RESULTS OF THE SUMMER 2005 SEDIMENT TOXICITY AND SEDIMENT-PROFILE IMAGING SURVEY AT THE HISTORIC AREA REMEDIATION SITE

FINAL REPORT

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ACKNOWLEDGEMENTS

This report presents the results of the Summer 2005 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, as a subcontractor to Offshore and Coastal Technologies, Inc (OCTI) under their existing Indefinite Delivery Order contract with the U.S. Army Corps of Engineers - New York District (NYD). Dr. Stephen Knowles was the NYD's manager of technical activities, Mr. Bill Grosskopf was OCTI's program manager, and Mr. Tom Waddington served as SAIC's project manager.

Sediment-profile / plan-view imaging and sediment toxicity sampling operations were conducted aboard the M/V *Beavertail.* The crew of the M/V *Beavertail* is commended for their skill in vessel handling while conducting the sampling operations, as well as their dedication during long hours of operation at the HARS. We would also like to thank the U.S. Coast Guard Sandy Hook Station for allowing the M/V *Beavertail* to temporarily dock at the station during the field sampling at the HARS. Our ability to use the Coast Guard facilities helped to improve the efficiency of our field operations. In addition, we would like to thank Dr. Mary Fabrizio of the James J. Howard Marine Science Laboratory at the NOAA Sandy Hook facility for offering the Lab's assistance with logistical support and cold storage of sediment samples during the field operations.

Natasha Pinckard of SAIC coordinated the field sampling activities, and was assisted in the field by Michael Cole, Pamela Luey, and Kate Montgomery, also of SAIC. Aqua Survey, Inc. (ASI) of Flemington, NJ conducted the toxicity testing and the geotechnical analyses on the sediment grab samples. Natasha Pinckard conducted the sediment-profile image analyses with technical review provided by Ray Valente of SeaRay Environmental. Christopher Woods and Greg Berman of SAIC were responsible for data tracking and management, as well as the development of the supporting GIS figures for the study report. Natasha Pinckard and Ray Valente authored the Study Report with a final review provided by Tom Waddington and Dr. Knowles. Linda Smith of SAIC was responsible for document production of the final Study Report.

EXECUTIVE SUMMARY

Since the closure of the Mud Dump Site (MDS) in September 1997 and its re-designation as the Historic Area Remediation Site (HARS), placement of remediation dredged 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 Region 2 of the Environmental Protection Agency (EPA).

Specifically, surface sediments collected during an EPA-sponsored survey in 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*. Two subsequent sediment toxicity monitoring surveys sponsored by the U.S. Army Corps of Engineers New York District (NYD) revealed a 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. Additional toxicity testing of surface sediment in and around the HARS and former MDS was conducted in the summer of 2005 to help establish temporal trends and observe the effects of additional remediation of the HARS.

This report, therefore, presents the results of the fourth HARS sediment toxicity survey, which was conducted during late August and early September of 2005. The 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 addition, a seafloor camera system was used to obtain sediment-profile images (SPI) and sediment plan-view images at each station to evaluate benthic recolonization status and overall benthic habitat quality, in both areas of the HARS that have received remediation material and in those that have not.

Consistent with the results of many past SPI/plan-view surveys in and around the HARS and the former MDS, the 2005 survey indicated that these areas continued to be characterized by a wide variety of surface sediment types. These sediments, which ranged in texture from silt-clays to gravels, included historic (i.e., relic) dredged material, fine-grained remediation material placed since 1997 in PRAs 1 through 4, and sands that represent the native sediment type in much of the New York Bight outside the HARS boundaries. The remediation material observed in PRAs 1 through 4 consisted of either "conventional" organic-rich mud or red clay that was either soft/unconsolidated or in cohesive clumps.

In response to the mosaic of different substrate types and benthic habitat conditions, the 2005 imaging results showed that benthic communities were equally varied. As in the past, small, opportunistic, Stage I polychaetes were abundant at many stations, reflecting their ability to colonize the sediment surface quickly and in high numbers in response to physical disturbance of the seafloor associated with either natural migration of sand (in areas outside the HARS) or following dredged material disposal within the HARS.

Stage I represents the climax infaunal successional stage in the mobile sands that comprise the seafloor over much of the New York Bight. On the other hand, the placement of muddy harbor sediments within both the HARS and the former MDS has resulted in soft-bottom conditions conducive to supporting infaunal succession beyond Stage I. The majority of stations within the HARS, including most of those with remediation material, had an advanced successional status consisting of either Stage II or III at the time of the Summer 2005 survey. In particular, biological features indicating the presence of a diverse assemblage of surface- and subsurface-dwelling benthic organisms were observed in the SPI and plan-view images over large portions of PRAs 1 through 4 where red clay (among other types of remediation material) has been placed on an ongoing basis since HARS designation in 1997.

Benthic habitat conditions, as indicated by Organism Sediment Index (OSI) values derived from analysis of the SPI images, were found to be either undisturbed or only moderately disturbed at the majority of stations in PRAs 1 through 4. Overall, the 2005 OSI values suggested a relatively advanced degree of benthic community recovery from the disturbance effects of both historic and more-recent disposal activities.

The results of the 2005 survey also indicated that surface sediments collected at 60 stations in and around the HARS were uniformly non-toxic, as measured by the standard 10-day acute toxicity test with the amphipod *Ampelisca abdita*. All of the 44 stations sampled in the original EPA survey of 1994 were included among the 60 stations sampled in both 2005 and 2002. Therefore, both the 2005 and 2002 toxicity testing results, as well as those from the survey conducted in October 2000, continue to contrast with the results of the original toxicity survey of 1994.

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
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
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
SPI	Sediment Profile Imaging
UTC	Universal Time Coordinate

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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 any 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 PRAs.

Since designation of the HARS in September 1997, placement of remediation material in PRAs 1, 2, 3, and 4 has been ongoing. As part of the tiered environmental monitoring program, the SMMP requires periodic assessments of sediment toxicity. The main objective of such assessments is to verify that placement of remediation material has significantly reduced the elevated levels of chemical contamination and associated toxicity that were observed previously in the EPA Region 2 survey of October 1994 (Figure 1.1-3).

An October 2000 sediment toxicity monitoring survey sponsored by the NYD involved sampling at stations located primarily in and around PRA 1 (Figure 1.1-3). Surface sediments were collected 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 subsequent laboratory testing, using the standard 10-day acute test with the amphipod *Ampelisca abdita*, revealed an unexpected absence of significant sediment toxicity, particularly at or near some of the same sampling locations where sediments had been found to be toxic using the same testing procedures in the previous October 1994 survey sponsored by EPA Region 2 (Battelle 1996).

Based on the discrepancy between the original October 1994 and subsequent October 2000 survey results, additional toxicity testing of surface sediments in and around the HARS was

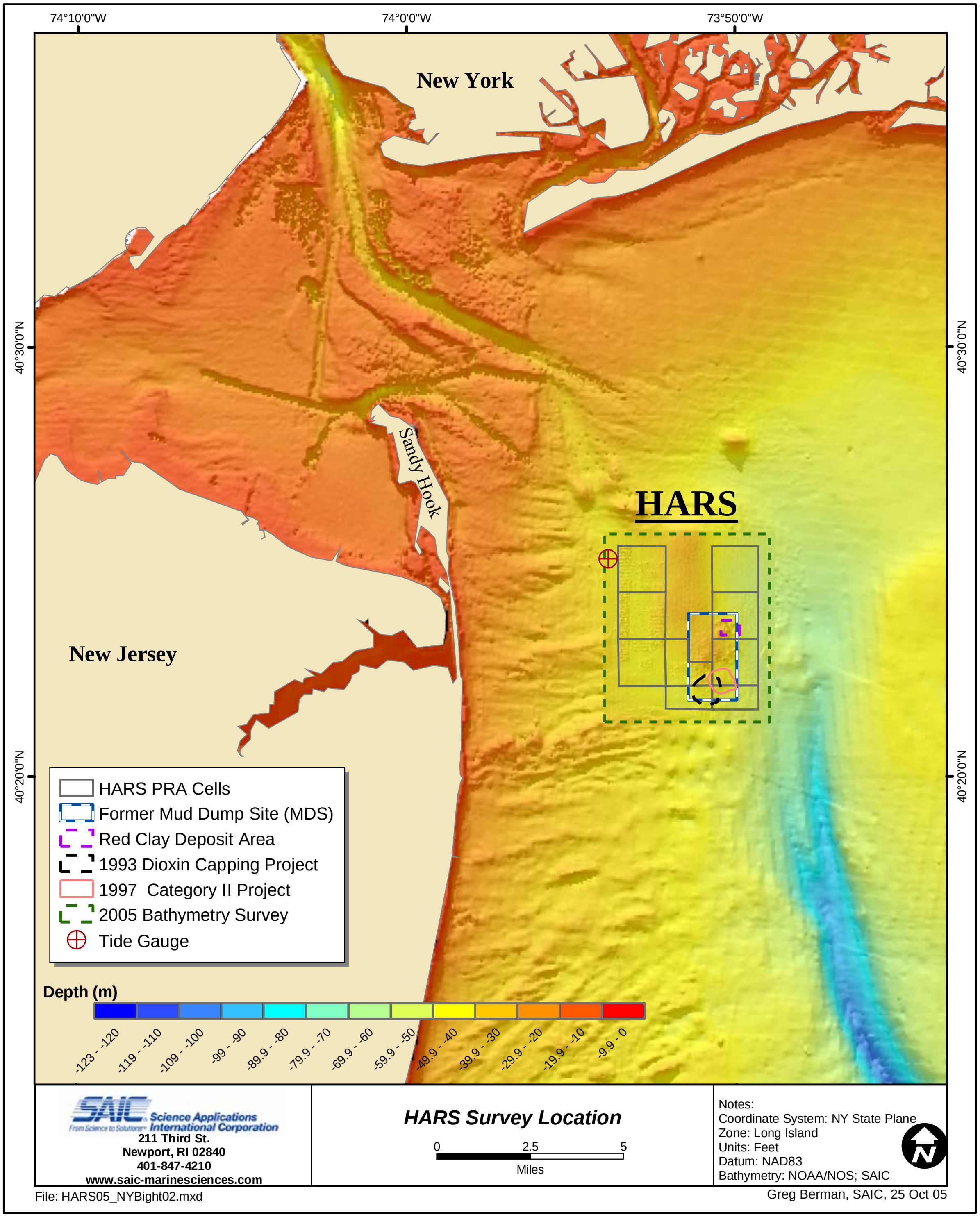


Figure 1.1-1. Map showing the locations of the former Mud Dump Site (MDS) and the Historic Area Remediation Site (HARS) in the New York Bight.

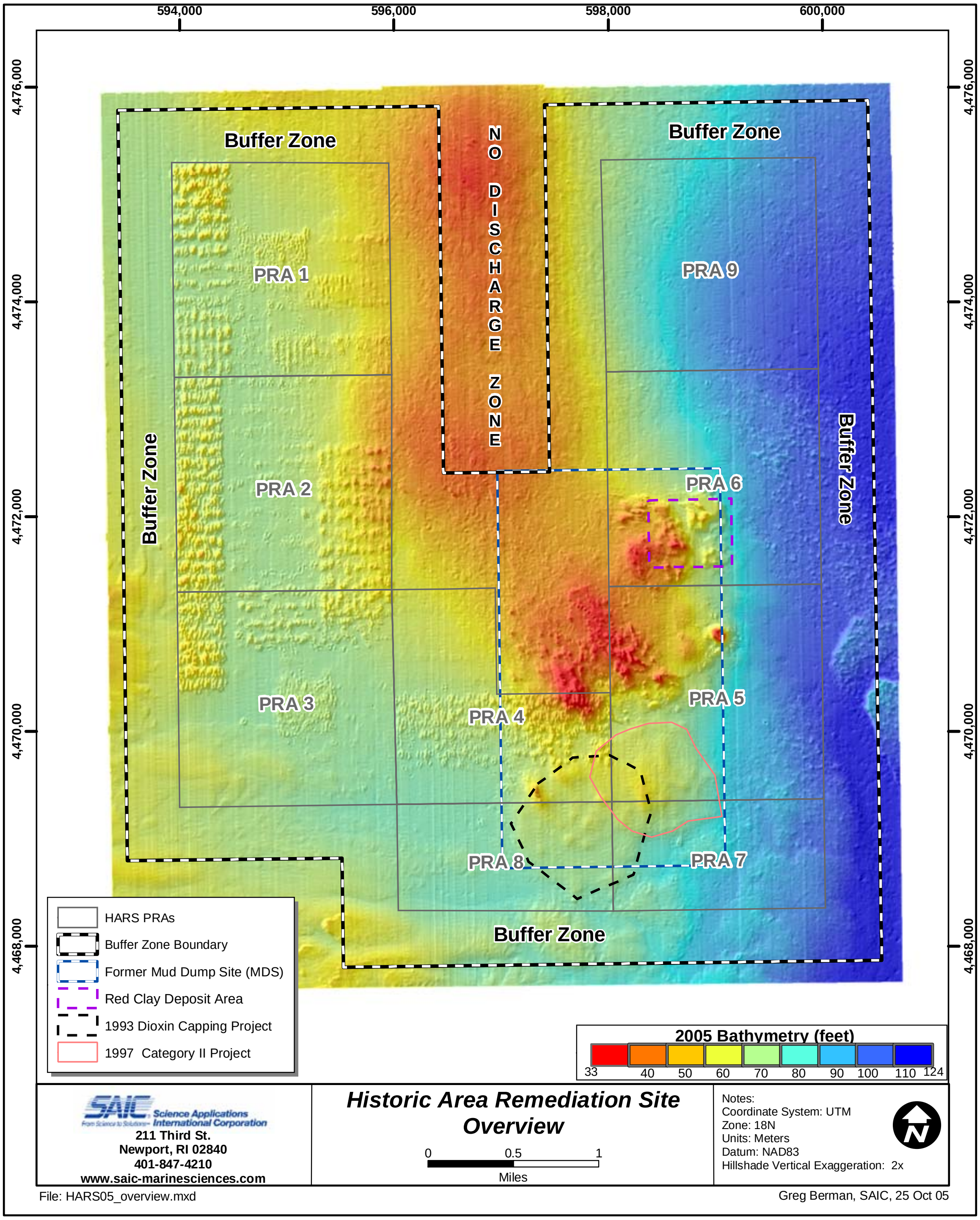


Figure 1.1-2. Map of the HARS PRAs, Buffer Zone and No Discharge Zone relative to 2005 survey bathymetry.

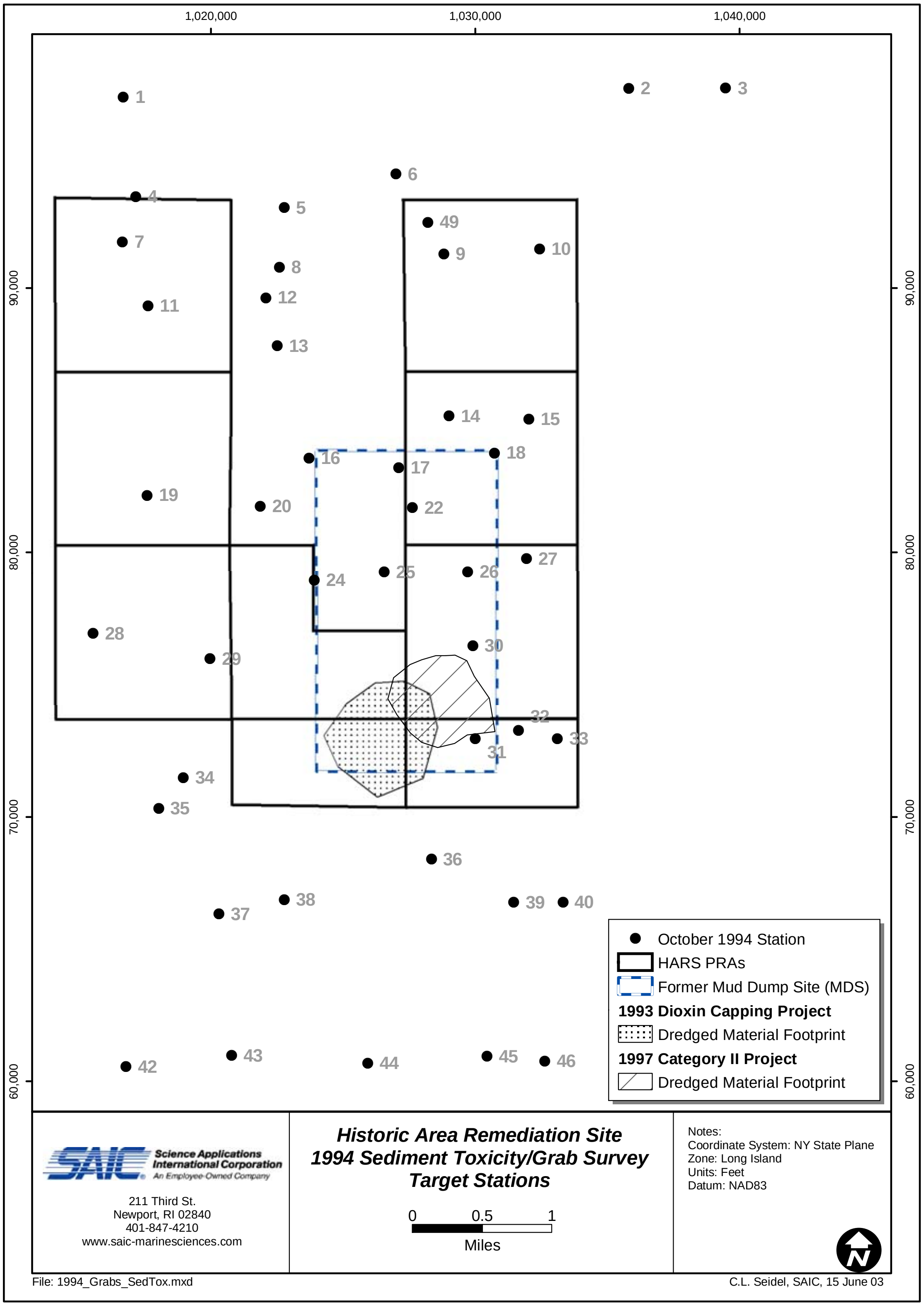


Figure 1.1-3. Locations of stations where sediment toxicity samples were collected in the EPA Region 2 survey of October 1994

undertaken in July 2002. The July 2002 survey involved re-sampling at the 44 stations originally sampled by EPA in October 1994, as well as at additional stations located in PRAs 1, 2, 3, and 4. The stations were located both in areas of the HARS where remediation material had already been placed, as well as in areas that had not yet received any remediation material.

Sediment-Profile Imaging (SPI) and sediment plan-view photography also were used in the July 2002 survey to evaluate benthic recolonization status and the degree of benthic habitat disturbance at each station. Due to the variety of substrates observed within the surveyed area and the varying lengths of time that the remediation material had been in place on the seafloor, a variety of infaunal successional stages were observed in the images. Benthic habitat conditions were considered to be largely undisturbed, or non-degraded, over most of the surveyed area.

None of the sediment samples collected at the 60 stations occupied in the July 2002 survey were found to have significant toxicity in the 10-day amphipod test (Figure 1.1-3). These results were consistent with those of the October 2000 survey but again contrasted with the observations of significant toxicity in the original October 1994 survey that was used in the development of the SMMP for the HARS, including the requirement that historic disposal areas be capped with 1 meter of sediment.

Managers at the EPA and NYD remain interested in continuing to evaluate whether remediated and non-remediated areas of the HARS have sediments that are toxic to aquatic biota. This will, in turn, help to determine if re-evaluation of the SMMP would be appropriate. Furthermore, it is of interest to continue to monitor the status of benthic communities, both in areas of the HARS that have received remediation material and in areas that have not, since remediation of the HARS in PRAs 1, 2, 3, and 4 has been occurring since 1998.

1.2 2005 Survey Objectives

During late August and early September of 2005, another survey involving both SPI/plan-view and sediment toxicity testing was conducted over remediated and unremediated areas within and outside the HARS. The primary objective of this survey was to assess any temporal changes in sediment toxicity or benthic habitat conditions that may have occurred since the last monitoring survey of July 2002. Specifically, the 2005 survey efforts involved the following techniques and objectives:

- Sediment grabs were collected to determine the toxicity of surface sediments at the 44 stations sampled previously by EPA and SAIC, to provide additional comparisons of present-day results with those from October 1994 and July 2002.

- Sediment grabs were collected at an additional 16 stations located within PRAs 1, 2, 3, and 4. These stations were sampled previously by SAIC in 2002 to determine the toxicity of surface sediments and the efficacy of on-going remediation efforts in these areas.

- Additional grabs and sediment-profile images were collected in a tight radius around a single station to evaluate small-scale spatial variability in sediment toxicity and benthic recolonization.
- Sediment-profile images and sediment plan-view photographs were collected at each of the 60 toxicity stations, as well as at an additional 60 stations within the HARS, to evaluate infaunal successional status and overall benthic habitat conditions.

2.0 METHODS

2.1 Field Operations and Sampling Design

The Summer 2005 sediment toxicity and SPI/plan-view survey took place between August 29 and September 3, 2005. The M/V *Beavertail,* based out of Jamestown, RI, was used for all field operations. SPI and plan-view images were collected on August 29 and 30 and September 2 and 3, while surface sediments for subsequent toxicity testing were collected using a grab sampler on September 1 and 2.

Both sediment toxicity and SPI/plan-view sampling were 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 by the EPA in October 1994 and by SAIC in July 2002, and the goal of sampling in the present study was to provide additional comparisons with these past surveys. The 44 stations are identified in Table 2.1-1 using numbers between 1 and 49; this numbering and the station coordinates are identical to those used in the 1994 EPA Region 2 study and the SAIC 2002 monitoring study (Battelle 1996; SAIC 2003). Both sediment toxicity and SPI/plan-view sampling also were 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 (PRAs) 1, 2, 3, and 4 that had both received or not yet received remediation material at the time of the Summer 2005 field operations.

Only SPI/plan-view sampling was conducted at an additional 60 “supplemental” stations within the HARS during the Summer 2005 survey; the objective of this sampling was to evaluate physical and biological sediment conditions and assess benthic recolonization status (Table 2.1-2 and Figure 2.1-2). These 60 supplemental SPI stations were located over areas that have remediation material of differing ages due to the placement of this material at different times over the past 7 years (1997 to 2005), as recorded in the Automated Disposal Surveillance System (ADISS) database.

Of the 60 primary stations listed in Table 2.1-1, Station 13 was selected for a special investigation to examine whether there might be significant differences in sediment toxicity across relatively short distances on the seafloor at the HARS (i.e., high small-scale spatial variability) that might help explain the differences in results among past surveys. Station 13 was selected because it met the following criteria: 1) the surface sediment at this station has previously exhibited a distinct stratigraphy, consisting of a surface layer of ambient fine sand overlying subsurface, 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 is located in an area (No Discharge Zone) where remediation material has not yet been placed and will not be placed in the future.

The investigation of small-scale spatial variability involved collecting sediment for toxicity testing at three additional stations (Stations 13W, 13N, and 13E), that were located, respectively, at a distance of 25 m to the west, north and east of Station 13 (Table 2.1-2 and Figure 2.1-2). For an additional evaluation of small-scale (i.e., “within-station”) spatial variability in toxicity,

Table 2.1-1.

Coordinates of the 60 primary stations sampled during the 2005 SPI 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. Stations 13N, 13W and 13E are not considered primary stations; they were sampled to assess spatial variability in the vicinity of primary Station 13.

Station	Easting	Northing	Latitude (NAD83)	Longitude (NAD83)
1	1016682	97234.3	40.43349989	-73.88350013
2	1035798	97570.9	40.43433345	-73.81483342
3	1039463	97578.9	40.43433339	-73.80166677
4	1017151	93470.3	40.42316663	-73.88183332
5	1022767	93053.5	40.42200001	-73.8616667
6	1026988	94335.7	40.42550013	-73.84650011
7	1016643	91769.5	40.41850009	-73.88366665
8	1022585	90806.6	40.41583345	-73.86233339
9	1028803	91302.9	40.4171667	-73.84000007
10	1032423	91491.9	40.41766659	-73.82699999
11	1017621	89342	40.41183339	-73.88016666
12	1022076	89652.1	40.41266672	-73.86416663
13*	1022497	87831.1	40.40766658	-73.86266652
13N	1022495	87911.67	40.40788774	-73.86267207
13W	1022414	87831.17	40.40766713	-73.86296556
13E	1022579	87831.17	40.40766642	-73.86237108
14	1029000	85170.5	40.40033333	-73.83933336
15	1032018	85054.8	40.40000005	-73.82850006
16	1023711	83582.6	40.39599986	-73.85833316
17	1027100	83224	40.39499988	-73.8461665
18	1030720	83777.2	40.39650013	-73.83316684
19	1017585	82176.9	40.39216654	-73.88033323
20	1021856	81758.1	40.39099996	-73.86499998
22	1027614	81706.9	40.3908332	-73.84433342
24	1023904	78968.2	40.38333325	-73.85766683
25	1026550	79276.3	40.38416674	-73.84816665
26	1029707	79282	40.3841668	-73.83683331
27	1031935	79772	40.3855001	-73.82883332
28	1015548	76952.3	40.37783328	-73.88766663
29	1019961	75986.9	40.37516679	-73.87183334
30	1029898	76489.2	40.37650006	-73.83616684
31	1029998	72967.6	40.36683335	-73.83583342
32	1031623	73274.3	40.36766668	-73.82999995
33	1033110	72973.6	40.36683326	-73.82466664
34	1018946	71492.1	40.36283333	-73.87550014
35	1018019	70337.1	40.35966661	-73.8788333
36	1028334	68410.5	40.35433327	-73.84183315
37	1020301	66332.9	40.34866679	-73.87066676
38	1022762	66883.1	40.35016668	-73.86183327
39	1031450	66776.9	40.34983332	-73.83066656
40	1033308	66780.6	40.34983342	-73.82400005
42	1016778	60559.5	40.33283333	-73.88333326
43	1020773	60990.2	40.33400002	-73.86899995
44	1025932	60694.9	40.3331668	-73.85049983
45	1030439	60945.8	40.33383323	-73.83433319
46	1032623	60767.9	40.33333331	-73.82649992
49	1028198	92516.2	40.42050002	-73.8421667
E0800	1015094	89796.48	40.41308999	-73.88924002
G1200	1016401	87171.41	40.40587999	-73.88456001
H2000	1019012	85863.44	40.40228	-73.87519001
I1200	1016404	84548.31	40.39868001	-73.88456
K0800	1015104	81919.87	40.39146999	-73.88924001
L1200	1016409	80610	40.38786999	-73.88456
L1600	1017716	80611.76	40.38787	-73.87986998
L2400	1020323	80615.48	40.38787001	-73.87051001
M1200	1016411	79298.45	40.38426999	-73.88456
M2800	1021632	79305.89	40.38427	-73.86582002
N2000	1019023	77990.48	40.38067	-73.87519
P2800	1021638	75367.59	40.37346	-73.86581999
Q1600	1017725	74050.36	40.36986001	-73.87987001
Q2400	1020333	74054.07	40.36985999	-73.87051
N3200	1022964	77966.41	40.38058765	-73.86104582
P3200	1022982	75335.8	40.37336698	-73.86099609

*Station 13 sampled for spatial variability

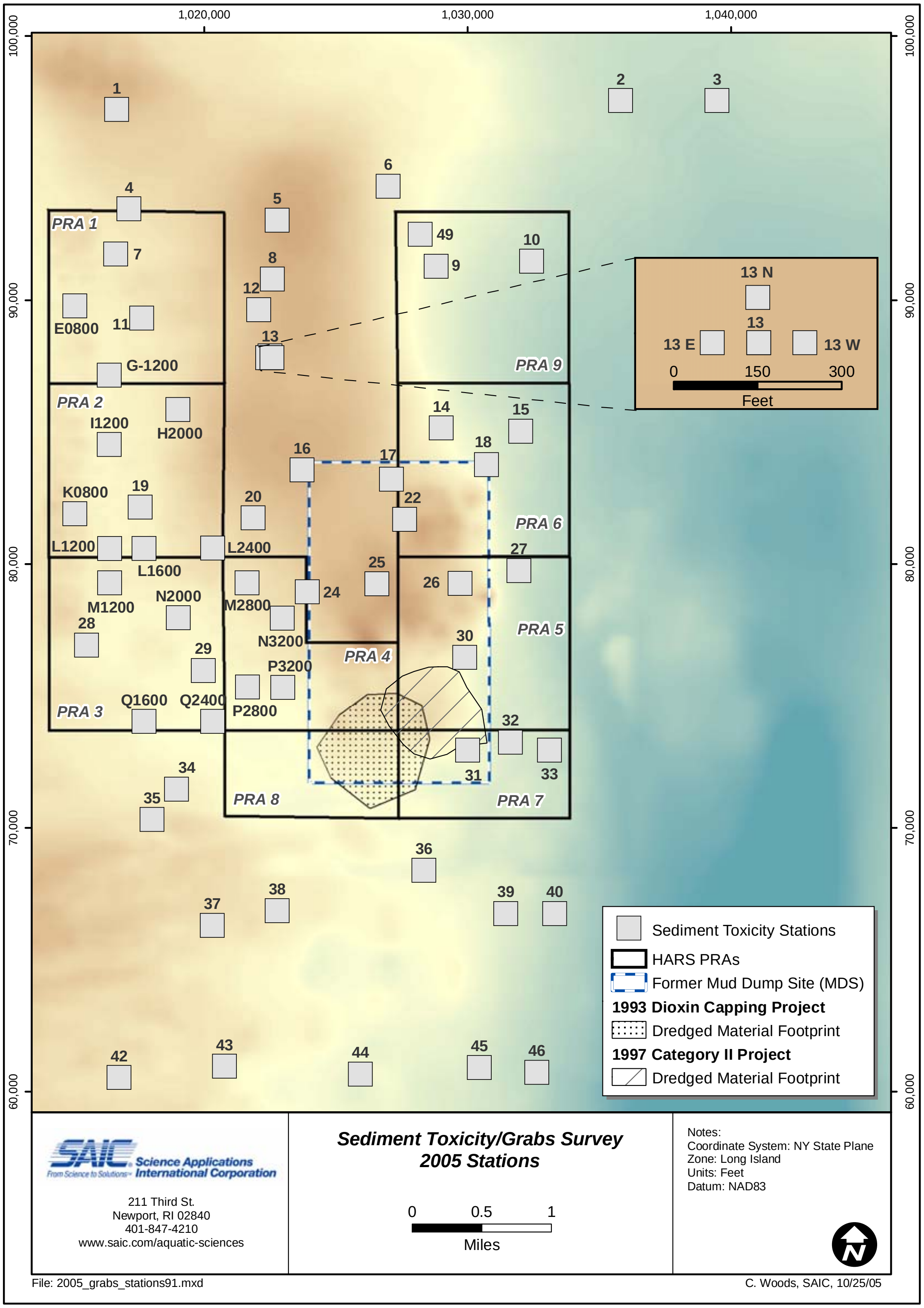


Figure 2.1-1. Locations of the 60 primary stations in and around the HARS where sediment toxicity samples and SPI/plan-view images were collected in the 2005 survey. The three sub-stations surrounding Station 13 (i.e., Stations 13W, 13N and 13E) are not considered primary stations.

Table 2.1-2.
Coordinates of the 60 supplemental SPI/plan-view stations for the 2005 survey at the HARS. Station names denote the year that remediation material was placed at that location within the HARS between 1997 and 2005.

