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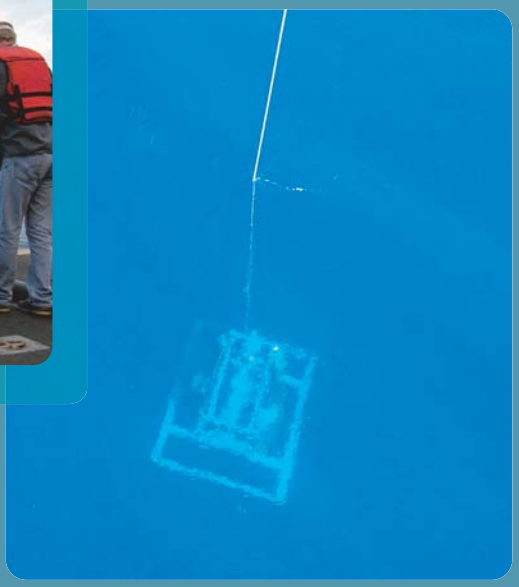
September, 2006

Rapid Seafloor Reconnaissance and Assessment of Southeast Florida Ocean Dredged Material Disposal Sites Utilizing Sediment Profile Imaging

May 2006 Post-Disposal SPI Mapping at the Miami ODMDS



Prepared for:

U.S. Environmental Protection Agency Region 4

Water Management Division,
Coastal Section

61 Forsyth Street
Atlanta, GA 30303

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1.0
INTRODUCTION

1.1 PROJECT BACKGROUND

Region 4 of the U.S. Environmental Protection Agency (EPA) is responsible for management of the three Ocean Dredged Material Disposal Sites (ODMDSs) offshore Southeast Florida: Palm Beach Harbor ODMDS, Port Everglades Harbor ODMDS, and Miami ODMDS. These sites were designated by EPA Region 4 pursuant to Section 102 of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The Site Management and Monitoring Plan (SMMP) for each site outlines a monitoring strategy and, in some cases, specific monitoring techniques and schedules for implementation.

Use of the Miami ODMDS area for dredged material disposal predates 1996 (the year the site was formally designated). Prior to this designation, the sediments in the ODMDS and vicinity were comprised primarily of very fine sands and coarse silt. As part of the Phase II Deepening Project at Miami Harbor, approximately 3 million cubic yards of silt, sand, and limestone gravel was disposed at the Miami ODMDS over the period 1995 to 1999. The Phase II Deepening Project was re-initiated in June 2005 and completed in late November 2005, during which time approximately 1.4 million cubic yards of limestone gravel mixed with fines was disposed within 500 feet of the center of the ODMDS. An additional 72,000 cubic yards of maintenance dredged material (mixture of sand, rock, mud and silt) were disposed in March and April of 2006.

The SMMP for the Miami ODMDS was developed and adopted in 1995 (EPA Region 4 1995). A major focus of the monitoring plan was to address concerns related to the potential offsite transport of disposal plume material shoreward toward near-shore reefs. A second monitoring objective was to assess the potential for long-term transport of dredged material at this site and determine if the 500-ft diameter disposal zone was adequate to contain the disposal mound (including apron) within the site boundaries.

1.2 STUDY PURPOSE

In support of EPA Region 4's on-going monitoring efforts at the Miami ODMDS, scientists from Germano & Associates, Inc. (G&A) conducted a Sediment Profile Imaging (SPI) survey in May 2006. Given the concerns about offsite transport and the significant volumes of dredged material placed at the Miami ODMDS during the Phase II deepening project, the objectives of this SPI survey were to:

- map the spatial distribution of disposed dredged material on the seafloor,
- characterize physical changes in the seafloor resulting from disposal, and
- evaluate benthic recolonization through the mapping of infaunal successional stages.

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2.0
MATERIALS AND METHODS

2.1 MAY 2006 SURVEY LOGISTICS

The SPI survey of the Miami ODMDS was conducted on May 23-24, 2006 aboard EPA's Ocean Survey Vessel (OSV) *Bold*. Scientists from G&A operated the SPI camera with assistance from EPA Region 4 scientists and OSV *Bold* personnel.

The sampling involved the collection of sediment-profile images at a total of 58 stations, which can be broken down as follows (see Figure 2-1):

- Three (3) reference stations (Stations R1 through R3) were located 1.1 miles (1.8 km) to the south of the disposal site center.
- Forty-one (41) stations were located within and to the north of the disposal site (labeled with prefixes A4 through G7 in Figure 2-1).
- Fourteen (14) stations were added in the field (station prefix of "X") based on a preliminary review of the results.

At each sampling station, the SPI camera was lowered onto the seafloor at least four times to ensure that three replicate images suitable for analysis would be obtained. Upon contact of the camera with the bottom, a navigational fix was recorded for each replicate. Due to the strong northward current that exists in this area, the actual location of each replicate tended to be slightly north of the original or "target" station coordinates (Figure 2-2). However, the replicates themselves were located relatively close together (Figure 2-2). The location of each station plotted in Figure 2-1 was determined by averaging the coordinates of the replicate camera drops depicted in Figure 2-2.

The original survey plan called for collecting one or more "plan-view" images of the sediment surface along with the replicate SPI images at each station. These plan-view images were to be obtained using G&A's downward-looking (plan view) camera system attached to the SPI camera frame. During a survey at the nearby Port Everglades ODMDS, conducted just prior to the Miami ODMDS SPI survey, the plan view camera system was sheared off the SPI camera frame by the vessel's winch wire. Although the plan view camera was recovered, it was found to be damaged beyond immediate repair. Therefore, it was not possible to collect the planned seafloor surface images during the Miami SPI survey.

2.2 SPI OVERVIEW

SPI was developed as a rapid reconnaissance tool for characterizing physical, chemical, and biological seafloor processes and has been used in numerous seafloor surveys throughout the United States, Pacific Rim, and Europe (Rhoads and Germano 1982,

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1986, 1990; Revelas et al. 1987; Valente et al. 1992). The sediment profile camera works like an inverted periscope. A Nikon D100 6-megapixel SLR camera, equipped with a 1-gigabyte compact flash card for image storage, is mounted horizontally inside a watertight housing on top of a wedge-shaped prism. The prism is the part that penetrates into the seafloor; it has a Plexiglas® faceplate at the front and a mirror placed at a 45° angle at the back. The camera lens looks down at the mirror, which reflects the image visible through the faceplate.

The prism has a strobe mounted inside, near the back of the wedge, to provide illumination for the image. Because the prism is filled with distilled water, the camera always has an optically clear path. The complete assembly, consisting of the watertight camera housing attached to the top of the water-filled prism, is mounted on a moveable carriage within a stainless steel frame. Onboard a survey vessel, this frame is attached to the winch wire and lowered slowly to the seafloor. Tension on the wire keeps the prism in its "up" position. When the frame comes to rest on the seafloor, the winch wire slackens (Figure 2-3) and the camera prism descends into the sediment at a slow, controlled rate that reduces disturbance at the sediment-water interface. As the prism descends and begins to penetrate into the sediment, it trips a trigger that activates a 15-second time-delay circuit. This time delay allows the prism to penetrate fully into the sediment before the image is taken. After the 15-second delay, the internal strobe discharges and the camera's shutter releases. In this manner, the camera takes a picture of the sediment-water interface and the upper portion of the sediment column that is in direct contact with the prism's Plexiglas® faceplate (i.e., a sediment cross-section or "profile" image). The resulting images give the viewer the same perspective as if looking through the side of an aquarium that is half-filled with sediment.

During the Miami ODMDS SPI survey of May 2006, the camera was lowered onto the seafloor four times at each sampling station, while the vessel maintained position at the sea surface. After the first drop, the camera frame was raised by the vessel's winch to a height of about 2 to 3 meters above the sediment surface, giving the strobe sufficient time (5 seconds) to recharge. The camera was then lowered immediately for the second drop, and, after the 15-second time delay and camera firing, the entire process of raising and lowering the camera was repeated again for the third and fourth drops. As depicted in Figure 2-2, the station replicates were typically very close to each station's target coordinates and within several meters of each other. In general, SPI surveys can be accomplished rapidly by "pogo-sticking" the camera across an area of seafloor while recording positional fixes on the surface vessel.

Most the sediments at the Miami ODMDS stations consisted of fine sand with varying amounts of silt. Because the sand was relatively firm, a full set of lead weights (250 lbs total) was added to the camera frame at the beginning of the survey to ensure that the prism penetrated to the maximum extent possible. Electronic software adjustments also were made to control the settings of the Nikon D100 digital camera. Camera settings (F-stop, shutter speed, ISO equivalents, digital file format, color balance, etc.) were selected

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through a water-tight USB port on the camera housing and Nikon Capture® software. For the May 2006 survey at the Miami ODMDS, the camera settings were as follows: ISO-equivalent was 200, shutter speed was 1/160, F/8, white balance set to flash, color mode to Adobe RGB, sharpening to none, noise reduction off, and storage in raw (NEF) format (2000 x 3008). Details of the camera settings for each raw digital image were recorded in the associated parameters file embedded in the electronic image file.

At the beginning of the survey, the time on the sediment profile camera's internal data logger was synchronized with the time on the vessel's navigation system. Each image was assigned a unique time stamp by the camera's data logger, while the time and position of each camera drop was recorded by taking navigational fix. The field crew also maintained a redundant electronic log where the time, coordinates (latitude and longitude), and water depth of each camera drop (replicate) were recorded. Images were downloaded periodically (sometimes after each station) to verify successful sample acquisition or to assess what type of sediment was present at a particular location. To assign each image to the appropriate station after downloading, the time stamp in the attributes file was matched against the time recorded by the field crew in the electronic logbook. Each digital image file was re-named to indicate the station and replicate number immediately after downloading.

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of each survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. After recovery of the camera on deck, the frame counter was checked to make sure that the requisite number of replicates had been taken. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth for at least one of the four replicate images. If images were missed (frame counter indicator or verification from digital download) or the penetration depth was insufficient (penetration indicator), the station was re-occupied and additional replicate images were taken.

Following completion of field operations, the digital images were analyzed from this survey using Bersoft Image Measurement© software version 3.06 (Bersoft, Inc.). The images were first adjusted in Adobe Photoshop® by using the levels command to expand the available pixels to their maximum light and dark threshold range; no other image adjustments were performed. Pixel width, used to measure linear distance and area, was calibrated within the image analysis software by measuring 1-cm gradations from the Kodak® Color Separation Guide. This calibration information was applied to all the SPI images analyzed. Linear and area measurements were recorded as number of pixels and converted to scientific units by using the calibration information.

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Measured parameters were recorded on a Microsoft® Excel© spreadsheet. Dr. Robert Diaz of Virginia Institute of Marine Science subsequently checked all these data as an independent quality assurance/quality control review of the measurements before final interpretation was performed. G&A's Senior Scientist, Dr. Joseph Germano, performed an additional QA/QC review of the data prior to report preparation.

2.3 MEASURING, INTERPRETING, AND MAPPING SPI PARAMETERS

2.3.1 Sediment Grain Size

The sediment grain-size major mode and range were visually estimated from the color images by overlaying a grain-size comparator that was at 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; Table 2-1) with the SPI camera. Seven grain-size classes, expressed in phi (ϕ) units, were on this comparator: >4 ϕ (silt-clay), 4 to 3 ϕ (very fine sand), 3 to 2 ϕ (fine sand), 2 to 1 ϕ (medium sand), 1 to 0 ϕ (coarse sand), 0 to (-1) ϕ (very coarse sand), and < -1 ϕ (granule and larger). The lower limit of optical resolution of the SPI photographic system was about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt ($\geq$ 4 ϕ). The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (Rhoads and Germano 1984).

The comparison of the SPI images with Udden-Wentworth sediment standards photographed through the SPI optical system also was used to map near-surface stratigraphy, such as sand-over-mud and mud-over-sand. In general, inferences can be made about sediment deposition and/or transport patterns from observing such stratigraphy. For example, if sandy sediment is placed on top of native muddy sediment at a dredged material disposal site, SPI images collected in and around the disposal location will show increasingly thinner layers of sand (over mud) with increasing distance from the disposal point. The SPI results can be used to prepare maps showing the thickness of the deposited layer and the overall footprint of the dredged material deposit on the seafloor.

2.3.2 Prism Penetration Depth

In general, overconsolidated or relic sediments and shell-bearing sands resist camera penetration, while deeper penetration occurs in unconsolidated muds. The greatest penetration typically occurs in muds having high water content and/or that are highly bioturbated, sulfidic, or methanogenic.

The SPI prism penetration depth was measured from the bottom of the image to the sediment-water interface. The area of the entire cross-sectional sedimentary portion of the image was digitized, and this number was divided by the calibrated linear width of the

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Table 2-1. Grain Size Scales for Sediment

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

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

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

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image to determine the average penetration depth. Linear maximum and minimum depths of penetration also were measured. All three measurements (maximum, minimum, and average penetration depths) were recorded in the data file. Because the weighting of the camera frame was held constant throughout the survey, the measured penetration depths presented herein provide an indication of variation in sediment compactness across the surveyed area.

2.3.3 Small-Scale Surface Boundary Roughness

Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment profile images typically ranges from 0.02 to about 4.0 cm and may be related to physical structures (ripples, rip-up structures, mud clasts) or biogenic features (burrow openings, fecal mounds, foraging depressions). Biogenic roughness can change seasonally as a result of the interaction of bottom turbulence and bioturbational activities.

2.3.4 Dredged Material Layer Thickness

During image analysis, the thickness of any newly deposited sedimentary layers attributed to dredged material disposal was determined by measuring the distance between the pre- and post-depositional sediment-water interface. Recently deposited layers of dredged material were evident because of their unique texture and color relative to the underlying material representing the pre-depositional surface. If the point of contact between the two layers was clearly visible, the thickness of the dredged material layer could be measured easily. In some images, dredged material occupied the entire area of imaged sediment. In such cases, it was assumed that the dredged material layer extended below the maximum imaging (i.e., penetration) depth of the camera prism. The thickness of the dredged material layer was measured from the sediment-water interface to the bottom of the prism window, and this thickness was expressed with a “greater than” sign to indicate that it is a minimal or conservative estimate of the actual thickness of the dredged material layer at that location.

2.3.5 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 SPI images. During analysis, the number of clasts was counted, the diameter of a typical clast was measured, and their oxidation state was assessed. In general, the abundance, distribution, oxidation state, and angularity of mud clasts can sometimes be used to make inferences about the recent pattern of seafloor disturbance in an area.

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2.3.6 Apparent Redox Potential Discontinuity Depth

In general, the apparent RPD (aRPD) provides an estimate of the depth to which sediment geochemical processes are primarily aerobic or oxidative; below this layer such processes are anaerobic or reducing. The term apparent is used because no actual measurements are made of porewater chemistry or redox potential (Eh). Given the complexities of iron and sulfate reduction-oxidation chemistry, it is assumed that the lighter, reddish-brown color tones of surface and near-surface sediments in SPI images indicate an oxidative, or at least not intensely reducing, geochemical state, in contrast with underlying anoxic sediments exhibiting darker (typically gray or black) coloration (Diaz and Schaffner 1988; Rosenberg et al. 2001). This is in accordance with the classical concept which associates the RPD layer depth with sediment color (Fenchel 1969; Lyle 1983; Vismann 1991).

To determine the depth of the aRPD layer in each sediment-profile image, the area of lighter-colored sediment observed at and just below the sediment-water interface was digitized and measured. This area (in cm^2) was divided by the width of the image to estimate the average aRPD layer depth for the image. In general, it has been demonstrated that the aRPD depth can be a reliable indicator of benthic habitat disturbance from physical factors (e.g., dredged material disposal, erosion, trawling), low dissolved oxygen, and/or excessive organic enrichment (Rhoads and Germano 1986; Diaz and Shaffner 1988; Valente et al. 1992; Nilsson and Rosenberg 2000).

Because the determination of the aRPD requires discrimination of the optical contrast between oxidized (high optical reflectance) and reduced (low optical reflectance) particles, it can be difficult to make this measurement in well-sorted sands of any size that have little to no silt or organic matter in them. Many of the stations sampled during the Miami ODMDS SPI survey were characterized by fine carbonate sands that were fairly homogenous in color. In the absence of an optical contrast and the apparent paucity of organic matter in these sediments, it was assumed that oxygen penetration was fairly deep and that these sediments, if not well-oxidized, were at least not strongly reducing. In many images, the layer of oxidized sediment was assumed to extend from the sediment-water interface to the bottom of the prism window (i.e., the penetration depth). The measured aRPD depth was expressed with a “greater than” sign to indicate that it was a minimal or conservative estimate of the actual aRPD depth (i.e., it is assumed that the actual layer of oxidized sediment extended below the camera’s imaging depth).

