NewFields

2013 Sediment Profile Imaging Surveys

Commencement Bay and Elliott Bay DMMP Sites

Final

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Photo taken during transit to Commencement Bay – September 2013

Table of Contents

1.0 Introduction 1
2.0 Background 1
2.1 DMMP Disposal Site Monitoring Program 1
2.2 Commencement Bay and Elliott Bay DMMP Sites 1
3.0 Methods 8
3.1 Field Survey and Deviations from the ICAP 8
3.2 Sediment Profile Imaging Overview 8
3.3 SPI Image Analysis 9
4.0 Results 12
4.1 Commencement Bay 12
4.1.1 CB Ambient Sediment Characteristics 12
4.1.2 Dredged Material Distribution 12
4.1.3 Physical and Sedimentary Features 13
4.1.4 Chemical and Biological Features 14
4.2 Elliott Bay 32
4.2.1 EB Ambient Sediment Characteristics 32
4.2.2 Dredged Material Distribution 32
4.2.3 Physical and Sedimentary Features 32
4.2.4 Chemical and Biological Features 33
5.0 Evaluation of the Physical Monitoring Data 50
5.1 Question 1: Does the Dredged Material Stay On Site? 50
5.1.1 Commencement Bay SPI Results 50
5.1.2 Elliott Bay SPI Results 50
6.0 References 51

Appendix A SPI Image Collection and Analysis Plan (ICAP)
Appendix B Geographic Coordinates
Appendix C SPI Image Analysis Results

List of Figures

Figure 2-1. Commencement Bay SPI sampling locations 4
Figure 2-2. Elliott Bay SPI sampling locations 5
Figure 3-1. SPI camera operations in Commencement and Elliott Bays. 10
Figure 3-2. Schematic diagram of the sediment profile camera and sequence of operation on deployment..... 11
Figure 4-1. SPI images from stations CBB03-A and CBF77-A..... 18
Figure 4-2. SPI images from stations CBF13-A and CBF28-B 19
Figure 4-3. SPI results for recent dredged material thickness 20
Figure 4-4. SPI images from stations CBZ01-B and CBC10-C 21
Figure 4-5. SPI images from stations CBC12-A and CBF10-B 22
Figure 4-6. SPI results for historical dredged material thickness 23
Figure 4-7. SPI images from stations CBS07-B and CBS21-C..... 24
Figure 4-8. SPI results for grain size major mode 25
Figure 4-9. SPI results for mean camera penetration 26
Figure 4-10. SPI results for mean boundary roughness..... 27
Figure 4-11. SPI results for mean apparent RPD depths 28
Figure 4-12. Idealized development of infaunal succession stages over time following a physical disturbance..... 29
Figure 4-13. SPI results for highest successional stage 30
Figure 4-14. SPI results for median OSI 31
Figure 4-15. SPI images from stations EBS18-E and EBT03-B 37
Figure 4-16. SPI images from stations EBP08-B and EBP10-B 38
Figure 4-17. Elliott Bay SPI results for recent dredged material 39
Figure 4-18. SPI images from stations EBZ01-B and EBR01-B..... 40
Figure 4-19. SPI images from stations EBC08-B and EBS06-B 41
Figure 4-20. Elliott Bay SPI results for historic dredged material 42
Figure 4-21. Elliott Bay SPI results for grain size major mode..... 43
Figure 4-22. SPI images from stations EBC06-A and EBP03-B..... 44
Figure 4-23. Elliott Bay SPI results for camera penetration..... 45
Figure 4-24. Elliott Bay SPI results for boundary roughness 46
Figure 4-25. Elliott Bay SPI results for apparent RPD depths 47
Figure 4-26. Elliott Bay SPI results for highest successional stage 48
Figure 4-27. Elliott Bay SPI results for median OSI 49

List of Tables

Table 2-1. The DMMP monitoring framework 3
Table 2-2. CB and EB dredged material disposal site characteristics and monitoring trigger volumes 6
Table 2-3. Disposal volumes (cubic yards) at the CB and EB dredged material disposal site since the last full SPI surveys 7
Table 4-1. Commencement Bay SPI summary table 16
Table 4-2. Elliott Bay SPI summary table..... 35

1.0 Introduction

The Dredged Material Management Program (DMMP) agencies (U.S. Army Corps of Engineers, Seattle District, U.S. Environmental Protection Agency, Washington Departments of Ecology and Natural Resources) jointly manage eight open-water dredged material disposal sites in Puget Sound, including five non-dispersive and three dispersive sites. The Washington Department of Natural Resources (DNR) is the lead agency for conducting chemical and biological monitoring at the non-dispersive sites and the U.S. Army Corps of Engineers, Seattle District (USACE) is the lead agency for conducting physical monitoring at both dispersive and non-dispersive sites. Physical monitoring includes bathymetric surveys at all eight sites and sediment profile imaging (SPI) surveys at the non-dispersive sites.

This report presents the results of the 2013 Sediment Profile Imaging (SPI) surveys conducted in support of physical monitoring at the Commencement Bay and Elliott Bay DMMP disposal sites. The SPI Image Collection and Analysis Plan (ICAP) (Appendix A) outlines the sampling methods and analysis protocols used for conducting the SPI surveys to determine the spatial extent of recent dredged material deposits and to examine near-surface, benthic habitat conditions at selected locations at the sites. NewFields, Edmonds, WA was contracted by ANAMAR Environmental Consulting, Inc., Gainesville, FL, to perform the SPI surveys.

2.0 Background

2.1 DMMP Disposal Site Monitoring Program

The original environmental monitoring plans for unconfined, open-water, dredged material disposal sites in central Puget Sound were published by the Puget Sound Dredged Disposal Analysis program agencies in 1988 (PSDDA 1988a). The monitoring plans were designed to verify that dredged material disposed at the sites remains within the disposal site boundaries and that unacceptable adverse effects do not occur either onsite or offsite due to dredged material disposal. Numerous revisions to the physical, chemical, and biological monitoring plans were made by the Dredged Material Management Program agencies between 1988 and 2007. The Updated Environmental Monitoring Plan (SAIC 2007) incorporated those changes, bringing the monitoring plans up to date. While changes have been adopted in the chemical and biological monitoring plans and procedures since 2007 (see USACE 2013), no changes have occurred to the physical monitoring plans.

DMMP disposal site monitoring is designed to answer three monitoring questions through the evaluation of six testable hypotheses (Table 2-1). An SPI survey is used to evaluate the first testable hypothesis under Question 1. Dredged material is determined to have remained on site if deposits of dredged material are no greater than 3 cm at the perimeter stations.

2.2 Commencement Bay and Elliott Bay DMMP Sites

The Updated Environmental Monitoring Plan (UEMP) includes the current physical monitoring requirements and procedures for the Commencement Bay (CB) and Elliott Bay (EB) sites. A description of these two sites is included in Table 2-2 and site maps are provided in Figures 2-1 and 2-2. The monitoring triggers listed in Table 2-2 are considered “soft” triggers, meaning that best professional judgment is applied by the DMMP agencies to determine the actual time at which monitoring will occur. At the EB site, approximately 590,000 cubic yards of material have been placed since the last SPI monitoring survey was conducted in 2002 (SEA 2002) (Table 2-3).

At the CB site, approximately 429,000 cubic yards have been placed since the last SPI survey in 2007 (SAIC 2008), which is short of the soft trigger (Table 2-3). However, the target disposal coordinates for the CB site were changed after the 2007 survey in order to reduce the height of the disposal mound (DMMP 2007). The revised coordinates are at the edge of the target area. After six years of disposal at the new coordinates, the DMMP agencies agreed that an SPI survey was appropriate to ensure that the new disposal coordinates are working as intended and the dredged material footprint is contained within the disposal site boundary.

Table 2-1. The DMMP monitoring framework

Question	Hypothesis	Monitored Variable	Interpretive Guideline	Action Item (When exceedances noted)[1]
No. 1 **Does the deposited dredged material stay on site?**	1. Dredged material remains within the site boundary.	Sediment Profile Imaging (SPI) System Onsite and Offsite	Dredged material layer is greater than 3 cm at the perimeter stations.	Further assessment is required to determine full extent of dredged material deposit.
	2. Chemical concentrations do not measurably increase over time due to dredged material disposal at offsite stations.	Sediment Chemistry Offsite	Washington State Sediment Quality Standards and Temporal analysis	Post-disposal benchmark station chemistry is analyzed and compared with appropriate baseline benchmark station data.
No. 2 **Are the biological effects conditions for site management [PSDDA-defined Site Condition II] exceeded at the site due to dredged material disposal? (PSDDA 1988b)**	3. Sediment chemical concentrations at the onsite monitoring stations do not exceed the chemical concentrations associated with PSDDA Site Condition II guidelines due to dredged material disposal.	Sediment Chemistry Onsite	Onsite chemical concentrations are compared to DMMP maximum levels.	DMMP agencies may seek adjustments of disposal guidelines <u>and</u> compare post-disposal benchmark chemistry with appropriate baseline benchmark station data.
	4. Sediment toxicity at the onsite stations does not exceed the PSDDA Site Condition II biological response guidelines due to dredged material disposal.	Sediment Bioassays Onsite	DMMP Bioassay Guidelines (Section 401 Water Quality Certification)	Benchmark station bioassays are performed (if archived after monitoring) and compared with baseline benchmark bioassay data.
No. 3 **Are unacceptable adverse effects due to dredged material disposal occurring to biological resources off site?**	5. No significant increase due to dredged material disposal has occurred in the chemical body burden of benthic infauna species collected downcurrent of the disposal site.	Tissue Chemistry Transect	Guideline values Metals: 3x the baseline concentrations Organics: 5x the baseline concentrations	Compare post-disposal benchmark tissue chemistry with baseline benchmark tissue chemistry data.
	6. No significant decrease due to dredged material disposal has occurred in the abundance of dominant benthic infaunal species collected downcurrent of the disposal site.	Infaunal Community Structure Transect	Guideline values Abundance of major taxa < ½ baseline macrobenthic infauna abundances	Compare post-disposal benchmark benthic data with baseline benchmark data.

1. To determine if observed changes in chemical conditions or infaunal benthos are due to dredged material disposal, data from the benchmark stations are considered. All decisions are subject to DMMP agency review and best professional judgment.

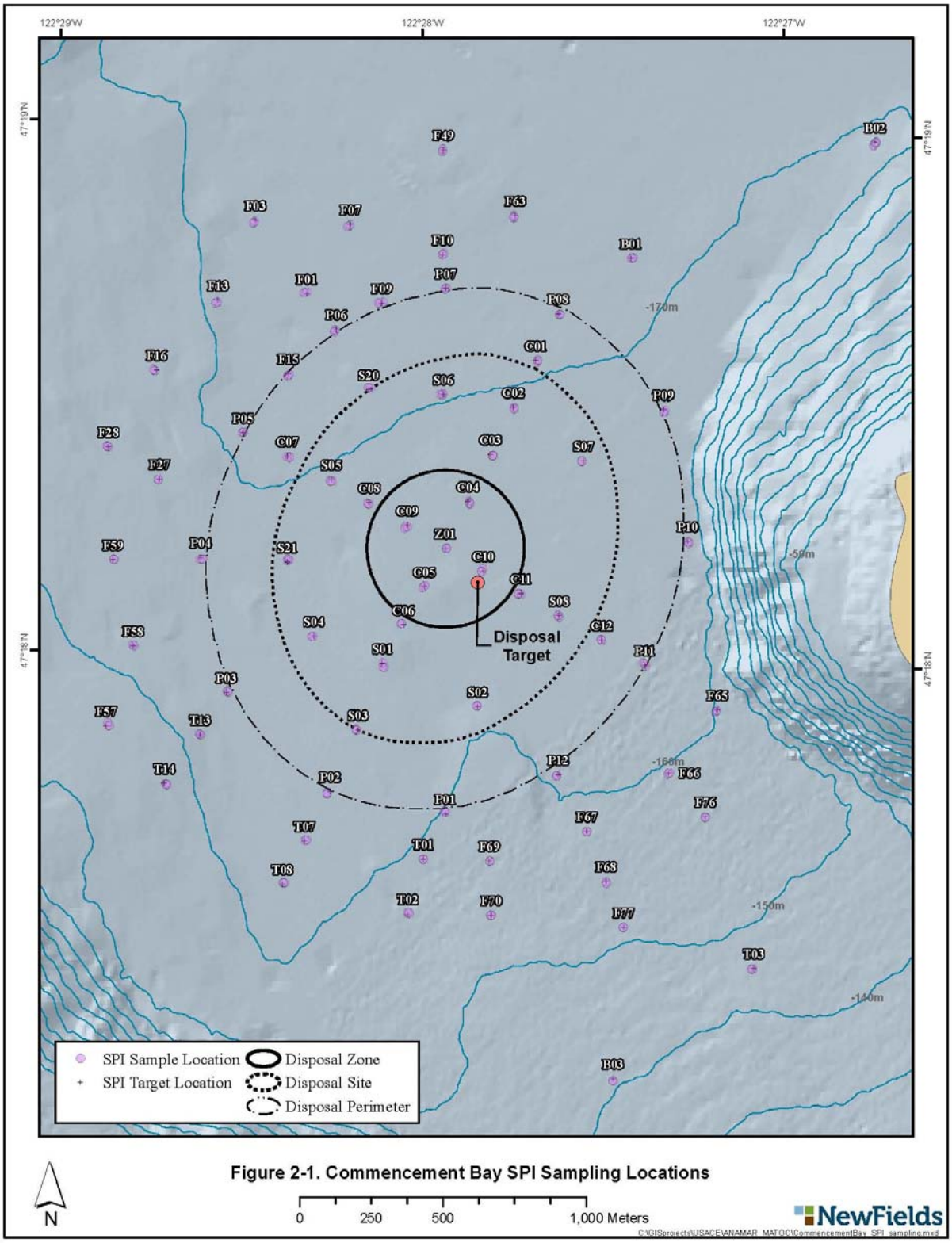


Figure 2-1. Commencement Bay SPI Sampling Locations

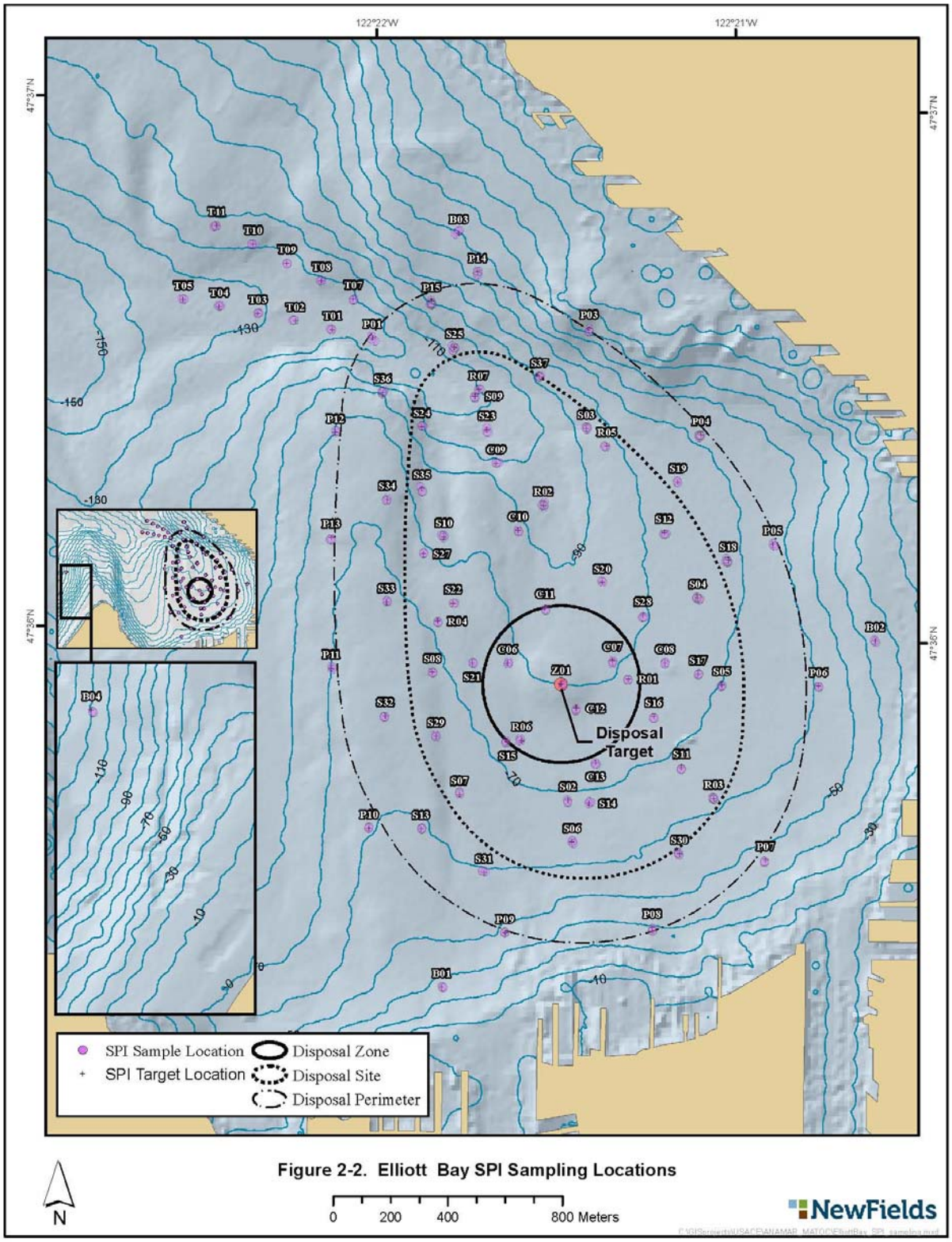


Figure 2-2. Elliott Bay SPI Sampling Locations

Table 2-2. CB and EB dredged material disposal site characteristics and monitoring trigger volumes

Site	Area (acres)	Depth (feet)	Disposal Zone Diameter (feet)	Target Area Diameter (feet)	Disposal Site Dimensions (feet)	Site Coordinates (Lat/Long: NAD83)	Monitoring Trigger Volume (cy)
Commencement Bay[1]	310	540–560	1,800 (circle)	1,200 (circle)	4,600 x 3,800 (ellipsoid)	47° 18.145’ 122° 27.815’	500,000
Elliott Bay[2]	415	300–360	1,800 (circle)	1,200 (circle)	6,200 x 4,000 (tear drop shape)	47° 35.91’ 122° 21.45’	500,000

Notes:
[1]The disposal coordinates were shifted to the location listed in this table on June 16, 2007. From 1988 to June 15, 2007 the disposal coordinates were as follows: 47° 18.21’, 122° 27.91’ (NAD 83). All disposal since the last full monitoring event in 2007 has occurred at the coordinates listed in the table.
[2] Following site monitoring in 1990, the original EB disposal coordinates were shifted 300 feet to the south by the DMMP agencies (Striplin 1991). The disposal zone was not changed, so the disposal coordinates plotted within the disposal zone will show the disposal coordinates are off center to the south relative to the center of the disposal zone.

Table 2-3. Disposal volumes (cubic yards) at the CB and EB dredged material disposal site since the last full SPI surveys

Dredge Year	Commencement Bay	Elliott Bay
2002	---	Last full SPI survey
2003	---	0
2004	---	15,602
2005	---	77,838
2006	---	3,801
2007	Last full SPI survey	24,250
2008	214,858	172,999
2009	18,803	20,133
2010	14,812	96,046
2011	179,160	11,486
2012	0	152,349
2013	1,673[a]	15,266[b]
Total:	**429,306**	**589,770**

a. Last dredged material disposal at Commencement Bay occurred on 9/28/12
b. Last dredged material disposal at Elliott Bay occurred on 10/8/12

3.0 Methods

3.1 Field Survey and Deviations from the ICAP

Sediment profile images were collected using a sediment-profile camera system (Figure 3-1), deployed from the research vessel (R/V) *Kittiwake,* as outlined in the ICAP (Appendix A). The SPI survey at the Commencement Bay (CB) DMMP site was conducted on September 13 and 14, 2013. The SPI survey at the Elliott Bay (EB) DMMP site was conducted on September 16 and 17, 2013. A total of 68 stations were sampled at the CB site and 79 stations at the EB site (see Figures 2-1 and 2-2, respectively). The ICAP specified a target of 68 stations at the CB site and 75 stations at the EB site. Triplicate images were collected at each location.

The SPI surveys require 2 field days to complete at each disposal site. The "traditional across-site approach" of sampling SPI stations was followed at both the CB and EB disposal sites (see SAIC 2007). At the conclusion of the first day of SPI collection at each site, the DMMP agencies were consulted regarding target stations for Day 2 in order to delineate the dredged material footprint. Due to the shift in the CB target disposal coordinates in 2007, eight additional floating stations (CBF65, CBF66, CBF67, CBF68, CBF69, CBF70, CBF76, and CBF77) were designated to confirm the absence of dredged material in the southeast portion of the CB site. At the EB site, SPI images were also collected at the seven randomly placed dioxin sampling locations (EBR01 through EBR07) identified and sampled as part of the chemical and biological monitoring program conducted by DNR in the summer of 2013 (Integral 2013).

