z, Nucula
11	B	6/26/2002	10:02	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	1	0.83	15.13	15.97	0.84	15.55	> 15.13	> 15.97	> 15.55	0	0	0	0.41	2.89	1.73	2	5.55	1.2	2	Biogenic	NO	Recent DM>pen = remed material, tan sandy m/blk sulfidic m, red clast, sm tubes, shell bits, methane bubbles, burrow-opening or bubble escape channel:Print for report = methane bubbles coming from sulfidic dm
12	B	6/25/2002	10:17	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	5	7.54	2.54	6.27	0	0	0	0	0	0	>5	>7.54	>6.27	0	0	0	7	Physical	NO	Ambient tan fine sand, sand ripple, RPD >pen
12	C	6/25/2002	10:18	INDET	3 phi	1 phi	3 to 2 phi	SA.F	0	0	-0.21	0.52	0.73	0.16	0	0	0	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Ambient tan fine sand, underpen
13	A	6/25/2002	10:26	ST I	> 4 phi	2 phi	3 to 2 phi	SA.F	1	0.29	7.91	8.49	0.58	8.2	0	0	3.46	0	0	0	3.30	4.85	4.41	0	0	0	7	Physical	NO	Ambient tan fine sand over relic dm, v red wiper clasts=obscured rpd, red clast, tubes, sand dollars-far, shell @ surf
13	C	6/25/2002	10:27	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.29	4.68	1.39	3.98	0	0	0	0	0	0	>3.29	>4.68	>3.98	0	0	0	7	Biogenic	NO	Ambient tan fine sand, shell bits, sand dollar @ surf, RPD >pen
14	A	6/25/2002	12:24	ST II on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	11.9	12.68	0.78	12.29	> 11.9	> 12.68	> 12.29	0	0	0	1.69	7.47	2.81	0	0	0	9	Biogenic	NO	Relic fine-grained DM>pen, tan/blk sandy m, stick amps, tubes, void, sm worms @z, Nucula?
14	C	6/25/2002	12:26	ST II to III	> 4 phi	2 phi	> 4 phi	UN.SF	3	0.52	13.38	14.06	0.68	13.72	> 13.38	> 14.06	> 13.72	0	0	0	0.14	3.13	1.56	0	0	0	7	Biogenic	NO	Relic fine-grained DM>pen, tan/blk sandy m, shell bits, dense stick amps, ox & red clsts, lg worm @z: print for report - dense stick amps & worm@z
15	D	6/26/2002	11:56	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	1	2.8	6	8.24	2.24	7.12	> 6	> 8.24	> 7.12	0	0	0	1.38	5.57	3.17	0	0	0	6	Physical	NO	Relic fine-grained DM>pen, tan/blk sandy m, tubes, shell bits, red clast, v sm void?, burrow opening?
15	F	6/26/2002	11:58	INDET	4 phi	-1 phi	1 to 0 phi	HR	0	0	0.13	2.31	2.18	1.22	> 0.13	> 2.31	> 1.22	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Relic DM>pen, Shells & rocks/brn sand, underpen
16	A	6/24/2002	16:20	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	2.27	4.81	2.54	3.54	0	0	0	0	0	0	>2.27	>4.81	>3.54	0	0	0	6	Physical	NO	Ambient fine sand, sand ripple, RPD >pen, sm tubes?
16	B	6/24/2002	16:21	INDET	3 phi	1 phi	3 to 2 phi	SA.F	2	0.66	-0.03	2.33	2.36	1.15	0	0	0	0	0	0	>-0.03	>2.33	>1.15	0	0	0	99	Physical	NO	Ambient fine sand, underpen, shell frags, ox clasts, tubes
17	A	6/25/2002	13:00	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	1	0.18	11.56	13.18	1.62	12.37	0	0	10.05	0	0	0	0.35	4.02	1.52	0	0	0	6	Physical	NO	Relic fine-grained DM>pen, Sand/dm, Tan sand/blk m, red clast, stick amp: Print for report=sand over reduced, relic dm
17	B	6/25/2002	13:00	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	5	0.51	9.81	11.25	1.44	10.53	> 9.81	> 11.25	> 10.53	0	0	0	0.14	5.65	1.74	0	0	0	4	Physical	NO	Relic DM>pen, tan sand/blk sulfidic sandy m, wiper clasts, red clasts, tubes
18	A	6/25/2002	12:49	ST II	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	12.24	13.54	1.3	12.89	> 12.24	> 13.54	> 12.89	0	0	0	0.64	3.98	2.29	0	0	0	7	Biogenic	NO	Relic fine-grained DM>pen, tan/blk sandy m, dense stick amps, shell bits, tubes, sm void?, biogenic mound
18	C	6/25/2002	12:50	ST II	> 4 phi	2 phi	> 4 phi	UN.SF	4	0.37	12.99	13.38	0.39	13.18	> 12.99	> 13.38	> 13.18	0	0	0	0.07	1.78	1.03	0	0	0	5	Physical	NO	Relic fine-grained DM>pen, tan/blk sandy m, stick amps, red clasts, worms @z, patchy RPD, tubes
19	B	6/26/2002	11:10	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	20.34	20.68	0.34	20.51	> 20.34	> 20.68	> 20.51	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, tan/blk m, overpen, tubes, void/burrow?