2.3.8 Infaunal Successional Stage

The widely accepted model for marine infaunal succession predicts that macrobenthic invertebrates belonging to specific functional groups will appear sequentially with time following a physical seafloor disturbance or with increasing distance along an organic

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enrichment gradient (McCall 1977; Pearson and Rosenberg 1978; Rhoads and Boyer 1982; Rhoads and Germano 1982; 1986). The continuum of change in animal communities after a disturbance or along an organic enrichment gradient has been divided subjectively into four stages, numbered 0 to 3 (Figure 2-4).

Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a physical disturbance or in close proximity to an organic enrichment source. Stage 1 is the initial community of tiny, densely populated polychaete assemblages that can appear within days following a disturbance. In the absence of any repeated disturbances over the following weeks to months, the initial tube-dwelling suspension or surface-deposit feeding taxa are followed by burrowing, head-down deposit-feeders that rework the sediment deeper and deeper over time and mix oxygen from the overlying water into the sediment. Stage 2 is the start of the transition to head-down deposit feeders, while Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders that typically develops, in the absence of disturbance, over time periods of months to years in soft muddy sediments (Figure 2-4).

The animals in the later-appearing communities (Stage 2 or 3) are larger, have lower overall population densities (10 to 100 individuals per m^2), and can rework the sediments to depths of 3 to 20 cm or more. These animals "loosen" the sedimentary fabric, increase the water content in the sediment, thereby lowering the sediment shear strength, and actively recycle nutrients because of the high exchange rate with the overlying waters resulting from their burrowing and feeding activities.

An important caveat exists with respect to the assignment of an infaunal successional stage to each of the Miami ODMDS images. Namely, while the successional dynamics of invertebrate communities in soft, organic-rich, muddy marine sediments have been well-documented (e.g., Figure 2-4), these dynamics are not well known in sand and coarser sediments. The successional model depicted in Figure 2-4, therefore, is not applicable to all substrata. This is particularly true of organic-poor sands, like those at the Miami ODMDS, which occur in a relatively deep, sub-tropical, open shelf environment characterized by relatively high current velocities. In such an environment, it is likely that benthic communities comprised of small-bodied, surface-dwelling suspension feeders (e.g., tube-dwelling polychaetes) remain dominant over the long-term, and the successional "end-point" (Stage 3) may not always consist of larger-bodied, subsurface deposit-feeders.

Although the successional models depicted in Figure 2-4 are not an ideal fit for an environment like the one at the Miami ODMDS, they nevertheless provided an established conceptual framework within which to evaluate the degree of infaunal activity observed in each image. A successional stage therefore was assigned to each image based on the observation of one or more of the features depicted in the models of

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Figure 2-4. None of the Miami ODMDS images showed Stage 0 (i.e., images lacking any visible evidence of macrofaunal life). Stage 1 was assigned based on the observation of low numbers of small, thin tubes on the sediment surface. Stage 2 was assigned if there were higher numbers of different types of tubes on the sediment surface and/or low numbers of small-bodied polychaetes visible within the upper sediment column, below the sediment surface. Low numbers of small polychaetes at depth within the sediment suggest the benthic community was beginning to become established below the sediment-water interface (so-called "infaunalization").

Stage 3 was assigned based on the presence of larger-bodied, head-down-deposit-feeding, "equilibrium" taxa. In general, Stage 3 organisms rarely are seen in images, but the distinct feeding chambers or "voids" that develop at depth near their head ends serve as visible evidence of their presence. Bioturbation by these deposit-feeders can significantly aerate the sediment and increase aRPD depths to several centimeters. An image from the Miami ODMDS SPI survey was designated as Stage 3 if any of the following five features were observed, alone or in combination: 1) a larger-bodied organism (typically a polychaete) at depth within the sediment column, 2) a biogenic mound at the sediment surface, 3) one or more relatively thick tubes at the sediment surface, 4) a sub-surface feeding void, and/or 5) a sub-surface burrow.

In dynamic estuarine and coastal environments, it is simplistic to assume that benthic communities always progress completely and sequentially through all four stages in accordance with the idealized conceptual model depicted in Figure 2-4. Various combinations of the four basic successional stages are possible. For example, surface- and near-surface-dwelling Stage 1 or 2 organisms can occur at the same time and place with Stage 3, resulting in the assignment of "Stage 1 on 3" or "Stage 2 on 3".

In the Miami ODMDS survey, Stage 1 on 3 was assigned to any image showing low numbers of small polychaetes at or near the sediment surface, along with one or more distinctly active feeding voids occurring at depth within the sediment column. If an image showed both high numbers of thicker, larger surface tubes and limited evidence of subsurface activity by Stage 3 organisms (e.g., just one or two small burrows at depth), then it was assigned to the transitional "Stage 2 going to 3" category. Images showing examples of the various successional stages are provided in Section 3 (Results).

2.3.9 Organism-Sediment Index

The Organism-Sediment Index (OSI) is a summary mapping statistic that was calculated from four independently measured SPI parameters: apparent mean RPD depth, presence of methane gas, low/no dissolved oxygen at the sediment-water interface, and infaunal successional stage. Table 2-2 shows how these parameters are summed to derive the OSI.

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The highest possible OSI is +11, which reflects a mature benthic community in relatively undisturbed conditions (generally a good yardstick for high benthic habitat quality). These conditions are characterized by deeply oxidized sediment with a low inventory of anaerobic metabolites and low sediment oxygen demand (SOD), and by the presence of a climax (Stage 3) benthic community. The lowest possible OSI is −10, which indicates that the sediment has a high inventory of anaerobic metabolites, has a high oxygen demand, and is azoic. In our mapping experience over the past 15 years, we have found that OSI values of +6 or less indicate that the benthic habitat has experienced physical disturbance, organic enrichment, or excessive bioavailable contamination in the recent past.

Table 2-2. Calculation of the SPI Organism-Sediment Index

PARAMETER	INDEX VALUE
A. Mean RPD Depth (choose one)	
0.00 cm	0
> 0-0.75 cm	1
0.76-1.50 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. Successional Stage (choose one)	
Stage 0	-4
Stage 1	1
Stage 1 → 2	2
Stage 2	3
Stage 2 → 3	4
Stage 3	5
Stage 1 on 3	5
Stage 2 on 3	5
C. Chemical Parameters (choose one or both if appropriate)	
Methane Present	-2
No/Low Dissolved Oxygen[a]	-4
Organism-sediment Index = Total of above subset indices (A+B+C)	
Range: -10 to +11	

[a] This is not based on a Winkler or polarigraphic electrode measurement. Instead, low DO conditions in the benthic boundary layer are inferred based on the imaged evidence of reduced, low reflectance (i.e., high-oxygen-demand) sediment at the sediment-water interface.

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2.3.10 Benthic Habitat Type

Similar to the approach used in Diaz (1995), a benthic habitat classification scheme was developed to provide a simple descriptive integration of several of the key physical and biological SPI parameters discussed above. First, a distinction was made between ambient (i.e., native) sediments and disposed dredged material. The ambient sediment was further characterized as either silty fine sand or soft silt, depending on the apparent ratio of silt versus sand. The presence of small tubes at the sediment surface was also noted. The dredged material (DM) was categorized as either fine or coarse sand; it was either layered (i.e., a relatively thin surface layer of DM was visible over ambient sediment) or else extended from the sediment surface to the bottom of the prism window. Finally, limestone rocks with encrusting epifauna represented another benthic habitat type. This limestone rubble typically occurred over an underlying substratum consisting of fine sand.

2.4 USING SPI DATA TO ASSESS BENTHIC QUALITY & HABITAT CONDITIONS

While various measurements of water quality such as dissolved oxygen, contaminants, or nutrients commonly can be used to assess regional habitat quality, interpretation often is difficult because of the transient nature of water-column phenomena. Measurement of a particular value of any water-column variable represents an instantaneous "snapshot" that can change within minutes after the measurement is taken. By the time an adverse signal in the water column such as a low dissolved oxygen concentration is persistent, the system may have degraded to the point where resource managers can do little but map the spatial extent of the phenomenon while gaining a minimal understanding of factors contributing to the overall degradation.

In contrast, surface sediments (upper 10 to 20 cm) have many biological and geochemical features that can persist over much longer time scales. Sea- and river-beds thereby provide an integrated record of long-term environmental conditions in overlying waters. Values for many measured sediment variables are the result of physical, chemical, and biological interactions on time scales much longer than those present in a rapidly moving fluid. The seafloor is thus an excellent indicator of environmental quality, both in terms of historical impacts and of future trends for any particular variable.

The following paragraphs discuss, in general terms, how various SPI parameters like the aRPD depth, infaunal successional stage, and the Organism-Sediment Index are used for assessing benthic habitat quality and response to disturbance. In response to physical

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disturbance or organic enrichment of the seafloor, these parameters have been shown to vary in predictable ways, both to each other and to more traditional measures like benthic species richness and abundance (Figures 2-4 and 2-5).

Physical measurements made with the SPI system from profile images provide background information about gradients in physical disturbance (caused by dredging, disposal, oil platform cuttings/drilling muds discharge, trawling, or storm resuspension and transport) in the form of maps of sediment grain size, boundary roughness, sediment textural fabrics, and structures. The concentration of organic matter and the sediment oxygen demand (SOD) can be inferred from the optical reflectance of the sediment column and the apparent RPD depth. Organic matter is an important indicator of the relative value of the sediment as a carbon source for both bacteria and infaunal deposit feeders. SOD is an important measure of ecological health; oxygen can be depleted quickly in sediment by the accumulation of organic matter and by bacterial respiration, both of which place an oxygen demand on the porewater and compete with animals for a potentially limited oxygen resource (Figure 2-5; see also Kennish 1986).

The aRPD depth is useful in assessing the quality of a habitat for epifauna and infauna from both physical and biological points of view. The aRPD depth in profile images has been shown to be directly correlated to the quality of the benthic habitat in polyhaline and mesohaline estuarine zones (Rhoads and Germano 1986; Revelas et al. 1987; Valente et al. 1992; Nilsson and Rosenberg 1997; 2000). Controlling for differences in sediment type and physical disturbance factors, apparent RPD depths < 1 cm can indicate chronic benthic environmental stress or recent catastrophic disturbance.

The distribution of successional stages in the context of the mapped disturbance gradients is one of the most sensitive indicators of the ecological condition of the seafloor (Rhoads and Germano 1986; Figure 2-5). The presence of Stage 3 equilibrium taxa (mapped from subsurface feeding voids as observed in profile images) can be a good indication of high benthic habitat stability and relative lack of disturbance from natural or anthropogenic factors. A Stage 3 assemblage indicates that the sediment surrounding these organisms has not been disturbed severely in the recent past and that the inventory of bioavailable contaminants is relatively small. These inferences are based on past work, primarily in temperate latitudes, showing that Stage 3 species are relatively intolerant to sediment disturbance, organic enrichment, and sediment contamination. Stage 3 species expend metabolic energy on sediment bioturbation (both particle advection and porewater irrigation) to control sediment properties, including porewater profiles of sulfate, nitrate, and RPD depth in the sedimentary matrix near their burrows or tubes (Aller and Stupakoff 1996; Rice and Rhoads 1989). Bioturbation results in an enhanced rate of decomposition of polymerized organic matter by stimulating microbial decomposition (“microbial gardening”). Stage 3 benthic assemblages are very stable and are also called climax or equilibrium seres.

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The metabolic energy expended in bioturbation is rewarded by creating a sedimentary environment where refractory organic matter is converted to usable food. Stage 3 bioturbation has been likened to processes such as stirring and aeration used in tertiary sewage treatment plants to accelerate organic decomposition (these processes can be interpreted as a form of human bioturbation). Physical disturbance, contaminant loading, and/or over-enrichment result in habitat destruction and in local extinction of the climax seres. Loss of Stage 3 species results in the loss of sediment stirring and aeration and may be followed by a buildup of organic matter (sediment eutrophication). Because Stage 3 species tend to have relatively conservative rates of recruitment, intrinsic population increase, and ontogenetic growth, they may not reappear for several years once they are excluded from an area.

The presence of Stage 1 seres (in the absence of Stage 3 seres) can indicate that the bottom is an advanced state of organic enrichment, has received high contaminant loading, or experienced a substantial physical disturbance. Unlike Stage 3 communities, Stage 1 seres have a relatively high tolerance for organic enrichment and contaminants. These opportunistic species have high rates of recruitment, high ontogenetic growth rates, and live and feed near the sediment-water interface, typically in high densities. Stage 1 seres often co-occur with Stage 3 seres in normal sediments as well as in marginally enriched areas. In these cases, Stage 1 seres feed on labile organic detritus settling onto the sediment surface, while the subsurface Stage 3 seres tend to specialize on the more refractory buried organic reservoir of detritus.

Stage 1 and 3 seres have dramatically different effects on the geotechnical properties of the sediment (Rhoads and Boyer 1982). With their high population densities and their feeding efforts concentrated at or near the sediment-water interface, Stage 1 communities tend to bind fine-grained sediments physically, making them less susceptible to resuspension and transport. Just as a thick cover of grass will prevent erosion on a terrestrial hillside, so too will these dense assemblages of tiny polychaetes serve to stabilize the sediment surface. Conversely, Stage 3 taxa increase the water content of the sediment and lower its shear strength through their deep burrowing and pumping activities, rendering the bottom more susceptible to erosion and resuspension. In shallow areas of fine-grained sediments that are susceptible to storm-induced or wave orbital energy, it is quite possible for Stage 3 taxa to be carried along in the water column in suspension with fluid muds. When redeposition occurs, these Stage 3 taxa can become quickly re-established in an otherwise physically disturbed surface sedimentary fabric.

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3.0
RESULTS

3.1 QA/QC DISCUSSION OF SPI DATASET

All of G&A's standard QA/QC procedures were followed in the field, as described previously in the Quality Assurance Project Plan (Germano and Associates, Inc. 2006). The frame counter on the camera was checked immediately following each camera retrieval on deck to ensure that the expected number of images had been taken. In addition, the images were downloaded using the SPI camera's external USB port and reviewed at regular intervals during the field operations to verify that they were of acceptable quality. Initial review of the images showed the sediments to be relatively firm, and the camera was operated using a full set of weights and the "stop collars" raised to a relatively high position.

At the majority of stations, three replicate images of acceptable quality for analysis were obtained. At each of four stations (stations A7, F5, F6 and X6), only two images of acceptable quality were obtained. At these stations, the camera failed to penetrate sufficiently on the other replicate drops due to the presence of rocks, and it was not possible to add any more weight to the camera to improve penetration.

As indicated, the planview camera system was damaged and therefore not used during the Miami ODMDS survey. In lieu of collecting and analyzing the planview images, fourteen additional SPI stations were occupied during the survey to improve the precision of mapping the dredged material footprint.

At each of the three reference stations (stations R1, R2, and R3), all four of the replicate SPI images were analyzed to increase the number of data points available for comparison with the disposal site stations. Average station values (i.e., averages of the n = 2, 3 or 4 replicate images that were analyzed at each station) for key SPI parameters are presented in the tables and figures that follow.

Following the completion of image analysis, Dr. Robert Diaz provided an independent QA/QC review of the measurement data. This was followed by secondary review of the dredged material distribution and infaunal successional stage designation results by Dr. Joseph Germano.

The results for some SPI parameters occasionally are indicated in the tables or on the maps as "Indeterminate" (Ind). This is a result of the sediments being either: 1) too compact for the profile camera to penetrate adequately, preventing observation of surface or subsurface sediment features, or 2) too soft to bear the weight of the camera, resulting in over-penetration to the point where the sediment-water interface was above the

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window (imaging area) on the camera prism. The sediment-water interface must be visible to measure most of the key SPI parameters like aRPD depth, penetration depth, and infaunal successional stage.

3.2 SPI PHYSICAL/CHEMICAL PARAMETERS

3.2.1 Sediment Grain Size

A complete set of measurement data for each replicate SPI image obtained in the May 2006 survey is provided in Appendix A. At the majority of the disposal site stations, the surface sediments consisted of either very fine sand (grain size major mode of 4 to 3 phi) or fine sand (grain size major mode of 3 to 2 phi) (Table 3-1; Figures 3-1 through 3-3).