Positioning and navigation were accomplished using the *Kittiwake's* differential Global Positioning System (DGPS) integrated to a computerized navigation and survey system. Geographic coordinates for each SPI replicate image are provide in Appendix B. All CB sampling stations were identified with a "CB" prefix and all EB stations were identified with an "EB" prefix. Due to the short duration of the SPI surveys, establishing a reference location at each site (e.g., marina slip) to conduct navigation checks was not feasible. Instead, the geographic coordinates obtained from the primary DGPS system were periodically compared to the *Kittiwake's* secondary Nobeltec® DGPS system to ensure that the navigation and survey system was operating correctly.

3.2 Sediment Profile Imaging Overview

SPI images were collected using a Benthos model 3731 sediment-profile camera (Benthos, Inc., North Falmouth, MA) equipped with an Ocean Imaging Systems digital camera (Figure 3-2). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglas face plate and a back mirror mounted at a 45 degree angle. Light was provided by an internal strobe. The camera obtains images of up to 20 cm of the upper sediment column in profile.

The camera prism was mounted on an assembly that can be moved up and down within a stainless steel frame by allowing tension or slack on the winch wire. As the camera was lowered, tension on the winch wire kept the prism in the up position. When the camera frame touched the seafloor, slack on the winch wire allowed the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) was controlled by an adjustable passive hydraulic piston, which minimized the disturbance of the sediment-water interface.

A trigger was tripped on impact with the bottom, activating a 13 second time-delay on the shutter release, allowing the prism to obtain maximum penetration before an image was taken. The camera was then raised from the bottom, a wiper blade automatically cleaned off any sediment

adhering to the prism faceplate, and the strobes were recharged. The camera was then lowered to collect another replicate image.

3.3 SPI Image Analysis

Computer image analysis of SPI images followed a formal and standardized technique developed by Rhoads and Germano (1982, 1986). Physical and biological parameters were measured directly from the digital images by an SPI image analyst using computer image analysis software. The image analysis parameters included:

- Camera prism penetration depth;
- Sediment grain size (major mode and range);
- Surface boundary roughness;
- Presence of mud clasts;
- Presence of methane;
- Depth of the apparent redox potential discontinuity (RPD);
- Infaunal successional stage;
- Calculation of the Organism-Sediment Index (OSI); and
- Dredged material thickness, including determination of recent or historical if possible.

All data were edited and verified by a senior-level scientist before final data synthesis, statistical analysis, and interpretation. Additional details regarding the specific measurement techniques and interpretive criteria for each parameter can be found in the ICAP (Appendix A).

Figure 3-1. SPI camera operations in Commencement and Elliott Bays.

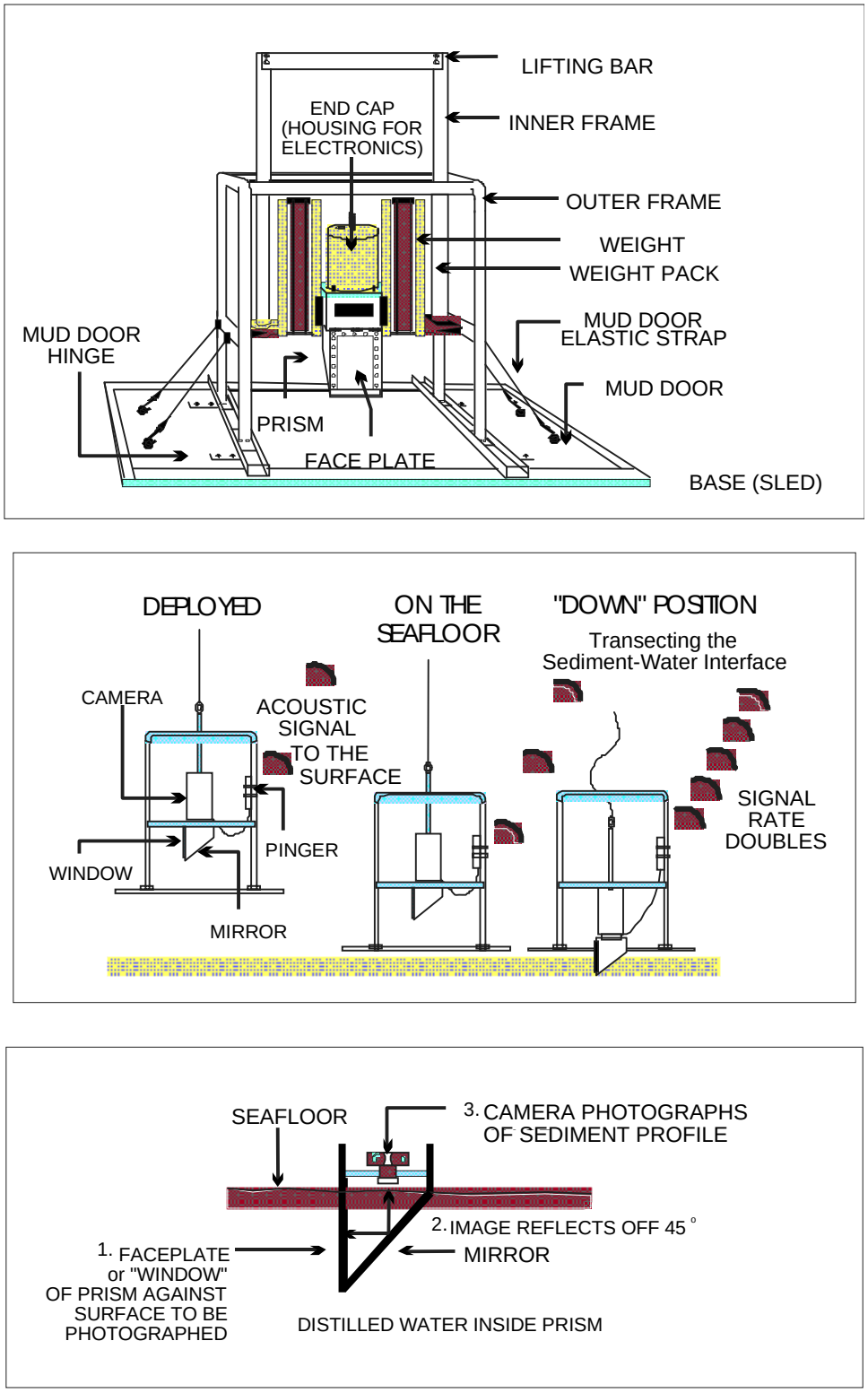


Figure 3-2. Schematic diagram of the sediment profile camera and sequence of operation on deployment.

4.0 Results

This section presents the results of the 2013 SPI surveys conducted at the Commencement Bay (CB) and Elliott Bay (EB) DMMP dredged material disposal sites. The CB results are presented in Section 4.1, and the EB results are presented in Section 4.2. An evaluation of the SPI data in accordance with the DMMP monitoring framework is provided in Section 5.0.

4.1 Commencement Bay

Triplicate SPI images were analyzed at 68 CB stations to map the dredged material footprint (see Figure 2-1). In addition, other physical (grain size major mode, prism penetration depth, boundary roughness), chemical (apparent RPD), and biological (successional stage and OSI) characteristics of site sediments were determined from the SPI images. A summary of mean and median values of the SPI results is provided in Table 4-1. A full summary of the image analysis results is provided in Appendix C. The primary objectives of the 2013 survey were to map the distribution of dredged material at the CB disposal site and examine near-surface, benthic habitat conditions. In addition, the survey was used to assess whether the shift in the CB target disposal coordinates in 2007 had affected the dredged material deposition patterns at the site.

4.1.1 CB Ambient Sediment Characteristics

Ambient sediment characteristics near the CB site were similar to previous disposal site observations (e.g., SEA 2001, SAIC 2005, SAIC 2008), consisting of tan brown to olive gray, unconsolidated (water-rich) silts and clays with minor amounts of fine sand. The apparent RPD depths were relatively deep in these ambient sediments. Feeding voids were visible, indicating extensive bioturbation of surface sediments by head-down deposit-feeding infaunal organisms. Representative SPI images showing ambient sediment conditions at the CB site are provided in Figure 4-1.

Based on previous monitoring surveys, it is known that ambient sediments to the north and northwest of the disposal site (approximately 0.5 mile or more from the northern site perimeter) consist primarily of medium to fine sands with silt. This distribution of coarse-grained sediments was observed at Commencement Bay during the original disposal site evaluation studies in central Puget Sound (PSDDA 1988a). The SPI survey grid utilized in 2013 did not extend as far to the northwest compared to previous surveys. However, five stations occupied in this northwest region in 2013 (CBF13, CBF16, CBF27, CBF28, and CBF59) showed evidence of sandy ambient sediment conditions (Figure 4-2).

4.1.2 Dredged Material Distribution

Dredged material is normally identified in SPI images by its contrasting optical appearance relative to the ambient seafloor. Multiple disposal events at a site can result in sedimentary layering with varying colors and textures, or a mixed and chaotic sedimentary fabric. Diagnostic characteristics can include differences in grain size, color and reflectivity, high boundary roughness, and a mixed or chaotic sedimentary fabric. The optical and physical characteristics of the dredged material may change over time due to the addition of newly deposited dredged material and subsequent biological mixing. However, many of the stratigraphic and textural features associated with dredged material deposits can remain the same over time.

Where possible, the dredged material observed in the SPI images collected at the CB site was classified as historical or recently placed. The dredged material was identified as historic when

enough time had passed for a deep apparent RPD to be developed, feeding voids were present, and sedimentary layering due to dredged material disposal (if present) was not completely obscured through bioturbation. The CB disposal site had not received significant amounts of dredged material since 2011 (see Table 2-3). Therefore, enough time had also passed for the most recently placed dredged material to also show characteristics that could be considered historical (e.g., presence of Stage III infauna and well developed apparent RPD depths). For this survey, dredged material was classified as recent if either of the following conditions was observed:

1. The majority of sedimentary layering related to dredged material disposal was still intact
2. Significant deposits of reduced dredged material was present at depth, with minimal biological mixing

The distribution of recent dredged material observed at the CB site is presented in Figure 4-3. Recent dredged material was detected in SPI images collected from 23 CB stations and the dredged material was confined within the perimeter of the disposal site, with the exception of trace or very thin accumulations detected just north of the site. A north to northwest trending pattern of dredged material is consistent with general depositional trends observed during previous monitoring surveys at the CB site (SEA 2001, SAIC 2007). Dredged material at the site center was composed of tan and gray medium and fine sands with silt (Figure 4-4). Prism penetration at stations within the disposal zone was low due to the presence of coarse-grained, consolidated dredged material. Recent dredged material along the outer flanks of the deposit consisted of trace amounts of fine sand or thin layers (0.68 to 1.44 cm) of tan and gray silt enriched with fine sand, overlying ambient sediments or historical dredged material deposits (Figure 4-5). The accumulation of recent dredged material beyond the site perimeter did not exceed the 3 cm DMMP criterion.

Dredged material identified as historic was detected in images from 22 stations, primarily within the disposal site perimeter (Figure 4-6). Historic dredged material consisted of discontinuous layers of dredged material at depth, where enough time has passed for significant biological mixing of the dredged material but some evidence of the layering remains visible in the SPI images (Figure 4-7). Historic dredged material was detected at 19 stations within or along the disposal site perimeter, and three floating stations located to the north outside of the disposal site perimeter (CBF07, CBF01, and CBF63).

4.1.3 Physical and Sedimentary Features

Physical and sedimentary features determined from SPI images include grain size major mode, camera prism penetration, and boundary roughness. Grain size major mode within the CB disposal zone generally consisted of fine sand (3-2 ϕ) and very fine sand (4-3 ϕ) due to the presence of coarse grained dredged material (Figure 4-8). Outside of the disposal zone, the sediment grain size consisted of very fine sand (4-3 ϕ) to silt-clays (> 4 ϕ). As discussed in Section 4.1.1, fine and very fine sand were present in ambient areas to the north and northwest of the disposal site. However, the major mode for those locations was still silt-clay. Where multiple sediment layers were present, the grain size major mode represented the sediment layer most prevalent within the SPI image.

The distribution of SPI camera prism penetration (in centimeters) in CB sediments is presented in Figure 4-9. Prism penetration provides a relative measure of sediment bearing capacity. Unconsolidated, fine-grained sediments that experience bioturbation generally have higher water

content and deeper prism penetration than coarse grained, compact sediments. The shallowest prism penetration was measured in the disposal zone (2.3 to 6.6 cm) due to the presence of compact, coarse-grained dredged material (see Figure 4-4). Prism penetration was deeper outside of the disposal zone, with an average of 15.5 cm (± 2.7 cm).

Mean bottom boundary roughness measurements during the 2013 SPI survey are shown in Figure 4-10. Mean small-scale boundary roughness (surface relief) can be physical or biological in nature, and is the difference between the highest and lowest penetration depth measured in an SPI image. Physical boundary relief can include surface ripples, mud clasts, and irregular surface features due to dredged material disposal or bottom currents. Biogenic activity that creates boundary roughness includes fecal mounds, burrow excavations, and foraging and feeding pits. The average surface relief during the 2013 survey was 2.03 cm (± 1.38 cm). The majority of surface relief was identified as biogenic (94% of stations). Mean boundary roughness at stations within the disposal site boundary were generally less than surrounding areas. Higher concentrations of dredged material were present onsite, particularly the disposal zone, which contained a higher proportion of sand and tended to maintain a lower surface relief (see Figure 4-6).

4.1.4 Chemical and Biological Features

Chemical and biological parameters include the apparent RPD depth, benthic infaunal successional stage, and calculation of the OSI. These parameters provide an assessment of the overall health of the benthic habitat at the Commencement Bay disposal site.

Apparent Redox Potential Discontinuity

The apparent RPD depth estimates the depth of oxygenation in the upper sediment column and provides an estimate of the biological mixing depth by infaunal organisms. Mean apparent RPD depths at the CB site range from 1.74 to 5.68 cm, with an average depth of 3.83 cm (Figure 4-11). The shallowest apparent RPD depths (<2.0 cm) were measured at the center of the disposal site, where the most dredged material disposal has occurred. The major mode of mean apparent RPD depths during the 2013 SPI survey was 3.5 to 4.0 cm, which is deeper than the most recent survey in 2007 (major mode of 2.5 to 3.0 cm) and the survey in 2005 (major mode of 3.0 to 3.5 cm). The deeper apparent RPD depths in 2013 are consistent with the hiatus of significant dredged material disposal at the CB site since 2011, allowing time for the benthic organisms to recolonize and biologically mix the dredged material sediments.

Benthic Infaunal Successional Stage

Benthic infaunal communities generally follow a three-stage succession following a disturbance of the seafloor (Figure 4-12) (Pearson and Rosenberg 1978, Rhoads and Germano 1986). Stage I infauna typically colonize the sediment surface soon after disturbance (e.g., following dredged material disposal). These opportunistic organisms may consist of small, tubicolous, surface-dwelling polychaetes. Stage II organisms are typically shallow-dwelling bivalves or tube-dwelling amphipods. Stage II communities are considered a transitional community before reaching Stage III, the high-order successional stage consisting of long-lived, infaunal deposit-feeding organisms. Stage III invertebrates may feed at depth in a head-down orientation and create distinctive feeding voids visible in SPI images.

Stage I on III benthic communities were observed at 55 stations at the CB site. Five stations within the site boundary (CBC04, CBC05, CBC08, CBS06, and CBZ01) showed the presence of

only Stage I succession. (Figure 4-13). Seven stations, including one within the disposal site (CBC06), one perimeter station (CBP02), three floating stations (CBF63, CBF70, CBF77), and two transect stations (CBT01, and CBT02), showed the presence of only Stage III succession. Stage II on III succession was observed at two stations; one within the disposal site (CBS21) and one floating station to the north (CBF07). The indicator species for Stage II classification at Commencement Bay was the stick building amphipod (*Podoceridae*) (see Figure 4-7). The benthic community appears to be in the last stages of transition to the highest order of succession (full Stage III community) following the most recent dredged material disposal.

Organism Sediment Index (OSI)

The Organism Sediment Index (OSI) provides a measure of general benthic habitat quality in shallow water environments based on dissolved oxygen conditions, depth of apparent RPD, infaunal successional stage, and presence or absence of sedimentary methane measured from SPI images (Rhoads and Germano 1986). The OSI is a numerical index ranging from -10 to +11. The lowest value is given to bottom sediments with low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment. The OSI for such a condition is -10 (highly disturbed or degraded benthic habitat quality). High OSI values are given to aerobic bottom sediments with deep apparent RPD depths, mature macrofaunal community, and no methane gas (unstressed or undisturbed benthic habitat quality). Previous SPI surveys conducted in various marine and coastal regions have shown that OSI values between +7 and +11 are typical of natural, undisturbed, fine grained sediments. OSI values less than +6 can indicate a stressed or disturbed benthic environment, and values less than 0 indicate degraded benthic habitat.

The distribution of median OSI values calculated at the CB site is presented in Figure 4-14. Median OSI values ranged from +5 to +11 within the disposal site boundary as well as offsite. The lowest median OSI values in Commencement Bay (+5) were observed at two stations (CBZ01 and CBC08) within or close to the disposal zone boundary. The vast majority of stations (97%) had OSI values equal to or greater than +6, which indicated natural or undisturbed benthic habitat in nearly all areas of the CB site. The two year hiatus of significant dredged material disposal at the CB site has confirmed that a healthy and resilient benthic infaunal community continues to thrive in Commencement Bay sediments.

Table 4-1. Commencement Bay SPI summary table

Station	Avg Prism Pen. (cm)	Dredged Material Thickness Recent (cm)	Dredged Material Thickness Historical (cm)	Grain Size Major Mode (phi)	Avg. Surface Boundary Roughness (cm)	Mud Clasts	Mean RPD	Highest Successional Stage	Median OSI
CBB01	17.71			>4 phi	2.13	present	4.85	Stage I on III	7
CBB02	19.76			4 to 3 phi	1.82		3.67	Stage I on III	11
CBB03	16.27			4 to 3 phi	1.61	present	3.8	Stage I on III	11
CBC01	16.56		0.64	>4 phi	1.3	present	3.53	Stage I on III	10
CBC02	16.9		2.26	>4 phi	1.32		4.31	Stage I on III	11
CBC03	15.42	0.75		3 to 2 phi	2.21	present	4.12	Stage I on III	11
CBC04	6.57	> 6.57		3 to 2 phi	1.67		3.34	Stage I	6
CBC05	2.98	> 2.98		>4 phi	1.11		>2.28	Stage I	7
CBC06	8.96	> 5.94	2.23	4 to 3 phi	2.52		3.45	Stage III	7
CBC07	13.35			>4 phi	3.89		3.7	Stage I on III	10
CBC08	5.04	2.29	2.75	>4 phi	1.37		3.2	Stage I	5
CBC09	5.98	> 3.95	> 1.81	>4 phi	1.41		>3.24	Stage I on III	7
CBC10	6.28	> 6.28		>4 phi	1.77		>2.19	Stage I on III	8
CBC11	7.8	> 7.80		>4 phi	1.2		1.89	Stage I on III	8
CBC12	14.4	0.59	> 9.86	>4 phi	1.59	present	2.17	Stage I on III	8
CBF01	16.95		2.79	>4 phi	1.61	present	3.85	Stage I on III	11
CBF03	16.64			>4 phi	1.56		3.95	Stage I on III	11
CBF07	16.39	0.23	1.41	4 to 3 phi	3	present	4.53	Stage II on III	11
CBF09	16.81			>4 phi	2.27		4.53	Stage I on III	11
CBF10	16.53			>4 phi	1.33		4.6	Stage I on III	11
CBF13	12.87			>4 phi	1.92		3.74	Stage I on III	10
CBF15	15.15			3 to 2 phi	2.1		3.65	Stage I on III	10
CBF16	15.23			4 to 3 phi	1.13		4.19	Stage I on III	11
CBF27	15.23			>4 phi	1.53		4.5	Stage I on III	11
CBF28	15.26			>4 phi	1.73		4.31	Stage I on III	11
CBF49	15.86	0.25		>4 phi	1.08		3.73	Stage I on III	10
CBF57	16.88			>4 phi	1.5		4.09	Stage I on III	11
CBF58	13.7			>4 phi	3.04		2.79	Stage I on III	10
CBF59	15.14			>4 phi	2.65	present	4.57	Stage I on III	11
CBF63	17.14		> 3.80	>4 phi	1.21	present	4.68	Stage III	11
CBF65	16.53			>4 phi	2.26		5.11	Stage I on III	11
CBF66	16.37			>4 phi	2		3.76	Stage I on III	10
CBF67	15.74			>4 phi	2.28		4.11	Stage I on III	10
CBF68	15.86			>4 phi	1.64	present	5.68	Stage I on III	11
CBF69	15.92			>4 phi	2.26		4.82	Stage I on III	11
CBF70	16.27			>4 phi	3.16		4.3	Stage III	11
CBF76	15.78			>4 phi	2.13		4.41	Stage I on III	11
CBF77	18.12			>4 phi	0.82	present	5.03	Stage III	11
CBP01	17.22			>4 phi	1.24		4.37	Stage I on III	11
CBP02	16.97			>4 phi	2.2	present	3.45	Stage III	10
CBP03	17.08			>4 phi	3.66		2.32	Stage I on III	9
CBP04	14.98		> 10.79	>4 phi	2.15		3.15	Stage I on III	10
CBP05	12.62			>4 phi	1.49		2.88	Stage I on III	9
CBP06	16.28			4 to 3 phi	4.82	present	4.09	Stage I on III	11
CBP07	15.91	0.09		>4 phi	1.73		3.84	Stage I on III	11
CBP08	17.21			>4 phi	3.43		3.95	Stage I on III	11
CBP09	16.74			>4 phi	3.13		3.98	Stage I on III	10
CBP10	15.95			>4 phi	1.71		3.71	Stage I on III	10
CBP11	16.12			>4 phi	1.51	present	3.52	Stage I on III	10