Station	Easting	Northing	Latitude (NAD83)	Longitude (NAD83)
NOREMED_1	1014411	74006.61	40.36975178	-73.891761
NOREMED_2	1031032	88517.45	40.40950967	-73.83201646
NOREMED_3	1030009	70852.98	40.36102901	-73.83580802
NOREMED_4	1022103	71790.56	40.36363967	-73.86416849
NOREMED_5	1032907	77288.06	40.37867684	-73.82536356
97_00_1	1015668	80676.04	40.3880539	-73.88721862
97_00_2	1017075	80633.43	40.38793187	-73.88217055
97_00_3	1018353	80633.43	40.38792705	-73.87758123
97_00_4	1026514	72983.82	40.3668951	-73.84833369
97_00_5	1025214	73005.13	40.36695968	-73.85299788
97_00_6	1027814	73900.07	40.36940379	-73.8436635
97_00_7	1030264	82598.96	40.39326843	-73.83481294
97_00_8	1029002	82298.92	40.39245132	-73.83934674
97_00_9	1030412	81237.54	40.3895308	-73.8342888
97_00_10	1029071	74709.78	40.37162006	-73.83914658
2001_1	1019163	75242.48	40.37312665	-73.87470237
2001_2	1020143	75263.79	40.37318124	-73.87118454
2001_3	1019973	77351.98	40.37891366	-73.87178536
2001_4	1019184	77351.98	40.37891679	-73.87461505
2001_5	1016372	83573.95	40.39600567	-73.88468079
2001_6	1017352	79354.94	40.3844216	-73.88118244
2001_7	1016286	82274.15	40.39243824	-73.8849929
2001_8	1017458	86045.69	40.40278619	-73.8807673
2001_9	1017394	84809.82	40.39939417	-73.88100286
2001_10	1017394	83637.87	40.39617737	-73.88100858
2002_1	1023403	79823.72	40.38568373	-73.85945811
2002_2	1022657	79291.02	40.38422481	-73.86213815
2002_3	1021219	78478.64	40.38200106	-73.86730527
2002_4	1021974	77945.94	40.38053572	-73.86459785
2002_5	1020049	81467.11	40.3902087	-73.87149124
2002_6	1020037	84383.65	40.39821416	-73.87151889
2002_7	1020058	83637.87	40.39616704	-73.87144635
2002_8	1020079	82849.47	40.39400292	-73.871374
2002_9	1020101	82082.38	40.3918973	-73.87130154
2002_10	1019333	83637.87	40.39616992	-73.87404726
2003_1	1014475	85065.51	40.4001064	-73.89148245
2003_2	1014475	84426.27	40.3983518	-73.89148529
2003_3	1014475	83787.03	40.39659719	-73.89148814
2003_4	1014454	79354.94	40.38443191	-73.89158434
2003_5	1014496	77927.3	40.38051313	-73.8914377
2003_6	1014454	78673.08	40.38256032	-73.89158737
2003_7	1014411	80036.8	40.38630365	-73.89173426
2003_8	1014433	81016.97	40.38899398	-73.89165345
2003_9	1014390	81847.99	40.39127514	-73.89180272
2003_10	1014496	85768.68	40.40203641	-73.89140281
2004_1	1017626	77164.87	40.37840919	-73.88020843
2004_2	1018458	77198.16	40.37849741	-73.87722088
2004_3	1017626	76399.11	40.37630731	-73.88021219
2004_4	1018392	76399.11	40.3763044	-73.87746386
2004_5	1021788	76632.17	40.37693043	-73.86527432
2004_6	1023120	76632.17	40.3769247	-73.8604946
2004_7	1023952	75999.58	40.37518467	-73.85751094
2004_8	1021721	76032.88	40.37528575	-73.86551662
2004_9	1024951	75566.76	40.37399214	-73.8539288
2004_10	1024951	76565.58	40.37673373	-73.85392283
2005_1	1020423	89084.09	40.41111451	-73.87010729
2005_2	1019524	89050.8	40.41102675	-73.87333546
2005_3	1019957	88285.04	40.40892314	-73.87178528
2005_4	1020456	86353.99	40.40362071	-73.8700023
2005_5	1019757	86387.28	40.40371491	-73.87251249

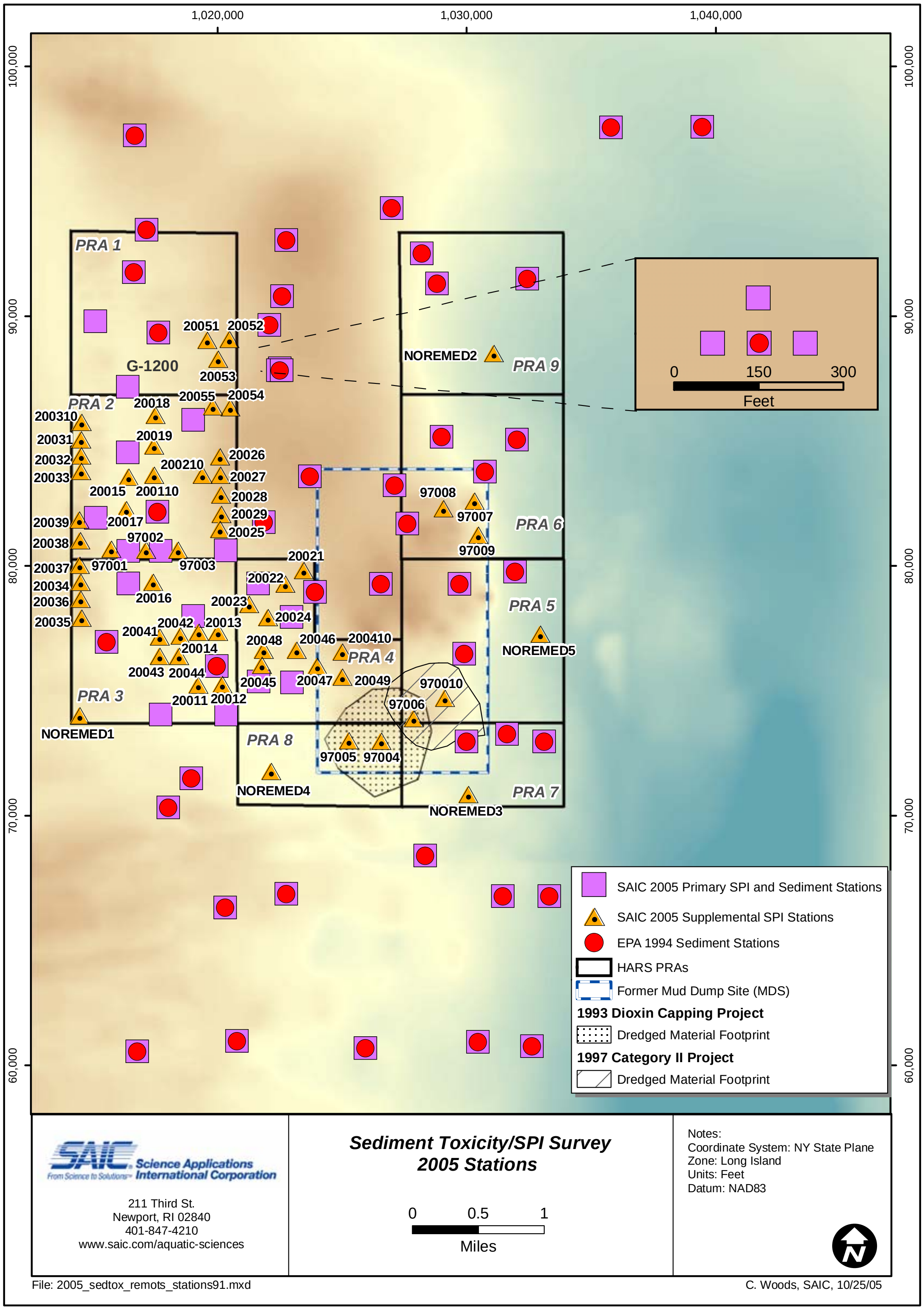


Figure 2.1-2. Locations of the 60 supplemental SPI/plan-view stations sampled in the 2005 survey. The locations of the 60 primary stations also are shown, as well as the locations of the 44 stations sampled in the original EPA study of 1994.

duplicate samples were collected for testing at 9 of the 60 primary stations. 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 the SPI and 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 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 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 13 was selected for use in testing small-scale spatial variability in sediment toxicity. Three substations (Stations 13E, 13W, and 13N) were located at a distance of 25 m to the west, north, and east of primary Station 13 (Figure 2.1-1), and a sediment toxicity sample and corresponding grain size sample were collected at Station 13, as well as at each of its three substations (Table 2.1-2). In total, 63 samples were collected during the field survey for toxicity testing and grain size analysis.

Immediately following collection, the sediment samples were placed in coolers with ice on board the M/V *Beavertail*. SAIC personnel delivered the samples for grain size analysis and toxicity testing to the Aqua Survey, Inc. facility in Flemington, NJ immediately following their collection during each of the three days.

2.3.2 Laboratory Methods for Sediment Grain Size Analysis

Sediment grain size was determined by Aqua Survey, Inc. (ASI) of Flemington, NJ using the procedures in ASTM Method D-4822-88 (*Standard Guide for Selection of Methods of Particle Size Analysis of Fluvial Sediments (Manual Methods)*). Samples also were analyzed for percent moisture content. 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). As a quality control measure, the samples from 5 stations (roughly 10% of the total number of samples) were split in the laboratory and analyzed in triplicate.

2.3.3 Laboratory Methods for Sediment Toxicity Testing

Aqua Survey, Inc. (ASI) of Flemington, NJ also conducted the toxicity testing on the sediment grab samples between 6 September and 2 October 2005. Sediment toxicity was evaluated using the standard 10-day acute test with the marine amphipod *Ampelisca abdita*, a representative benthic species, in accordance with the following documents:

- ASTM E1367-92 *Standard Guide for Conducting 10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods.*

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 > 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 classes are based on the Phi scale ($-\log_2$ mm) 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.

- EPA/USACE 1991 Evaluation of Dredged Material Proposed for Ocean Disposal (Testing Manual).
- New York District Army Corps of Engineers/U.S. EPA 1994 *Guidance for Performing Tests on Dredged Material Proposed for Ocean Disposal.*
- Memorandum from T. Davies, D. Davis and J. Elmore to EPA Regional Ocean Dumping Coordinators, EPA Regional Wetland Coordinators, and Corps of Engineers *Regulatory and Civil Works Elements, 1993 Technical Panel Recommendations Concerning Use of Acute Amphipod Tests in Evaluation of Dredged Material*.

The sediment samples were received at ASI following chain-of-custody procedures on the same day collected. Upon arrival at ASI, all samples were logged in and assigned unique sample numbers and stored at 2-4°C prior to testing. Prior to testing, each of the sediment samples was homogenized by hand or with a stainless steel mixer until uniform in color and texture. The samples from 9 of the 60 stations were split into two equal halves that were each tested individually for toxicity (laboratory duplicates). After homogenization and splitting of this subset, all of the samples were then allocated for biological and physical testing. Total ammonia in the pore water of all of the 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.

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.

Whole sediment toxicity of the sediment samples was assessed for acute toxicity through a 10-day exposure with the amphipod, *Ampelisca abdita*. The *A. abdita* used in testing ranged from 2 to 4 mm in length and were field-collected by ASI personnel at an offshore boat basin at the Atlantic Highlands Marina, NJ. Six rounds of testing were completed. All rounds were conducted as static exposures. However, the initial pore-water ammonia for the sediment samples in Round 5 (Stations Q2400, N2000 and H2000) exceeded the EPA-specified threshold of 20 mg/L (actual concentrations were 30.7 mg/L, 48.3 mg/L, and 22.9 mg/L, respectively), so this round was conducted as a static-renewal exposure.

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 organisms were previously 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}.

2.3.4 Sediment Toxicity Data Analysis

To standardize results for comparisons among the three previous sediment toxicity surveys (1994, 2000, and 2002), all test sediment survival rates were normalized to their respective control sediment survival rate. To calculate the normalized values the following equation was used:

Normalized % survival = [(% survival in test sediment)/(% 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 survival rate for the controls used in the 2002 study ranged from 90 to 98%. The normalized results for each group were calculated to the corresponding 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 Sediment-Profile and Sediment Plan-View Imaging

During the SPI/plan-view survey operations, at least two replicate sediment-profile images and one plan-view image were collected at each of the 60 primary stations and 60 supplemental stations (Table 2.1-1; Figure 2.1-2). The survey was conducted using an SPI camera frame configured with an Ocean Imaging Systems Model 3731-D digital camera system and a Photoseas 35-mm film-based, camera system for plan-view photography (Figure 2.4-1).

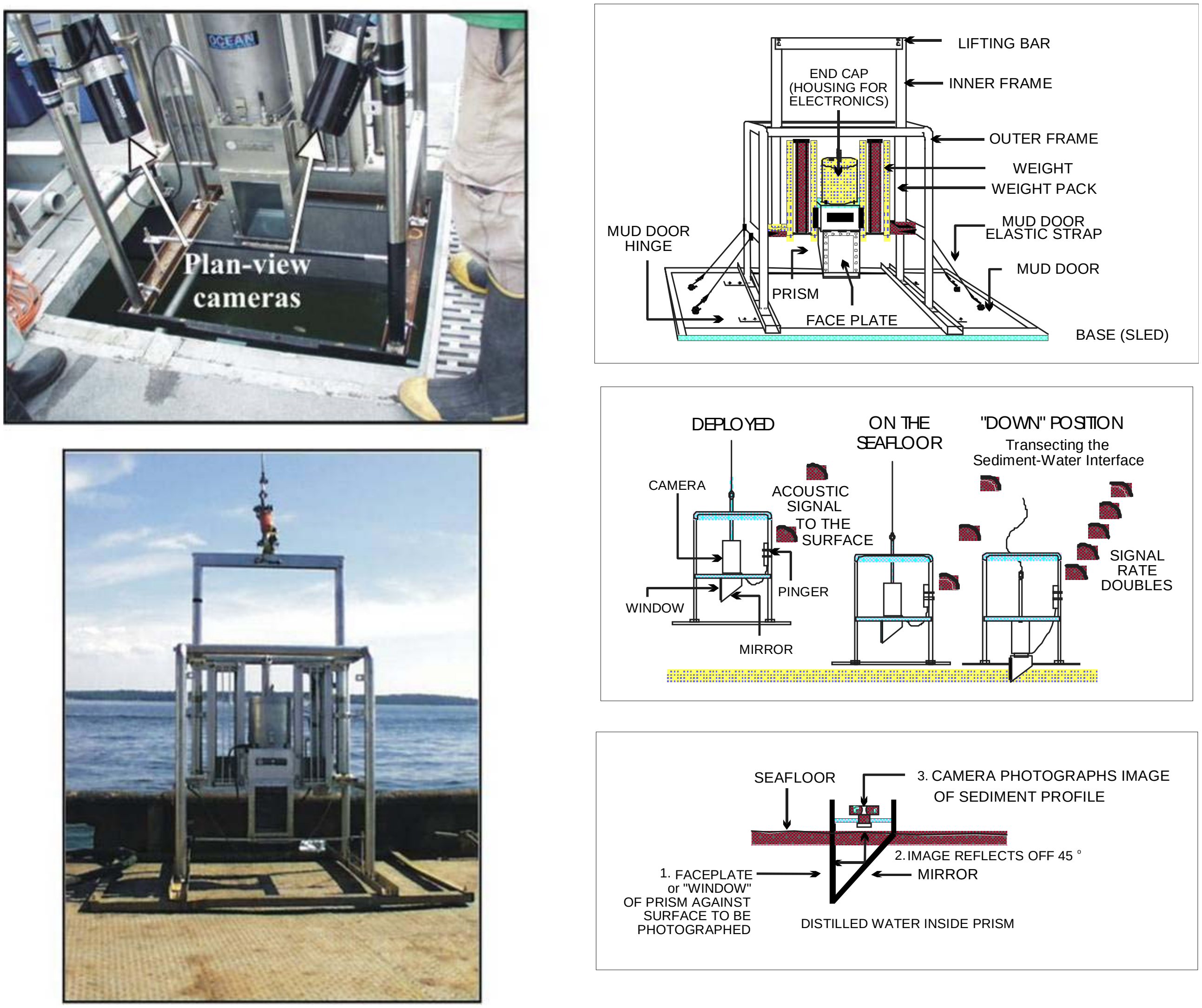


Figure 2.4-1. Schematic diagram of Benthos, Inc. Model 3731 REMOTS® (and Ocean Imaging Systems digital head) sediment-profile camera and sequence of operation on deployment. The image in the upper left shows the sediment-profile camera with plan-view camera attached.

2.4.1 Sediment-Profile Image Acquisition

A detailed description of SPI and the concepts underlying image interpretation are provided in Rhoads and Germano (1982 and 1986). The SPI 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 6-megapixel digital camera (Nikon D-70) is mounted in a water-tight housing 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 an image is acquired. Because the sediment image acquired is directly against the face plate, turbidity of the ambient seawater does not affect image quality. When the camera is raised, a wiper blade cleans off the faceplate, the strobe is recharged, and the camera can be lowered for another replicate image. At least two replicate sediment-profile images were obtained at each station.

The digital sediment-profile camera system allows nearly real-time review of the image quality and results. This facilitates obtaining suitable replicate images that can be downloaded and viewed, if necessary, while still on-station. Confirmation of a good-quality SPI image was obtained by downloading images from the digital camera once the frame was on board. When necessary, the survey team downloaded images between sampling stations to verify camera settings were appropriate for the disposal site, and modified as necessary. The images were stored directly to the camera Microdrive. Once the camera settings were confirmed and there were no evident problems obtaining two to three replicate images at each station, downloads were typically conducted after collecting 60 images (or roughly 20 stations). Images were backed up daily to a CD-ROM. In addition to timely viewing of images, the high-resolution digital images were easily integrated directly into the computer-aided digital analysis system.

2.4.2 Sediment-Profile Image Analysis

The high-resolution digital sediment-profile images were easily imported directly into the image analysis system. SAIC's in-house computer-based image-processing system consists of a Visual Basic customized interface, with information stored in a Microsoft Access database, to consistently characterize the images and to catalogue all relevant quantitative and qualitative results. Analysis of each SPI image yielded a suite of standard measured parameters, including sediment grain-size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (a summary parameter reflecting overall benthic habitat quality). Summaries of the standard SPI measurement parameters presented in this report are presented in the subsections below.

Automatic database storage of all measured parameters allowed data from variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. Following the initial analysis of the SPI images, the measurements were subjected to an independent QA/QC review by a Senior Scientist before the dataset was considered final. The final SPI data were used in preparing the statistical analyses, summary tables, and maps that appear in this report. All of the analyzed sediment-profile and plan-view image data were retained in pre-formatted spreadsheets and incorporated into the project GIS and data management system.

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 SPI 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 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 of the image area 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 sediment-profile image data file.

2.4.2.2 Benthic Habitat Classification

Based on extensive past SPI survey experience in coastal New England, five basic benthic habitat types have been found to exist in shallow-water estuarine and open-water nearshore 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 SPI 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 burrow 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 sediment-profile images. During image analysis, the number of clasts is 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 sulfate 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 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 SPI 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 SPI 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 SPI 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 SPI 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 SPI 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 SPI 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 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 SPI 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 SPI 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 SPI image interpretation can be found in Rhoads and Germano (1982, 1986).

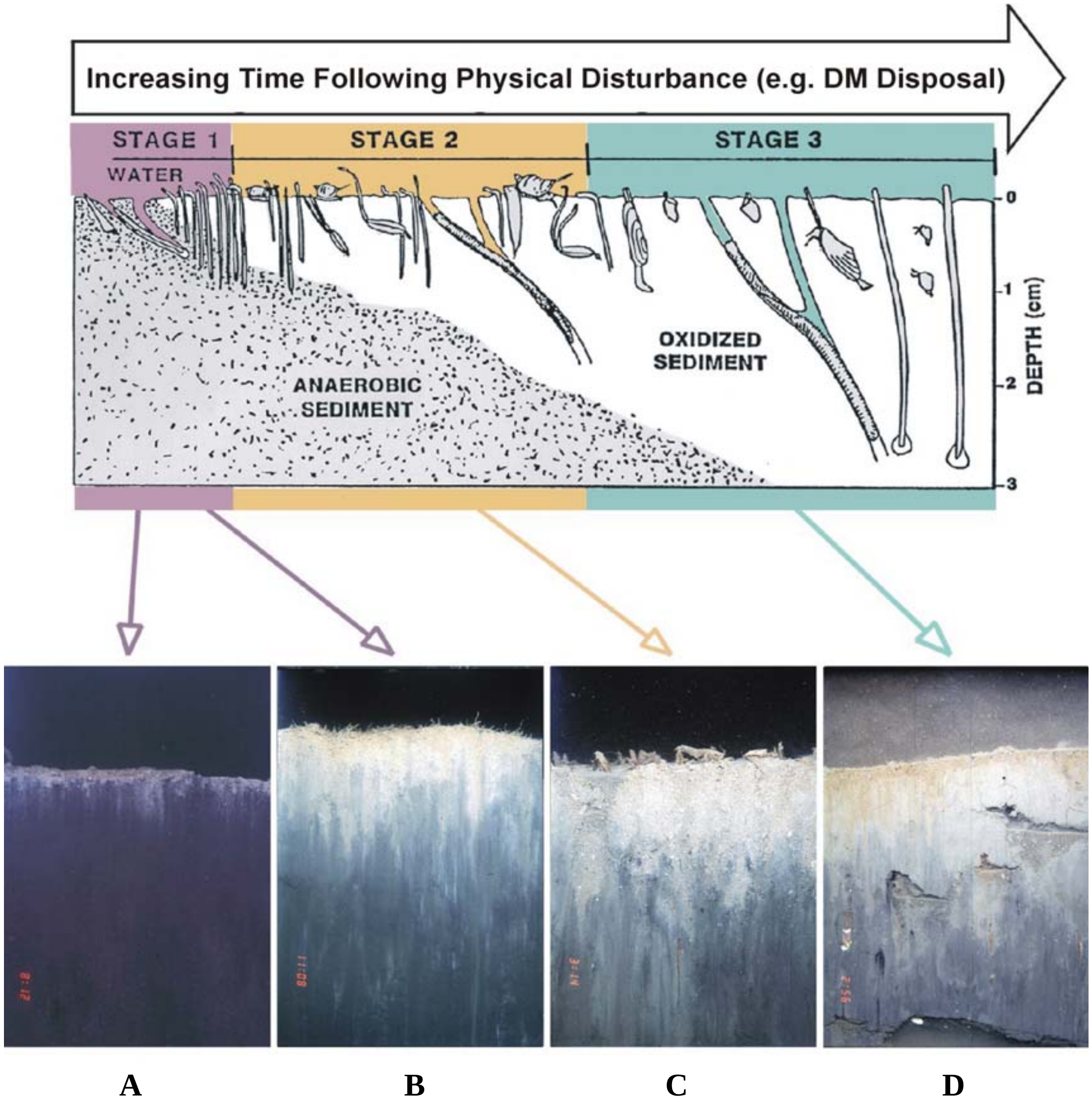


Figure 2.4-2. Schematic illustration of infaunal successional stages over time following a physical disturbance and a representative SPI image for each stage. Image A shows highly reduced sediment with a very shallow redox layer (contrast between light-colored surface sediments and dark underlying sediments) 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 apparent RPD 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.

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 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 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 post-disposal 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 Organism-Sediment Index (OSI) has been constructed to characterize the degree of benthic habitat disturbance or degradation based on analysis of SPI images. Benthic habitat disturbance 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 SPI criteria for these conditions). The OSI for such a condition is –10 (highly disturbed or degraded benthic habitat conditions). 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 conditions).

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 SPI image. 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).

Table 2.4-2.
Calculation of SPI Organism Sediment Index

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

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 SPI 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 SPI camera frame (Figure 2.4-1). The plan-view images were acquired immediately prior to the landing of the SPI camera frame on the seafloor, providing an undisturbed record of the surface sediments before penetration of the SPI camera prism. Once the camera frame was lifted above the sediments, the plan-view camera system automatically cycled the film and recharged the strobe in preparation for the next image. In this manner, a corresponding plan-view image was usually obtained for each SPI image acquired.

At the end of each survey day, the exposed film was removed from the plan-view camera and processed at a laboratory to ensure that adequate image quality was obtained. If less than one good-quality photograph was acquired at a particular station, the station was reoccupied to acquire additional photographs.

The plan-view photograph analysis supplemented the more detailed and comprehensive SPI characterization of the seafloor. The 35-mm plan-view slides selected for analysis were manually analyzed based on established image review protocols. The plan-view analysis consisted of qualitative and quantitative descriptions of key sediment characteristics (e.g., sediment type, bedforms, and biological features) based on a manual review of the scanned 35-mm slides. The presence of shell debris and any evidence of epifaunal or infaunal organisms (e.g., tubes, burrow openings, etc.) also were recorded.

Because of poor image quality (turbid water column) in various plan-view images, not all of the acquired plan-view images were subjected to analysis. Therefore, plan-view imaging results are presented only from images where qualitative assessments were possible, which added to the substrate information obtained from analysis of the sediment-profile images at each station.
In addition, differences in the appearance of plan-view and sediment-profile image at the same station were due to differences in the camera configuration of the two systems and illumination.

3.0 RESULTS

3.1 Sediment Toxicity

3.1.1 Toxicity Survey

Although a total of 63 sediment toxicity samples were collected in the field, the laboratory had been instructed to limit the testing to a total of 60 samples. The 60 samples that ultimately were tested included 57 of the 60 primary stations and the 3 sub-stations associated with Station 13. Because the sediments collected at primary Stations G1200, L1200 and L2400 were coarser-grained (i.e., primarily sand or gravel) and therefore likely to have low levels of contaminants and toxicity, the decision was made to exclude these three stations from testing.

The sediment toxicity testing was conducted in six sample groups, each with its own control sample. The survival rate of *A. abdita* organisms in all control sediment ranged from 93% to 100%, exceeding the requirement for 80% survival for an acceptable test. The survival rates of organisms in the test sediments ranged from 92 to 100% and were all greater than 92% when normalized to their respective control results (Table 3.1-1). Because survival in test sediments was greater than 80% in all cases, there was no need to conduct statistical analyses. The high survival in site sediments strongly demonstrated an absence of any acute toxicity to *A. abdita*. The results of the 2005 survey therefore indicate that sediments at each of the 57 primary stations tested were non-toxic (Table 3.1-1; Figure 3.1-1). The raw laboratory results, including the percent survival data for each sediment sample, are provided in Appendix A.

For three stations (Stations Q2400, N2000 and H2000), where initial pore-water ammonia concentrations were found to be above the threshold of 20 mg/L, sediments were purged twice daily for four days to achieve concentrations less than 20 mg/L (U.S.ACE and EPA 1993). Initial concentrations were 30.7 mg/L at Station Q2400, 48.5 mg/L at Station N2000, and 22.9 mg/L at Station H2000 (Appendix A, Table A-1). Tests with these sediments were conducted as a separate batch under flow-through conditions, and the batch included a control that underwent purging. For all other batches, toxicity tests were conducted with daily renewals rather than under flow-through conditions.

Measurements in several other sediments yielded initial pore-water ammonia concentrations between 10 and 20 mg/L, and most concentrations declined over the course of the test. For the three sediments that were purged, measurements of overlying ammonia were less than 1.0 mg/L throughout the test, indicating that pore-water concentrations remained well below 20 mg/L.

3.1.2 Evaluation of Small-Scale Spatial Variability

As previously indicated, Station 13 was selected for the 25-m assessment of small-scale 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 ambient fine sand over fine-grained, historic dredged material, and 3) it was located in an area that has not yet received remediation material.

Table 3.1-1.
Percent Organism Survival at the 60 Primary Stations
Sampled During the 2005 Sediment Toxicity Survey at the HARS

Station[1]	Mean % Survival	Normalized % Survival[2]
1	95	102
2	100	101
3	100	101
4	95	102
5-A[3]	100	101
5-B	98	98
6-A	96	97
6-B	99	99
7	98	105
8-A	96	97
8-B	100	100
9	96	97
10	100	101
11	97	104
12-A	100	101
12-B	100	100
13[4]	100	108
13E	97	98
13N	97	98
13W-A	99	100
13W-B	100	100
14	97	104
15	99	100
16-A	97	98
16-B	99	99
17	100	108
18	96	103
19	99	101
20	98	100
22	100	108
24	97	99
25-A	97	98
25-B	100	100
26-A	97	98
26-B	100	100
27	96	97
28	93	94
29	98	99
30	94	95
31	97	98
32	98	100
33	99	100
34	99	100
35	97	98
36	100	102
37	99	101
38	99	100
39	98	100
40	100	102
42	93	95
43	98	99
44	99	100
45	99	101
46	98	100
49-A	100	101
49-B	100	100
E0800	92	99
H2000	96	96
K0800	95	96
I1200	97	99
L1600	100	102
M1200	95	96
M2800	97	99
N2000	99	99
N3200	95	97
P2800	97	98
P3200	99	100
Q1600	92	93
Q2400	97	97

[1]Staions numbered between 1 and 49 correpsond to the Battelle October 1994 sampling location; the remainder are 16 staions located in selected areas of PRAs 1, 2, 3, and 4.

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

[3]A and B denote laboratory replicates.

[4]Station 13 sampled for spatial variability.

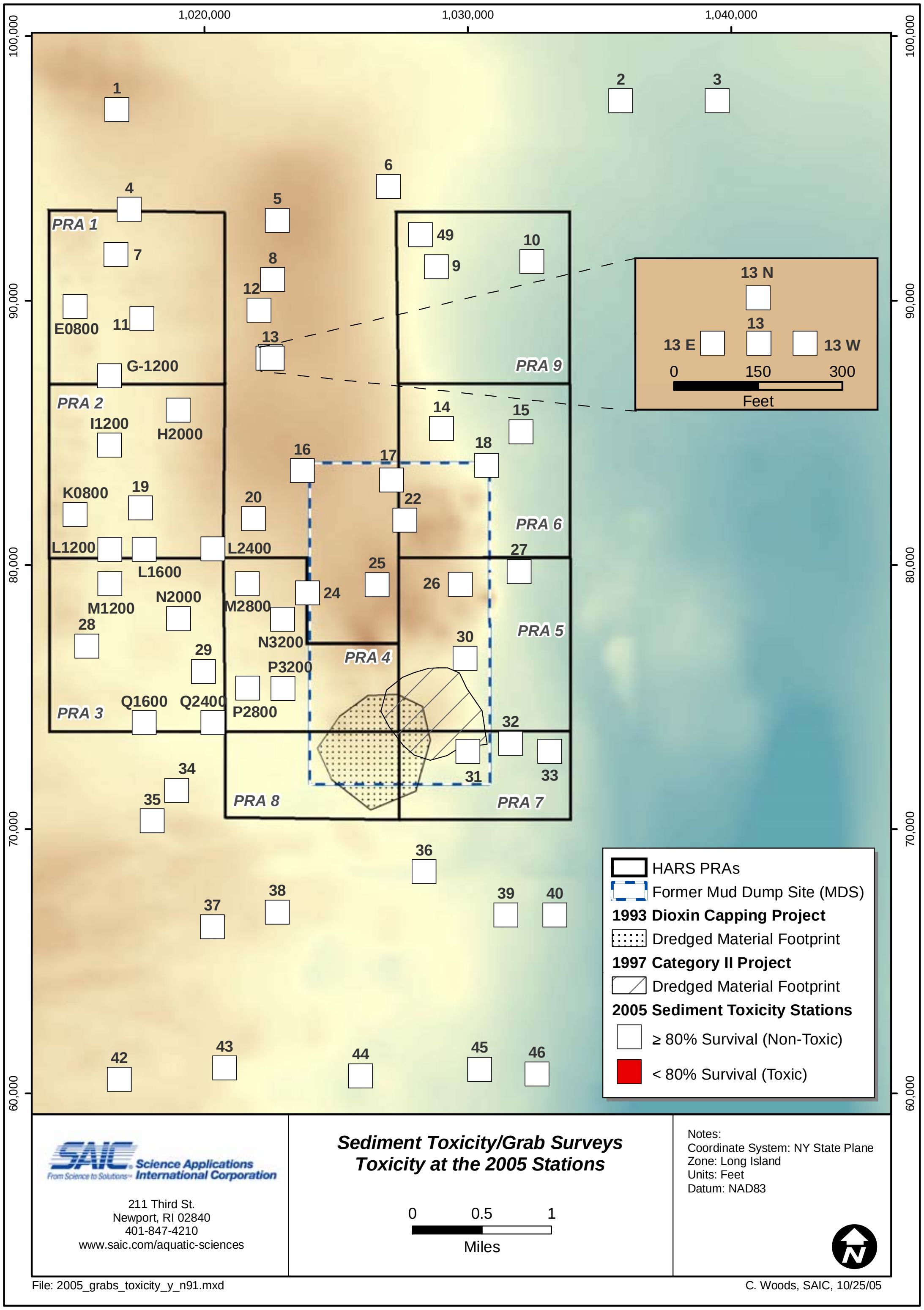


Figure 3.1-1. Sediment toxicity test results at the primary stations sampled in the 2005 survey. Sediments from all stations were characterized by ≥ 80% survival of *A. abdita* during 10-day toxicity tests.

The sediments collected at primary Station 13 and each of its three sub-stations were all non-toxic (Table 3.1-1; Figure 3.1-1). All of these sediments had a normalized percent survival rate of 98% or more, indicating an absence of any small-scale spatial variability in sediment toxicity in the vicinity of Station 13.

3.1.3 Comparison to Previous Surveys

As indicated, stations within and around the HARS were sampled for sediment toxicity in October 1994 by Battelle (under contract to EPA Region 2), as well as in October 2000 and July 2002 by SAIC. Results from these previous surveys are briefly summarized here for a comparison to the 2005 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 3.1-2; Figure 3.1-2). Normalized organism survival ranged from 0% to 104% for that data set (Table 3.1-2). 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 3.1-2). Normalized organism survival percentages ranged from 59% to 103% for the 2000 data set (Table 3.1-3). Only two stations (WNW-700 and WNW-900) sampled in the 2000 survey had sediments that were considered toxic (Table 3.1-3; Figure 3.1-2). 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 3.1-2).

Fifteen (15) of the 33 stations sampled in 2000 had been sampled in the 1994 survey (Figure 3.1-2). Two other 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 3.1-3; Figure 3.1-2). Six of the 15 corresponding stations were toxic in 1994 but not in 2000. In addition, Stations E1600 and 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 July 2002 survey.