The sand appeared to contain varying proportions of silt; stations with higher apparent fractions of silt were mapped with a grain size major mode of >4 to 3 (Figure 3-1). At a number of stations, the sediment appeared to be both softer and with more silt-clay than fine sand. These silt-clay stations (grain size major mode of >4 phi) included stations X9, E3, F3, F4 and G4 located in the northeast quadrant of the station grid (Table 3-1 and Figure 3-1).

Similar to most of the disposal site stations, reference stations R1 and R3 were characterized by silty, very fine sand, while soft silt was found at reference station R2 (Figures 3-1 and 3-2; Table 3-2).

Coarser sediments consisting of medium sand (grain size major mode of 2 to 1 phi) and gravel (major mode of <-1 phi) also were observed during the survey. At stations clustered within and around the circular disposal zone, as well as to the north of this zone, the coarser sediment represented dredged material that appeared to be of recent origin (discussed in greater detail in section 3.1.2 below).

In addition to the recent dredged material, rocks also were observed on top of the sand at stations A5, A6, X1 and X2 on the western side of the disposal site and at stations F5, F6, F7, G6 and G7 on the eastern side (mapped with solid black symbols in Figure 3-1). The rocks at these stations were heavily encrusted with epifauna, such as anemones and hydrozoans (Figure 3-4). Given the extent of the biological growth, it is assumed that these rocks had been in place on the seafloor for some time. It is possible that these rocks occur in patchy “rubble” areas resulting from past dredged material disposal activities, prior to the Phase II Deepening Project. If sand was clearly visible beneath the rocks in a given image, that image was assigned a grain size major mode of sand (3 to 2 or 2 to 1 phi). If only the rocks were visible, the image was assigned a grain size major of gravel (<-1 phi) (Figures 3-1 and 3-4).

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Table 3-1. Summary SPI results (averages or median values) for the disposal site stations sampled during the May 2006 survey of the Miami ODMDS.

Station	Grain Size Major Mode (phi)	Average Penetration Depth (cm)	Avg. boundary roughness (cm)	Avg. RPD depth (cm)	Avg. no. of mud clasts	Avg. thickness of DM layer	Methane or Low DO?	Highest Successional Stage	Median OSI
A4	>4 to 3	10.8	0.8	5.3	0		No	Stage 3	+10
A5	4 to 3	0.4	0.9	>1.1	0		No	Stage 3	+7
A6	>4 to 3	2.7	0.5	6.9	0		No	Stage 2 -> 3	+10
A7	>4 to 3	5.2	2.2	>5.2	0		No	Stage 3	+10
B3	4 to 3	16.9	1.2	5.3	0		No	Stage 1 on 3	+11
B4	4 to 3	12.2	1.4	5.3	0		No	Stage 1 on 3	+11
B5	4 to 3	10.1	2.1	4.7	0		No	Stage 3	+11
B6	>4 to 3	7.2	0.5	3.2	0	Trace	No	Stage 2 -> 3	+9
B7	4 to 3	5.3	1.2	>2.6	0		No	Stage 3	+7
B8	4 to 3	5.0	2.6	>5.0	0		No	Stage 2	+9
C3	>4 to 3	16.3	0.8	5.6	0	2.0	No	Stage 1 on 3	+11
C4	>4 to 3	12.1	0.9	5.2	0	5.1	No	Stage 1 on 3	+11
C5	4 to 3	5.1	0.9	>4.6	1	4.5	No	Stage 2 -> 3	+9
C6	4 to 3	9.3	0.9	5.6	0	8.4	No	Stage 1 on 3	+10.5
C7	3 to 2	7.5	1.0	6.2	0	>7.5	No	Stage 2 -> 3	+9
C8	>4 to 3	10.1	1.4	4.8	0		No	Stage 1 on 3	+10
D1	>4 to 3	11.9	2.5	5.8	0		No	Stage 1 on 3	+11
D2	>4 to 3	12.1	3.8	6.9	0	Trace	No	Stage 2 -> 3	+9
D3	3 to 2	12.8	1.0	6.5	0	3.2	No	Stage 1 on 3	+11
D4	3 to 2	6.6	1.8	7.0	0	4.4	No	Stage 2 -> 3	+9
D5	2 to 1	4.2	0.5	3.3	0	>4.2	No	Stage 2 -> 3	+7.5
D6	<-1	5.4	0.8	>3.4	0	>5.4	No	Stage 2 -> 3	+8
D7	2 to 1	2.2	1.8	>3.1	0	>2.2	No	Stage 2	+7
D8	4 to 3	6.9	1.0	4.6	0	3.9	No	Stage 2	+9
D9	4 to 3	4.4	0.9	>4.4	0		No	Stage 2	+8
E3	>4	14.3	2.2	5.6	0	Trace	No	Stage 1 on 3	+11
E4	>4 to 3	14.6	1.7	6.2	0	6.6	No	Stage 1 on 3	+11
E5	3 to 2	7.3	1.4	>6.9	0	>7.3	No	Stage 1 on 3	+11
E6	3 to 2	6.8	1.0	Ind	0	>6.8	No	Stage 2 -> 3	Ind
E7	2 to 1	4.3	0.8	Ind	0	>4.3	No	Stage 2 -> 3	Ind
E8	4 to 3	9.4	1.4	5.3	0	Trace	No	Stage 1 on 3	+11
F3	>4	14.0	0.9	7.8	0		No	Stage 1 on 3	+11
F4	>4	17.2	1.8	7.6	0		No	Stage 1 on 3	+11
F5	>4 to 3	4.1	1.4	>7.7	0		No	Stage 1 on 3	+11
F6	>4 to 3	1.4	2.4	>2.7	0		No	Ind	Ind
F7	4 to 3	0.8	1.0	>2.0	0		No	Ind	Ind
F8	>4 to 3	13.3	1.6	7.1	0		No	Stage 1 on 3	+11
G4	>4	6.8	1.0	>6.8	0		No	Stage 1 on 3	+11
G5	>4 to 3	7.7	1.1	>5.6	0		No	Stage 1 on 3	+11
G6	>4 to 3	2.5	1.6	>4.0	0		No	Stage 3	+8.5
G7	>4 to 3	6.6	4.0	>6.6	0		No	Stage 1 on 3	+11
X1	<-1	2.1	0.5	>6.3	0		No	Stage 1 on 3	+11
X2	4 to 3	2.6	1.1	>2.6	0		No	Stage 2	+9
X3	2 to 1	5.0	0.6	>5.0	0	>5.0	No	Stage 2 -> 3	+9
X4	2 to 1	7.6	1.0	>7.6	0	>7.6	No	Stage 2 -> 3	+10
X5	2 to 1	4.6	1.3	>4.6	0	>4.6	No	Stage 2	+9
X6	3 to 2	4.7	1.2	>4.7	0	>4.7	No	Stage 2 -> 3	+10
X8	4 to 3	1.2	1.0	>1.2	0		No	Stage 3	+7
X9	>4	16.9	2.4	6.3	0	Trace	No	Stage 1 on 3	+11
X10	4 to 3	11.2	1.0	6.2	0	2.8	No	Stage 1 on 3	+10
X11	3 to 2	4.8	1.3	>4.8	0	4.0	No	Stage 2 -> 3	+9.5
X12	3 to 2	4.1	1.0	>4.1	0	4.8	No	Stage 2	+7
X13	>4	13.7	0.8	6.4	0		No	Stage 1 on 3	+10
X14	>4	12.9	0.7	5.9	0		No	Stage 2	+9
X15	>4	11.6	1.4	5.8	0		No	Stage 1 on 3	+11

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Table 3-2. Summary SPI results (averages or median values) for the reference stations sampled during the May 2006 survey of the Miami ODMDS.

Station	Grain Size Major Mode (phi)	Average Penetration Depth (cm)	Avg. boundary roughness (cm)	Avg. RPD depth (cm)	Avg. no. of mud clasts	Avg. thickness of DM layer	Methane or Low DO?	Highest Successional Stage	Median OSI
R1	>4 to 3	14.3	0.6	5.5	0		No	Stage 1 on 3	+11
R2	>4	19.6	Ind	6.9	0		No	Stage 1 on 3	+11
R3	4 to 3	6.3	1.2	>6.3	0		No	Stage 1 on 3	+11

3.2.2 Dredged Material Layer Thickness and Spatial Distribution

Dredged material was observed in the images at 27 of the 55 stations located within and to the north of the disposal site; there was no dredged material observed at any of the three reference stations (Tables 3-1 and 3-2). The overall footprint of the dredged material deposit formed an ellipse that was elongated in the north-south direction (Figure 3-5). Within this ellipse, the average thickness of the surface dredged material layer ranged from 8.4 cm at station C6 to trace amounts at several perimeter stations (Table 3-1 and Figure 3-5).

There were differences among stations in the color and texture of the dredged material. The coarsest dredged material, ranging from coarse sand to various sizes of gravel, occurred at the stations within and near the circular disposal zone (Figure 3-6). At most of these stations, the dredged material extended from the sediment surface to below the camera's imaging depth, resulting in the mapped thickness values being displayed with a "greater than" sign in Figure 3-5. The replicate images from Station E7 serve to illustrate some of the variability observed in the texture of the dredged material (Figure 3-7).

To the north of the disposal zone, outside the disposal site boundary, discrete layers of dredged material were observed overlying the ambient (i.e., pre-disposal) sediment surface (Figure 3-5). The dredged material comprising these relatively thin, discrete surface layers consisted of fine to very fine sand, while the underlying ambient sediment appeared to have a somewhat finer, more silty texture (Figure 3-8). In general, the dredged material became both finer-grained and occurred in gradually thinner layers moving northward away from the circular disposal zone. Overall, the dredged material in the images (e.g., Figures 3-6 though 3-8) was clearly distinguishable from the ambient surface sediments (e.g., Figure 3-3).

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3.2.3 Mud Clasts and Surface Boundary Roughness

Given the overall absence of consolidated/cohesive muddy sediments at the sampled stations, mud clasts were not observed in any significant numbers in the SPI images from this survey (Tables 3-1 and 3-2). Average small-scale boundary roughness values at the disposal site stations ranged from 0.5 to 4.0 cm, with 46 of the 55 stations (84%) having values of 2.0 cm or less (Table 3-1). The average boundary roughness values at the reference stations likewise were less than 2.0 cm (Table 3-2). In general, these are low values indicating very little small-scale relief across the 14 cm field of view in most of the images, reflecting the largely unconsolidated nature of the surface sediments.

In 61% of the analyzed images at the disposal site stations, the boundary roughness was considered to be of biogenic origin (Appendix A). The boundary roughness was of physical origin in 28% of the disposal site images, and of indeterminate origin in 11% of the images. The biogenic boundary roughness was due to the presence of both upright tubes and small mounds of sediment excavated by organisms (Figure 3-9). At the reference stations, the boundary roughness likewise was of biological origin in 67% of the images, and of indeterminate origin in 33% of the images (Appendix A).

3.2.4 Prism Penetration Depth

The SPI prism penetration depth measurement has a potential range from 0 cm (no penetration) to about 20 cm (close to the maximum vertical height of the prism window). The average prism penetration depth values at the disposal site stations ranged widely, from a low of 0.4 cm at station A5 to a high value of 17.2 cm at station F4 (Table 3-1). The deepest penetration values, indicating moderately soft sediments, occurred most consistently at a cluster of stations (stations D2, X9, B3 through F3, B4, C4, E4 and F4) located north of the disposal site (Figure 3-10). The sediment at most of these stations consisted of ambient silty fine sand, either with or without a thin surface layer of dredged material.

Stations X13 through X15 located along the eastern boundary of the disposal site, as well as nearby station F8 and reference stations R1 and R2, also had relatively deep penetration values (Figure 3-10). These values reflect the moderately soft, unconsolidated, silty sediments found at these stations. The sediment at station R1 was particularly soft, resulting in over-penetration of the camera prism in 3 of the 4 replicate images. Compared to the other two reference stations, the sediment at station R3 was sandier and therefore firmer, resulting in a lower prism penetration value (Table 3-2 and Figure 3-10).

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3.2.5 Methane Gas and Low Dissolved Oxygen

There were no methane gas bubbles in the sediment or low dissolved oxygen conditions in the benthic boundary layer at any of the stations sampled in the May 2006 survey at the Miami ODMDS.

3.2.6 Apparent Redox Potential Discontinuity Depth

Surface sediments at many stations across the surveyed area had uniformly high optical reflectance, with a notable absence of any strong vertical color contrasts that typically denote the transition from a positive to negative redox state with depth in the sediment column (Figure 3-11). At some stations, particularly those with more fine-grained sediment (i.e., higher apparent silt-clay content), there were some patches of darker sediment at depth that probably indicated the transition to more reducing conditions However, these patches of darker, more reduced sediment typically occurred beneath a relatively thick layer of light-colored (i.e., oxidized) sediment (Figure 3-12).

In general, aRPD depths greater than 3 cm are considered indicative of good oxygen penetration into estuarine and coastal marine surface sediments. The average aRPD depths measured in the Miami ODMDS survey were consistently above 3 cm, ranging from 3.2 to 7.8 cm at the disposal site stations and from 5.5 to 6.9 cm at the reference stations (Tables 3-1 and 3-2; Figures 3-13 and 3-14).

At 25 of the 55 disposal site stations and at reference station R3, the sediment was considered to be oxidized from the sediment surface to below the camera's imaging depth, and the measured aRPD depth was indicated with a "greater than" sign to show that it is a minimum or conservative estimate of the actual aRPD depth (e.g., Figure 3-11). This occurred particularly at stations within the disposal site boundary, where the camera penetration was limited due to the sediment being either coarser dredged material or sandy ambient sediment (Figure 3-11).

3.3 SPI BIOLOGICAL PARAMETERS

3.3.1 Infaunal Successional Stage

The infaunal successional status at the disposal site stations was relatively advanced, consisting of various mixtures of Stages 2 and 3 (Table 3-1 and Figure 3-15). The Stage 2 designation was based on observing moderate to high numbers of different-sized tubes at the sediment surface (Figure 3-16); this was the highest successional stage at 8 of the 55 disposal site stations (Figure 3-17). Four of the 8 stations with the Stage 2 designation (Stations X12, X5, D7 and D8) were located within the dredged material footprint (Figures 3-5 and 3-15).

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At 14 of the 55 disposal site stations, Stage 2 going to 3 was the highest successional designation (Figure 3-17). At these stations, in addition to the moderate numbers of different types of surface tubes, there was also evidence of some subsurface activity (Figure 3-18). With the exception of Station A6, all of the stations with this successional designation were located within the dredged material footprint (Figures 3-5 and 3-15).

The majority of the disposal site stations (31 of 55, or 56%) had an advanced successional stage consisting of either Stage 1 on 3 or Stage 3 (Table 3-1; Figures 3-15 and 3-17). At some stations, the Stage 3 designation was assigned because of the presence of biogenic mounds at the sediment surface (Figure 3-19). At other stations, the presence of Stage 3 was inferred from the observation of distinct feeding voids at depth within the sediment column (Figure 3-20).

Stage 1 on 3 and/or Stage 3 occurred primarily where the sediment was relatively fine-grained and/or silty, including a number of the stations located to the north of the disposal site (both with and without thin surface layers of dredged material), as well as several stations near the eastern boundary of the site (Figure 3-15). All of the reference stations had Stage 1 on 3 as the highest successional stage (Table 3-2; Figures 3-15, 3-17 and 3-20).

3.3.2 Organism-Sediment Index

As described in Section 2.3.9 and illustrated in Figure 2-4, the OSI is a summary metric that provides a way to order, or rank, the stations in terms of the relative degree of benthic habitat disturbance or degradation. For the May 2006 SPI survey at the Miami ODMDS, the median OSI values at all of the disposal site and reference stations were in the range of +7 to +11 (Figures 3-21 and 3-22). Values in this range are considered indicative of little or no appreciable benthic habitat disturbance.

It is notable that the relatively high OSI values were found at stations both within and outside the dredged material footprint. These values reflect a combination of relatively deep RPD depths across all of the surveyed stations in combination with a relatively advanced successional status.

3.3.3 Benthic Habitat Type

The benthic habitat classification scheme developed for the Miami ODMDS largely reflects the information on sediment grain size, presence/absence of dredged material layers, and biological features discussed above. Stations with relatively coarse dredged material exceeding the camera's penetration depth (Stations D7, X4, X5 and D6) were located within and immediately to the north of the disposal zone (Figure 3-23). A second group of stations also exhibited dredged material layers that exceeded the camera prism penetration depth, but the disposed sediment consisted of very-fine to fine sand. Thin

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surface layers of sandy dredged material overlying ambient silty/sandy sediment occurred at stations on the outer edges of the dredged material deposit, particularly to the north of the disposal site boundary (Figure 3-23).