Station	Avg Prism Pen. (cm)	Dredged Material Thickness Recent (cm)	Dredged Material Thickness Historical (cm)	Grain Size Major Mode (phi)	Avg. Surface Boundary Roughness (cm)	Mud Clasts	Mean RPD	Highest Successional Stage	Median OSI
CBP12	16.28		> 1.02	>4 phi	2.16	present	4.56	Stage I on III	11
CBS01	13.8	0.52		>4 phi	1.38	present	3.74	Stage I on III	11
CBS02	16.36	1.03	> 12.10	>4 phi	1.11	present	3.88	Stage I on III	11
CBS03	16.31		3.85	>4 phi	0.93	present	2.8	Stage I on III	9
CBS04	17.78		> 13.62	>4 phi	1.77	present	4.33	Stage I on III	11
CBS05	11.08	0.83	> 8.29	>4 phi	2.83		3.33	Stage I on III	10
CBS06	13.21	0.63	> 11.40	>4 phi	3.2		3.53	Stage I	6
CBS07	18.11		> 14.05	>4 phi	2.32		3.47	Stage I on III	10
CBS08	14.49	1.12	> 10.31	>4 phi	1.79		3.94	Stage I on III	7
CBS20	14.1	0.43	> 11.55	>4 phi	2		3.99	Stage I on III	11
CBS21	14.37	0.11	> 9.65	>4 phi	3.11	present	3.37	Stage II on III	10
CBT01	17.74			>4 phi	1.63		4.59	Stage III	11
CBT02	16.61			>4 phi	1.93		3.36	Stage III	9
CBT03	14.12			>4 phi	3.13		3.46	Stage I on III	7
CBT07	16.46			>4 phi	2.39		4.17	Stage I on III	10
CBT08	16.65			>4 phi	1.5	present	4.64	Stage I on III	11
CBT13	16.52			>4 phi	3.66		3.25	Stage I on III	10
CBT14	16.27			>4 phi	2	present	3.45	Stage I on III	10
CBZ01	15.78	present		>4 phi	1.19		>1.74	Stage I	5

Note: Grain size major mode ranges can be found in Appendix C.

CBB03-A **CBF77-B**

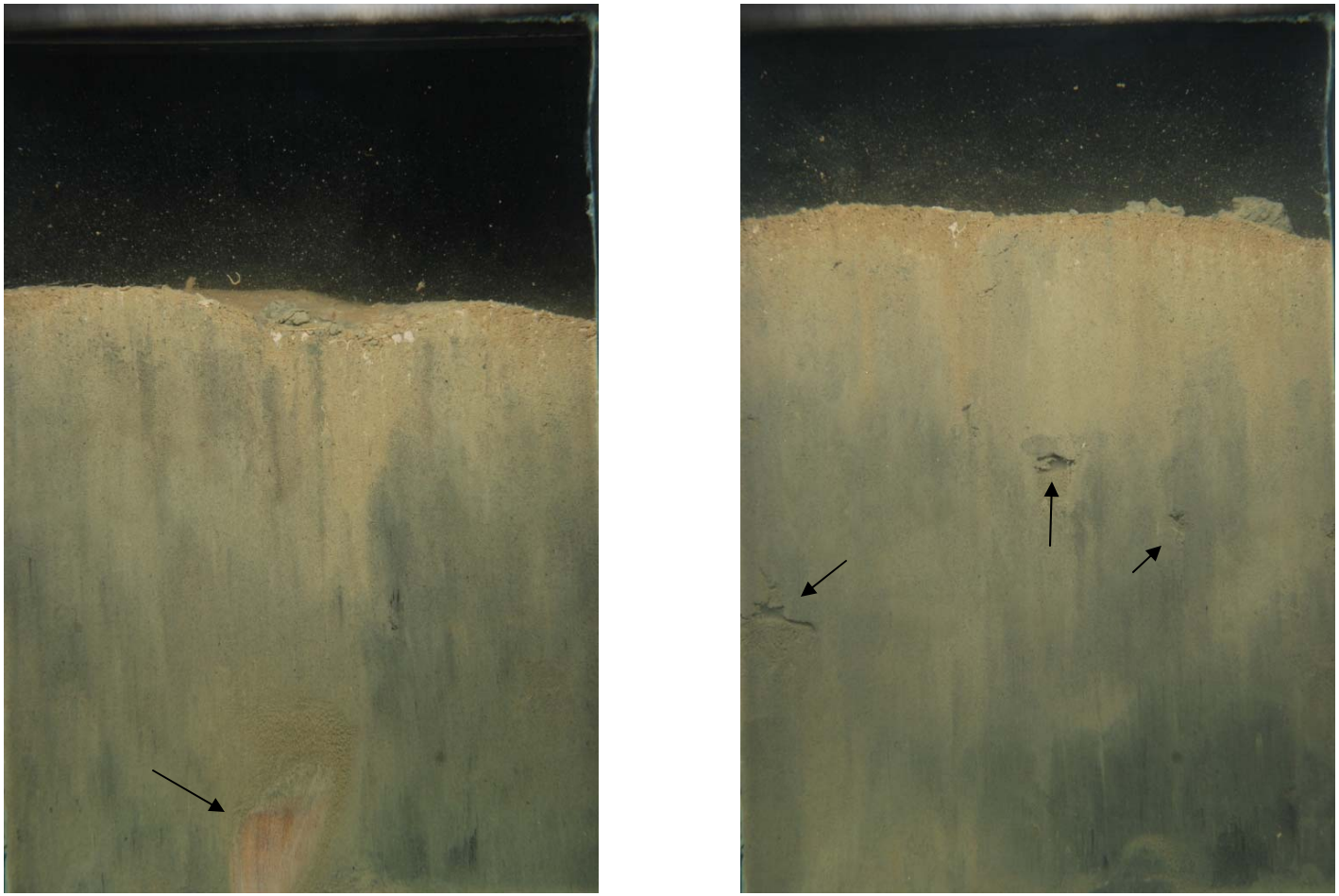


Figure 4-1. SPI images from stations CBB03-A and CBF77-A

Station CBB03 replicate A (CBB03-A) and Station CBF77 replicate B (CBF77-B) showed fine-grained ambient sediments observed near the Commencement Bay DMMP disposal site. Both locations showed relatively deep apparent RPD depths and evidence of well-established benthic infaunal communities. A sea cucumber (*Molpadia intermedia*) was observed at depth at CBB03-A (arrow), and well developed feeding voids were observed at CBF77-B (arrows) created by head-down deposit-feeding organisms (Stage III successional stage). Image width is 14.6 cm.

CBF13-A **CBF28-B**

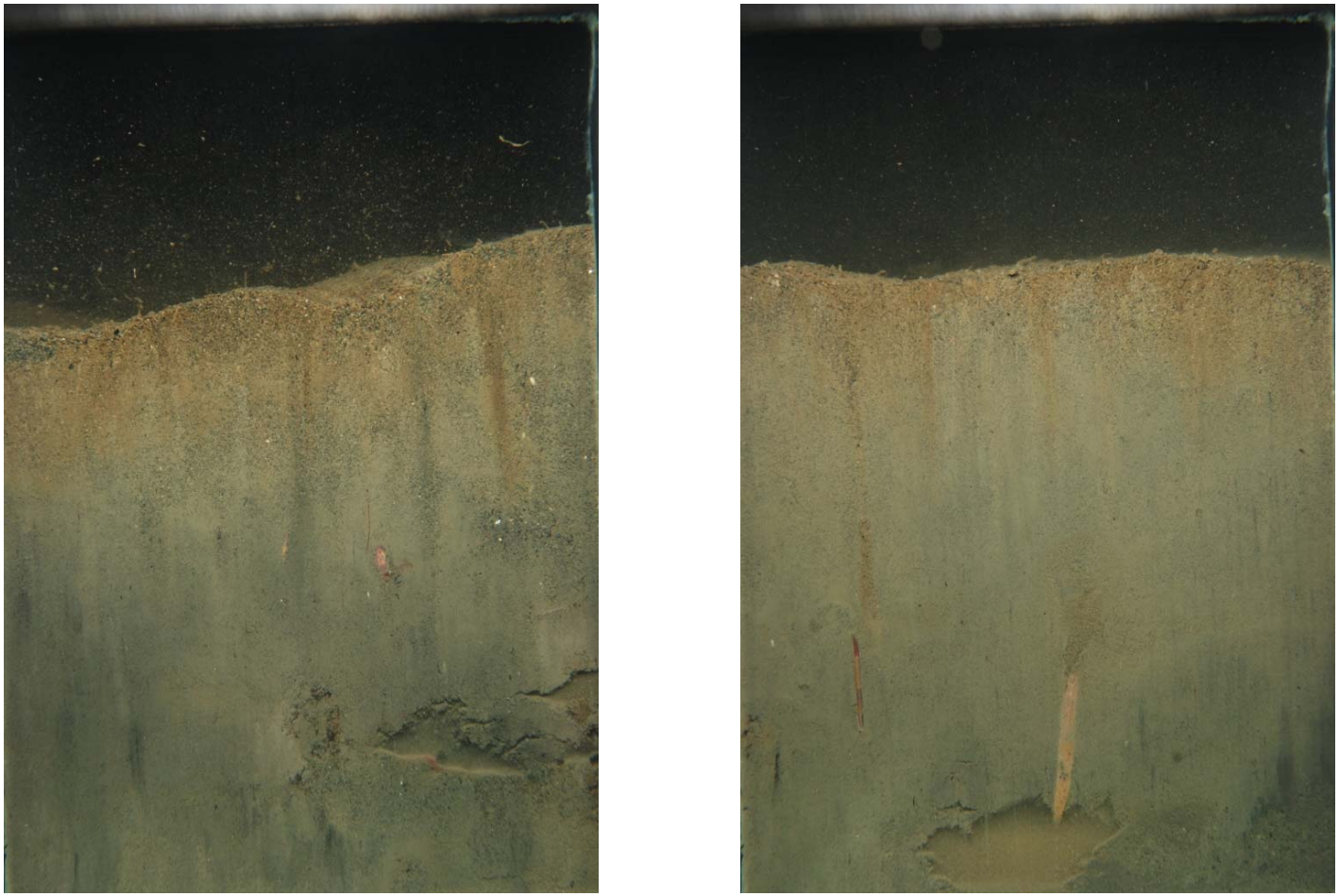


Figure 4-2. SPI images from stations CBF13-A and CBF28-B

Stations CBF13-A and CBF28-A are located to the northwest of the disposal site and showed the presence of ambient sediments containing higher proportions of sand. The sediments consisted of brown to gray silty fine sands grading to gray silt with depth. Both images showed polychaetes at depth with well developed feeding voids created by head-down deposit feeding organisms. Image width is 14.6 cm.

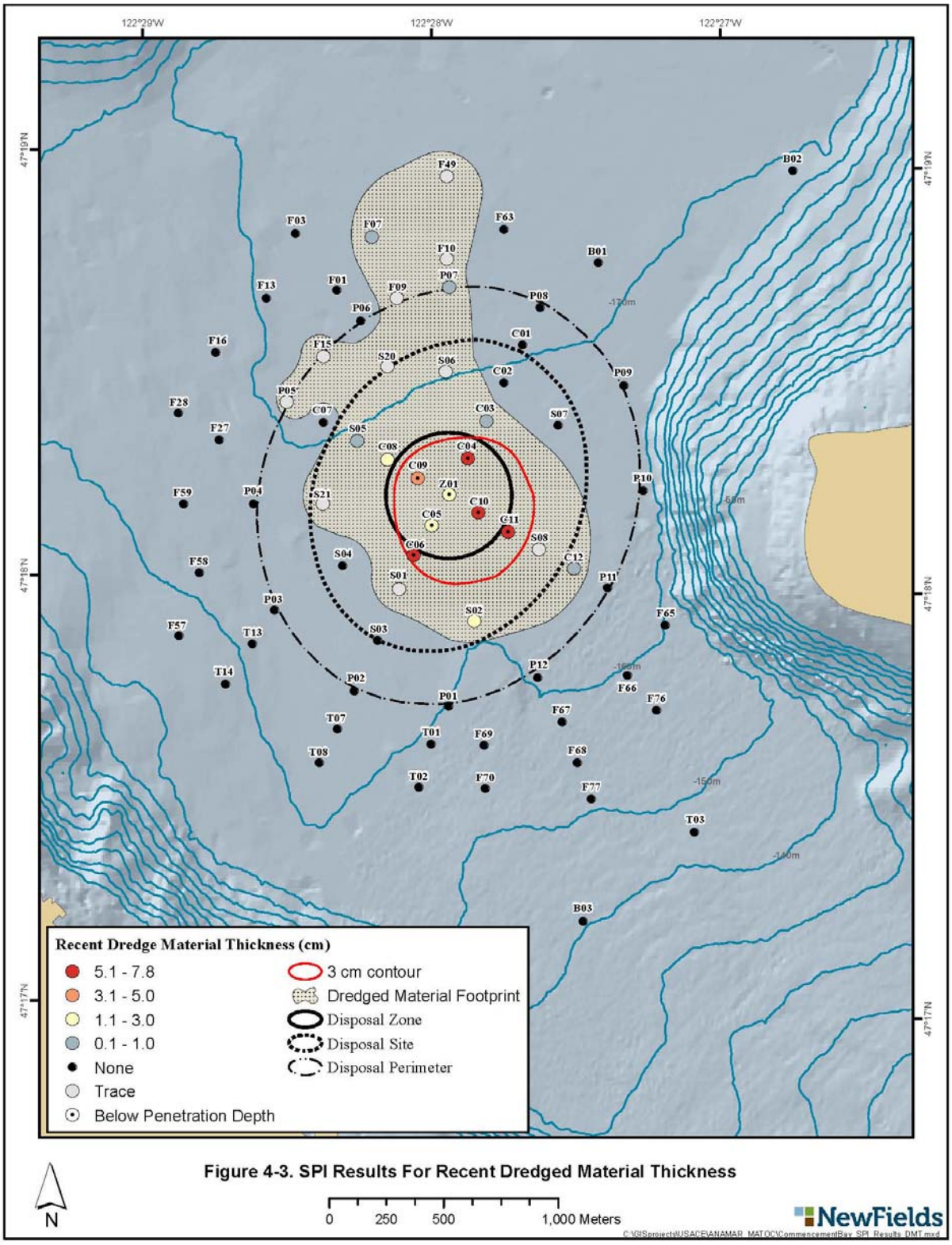


Figure 4-3. SPI Results For Recent Dredged Material Thickness

CBZ01-B **CBC10-C**

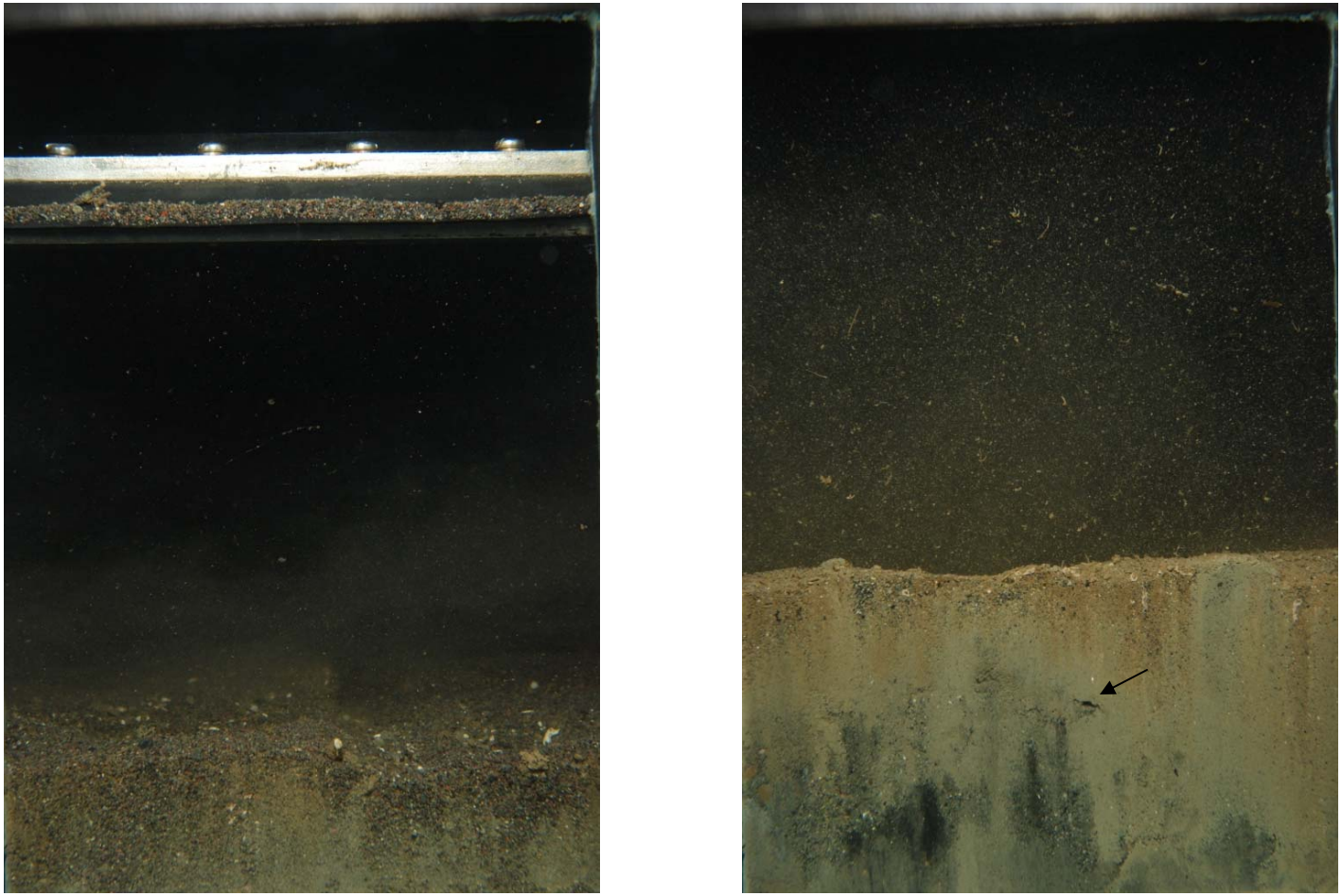


Figure 4-4. SPI images from stations CBZ01-B and CBC10-C

Stations CBZ01-B and CBC10-C are located within the disposal zone and showed the presence of recent dredged material deposits consisting of compact sands intermixed with silt. Camera prism penetration was relatively low due to the coarse-grained consolidated nature of the dredged material. A small feeding void (arrow) was visible within the sediment column at CBC-10A, indicating the recolonization of head-down deposit feeding organisms near the site center. Image width is 14.6 cm.