19	E	6/26/2002	11:17	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	19.11	19.61	0.5	19.36	> 19.11	> 19.61	> 19.36	0	0	0	3.03	6.34	5.27	0	0	0	11	Physical	NO	Recent DM>pen = remed material, tan sandy m/blk m, tubes, voids, worm @z: print for report - classic stage I on III in dm
2	A	6/25/2002	11:31	INDET	0 phi	< -1 phi	< -1 phi	HR	0	0	-0.12	1.72	1.84	0.8	0	0	0	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Ambient rock & cobble (or dm??), underpen, macro algae/sponge?
2	B	6/25/2002	11:32	INDET	> 4 phi	0 phi	4 to 3 phi	SA.F	0	0	1.66	2.93	1.27	2.3	0	0	0	0	0	0	0.35	1.91	1.31	0	0	0	99	Physical	NO	Ambient tan/gry fine sand, underpen, rocks, hydroids-far, burrow openings
20	A	6/24/2002	15:58	ST I	4 phi	2 phi	3 to 2 phi	SA.F	0	0	3.63	4.29	0.66	3.96	0	0	0	0	0	0	>3.63	>4.29	>3.96	0	0	0	7	Physical	NO	Ambient brn fine sand, RPD >pen, sand dollar-far
20	B	6/24/2002	15:59	ST I	4 phi	2 phi	3 to 2 phi	SA.F	0	0	2.04	4.74	2.7	3.39	0	0	0	0	0	0	>2.04	>4.74	>3.39	0	0	0	6	Physical	NO	Ambient brn fine sand, sand ripple, RPD >pen
22	B	6/25/2002	13:09	ST I	> 4 phi	0 phi	1 to 0 phi	SA.G	2	0.36	12.52	13.4	0.88	12.96	0	0	6.29	0	0	0	5.90	7.96	6.63	0	0	0	7	Physical	NO	Relic DM>pen, brn coarse sand&pebbles/blk muddy fine sand, distinct sed layering, red clasts, shell frags; print for report - distinct coarse sand/dm layering
22	C	6/25/2002	13:10	ST I	> 4 phi	< -1 phi	1 to 0 phi	SA.G	1	1.89	7.15	8.41	1.26	7.78	> 7.15	> 8.41	> 7.78	0	0	0	0.92	3.25	2.27	0	0	0	5	Physical	NO	Relic DM>pen, poorly sorted, Brn sand & pebbles/blk muddy fine sand, shell frags, lg red clast
24	A	6/24/2002	15:37	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	19.02	19.52	0.5	19.27	> 19.02	> 19.52	> 19.27	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	overpen, soft relic or Recent DM>pen (?), Tan muddy fine sand/blk m
24	C	6/24/2002	15:38	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	3	1.03	13.25	14.65	1.4	13.95	> 13.25	> 14.65	> 13.95	0	0	0	0.07	1.48	0.54	0	0	0	2	Physical	NO	Recent fine-grained DM>pen, tan sandy m/blk sulfidic m, shallow RPD, ox & red clasts, sm tubes
25	A	6/24/2002	15:47	ST I	2 phi	-1 phi	1 to 0 phi	SA.G	1	0.44	5.75	6.07	0.32	5.91	> 5.75	> 6.07	> 5.91	0	0	0	>5.75	>6.07	>5.91	0	0	0	7	Physical	NO	Relic DM>pen, Coarse sand & pebbles, RPD >pen, red clast
25	B	6/24/2002	15:47	ST I	2 phi	-1 phi	1 to 0 phi	SA.G	0	0	8.54	9.47	0.93	9.01	> 8.54	> 9.47	> 9.01	0	0	0	2.40	5.36	4.91	0	0	0	7	Physical	NO	Relic DM>pen, coarse sand & pebbles, shell frags
26	B	6/25/2002	13:26	ST I	> 4 phi	1 phi	3 to 2 phi	SA.F	0	0	1.27	5.02	3.75	3.14	> 1.27	> 5.02	> 3.14	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Relic DM>pen, Brn fine sand mixed w/ red clay, sloping topo or ripple
26	C	6/25/2002	13:26	ST I	3 phi	1 phi	3 to 2 phi	SA.F	1	0.29	1.56	3.06	1.5	2.31	> 1.56	> 3.06	> 2.31	0	0	0	>1.56	>3.06	>2.31	0	0	0	5	Physical	NO	Brn fine ambient sand>pen, sand ripple, RPD >pen, shell frags-far
27	A	6/25/2002	14:01	ST II on III	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	14.45	15.24	0.79	14.84	> 14.45	> 15.24	> 14.84	0	0	0	0.07	2.83	0.76	0	0	0	7	Physical	NO	Relic, fine-grained DM>pen, tan/blk m, stick amps, thin RPD, burrow, shell bits, voids, Nucula?