Outside of the dredged material footprint, there were three basic types of benthic habitats: 1) silty, ambient fine sand with surface tubes, 2) relatively soft (i.e., muddy) ambient sediment with surface tubes, and, as discussed previously, limestone rubble with epifauna overlying ambient fine sand sediment (Figure 3-23).

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4.0
DISCUSSION

The first objective of the May 2006 SPI survey at the Miami ODMDS was to map the spatial distribution of disposed dredged material on the seafloor. The SPI images revealed dredged material layers of relatively recent origin (i.e., deposited within the past year or two) occurring at a number of the sampling locations. Based on using a grid of evenly spaced stations, it was possible to create a contour map showing the overall footprint of recently deposited dredged material. The deposit formed an ellipse that was elongated in the north-south direction, with the lower half of the ellipse centered within the disposal site, and the upper half occurring to the north of the disposal site (Figure 4-1). Compared to the predicted dredged material footprint (determined using the STFATE model), the actual footprint was more elongated in a north-south direction and occurred to a greater extent outside the northern site boundary (Figure 4-1).

The coarsest dredged material, consisting of coarse sand and gravel, was located within and near the circular (i.e., 500-ft. diameter) disposal zone in the center of the disposal site. All of the dredged material layers in this area had a thickness exceeding the penetration depth of the profile camera. With increasing distance northward of the disposal zone, the dredged material became increasingly finer in texture (generally ranging from medium to fine sand) and deposited in increasingly thinner layers.

Due to the high velocity of the Florida Current, which runs from south to north at this site, it appears that dredged material released within the disposal zone is transported northward during its descent through the water column. Because the coarsest and heaviest sediments fractions within the dredged material plume (consisting of coarse sands and gravels at this site) fall more quickly to the seafloor, they have accumulated on the seafloor preferentially near the point of disposal. The finer sediment fractions are carried further along by the current (i.e., so-called “stripping of fines”) before becoming deposited in increasingly thinner layers on the seafloor.

If a future site management goal is to keep more of the dredged material deposit confined within the ODMDS boundaries, the disposal zone (surface release point) should be located to the south of its present location. Given the size of the designated site boundary versus the size of the dredged material footprint (Figure 4-1), even locating the disposal zone more to the south would still not result in all of the dredged material remaining within the site boundaries. However, the May 2006 SPI survey serves to demonstrate relatively rapid recovery of the local benthic community following disposal of the type of material observed (discussed in greater detail below).

There were two areas in the northern half of the disposal site, to the east and west of the elliptical dredged material deposit, where small rocks occurred at the sediment surface.

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These rocks appeared to have a patchy distribution, and they were covered extensively by epifaunal organisms. It is hypothesized that the rocks in these areas represent older dredged material deposits consisting of limestone rubble. With the passage of time, the limestone rocks and gravel have become covered with encrusting organisms. The rocks in these areas thus did not appear to be of recent origin at the time of the May 2006 SPI survey.

The second objective of the survey was to characterize physical changes in the seafloor resulting from disposal. The SPI images showed that the main physical change was a shift in sediment texture, with the new surface layers of dredged material having a grain size major mode that was slightly to greatly coarser than that of the surface sediments comprising the ambient seafloor. Specifically, the ambient surface sediments at the stations located outside the dredged material footprint, as well as at the reference stations, were predominantly fine-grained, consisting of silty, very fine sand or soft silt-clay. In contrast, the recent dredged material layers ranged from gravel/coarse sand to fine sand.

Based on their uniform light color, it is assumed that the ambient surface sediments were well oxidized and contained relatively low levels of labile organic carbon. The deposited dredged material likewise was predominantly light colored, with apparent low organic carbon concentration. Given these similarities, it did not appear that the dredged material disposal had resulted in any adverse changes in oxygen demand, redox state, or other geochemical properties within or in the areas surrounding the disposal site.

The third and final objective of the survey was to evaluate benthic recolonization through the mapping of infaunal successional stages. Overall, the areas having surface layers of dredged material appeared to be in an intermediate (Stages 2 or 2 going to 3) to advanced (Stages 3 or 1 on 3) stage of benthic recolonization. The recolonizing community consisted of both surface-dwelling opportunists, as evidenced by low to moderate numbers of surface tubes visible in most of the images, as well as subsurface-dwelling Stage 3 taxa capable of extensive bioturbation. Evidence of Stage 3 consisted of both biogenic mounds and subsurface feeding voids (e.g., Figures 3-19 and 3-20).

Although the recolonization pattern observed at the Miami ODMDS in the May 2006 SPI survey generally conformed with the conceptual model depicted in Figure 2-4, a key difference relates to organism density. Following disposal of organic-rich dredged material in many nearshore environments, dense mats of Stage 1 tubes are typically observed at the sediment surface within days to weeks. The surface- and near-surface-dwelling Stage 1 and 2 communities observed at the Miami stations within the disposal footprint appeared to have much lower tube densities. Surface tube densities on the surrounding ambient seafloor also appeared to be low. This is attributed to the much lower organic carbon content of both the ambient sediments and the disposed dredged material at the Miami ODMDS.

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Evidence of Stage 3 taxa likewise was typically limited to a single feeding void, biogenic mound or subsurface polychaete in any given image. This suggests that the Stage 3 taxa also had very low apparent densities over the dredged material deposit and surrounding areas of ambient sediment. This again is attributed to the low apparent organic content of the ambient surface sediments within and near the Miami ODMDS.

In general, it appears that the normal "climax" or "equilibrium" community in many of the areas surrounding the disposal site is comprised predominantly of low or moderate numbers of surface-dwelling suspension feeders (Stages 1 and 2) and low densities of subsurface deposit-feeders (Stage 3). Therefore, the observed recolonization of the dredged material deposit by Stage 2 and 3 communities largely represents a return to ambient seafloor conditions relatively soon following disposal. Due to the high current velocities in the general area where the Miami ODMDS is located, native benthic communities presumably are adapted to frequent physical disturbance. The relatively rapid benthic recolonization of the areas affected by dredged material disposal therefore is not surprising.

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CONCLUSIONS AND RECOMMENDATIONS

1. The May 2006 SPI survey at the Miami ODMDS showed that dredged material of relatively recent origin formed an elliptical deposit on the seafloor. The deposit was elongated in the north-south direction, with the lower half of the ellipse centered within the disposal site, and the upper half occurring to the north of the disposal site.

2. The thickest layers of dredged material, consisting of coarse sand and gravel, were located within and near the circular (i.e., 500-ft. diameter) disposal zone in the center of the disposal site. With increasing distance northward of the disposal zone, the dredged material became increasingly finer in texture (generally ranging from medium to fine sand) and deposited in increasingly thinner layers.

3. Given the strong northward drift of the dredged material following its release at the Miami ODMDS, it is recommended that the disposal zone be located to the south of its present location. This should help to ensure that more of the resulting seafloor is located within the ODMDS boundaries. However, even moving the disposal point to the southern end of the currently designated site perimeter will not result in dredged material remaining within the site boundary given the conditions at this particular location.

4. The main physical change resulting from disposal appeared to be a shift in sediment texture, with the new surface layers of dredged material having a grain size major mode that was slightly to greatly coarser than that of the surface sediments comprising the ambient seafloor.

5. Both the ambient surface sediments and deposited dredged material were light-colored and well-oxidized, with an overall absence of any dark-colored subsurface sediments and/or strong redox contrasts. It did not appear that the dredged material disposal had resulted in any adverse changes in oxygen demand, redox state, or other geochemical properties within or in the areas surrounding the disposal site.

6. Given the lack of adverse effects to surface sediments as a result of disposal, stations within the dredged material footprint appeared to be in an intermediate to advanced stage of benthic recolonization. The recolonizing community consisted of both surface-dwelling opportunists, as evidenced by low to moderate numbers of surface tubes visible in most of the images, as well as subsurface-dwelling Stage 3 taxa capable of extensive bioturbation.

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7. Benthic communities inhabiting both the dredged material layers and native sediments appeared to be characterized by low to moderate organism density. This was attributed to the low apparent organic content of the surface sediments. The native community is probably well-adapted to frequent physical disturbance resulting from high near-bottom current velocities, and it is therefore not surprising that this community was able to recolonize areas that had been disturbed by dredged material disposal.

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6.0
REFERENCES CITED

Aller, J.Y. and I. Stupakoff. 1996. The distribution and seasonal characteristics of benthic communities on the Amazon shelf as indicators of physical processes. Continental Shelf Research 16: 717-751.

Diaz, R.J. 1995. Benthic habitat classification of selected areas of Narragansett Bay and the Providence River, Rhode Island. Report No. R-13116.036. Prepared for U.S. Army Corps of Engineers-Planning Division (under contract to Normandeau Associates). 12 pp. + figures, tables, appendices.

Diaz, R. J. and L. C. Schaffner. 1988. Comparison of sediment landscapes in the Chesapeake Bay as seen by surface and profile imaging, p. 222-240 In M. P. Lynch and E. C. Krome (eds.), Understanding the Estuary: Advances in Chesapeake Bay Research, Chesapeake Bay Research Consortium Publication 129, Chesapeake Bay Program 24/88.

Fenchel, T. 1969. The ecology of marine microbenthos. IV. Structure and function of the benthic ecosystem, its chemical and physical factors and microfauna communities with special reference to the ciliated Protozoa. Ophelia 6:1-182.

Kennish, M.J. 1986. Ecology of Estuaries. Vol. I: Physical and chemical aspects. CRC Press, Boca Raton, FL.

Germano and Associates, Inc. 2006. Rapid Seafloor Reconnaissance and Assessment of Southeast Florida Ocean Dredged Material Disposal Sites Utilizing Sediment Profile Imaging: Quality Assurance Project Plan. Submitted to U.S. EPA Region 4, Water Management Division, Coastal Section, Atlanta, GA, 36 pp.

Lyle, M. 1983. The brown-green colour transition in marine sediments: A marker of the Fe(III) – Fe(II) redox boundary. Limnology and Oceanography 28(5):1026-1033.

McCall, P. L. 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. Journal of Marine Research 35:221-266.

Nilsson, H. C. and R. Rosenberg. 1997. Benthic habitat quality assessment of an oxygen stressed fjord by surface and sediment profile images. Journal of Marine Systems 11:249-264.

Nilsson, H. C. and R. Rosenberg. 2000. Succession in marine benthic habitats and fauna in response to oxygen deficiency: analyzed by sediment profile imaging and by grab samples. Marine Ecology Progress Series 197:139-149.

US EPA ARCHIVE DOCUMENT

Pearson, T.H. and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: An Annual Review 16: 229-311.

Revelas, E.C., J.D. Germano, and D.C. Rhoads. 1987. REMOTS reconnaissance of benthic environments. pp. 2069-2083. In: Coastal Zone '87 Proceedings, ASCE, WW Division, May 26-29, Seattle, WA.

Rhoads, D.C. and L.F. Boyer. 1982. The effects of marine benthos on physical properties of sediments. pp. 3-52. In: Animal-Sediment Relations. McCall, P.L. and M.J.S. Tevesz (eds). Plenum Press, New York, NY.

Rhoads, D.C. and J.D. Germano. 1982. Characterization of benthic processes using sediment profile imaging: An efficient method of remote ecological monitoring of the seafloor (REMOTS™ System). Marine Ecology Progress Series 8:115-128.

Rhoads, D.C. and J.D. Germano. 1984. Chesapeake Bay Disposal Sites Survey: REMOTS Baseline Monitoring, February, 1984. Report submitted by Marine Surveys, Inc. under contract to Virginia Institute of Marine Science, Gloucester Pt, VA.

Rhoads, D.C. and J.D. Germano. 1986. Interpreting long-term changes in benthic community structure: A new protocol. Hydrobiologia. 142:291-308.

Rhoads, D.C. and J.D. Germano. 1990. The use of REMOTS® imaging technology for disposal site selection and monitoring. pp. 50-64. In: Geotechnical Engineering of Ocean Waste Disposal, K. Demars and R. Chaney (eds). ASTM Symposium Volume, January, 1989. Orlando, FL.

Rice, D.L. and D.C. Rhoads. 1989. Early diagenesis of organic matter and the nutritional value of sediment. pp. 59-97. In: Ecology of Marine Deposit Feeders, Vol. 31, Lecture notes on coastal and estuarine deposit feeders. Lopez, G., G. Tagon, and J. Levinton, (eds.). Springer-Verlag, New York, NY.

Rosenberg, R., H. C. Nilsson, and R. J. Diaz. 2001. Response of benthic fauna and changing sediment redox profiles over a hypoxic gradient. Estuarine, Coastal and Shelf Science 53:343-350.

U.S. EPA Region 4. 1995. Final Environmental Impact Statement for the Designation of an Ocean Dredged Material Disposal Site Located Offshore Miami, Florida. Atlanta, GA. August 1995.

Valente, R.M., D.C. Rhoads, J.D. Germano, and V.J. Cabelli. 1992. Mapping of benthic enrichment patterns in Narragansett Bay, RI. Estuaries 15:1-17.

US EPA ARCHIVE DOCUMENT

Vismann, B. 1991. Sulfide tolerance: physiological mechanisms and ecological implications. Ophelia 34:1-27.

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FIGURES

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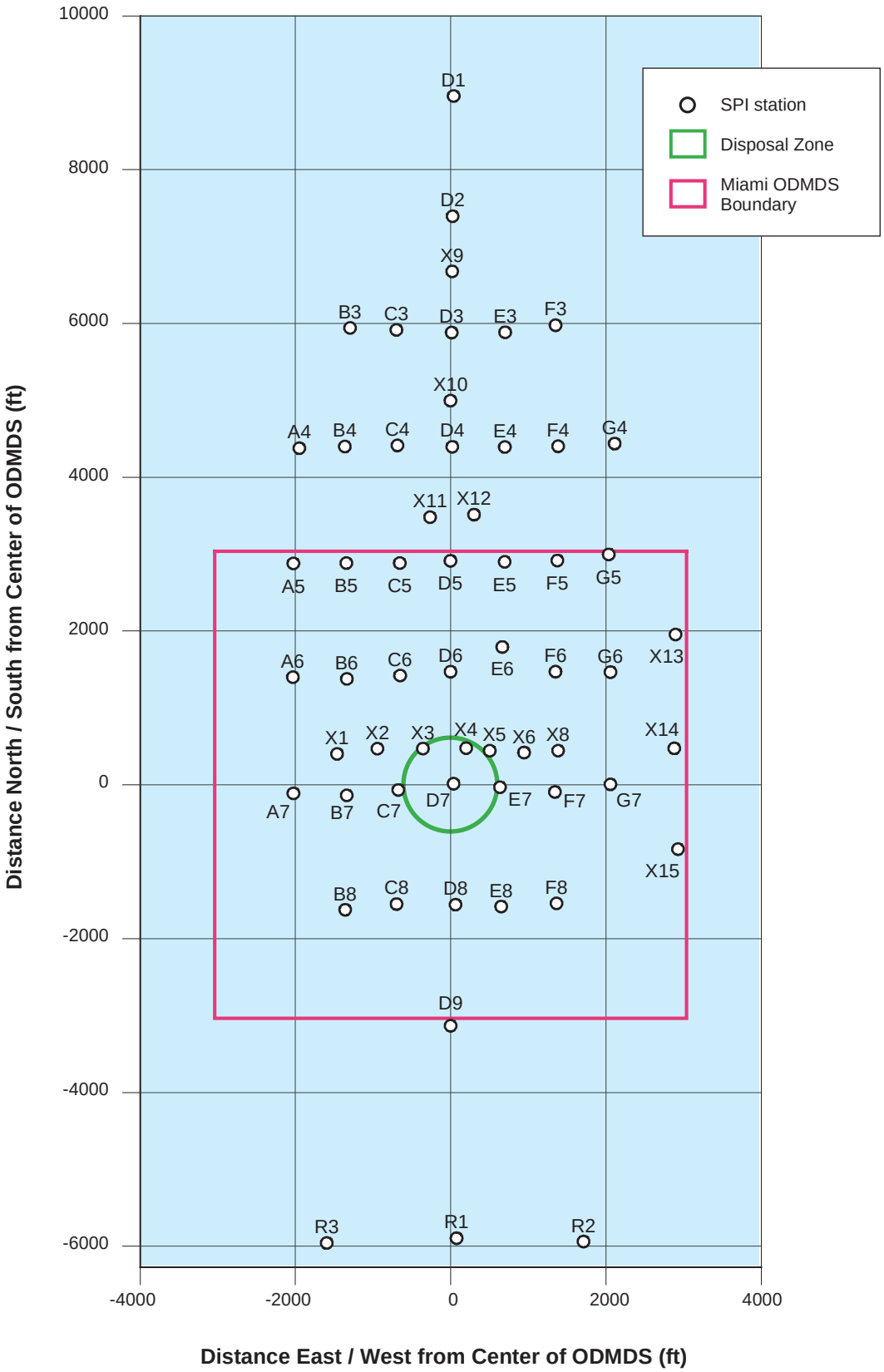

Figure 2-1: SPI sampling locations for the May 2006 survey at the Miami ODMDS.