All 60 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 (Table 3.1-4 and Figure 3.1-2). 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 3.1-2). With the exception of stations G1200, L1200 and L2400, all of the

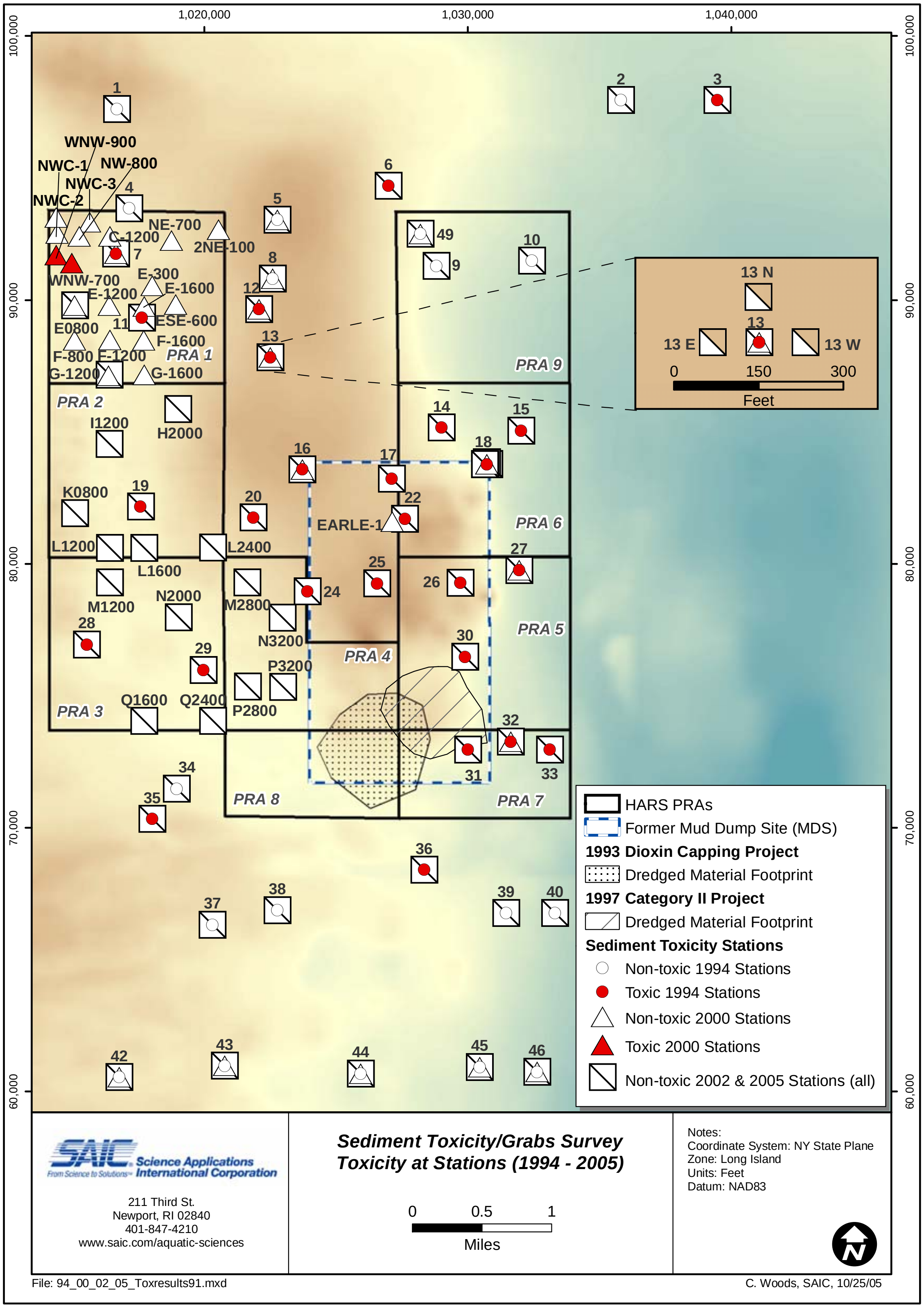


Figure 3.1-2. Summary of sediment toxicity results for surveys conducted in 1994, 2000, 2002 and 2005.

Table 3.1-2.
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

A “-“ sign for mean % survival indicates samples collected and analyzed in January 1996 by the EPA that were not comparable to the samples analyzed in 1994 by Battelle.

Table 3.1-3.
Percent Organism Survival at the 33 Stations Sampled in the October 2000 Sediment Toxicity Survey at the HARS. Shaded rows indicated significant 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

Table 3.1-4.
Percent Organism Survival at the 60 Primary Stations Sampled in the July 2002 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)

July 2002 stations were re-sampled in the present (2005) survey and again found to be non-toxic (Table 3.1-1 and Figure 3.1-2).

3.2 Sediment Grain Size

The laboratory analysis of the subsamples taken from each sediment toxicity grab showed that grain size was highly variable over the study area (Table 3.2-1, Figure 3.2-1). Grain size ranged from silty clay to gravelly sand, and some samples (e.g., Stations P2800, P3200, 33, 24, and 10) had significant fractions in 3 or 4 size classes (Table 3.2-1, Figure 3.2-1). Coarser sediments consisting predominantly of gravel and sand were found at Stations 8, 16, 24, 25, 38, L1200, M1200 and Q1600. With the exception of Stations L1200 and M1200, most of this coarser material was ambient sediment. The majority of the remaining samples were made up of sand, silt, and clay in varying proportions.

As in previous surveys, ambient sandy sediments were 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; Table 3.2-1, Figure 3.2-1). Within the PRAs, sediment types ranged from clay to gravelly sand (Table 3.2-1). PRAs 1, 2, 3, and 4 contained mostly fine-grained (i.e., clay and silt) remediation material. There was very good agreement among the triplicate samples analyzed at Stations 7, 16, 46, M1200 and N3200, indicating a high level of laboratory precision in these grain size analyses.

3.3 SPI and Plan-View Imaging Survey

The SPI and plan-view imaging results from the 2005 survey at the 60 primary and 60 supplemental stations in and around the HARS are presented below. A complete set of SPI image analysis results are provided in Appendix B for the primary (Table B-1) and supplemental (Table B-2) stations. These results are summarized in Tables 3.3-1 and 3.3-2, respectively.

3.3.1 Dredged Material Distribution and Physical Sediment Characteristics

Similar to the previous SPI survey of July 2002, analysis of the SPI images from the 2005 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, remediation material, ambient sand, or sand over fine-grained relic dredged material (Figures 3.3-1, 3.3-2, 3.3-3 and 3.3-4A). 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 of recent origin. Predominantly fine-grained remediation material was present at the majority of stations within PRAs 1, 2, 3 and 4 (Figures 3.3-1 and 3.3-2). However, coarser-grained remediation material was detected at several stations located on the eastern side of PRA 2 (Figure 3.3-2). The thickness of the surface layer of relic dredged material or remediation material exceeded the camera prism penetration depth (i.e., imaging depth) at most of the

Table 3.2-1.
Grain Size Results for the Sediment Toxicity Stations Sampled in the 2005 Survey

Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Moisture (%)
Sieve Number or Particle Size	#4	#10-#200	0.074-0.005 mm	<0.005 mm	
1	0.57	95.8	1.04	2.54	20.2
2	6.62	74	9.13	10.3	35.3
3	0.46	77.5	9.19	12.9	39.3
4	0	94.8	1.59	3.59	24.2
5	0.18	98.7	0	1.97	20.6
6	0.41	96.3	0.66	2.66	19.3
7-A[1]	0	26.7	48.4	24.9	46.4
7-B	0	25.1	49.5	25.4	
7-C	0	25	49.8	25.2	
8	19.9	78.6	0.48	1.01	16.2
9	0	87.9	5.18	6.91	28.5
10	7.58	64.4	15.2	12.9	38.1
11	11	49.8	27	12.2	27
12	5.12	87.3	3.76	3.81	16.5
13[2]	0.14	97.2	1.76	0.92	22.4
13E	0.26	97.1	0	3.13	21.6
13N	0.2	96.4	1.01	2.42	19.2
13W	0	97	0.64	2.39	20.9
14	1.87	29.8	42.4	26	47.1
15	6.72	26.3	39.7	27.3	52.2
16-A	9.63	85.5	0.91	4	17.5
16-B	14.44	83	0	2.57	
16-C	10.9	86.2	0.59	2.38	
17	3.65	50.1	24.5	21.7	43
18	1.61	34	40.6	23.9	43.7
19	0.05	25.6	44.9	29.5	53.2
20	0.64	97.8	0	1.95	23.3
22	0.4	96.5	0.33	2.75	20.9
24	33.8	45.3	11.3	9.66	30.5
25	55.5	43.9	0.02	0.53	11.7
26	0.39	97.2	0.2	2.22	16.6
27	0	11.3	57.3	31.5	51.2
28	0.14	48.6	27.2	24.1	40.3
29	0	13.4	51.3	35.3	52.8
30	0.33	66.9	16.1	16.6	36.7
31	0.13	100	0	1.27	17.8
32	6.28	70.7	12	11.1	32.7
33	13.8	70.3	8.28	7.65	28.3
34	5.58	89.3	1.08	4.05	19.1
35	4.41	91.7	0	3.86	18.1
36	0.19	97.6	0.69	1.51	20
37	1.18	97	1.2	0.64	20.5
38	30.7	66.7	0	3.98	15.5
39	0.55	99.9	0	1	18.7
40	2.21	93.8	0.84	3.11	16.2
42	0.18	96.7	0	3.96	24.4
43	0.33	97.5	0	3.93	19.8
44	0.24	97.6	0.04	2.13	20.5
45	0.09	97.6	0	3.45	20.6
46-A	2.92	59.1	18.7	19.2	42
46-B	1.85	59.8	19.5	18.9	
46-C	3.16	58.5	19.5	18.8	
49	5.19	91	0.61	3.21	19.8
E0800	0	13	53.1	33.9	46.2
H2000	3.15	0	59	37.9	62.9
I1200	0.31	9.25	54.1	36.3	56.1
K0800	0	10.3	33.1	56.6	43.1
L1200	45.8	14.2	21.8	18.2	27.7
L1600	0.2	28.5	44.1	27.2	45.3
L2400	30	65.1	2.15	2.79	19.1
M1200-A	9.76	64.2	13.4	12.7	29.6
M1200-B	14.1	63	11	11.9	
M1200-C	13.5	62.3	12	12.2	
M2800	0	36.2	36.4	27.4	53.1
N2000	0	6.32	57.5	36.2	58
N3200-A	0.35	68.3	18	13.4	30.9
N3200-B	0.5	69.3	17.4	12.8	
N 3200-C	0.51	67.9	18.5	13.1	
P2800	12.4	45.7	25.3	16.6	28
P3200	8.97	42.2	26.6	22.2	32.8
Q1600	20.9	73.8	1.06	4.26	19.5
Q2400	0.21	6.04	55.5	38.2	57.3

[1]A, B, and C indicate replicates.
[2]Station 13 sampled for spatial variability.

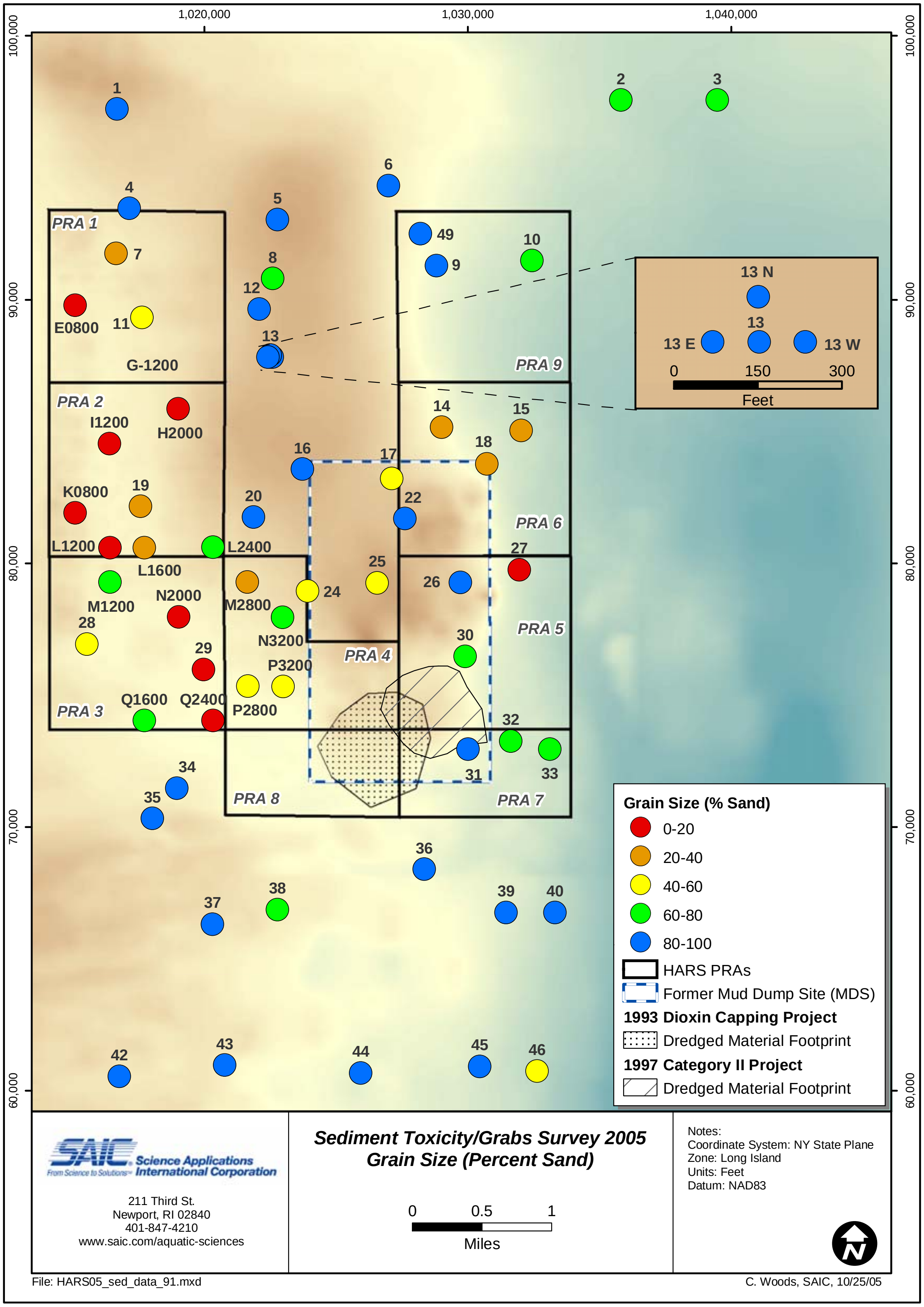


Figure 3.2-1. Sediment grain size analysis at each of the 2005 SPI stations.

Table 3.3-1.

Summary of Sediment-Profile Imaging Results for the 60 Primary Sediment Toxicity Stations, Summer 2005 Survey[1]

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Highest Stage Present	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean[2]
1	3 to 2 phi (2)	4.01	0.00	0	1.86	SA.F (2)	ST I	ST I (2)	> 4.01	**7.0**
2	> 4 phi (2)	12.71	0.00	0	1.63	UN.SI (2)	ST I on III	ST I on III (2)	1.04	8.5
3	4 to 3 phi (2)	5.97	0.00	0	1.02	AM (2)	ST II on III	ST II on III (2)	2.32	8.5
4	4 to 3 phi (2)	4.32	0.00	0	0.81	UN.SI (1), UN.SS (1)	ST I to II	ST I to II (2)	2.43	6.0
5	3 to 2 phi (2)	0.91	0.00	0	0.66	SA.F (2)	ST I	INDET (1), ST I (1)	> 1.55	4.0
6	2 to 1 phi (1), 3 to 2 phi (1)	5.38	0.00	0	0.45	SA.M (1), UN.SS (1)	ST I	ST I (2)	2.78	5.5
7	> 4 phi (2)	14.43	> 14.44	2	0.98	UN.SI (2)	ST III	ST II to III (1), ST III (1)	2.43	8.5
8	3 to 2 phi (2)	3.27	0.00	0	1.11	SA.F (2)	ST I	ST I (2)	> 3.27	6.0
9	> 4 phi (1)	7.88	7.88	1	1.19	UN.SI (1)	ST II on III	ST II on III (1)	2.09	8.0
10	> 4 phi (2)	9.21	> 9.21	2	0.57	UN.SI (2)	ST II to III	ST II to III (2)	2.00	7.0
11	> 4 phi (2)	10.08	> 10.08	2	0.31	UN.SI (2)	ST I on III	ST I (1), ST I on III (1)	2.95	6.5
12	2 to 1 phi (1), 3 to 2 phi (1)	4.16	0.00	0	2.94	SA.F (1), SA.M (1)	ST I	ST I (2)	> 4.16	**7.0**
13	3 to 2 phi (2)	3.80	0.00	0	1.93	SA.F (2)	ST I	ST I (2)	2.23	**4.5**
13E	3 to 2 phi (2)	1.81	0.00	0	1.49	SA.F (2)	ST I	ST I (2)	> 1.81	**4.0**
13N	3 to 2 phi (2)	1.22	0.00	0	0.79	SA.F (2)	ST I	ST I (2)	> 1.22	**3.5**
13W	3 to 2 phi (2)	2.41	0.00	0	0.96	SA.F (2)	ST I	ST I (2)	> 2.41	**5.0**
14	> 4 phi (2)	7.69	> 7.69	2	0.52	UN.SI (2)	ST I on III	ST I on III (1), ST I to II (1)	1.42	6.0
15	> 4 phi (2)	9.23	> 9.23	2	0.98	UN.SI (2)	ST I on III	ST I on III (2)	1.33	7.0
16	1 to 0 phi (1), 2 to 1 phi (1)	3.74	0.00	0	1.29	SA.G (1), SA.M (1)	ST I	ST I (2)	2.43	**4.5**
17	> 4 phi (2)	5.55	0.00	0	0.93	UN.SS (2)	ST I	ST I (2)	2.70	5.5
18	> 4 phi (2)	8.01	> 8.01	2	1.22	UN.SI (2)	ST I to II	ST I to II (2)	1.13	4.0
19	> 4 phi (2)	10.02	> 10.02	2	0.89	UN.SI (2)	ST II to III	ST II to III (2)	1.48	6.5
20	3 to 2 phi (2)	2.32	0.00	0	2.04	SA.F (2)	ST I	ST I (2)	> 2.32	**4.5**
22	3 to 2 phi (2)	5.54	0.00	0	2.33	SA.F (2)	ST I	ST I (2)	> 5.54	**6.5**
24	3 to 2 phi (2)	3.51	0.00	0	1.51	SA.F (1), UN.SS (1)	ST I	ST I (2)	2.70	**5.0**
25	0 to -1 phi (1), 1 to 0 phi (1)	1.00	> 1.0	2	1.17	SA.M (1), SH.SA (1)	ST I	INDET (1), ST I (1)	> 1.51	**4.0**
26	2 to 1 phi (2)	1.84	> 1.84	2	0.85	SA.G (1), SA.M (1)	ST I	ST I (2)	> 1.84	**4.0**
27	> 4 phi (2)	13.08	> 13.08	2	0.50	UN.SI (2)	ST I on III	ST I on III (2)	1.83	8.0
28	> 4 phi (2)	9.65	> 9.65	2	1.10	UN.SI (2)	ST I on III	ST I (1), ST I on III (1)	1.75	5.5
29	> 4 phi (2)	13.91	> 13.91	2	1.03	UN.SI (2)	ST I on III	ST I on III (1), ST II to III (1)	1.30	6.5
30	> 4 phi (2)	6.15	> 6.15	2	0.66	UN.SI (2)	ST II on III	ST II on III (1), ST II to III (1)	1.41	7.0
31	> 4 phi (1), 3 to 2 phi (1)	6.44	> 5.05	1	1.63	UN.SI (1), UN.SS (1)	ST II	ST I (1), ST II (1)	1.64	4.5
32	3 to 2 phi (2)	5.98	> 5.98	2	0.77	UN.SI (1), UN.SS (1)	ST II on III	ST I (1), ST II on III (1)	3.66	8.5
33	3 to 2 phi (2)	4.59	0.00	0	1.19	UN.SI (1), UN.SS (1)	ST II to III	ST I (1), ST II to III (1)	2.32	6.0
34	3 to 2 phi (2)	2.91	0.00	0	1.43	SA.M (2)	ST I	ST I (2)	> 2.91	**5.0**
35	3 to 2 phi (2)	3.43	0.00	0	0.53	SA.F (2)	ST I	ST I (2)	> 3.43	**6.0**
36	> 4 phi (1), 4 to 3 phi (1)	2.71	0.00	0	0.63	UN.SI (1), UN.SS (1)	ST II	ST II (2)	1.26	**5.0**
37	3 to 2 phi (2)	3.32	0.00	0	1.51	SA.M (2)	ST I	ST I (2)	> 3.32	**6.0**
38	2 to 1 phi (2)	2.43	0.00	0	2.09	SA.G (1), SA.M (1)	ST I	ST I (2)	> 2.43	**5.0**
39	3 to 2 phi (2)	1.45	0.00	0	0.60	SA.F (2)	ST I	ST I (2)	> 1.45	**3.5**
40	3 to 2 phi (2)	3.52	0.00	0	1.05	UN.SS (2)	ST I	ST I (2)	> 3.52	**6.0**
42	3 to 2 phi (2)	2.78	0.00	0	0.51	SA.F (2)	ST I	ST I (2)	> 2.78	**5.0**
43	4 to 3 phi (2)	1.57	0.00	0	0.74	UN.SS (2)	ST I	ST I (2)	> 1.57	**3.5**
44	3 to 2 phi (2)	2.82	0.00	0	0.53	SA.F (2)	ST I	ST I (2)	> 2.82	**5.5**
45	3 to 2 phi (2)	2.15	0.00	0	0.45	SA.F (2)	ST I	ST I (2)	> 2.15	**4.5**
46	> 4 phi (2)	9.06	0.00	0	1.40	UN.SI (2)	ST II on III	ST II (1), ST II on III (1)	0.47	7.0
49	> 4 phi (1), N/A (1)	4.48	> 4.48	1	0.32	HR (1), UN.SI (1)	ST I on III	INDET (1), ST I on III (1)	0.89	7.0
EO800	> 4 phi (2)	11.84	> 11.84	2	0.70	UN.SI (2)	ST I on III	ST I on III (2)	2.40	8.5
G1200	> 4 phi (2)	6.85	> 6.85	2	0.76	UN.SI (2)	ST I on III	ST I (1), ST I on III (1)	1.63	6.0
H2000	> 4 phi (2)	10.33	> 10.33	2	0.53	UN.SI (2)	ST I on III	ST I (1), ST I on III (1)	1.05	5.0
I1200	> 4 phi (2)	8.52	> 8.52	2	1.69	UN.SI (2)	ST I on III	ST I on III (1), ST I to II (1)	0.96	5.5
K0800	> 4 phi (2)	6.08	> 6.08	2	5.74	UN.SF (2)	ST III	ST I (1), ST III (1)	INDET	INDET
L1200	> 4 phi (2)	2.77	> 2.78	2	1.12	UN.SI (2)	ST I	INDET (1), ST I (1)	1.39	3.0
L1600	> 4 phi (1)	13.74	13.74	1	0.34	UN.SI (1)	ST II	ST II (1)	2.60	7.0
L2400	< -1 phi (1)	1.74	0.00	0	2.28	HR (1)	INDET	INDET (1)	INDET	INDET
M1200	> 4 phi (1), N/A (1)	1.95	> 1.95	1	1.54	HR (1), UN.SI (1)	ST I	INDET (1), ST I (1)	1.99	4.0
M2800	> 4 phi (2)	9.31	> 9.31	2	0.94	UN.SI (2)	ST II on III	ST I on III (1), ST II on III (1)	1.69	8.0
N2000	> 4 phi (2)	13.68	> 13.68	2	0.80	UN.SI (2)	ST I on III	ST I on III (2)	1.88	8.0
N3200	> 4 phi (1), 4 to 3 phi (1)	8.13	> 8.13	2	0.61	UN.SI (2)	ST I on III	ST I on III (1), ST II to III (1)	2.58	8.5
P2800	> 4 phi (2)	7.10	> 7.1	2	2.03	UN.SF (1), UN.SI (1)	ST I on III	ST I (1), ST I on III (1)	1.64	5.5
P3200	> 4 phi (2)	7.68	> 7.68	2	2.13	UN.SI (2)	ST I	ST I (2)	2.09	4.5
Q1600	2 to 1 phi (1), 4 to 3 phi (1)	2.08	0.00	0	1.22	SA.M (1), UN.SS (1)	ST I	INDET (1), ST I (1)	3.22	**6.0**
Q2400	> 4 phi (2)	16.34	> 16.34	2	0.62	UN.SI (2)	ST II	ST II (2)	1.99	6.0
AVG		6.0	4.2	0.9	1.2				1.9	5.9
MAX		16.3	>16.3	2.0	5.7				3.7	8.5
MIN		0.9	0.0	0.0	0.3				0.5	3.0

[1] The OSI was developed for characterizing disturbance primarily in soft-bottom, muddy environments. The values shown in bold are for stations having ambient sand, representing largely non-degraded habitat conditions that are not adequately reflected in the OSI.

[2] The overall average OSI Mean excluding the ambient sandy stations was 6.4

Table 3.3-2.
Summary of Sediment-Profile Imaging Results for the Additional 60 Stations Sampled within the HARS, Summer 2005 Survey[1]

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Reps With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean[2]
97001	> 4 phi (2)	7.02	> 7.03	2	0.37	UN.SI (2)	ST I on III (1), ST II (1)	1.83	7.00
970010	3 to 2 phi (2)	2.01	0.00	0	2.10	SA.M (2)	ST I (2)	> 2.01	4.00
97002	> 4 phi (2)	13.39	> 13.39	2	0.70	UN.SI (2)	ST II (1), ST II to III (1)	1.96	7.00
97003	3 to 2 phi (1), 4 to 3 phi (1)	7.03	0.00	0	0.84	UN.SS (2)	ST I (1), ST I to II (1)	4.29	6.50
97004	3 to 2 phi (2)	2.26	0.00	0	0.74	SA.F (2)	ST I (2)	> 2.26	4.50
97005	3 to 2 phi (2)	1.97	0.00	0	0.51	SA.F (1), UN.SS (1)	ST I (2)	> 1.97	4.00
97006	3 to 2 phi (2)	2.00	0.00	0	0.97	SA.F (2)	ST I (2)	> 2.00	4.00
97007	> 4 phi (2)	4.82	> 4.83	2	3.24	UN.SI (2)	ST I (2)	1.88	4.00
97008	> 4 phi (2)	6.71	> 6.71	2	2.38	UN.SI (2)	ST I on III (2)	3.39	10.00
97009	> 4 phi (2)	8.88	> 8.88	2	0.77	UN.SI (2)	ST I (1), ST II on III (1)	2.36	6.50
20011	> 4 phi (2)	10.38	> 10.38	2	0.66	UN.SI (2)	ST I on III (1), ST II on III (1)	1.19	7.00
200110	> 4 phi (2)	6.30	> 6.3	2	1.60	UN.SI (2)	ST I (1), ST I on III (1)	0.84	7.00
20012	> 4 phi (2)	16.09	> 16.09	2	0.58	UN.SI (2)	ST I on III (1), ST II to III (1)	2.12	8.00
20013	> 4 phi (2)	14.56	> 14.56	2	0.49	UN.SI (2)	ST I to II (1), ST II on III (1)	1.82	6.50
20014	> 4 phi (2)	14.95	> 14.95	2	0.58	UN.SI (2)	ST I on III (1), ST I to II (1)	1.18	5.50
20015	> 4 phi (2)	9.10	> 9.12	2	0.74	UN.SI (2)	ST I (1), ST I on III (1)	0.83	4.50
20016	4 to 3 phi (1)	4.96	0.00	0	1.14	UN.SS (1)	ST I (1)	> 4.96	7.00
20017	> 4 phi (2)	9.00	> 9	2	0.49	UN.SI (2)	ST II on III (2)	1.51	7.50
20018	> 4 phi (2)	5.79	> 5.79	2	0.94	UN.SI (2)	ST I (1), ST I on III (1)	1.64	5.50
20019	> 4 phi (2)	6.99	> 6.99	2	3.01	UN.SI (2)	ST I (1), ST I on III (1)	2.40	6.50
20021	> 4 phi (2)	15.28	> 15.29	2	0.81	UN.SI (2)	ST I on III (2)	2.45	9.00
200210	> 4 phi (1), 2 to 1 phi (1)	2.34	> 2.34	2	1.48	SH.SI (2)	INDET (1), ST I (1)	1.38	3.00
20022	> 4 phi (2)	10.80	> 10.80	2	0.65	UN.SI (2)	ST I on III (2)	2.37	9.00
20023	3 to 2 phi (1), 4 to 3 phi (1)	6.39	0.00	0	1.40	UN.SI (1), UN.SS (1)	ST I (2)	3.22	5.50
20024	> 4 phi (2)	14.75	> 14.75	2	0.87	UN.SF (1), UN.SI (1)	ST I on III (1), ST I to II (1)	1.88	6.50
20025	< -1 phi (1)	0.07	0.07	1	0.14	HR (1)	INDET (1)	INDET	INDET
20026	> 4 phi (2)	4.14	> 4.14	2	1.58	SH.SI (1), UN.SI (1)	ST I (2)	1.12	3.00
20027	2 to 1 phi (2)	2.10	> 2.1	2	2.35	SH.SA (1), UN.SI (1)	ST I (2)	1.20	3.00
20028	< -1 phi (1), > 4 phi (1)	1.79	> 1.79	2	1.40	SH.SI (2)	INDET (1), ST I (1)	1.71	4.00
20029	N/A (1)	0.00	0.00	0	0.00	HR (1)	INDET (1)	INDET	INDET
20031	> 4 phi (2)	7.43	> 7.43	2	0.71	UN.SF (2)	ST I (1), ST II on III (1)	2.10	8.00
200310	> 4 phi (2)	6.22	> 6.22	2	1.32	UN.SF (1), UN.SI (1)	ST I on III (2)	1.48	7.50
20032	> 4 phi (2)	11.00	> 11	2	0.63	UN.SF (1), UN.SI (1)	ST I on III (2)	2.03	8.50
20033	> 4 phi (2)	3.82	> 3.82	2	1.84	UN.SF (2)	ST I on III (2)	2.70	9.00
20034	> 4 phi (2)	5.57	> 5.57	2	3.21	UN.SF (2)	ST I on III (2)	2.07	8.50
20035	> 4 phi (2)	8.93	> 8.93	2	6.02	UN.SF (2)	ST I (1), ST I on III (1)	1.74	6.00
20036	> 4 phi (2)	13.03	> 13.03	2	1.18	UN.SI (2)	ST I on III (2)	2.37	8.50
20037	> 4 phi (2)	11.60	> 11.61	2	2.32	UN.SF (2)	ST II on III (1), ST III (1)	3.47	10.00
20038	> 4 phi (2)	10.26	> 10.26	2	1.11	UN.SI (2)	ST II on III (1), ST III (1)	2.90	9.50
20039	> 4 phi (1)	14.47	14.47	1	2.26	UN.SI (1)	ST I on III (1)	3.25	10.00
20041	> 4 phi (2)	16.90	> 16.9	2	0.76	UN.SI (2)	ST I on III (1), ST I to II (1)	3.30	8.50
200410	> 4 phi (1), 4 to 3 phi (1)	2.21	> 2.21	2	2.07	UN.SI (1), UN.SS (1)	ST I (2)	1.92	4.00
20042	> 4 phi (2)	5.24	> 5.24	2	1.95	UN.SI (2)	ST I (1), ST I on III (1)	2.53	6.50
20043	> 4 phi (2)	13.03	> 13.03	2	0.79	UN.SI (2)	ST I on III (1), ST I to II (1)	1.65	6.00
20044	> 4 phi (1), 4 to 3 phi (1)	4.84	> 4.84	2	4.86	UN.SI (1), UN.SS (1)	ST I on III (2)	1.70	7.50
20045	< -1 phi (1), 4 to 3 phi (1)	5.03	> 5.04	1	0.37	HR (1), UN.SS (1)	INDET (1), ST I (1)	INDET	INDET
20046	> 4 phi (1), N/A (1)	4.68	> 4.68	2	1.29	HR (1), UN.SI (1)	INDET (1), ST I (1)	1.81	4.00
20047	< -1 phi (1), 4 to 3 phi (1)	5.38	> 5.38	2	0.62	HR (1), UN.SS (1)	Azoic (1), INDET (1)	INDET	INDET
20048	> 4 phi (2)	6.48	> 6.49	2	4.16	UN.SI (2)	ST I on III (2)	2.48	9.00
20049	> 4 phi (2)	3.40	> 3.4	2	2.17	HR (1), UN.SI (1)	INDET (1), ST I (1)	2.06	4.00
20051	> 4 phi (2)	14.34	> 14.35	2	1.32	UN.SI (2)	ST I (1), ST I on III (1)	0.32	4.00
20052	> 4 phi (2)	15.88	> 15.88	2	1.41	UN.SI (2)	ST I (1), ST I on III (1)	0.87	5.00
20053	> 4 phi (2)	15.08	> 15.09	2	1.12	UN.SF (2)	ST I on III (2)	0.44	6.00
20054	> 4 phi (2)	11.03	> 11.03	2	0.86	UN.SI (2)	ST I on III (2)	0.61	6.00
20055	> 4 phi (2)	15.31	> 15.31	2	0.96	UN.SI (2)	ST I on III (1), ST III (1)	1.10	7.00
NOREMED1	4 to 3 phi (2)	2.09	0.00	0	0.44	UN.SS (2)	ST II (2)	> 2.09	**6.00**
NOREMED2	> 4 phi (2)	8.06	> 8.07	2	0.70	UN.SI (2)	ST II on III (2)	0.52	7.50
NOREMED3	3 to 2 phi (2)	1.73	0.00	0	0.65	UN.SS (2)	ST I (2)	> 1.73	**3.50**
NOREMED4	3 to 2 phi (2)	1.86	0.00	0	1.19	SA.F (1), UN.SS (1)	ST I (2)	> 1.86	**4.00**
NOREMED5	> 4 phi (2)	5.26	> 5.26	2	1.07	UN.SI (2)	ST I (1), ST I on III (1)	1.47	5.50
AVG		7.7	7.2	1.6	1.4			2.0	6.3
MAX		16.9	> 16.9	2.0	6.0			4.3	10.0
MIN		0.0	0.0	0.0	0.0			0.3	3.0

[1] The OSI was developed for characterizing disturbance primarily in soft-bottom, muddy environments. The values shown in bold are for stations having ambient sand, representing largely non-degraded habitat conditions that are not adequately reflected in the OSI.