27	C	6/25/2002	14:02	ST II	4 phi	3 phi	> 4 phi	UN.SF	3	0.93	12.84	14.13	1.29	13.49	> 12.84	> 14.13	> 13.49	0	0	0	0.07	3.39	1.66	0	0	0	6	Physical	NO	Relic fine-grained DM>pen, tan/blk m, red clasts, stick amps, tubes, patchy RPD
28	A	6/25/2002	15:42	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SI	0	0	5.11	5.34	0.23	5.23	> 5.11	> 5.34	> 5.23	0	0	0	0.64	2.68	1.46	0	0	0	3	Physical	NO	Relic DM>pen, no remediation material, tan/blk sandy m, shell frags, tubes, Nucula?
29	A	6/25/2002	15:03	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	1	0.34	20.24	20.61	0.37	20.42	> 20.24	> 20.61	> 20.42	0	0	0	0.28	1.69	1.26	0	0	0	7	Physical	NO	Recent fine-grained DM>pen = remed material, tan/blk m, shell bits, ox clasts, sm tubes, voids, overpen
29	B	6/25/2002	15:03	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	11.93	12.27	0.34	12.1	> 11.93	> 12.27	> 12.1	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent fine-grained DM>pen = remed material, dist surf/smearing, gry m
3	C	6/25/2002	11:47	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	7.81	8.47	0.66	8.14	0	0	0	0	0	0	0.49	3.59	2.68	0	0	0	7	Physical	NO	Ambient tan/gry sandy m, shell frags, lg shell @ surf, stick amps, orgs-far?
30	A	6/25/2002	14:13	ST II	4 phi	0 phi	3 to 2 phi	SA.F	0	0	2.18	3.75	1.57	2.97	0	0	0	0	0	0	0.07	3.65	2.64	0	0	0	7	Biogenic	NO	Ambient fine sand>pen, shell frags, stick amps, burrow opening?, rock @ surf
30	C	6/25/2002	14:15	ST I on III	> 4 phi	1 phi	> 4 phi	UN.SS	0	0	6.18	6.77	0.59	6.47	> 6.18	> 6.77	> 6.47	0	0	0	0.21	4.15	1.91	0	0	0	8	Physical	NO	Relic DM>pen, Fine sand/blk m, red clay, tubes, voids, shell frags
31	A	6/24/2002	14:40	ST I	4 phi	2 phi	3 to 2 phi	SA.F	0	0	3.91	5.34	1.43	4.62	0	0	0	0	0	0	>3.91	>5.34	>4.62	0	0	0	7	Physical	NO	Category II capping project sand>pen, sand ripple, RPD >pen, sm tubes, shell frags
31	C	6/24/2002	14:41	ST I	4 phi	2 phi	3 to 2 phi	SA.F	0	0	3.93	5.82	1.89	4.88	0	0	0	0	0	0	>3.93	>5.82	>4.88	0	0	0	7	Physical	NO	Category II capping project sand>pen, ripple, shell frag, RPD >pen
32	A	6/24/2002	14:32	ST II	> 4 phi	1 phi	4 to 3 phi	SA.F	0	0	6.75	8.74	1.99	7.74	> 6.75	> 8.74	> 7.74	0	0	0	0.35	5.85	2.83	0	0	0	7	Physical	NO	Relic DM>pen, tan sand/blk sandy m, shell bits, stick amps, fecal casts, tubes
32	B	6/24/2002	14:32	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SS	0	0	6.75	7.65	0.9	7.2	> 6.75	> 7.65	> 7.2	0	0	0	0.07	7.33	3.30	0	0	0	8	Physical	NO	Relic DM>pen, wiper clast, stick amps, tubes, shell bits, red sed @z
33	B	6/24/2002	14:24	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	11.02	12.38	1.36	11.7	> 11.02	> 12.38	> 11.7	0	0	0	0.07	3.77	1.54	0	0	0	8	Physical	NO	Relic fine-grained DM>pen, tan/blk sandy m, tubes, sm voids, red sed @z, shell bits, Nucula
33	C	6/24/2002	14:25	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	3	0.27	13.2	13.93	0.73	13.57	> 13.2	> 13.93	> 13.57	0	0	0	0.07	3.31	0.88	0	0	0	3	Physical	NO	Relic fine-grained DM>pen, patchy RPD, red clasts, sm tubes, worm @ z, fecal/flock lyr
34	B	6/24/2002	15:12	ST I	3 phi	1 phi	2 to 1 phi	SA.M	0	0	3.91	6	2.09	4.95	0	0	0	0	0	0	>3.91	>6	>4.95	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, ripple, RPD >pen, sm tubes