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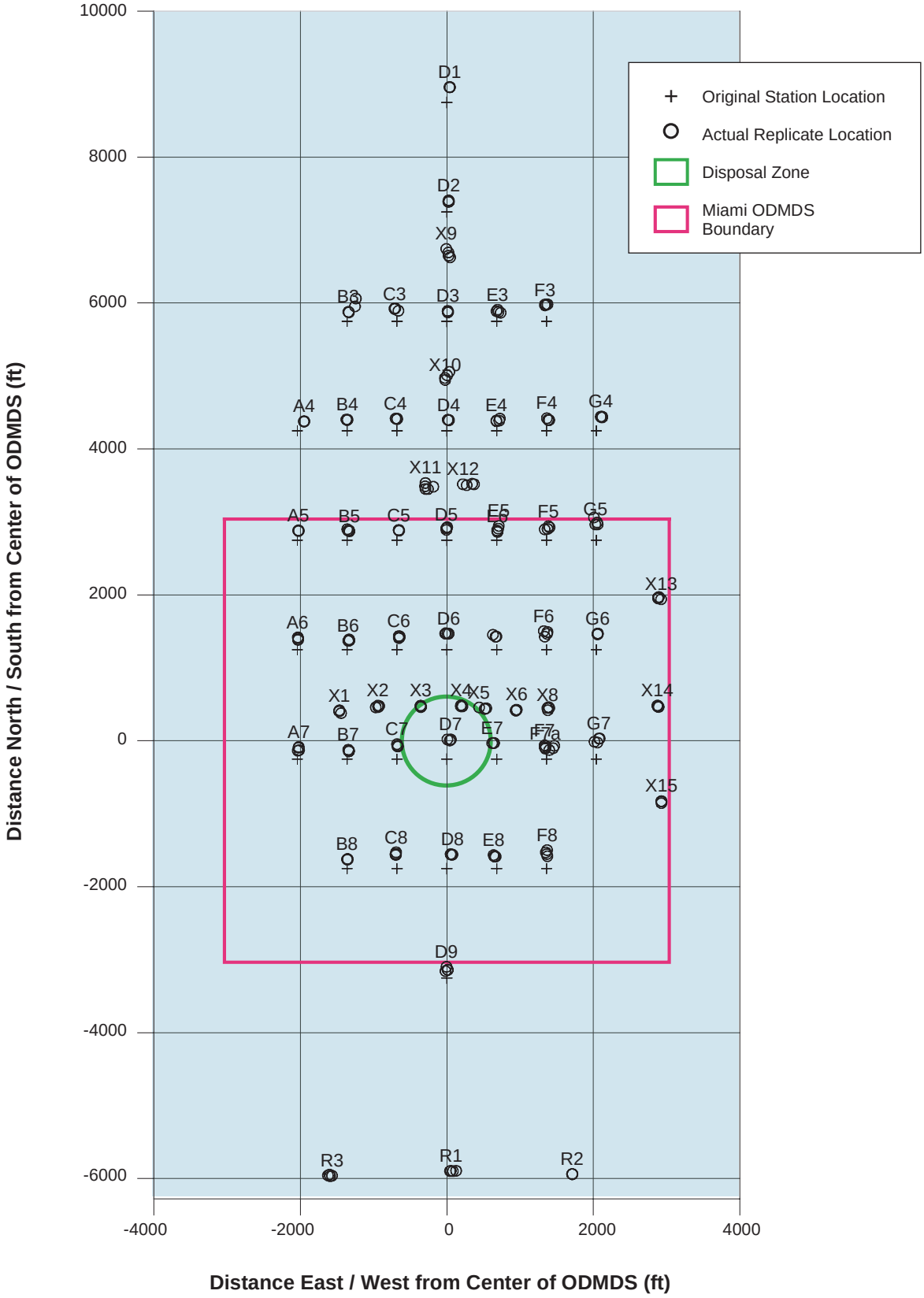

Figure 2-2: Map showing the target sampling location versus the actual location of each replicate camera drop for the May 2006 SPI survey at the Miami ODMDS.

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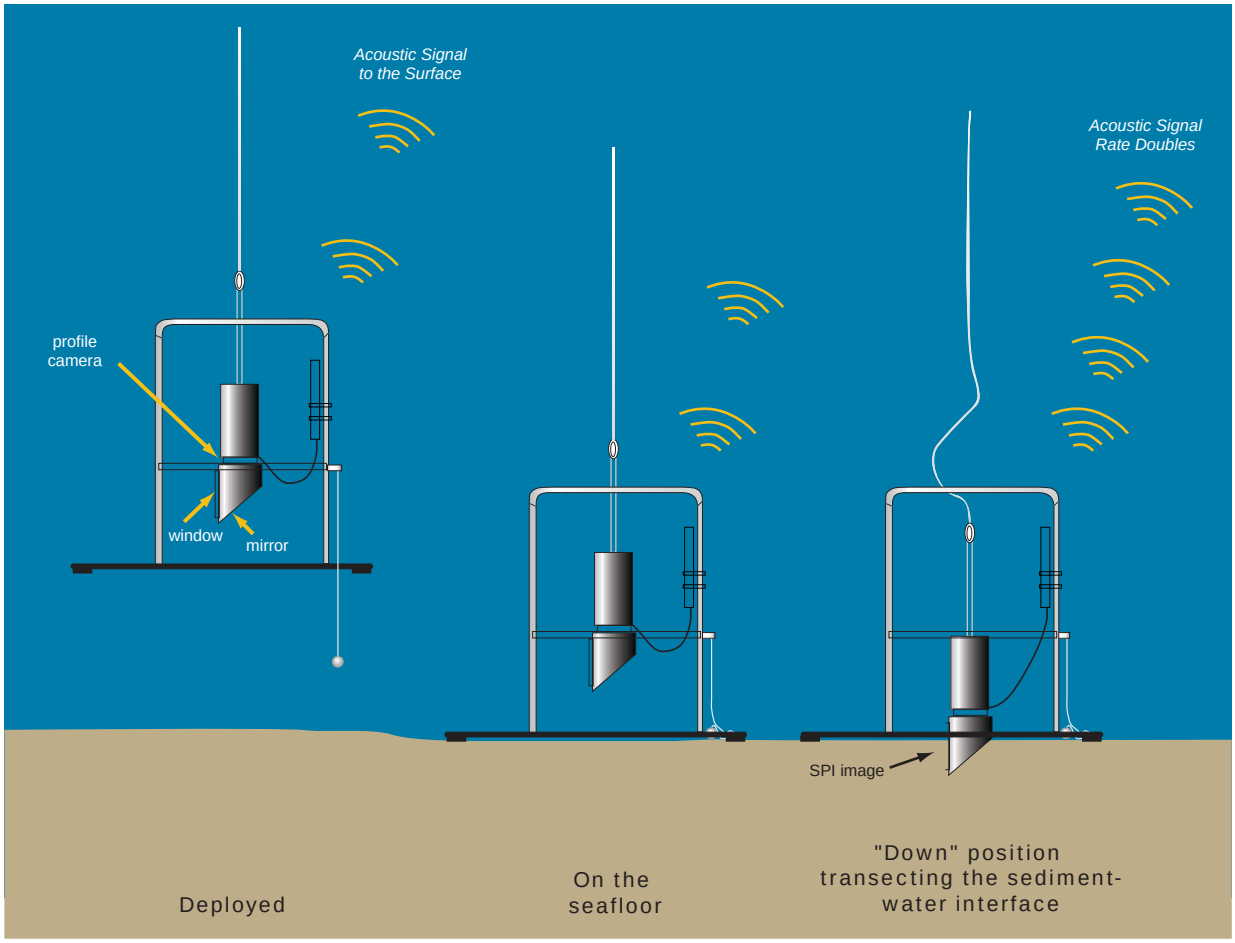

Figure 2-3: Operation of the sediment-profile camera during deployment. The central cradle of the camera is held in the "up" position by tension on the winch wire as it is being lowered to the seafloor (left); once the frame base hits the bottom (center), the prism is then free to penetrate the bottom (right) and take the photograph.

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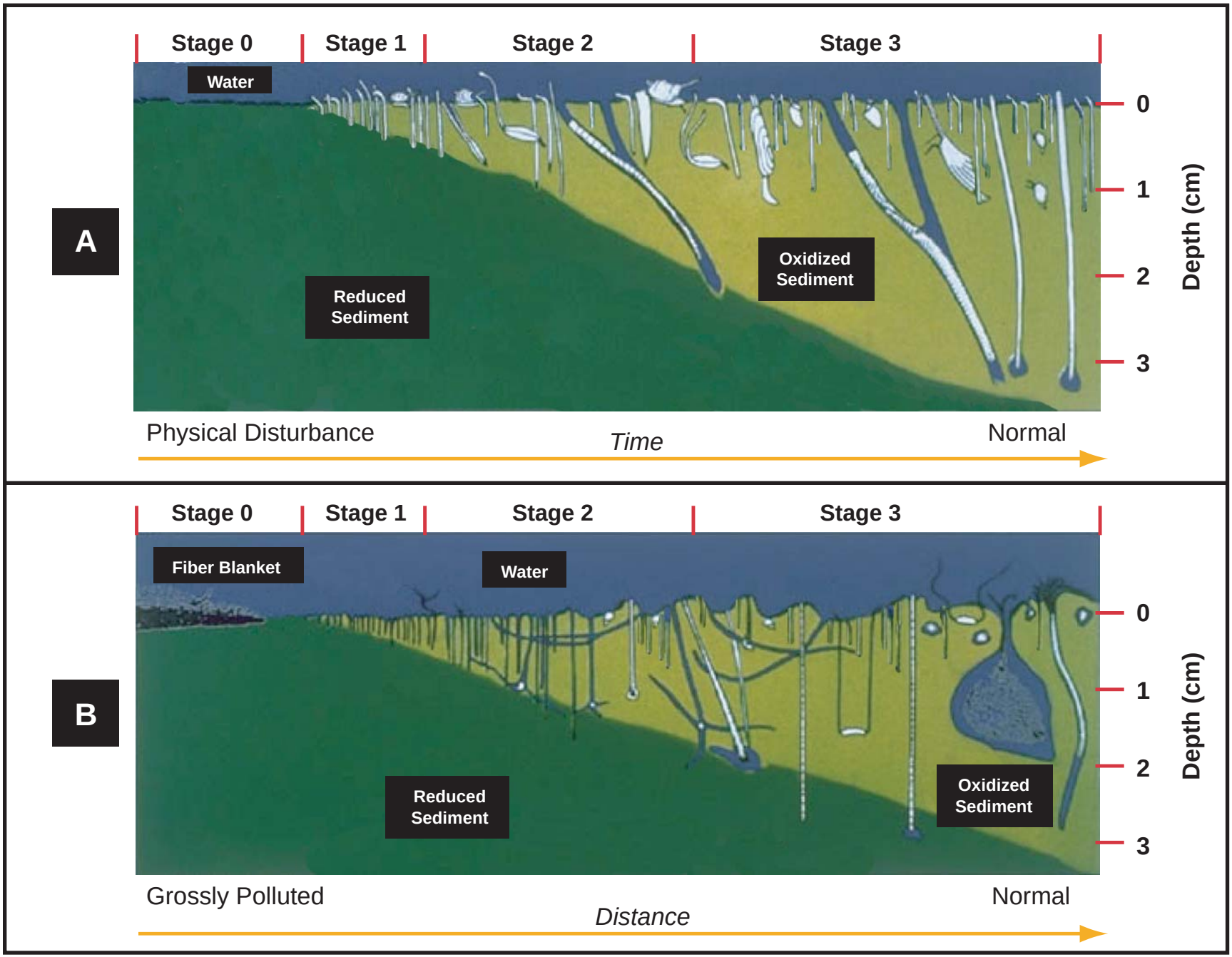

Figure 2-4: Soft-bottom benthic community response to physical disturbance (top panel) or organic enrichment (bottom panel). From Rhoads and Germano, 1982.

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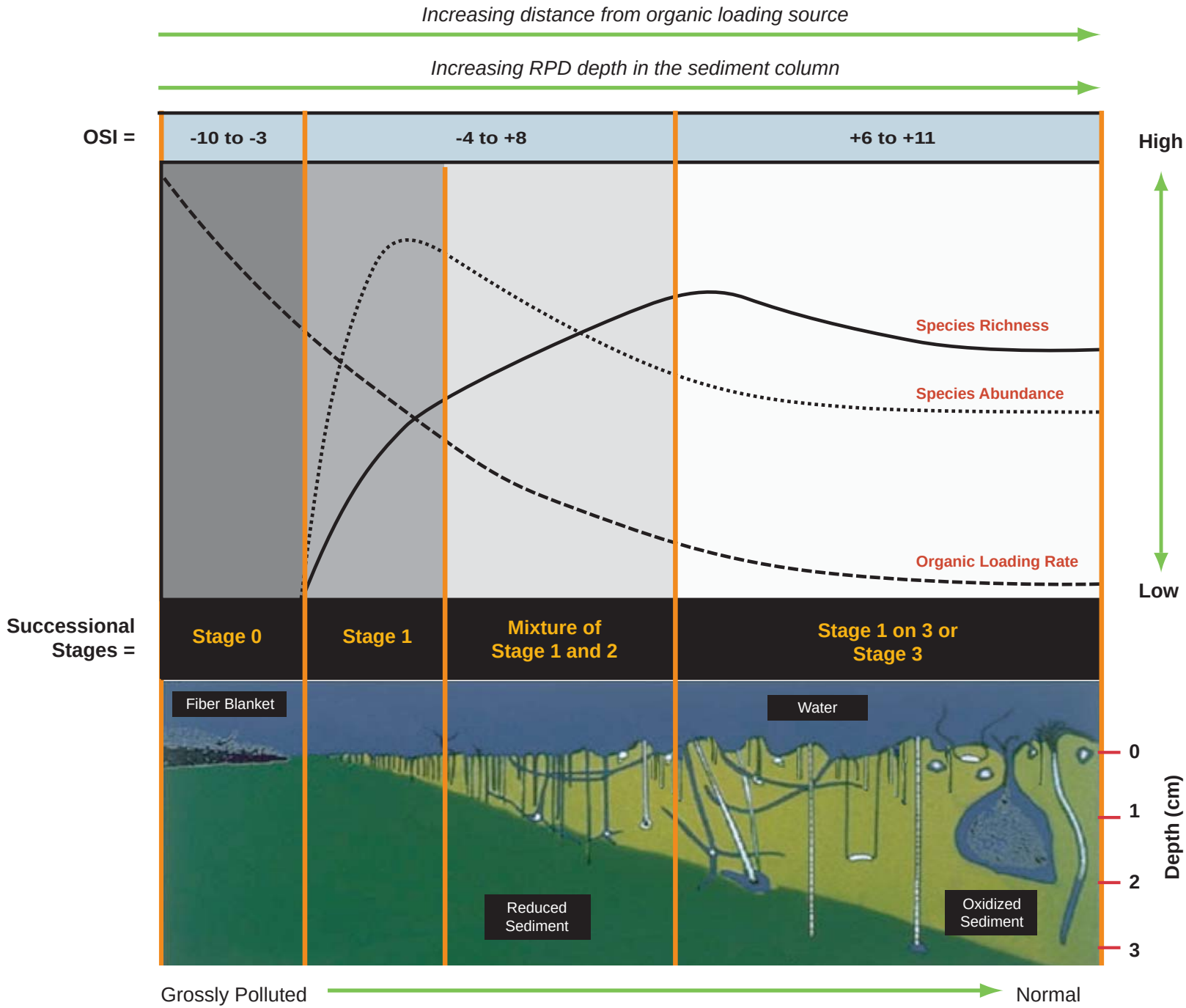

Figure 2-5: Model illustrating the relationships among key SPI parameters and traditional measures of species richness and abundance along an organic enrichment gradient.