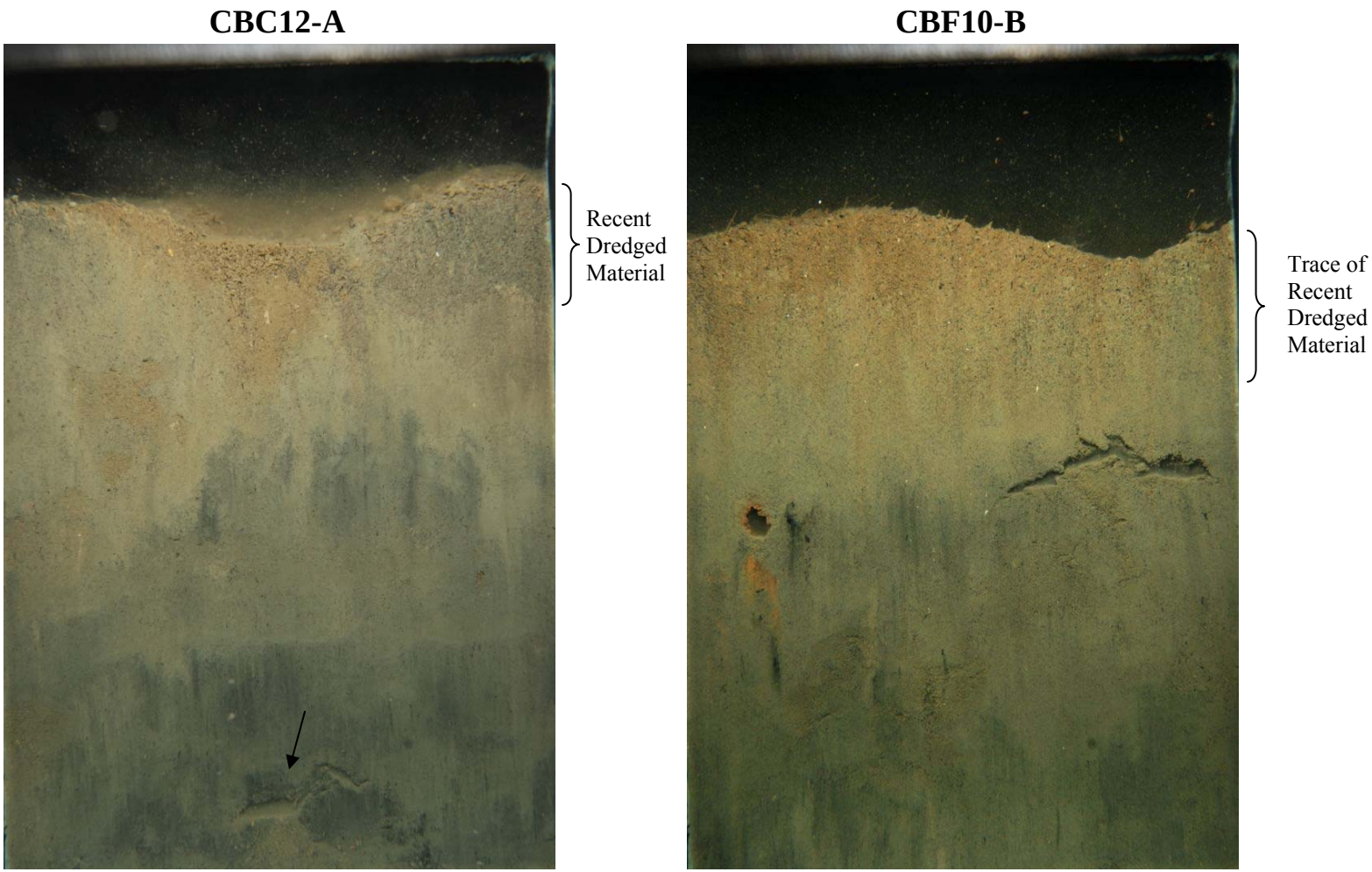


Figure 4-5. SPI images from stations CBC12-A and CBF10-B

Thin layers of dredged material were observed at stations CBC12-A and CBF10-B along the flanks of the dredged material deposit. CBC12-A showed surface concentrations of gray fine sand interpreted to be recent dredged material. Historical dredged material was visible at depth evidenced by discontinuous reduced sedimentary layers and extensive biological mixing (arrow pointing to feeding void at depth). Traces of fine sand mixed in the surface at CBF10-B along the northern flanks of the deposit were interpreted to be recent dredged material. Subsurface sediments are well mixed indicative of ambient sediment conditions. Image width is 14.6 cm.

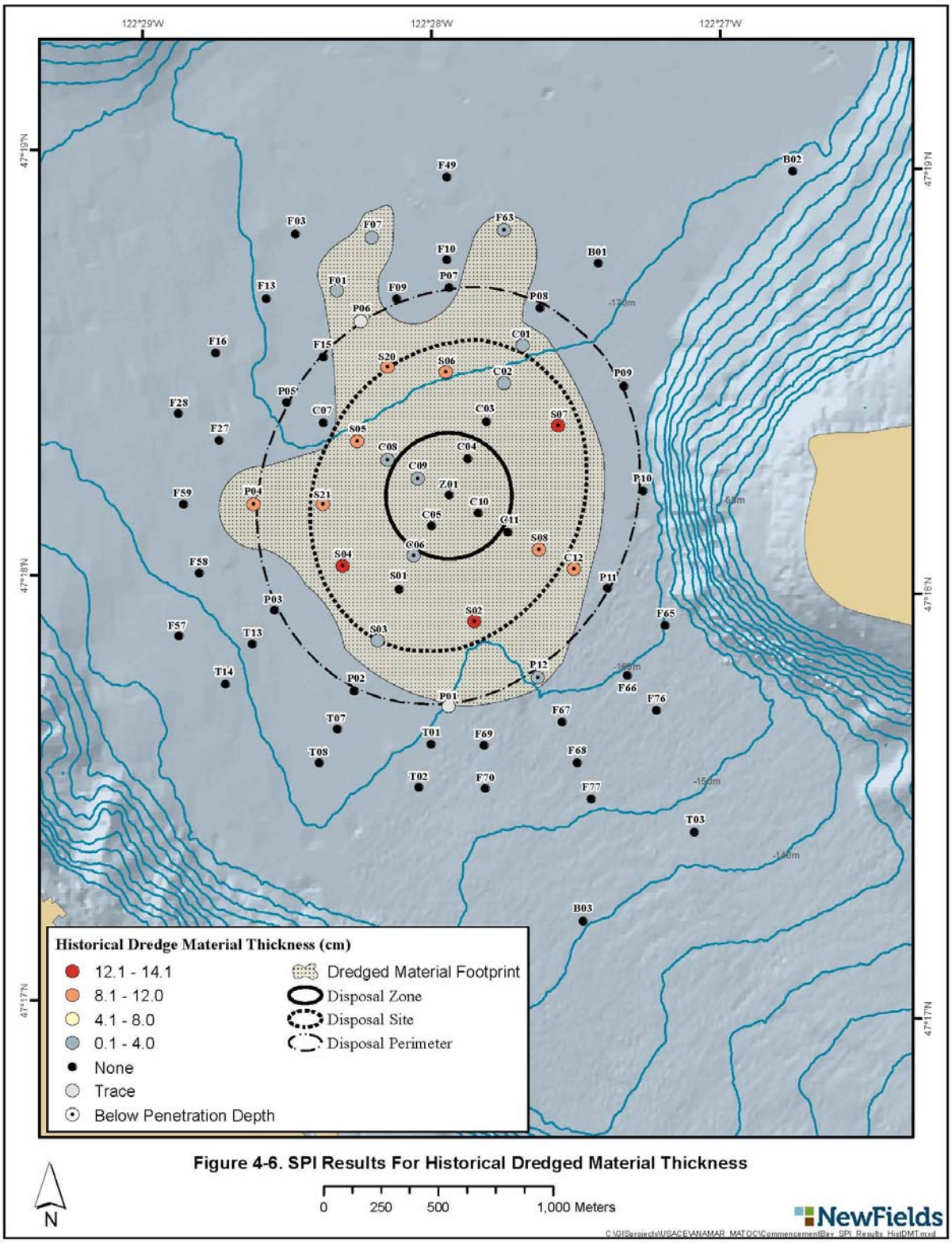


Figure 4-6. SPI Results For Historical Dredged Material Thickness

CBS07-B **CBS21-C**

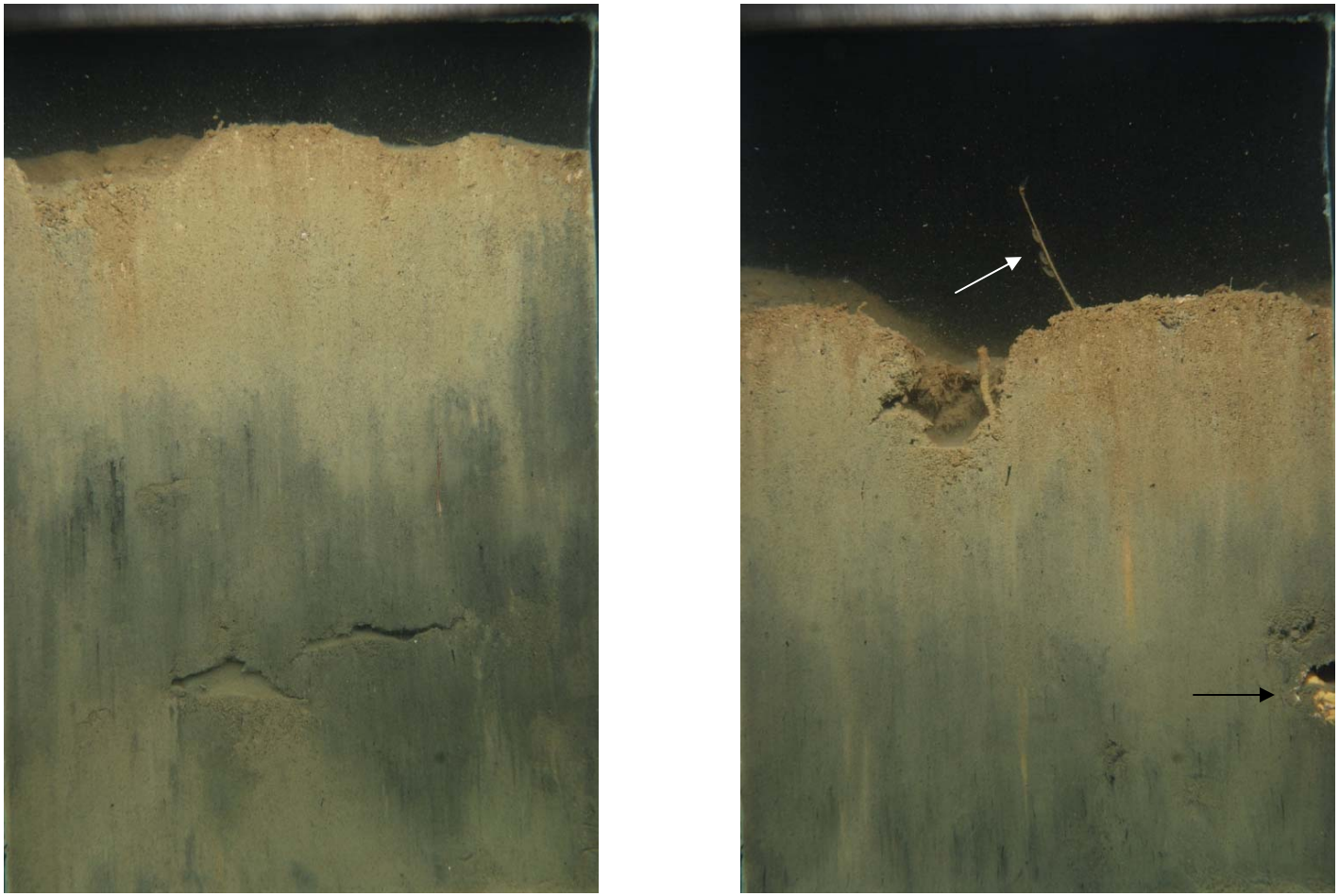


Figure 4-7. SPI images from stations CBS07-B and CBS21-C

Stations CBS07-B and CBS21-C are located onsite within the disposal site boundary and showed the presence of historical dredged material deposits. The historical dredged material consisted of reduced sediments at depth that have experienced extensive mixing by infaunal organisms. CBS07-B showed well developed feeding voids within the reduced sediment layer. The optical signature of the reduced layer was further obscured in CBS21-C with a possible burrowing shrimp (black arrow) at depth. Stick building amphipods (*Podoceridae*) are present on the sediment surface (white arrow), a Stage II infaunal organism. Image width is 14.6 cm.