[2] The overall average OSI Mean excluding the ambient sandy stations was 6.4

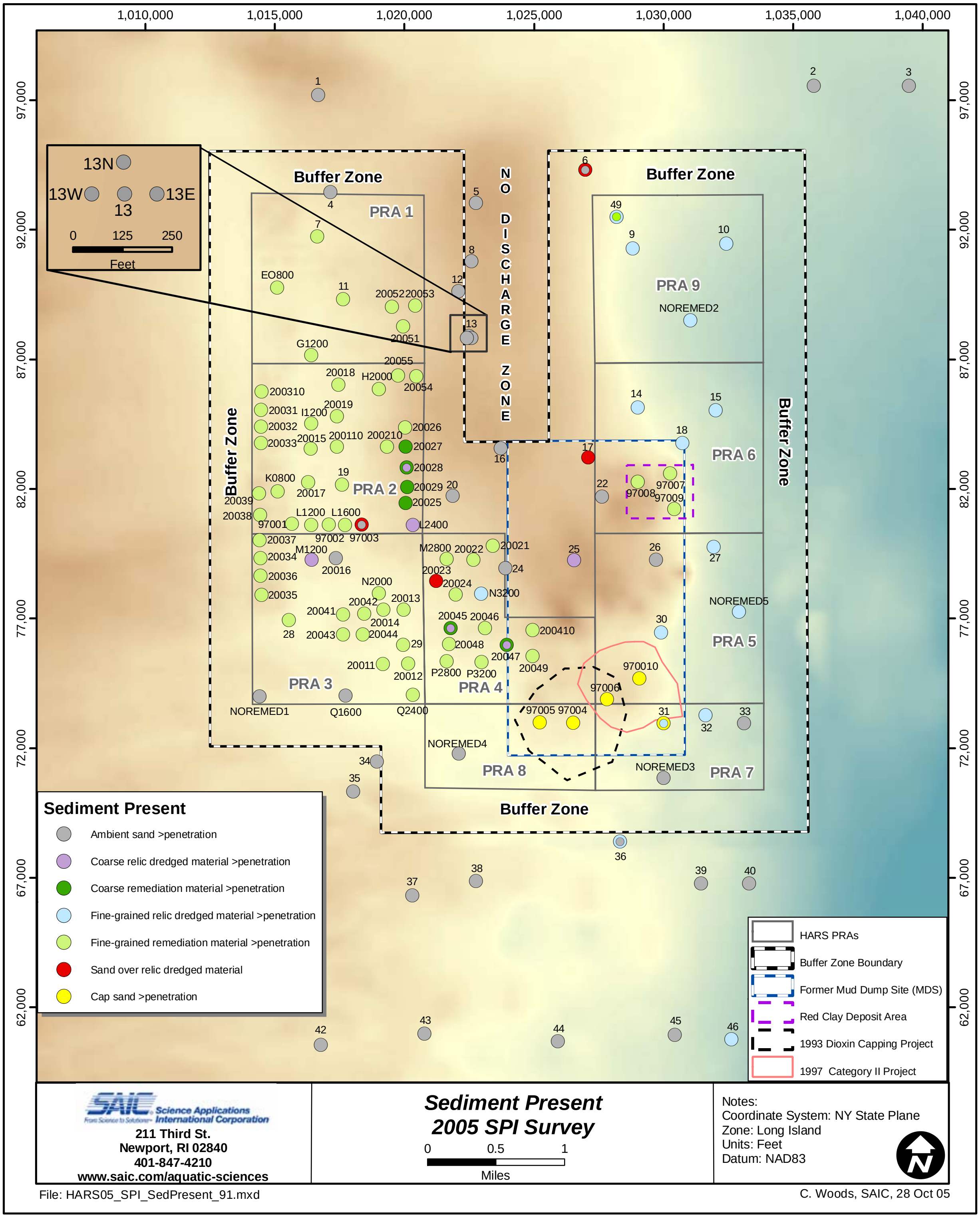


Figure 3.3-1. Sediment types observed at the 2005 SPI stations

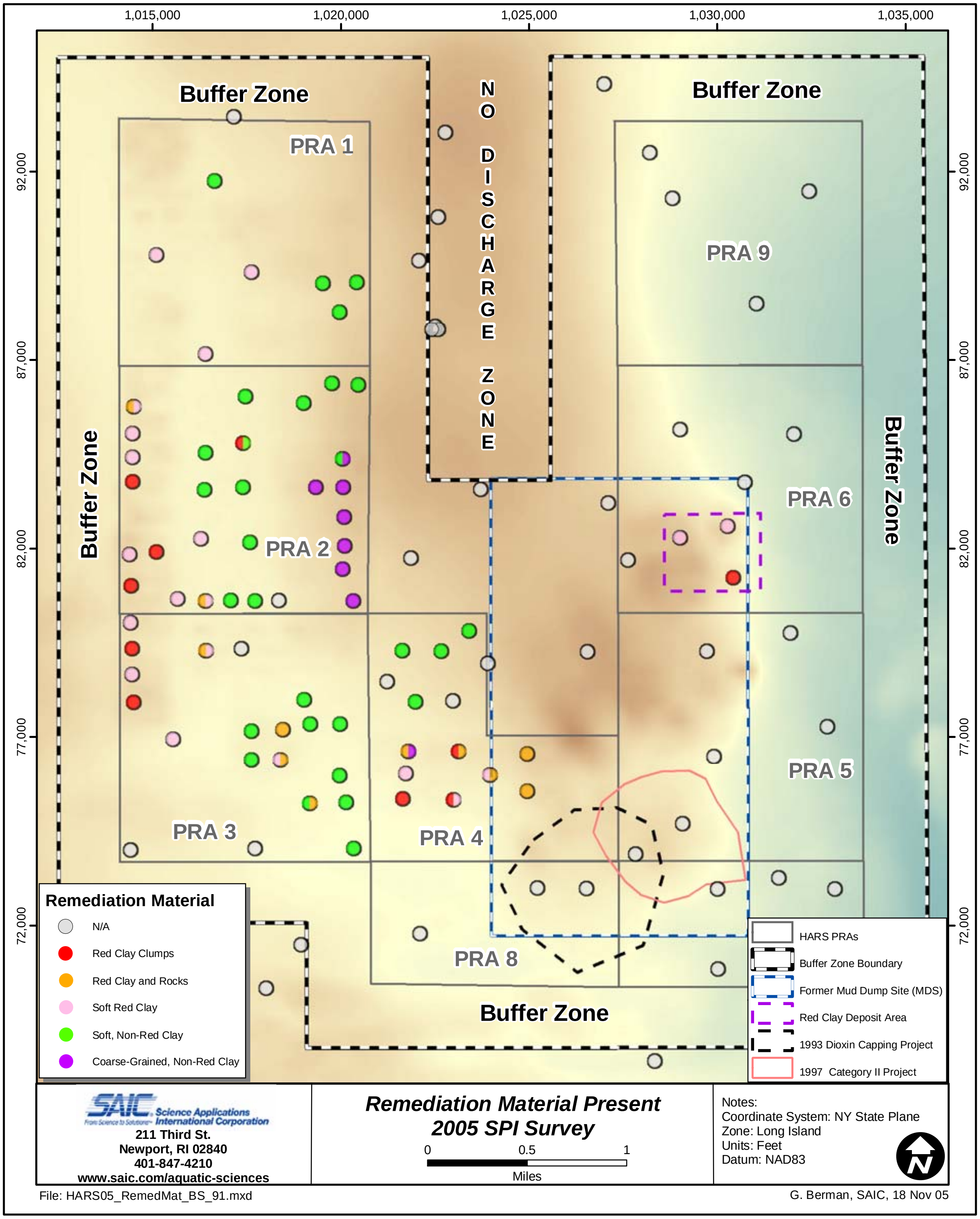
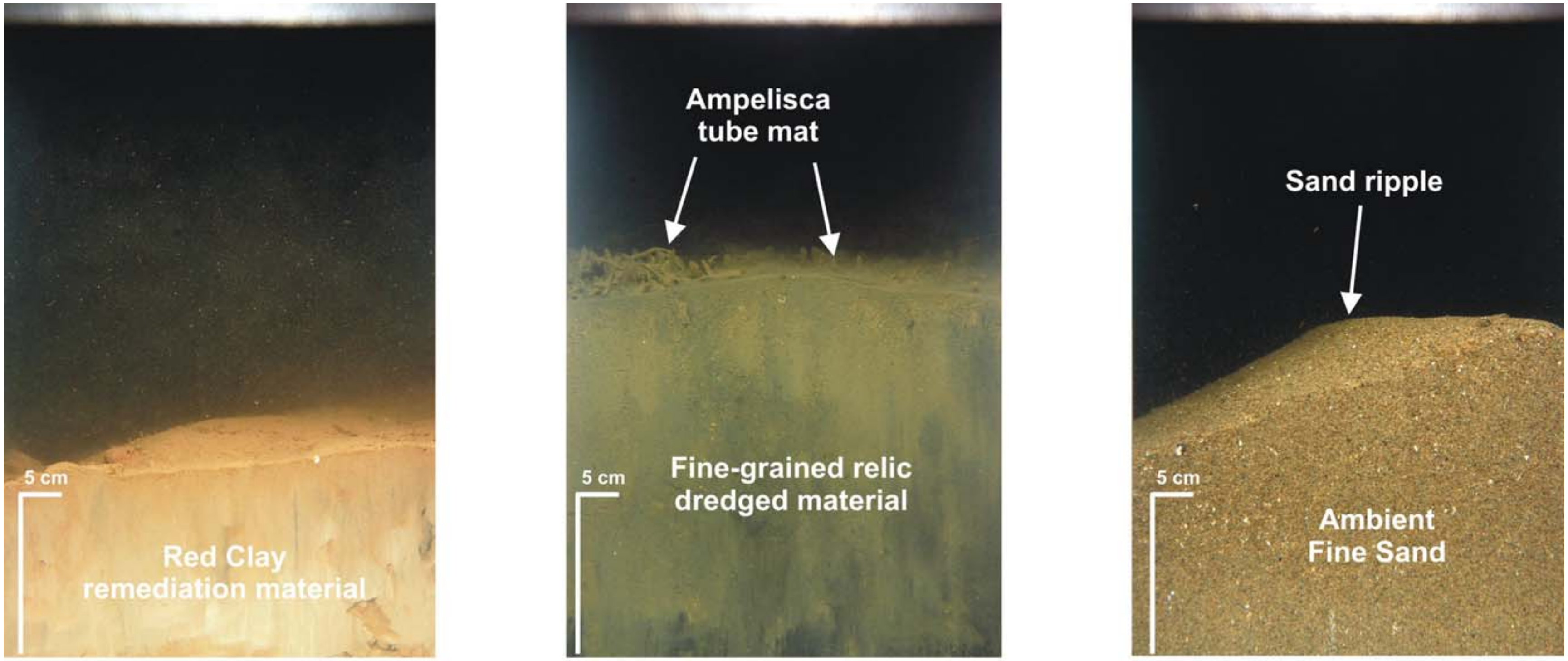


Figure 3.3-2. Types of remediation material observed at the 2005 SPI stations



A B C

Figure 3.3-3. SPI images from Stations 2003 (A), 46 (B), and 22 (C) illustrating the various types of sediment observed over the surveyed area. Fine-grained remediation material composed of red clay (grain size major mode of >4 phi) is shown in image A. Image B display fine-grained relic dredged material (grain size major mode of >4 phi), while Image C shows ambient fine sand (grain size major mode of 3 to 2 phi).

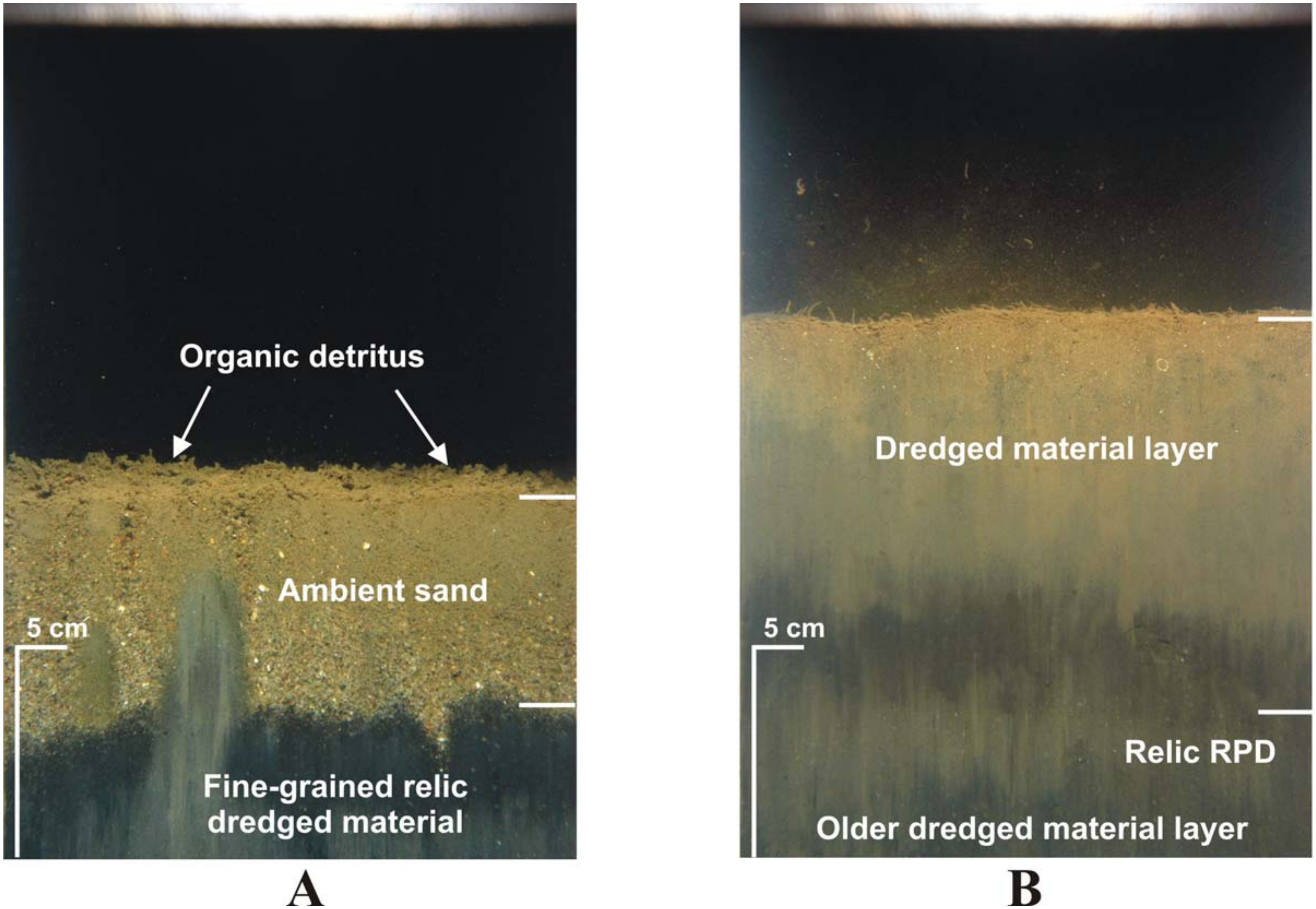


Figure 3.3-4. SPI images from Station 6 (A) and N2000 (B) illustrating multiple sediment layers. Image A shows a layer of ambient sand over underlying fine-grained relic dredged material, while Image B displays multiple dredged material layers. A relic RPD is also visible at depth in Image B.

primary and supplemental stations (i.e., denoted by a greater than symbol in Tables 3.3-1 and 3.3-2). Due to the ongoing disposal of material within the HARS, multiple dredged material layers were often noted in the images (Figure 3.3-4B). Variability in the appearance of the dredged material within the same station was also noted (Figure 3.3-5).

Consistent with the variability in sediment types, a wide range of grain size major modes was observed among the SPI stations, ranging from >4 phi (silt-clay) to < -1 phi (cobble) (Figure 3.3-6). However, the majority of stations were characterized by either silt-clay (>4 phi) or very fine to fine sand (4 to 3 and 3 to 2 phi; Tables 3.3-1 and 3.3-2 and Figures 3.3-3, 3.3-6, and 3.3-7). At a few stations, significant variability in grain size and sediment composition was observed between the two replicate images (Figures 3.3-5 and 3.3-8). Although located in PRA 2, Station 97003 displayed a unique stratigraphy of apparent ambient sand over an underlying layer of relic dredged material in one replicate image and apparent ambient sand greater than camera prism penetration in the other replicate image (Figure 3.3-8). The apparent lack of remediation material at this station may be the result of camera placement in a small unremediated portion of the PRA. In general, there was good agreement between the SPI grain size results (see Figure 3.3-6) and the grain size analysis of the grab subsamples (see Figure 3.2-1).

The depth of penetration of the SPI 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 SPI 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 tend to be firm and resistant to camera prism penetration. Mean camera penetration measurements at the 60 primary SPI stations ranged from 0.9 cm at Station 5 to 16.3 cm at Station Q2400, while the measurements at the supplemental stations ranged from 0.0 cm at Station 20029 to 16.9 cm at Station 20041 (Tables 3.3-1 and 3.3-2). The wide range of values reflects the wide variety of sediment types observed across the surveyed area. In general, moderate to deep penetration was achieved at the stations with fine-grained relic dredged material or fine-grained remediation material within the HARS, while relatively shallow penetration occurred most consistently in the more compact sandy sediments at stations outside the HARS boundary (Figure 3.3-9). Apparent hard-bottom conditions (cobble, rock, or compact sand) resulted in a lack of 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.

Excluding any stations where there was a lack of penetration of the camera prism into the sediment, small-scale boundary roughness values for the 60 primary SPI stations ranged from 0.3 cm at Stations 11, 49, and L1600 to 5.7 cm at Station K0800, while boundary roughness at the supplemental SPI stations ranged from 0.1 cm at Station 20025 to 6.0 cm at Station 20035 (Tables 3.3-2 and 3.3-3). The overall average of 1.3 cm for both the primary and supplemental stations reflects only a minor amount of small-scale surface relief. Higher surface boundary roughness generally was observed at stations having clumps of highly cohesive red clay remediation material in PRAs 2, 3 and 4 (Figure 3.3-10). Surface roughness was attributed to physical factors at most of the stations, partly due to bedforms (sand ripples) at the sediment-water interface (Figure 3.3-11A). However, a number of stations also exhibited biogenic surface

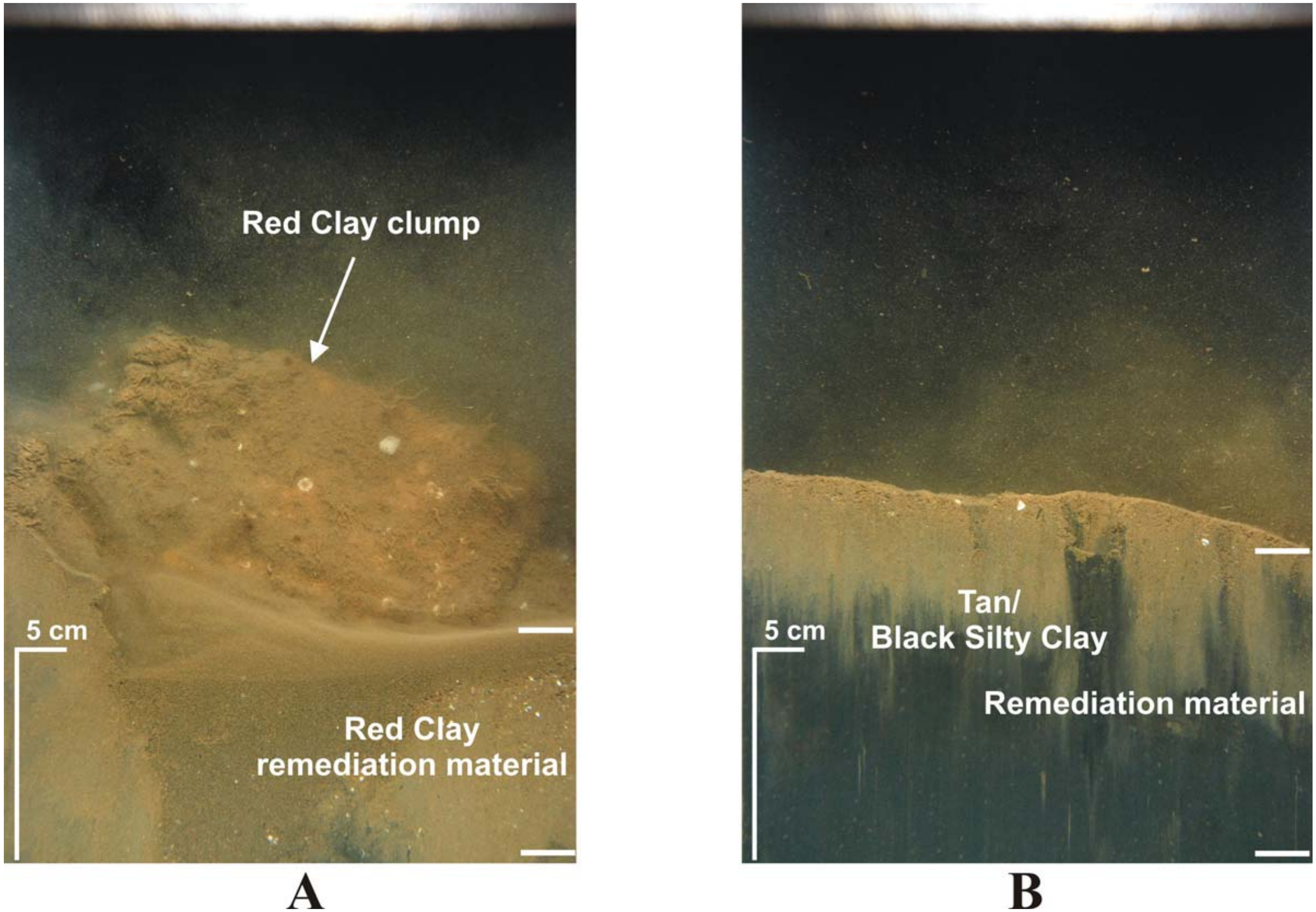


Figure 3.3-5. SPI images from Station 20019 showing small-scale variability in the appearance of dredged material. Image A shows fine-grained remediation material composed of red clay, while the sediment in Image B is composed of fine-grained silt-clay.

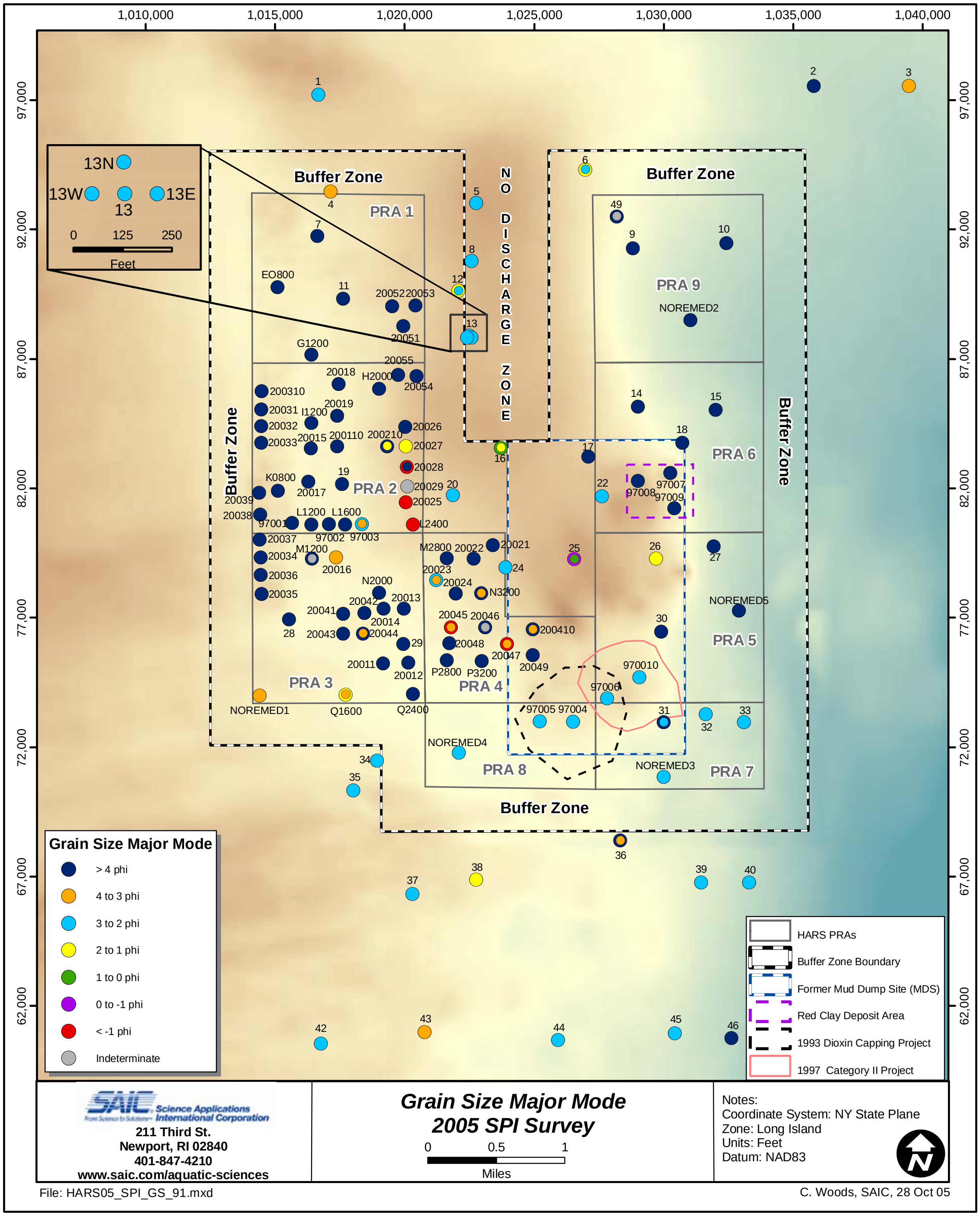


Figure 3.3-6. Grain size major mode (in phi units) of surface sediments observed at the 2005 SPI stations.

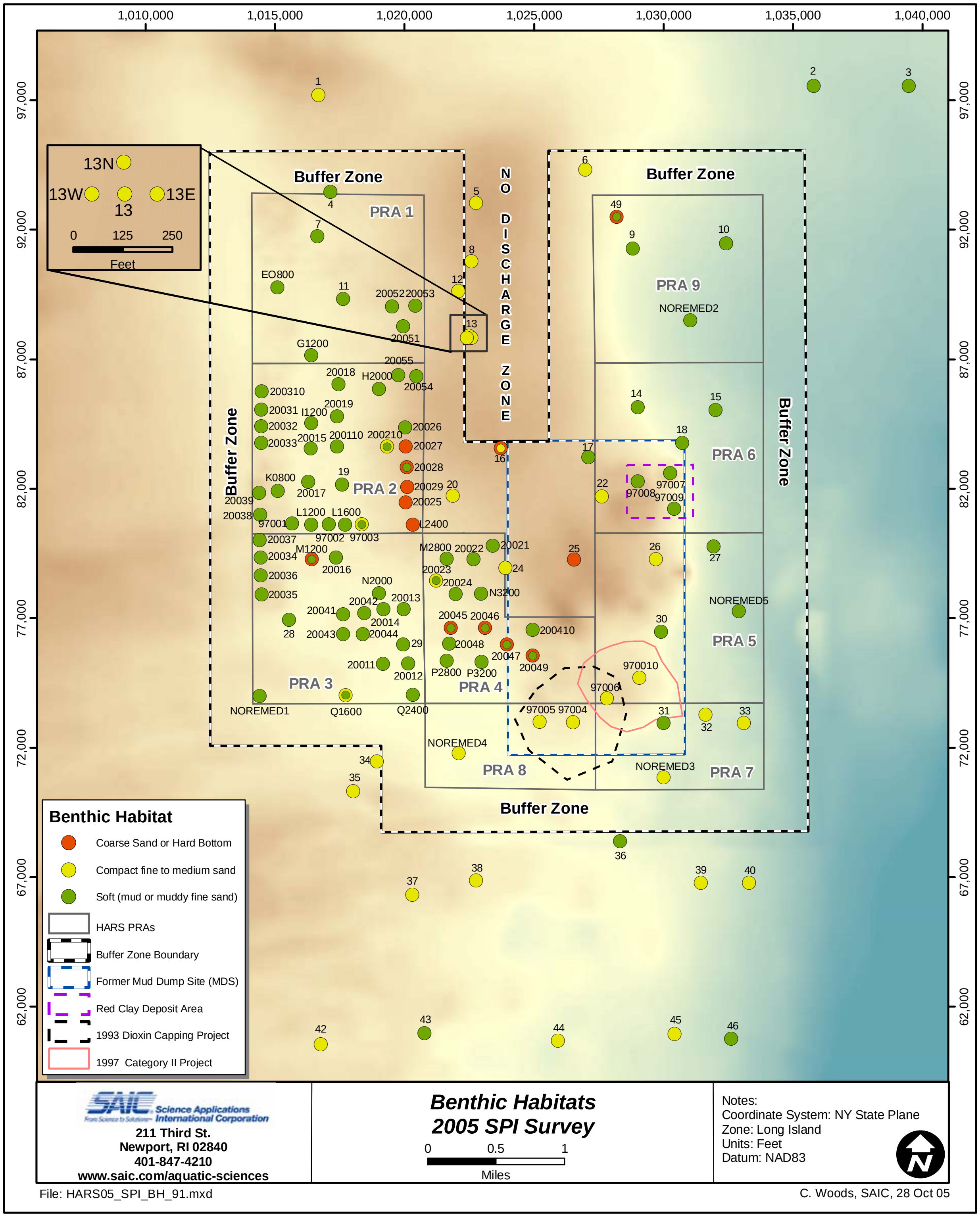


Figure 3.3-7. Benthic habitat types at the SPI stations.