34	C	6/24/2002	15:12	ST I	3 phi	1 phi	2 to 1 phi	SA.M	0	0	3.16	4.9	1.74	4.03	0	0	0	0	0	0	>3.16	>4.9	>4.03	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, ripple, RPD >pen, sm tubes
35	A	6/24/2002	15:04	ST I	3 phi	1 phi	2 to 1 phi	SA.M	0	0	4.09	5.06	0.97	4.57	0	0	0	0	0	0	>4.09	>5.06	>4.57	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, RPD >pen, tubes, fecal casts-far
35	C	6/24/2002	15:05	ST I	3 phi	1 phi	2 to 1 phi	SA.M	0	0	4.99	5.68	0.69	5.34	0	0	0	0	0	0	>4.99	>5.68	>5.34	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, RPD >pen, tubes, fecal casts-far
36	A	6/24/2002	13:38	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	1	0.31	8.82	9.18	0.36	9	> 8.82	> 9.18	> 9	0	0	0	1.27	4.65	2.50	0	0	0	9	Physical	NO	Relic sandy dm>pen, sulfidic dm, shell frags, tubes, voids, red clast, org near surf?
36	B	6/24/2002	13:398	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	0	0	4.02	4.56	0.54	4.29	0	0	0	0	0	0	0.28	2.94	1.99	0	0	0	4	Physical	NO	Relic sandy dm>pen, shell frags, red clasts-far, wiper clasts, tubes, stick amps-far
37	A	6/24/2002	13:16	ST I	2 phi	0 phi	2 to 1 phi	SA.M	0	0	3.88	6.57	2.69	5.23	0	0	0	0	0	0	>3.88	>6.57	>5.23	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, RPD >pen, sm pebbles, sand dollars-far, shell frags
37	C	6/24/2002	13:18	ST I	2 phi	1 phi	2 to 1 phi	SA.M	0	0	4.02	4.91	0.89	4.47	0	0	0	0	0	0	>4.02	>4.91	>4.47	0	0	0	7	Physical	NO	Ambient tan medium sand>pen, RPD >pen, tubes
38	A	6/24/2002	13:27	ST I	2 phi	0 phi	1 to 0 phi	SA.G	1	0.25	6.22	6.56	0.34	6.39	0	0	0	0	0	0	>6.22	>6.56	>6.39	0	0	0	7	Physical	NO	Ambient brn sand & gravel>pen, RPD >pen, red clast, shell frags
38	C	6/24/2002	13:28	ST I	2 phi	-1 phi	1 to 0 phi	SA.G	0	0	5.07	5.86	0.79	5.47	0	0	0	0	0	0	>5.07	>5.86	>5.47	0	0	0	7	Physical	NO	Ambient brn sand & gravel>pen, RPD >pen
39	A	6/24/2002	13:49	ST I	3 phi	2 phi	3 to 2 phi	SA.F	0	0	4.41	5.81	1.4	5.11	0	0	0	0	0	0	>4.41	>5.81	>5.11	0	0	0	7	Physical	NO	Ambient brn fine sand>pen, ripple, RPD >pen, tubes, stick amps?, shell-far
39	B	6/24/2002	13:49	ST II	3 phi	2 phi	3 to 2 phi	SA.F	0	0	3.45	4.27	0.82	3.86	0	0	0	0	0	0	>3.45	>4.27	>3.86	0	0	0	9	Physical	NO	Ambient brn fine sand>pen, shell frags, stick amps, RPD >pen
4	A	6/25/2002	09:43	ST I	4 phi	1 phi	3 to 2 phi	SA.F	0	0	2.15	4.11	1.96	3.13	0	0	0	0	0	0	0.42	3.31	1.84	0	0	0	4	Physical	NO	Ambient muddy fine sand>pen, shell bits, sand ripple, tubes
4	B	6/25/2002	09:44	ST II	4 phi	2 phi	3 to 2 phi	SA.F	0	0	2.99	3.97	0.98	3.48	0	0	0	0	0	0	1.55	2.81	2.24	0	0	0	6	Physical	NO	Ambient brn fine sand>pen, shell frags, stick amp-far, tubes
40	B	6/24/2002	14:09	ST II	> 4 phi	1 phi	4 to 3 phi	UN.SI	3	0	4.77	6.82	2.05	5.8	0	0	0	0	0	0	1.98	3.90	3.22	0	0	0	8	Physical	NO	Ambient poorly sorted tan sandy m w/medium sand, relic dm???, dense stick amps, wiper clasts, red clasts, sm void?, tubes
40	C	6/24/2002	14:09	ST II on III	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	10.63	11.54	0.91	11.09	0	0	0	0	0	0	1.84	6.08	2.91	0	0	0	9	Biogenic	NO	Ambient tan/gry sandy m, relic dm??,dense stick amps, Ampelisca?, poly tubes, worm @ z, voids, surf rework, good example of St II on III.