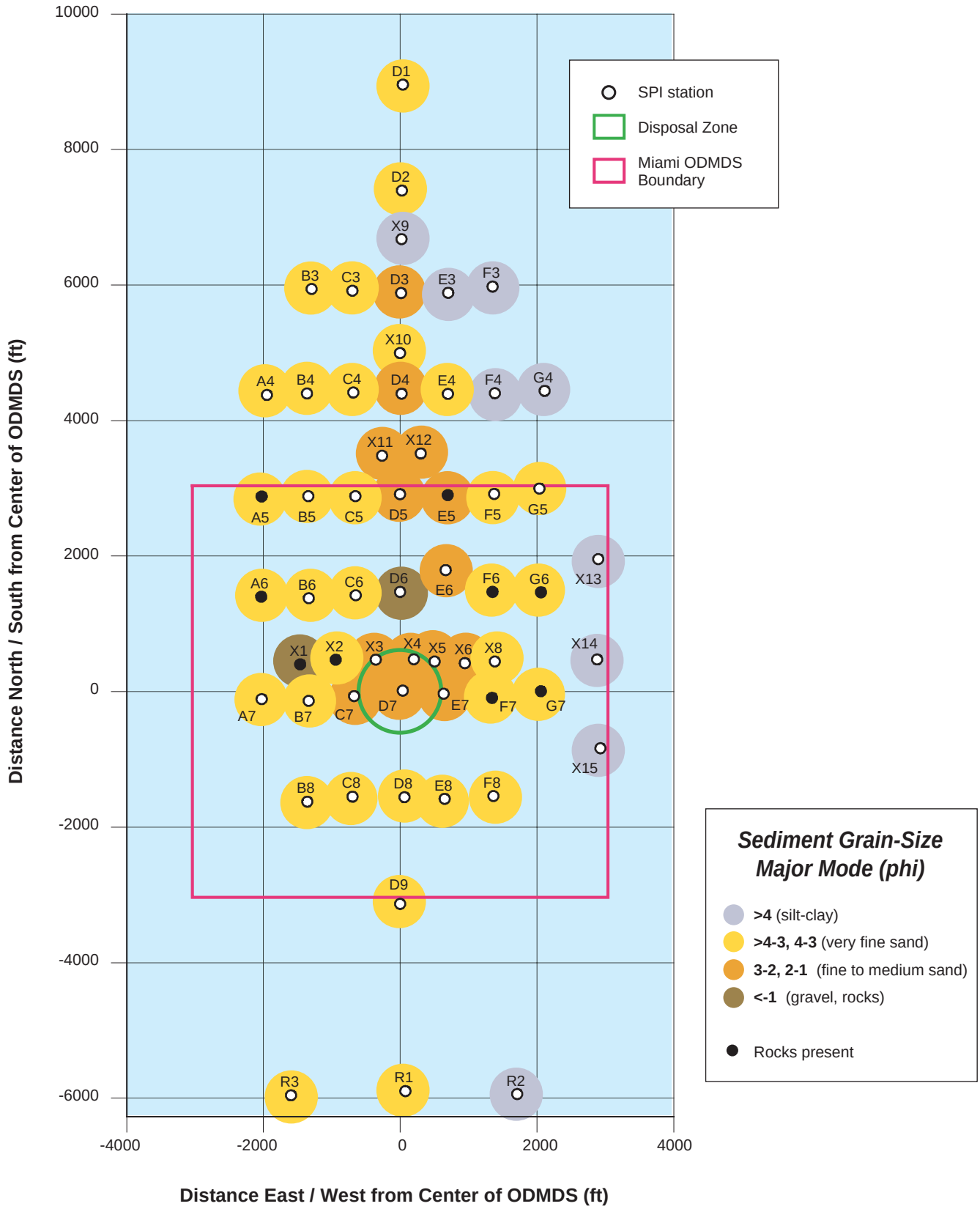

Figure 3-1: Grain size major mode (in phi units) at the Miami ODMDS SPI stations.

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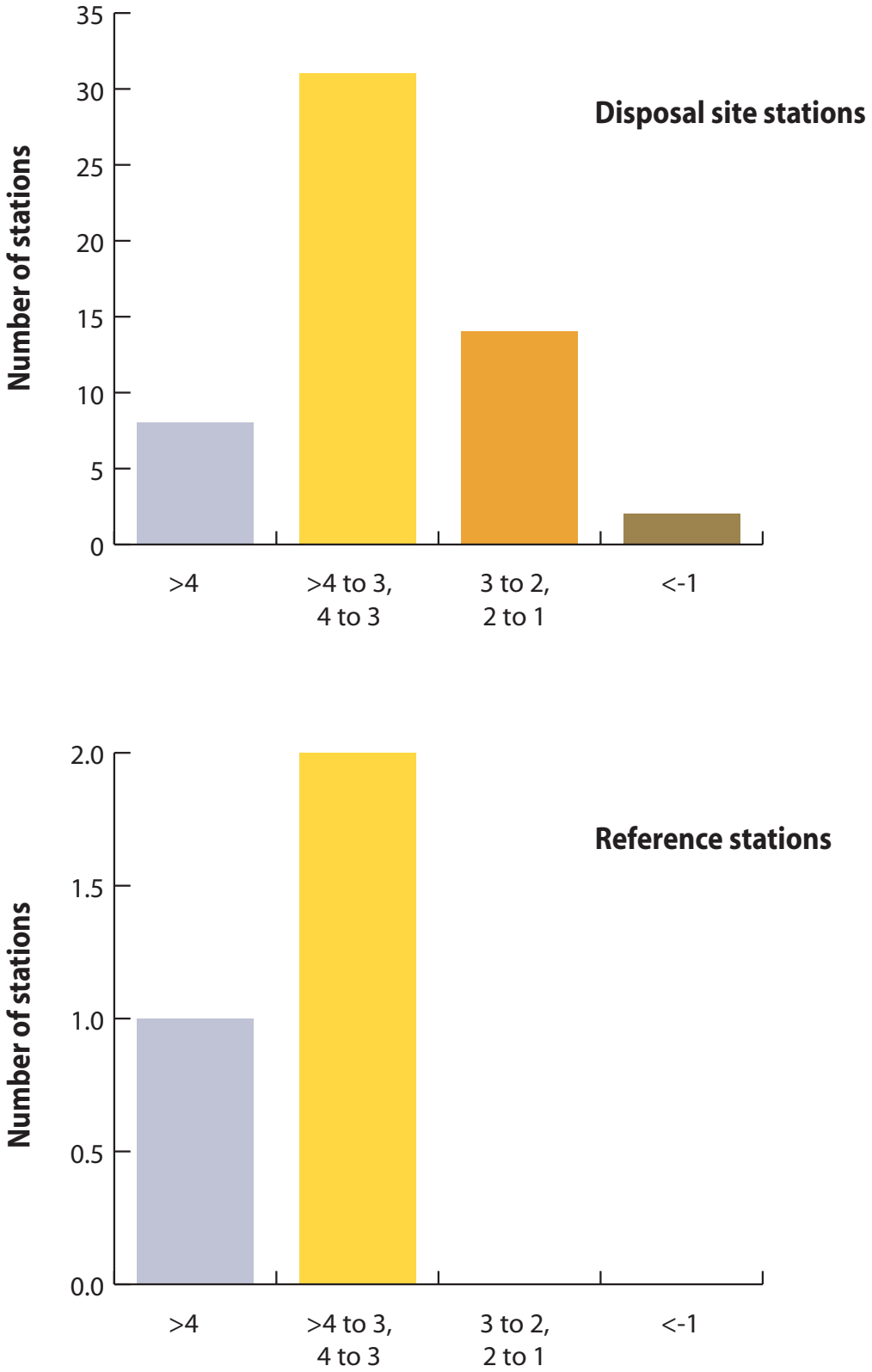

Figure 3-2: Frequency distribution of grain size major modes (in phi units) at the disposal site stations (top) and reference stations (bottom).

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Figure 3-3: SPI image from Station B3 showing typical ambient sediment outside the disposal site consisting of relatively soft, silty, very fine sand (grain size major mode of 4 to 3 phi). Small tubes occur at the sediment surface, and a feeding void is visible at depth (arrow), resulting in a "Stage 1 on 3" successional designation for this image. Scale: actual image width is 14.4 cm.

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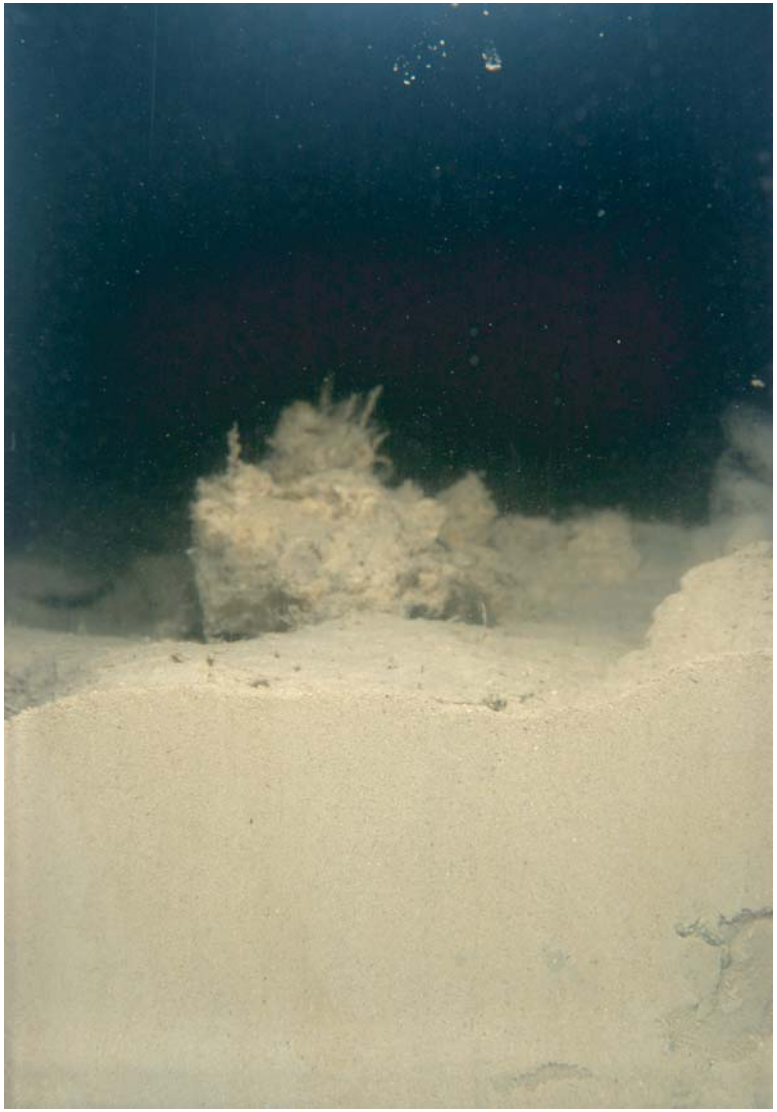
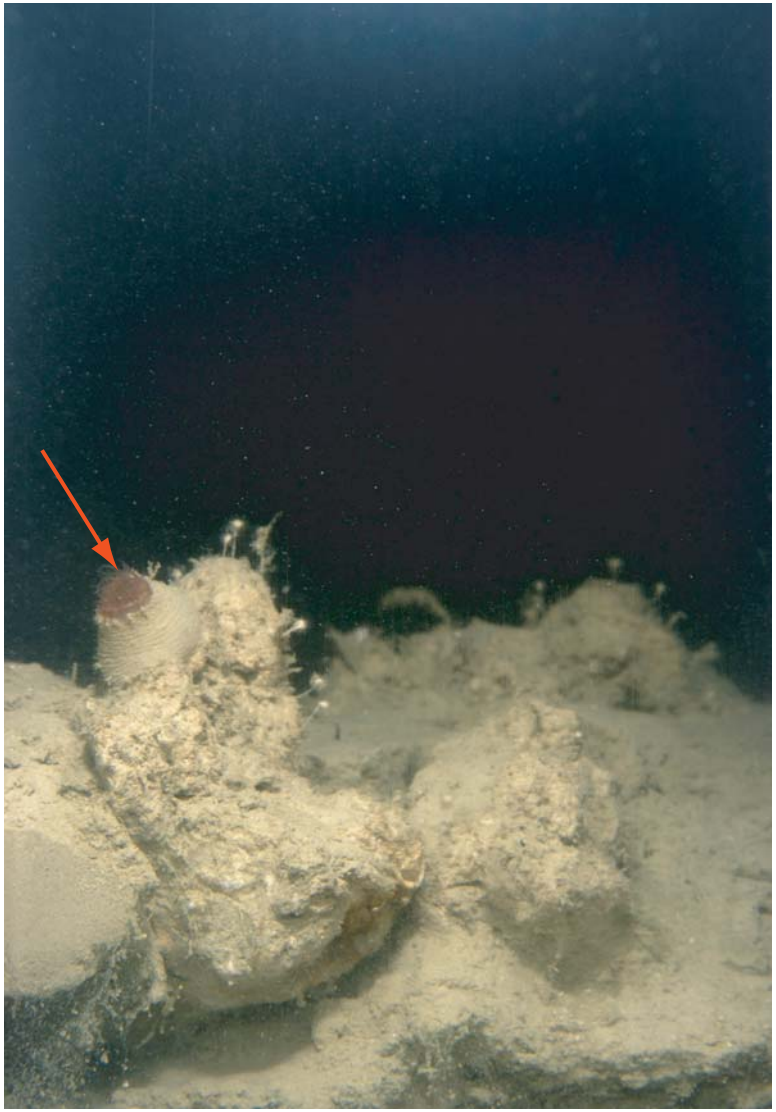


A. Station F5



B. Station G6

Figure 3-4: SPI images from stations F5 (left) and G6 (right) showing small rocks present at the sediment surface. A grain size major mode of >4 to 3 phi was assigned to the left image due to the silty, very fine sand underlying the rocks, while only the rocks themselves are visible in the right image (grain size major mode of <-1). In both images, the rocks are heavily encrusted with epifauna (the arrow points to a retracted anemone growing on the rock in the right image). Scale: actual image width is 14.4 cm.

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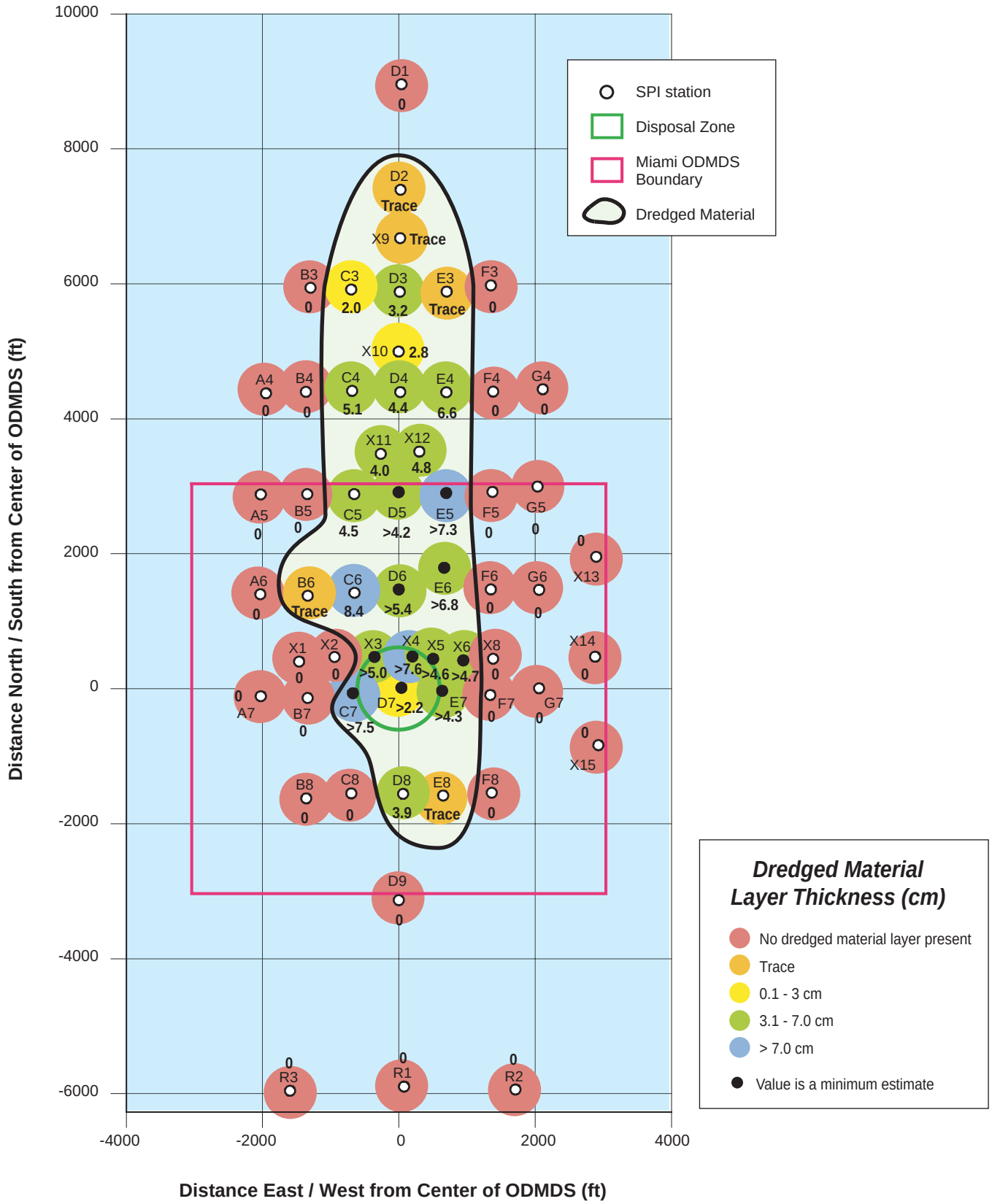

Figure 3-5: Average thickness of the dredged material layer at each of the Miami ODMDS SPI stations.