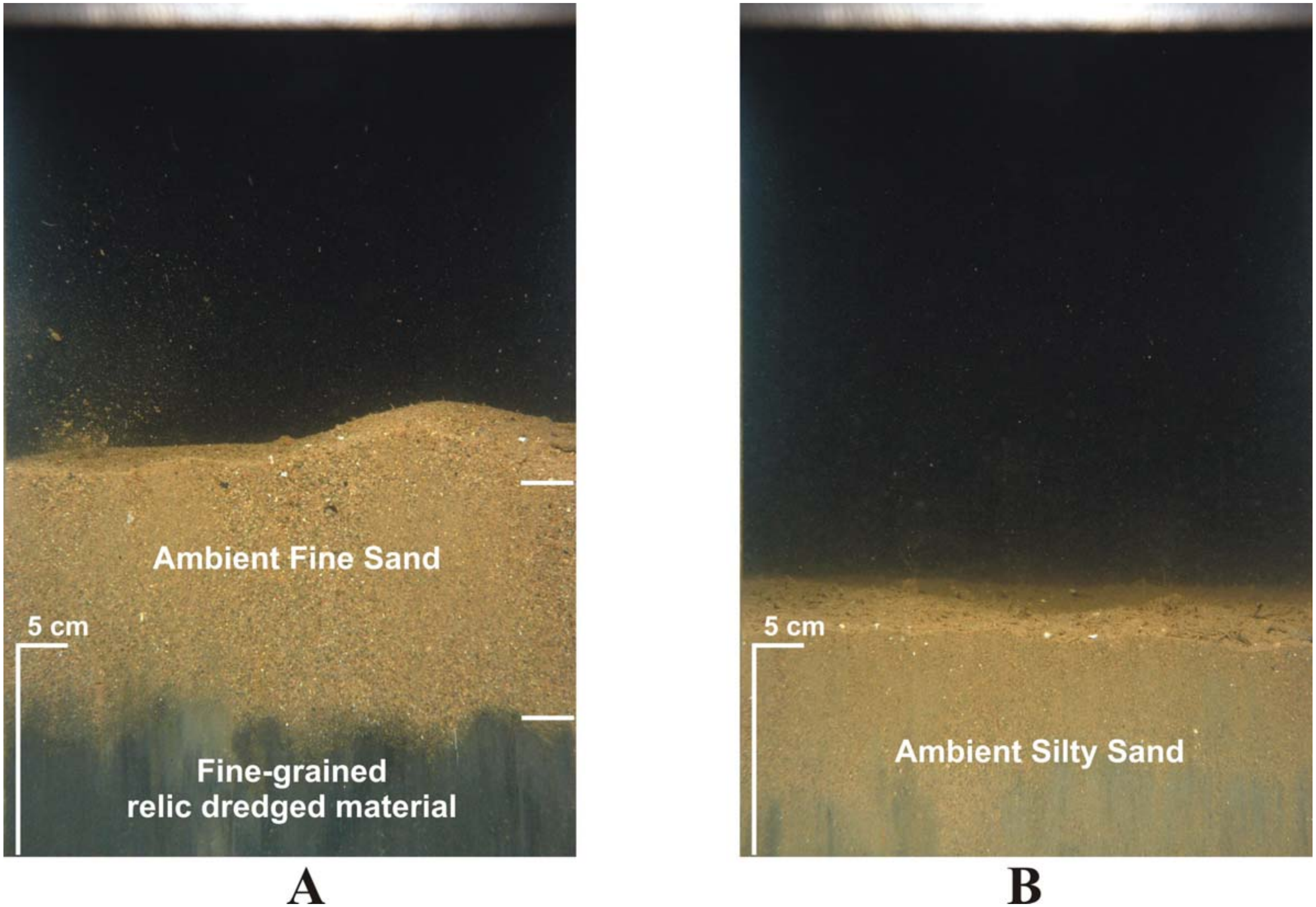


Figure 3.3-8. SPI images from Station 97003 illustrating small-scale spatial variability in sediment composition. Image A shows a layer of ambient fine sand over fine-grained relic dredged material (grain size major mode of 3 to 2 phi), while the sediment in Image B is composed of ambient silty sand (grain size major mode 4 to 3 phi). No remediation material is visible at this station located in PRA 2.

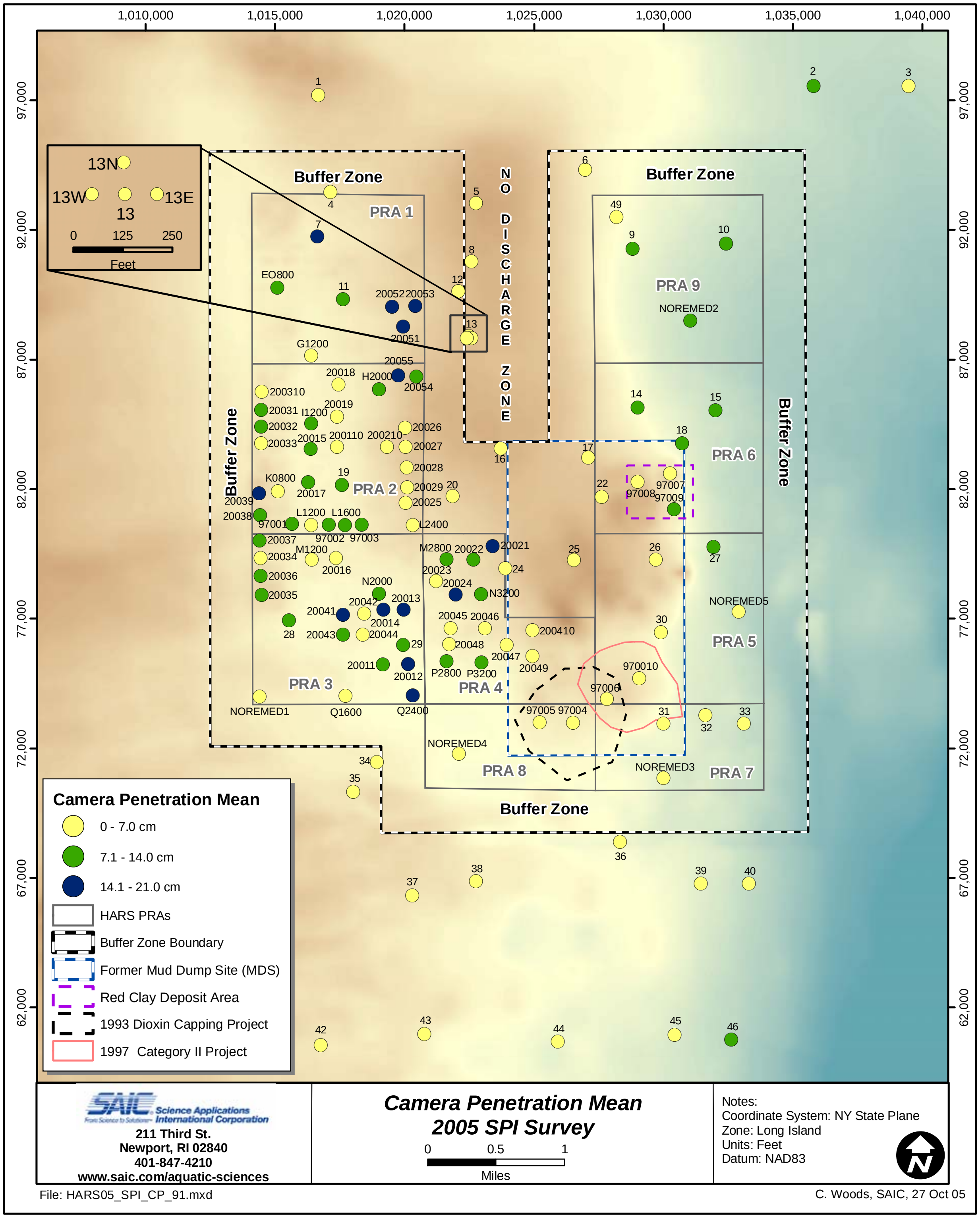


Figure 3.3-9. Mean prism penetrations depths at the 2005 SPI stations.

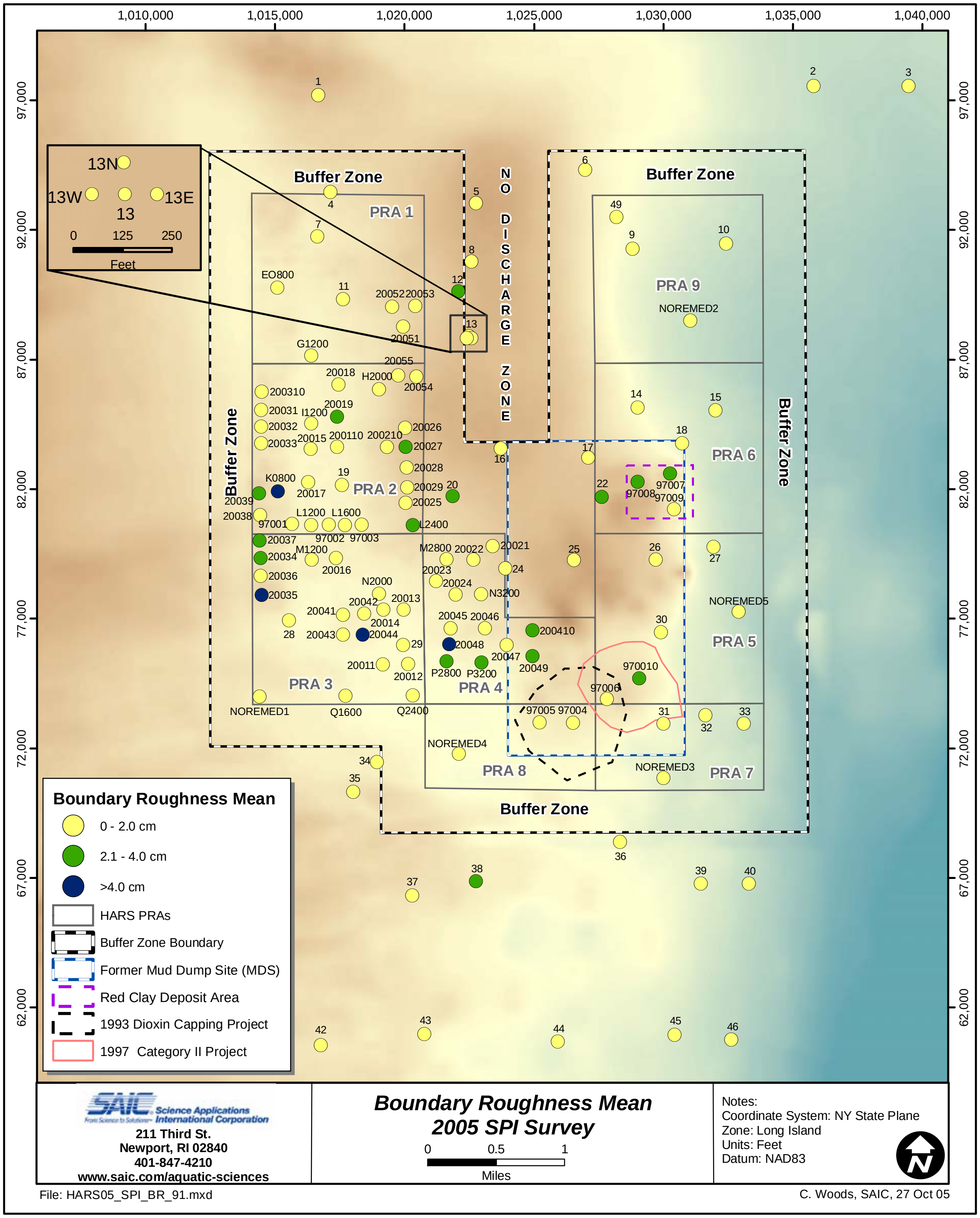
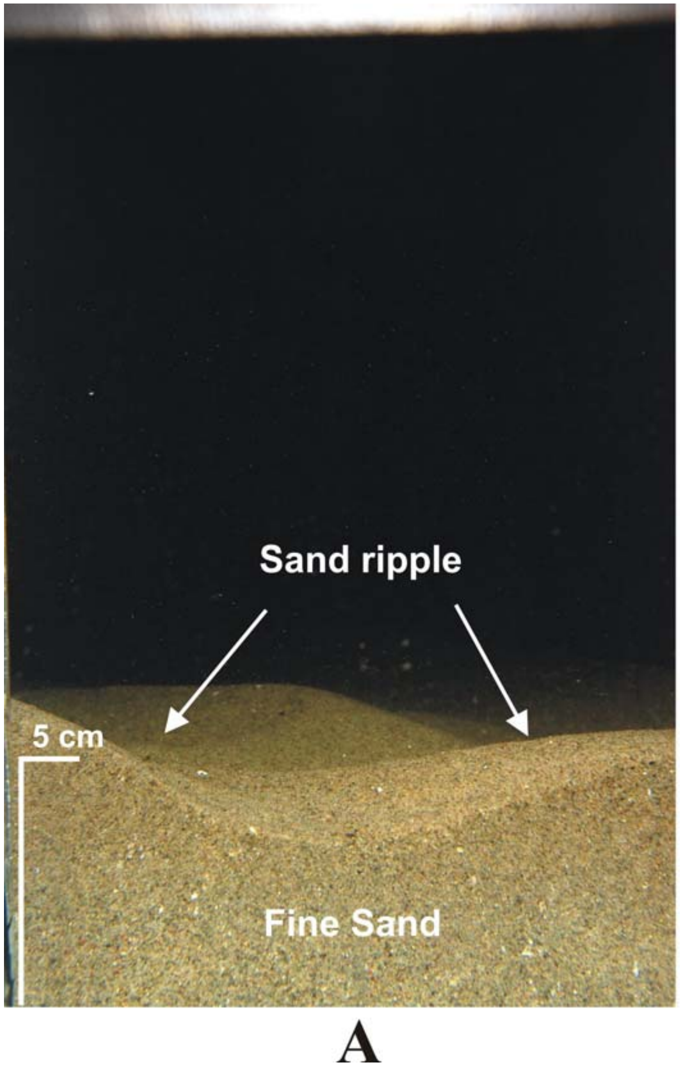


Figure 3.3-10. Average small-scale surface boundary roughness at the 2005 SPI stations.



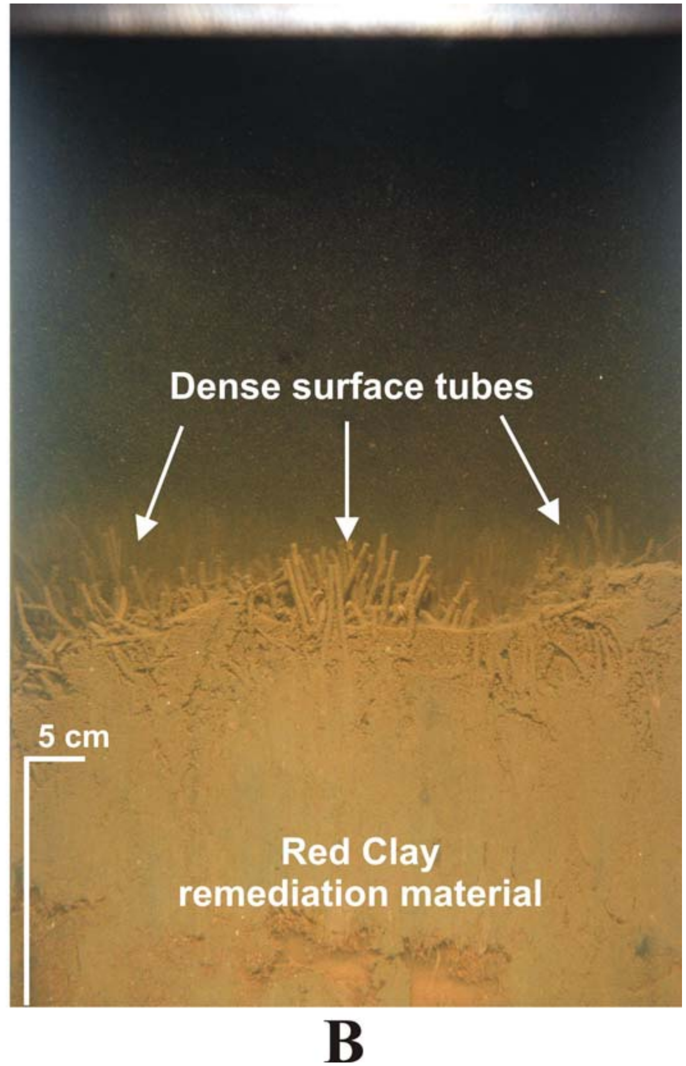


Figure 3.3-11. SPI images from Stations 1 (A) and 20048 (B) displaying physical and biogenic surface roughness. Image A shows physical surface roughness due to compact, rippled fine sand. Biogenic surface roughness due to the presence of dense polychaete tubes (*Asabellides oculata*) at the sediment-water interface is illustrated in Image B.

roughness due to the presence of polychaete tubes, amphipods stalks (i.e., “stick amphipods” of the Family Podoceridae), and tube-dwelling amphipods (*Ampelisca* sp), as well as biological reworking by burrowing infauna at the sediment-water interface (Figure 3.3-11B). A depositional layer of brown flocculent material (organic detritus), often with small tubes or organisms, was observed at the sediment-water interface in a significant number of images across the survey area (Figures 3.3-4A and 3.3-12)

The sediment plan-view images supported the results of the SPI analysis, revealing a variety of sediment types including silts, fine sand, and hard-bottom conditions over the surveyed area. A number of stations (18 of the 60 primary stations and 35 of the 60 supplemental stations) were of poor image quality and were therefore not analyzed. Fine-grained sediment dominated the plan-view images collected from stations within PRAs 1 through 6 and 9 (Figure 3.3-13). Remediation material composed of red clay was visible in the plan-view images and agreed well with the corresponding SPI image (Figure 3.3-14). Plan-view images from PRAs 7 and 8, as well as the No Discharge Zone and regions north and south of the HARS also agreed well with the SPI results, showing mainly sandy (fine to medium) substrate (Figure 3.3-15). Hard-bottom conditions were detected in plan-view images of various stations, primarily in the eastern quadrant of PRA2 and at various stations within PRAs 3 and 4 (Figure 3.3-16).

Small-scale spatial variability was detected at various stations with respect to grain size and benthic habitat. For example, the SPI image from Station 15 revealed fine-grained sediment, while the plan-view image from the same station showed a hard bottom consisting of rock and cobble (Figure 3.3-17). This discrepancy in benthic habitat suggests small-scale spatial variability in the sediment in the eastern portion of PRA 6, with sediment characterized by both fine- and coarse-grained relic dredged material.

3.3.2 Benthic Recolonization Status and Benthic Habitat Conditions

Analysis of the plan-view images also provided insight into the nature and degree of benthic recolonization in areas of the HARS where dredged material has been placed. A number of biological features were detected in the sediment plan-view images including starfish, crabs, infaunal burrows, sand dollars, anemones, polychaete and amphipod tubes, and shrimp (Figures 3.3-13, 3.3-15, 3.3-16, 3.3-18, and 3.3-19). These organisms often appeared in the corresponding SPI images. Dense tube mats of the polychaete *Asabellides oculata* were observed at the surface of red clay remediation material at six stations (Figure 3.3-20). In addition, clusters of juvenile mussels were observed at the surface of both the sediment plan-view and SPI images at nine stations (Figure 3.3-21). Layers of brown organic flocculent material were also detected at the sediment surface of both the SPI and plan-view images at 15 stations over the surveyed area (Figure 3.3-19B).

In terms of the SPI images, three parameters were used to assess benthic recolonization status and overall benthic habitat conditions within the surveyed area: apparent RPD depth, infaunal successional status, and Organism Sediment Index (OSI). A wide variety of 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

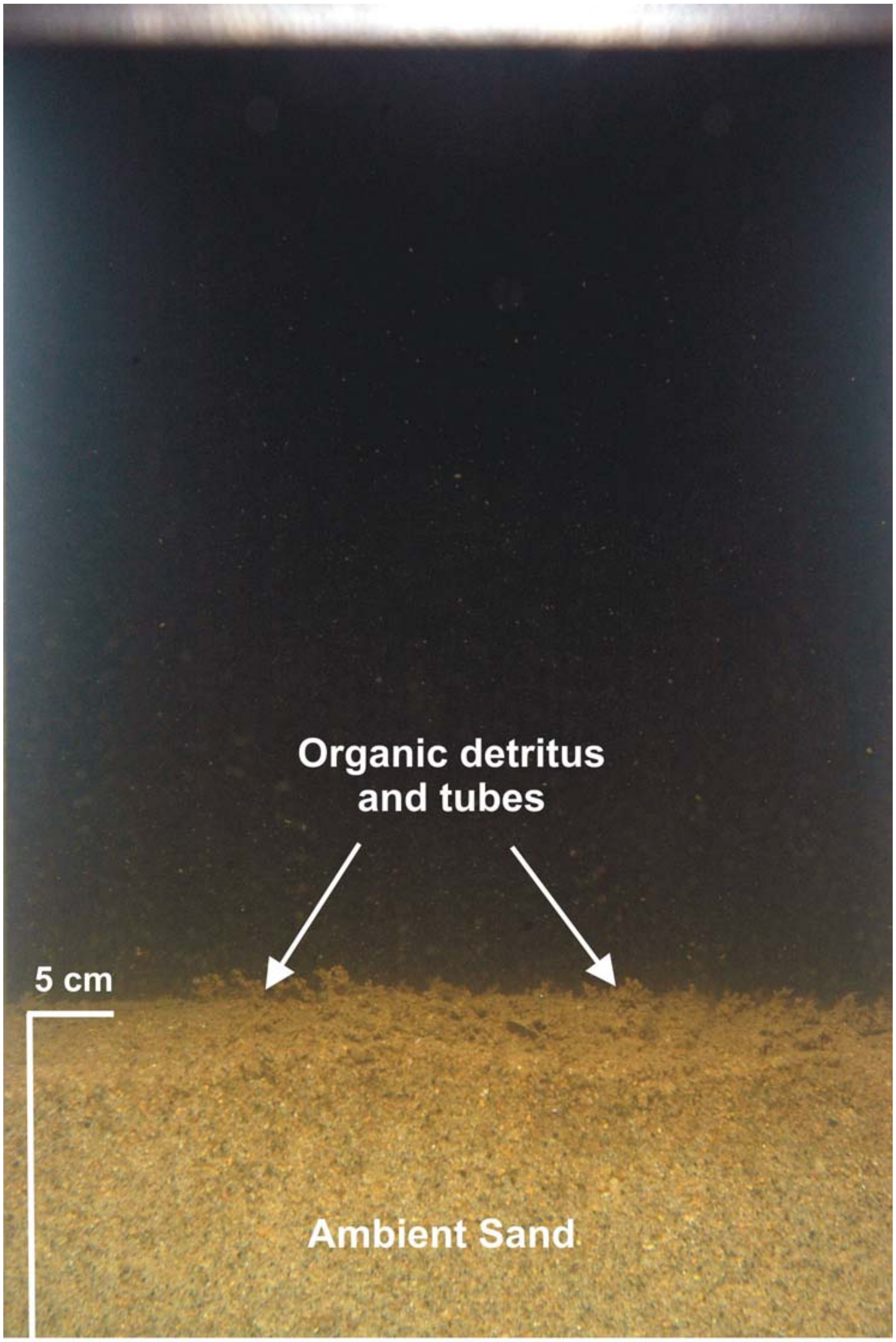


Figure 3.3-12. SPI image from Station 37 displaying a depositional layer of brown organic flocculent material with surface tubes at the sediment-water interface.

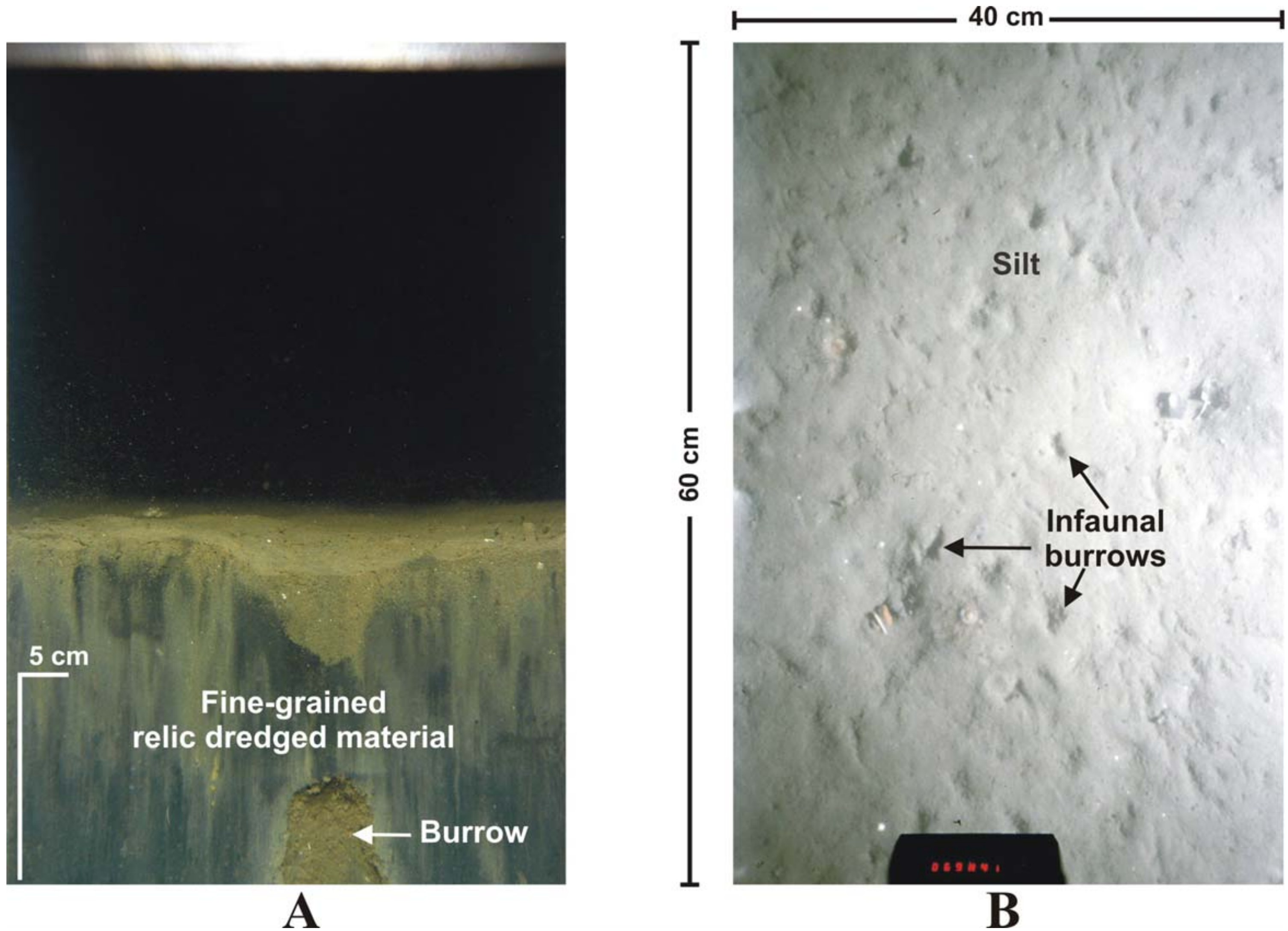


Figure 3.3-13. SPI image (A) and corresponding plan-view image (B) from Station NOREMED2 showing agreement in sediment composition. The SPI image shows fine-grained relic dredged material. A silty bottom with infaunal burrows is also visible in the plan-view image.

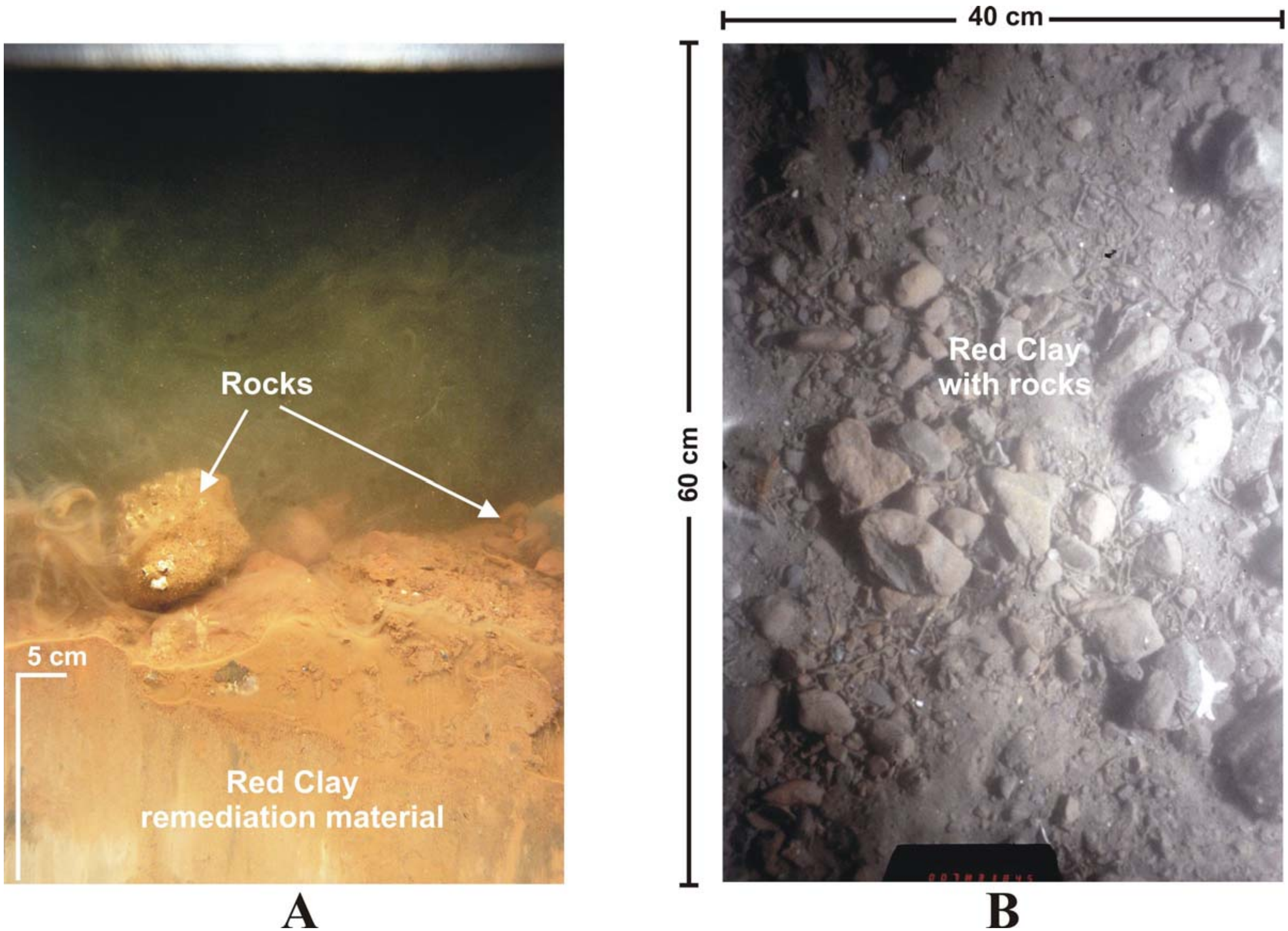


Figure 3.3-14. SPI image (A) and corresponding plan-view image (B) from Station 200410 showing agreement in sediment composition, with remediation material composed of red clay and rocks visible in both images.