42	A	6/24/2002	12:58	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	4.22	4.86	0.64	4.54	0	0	0	0	0	0	>4.22	>4.86	>4.54	0	0	0	7	Physical	NO	Ambient brn fine sand, ripples-far, RPD >pen
42	B	6/24/2002	13:00	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.11	4.82	1.71	3.97	0	0	0	0	0	0	>3.11	>4.82	>3.97	0	0	0	7	Physical	NO	Ambient brn fine sand, ripples-far, RPD >pen, tubes
43	A	6/24/2002	12:43	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	4.59	5.13	0.54	4.86	0	0	0	0	0	0	>4.59	>5.13	>4.86	0	0	0	7	Physical	NO	Ambient brn fine sand, shell frags. RPD >pen, sand dollar-far
43	C	6/24/2002	12:44	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	5.99	6.93	0.94	6.46	0	0	0	0	0	0	0.78	4.58	3.57	0	0	0	6	Physical	NO	Ambient brn fine sand>pen, sm tubes
44	B	6/24/2002	12:28	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.18	4.68	1.5	3.93	0	0	0	0	0	0	2.33	3.88	3.09	0	0	0	6	Physical	NO	Ambient brn fine sand>pen, ripple
44	C	6/24/2002	12:28	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	1.95	3.04	1.09	2.49	0	0	0	0	0	0	>1.95	>3.04	>2.49	0	0	0	5	Physical	NO	Ambient brn fine sand>pen, RPD >pen, ripple
45	B	6/24/2002	12:14	ST II	> 4 phi	1 phi	4 to 3 phi	UN.SS	0	0	12.02	12.38	0.36	12.2	0	0	2.57	0	0	0	0.35	2.61	2.30	0	0	0	7	Physical	NO	Ambient muddy fine sand/silt/muddy fine sand over relic DM, sed horizons, stick amps, tubes, shell bits, red sed patch @ z
45	C	6/24/2002	12:15	ST II	> 4 phi	1 phi	4 to 3 phi	UN.SS	5	0.4	10.52	11.49	0.97	11.01	0	0	3.79	0	0	0	2.45	5.12	3.80	0	0	0	9	Physical	NO	Ambient tan sand/blk sulfidic dm, distinct S/DM stratigraphy, ox & red clasts, stick amps, tubes, v red sed @z
46	A	6/24/2002	12:03	ST II on III	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	13.43	13.81	0.38	13.62	> 13.43	> 13.81	> 13.62	0	0	0	0.56	4.01	2.30	0	0	0	9	Biogenic	NO	Relic sandy dm>pen, sulfidic@z, stick amps, tubes, voids, lg worms @ z, amp tube?