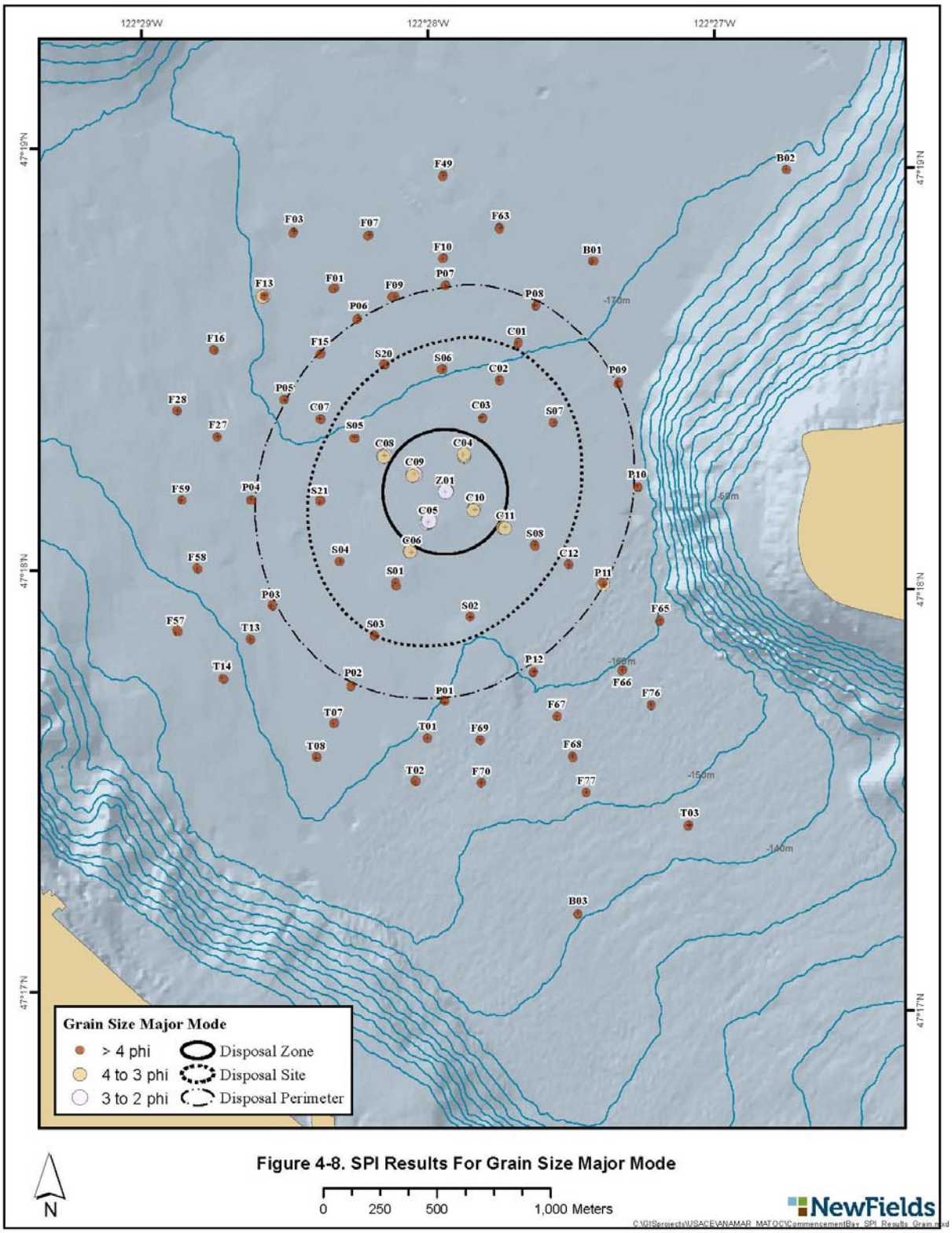


Figure 4-8. SPI Results For Grain Size Major Mode

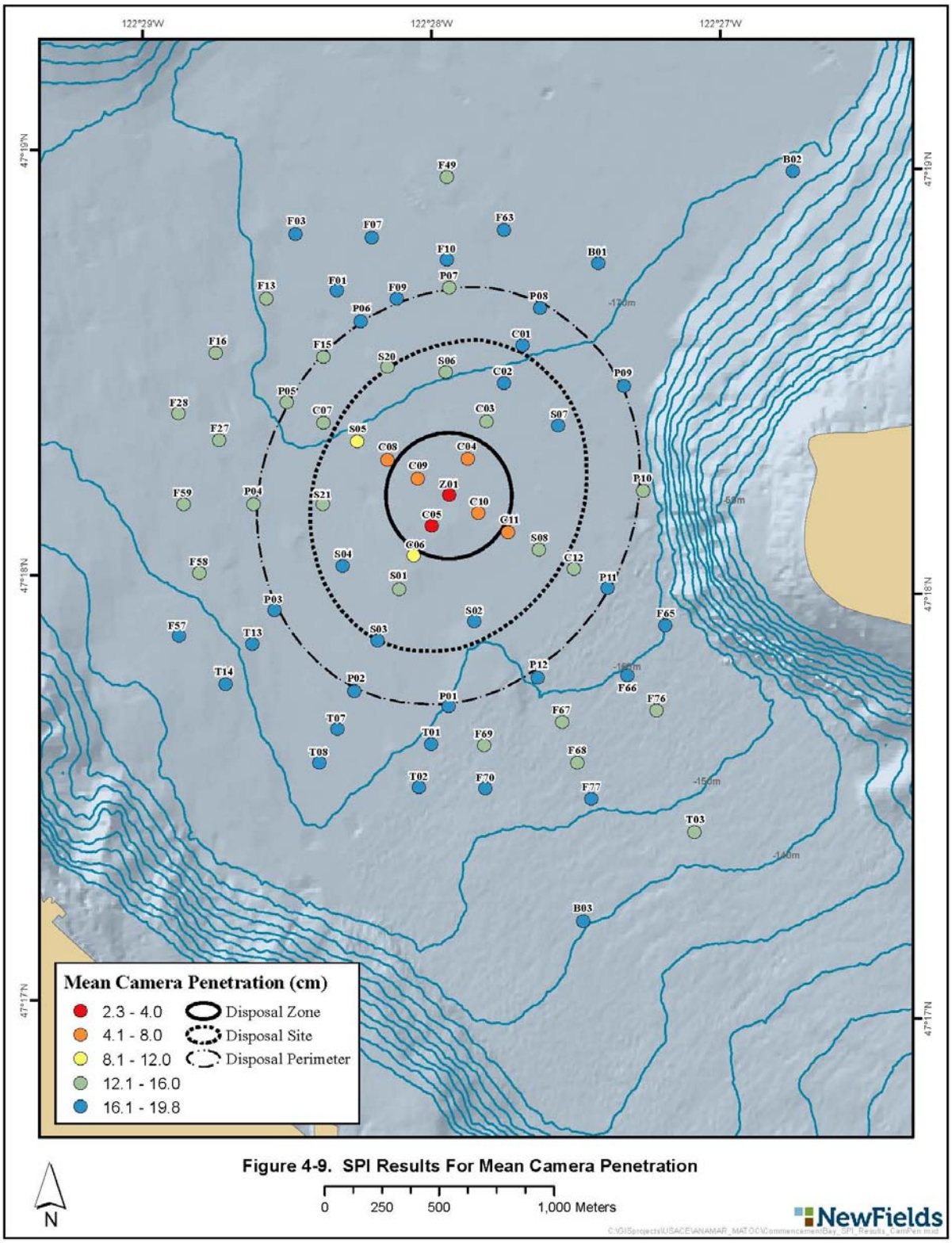


Figure 4-9. SPI Results For Mean Camera Penetration

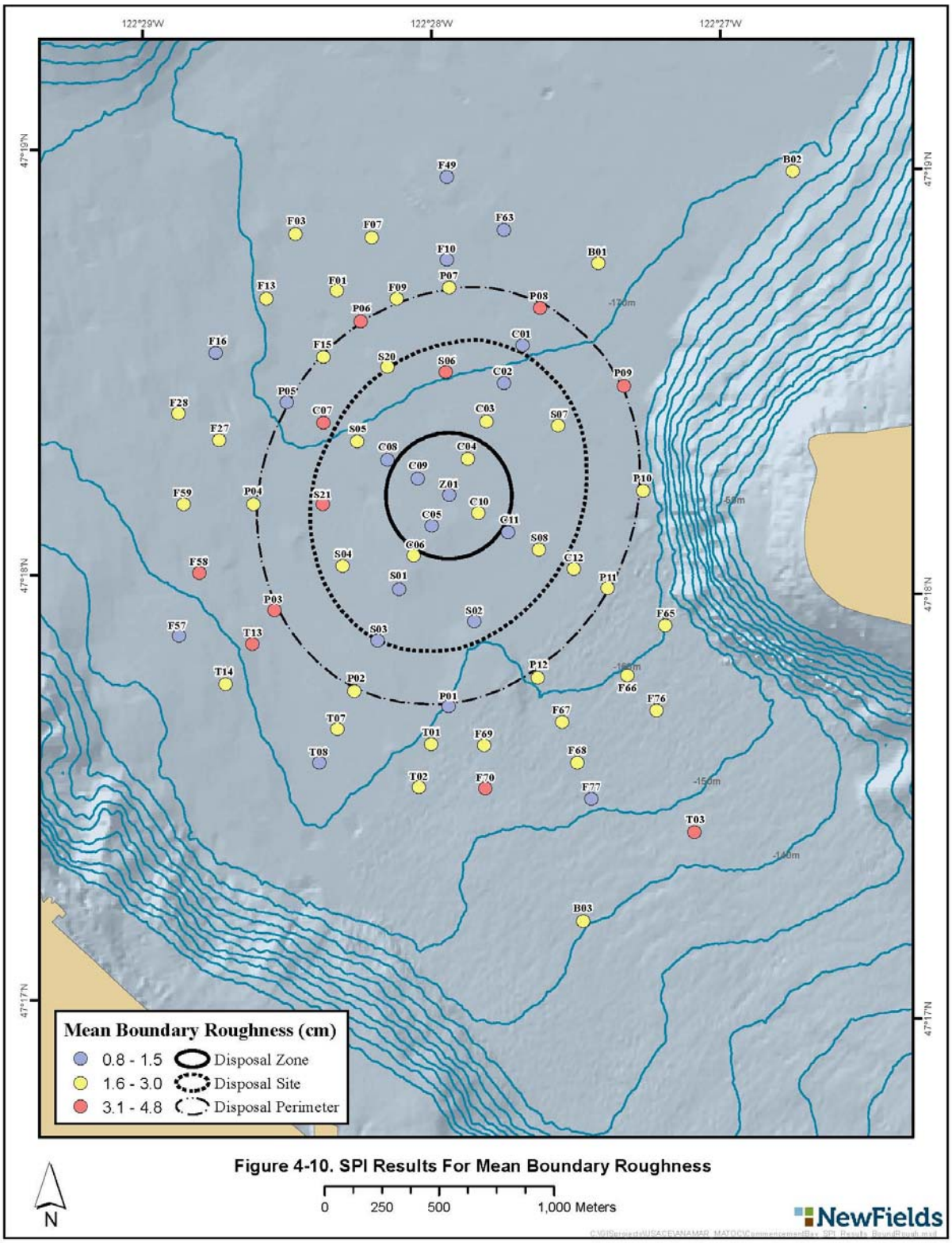


Figure 4-10. SPI Results For Mean Boundary Roughness

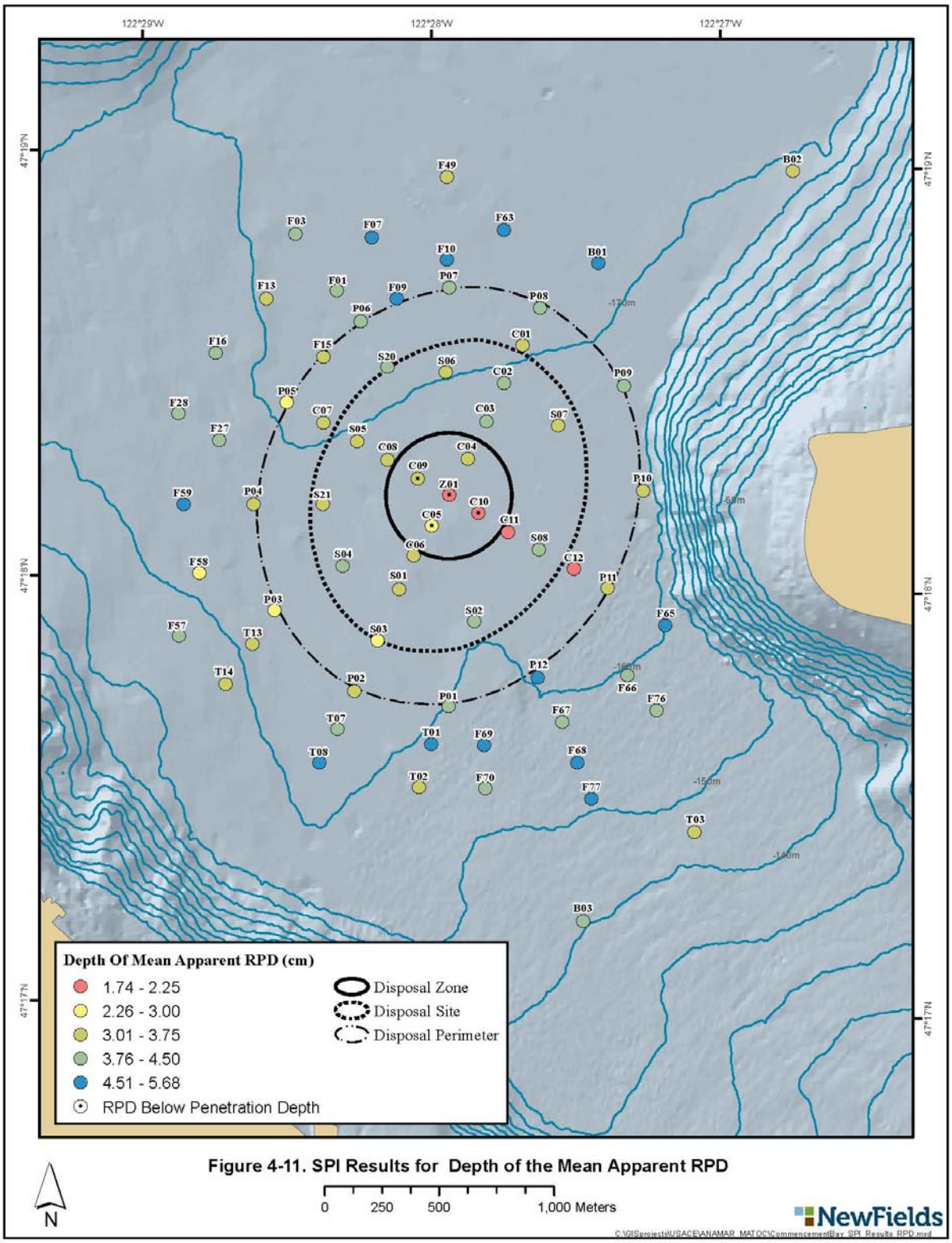


Figure 4-11. SPI Results for Depth of the Mean Apparent RPD

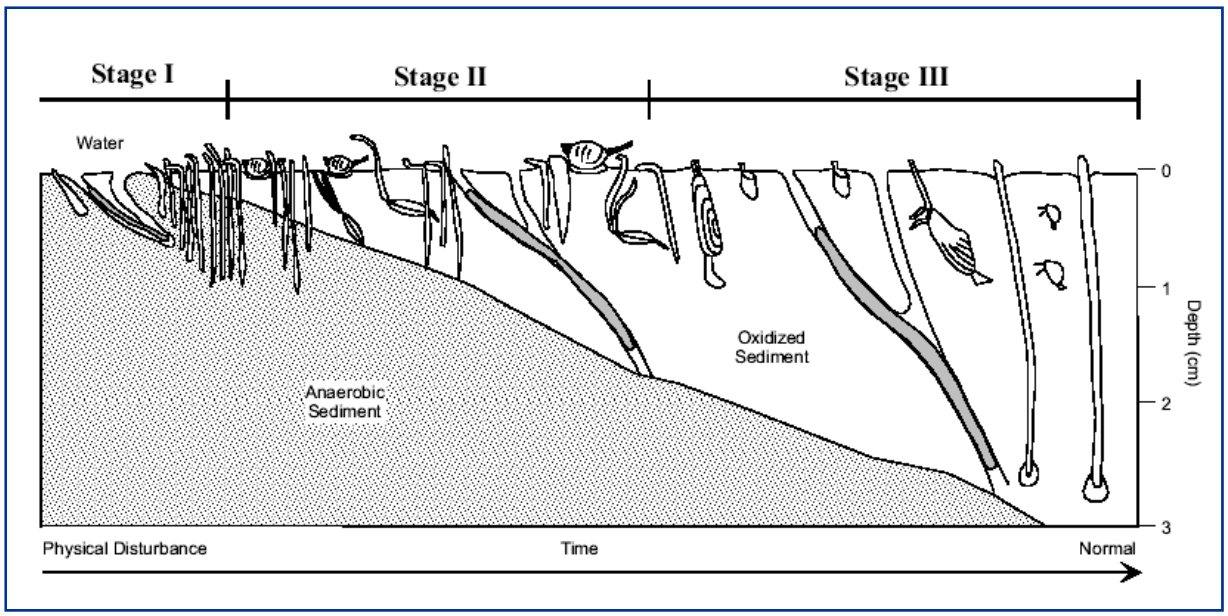


Figure 4-12. Idealized development of infaunal succession stages over time following a physical disturbance

Source: Rhodes and Germano (1986), modified from Pearson and Rosenberg (1978)

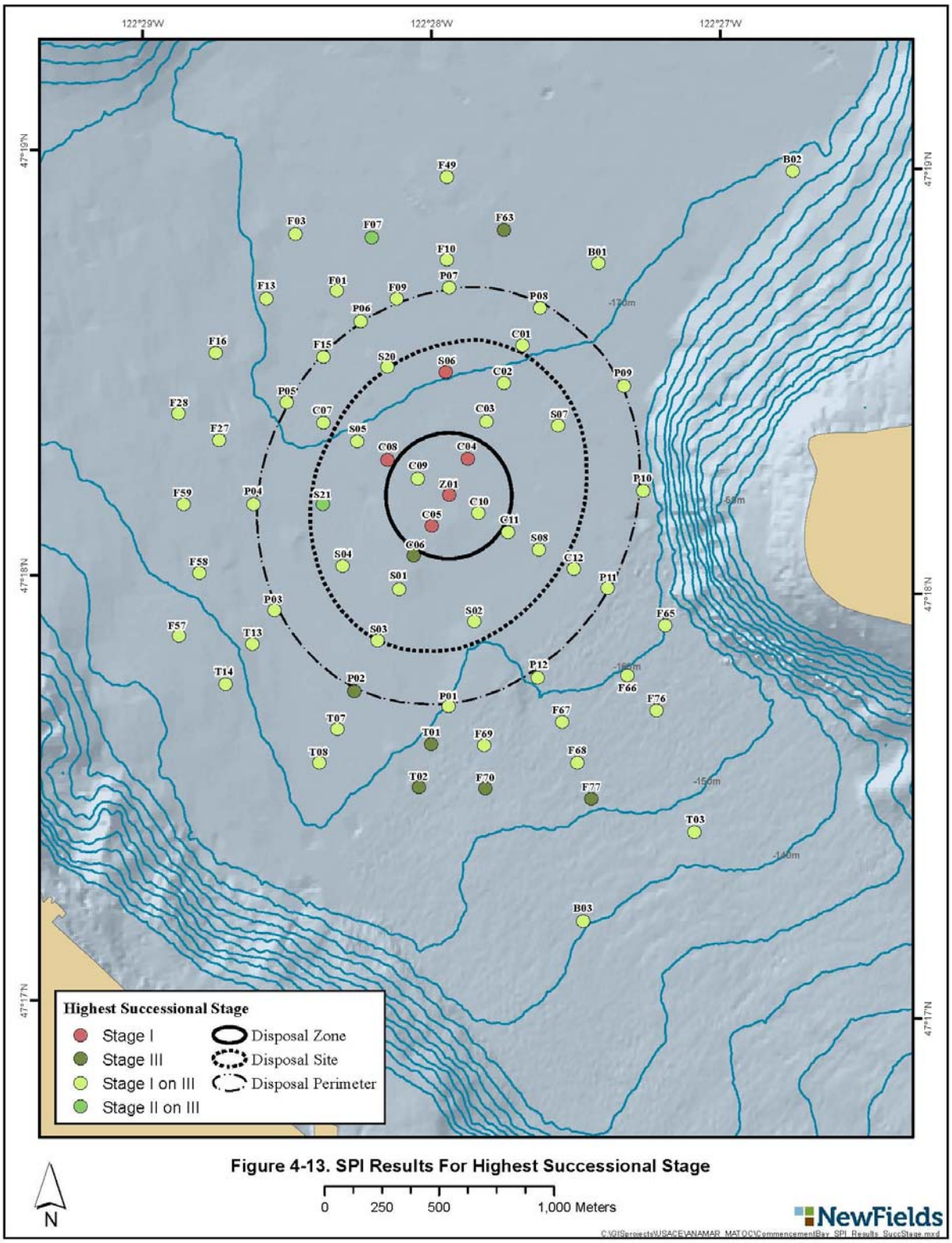


Figure 4-13. SPI Results For Highest Successional Stage

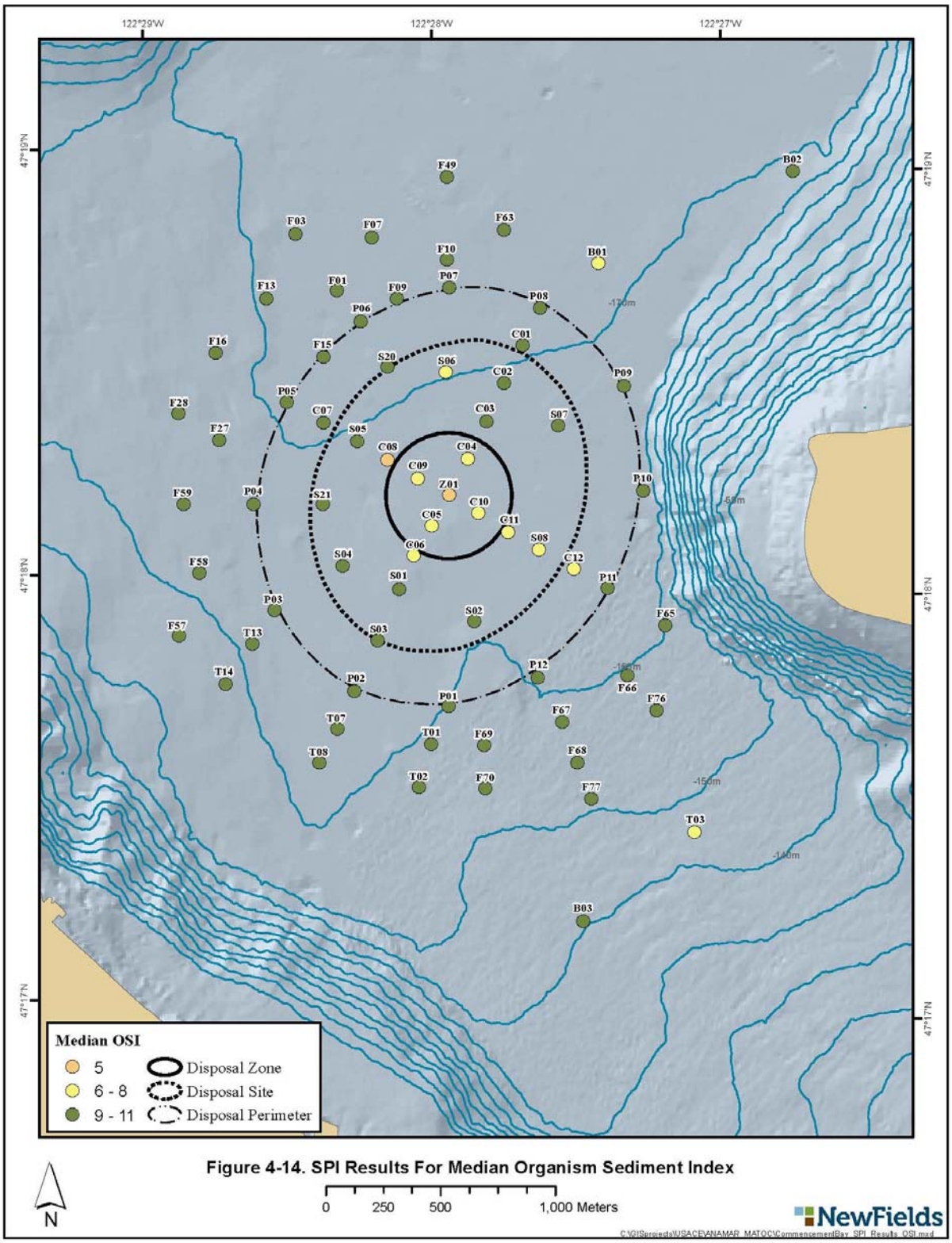


Figure 4-14. SPI Results For Median Organism Sediment Index

4.2 Elliott Bay

Triplicate SPI images were analyzed at 79 EB stations to map the dredged material footprint and physical (grain size major mode, prism penetration depth, boundary roughness), chemical (apparent RPD depth), and biological (successional stage and OSI) characteristics of site sediments. A summary of mean and median values of the SPI results is provided in Table 4-2. The full summary of the image analysis results is provided in Appendix C.

4.2.1 EB Ambient Sediment Characteristics

Ambient sediment characteristics in Elliott Bay have historically consisted of silty fine sand to fine sandy silt in shallower areas to the south and near-shore, and water-rich unconsolidated silt and clay in the central trough region. The 2013 SPI results at the EB site were consistent with these characteristics and example SPI images showing fine-grained ambient sediments are provided in Figure 4-15. Apparent RPD depths were relatively deep in these ambient sediments. Feeding voids were visible indicating extensive bioturbation of surface sediments by head-down deposit-feeding infaunal organisms. The ambient sediment grain size in the southern portion of EB is influenced by the sediment loadings from the Duwamish River. Consequently, coarser tan to gray fine sand was present along the southern and eastern shores of Elliott Bay, appearing in SPI images as homogeneous silty fine sand to fine sandy silt, or sand inter-mixed into the underlying fine-grained sediments (Figure 4-16).

4.2.2 Dredged Material Distribution

Recent dredged material was detected in SPI images collected from 18 stations at the EB site, and the dredged material was confined within the perimeter of the disposal site (Figure 4-17). Dredged material within the disposal zone was composed of light gray silt and clay with some very fine sand, or layers of reduced organic silt and fine sand (Figure 4-18). At the site center (CBZ01), light gray and dark gray silt and clay layers were overlain by tan brown oxidized sandy silt. Along the flanks of the dredged material deposit, recent dredged material consisted of elevated concentrations of fine sand in surface sediments typically overlying historical dredged material deposits (Figure 4-19). The accumulation of recent dredged material was contained within the site perimeter and the 3 cm DMMP criterion for dredged material accumulation was not exceeded.

Historic dredged material was detected in images from 14 stations (three central cross stations and 11 site stations), all located within the disposal site boundary (Figure 4-20). The dredged material was identified as historic primarily if sedimentary layering of the dredged material had been obscured by bioturbation, but the optical signature of the dredged material layers could still be recognized. Examples of historical dredged material observed at the EB site are provided in Figure 4-19. In these examples, a thin layer of recent dredged material was also present above the historical deposit. The overall footprint of historical dredged material was similar to the recent dredged material, which suggests that the dredged material deposition pattern following disposal at the EB site has remained relatively consistent. When disposed, the dredged material appears to settle in and around the disposal zone region and is contained within the disposal site perimeter.

4.2.3 Physical and Sedimentary Features

Physical and sedimentary features determined from SPI images included grain size major mode in phi (Φ) sizes and camera prism penetration. The grain size major mode was >4 Φ at 81% of

the EB stations (64 stations) and 4–3 Φ at 16 stations to the southwest and extending to the northwest along the western rise originating near the mouth of the West Waterway of the Duwamish River (Figure 4-21). The coarser grained sediment observed along this rise is likely attributed to sediment loading by the Duwamish River, which enters Elliott Bay in the southeast and flows across the EB disposal site to the northwest. The Denny Hill re-grade area also appeared to contribute to the coarser grain material observed in the northeast region of the disposal site near the disposal perimeter (Figure 4-22).

Camera penetration depths varied significantly throughout the disposal site (range of 1.34 to 21.07 cm) with a mean of 13.98 cm (± 4.02 cm) (Figure 4-23). The deepest penetration depths were observed in the northern portion of the disposal site and northwest of the disposal perimeter along the transect stations. Generally shallower penetration was observed near the disposal zone. The lowest camera penetration within the disposal zone occurred at a single station within the disposal zone (EBC06) due the presence of compact dredged material (see Figure 4-22). Lower camera penetration was observed at several stations located along the western rise, including two stations within the disposal site boundary (EBS29 and EBS32) as well as perimeter station EBP13. Low penetration was also observed at northeastern perimeter station CBP03 where sands and rocks were present.

Mean bottom boundary roughness measurements (surface relief) during the 2013 SPI survey are shown in Figure 4-24. Similar to Commencement Bay, the boundary roughness was classified as biological at nearly all SPI stations (96 percent of stations) at the EB site. The average surface relief during the 2013 survey was 1.80 cm (±1.21 cm) with a range of 0.2 cm to 7.39 cm. Much of the high surface relief observed could be attributed to biogenic activity that has created large surface burrow excavations (e.g., Figure 4-15). Mean boundary roughness at stations within the disposal site boundary, particularly near the disposal zone, were generally less than surrounding areas due to the presence of dredged material where the presence of large burrows was less frequent.

4.2.4 Chemical and Biological Features

Chemical and biological parameters include the apparent RPD depth, benthic infaunal successional stage, and calculation of the OSI. These parameters provide an assessment of the overall health of the benthic habitat at the Elliott Bay disposal site.