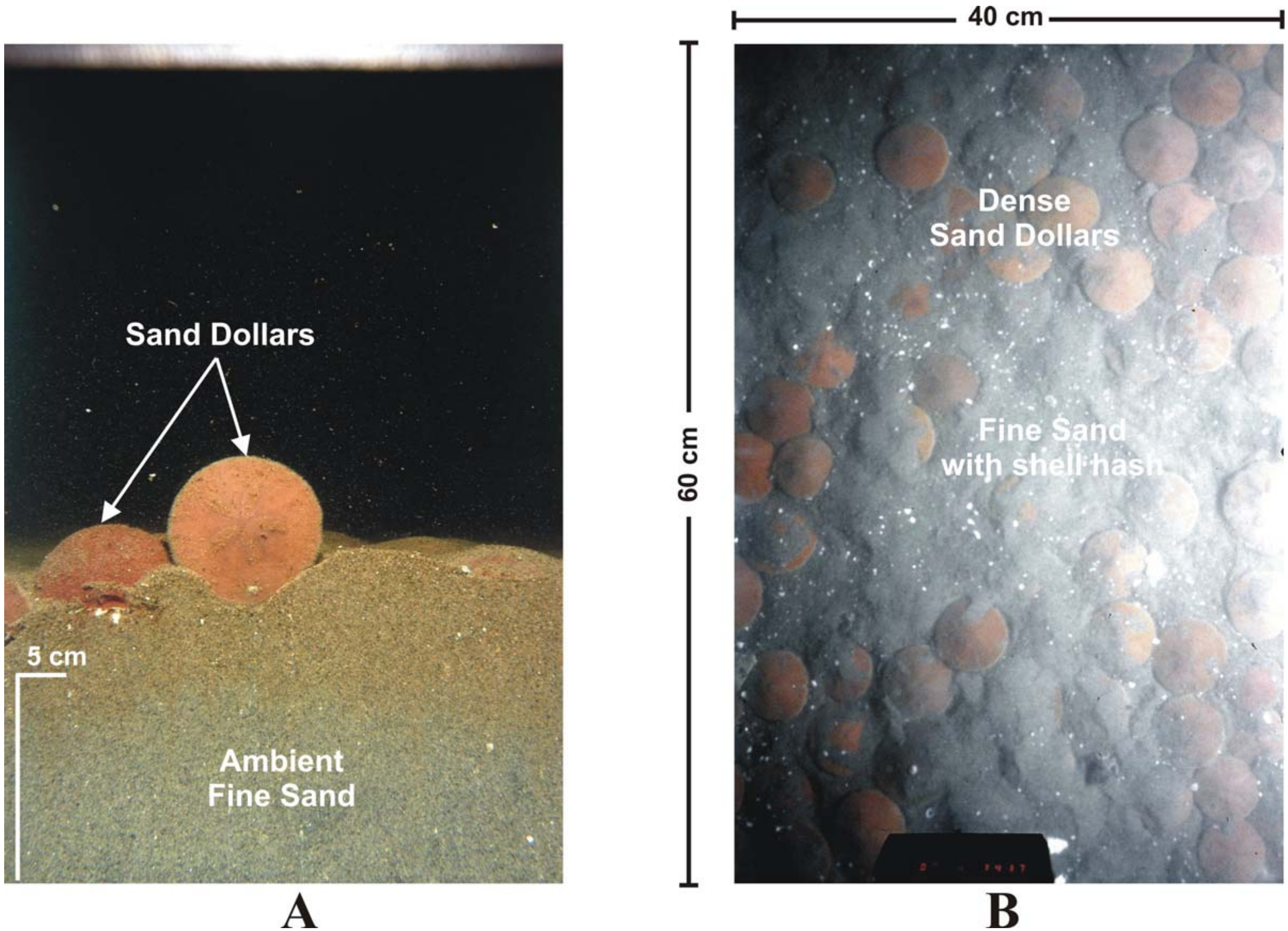
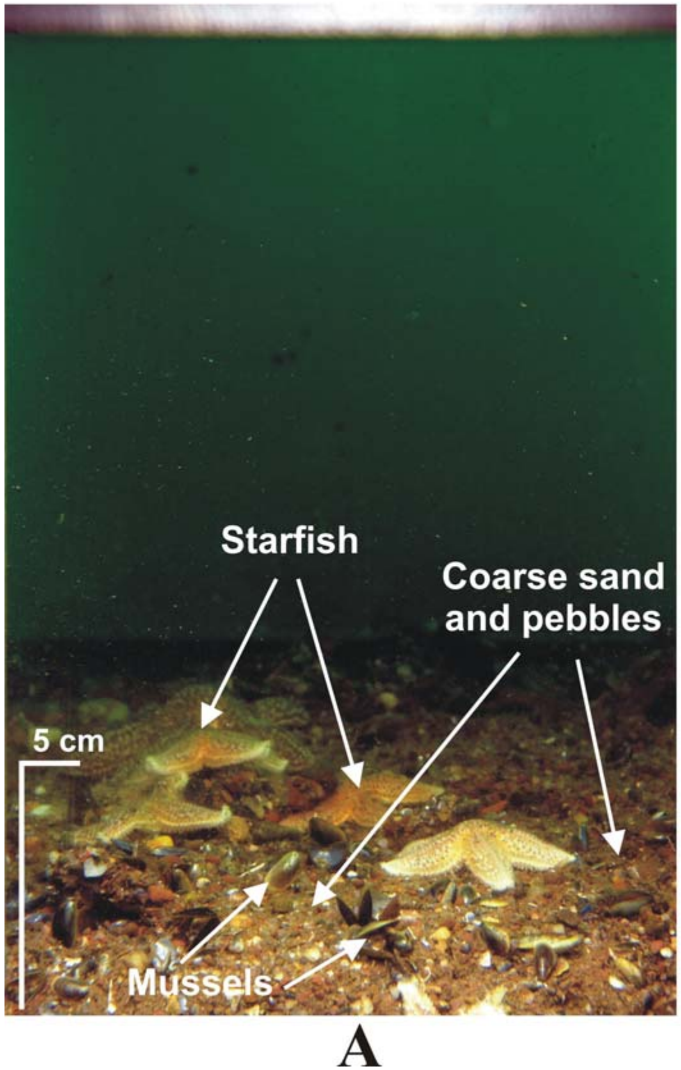


Figure 3.3-15. SPI image (A) and corresponding plan-view image (B) from Station 13 showing agreement with a sandy bottom and dense sand dollars visible in both images at this station.



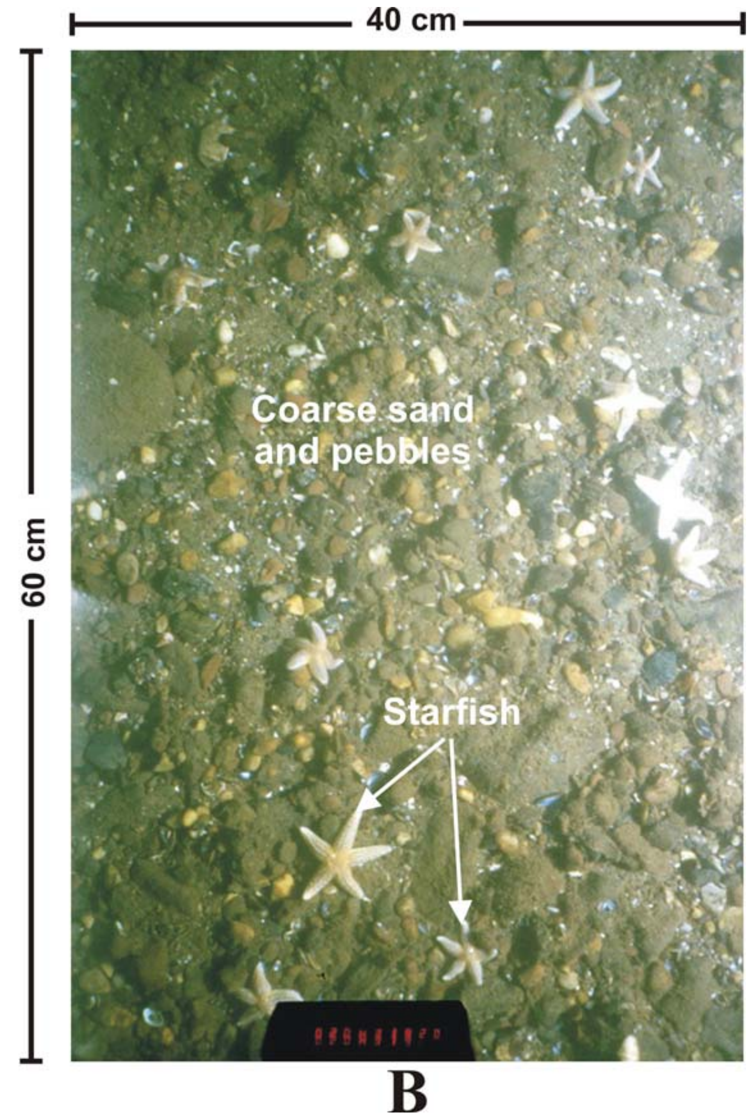


Figure 3.3-16. SPI image (A) and corresponding plan-view image (B) from Station 25 displaying hard bottom conditions consisting of coarse sand and pebbles at this station. Starfish are visible at the sediment surface of both images.

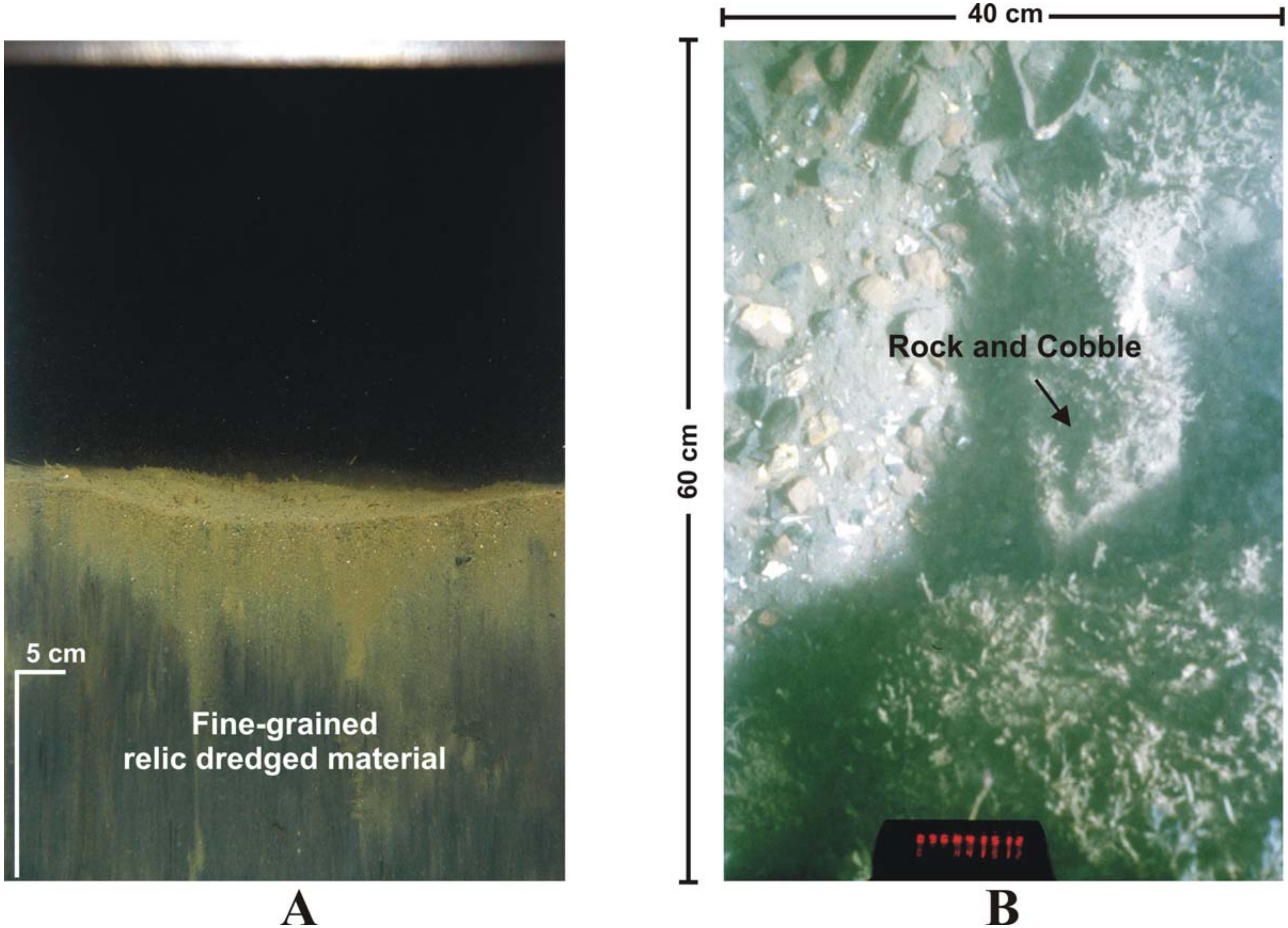


Figure 3.3-17. SPI image (A) and corresponding plan-view image (B) from Station 15 illustrating within-station variability in sediment types. A soft, silt bottom is detected in Image A, while a hard rock and cobble bottom in present in Image B.

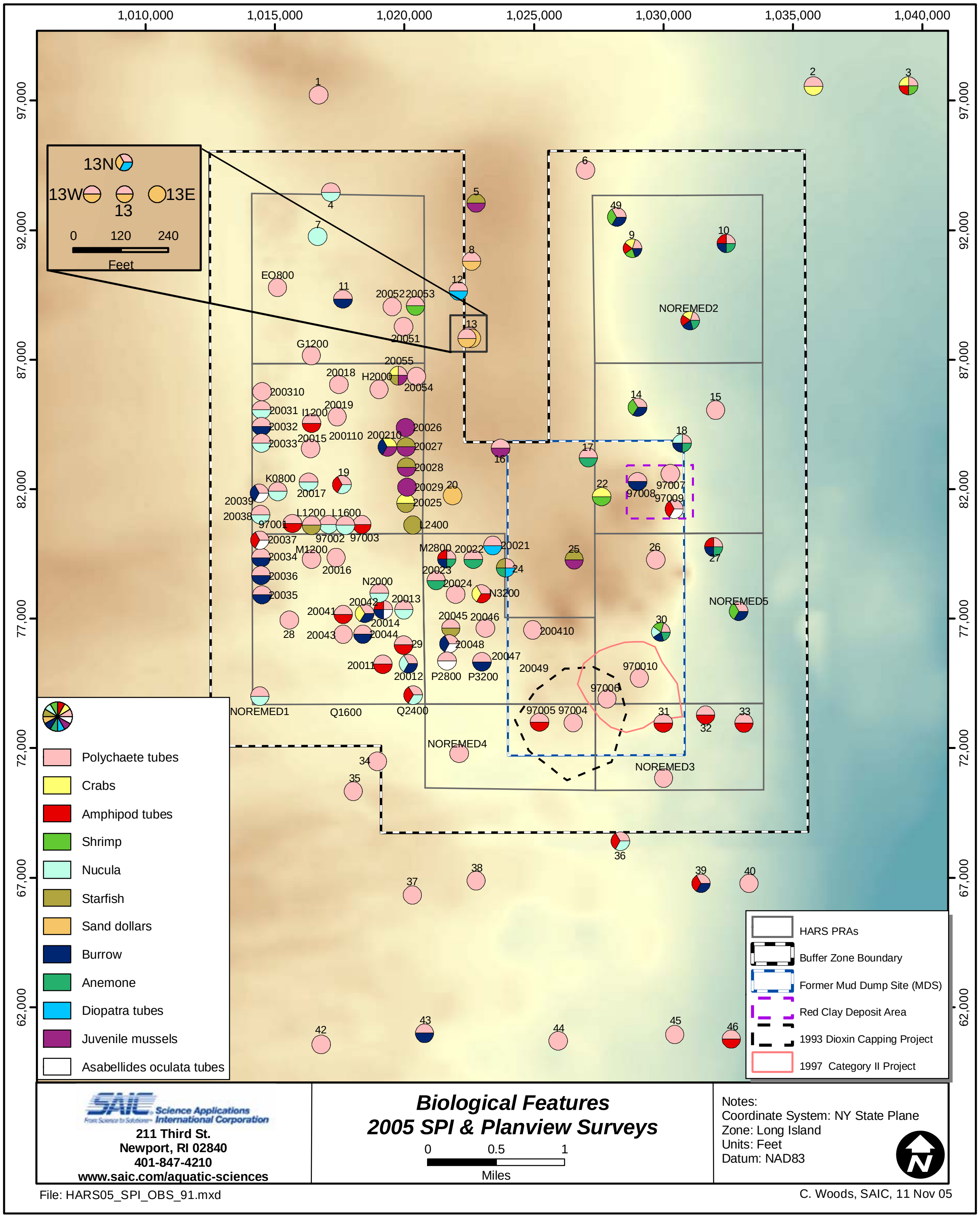


Figure 3.3-18. Map of biological features observed at the sediment surface of SPI and plan-view images.

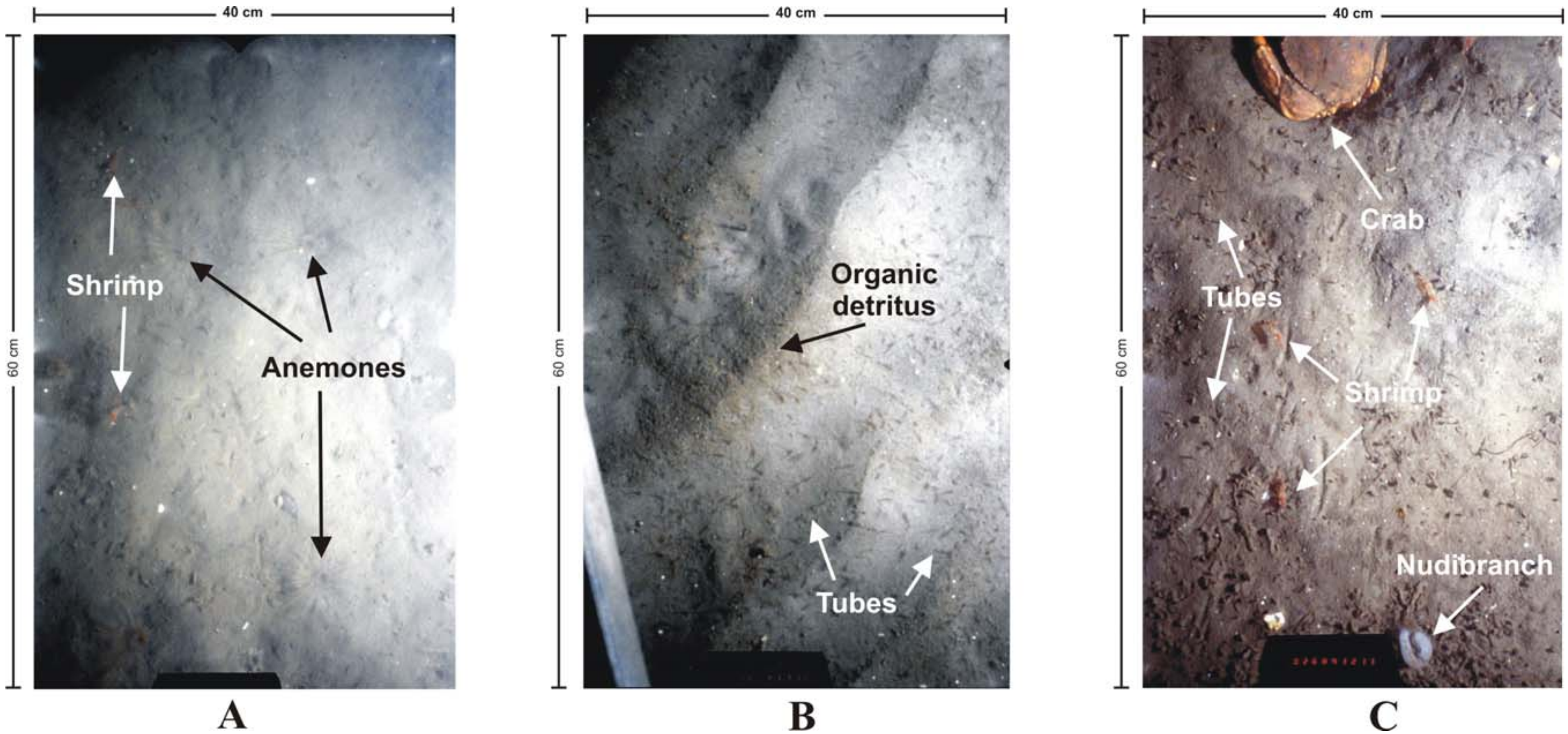


Figure 3.3-19. Plan-view images from Stations 30 (A), 97006 (B), and 3 (C) showing a variety of biological features at the sediment surface. Image A shows anemones and shrimp at the sediment surface, while Image B shows a layer of brown organic detritus on a rippled sand bottom with surface tubes. A crab, nudibranch, surface tubes, and shrimp are visible at the sediment surface of Image C.

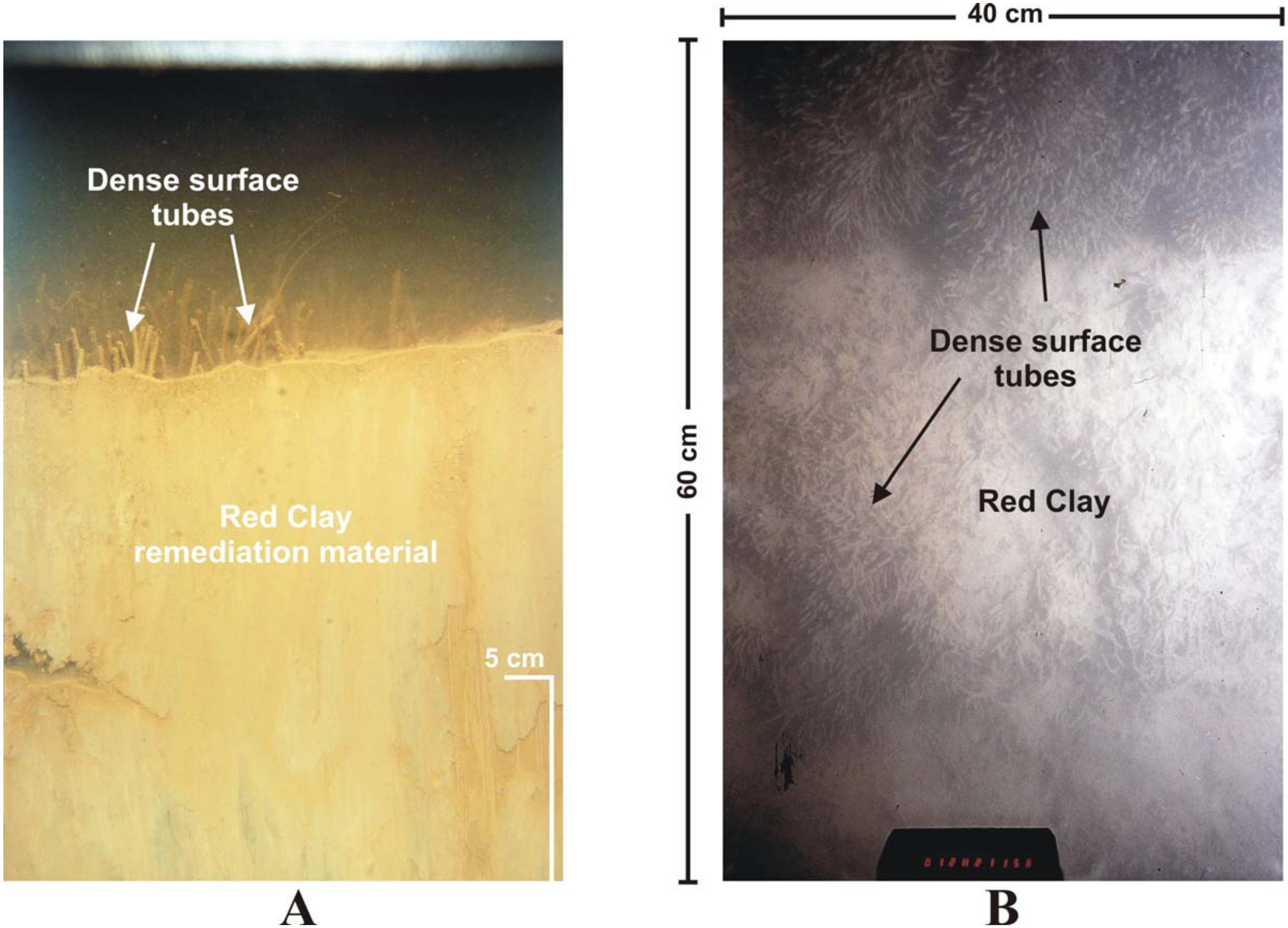


Figure 3.3-20. SPI image (A) and corresponding plan-view image (B) from Station 20037 showing red clay remediation material colonized by tubicolous polychaetes (*Asabellides oculata*).

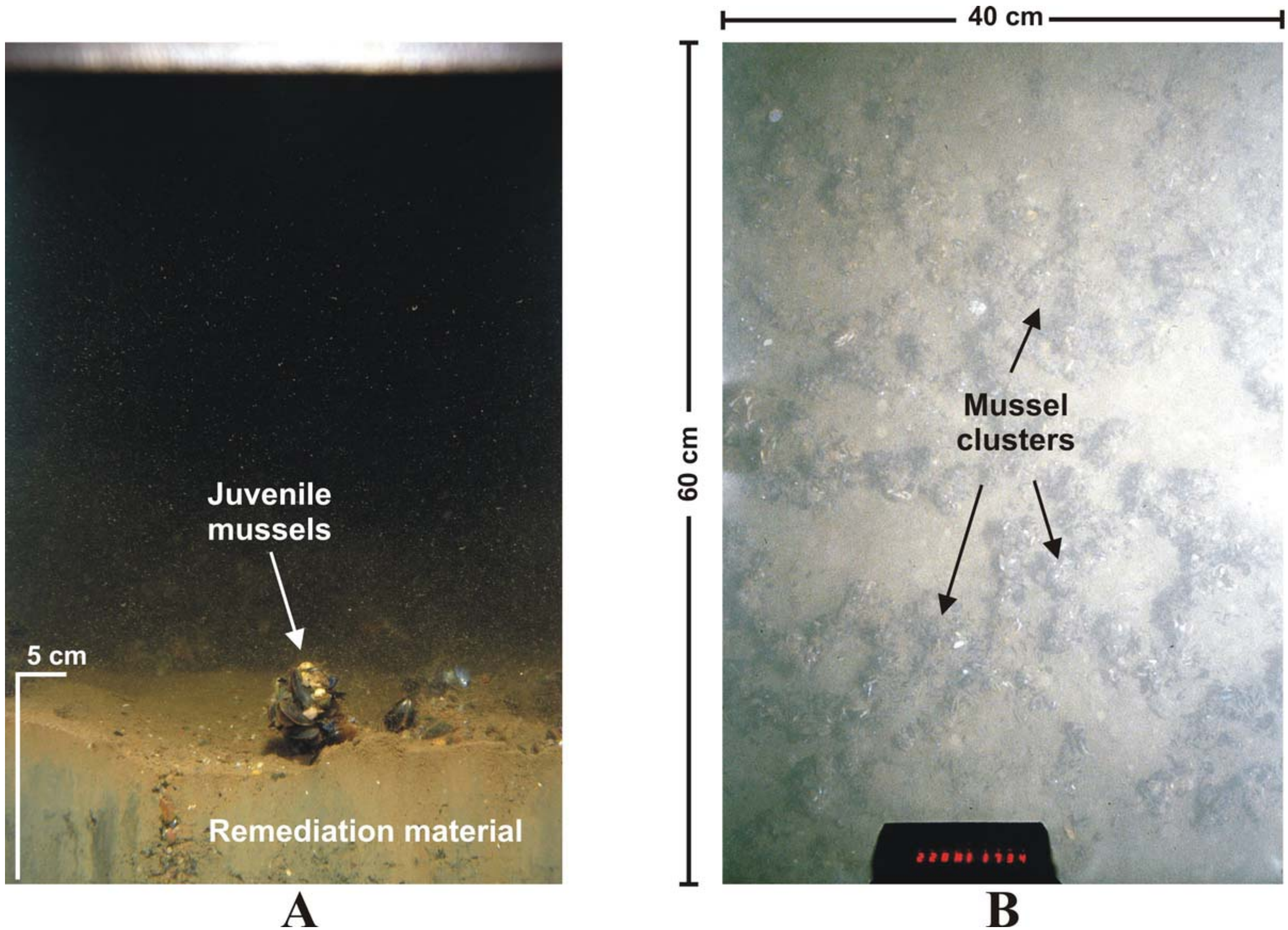


Figure 3.3-21. SPI image (A) and corresponding plan-view image (B) from Station 20028 displaying clusters of juvenile mussels at the sediment surface.

(Tables 3.3-1 and 3.3-2 and Figure 3.3-22). Stage I pioneering, tubicolous polychaetes occurred alone at 51% of the primary 60 stations and 34% of the supplemental stations. Stage I only was observed most consistently at the sandy stations within and outside the HARS boundary (Figures 3.3-22 and 3.3-23). 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. Azoic conditions were observed in one replicate image of Station 20047 (Figure 3.3-22).

Stage II taxa were prevalent throughout the survey area; these taxa tend to live at or just below the sediment-water interface. Examples of these shallow-dwelling taxa include the stick amphipods (Family Podoceridae), tube-dwelling amphipods (*Ampelisca* sp.), and the shallow-dwelling bivalve (*Nucula* sp.) (Figures 3.3-24, 3.3-25, and 3.3-26). A total of 12 replicate images displayed a Stage I to II successional status (Stage I community with evidence toward an intermediate successional status).

Higher successional stages (Stages II and III), indicative of advanced benthic recolonization, were observed most consistently at the stations with fine-grained relic dredged material or remediation material within the HARS boundary (Figure 3.3-22). A Stage II to III successional status designation was assigned to a total of 11 replicate images and represents an intermediate successional status with some evidence of progression to a Stage III equilibrium community (e.g., burrowing infauna; Figure 3.3-26A). Evidence of Stage III head-down, deposit-feeding infauna (active feeding voids in the subsurface sediments) was detected in 23% of the primary 60 stations and 47% of the supplemental stations. When present, Stage III organisms were generally accompanied by either Stage I or Stage II organisms at the sediment-water interface (Figures 3.3-24 and 3.3-25). Three stations were given an indeterminate successional status designation due to hard bottom conditions in both replicate images.

The RPD provides a measure of the apparent depth within the sediment column where geochemical conditions are predominantly oxidizing. Below the RPD, these conditions are predominantly reducing. The mean apparent RPD depth at the 60 primary stations was 2.0 cm, while the mean RPD at the 60 supplemental stations was 1.9 cm (Tables 3.3-1 and 3.3-2). These are intermediate RPD depths indicative of a moderate to high degree of surface sediment aeration and biogenic mixing. The majority of average RPD values across the surveyed area fell in the range 0 to 4 cm (Figure 3.3-27). At the sandy stations located primarily outside the remediation areas of the HARS (ambient stations), this oxidation was attributed to physical mixing of the uppermost sediment layer related to periodic bedload movement of 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; Figures 3.3-23 and 3.3-27). At stations characterized by fine-grained recent and relic dredged material, the creation and maintenance of oxidizing conditions within the sediment column, and corresponding increases in the RPD depth, were attributed primarily to the bioturbation activities of infaunal organisms.

Although no evidence of redox rebound intervals was noted in the surficial sediments, a relic RPD (an indicator of sediment layering) was detected at some stations mainly displaying multiple dredged material layers (Figure 3.3-4B). Relic RPDs usually occur when a relatively

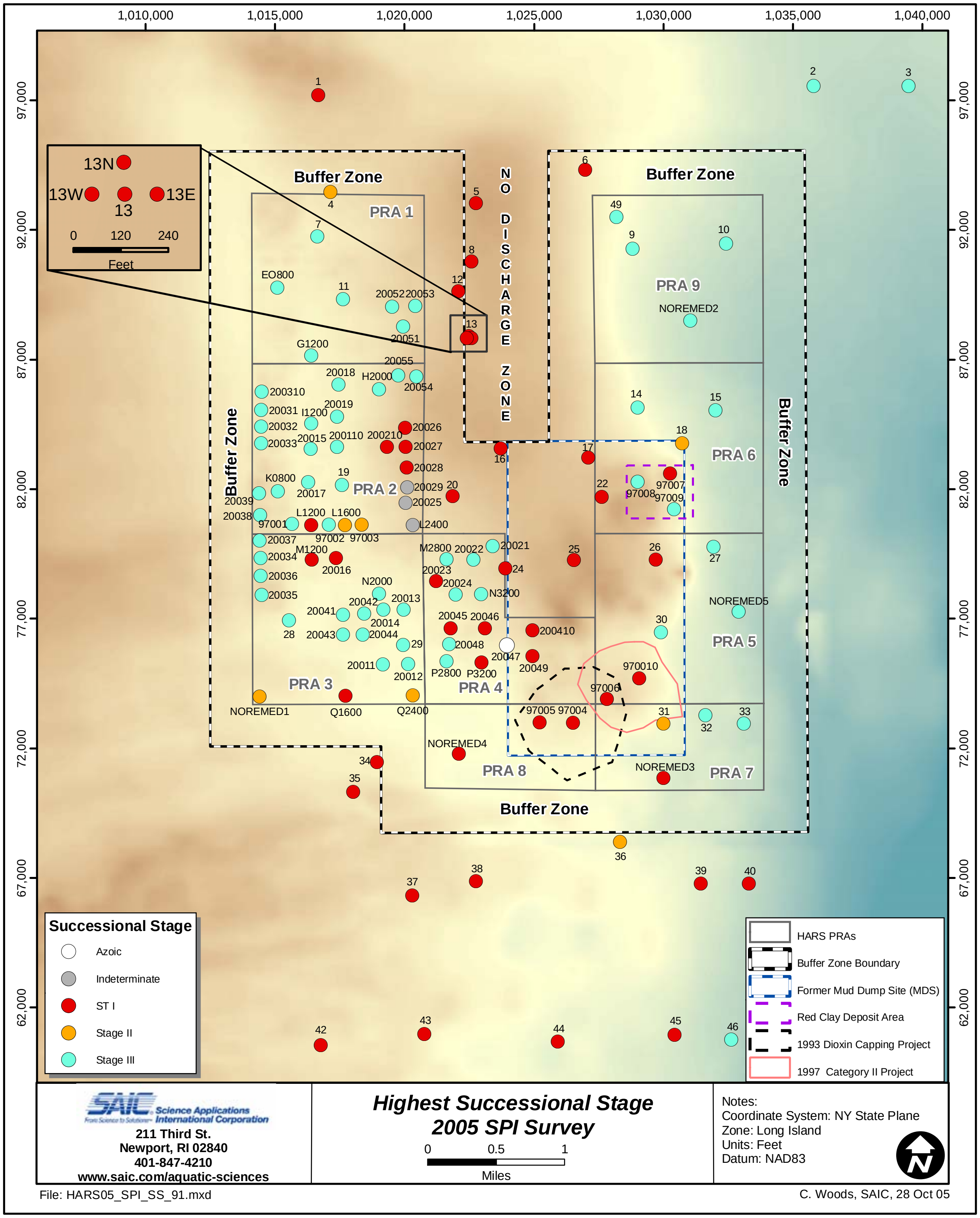


Figure 3.3-22. Highest successional stage observed at each of the 2005 SPI stations.