46	B	6/24/2002	12:04	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	3	0.41	11.95	12.81	0.86	12.38	> 11.95	> 12.81	> 12.38	0	0	0	0.28	2.88	1.29	0	0	0	3	Physical	NO	Relic fine grained dm>pen, patchy RPD, red clasts, tubes, worm @z, red sed @z
49	A	6/25/2002	10:53	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	6.2	7.5	1.3	6.85	> 6.2	> 7.5	> 6.85	0	0	0	0.14	2.90	1.55	0	0	0	4	Physical	NO	Relic DM>pen?, tan/blk sandy m, shell bits, tubes, void, stick amp-far?, fecal lyr
49	B	6/25/2002	10:54	ST I on III	> 4 phi	2 phi	4 to 3 phi	UN.SS	5	0.28	6.97	7.79	0.82	7.38	> 6.97	> 7.79	> 7.38	0	0	0	0.21	3.24	2.27	0	0	0	9	Physical	NO	Relic sandy DM>pen, Tan muddy fine sand/blk sandy m, shell bits, red clasts, tubes, void

Appendix B

REMOTS Sediment-Profile Imaging Data for the Sediment Toxicity Stations, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low	Comments
				Stage	Min	Max	Maj Mode	Habitat	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam		Roughness	DO	
5	B	6/25/2002	10:00	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.38	6.82	3.44	5.1	0	0	0	0	0	0	>3.38	>6.82	>5.1	0	0	0	7	Physical	NO	Ambient tan fine sand>pen, ripple, RPD >pen, shell frags
5	C	6/25/2002	10:01	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.81	4.97	1.16	4.39	0	0	0	0	0	0	>3.81	>4.97	>4.39	0	0	0	7	Physical	NO	Ambient tan fine sand>pen, ripple, RPD >pen, shell frags, org-far?
6	A	6/25/2002	10:43	ST I	> 4 phi	1 phi	3 to 2 phi	SA.F	0	0	10.88	12.32	1.44	11.6	0	0	3.24	0	0	0	2.68	6.06	5.13	0	0	0	7	Physical	NO	Ambient tan fine sand/blk sulfidic m, distinct S/M stratigraphy, ambient/dm, shell frags, v red sed @z, ripple: print for report = ambient sand/blk relic dm
6	C	6/25/2002	10:44	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	3.27	4.91	1.64	4.09	0	0	0	0	0	0	>3.27	>4.91	>4.09	0	0	0	7	Physical	NO	Ambient brn fine sand, RPD>pen, shell frags, tubes
7	A	6/26/2002	09:38	ST II	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	7.86	8	0.14	7.93	> 7.86	> 8	> 7.93	0	0	0	0.62	5.37	2.11	0	0	0	6	Biogenic	NO	Recent DM>pen = remed material, tan/blk sandy m, dense tubes, stick amp, red sed @z
7	C	6/26/2002	09:39	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	3	0.26	10.66	11.15	0.49	10.9	> 10.66	> 11.15	> 10.9	0	0	0	0.62	4.20	2.47	0	0	0	7	Physical	NO	Recent DM>pen = remed material, tan/blk sandy m, red sed @z, stick amps, red clasts, smear artifact=obscured rpd
8	B	6/25/2002	10:09	ST I	3 phi	1 phi	3 to 2 phi	SA.F	0	0	4.61	7.63	3.02	6.12	0	0	0	0	0	0	>4.61	>7.63	>6.12	0	0	0	7	Physical	NO	Ambient fine sand >pen, ripple, RPD >pen
8	C	6/25/2002	10:10	ST I	3 phi	0 phi	2 to 1 phi	SA.M	0	0	4.38	5.24	0.86	4.81	0	0	0	0	0	0	>4.38	>5.24	>4.81	0	0	0	7	Physical	NO	Ambient brn medium sand>pen, shell frags, ripple, RPD >pen
9	A	6/25/2002	11:12	ST II to III	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	10.57	10.82	0.25	10.69	> 10.57	> 10.82	> 10.69	0	0	0	0.94	2.66	2.14	0	0	0	7	Physical	NO	Relic DM>pen, tan/blk sandy m, shell frags, tubes, stick amps, burrowing anenome @z, Nucula?
9	C	6/25/2002	11:13	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	7	0.52	9.93	10.77	0.84	10.35	> 9.93	> 10.77	> 10.35	0	0	0	0.42	3.60	1.89	0	0	0	6	Biogenic	NO	Relic DM>pen, tan/blk sandy m, dense stick amps, ox & red clasts, shell frags, red sed @z
E0800	C	6/26/2002	09:51	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	1	0.4	15.47	15.75	0.28	15.61	> 15.47	> 15.75	> 15.61	0	0	0	0.14	6.46	3.55	0	0	0	6	Physical	NO	Recent DM>pen = remed material, tan m, red sed @z, ox clast
E0800	E	6/26/2002	09:52	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	4	0.44	16.9	17.54	0.64	17.22	> 16.9	> 17.54	> 17.22	0	0	0	0.35	3.80	1.83	0	0	0	4	Physical	NO	Recent DM>pen = remed material, tan/gry m, ox & red clasts, sm tubes, surf rework, v sm void?