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A. Station D6

B. Station D7

Figure 3-6: SPI images from stations D6 (left) and D7 (right) showing recent dredged material consisting of very coarse sand and gravel. In both images, the dredged material layer extends from the sediment surface to below the camera's imaging depth (i.e., thickness value mapped with a "greater than" sign in Figure 3-5). Scale: actual image width is 14.4 cm.

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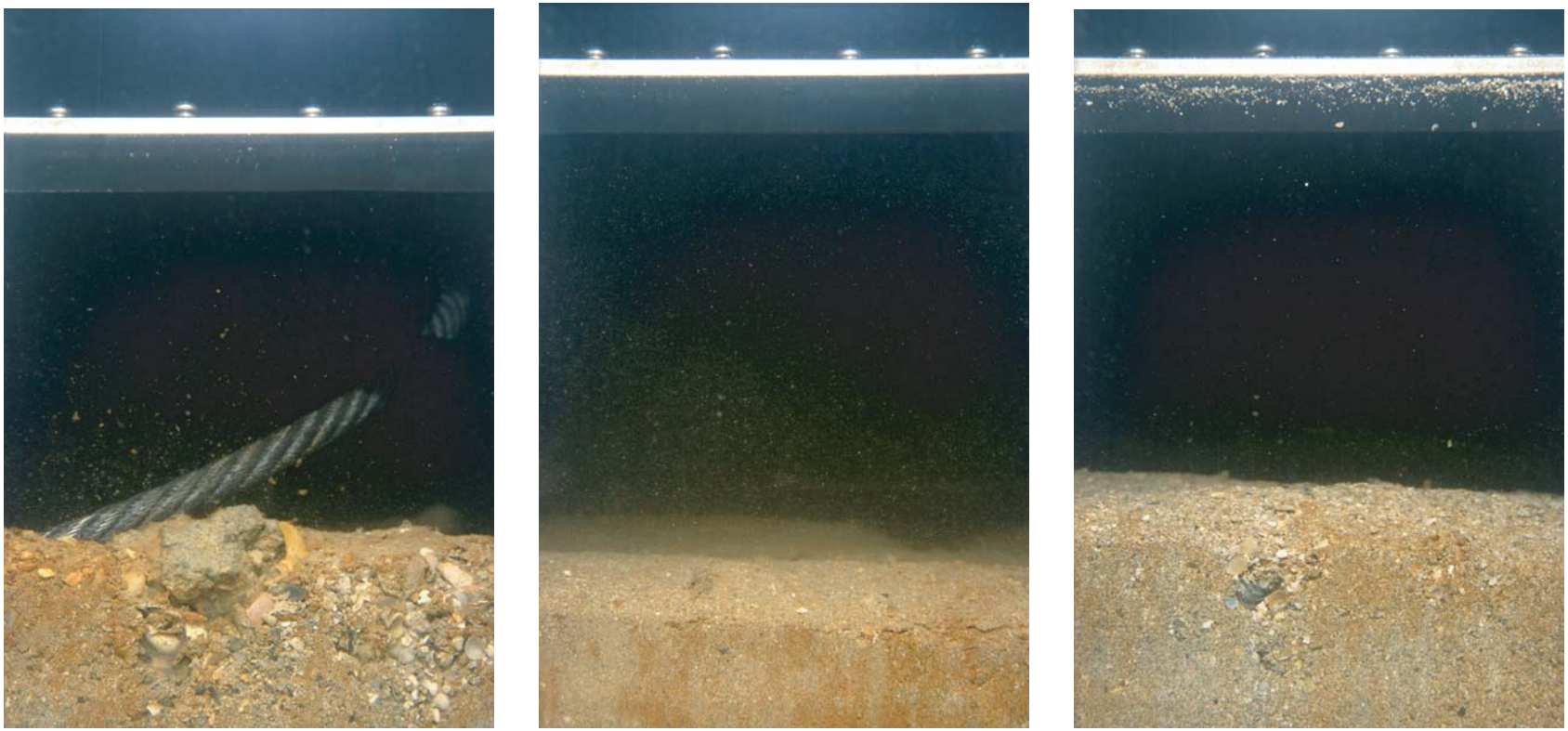

Figure 3-7: Three replicate SPI images from station E7 illustrating within-station variability in the texture of the dredged material, ranging from very coarse sand with gravel and shell fragments (left) to fine sand (middle) to medium sand (right). Note the reddish/rust coloration in all three images. Scale: actual image width is 14.4 cm.

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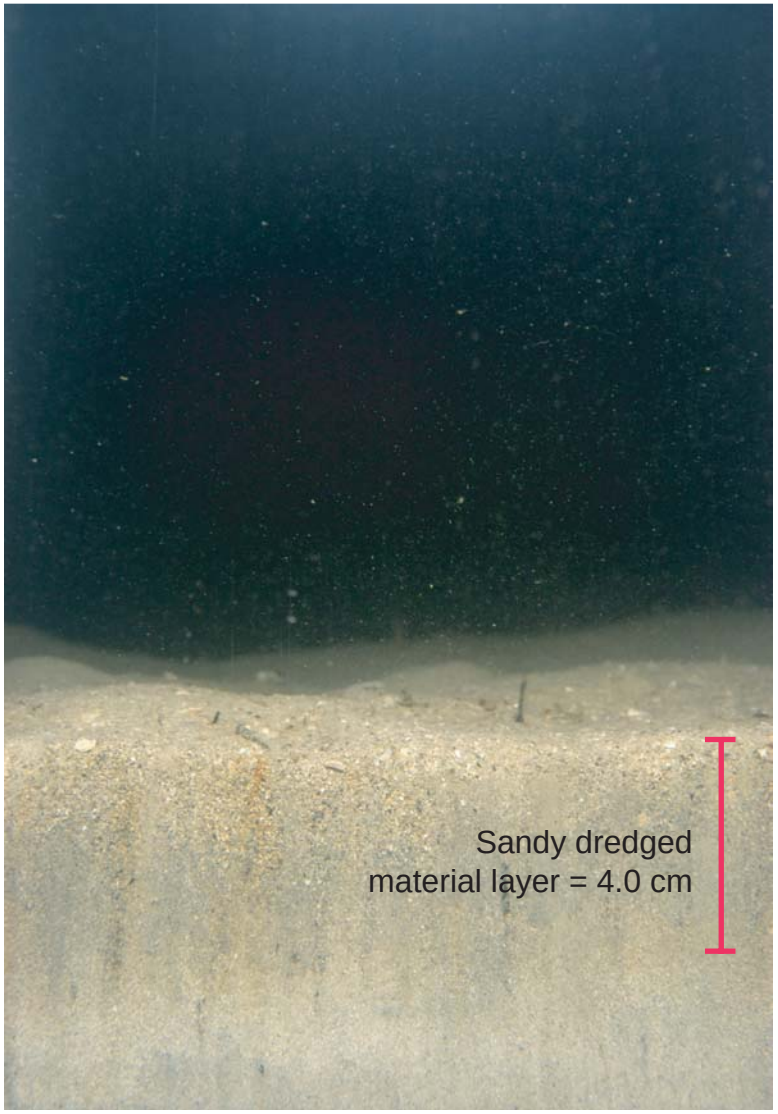
A. Station D4



B. Station X11

Figure 3-8: SPI images from stations D4 (left) and X11 (right) showing discrete surface layers of dredged material consisting of fine to medium sand overlying ambient sediment at depth. The measured thickness of the surface dredged material layer is 4.5 cm in the left image and 4.0 cm in the right image. Scale: actual image width is 14.4 cm.

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Figure 3-9: In this SPI image from station F8, the small-scale vertical relief across the field-of-view (i.e., "boundary roughness") is due both to sediment accumulation around the upright tubes and to the biogenic mound at left (arrow). This is an example of biogenic boundary roughness. Scale: actual image width is 14.4 cm.

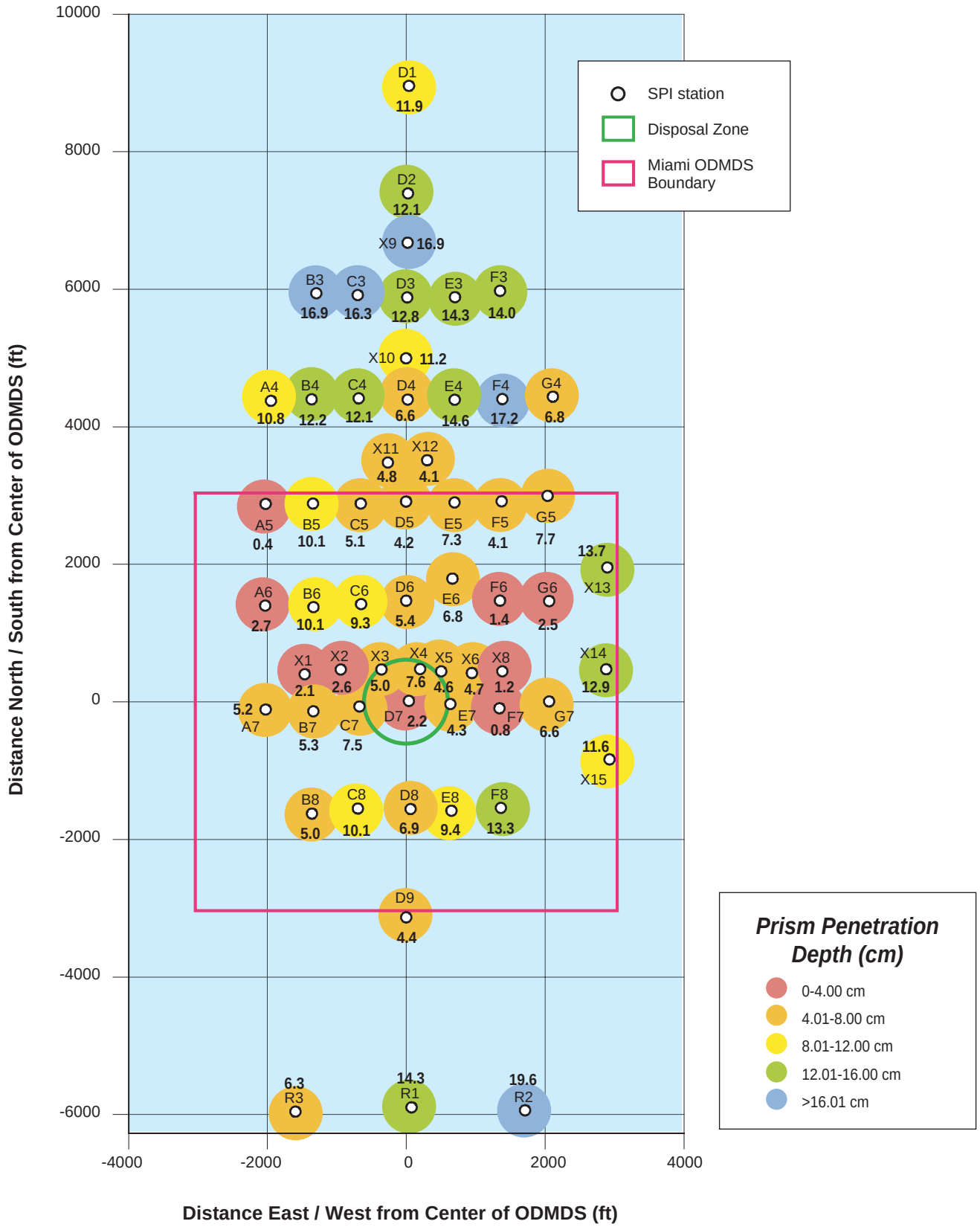

Figure 3-10: Average prism penetration depths (cm) at the Miami ODMDS SPI stations.

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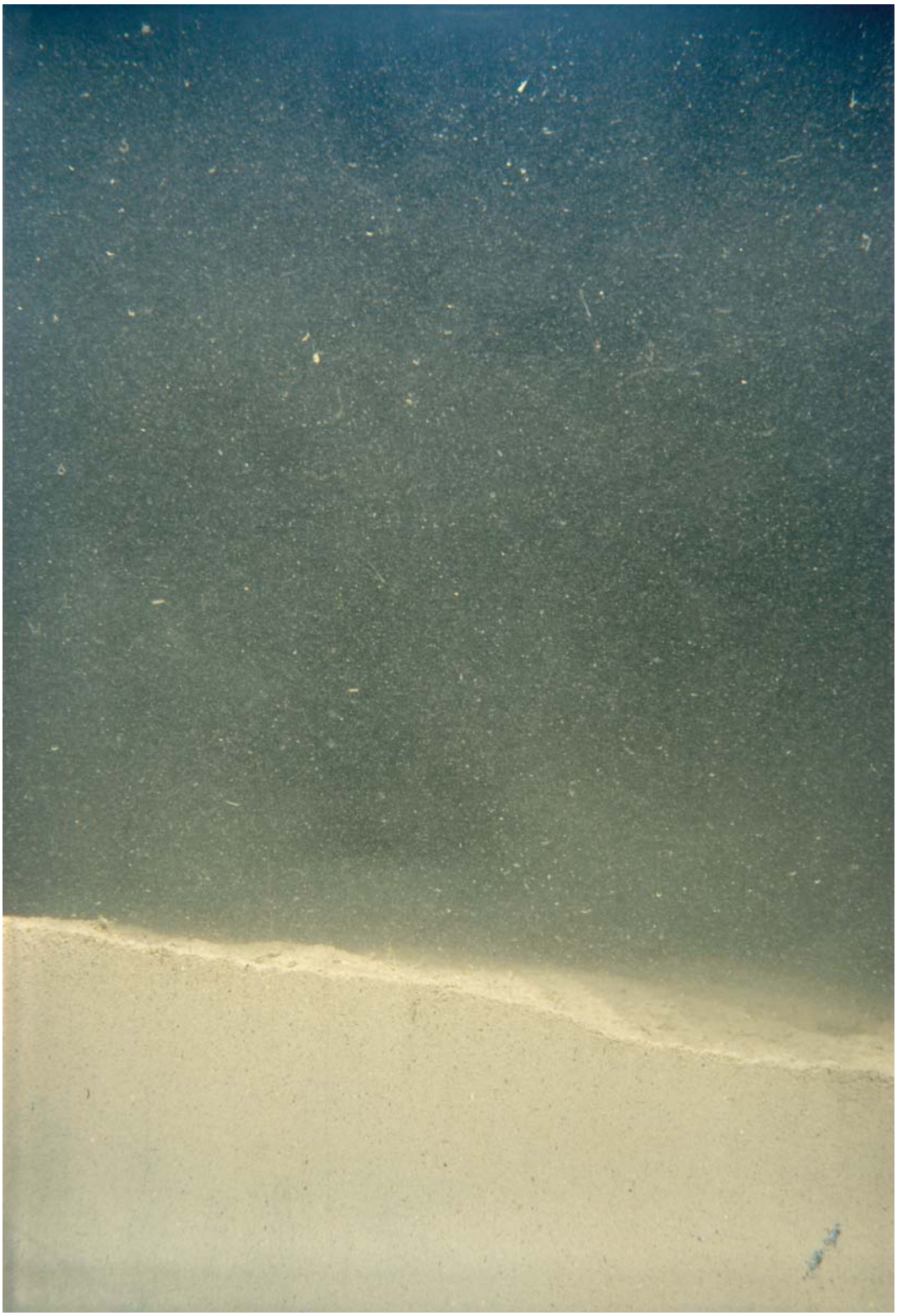

Figure 3-11: SPI image from station A7 showing uniformly light-colored, very silty fine sand. The aRPD depth for this image is considered to be greater than the penetration depth and is expressed as >5.1 cm (i.e., the average vertical distance from the sediment surface to the bottom of the image). Scale: actual image width is 14.4 cm.