Apparent Redox Potential Discontinuity

The apparent RPD depth estimates the depth of oxygenation in the upper sediment column and provides an estimate of the biological mixing depth by infaunal organisms. Mean apparent RPD depths at the Elliott Bay site range from 1.34 to 4.67 cm, with an average depth of 3.16 cm (± 0.87 cm) (Figure 4-25). The shallowest apparent RPD depths (<2.25 cm) were measured just outside the disposal zone (Stations EBS11, EBS16, EBS20, EBS21 and EBC08). Interestingly, the apparent RPD depths within the disposal zone were slightly deeper, ranging from 1.39 to 4.38 cm with an average of 2.83 cm (± 0.82 cm) (see Figure 4-18).

Benthic Infaunal Successional Stage

Stage I on III benthic communities were observed at 67% of the EB stations (53 stations) and Stage III succession was observed at 27% of the EB stations (21 stations). Two stations within the site boundary (EBC06 and EBS29) and two perimeter stations (EBP03 and EBP08) showed the presence of only Stage I succession. (Figure 4-26). Overall, the EB site benthic community

appears to be in a climax situation with the highest order of succession (Stage III communities) present at 95% of the stations following the most recent dredged material disposal.

Organism Sediment Index (OSI)

The distribution of median OSI values calculated at the EB site is presented in Figure 4-27. Median OSI values ranged from +3 to +11 within the disposal site boundary as well as offsite. The lowest OSI value in Elliott Bay (+3) was observed just outside the disposal zone at station EBS21. Five additional stations within the disposal site boundary (EBS16, EBS29, EBS32 EBC12 and EBC06) had OSI values of +5 or less indicating a potentially distressed or disturbed benthic habitat. The disposal of dredged material within the disposal site boundary is expected to have a short term impact on the benthic community, and lower OSI values are expected following recent dredged material disposal. OSI values of +5 or less were also observed at three perimeter stations (EBP03, EBP08 and EBP13). The sediments at these locations consisted of consolidated coarse grained sediments where Stage III infauna was not present and camera penetration was very low. The majority of stations (87%) had OSI values equal to or greater than +6, which indicates natural or undisturbed benthic habitat throughout much of Elliott Bay.

Table 4-2. Elliott Bay SPI summary table

Station	Avg Prism Pen. (cm)	Dredged Material Thickness Recent (cm)	Dredged Material Thickness Historical (cm)	Grain Size Major Mode (phi)	Avg. Surface Boundary Roughness (cm)	Mud Clasts	Mean RPD	Highest Successional Stage	Median OSI
EBB01	7.47			4 to 3 phi	1.32		2.3	Stage I on III	8
EBB02	13.60			> 4 phi	0.84		3.39	Stage I on III	7
EBB03	17.94			> 4 phi	1.29		3.16	Stage I on III	9
EBB04	15.21			> 4 phi	1.68		2.46	Stage III	9
EBC06	4.04	> 4.04		4 to 3 phi	0.51	present	>2.43	Stage I	5
EBC07	11.65	> 11.65		> 4 phi	1.22		2.96	Stage I on III	8
EBC08	13.08	> 5.83	> 8.37	> 4 phi	1.58		2.18	Stage I on III	8
EBC09	16.58			> 4 phi	2.87		4.53	Stage I on III	11
EBC10	16.68		> 7.87	> 4 phi	1.5		2.91	Stage I on III	10
EBC11	16.32	> 16.33		> 4 phi	0.81		3.66	Stage III	11
EBC12	10.68	> 10.68		> 4 phi	1.08		2.3	Stage I on III	5
EBC13	16.40	3.02	> 11.14	> 4 phi	1.41		2.83	Stage I on III	10
EBP01	17.84			> 4 phi	3.05		2.6	Stage III	9
EBP03	4.60			4 to 3 phi	1.48		2.77	Stage I	5
EBP04	17.06			> 4 phi	1.51		3.04	Stage I on III	10
EBP05	17.93			> 4 phi	1.81	present	4.43	Stage I on III	7
EBP06	17.00			> 4 phi	1.55		3.26	Stage I on III	10
EBP07	12.28			4 to 3 phi	2.28		2.87	Stage I on III	9
EBP08	11.46			4 to 3 phi	1.23		2.55	Stage I	5
EBP09	12.21			4 to 3 phi	0.83		2.83	Stage I on III	9
EBP10	13.36			4 to 3 phi	1.51		2.87	Stage I on III	9
EBP11	11.89			> 4 phi	1.16	present	2.79	Stage I on III	9
EBP12	12.74			> 4 phi	2.05		3.1	Stage I on III	10
EBP13	5.42			4 to 3 phi	3.55		2.33	Stage I on III	5
EBP14	18.17			> 4 phi	1.44		2.88	Stage I on III	9
EBP15	17.03			> 4 phi	2.26	present	3.65	Stage III	11
EBR01	15.62	> 15.60		> 4 phi	1.37		3.79	Stage III	11
EBR02	14.34			> 4 phi	3.18		3.42	Stage III	10
EBR03	8.00			> 4 phi	1.06		>3.04	Stage I on III	7
EBR04	17.65	1.49		> 4 phi	1		3.63	Stage I on III	11
EBR05	16.78			> 4 phi	1.69		3.46	Stage I on III	11
EBR06	15.76	> 15.73		> 4 phi	1.38		2.57	Stage III	9
EBR07	16.25			> 4 phi	1.77	present	3.62	Stage I on III	10
EBS02	17.31	1.36	> 6.71	> 4 phi	1.17		2.27	Stage I on III	7
EBS03	17.77			> 4 phi	1.48		3.99	Stage III	11
EBS04	16.10			> 4 phi	2.1		3.49	Stage I on III	10
EBS05	13.53			> 4 phi	1.49		2.61	Stage III	9
EBS06	17.11	1.84	2.66	> 4 phi	2.12		3.5	Stage III	11
EBS07	15.49			> 4 phi	0.99	present	3.34	Stage III	10
EBS08	8.69	0.45	1.79	> 4 phi	1.65	present	3.25	Stage I on III	9
EBS09	14.96	0.66		> 4 phi	1.97		3.77	Stage I on III	11
EBS10	15.07			> 4 phi	1.48		3.24	Stage I on III	10
EBS11	11.75		> 8.5	> 4 phi	2.23		1.98	Stage I on III	8
EBS12	14.47			> 4 phi	2.5		4.02	Stage III	10
EBS13	15.47			4 to 3 phi	1.69		3.61	Stage I on III	11
EBS14	16.27		2.5	> 4 phi	1.17		4.31	Stage III	11
EBS15	10.67	1.88	> 8.04	4 to 3 phi	1.73		2.34	Stage I on III	9
EBS16	9.92	> 3.63	> 4.58	> 4 phi	1.15	present	1.99	Stage I on III	4
EBS17	15.69		4.07	> 4 phi	1.93		3.11	Stage III	9

Station	Avg Prism Pen. (cm)	Dredged Material Thickness Recent (cm)	Dredged Material Thickness Historical (cm)	Grain Size Major Mode (phi)	Avg. Surface Boundary Roughness (cm)	Mud Clasts	Mean RPD	Highest Successional Stage	Median OSI
EBS18	15.91			> 4 phi	4.41		4.38	Stage III	11
EBS19	15.76			> 4 phi	1.85		3.14	Stage III	10
EBS20	11.67	> 7.77	> 3.47	> 4 phi	1.78	present	2.16	Stage I on III	8
EBS21	9.60	> 9.61		> 4 phi	1.56	present	1.34	Stage I on III	3
EBS22	10.43		2.93	> 4 phi	3.64	present	4.32	Stage III	11
EBS23	12.27			> 4 phi	5.23		3.67	Stage III	10
EBS24	14.82			> 4 phi	1.48		2.94	Stage I on III	10
EBS25	18.70	0.51		> 4 phi	2.46	present	4.67	Stage I on III	11
EBS27	12.52			> 4 phi	2.08		4.41	Stage III	11
EBS28	16.86	> 11.43	> 4.60	> 4 phi	1.78		3.13	Stage I on III	6
EBS29	4.17			> 4 phi	1.86	present	2.5	Stage I	5
EBS30	12.64			4 to 3 phi	1.64		4.11	Stage III	11
EBS31	11.64			> 4 phi	0.84	present	3.38	Stage I on III	10
EBS32	7.44			> 4 phi	1.61	present	2.08	Stage I on III	5
EBS33	10.39			> 4 phi	1.29		3.01	Stage I on III	9
EBS34	12.03			> 4 phi	1.32		2.95	Stage I on III	9
EBS35	18.22			> 4 phi	2.13	present	4.64	Stage III	11
EBS36	9.89			> 4 phi	0.92		3.3	Stage I on III	10
EBS37	17.05			> 4 phi	1.5		4.27	Stage I on III	11
EBT01	13.78	0.23		> 4 phi	2.94		2.58	Stage I on III	9
EBT02	16.39			4 to 3 phi	2.76		2.88	Stage I on III	5
EBT03	15.35			> 4 phi	2.08		2.46	Stage I on III	8
EBT04	16.79			4 to 3 phi	1.59		3.9	Stage I on III	10
EBT05	17.64			4 to 3 phi	2.07		2.92	Stage I on III	6
EBT07	17.98			4 to 3 phi	1.97		3.38	Stage I on III	10
EBT08	16.38			> 4 phi	2.28		2.85	Stage I on III	9
EBT09	18.30			> 4 phi	1.62	present	3	Stage I on III	10
EBT10	16.99			> 4 phi	1.78		3.18	Stage I on III	9
EBT11	17.47			> 4 phi	2.08		3.6	Stage III	7
EBZ01	12.42	> 12.40		4 to 3 phi	2.04		2.43	Stage I on III	9

Note: Grain size major mode ranges can be found in Appendix C.

EBS18-E **EBT03-B**

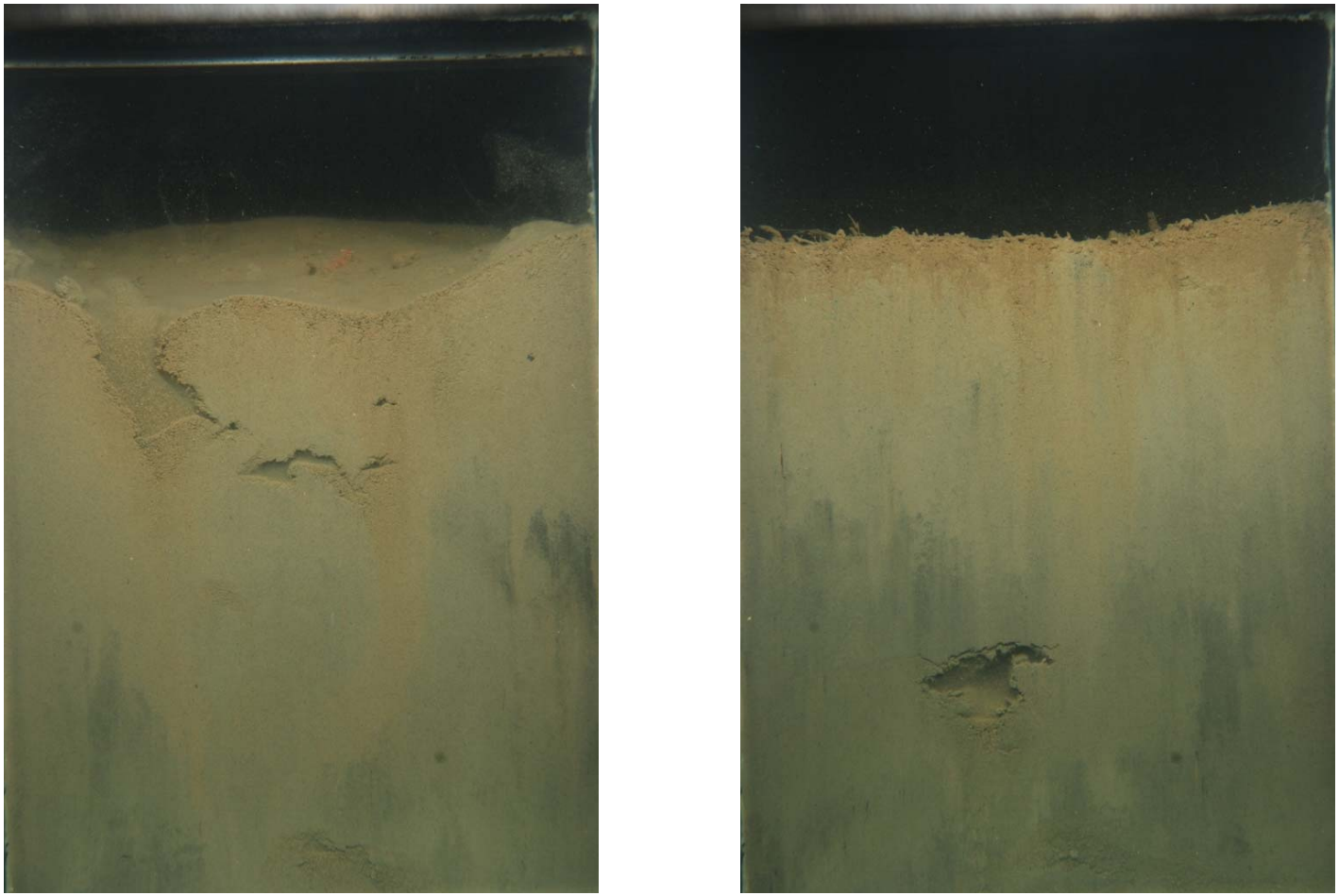


Figure 4-15. SPI images from stations EBS18-E and EBT03-B

Station EBS18-E and EBT03-B showed fine-grained ambient sediments observed in the vicinity of the Elliott Bay DMMP disposal site. Both locations showed homogeneous silt clay with deep apparent RPD depths and evidence of well-established benthic infaunal communities with Stage III infauna. A large surface burrow and void were present at EBS18-E, and a large, well formed feeding void was observed at EBT03-B. Image width is 14.6 cm.

EBP08-B **EBP10-B**

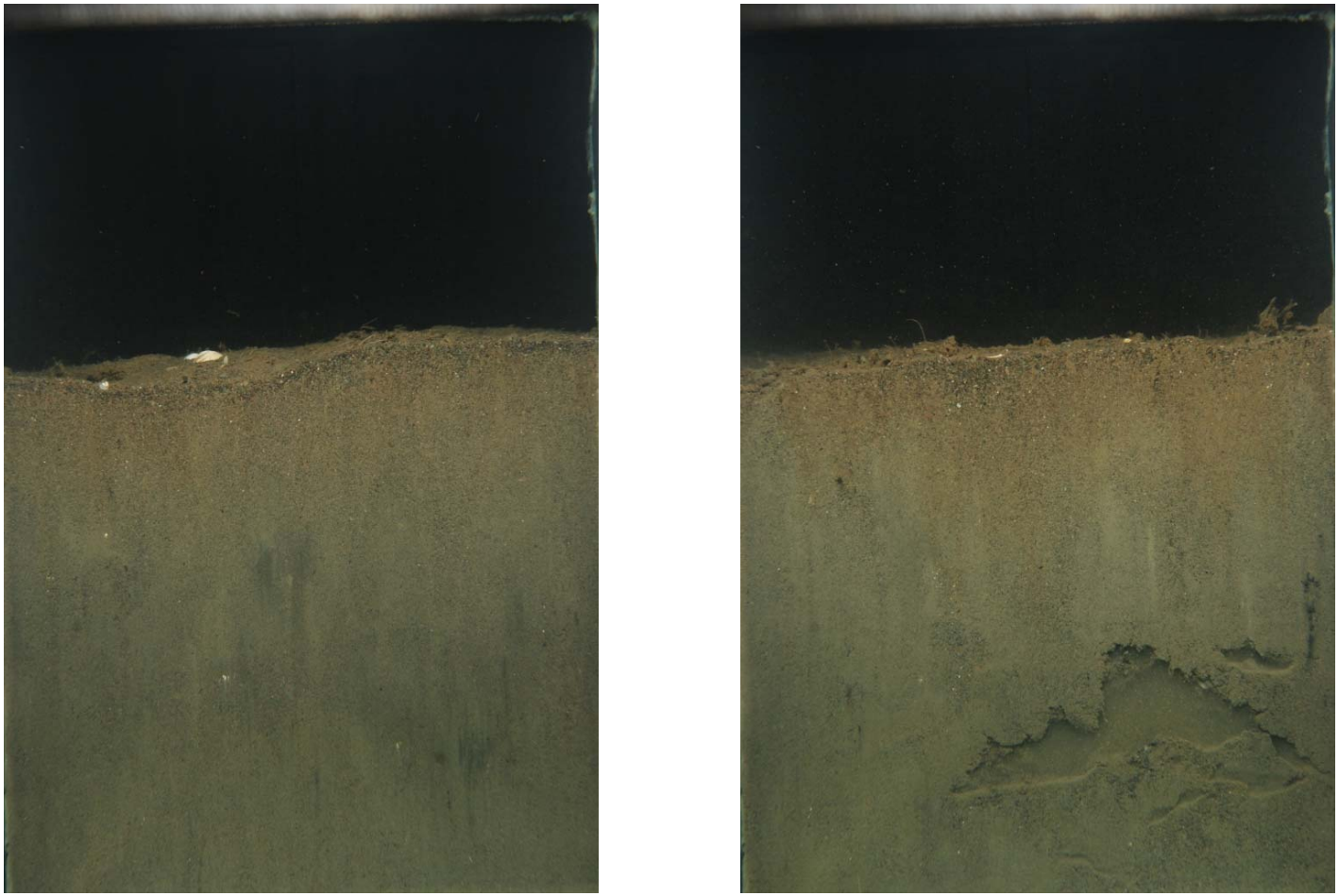


Figure 4-16. SPI images from stations EBP08-B and EBP10-B

Station EBP08-B and EBP10-B, along the south and southwest perimeter showed ambient sediments consisting of tan to gray fine sandy silt. The elevated concentration of sand present in the southern portion of EB was likely due to sediment loadings from the Duwamish River. Stage I surface tubes were visible in both images, and a very large, well developed feeding void was present at depth at EBP10-B. Image width is 14.6 cm.