G1200	B	6/26/2002	10:14	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	1	0.44	13.7	14.07	0.37	13.89	> 13.7	> 14.07	> 13.89	0	0	0	0.55	4.67	2.56	0	0	0	5	Physical	NO	Recent DM>pen = remed material, tan/blk m, red clast, tubes, shell bits, patchy RPD, red sed @ surf, worm @z, smearing artifact=obscured rpd
G1200	C	6/26/2002	10:20	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	13.22	14.06	0.84	13.64	> 13.22	> 14.06	> 13.64	0	0	0	0.07	3.65	1.57	0	0	0	4	Physical	NO	Recent DM>pen = remed material, tan/blk sulfidic m, tubes, Nucula
H2000	A	6/26/2002	10:31	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	2	0.31	14.2	14.66	0.46	14.43	> 14.2	> 14.66	> 14.43	0	0	0	1.44	4.68	3.34	0	0	0	10	Physical	NO	Recent DM>pen = remed material, dm layers=relic rpd, tan/blk sandy m, tubes, ox & red clasts, voids, shell bits, burrow, Nucula?: print for report = classic DM layering with relic rpd and stage III voids
H2000	C	6/26/2002	10:32	ST I on III	> 4 phi	3 phi	> 4 phi	UN.SF	3	0.36	13.97	14.31	0.34	14.14	> 13.97	> 14.31	> 14.14	0	0	0	1.65	4.06	3.17	0	0	0	10	Physical	NO	Recent DM>pen = remed material, tan/gry sandy m, ox clasts, tubes, voids, worms @z, smearing artifact=obscured RPD
I1200	A	6/26/2002	10:42	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	20.59	20.68	0.09	20.64	> 20.59	> 20.68	> 20.64	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, overpen, tan & gry m, sm voids
I1200	B	6/26/2002	10:42	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	20.52	20.63	0.11	20.58	> 20.52	> 20.63	> 20.58	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, tan &gry m, overpen
K0800	B	6/26/2002	10:57	INDET	4 phi	2 phi	4 to 3 phi	UN.SS	0	0	0.09	1.16	1.07	0.62	> 0.09	> 1.16	> 0.62	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Underpen=hard bottom=KVK material in PRA2=remed material, tan/gry muddy fine sand
K0800	C	6/26/2002	10:58	INDET	4 phi	< -1 phi	1 to 0 phi	HR	0	0	-0.35	1.29	1.64	0.47	> -0.35	> 1.29	> 0.47	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Underpen- hard bottom, Rocks from KVK project in PRA 2=remediation material, byrozoans
L1200	A	6/25/2002	16:19	INDET	3 phi	< -1 phi	< -1 phi	HR	0	0	0	0	0	0	> 0	> 0	> 0	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Underpen, hard bottom = rocks from KVK project in PRA 2
L1200	C	6/25/2002	16:21	INDET	< -1 phi	< -1 phi	< -1 phi	HR	0	0	-0.16	4.13	4.29	1.99	> -0.16	> 4.13	> 1.99	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Underpen, hard bottom, rock& cobble fromKVK project in PRA 2, bryozoans: Print for report - rocks from KVK project in PRA 2
L1600	A	6/25/2002	16:12	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	14.72	15.32	0.6	15.02	> 14.72	> 15.32	> 15.02	0	0	0	0.14	5.31	3.64	0	0	0	10	Physical	NO	Recent DM>pen = remed material, tan/blk m, tubes, voids, red sed @z, shell frags, Nucula?
L1600	C	6/25/2002	16:14	ST II	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	15.15	16.15	1	15.65	> 15.15	> 16.15	> 15.65	0	0	0	3.17	5.15	4.30	0	0	0	9	Physical	NO	Recent DM>pen = remed material, tan/gry&blk m, smearing artifact=obscured rpd, stick amps, tubes, flock lyr
L2400	A	6/25/2002	16:03	ST I	3 phi	-1 phi	1 to 0 phi	SA.G	0	0	5.95	6.54	0.59	6.24	0	0	0	0	0	0	>5.95	>6.54	>6.24	0	0	0	7	Physical	NO	Ambient coarse sand>pen, brn medium sand w/rocks & pebbles, RPD >pen
L2400	B	6/25/2002	16:03	INDET	0 phi	< -1 phi	< -1 phi	HR	0	0	0	0	0	0	> 0	> 0	> 0	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Underpen, hard bottom, rock & cobble=KVK dredged material in PRA 2?