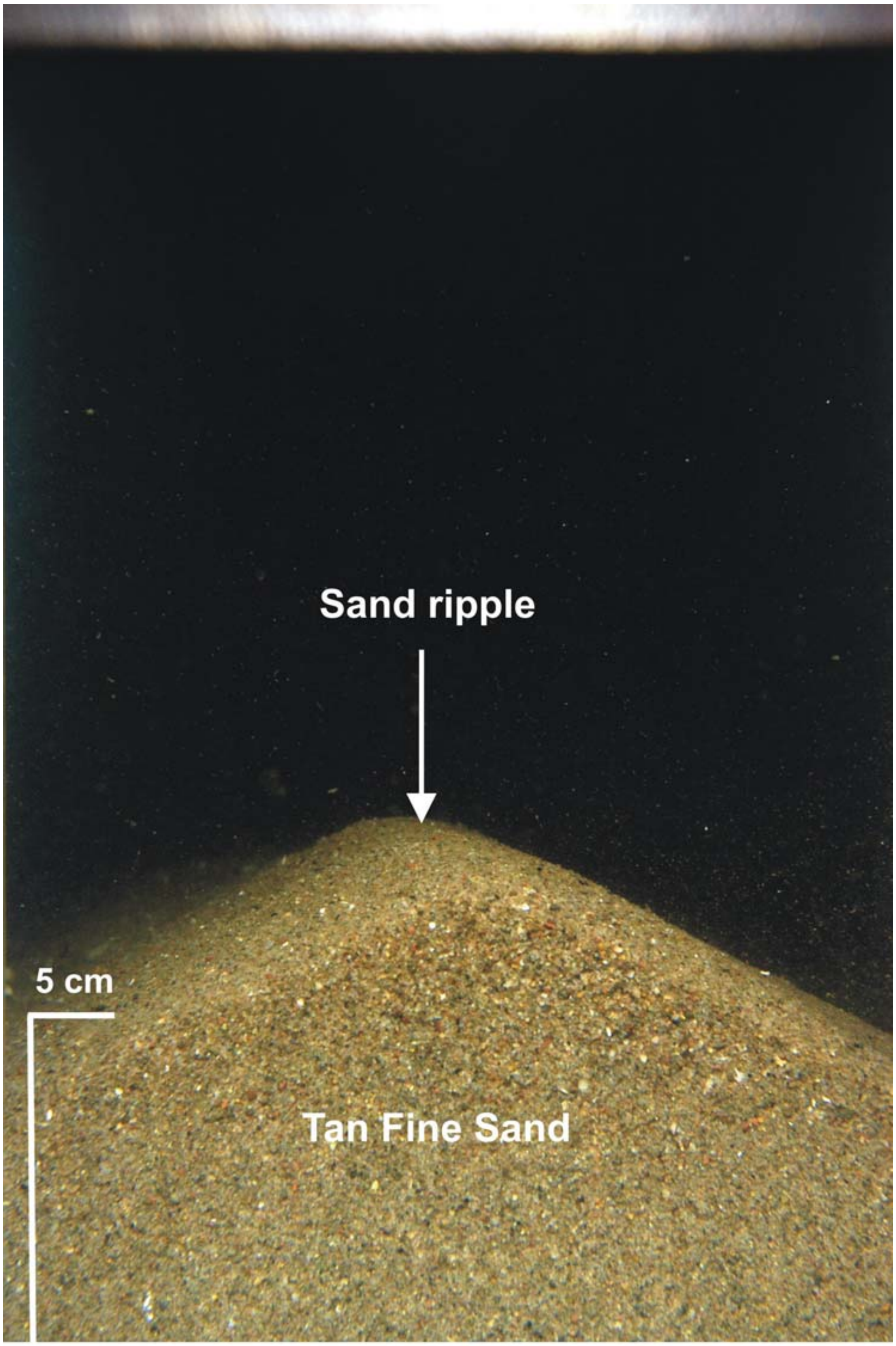
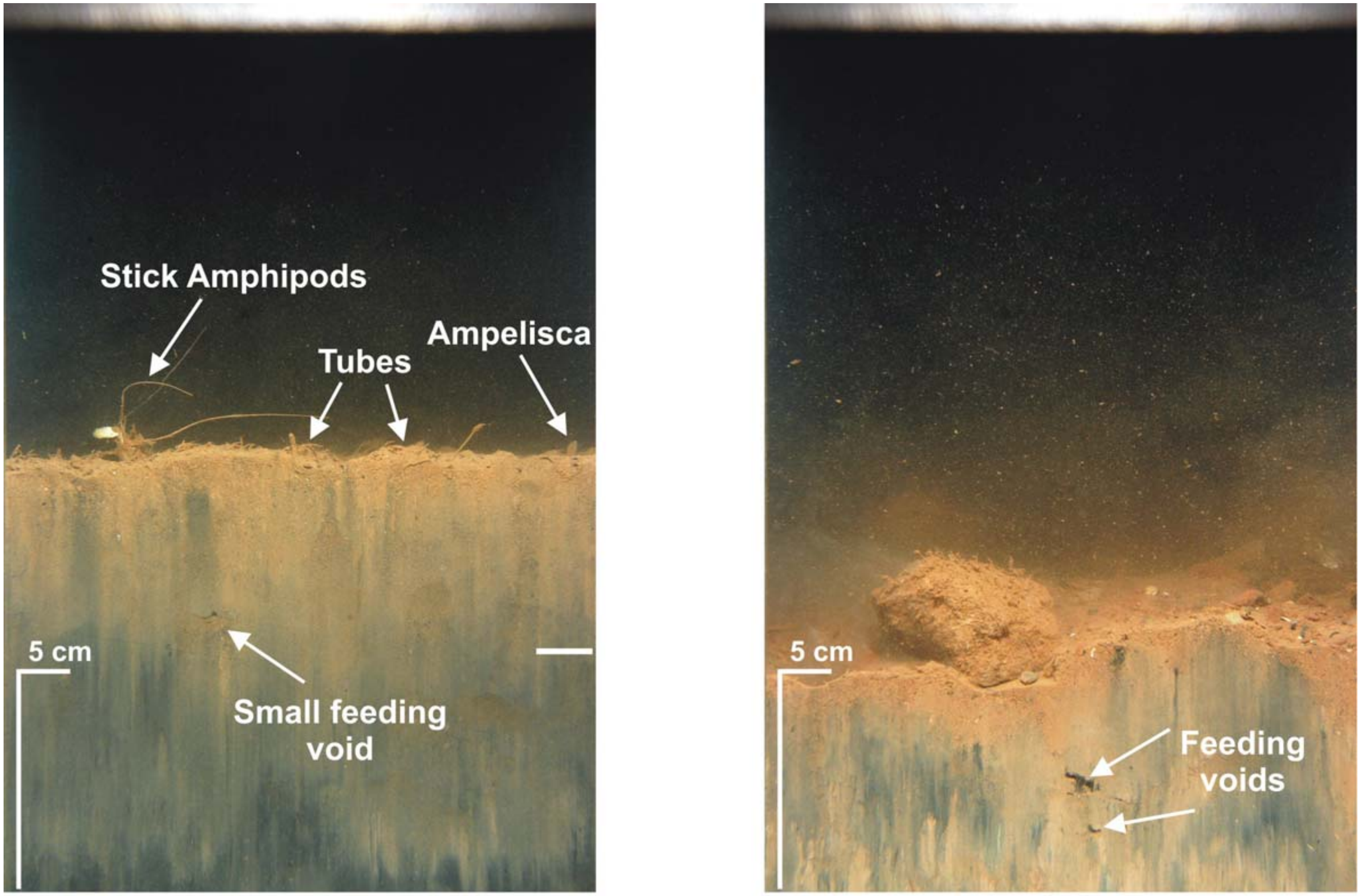


Figure 3.3-23. SPI image from Station 21 illustrating an RPD depth measurement greater than camera prism penetration (i.e., RPD>pen). This image was given a Stage I successional status designation which resulted in an OSI of +7.



A B

Figure 3.3-24. SPI images from Stations 97001 (A) and 200310 (B) illustrating advanced recolonization of the remediation material. A diverse community of stick amphipods, *Ampelisca* tubes, and polychaetes tubes are visible at the sediment-water interface over a subsurface feeding void in Image A (OSI +8). Image B shows advanced recolonization of red clay remediation material with surface tubes and feeding voids at depth (OSI +7).

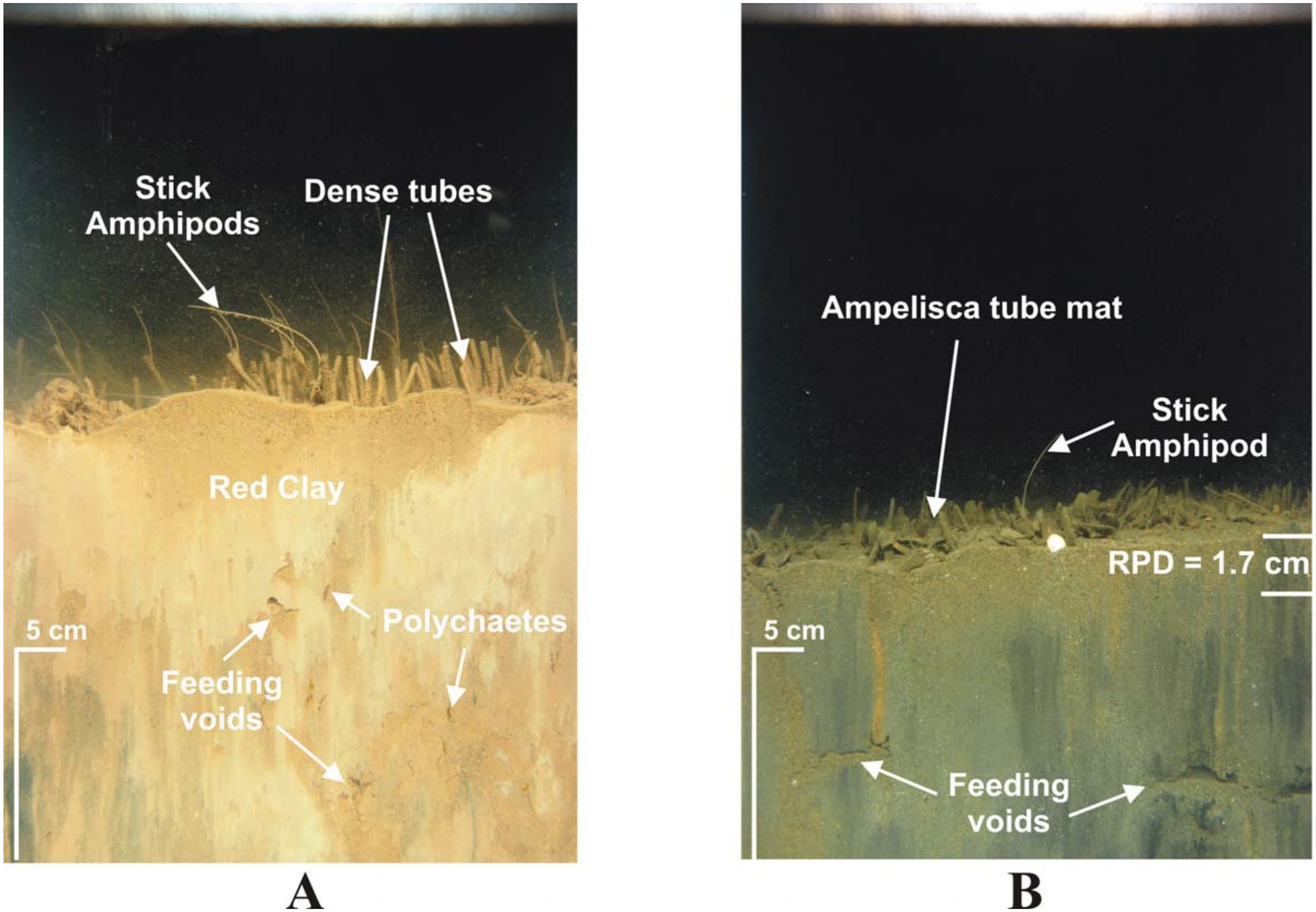


Figure 3.3-25. SPI images from Stations 97009 (A) and 3 (B) illustrating an advanced recolonization of the surface sediment. A Stage II on III successional status was assigned to both images as a result of Stage II taxa (stick amphipods and *Ampelisca* tubes) at the sediment-water interface over Stage III feeding voids at depth. The presence of these advanced successional stages and moderate RPD depths results in an OSI of +8 for both images (undisturbed benthic habitat quality).

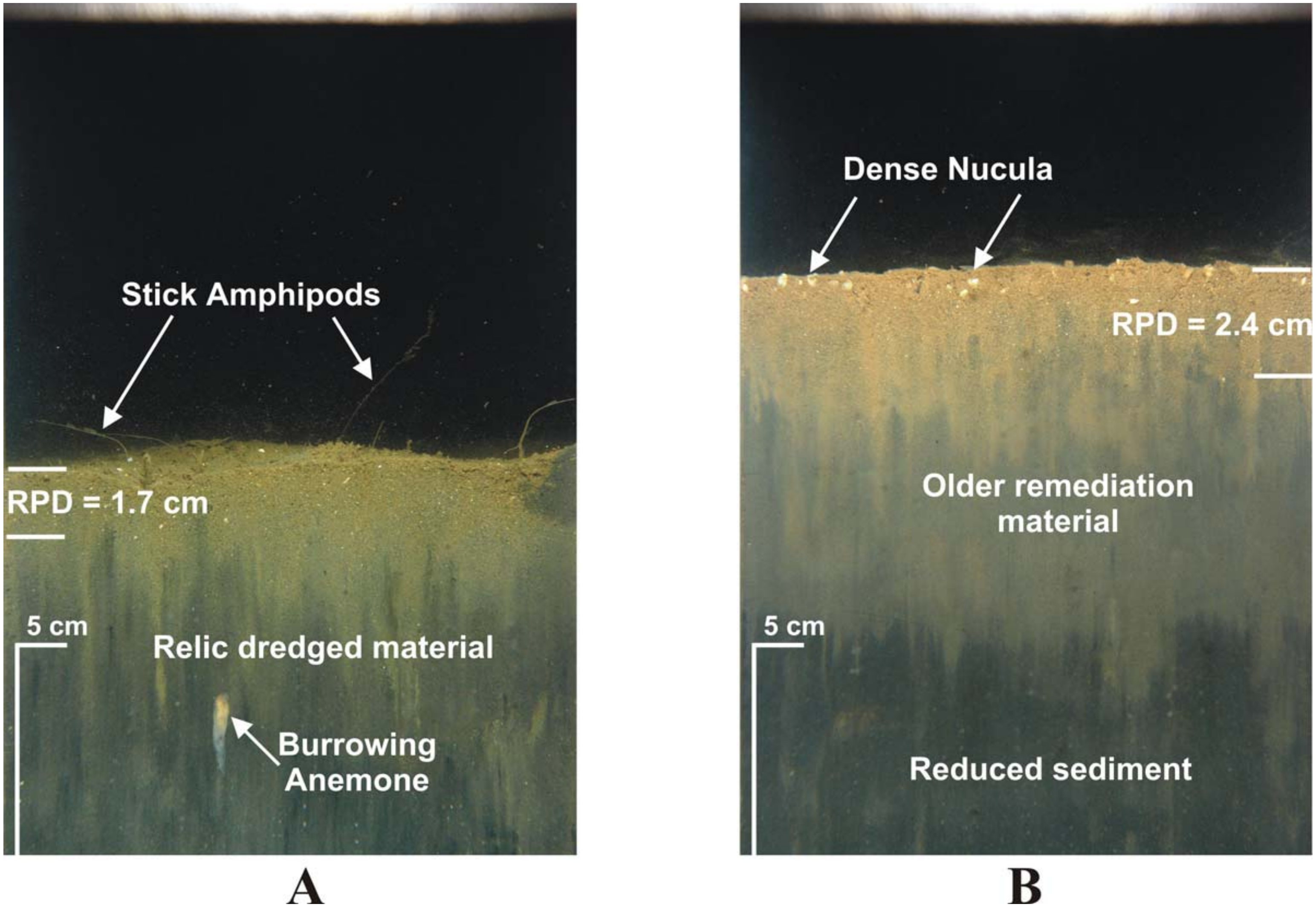


Figure 3.3-26. SPI images from Stations 10 (A) and 97002 (B) displaying Stage II organisms at the sediment-water interface. Stick amphipods (Family Podoceridae) are visible in Image A, while shallow-dwelling bivalves (*Nucula*) are visible in Image B. Image A shows some evidence of progression to an advanced Stage III community (e.g. burrowing anemone) and was, therefore assigned a Stage II to III successional status.

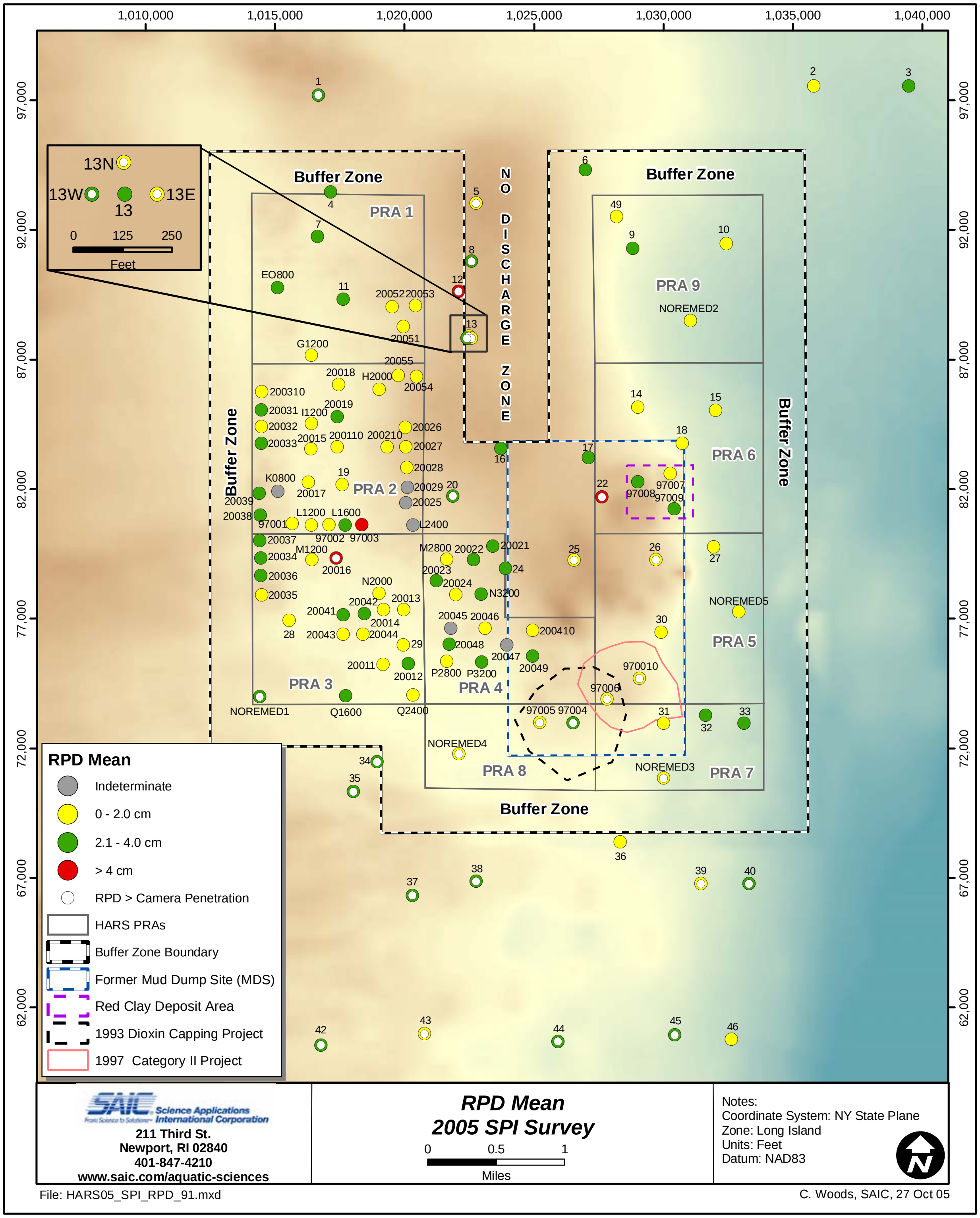


Figure 3.3-27. Mean apparent RPD depths at the 2005 SPI stations.

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 there was no evidence of low sediment dissolved oxygen conditions found in any of the SPI images obtained in the 2005 survey, a few methane bubbles were noted in the SPI image obtained at Station 11 in PRA1 (Figure 3.3-28). This methane is assumed to be the product of anaerobic decomposition of organic matter in the underlying anoxic mud at this station. Methane had been detected previously at this station in the 2002 survey, suggesting that some of the remediation material placed at this location likely had a high organic-matter content.

The mean OSI value was +5.9 for the 60 primary SPI stations and +6.3 for the 60 supplemental stations (Tables 3.3-1 and 3.3-2). These values are generally indicative of undisturbed or only moderately disturbed benthic habitat conditions. Four stations (L1200, 200210, 20026, and 20027) with OSI values between 0 and +3 were located in PRA 2; these values reflect physical disturbance due to the placement of remediation material at these locations in the recent past (i.e., since 2001; Figure 3.3-29). The intermediate to high OSI values calculated at the other stations within the HARS boundary indicate a fairly advanced degree of recovery from disturbance associated with either post-HARS placement of remediation material or disposal of dredged material in the more-distant past (i.e., prior to designation of the HARS in 1997; Figure 3.3-29). Because the OSI was developed for characterizing disturbance primarily in soft-bottom, muddy environments, the values calculated for the sandy stations, where penetration of the SPI camera was often low, are considered to be somewhat poor indicators of habitat conditions. These stations were labeled as having non-degraded habitat conditions, with the habitat consisting of clean, ambient sand (Tables 3.3-1 and 3.3-2; Figure 3.3-29). The overall OSI value for both the primary and supplemental stations excluding the ambient sandy stations was +6.4. OSI calculations were not possible at six stations due to either an indeterminate RPD depth and/or successional status.

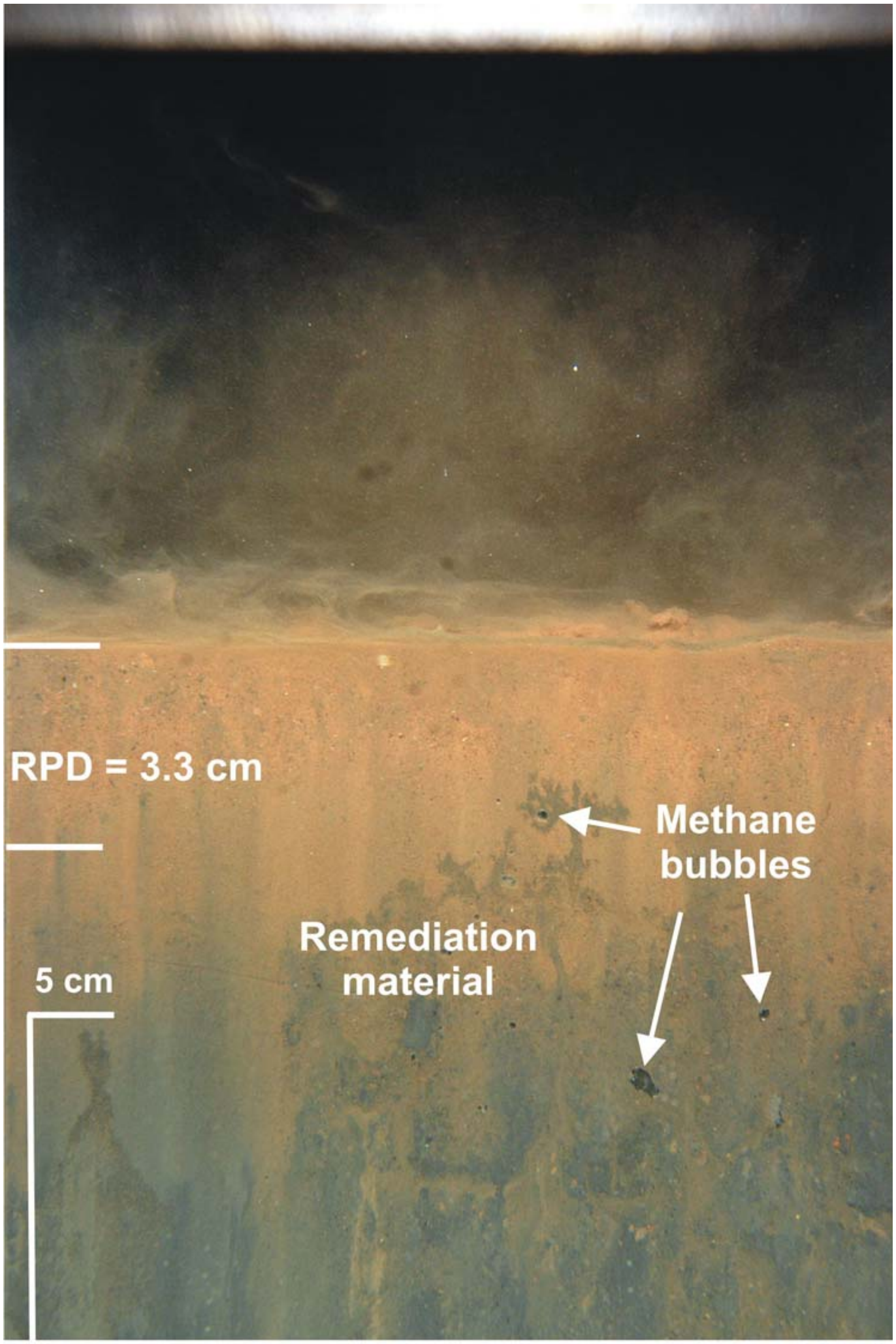


Figure 3.3-28. SPI image from Station 11 located within PRA 1 illustrating methane gas bubbles entrained within the remediation material at depth. The presence of methane and a Stage I successional status resulted in an OSI of +4 (moderately disturbed benthic habitat quality) for this replicate image.

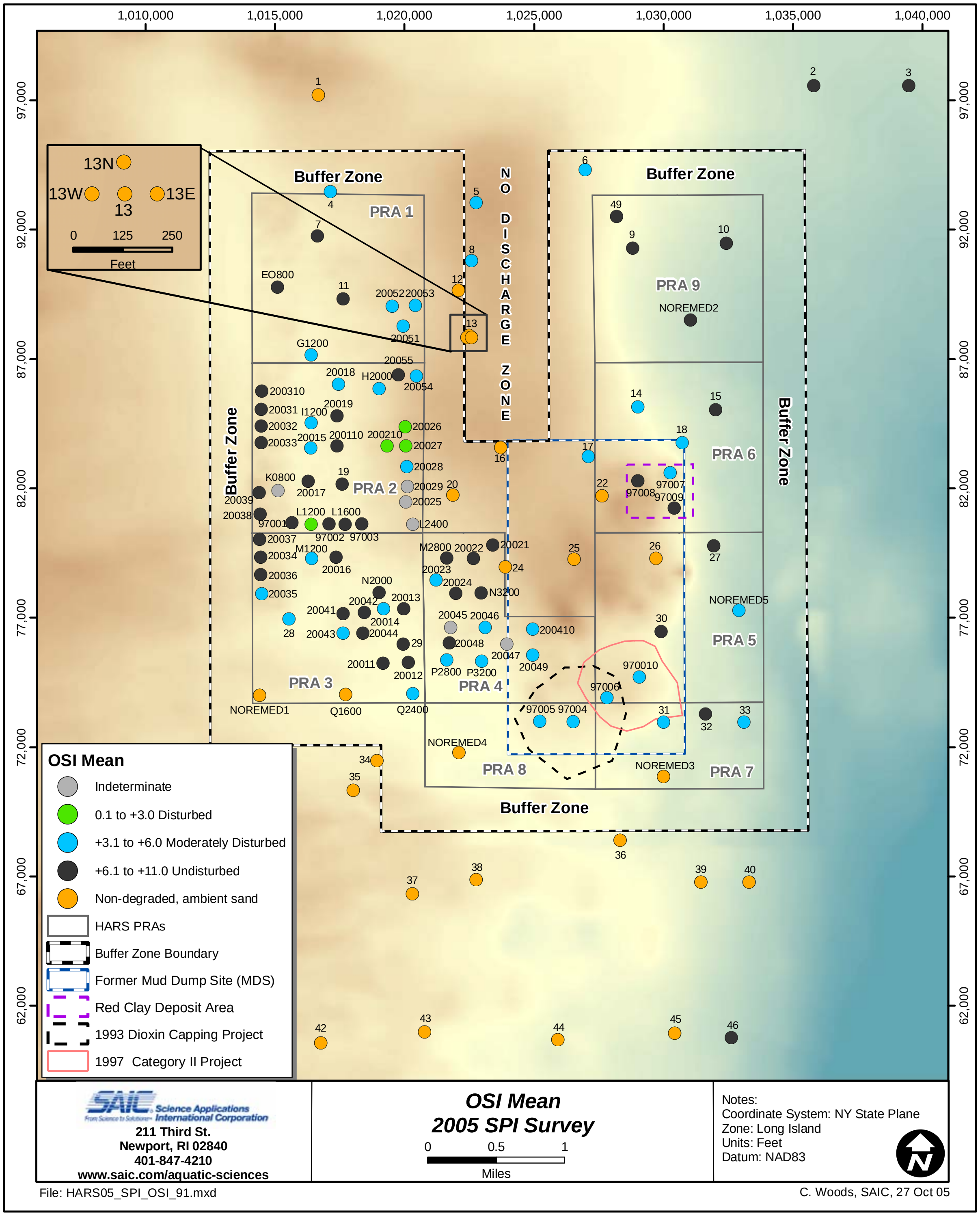


Figure 3.3-29. Mean OSI values at the 2005 SPI stations.

4.0 DISCUSSION

In the previous survey of Summer 2002, sediment toxicity and SPI/plan-view data were collected simultaneously at 60 stations located within and around the HARS, in areas that had both received or not yet received remediation material. Disturbed benthic habitat conditions were observed at only 3 of the 60 stations, while the remaining stations had undisturbed or only moderately disturbed conditions. Benthic recolonization was found to be progressing to varying degrees in PRAs 1 through 3 in response to the placement, since September 1997, of different types and quantities of remediation material. The 2002 survey also found an overall absence of sediment toxicity at the 60 stations, in contrast to the results of surveys conducted in 1994 and 2000.

Given this background, the objectives of the 2005 HARS survey involving SPI/plan-view imaging and sediment toxicity testing were twofold: 1) to continue evaluating infaunal successional status and overall benthic habitat conditions at stations in and around the HARS, and 2) to assess any temporal changes in sediment toxicity or benthic habitat conditions that may have occurred since the previous survey of 2002.

4.1 Physical Benthic Habitat Conditions

Similar to the 2002 survey, there were two basic types of sediment observed in the 2005 SPI and plan-view images: 1) dredged material that had been in place on the seafloor for various lengths of time, and 2) native or “ambient” sediment, typically consisting of rippled, compact fine sand. The latter is common across wide areas of the New York Bight, and the presence of ripples indicates that the sand is subject to periodic movement by bottom currents. Rippled fine sand, either homogenous or containing significant amounts of silts and clays, was found at all of the stations located outside the HARS boundary, including the group of five stations (stations 5, 6, 8, 12 and 13) located in the no-discharge zone/buffer zone between PRAs 1 and 9.

At four stations (Stations 6, 17, 97003 and 20023), the SPI images revealed a 5 to 8 cm surface layer of native fine sand overlying fine-grained, black dredged material (e.g., Figures 3.3-4 and 3.3-8). In general, such layering has been observed routinely in a number of past SPI surveys conducted in and around the HARS and the former MDS. It results when ambient fine sand is transported by bottom currents into areas where organic-rich, fine-grained dredged material was placed in the past, in effect representing a natural capping process. When exposed to near-bottom water containing oxygen, reduced dredged material gradually becomes oxidized and develops an RPD layer through the processes of diffusion and bioturbation. The presence of a sand cap, however, inhibits such oxidation. The “capped” dredged material therefore retains a dark grey or black coloration through time, indicative of a high inventory of sulfides and a reduced oxidative state.

At Stations 6 and 17, the sand-over-dredged-material stratigraphy was detected in both the 2002 and 2005 SPI surveys. In contrast, stations 13, 22 and 46 exhibited this stratigraphy in 2002, but not in 2005. One reason for this temporal difference could be that the underlying dredged material originally occurred in small patches before being covered by the sand. Therefore, it could easily be missed in the spaces between individual camera placements, both within a given survey and among surveys conducted at different times. Another explanation is that the thickness of the overlying sand layer varied through time as the sand shifted and migrated. The underlying dredged material layer therefore would only be captured in an SPI image in places where, or at times when, the sand layer was relatively thin, given that the penetration of the SPI camera in sandy sediments tends to be limited to a maximum depth of about 10 cm.