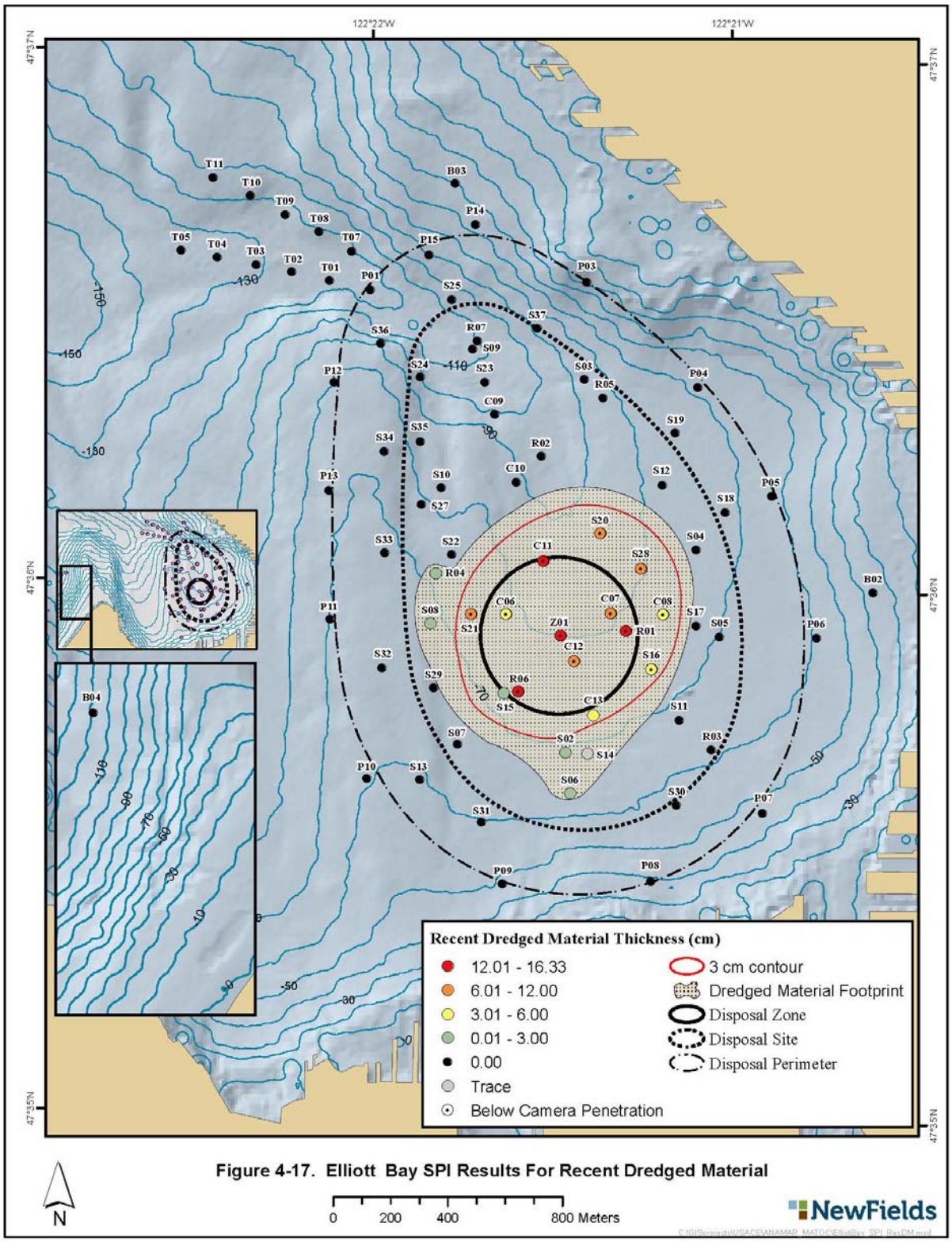


Figure 4-17. Elliott Bay SPI Results For Recent Dredged Material

EBZ01-B **EBR01-B**

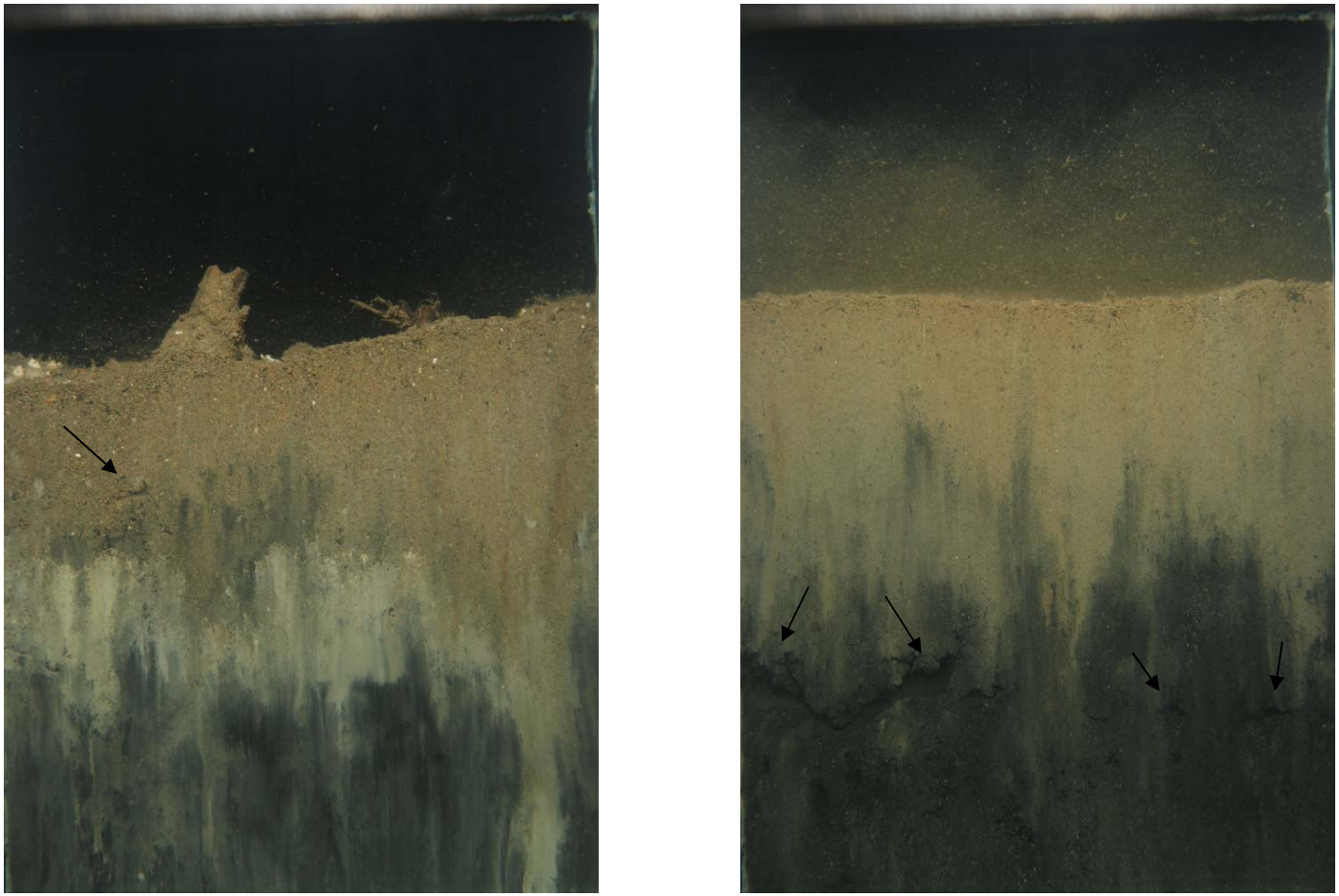


Figure 4-18. SPI images from stations EBZ01-B and EBR01-B

Stations EBZ01-B and EBR01-B showed recent dredged material greater than camera penetration observed at the disposal zone. The recent dredged material consisted of light and dark gray silt clay layers with sand. Both images showed brownish gray fine sand and silt surface layers, which signified relatively deep apparent RPD depths. Woody debris was present at the surface of EBZ01-B and feeding voids (Stage III infauna) were present at the dredged material layer interface (arrows). The subsurface dredged material layers have remained mostly intact. Image width is 14.6 cm.

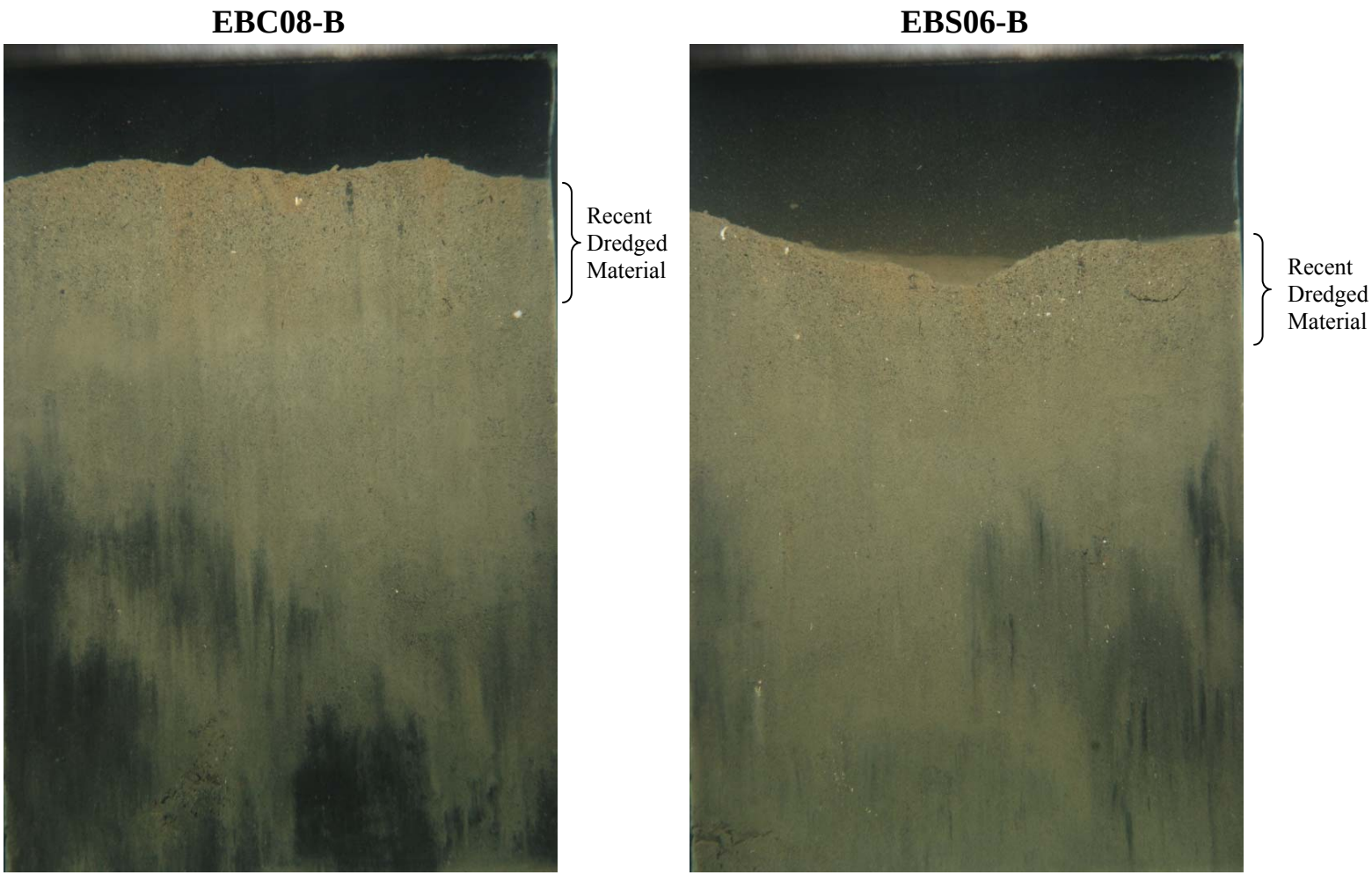


Figure 4-19. SPI images from stations EBC08-B and EBS06-B

Stations EBC08-B and EBS06-B showed thin surface layers of recent dredged material overlying historic dredged material. The recent dredged material consisted of elevated concentrations of fine sand in the upper few centimeters of the sediment surface. The historic dredged material at depth consisted of discontinuous reduced sedimentary layers. Enough time had passed for extensive bioturbation of the dredged material, which masked much of the sedimentary layering. Image width is 14.6 cm.

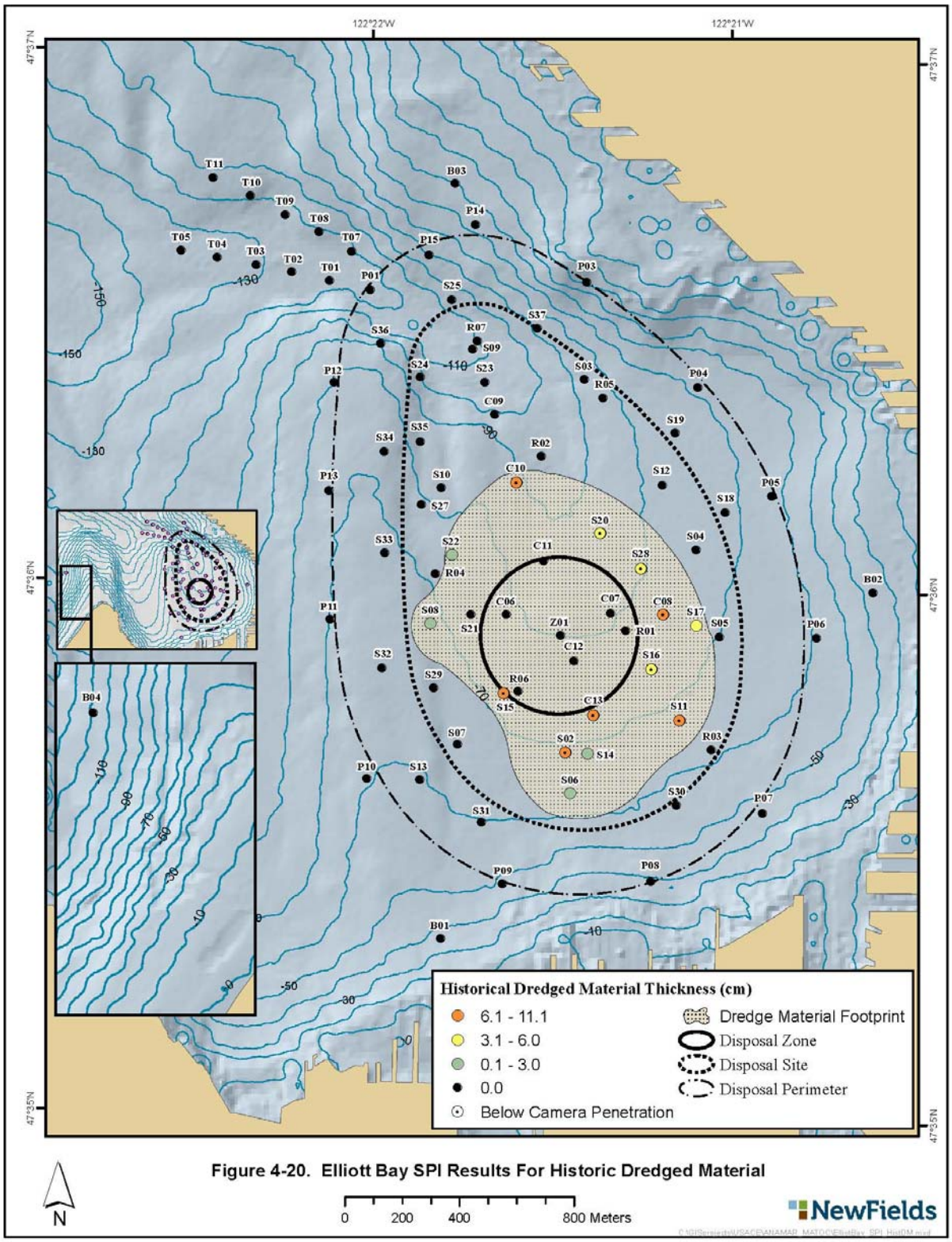


Figure 4-20. Elliott Bay SPI Results For Historic Dredged Material

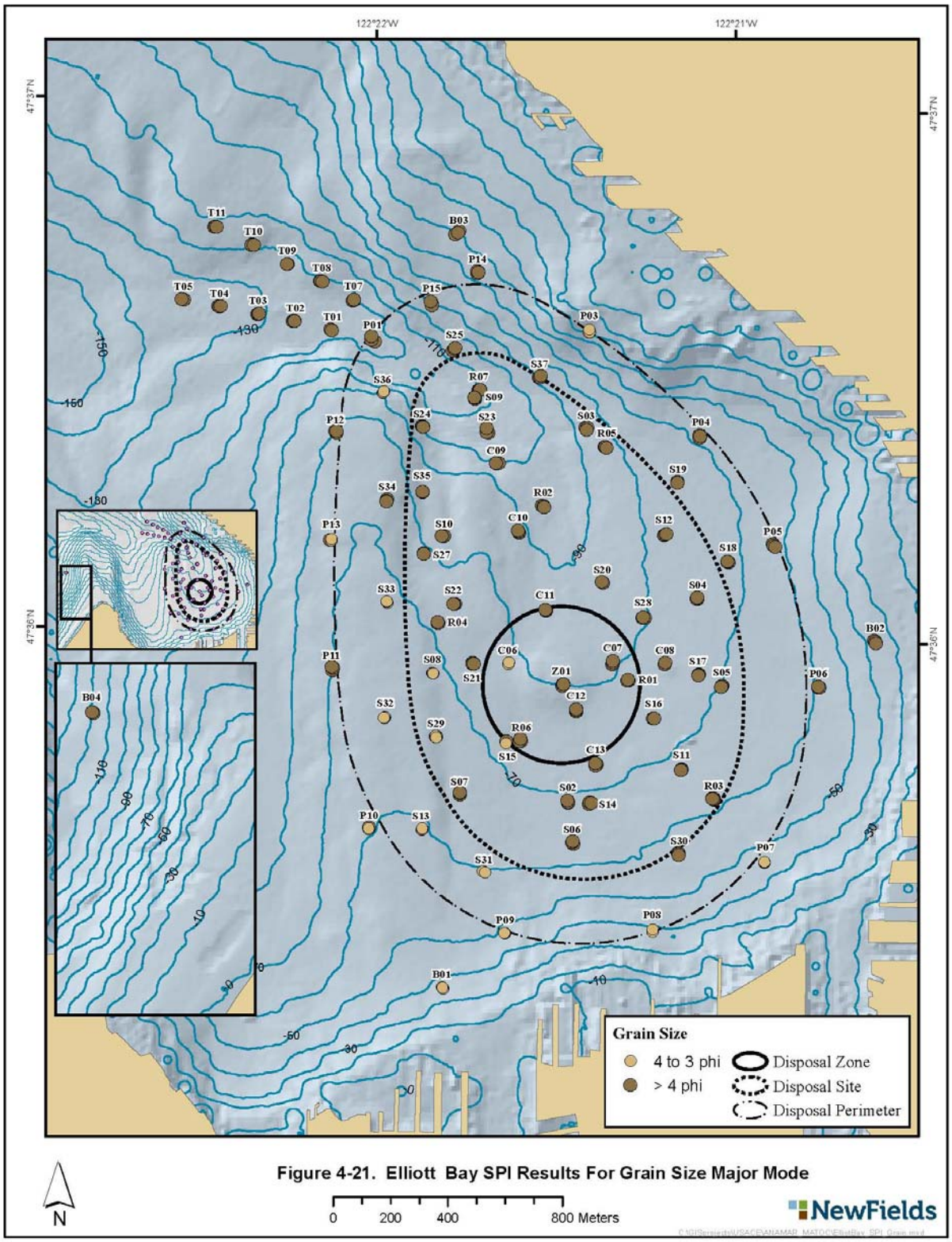
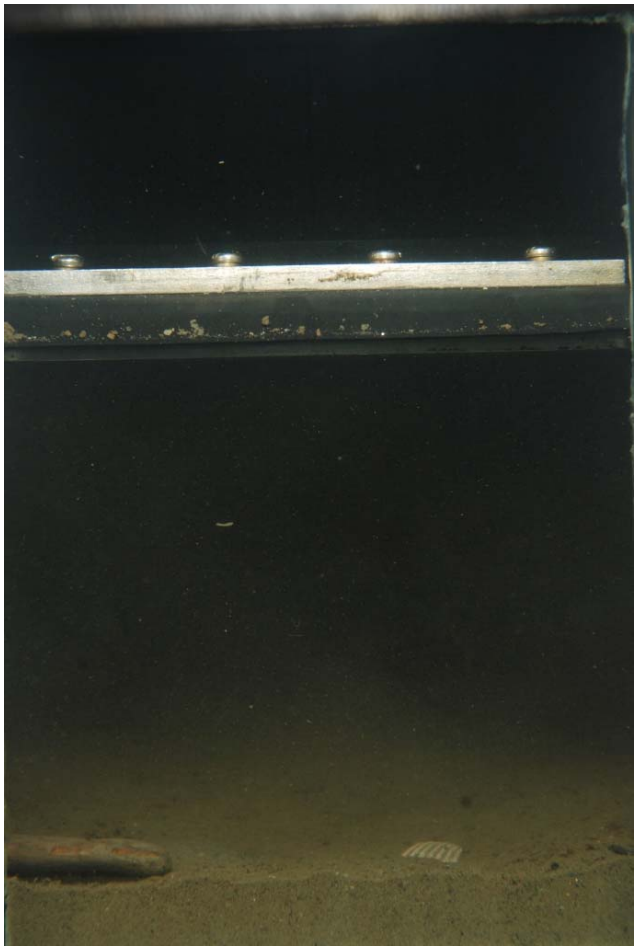


Figure 4-21. Elliott Bay SPI Results For Grain Size Major Mode

EBC06-A



EBP03-B

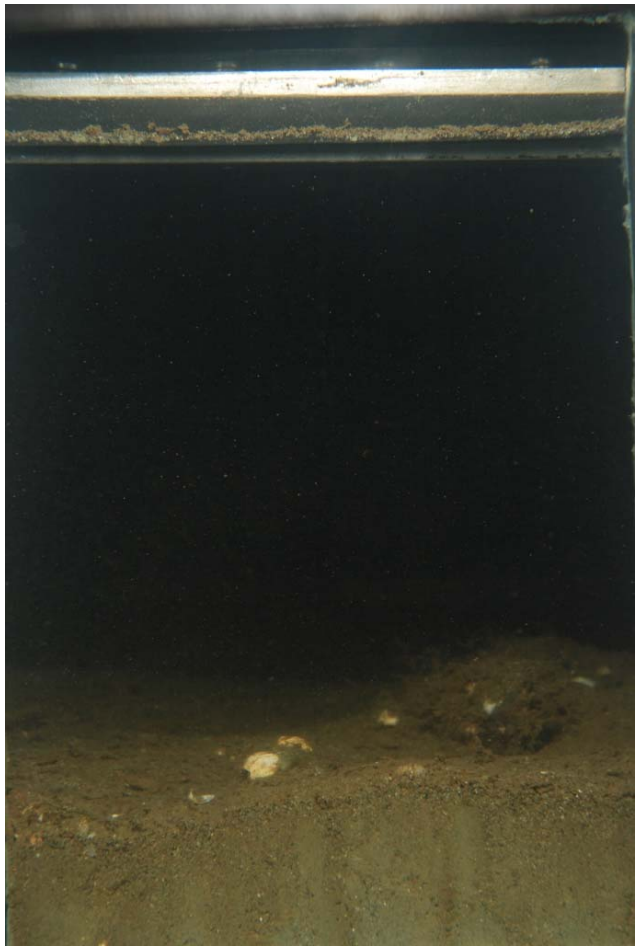


Figure 4-22. SPI images from stations EBC06-A and EBP03-B

Onsite station EBC06-A showed very low camera penetration due to the presence of compact sands, presumed to be dredged material. A rounded wood piece and shell were present on the sediment surface. Perimeter station EBP03-B is located along the northeast perimeter of the site and showed the presence of compact sands and rocks with shell debris. This coarse grained sediment may be related to materials deposited from the Denny Hill re-grade. Image width is 14.6 cm.