M1200	A	6/25/2002	15:51	ST I	4 phi	1 phi	4 to 3 phi	SA.F	0	0	2.24	5.43	3.19	3.84	> 2.24	> 5.43	> 3.84	0	0	0	0.21	3.13	1.78	0	0	0	4	Indeterminate	NO	Sandy DM >pen = recent remed material?, tan/gry muddy fine sand, dist surf
M1200	B	6/25/2002	15:51	INDET	4 phi	< -1 phi	1 to 0 phi	HR	0	0	0	0	0	0	> 0	> 0	> 0	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Underpen, hard bottom, DM, recent or relic???, brn sand w/ rocks, bryozoans
M2800	D	6/26/2002	12:22	INDET	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	19.75	20.02	0.27	19.89	> 19.75	> 20.02	> 19.89	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, overpen, tan/blk m, burrow-opening
M2800	H	6/26/2002	12:25	INDET	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	20.47	20.7	0.23	20.58	> 20.47	> 20.7	> 20.58	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, overpen, tan/blk m, voids, shell bits
N2000	A	6/25/2002	15:31	ST III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	19.36	19.52	0.16	19.44	> 19.36	> 19.52	> 19.44	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	NO	Recent DM>pen = remed material, overpen, tan/blk m, voids, shell bits
N2000	B	6/25/2002	15:32	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	5	0.46	15.43	16.9	1.47	16.17	> 15.43	> 16.9	> 16.17	0	0	0	0.07	2.03	0.70	0	0	0	2	Physical	NO	Recent fine-grained DM>pen = remed material, tan/gry m, red clasts, tubes, red sed@surf, shallow RPD, reduced clasts
N3200	B	6/25/2002	15:14	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	7	0.28	10.11	10.63	0.52	10.37	> 10.11	> 10.63	> 10.37	0	0	0	3.95	6.42	4.86	0	0	0	7	Physical	NO	Relic dm>pen, smearing artifact=obscured RPD, tan/gry sandy m, red clasts, tubes
N3200	C	6/25/2002	15:15	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	2	1.21	9.47	10.36	0.89	9.91	> 9.47	> 10.36	> 9.91	0	0	0	0.56	3.95	3.02	0	0	0	6	Physical	NO	Relic DM>pen, smearing artifact, tan/blk sandy m, ox & red clasts, tubes, red sed @z
P2800	A	6/25/2002	14:38	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	12.59	13.09	0.5	12.84	> 12.59	> 13.09	> 12.84	0	0	0	0.84	3.80	2.33	0	0	0	9	Physical	NO	Relic DM>pen, tan/blk mud, tubes, voids. Nucula
P2800	B	6/25/2002	14:38	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	3	0.43	12.31	12.65	0.34	12.48	> 12.31	> 12.65	> 12.48	0	0	0	0.07	3.74	1.50	0	0	0	3	Physical	NO	Relic DM>pen, tan/blk m, red clasts, sm tubes, worm @ z, fecal lyr
P3200	A	6/25/2002	14:27	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	9.25	9.47	0.22	9.36	> 9.25	> 9.47	> 9.36	0	0	0	2.42	4.41	3.22	0	0	0	6	Physical	NO	Relic DM>pen, tan/blk sandy m, tubes, Nucula?
P3200	C	6/25/2002	14:29	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	2	0.24	10.79	11.04	0.25	10.91	> 10.79	> 11.04	> 10.91	0	0	0	0.78	3.67	2.49	0	0	0	5	Physical	NO	Relic DM>pen, Tan/blk sandy m, tubes, red clasts, shell bits, Nucula?
Q1600	A	6/24/2002	15:21	ST I	4 phi	1 phi	2 to 1 phi	SA.F	0	0	4.06	4.68	0.62	4.37	0	0	0	0	0	0	1.69	4.29	3.66	0	0	0	6	Physical	NO	Ambient sand>pen, no visible remed material, brn fine sand, sm tubes
Q1600	B	6/24/2002	15:22	ST I	> 4 phi	1 phi	2 to 1 phi	UN.SS	5	0.65	4.47	5.02	0.55	4.74	> 4.47	> 5.02	> 4.74	0	0	0	0.91	4.64	3.55	0	0	0	6	Physical	NO	Relic dm>pen, Brn sand/blk sandy m, red clasts, shell frags, m clumps-far, sm tubes
Q2400	A	6/25/2002	14:48	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SF	0	0	16.59	16.9	0.31	16.74	> 16.59	> 16.9	> 16.74	0	0	0	0.07	4.09	1.58	0	0	0	8	Physical	NO	Recent DM>pen = remed material or relic dm??, tan sandy m/blk m, tubes, shell bits, voids, Nucula
Q2400	C	6/25/2002	14:50	ST I	> 4 phi	2 phi	> 4 phi	UN.SF	1	0.32	16.47	16.97	0.5	16.72	> 16.47	> 16.97	> 16.72	0	0	0	0.07	4.56	1.87	0	0	0	4	Physical	NO	Recent DM>pen = remed material or relic dm??, tan/blk m, red clast, tubes, stick amp?, shell bits, red sed @ surf