A surface deposit of fines and organic detritus occurred at many stations. Because of its finer texture and darker color, this deposited material was most clearly visible in the SPI images when contrasted against a backdrop of lighter-colored, ambient sand (e.g., Figures 3.3-4A and 3.3-12). Small mud tubes constructed by surface-dwelling worms and other organisms were frequently observed as part of the organic surface deposits (Figure 3.3-12). Such deposits have been observed in past SPI surveys at the HARS, primarily in images collected during the late summer or early fall, following the annual peak of biological production in the overlying water column. Higher production and more quiescent conditions during the warmer months favor the accumulation of flocculent organic detritus at the sediment surface. During the higher-energy winter months, the thin surface deposits resulting from this summertime “organic draping” effect are typically swept away, along with any resident benthic organisms. In this way, population levels of some of the benthic taxa visible in the SPI and plan-view images are closely tied to the annual cycle of organic matter erosion and deposition.

Dredged material was found at almost all of the SPI stations located within the HARS. At each station, the dredged material was placed into one of the following three basic categories: 1) older or “relic” dredged material that has been in place on the seafloor since before the HARS was designated in September 1997, 2) remediation material that has been placed in a carefully controlled manner in PRAs 1 through 4 following the designation of the HARS, and 3) sand used to cap dioxin-contaminated dredged material in the south end of the former MDS as part of major capping projects undertaken in 1993 and 1997.

Most of the relic dredged material was fine-grained, and it was found primarily in PRAs 5, 6, 7 and 9. This is an expected result, as there was significant historic disposal in these areas, none of which has yet received any remediation material. In contrast, the dredged material observed at the majority of stations in PRAs 1 through 4 was remediation material, and its distribution on the seafloor closely matched the release points at the sea surface that were recorded by the Automated Disposal Surveillance System (ADISS) installed on the disposal scows (Figure 4.1-1).

The remediation material consisted primarily of either “conventional” organic-rich mud or red clay that was either soft/unconsolidated or in cohesive clumps (Figure 4.1-1). The widespread presence of either red clay or soft conventional dredged material across the sediment surface is notable in some areas of PRA 2 and the northern part of PRA 3, where rocks from the Kill Van Kull (KVK) channel-deepening project were placed in the past. The quantities of the softer remediation material apparently have been sufficient to cover much of the formerly exposed larger rocks in these areas. Conventional dredged material consisting of some coarser-grained sediment, mainly pebbles mixed with sand, was found at a group of stations located near the

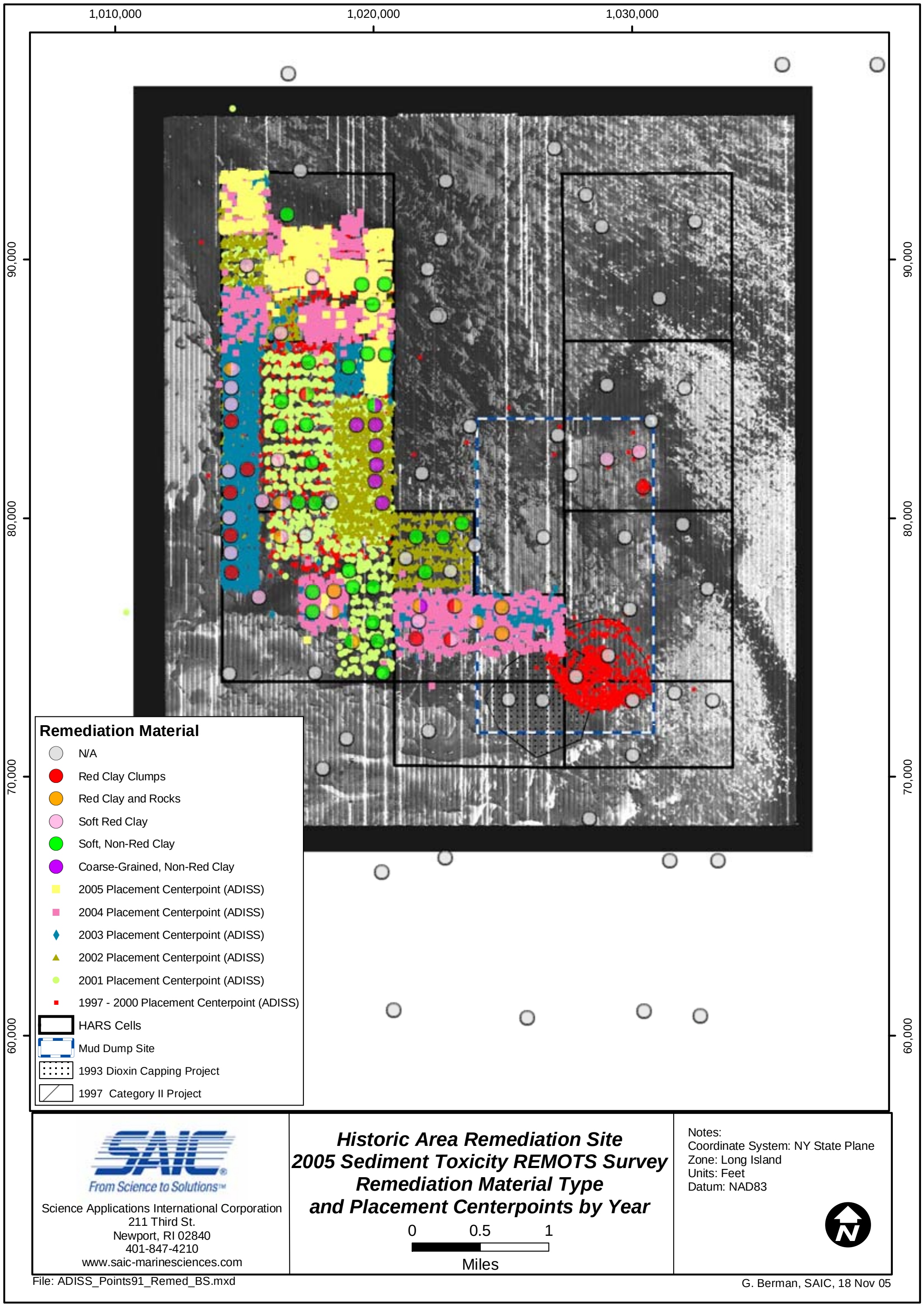


Figure 4.1-1. Locations of the 1994, 2000, 2002 and 2005 sediment toxicity stations within and immediately outside the HARS in relation to dredged material placement events over the period March 1998 to July 2005 and the type of remediation material observed in the 2005 survey.

eastern boundary of PRA 2. These stations were all located in an area where placement of remediation material had occurred in 2002 (Figure 4.1-1).

In general, there appeared to be good agreement between the SPI results and the acoustic backscatter results from the 2005 bathymetric survey (Figure 4.1-2). Stations where the remediation material was found to be mostly soft or unconsolidated in the SPI images correspond to areas of higher reflectance (i.e., lighter color) on the backscatter map, while coarser-grained material or mixtures of red clay clumps and rocks correspond with areas of lower reflectance (darker color; Figure 4.1-2).

At a few stations within PRAs 1, 2, 3 and 4, most notably Station 20016, the surface sediment consisted of ambient fine sand instead of remediation material. This result is expected at stations NOREMED1 and Q1600, as these are both located in the southern part of PRA 3 where remediation material has not yet been placed. Both Stations 20016 and 24, however, are located in or near areas where some amount of remediation material has already been placed. It is possible that these two stations were located over patches of ambient sediment that may still exist among the many small, individual mounds created when remediation first begins in a new area. Alternatively, the presence of ambient sand at Stations 20016 and 24 may be due to nearby sand waves that covered the underlying dredged material at these stations. As disposal of remediation material continues in these areas and the spaces among mounds are filled in, all of the pre-existing bottom, consisting of either relic dredged material or ambient sediment, will eventually be covered.

Clean fine sand was observed at Stations 97004 and 97005 located over the 1993 Dioxin Capping Project Mound, as well as at Stations 97006 and 970019 located over the 1997 Category II Project Mound. This sand represents the sediment that was originally dredged from Ambrose Channel and used for capping of the underlying fine-grained sediment containing low levels of dioxin. The continued presence of sand at these SPI stations provides continuing evidence that the integrity of the two caps has not been compromised, at least at these limited SPI sampling locations. The results of the 2005 bathymetric survey at the HARS provide additional evidence that the sand caps remain intact, as both capped mounds show up clearly as distinct features on the backscatter map (Figure 4.1-2). Overall, both the SPI and bathymetric results from 2005 agreed well with the results of numerous past monitoring surveys that have demonstrated long-term stability of the sand caps since their creation.

Overall, the physical habitat conditions observed in 2005 were similar to those of the previous 2002 survey. In both surveys, the stations outside the HARS were characterized by rippled fine sand representing ambient sediment, while stations within the HARS had either relic dredged material (in unremediated areas) or various types of remediation material in PRAs 1 through 4. However, many locations in PRAs 1 through 4 that had either conventional fine-grained remediation material or KVK rocks in 2002 exhibited red clay in 2005. A few stations in PRAs 3 and 4 that had exhibited relic dredged material in 2002 (e.g., Stations 28, P2800, P3200) were found to be covered by new layers of remediation material in 2005, as a result of the on-going remediation activities in these locations.

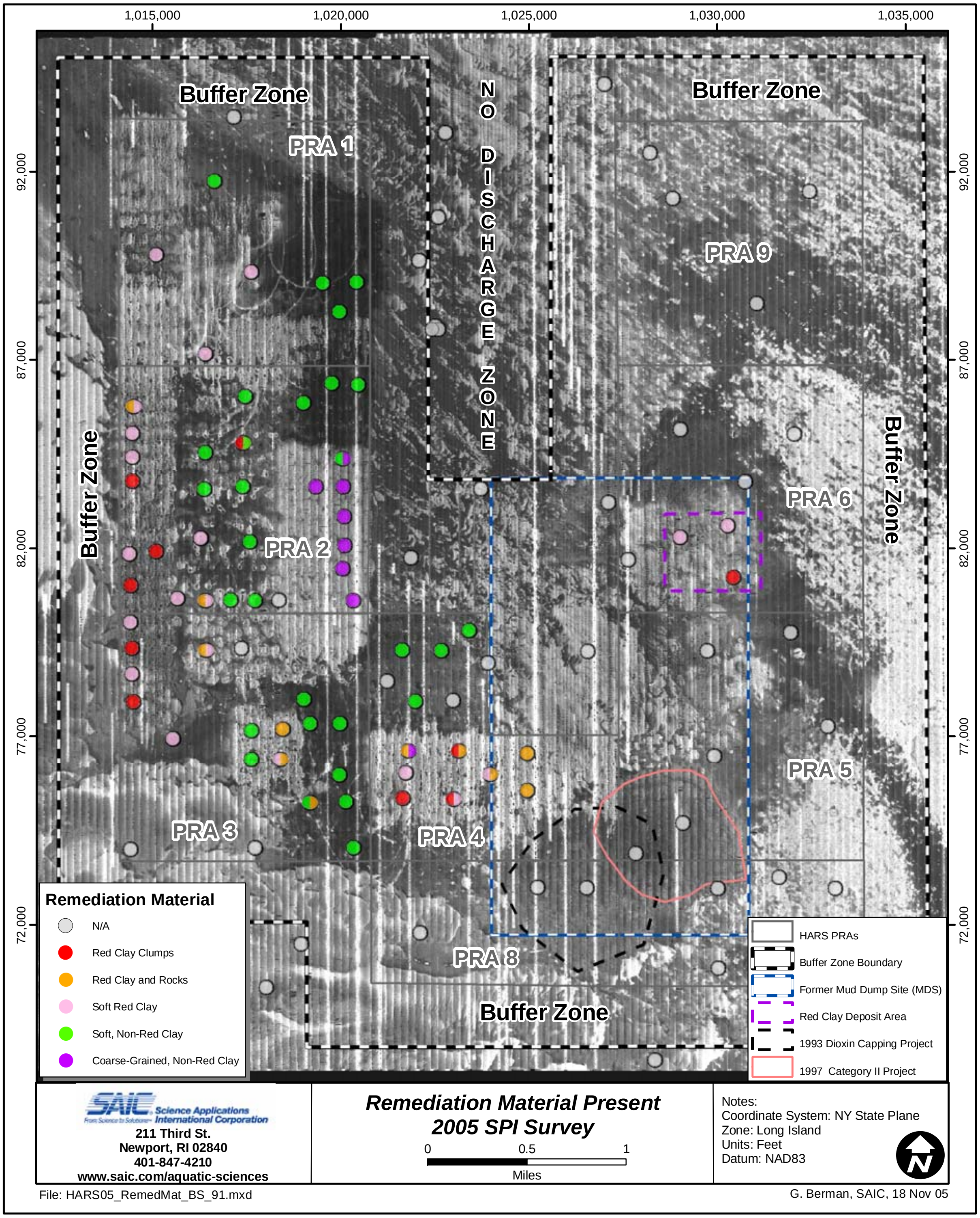


Figure 4.1-2. Type of remediation material observed at the 2005 SPI stations within and immediately outside the HARS in relation to backscatter data from the 2005 bathymetry survey.

4.2 Biological Conditions and Benthic Recolonization Status

The 2005 survey echoed the results of numerous past investigations in showing that the seafloor in and around the HARS was a patchy mosaic of different habitat conditions, in terms of both substrate type and disturbance history. In response to this mosaic, benthic communities were found to be in various stages of succession. As in the past, small opportunistic, Stage I polychaetes were abundant at many stations, reflecting their ability to colonize the sediment surface quickly and in high numbers following the physical seafloor disturbance associated with dredged material disposal. Because they are well-adapted to the physical disturbance associated with periodic sand movement, Stage I organisms also continued to be abundant in the native sandy sediments that characterize areas surrounding HARS (Figure 3.3-2). These populations provide a ready source of larva to establish new colonies in fresh dredged material deposits.

The general scarcity of organic-rich, fine-grained sediments in the sandy seafloor areas surrounding the HARS inhibits the process of succession that ultimately leads to the establishment of a typical "soft-bottom" benthic community. Such a community tends to be populated by higher proportions of larger-bodied organisms that live and/or feed deeper within the sediment column, including Stage II taxa that inhabit the zone at and just below the sediment-water interface, as well as Stage III taxa that ingest subsurface sediments and thereby create distinct feeding voids at depth. In addition to being dominated by smaller-bodied Stage I polychaetes, there are often high numbers of the sand dollar *Echinarachnius parma* observed on sandy bottoms around the HARS (Figure 3.3-15). Several species of small polychaetes and amphipods, together with *E. parma*, appear to comprise a basic natural benthic assemblage in the New York Bight (Chang et al. 1992).

While Stage I opportunists are the long-term dominants on sandy bottoms around the HARS, the placement of fine-grained dredged sediments within both the HARS and the former MDS has resulted in soft-bottom conditions conducive to supporting infaunal succession beyond Stage I. Both the 2002 and 2005 SPI/plan-view results served to confirm that such advanced succession has in fact been occurring, most notably in PRAs 1 through 4 where remediation activities have been on-going since 1997. The majority of stations within the HARS, including most of those with remediation material, had either Stage II or III as the highest successional stage (Figure 3.3-22).

Stage II taxa tend to live at or just below the sediment-water interface; examples of such shallow-dwelling taxa in the 2005 SPI images include stick-dwelling amphipods (Family Podoceridae), tube-dwelling Ampeliscid amphipods (*Ampelisca* sp.), and the shallow-dwelling nut clam *Nucula* sp. All of these organisms have been observed in SPI/plan-view surveys conducted over the past several years in and around the HARS. Both *Nucula* sp. and the Ampeliscid amphipods have been observed to colonize deposits of fine-grained sediment, including dredged material, in very high numbers. Both have also been commonly reported in historical benthic studies of the inner New York Bight (Caracciolo and Steimle, 1983; Chang et al., 1992).

The Stage II Podocerid amphipods have not been as commonly reported in historical studies; however, they appear to have become increasingly abundant across the surveyed area over the past several years. These organisms are clearly identifiable in SPI images by the distinctive whip-like stalks or "masts" that they construct out of mud and organic debris to raise themselves a few centimeters above the seafloor and thereby facilitate suspension-feeding (e.g., Figure 3.3-19). There is a likelihood that the organism observed in the present and past SPI surveys is the species *Dulichia porrecta*; this was the only Podocerid amphipod that was identified in the benthic grab samples taken at the HARS in the summer of 2002.

The occurrence of Ampeliscid amphipods at various stations is particularly noteworthy, because it reinforces the results of the sediment toxicity testing: not only were the sampled sediments found to be non-toxic to *Ampelisca abdita* in the laboratory, but this amphipod (or a closely related sibling species like *A. vadorum* or *A. agassizi*) also was observed to have high *in-situ* abundance at a number of stations (e.g., Figure 3.3-23B). In a previous study of the relationship between macrofaunal abundance and habitat quality, Chang et al. (1992) noted that *A. aggasizi* and other amphipods tend to be indicative of minimally contaminated benthic habitats in the New York Bight.

Various polychaetes and taxa like *Nucula* sp. (nut clam), *Ampelisca* sp. (tube-dwelling amphipod), *Dulichia porrecta* (stick-dwelling amphipod) and *Echinarachnius parma* (sand dollar) have been observed routinely in previous surveys of the HARS and former MDS. Prior to the 2005 survey, there appeared to have been successful recruitment of two taxa that have been observed on a more sporadic basis in past monitoring efforts. Specifically, beds of juvenile mussels were seen at a group of stations along the eastern boundary of PRA 2, where coarser-grained remediation material (i.e., pebbles and cobbles) had been placed (e.g., Figure 3.3-21). Dense tube mats of the surface-dwelling polychaete *Asabellides oculata* also occurred at a few stations having red clay remediation material (e.g., Figures 3.3-10B and 3.3-19). In general, this tube-builder is known to form occasional tube mats in sandy sediments on the mid-Atlantic inner continental shelf (Diaz et al., 2004), including nearshore zone off New Jersey (U.S. Army Corps of Engineers, 2001). Trapping of fine-grained sediment within *A. oculata* tube mats resulted in creation of low mounds and thus was reported to have influenced topography on the inner shelf of New Jersey in May of 2002 (Clapp et al., 2002).

The 2005 survey results are particularly significant in terms of addressing any on-going questions or concerns about the ability of benthic organisms to colonize areas of red clay. Originally, red clay dredged from Newark Bay in 1997 was placed in the northeast quadrant of the former MDS, and intensive SPI/plan-view surveys were conducted both one year and five years following its placement. Although the benthic recolonization process was found to be slower than normal, with only low numbers of Stage I organisms visible in the 1998 images, by 2002 it was found that the red clay deposits had become colonized by diverse and abundant communities of both infauna and epifauna (SAIC 1998; 2003; Valente 2006). The present survey echoed the 2002 results: biological features indicating the presence of a diverse assemblage of surface- and subsurface-dwelling benthos were observed in the SPI and plan-view images over large portions of PRAs 1 through 4, where red clay remediation material (among other types of material) has been placed on an on-going basis since HARS designation in 1997 (Figure 3.3-18).

Evidence of Stage III taxa in the SPI images included subsurface burrows, feeding voids and, in a few cases, the organisms themselves visible at depth within the sediment column (e.g., Figures 3.3-13A, 3.3-24 and 3.3-25). Based on previous surveys involving grab sampling to "ground truth" the SPI interpretations, the Stage III communities likely included a variety of deposit-feeding polychaetes, such as *Aricidea catherinae*, *Levinsenia gracilis*, *Scoletoma verilli*, *Nephtys incisa* and *Ninoe nigripes*. All of these taxa are common in the New York Bight, and most are considered to be relatively insensitive to contaminants and/or associated with areas where organic-rich, fine-grained dredged material has been disposed in the past (Caracciolo and Steimle, 1983; Chang et al., 1992).

Average RPD depths were moderately well-developed over the HARS and surrounding area in the 2005 survey. It was difficult to measure the RPD in a number of images displaying red clay due to the uniform color and texture of this material. As in the previous survey of 2002, methane bubbles were visible in the sediment column at Station 11 in PRA 1, again suggesting that some of the dredged material that is buried at depth (either remediation material or the original relic dredged material) has a high concentration of organic matter that is slowly decomposing under anaerobic conditions.

Benthic habitat conditions, as indicated by OSI values, were either undisturbed or moderately disturbed at the majority of stations in PRAs 1 through 4 (Figure 3.3-29). This is an expected result, as the OSI values reflect various stages of benthic recovery from the physical disturbance associated with placement of remediation material at various times and locations within these PRAs over the past several years. There did not appear to be any consistent patterns in the relationship between OSI values versus either length of time since placement or type of remediation material. Overall, the OSI values indicate an intermediate to advanced degree of recovery from the disturbance effects of both historic and more-recent disposal activities, as evidenced by the diverse and abundant infaunal and epifaunal communities observed in the SPI and plan-view images at the HARS stations. The sandy stations located outside the HARS boundaries were considered to have non-degraded habitat conditions. This represents the background or ambient condition of bottom areas surrounding the HARS and former MDS where dredged material placement is not known to have occurred in the recent or distant past.

4.3 Sediment Toxicity

In the standard 10-day acute toxicity test, *Ampelisca abdita* exposed to surface sediments collected at the 57 primary stations in and around the HARS had a consistently high survival rate (i.e., survival in each of the test sediments was >92% of control survival). The results of the 2005 survey therefore clearly demonstrated that these surface sediments were non-toxic, as defined by this test. These testing results were identical to those obtained at the same set of stations in the previous survey of Summer 2002. In both surveys, the sediment that was collected and tested at each station fell into one of the following three basic categories: relic dredged material, remediation material, or native sand.

The 2005 and 2002 results, as well as those from the sediment toxicity survey conducted in October 2000, stand in contrast to the results of the original toxicity survey of 1994.

Specifically, all 26 of the stations located in and around the former MDS that were found to be toxic in the 1994 survey have been found to be non-toxic in the three subsequent surveys, and the two most-recent surveys (2002 and 2005) have failed to find significant toxicity at any sampling station.

Remediation material was present at several of the stations sampled in October 2000 and at even more of the 2002 and 2005 stations, as the on-going placement activities have continued to cover an expanding area (Figure 4.3-1). Placement of remediation material, therefore, could reasonably explain the change from toxic to non-toxic conditions observed between the October 1994 and the three subsequent surveys at Stations 7, 11, 19, 24, 28 and 29. All of these stations are located in areas of PRAs 1 through 4 that have received remediation material to date (Figure 4.3-1).

However, as discussed in the previous sediment toxicity report (SAIC 2003), there are several other possible explanations for the difference in results between the 1994 versus the other three surveys, including: 1) sampling and analysis errors were prevalent during the 1994 survey, leading to erroneous (i.e., false positive) sediment toxicity results, 2) small-scale spatial variability in sediment contaminant concentrations may have confounded the between-survey comparisons, and 3) natural physical and biological processes have led to actual reductions in toxicity over time.

In terms of the sampling and analysis errors, the most significant difference between the 1994 and the three subsequent surveys involved the treatment of ammonia in the sediment samples prior to the laboratory testing. In the three latter surveys, pore water ammonia was purged from the sediment if it was found to be above the EPA-specified threshold of 20 mg/L, so that high ammonia concentrations could not potentially affect the mortality rate of the test organism, *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/or ammonia-enhanced toxicity may have occurred, and many or all of the results represent false positives.

The second hypothesis postulated above was that sediment contaminant concentrations and hence toxicity characteristics may vary considerably over very small distances on the seafloor (i.e., on the order of a few to tens of meters) in areas of the HARS where dredged material was placed in the past. Due to the combined effect of navigational offsets, vessel movement and the influence of currents, grabs used to collect surface sediments at each station rarely sample the exact same patch of the seafloor. If sediment contaminant concentrations and toxicity actually did vary considerably over small distances, then widely different results could be obtained within and among surveys based on grab sampling at a fixed set of stations.

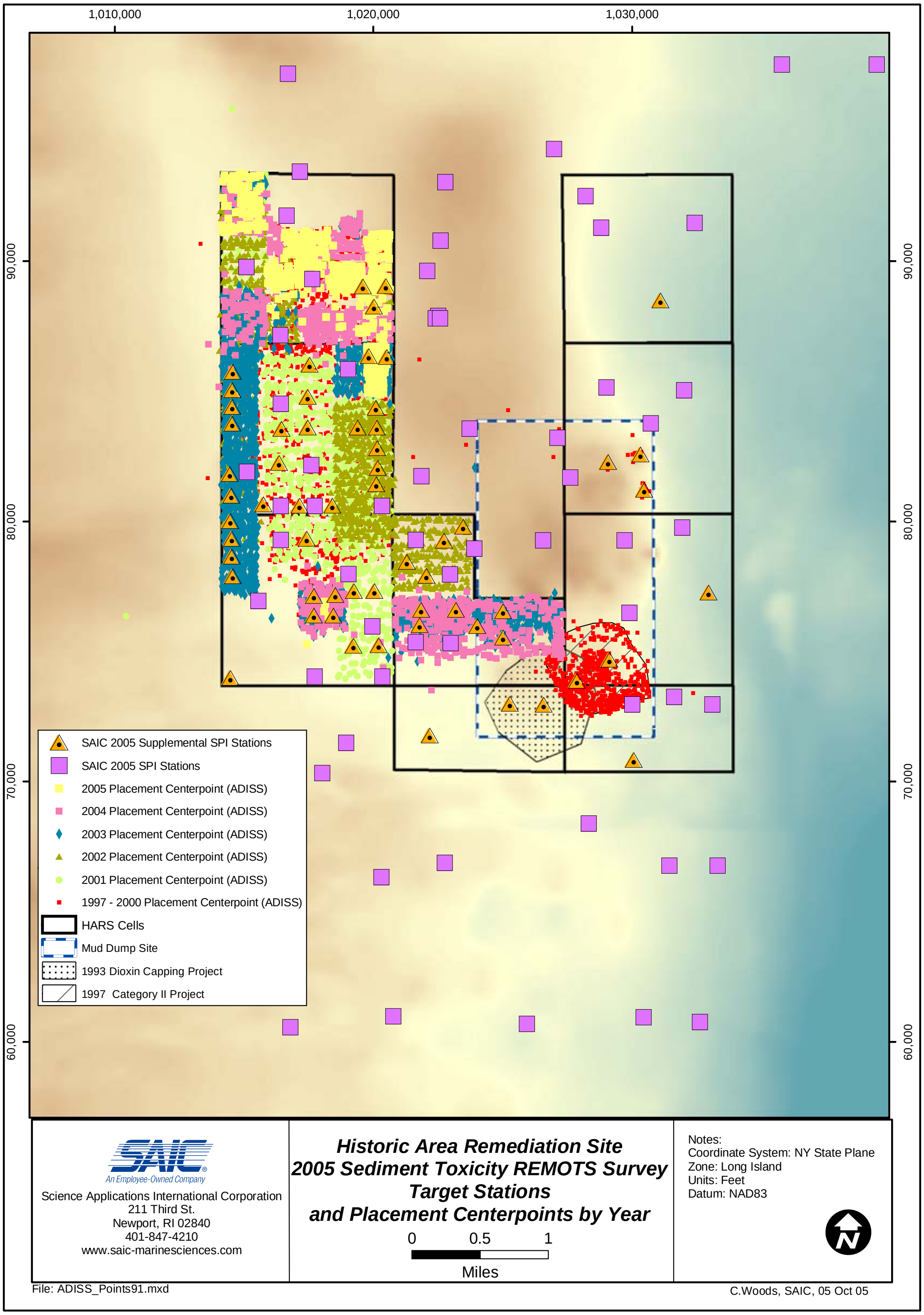


Figure 4.3-1. Locations of the 1994, 2000, 2002 and 2005 sediment toxicity stations within and immediately outside the HARS in relation to dredged material placement events over the period March 1998 to July 2005.

To examine this possibility, multiple grab samples for toxicity testing were collected at and around Station 13 during the 2005 survey. Sediments at this station were found to be toxic in the original 1994 survey and, because it is located in the no-discharge zone, it has not received any remediation material. The 2005 toxicity testing failed to show any toxicity at this station or at its three sub-stations located within 25 meters to the west, north and east. In the previous survey of 2002, a similar lack of toxicity was found at Station 18 and each of three 25-m sub-stations. Furthermore, the 2002 survey showed an absence of toxicity regardless of whether the collected sediment was from the surface or subsurface.

Both the 2002 and 2005 results were consistent, therefore, in showing an absence of variability in sediment toxicity across relatively short horizontal distances at Stations 13 and 18. The 2002 results also indicated an absence of any toxicity differences related to the depth in the sediment column from which the sample was taken. Based on these results, it is considered unlikely that small-scale spatial variability was a leading cause of the differences in toxicity between the 1994 and the three later surveys.

Finally, it is possible that the negative results of the three later surveys were due to natural attenuation of the chemical contaminants responsible for the original toxicity. Such attenuation could result from either natural accumulation of cleaner sediment or biologically-mediated contaminant breakdown. Bioturbation of the surface sediment would cause a reduction in toxicity over time, as the original toxic sediment was mixed with newly deposited, less toxic sediment transported from elsewhere by bottom currents. The sand-over-dredged-material stratigraphy observed in the SPI images at some stations indicates that such sediment transport processes are active in and around the HARS. Hence, natural physical and biological factors could be responsible for at least some of the apparent reduction in sediment toxicity observed among the consecutive monitoring surveys at the HARS.

5.0 SUMMARY

- Similar to the results of many past SPI surveys in and around the HARS and former MDS, the 2005 survey indicated that a wide variety of surface sediments continue to exist in these areas. These sediments, which range in texture from silt-clays to gravels, include historic (i.e., relic) dredged material, predominantly fine-grained remediation material placed since 1997 in PRAs 1 through 4, and sand that represents the native sediment in areas outside the HARS boundaries.

- The remediation material found at the surface and near-surface in PRAs 1 through 4 consisted primarily of either “conventional” organic-rich mud or red clay that was either soft/unconsolidated or in cohesive clumps.

- As in past surveys, the surface sediments at several stations displayed a unique stratigraphy consisting of a thin surface layer of native fine sand overlying fine-grained, black dredged material. This stratigraphy is presumed to result when ambient fine sand is transported by bottom currents into areas where organic-rich, fine-grained dredged material was placed in the past, in effect representing a natural capping process.

- A thin surface deposit of fines and flocculent organic detritus occurred at many stations. Such deposits are commonly observed in SPI images collected at the HARS during the late summer and early fall, following the annual peak of biological production in the overlying water column. During the winter months, these thin surface deposits are typically swept away by higher-energy wave and bottom currents.

- Clean fine sand was observed in the SPI images at several stations located over the two capped mounds in the southern end of the former MDS. This sand represents the sediment that was originally dredged from Ambrose Channel and used for capping of fine-grained dredged material containing low levels of dioxin. The continued presence of sand at these SPI stations provides continuing evidence that the integrity of the two caps has not been compromised, at least at these limited sampling locations.

- In response to the patchy mosaic of different substrate types and benthic habitat conditions, the 2005 imaging results showed that benthic communities were in various stages of succession. As in the past, small opportunistic, Stage I polychaetes were abundant at many stations, reflecting their ability to colonize the sediment surface quickly and in high numbers in response to the physical seafloor disturbance associated with either natural migration of sand in areas outside the HARS or following dredged material disposal within the HARS.

- While Stage I opportunists are the long-term dominants on sandy bottoms around the HARS, the placement of fine-grained dredged sediments within both the HARS and the former MDS has resulted in soft-bottom conditions conducive to supporting infaunal succession beyond Stage I. Both the 2002 and 2005 SPI/plan-view results served to confirm that such advanced succession has in fact been occurring, most notably in PRAs 1 through 4 where remediation activities have been on-going since 1997.

- The majority of stations within the HARS, including most of those with remediation material, had an advanced successional status consisting of either Stage II or III. Abundant Stage II taxa included stick-dwelling amphipods (Family Podoceridae), tube-dwelling Ampeliscid amphipods (*Ampelisca* sp.), and the shallow-dwelling nut clam *Nucula* sp. Dense tube mats of the surface-dwelling polychaete *Asabellides oculata* also occurred at a few stations having red clay remediation material. Evidence of Stage III taxa in the SPI images included subsurface burrows, feeding voids and, in a few cases, the organisms themselves visible at depth within the sediment column

- The 2005 survey results are particularly significant in terms of addressing any on-going questions or concerns about the ability of benthic organisms to colonize areas of red clay. Biological features indicating the presence of a diverse assemblage of surface- and subsurface-dwelling benthic organisms were observed in the SPI and plan-view images over large portions of PRAs 1 through 4 where red clay remediation material (among other types of material) has been placed on an on-going basis since HARS designation in 1997.

- Benthic habitat conditions, as indicated by OSI values, were either undisturbed or moderately disturbed at the majority of stations in PRAs 1 through 4. Overall, the OSI values indicate a relatively advanced degree of recovery from the disturbance effects of both historic and more-recent disposal activities.

- The results of the 2005 survey clearly demonstrate that surface sediments collected in and around the HARS were non-toxic, as measured in the standard 10-day acute toxicity test with the amphipod *Ampelisca abdita*. Both the 2005 and 2002 toxicity testing results, as well as those from a survey conducted in October 2000, contrast with the results of the original toxicity survey of 1994.

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