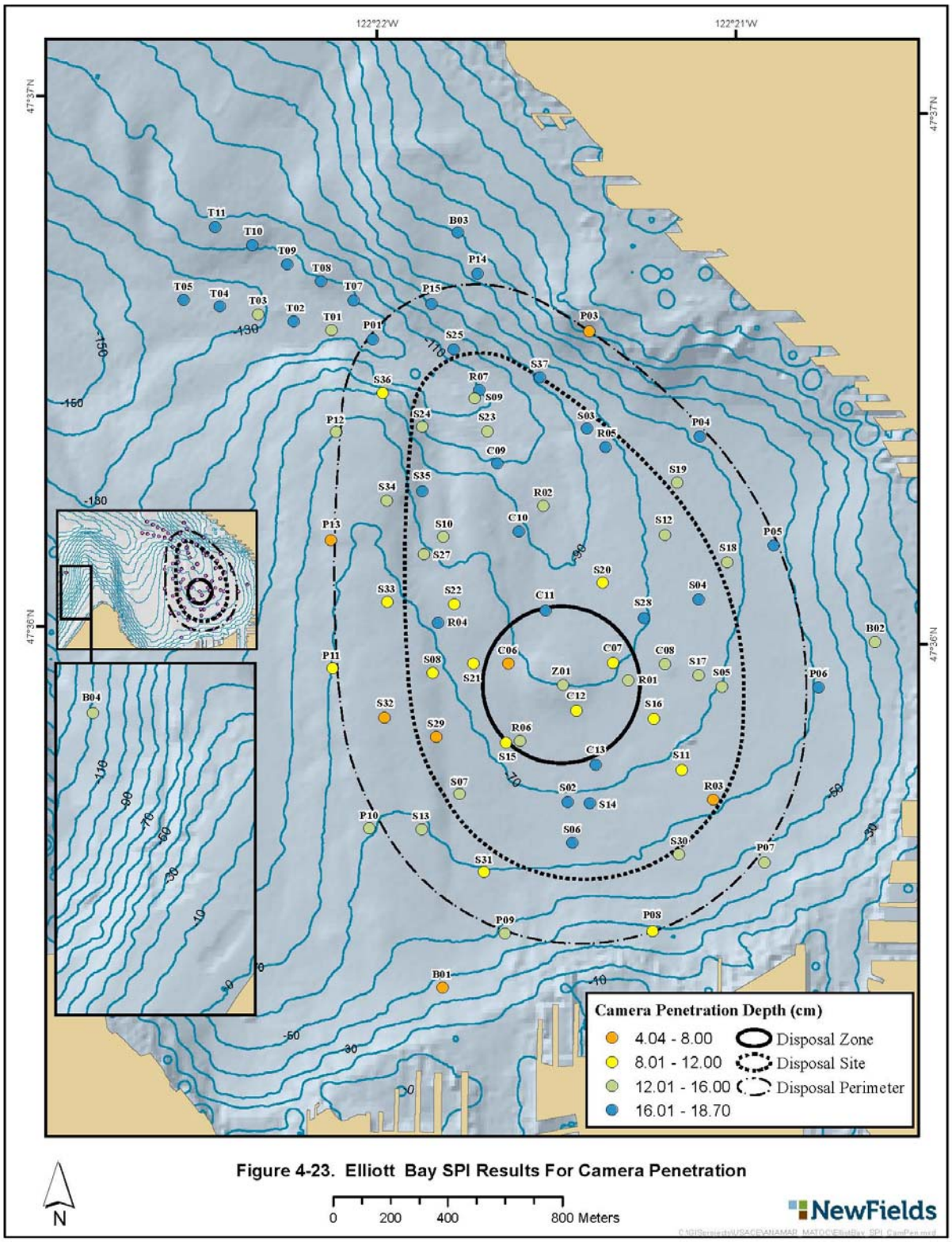


Figure 4-23. Elliott Bay SPI Results For Camera Penetration

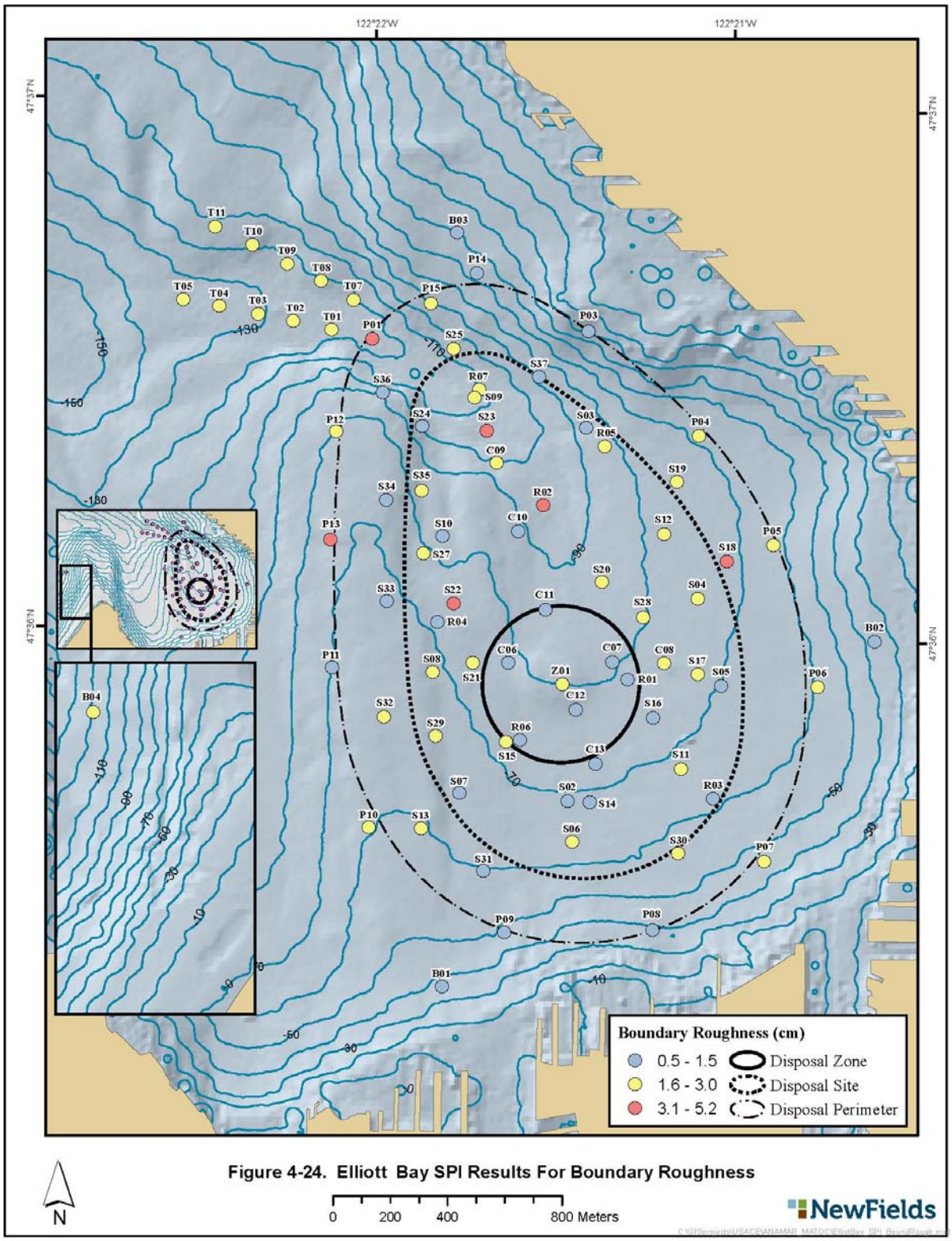


Figure 4-24. Elliott Bay SPI Results For Boundary Roughness

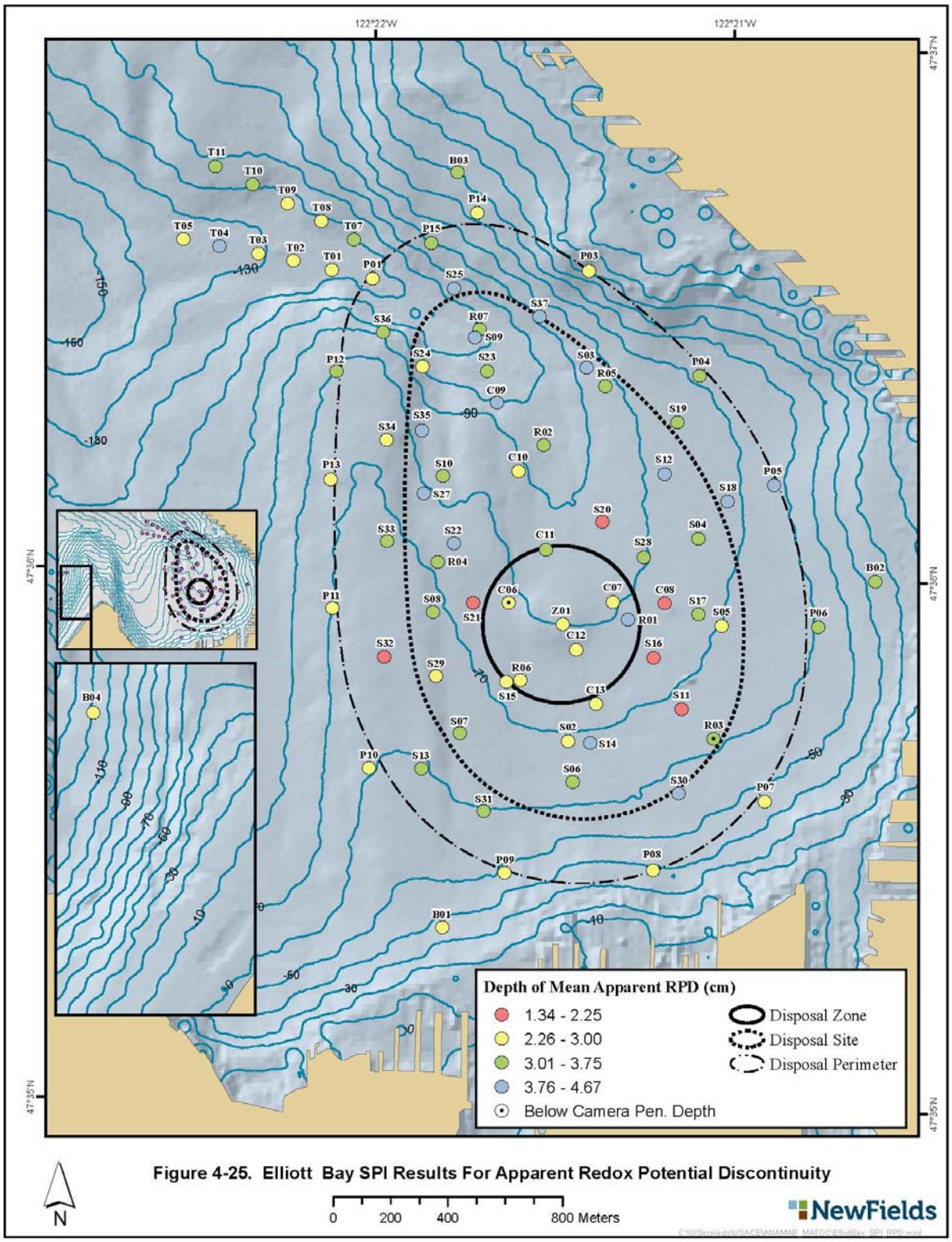


Figure 4-25. Elliott Bay SPI Results For Apparent Redox Potential Discontinuity

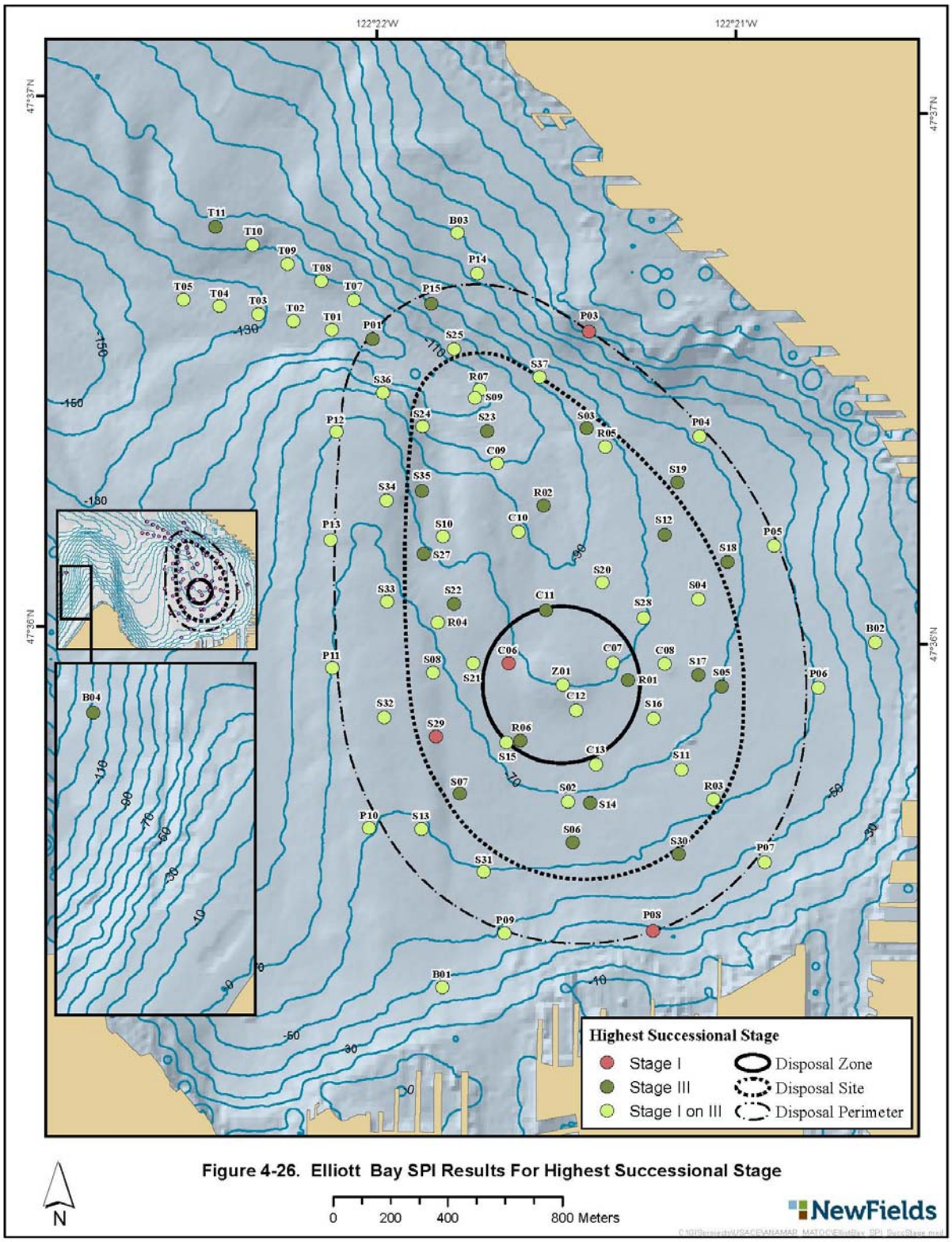


Figure 4-26. Elliott Bay SPI Results For Highest Successional Stage

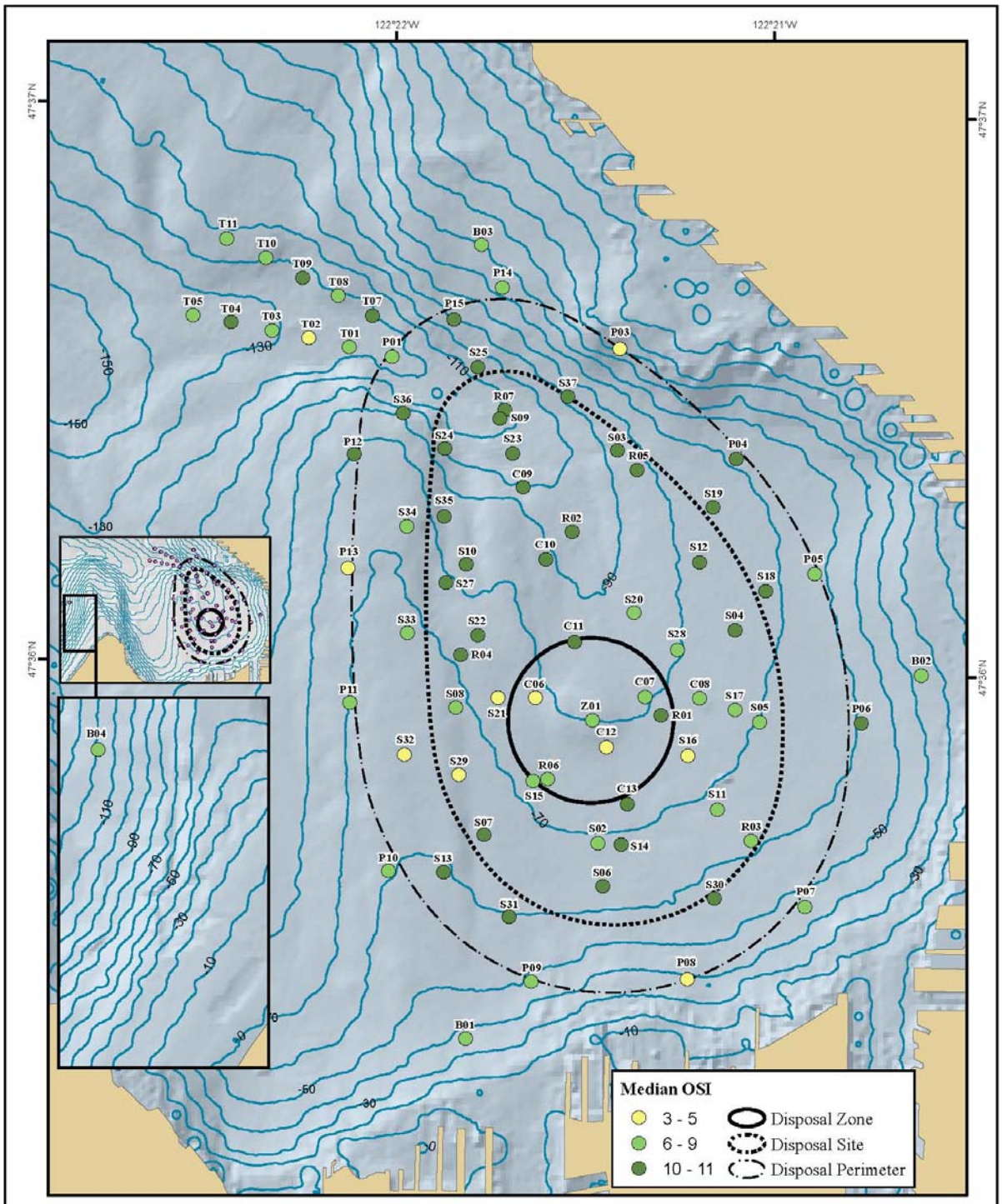


Figure 4-27. Elliott Bay SPI Results For Median Organism Sediment Index

5.0 Evaluation of the Physical Monitoring Data

This section evaluates the 2013 SPI physical monitoring data collected at the Commencement Bay and Elliott Bay sites using the DMMP interpretive guidelines described in Section 2.0. The evaluation is organized according to the questions and hypotheses of the DMMP monitoring framework.

5.1 Question 1: Does the Dredged Material Stay On Site?

5.1.1 Commencement Bay SPI Results

Hypothesis No. 1: Dredged material remains within the disposal site boundary.

The 2013 SPI survey at Commencement Bay did not identify the presence of recent dredged material beyond the disposal site perimeter that exceeded the 3 cm DMMP interpretive criteria. Under the monitoring framework for non-dispersive dredged material disposal sites, ***Hypothesis No. 1 is accepted*** (i.e., dredged material remains within the disposal site boundary). In addition, the 2007 revision of the target disposal coordinates at the Commencement Bay site appears to have shifted the deposition pattern of dredged material slightly to the southeast (see 3 cm contour in Figure 4-3) but the dredged material footprint remains contained within the southeast disposal perimeter.

5.1.2 Elliott Bay SPI Results

Hypothesis No. 1: Dredged material remains within the disposal site boundary.

The 2013 SPI survey at Elliott Bay did not identify the presence of dredged material beyond the disposal site perimeter that exceeded the 3 cm DMMP interpretive criteria. Both recent and historic dredged material remained within the disposal site, which suggests relatively stable dredged material deposition patterns at the site. Under the monitoring framework for non-dispersive dredged material disposal sites, ***Hypothesis No. 1 is accepted*** (i.e., dredged material remains within the disposal site boundary).

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