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Figure 3-12: SPI image from station F4 showing mostly light-colored silt-clay sediment with intermittent patches of darker sediment at depth. The surface layer of light-colored sediment is fairly thick; the measured aRPD depth for this image is 6.8 cm. Scale: actual image width is 14.4 cm.

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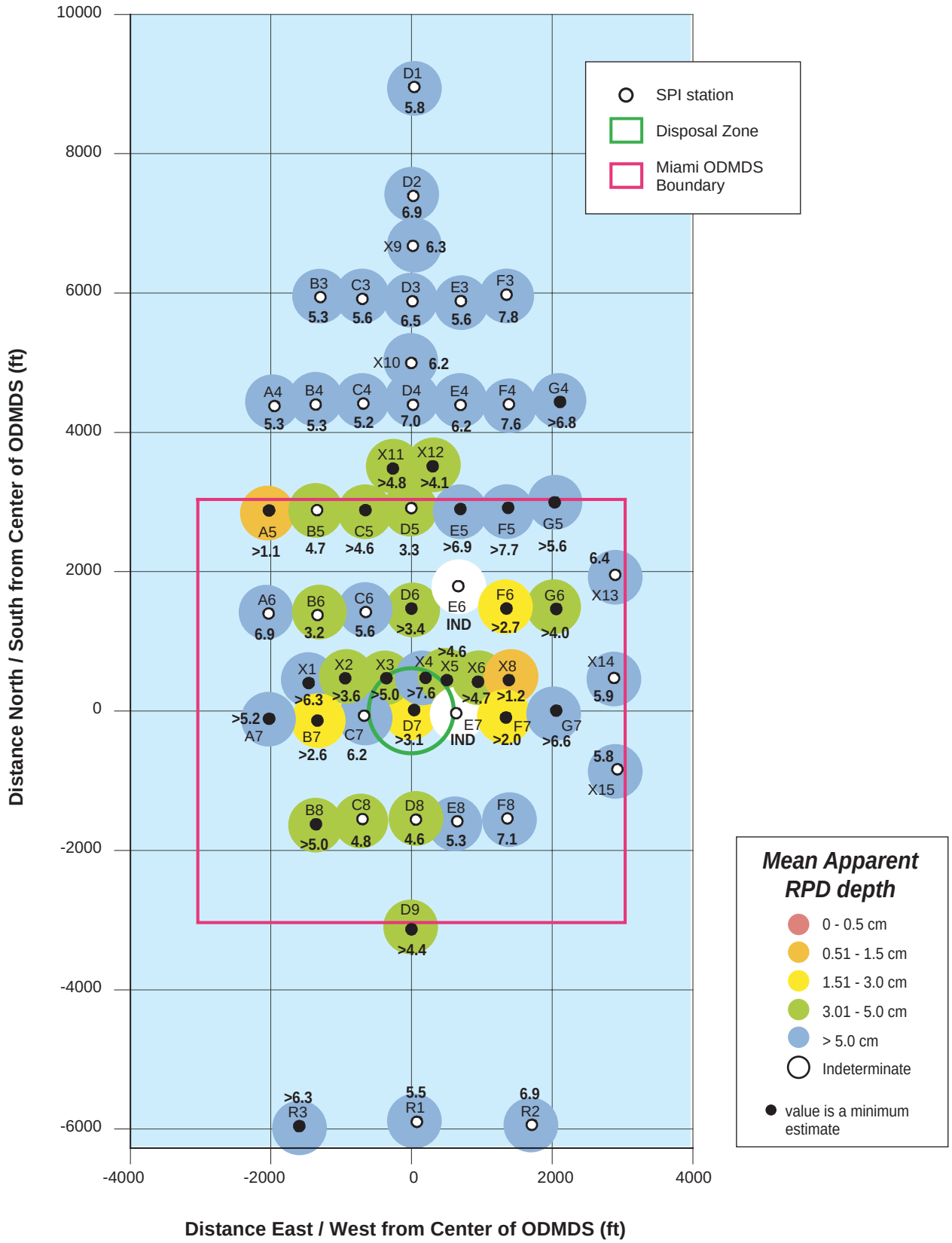

Figure 3-13: Average aRPD depths (cm) at the Miami ODMDS SPI stations.

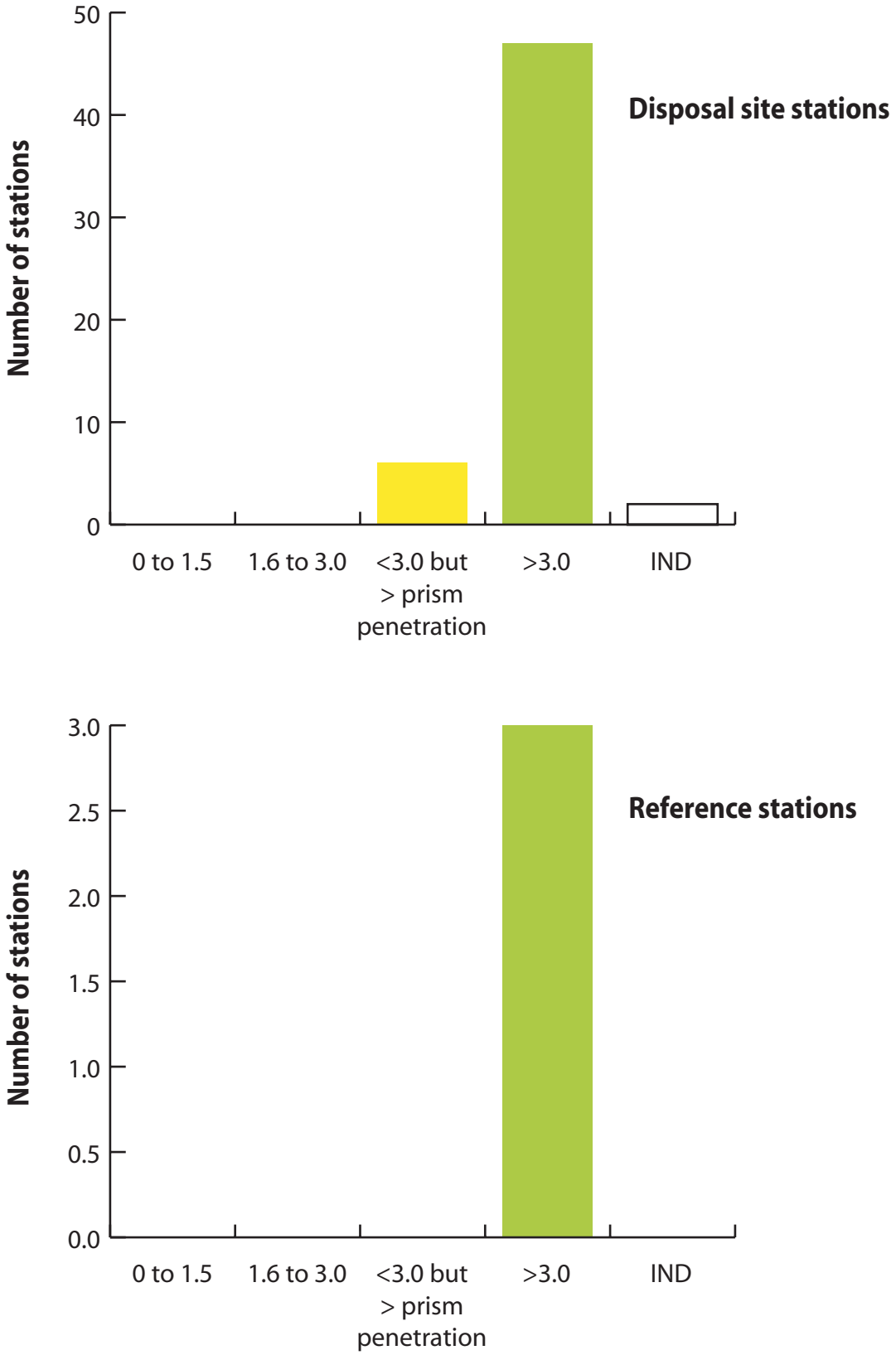

Figure 3-14: Frequency distribution of average RPD depths at the disposal site stations (top) and reference stations (bottom).

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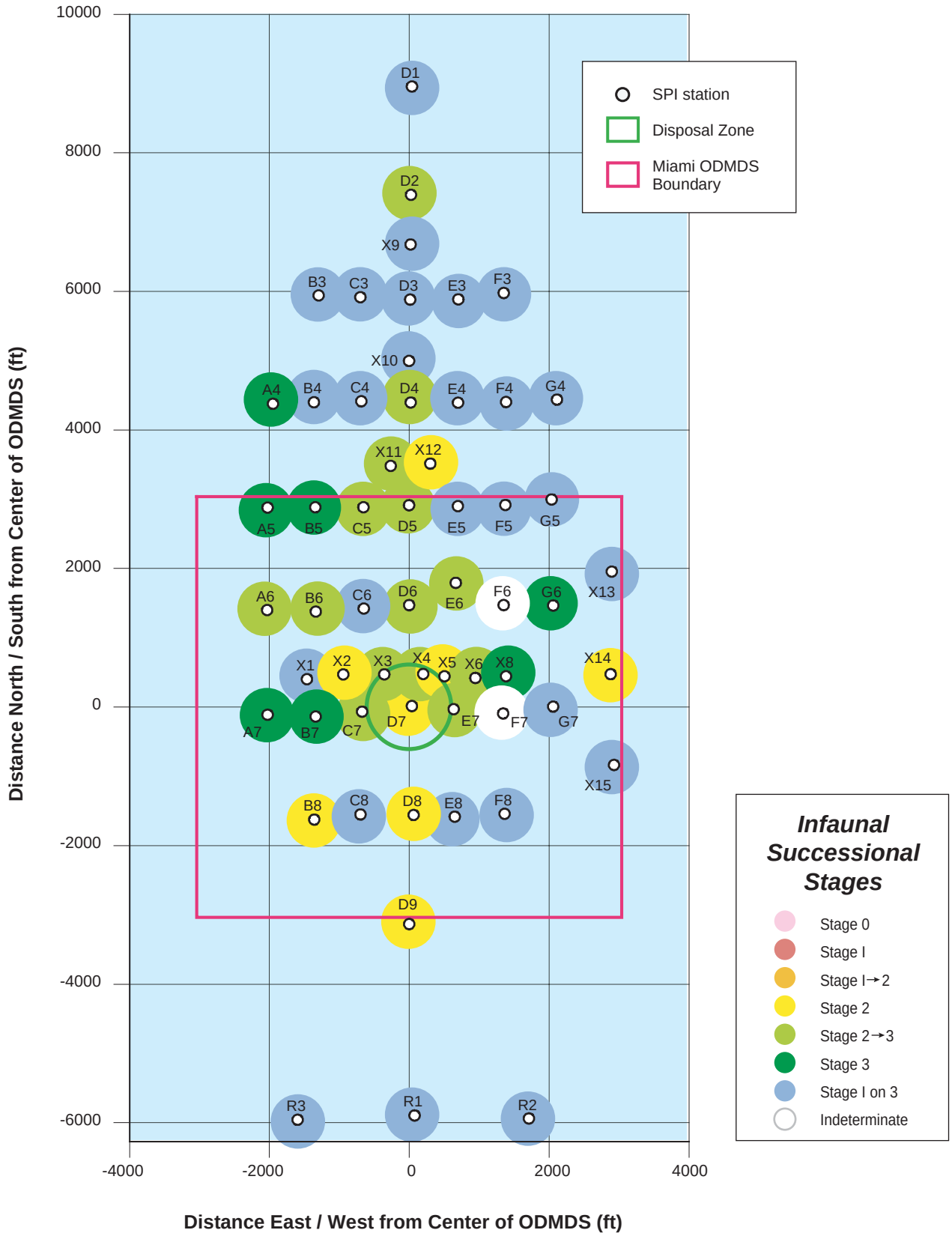

Figure 3-15: Map showing the highest infaunal successional stage observed among the replicate SPI images analyzed at each station in the May 2006 survey.

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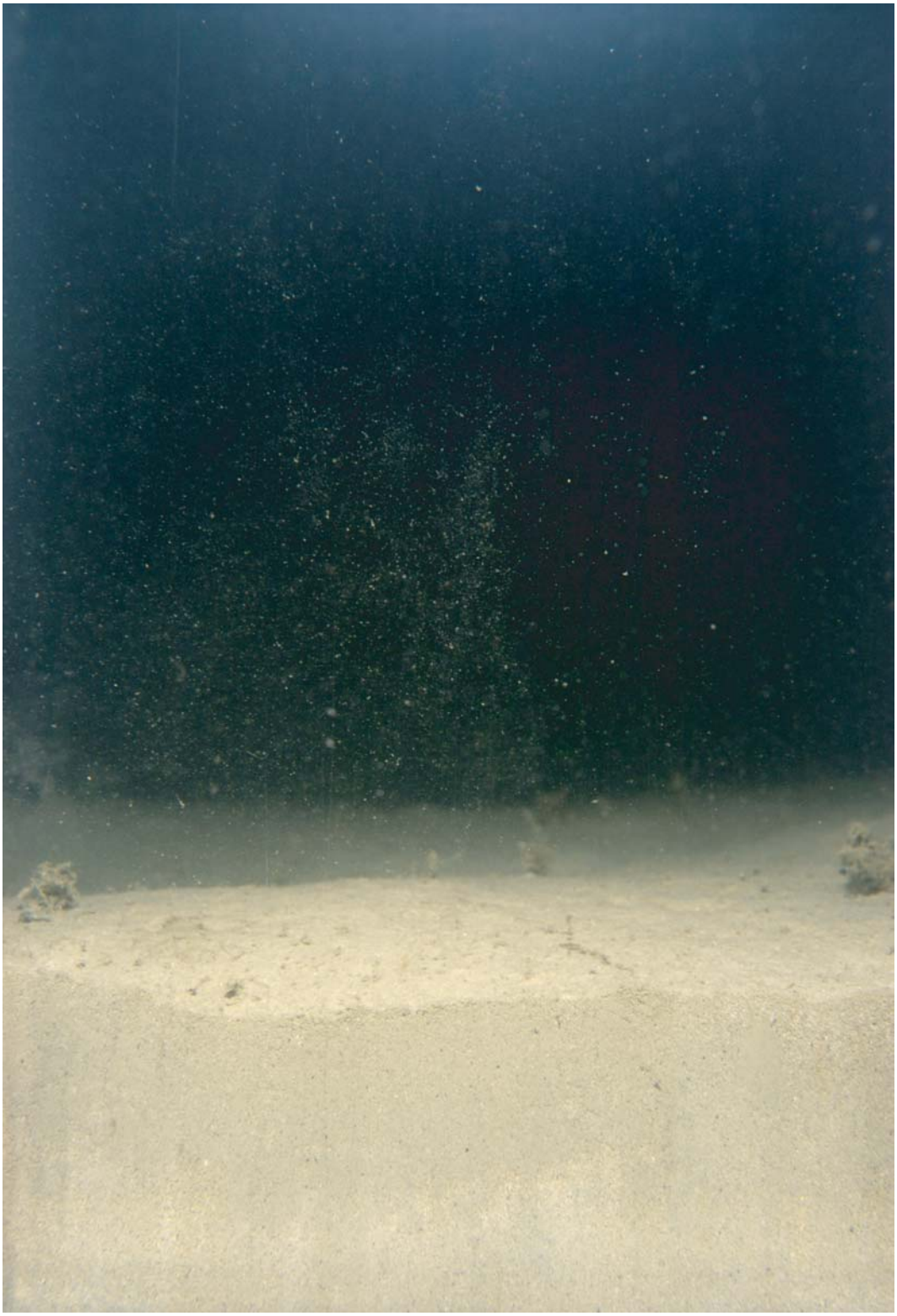

Figure 3-16: SPI image from station D9 illustrating Stage 2, where the visible evidence of biological activity consisted of several different types/sizes of tubes occurring at the sediment surface. Scale: actual image width is 14.4 cm.

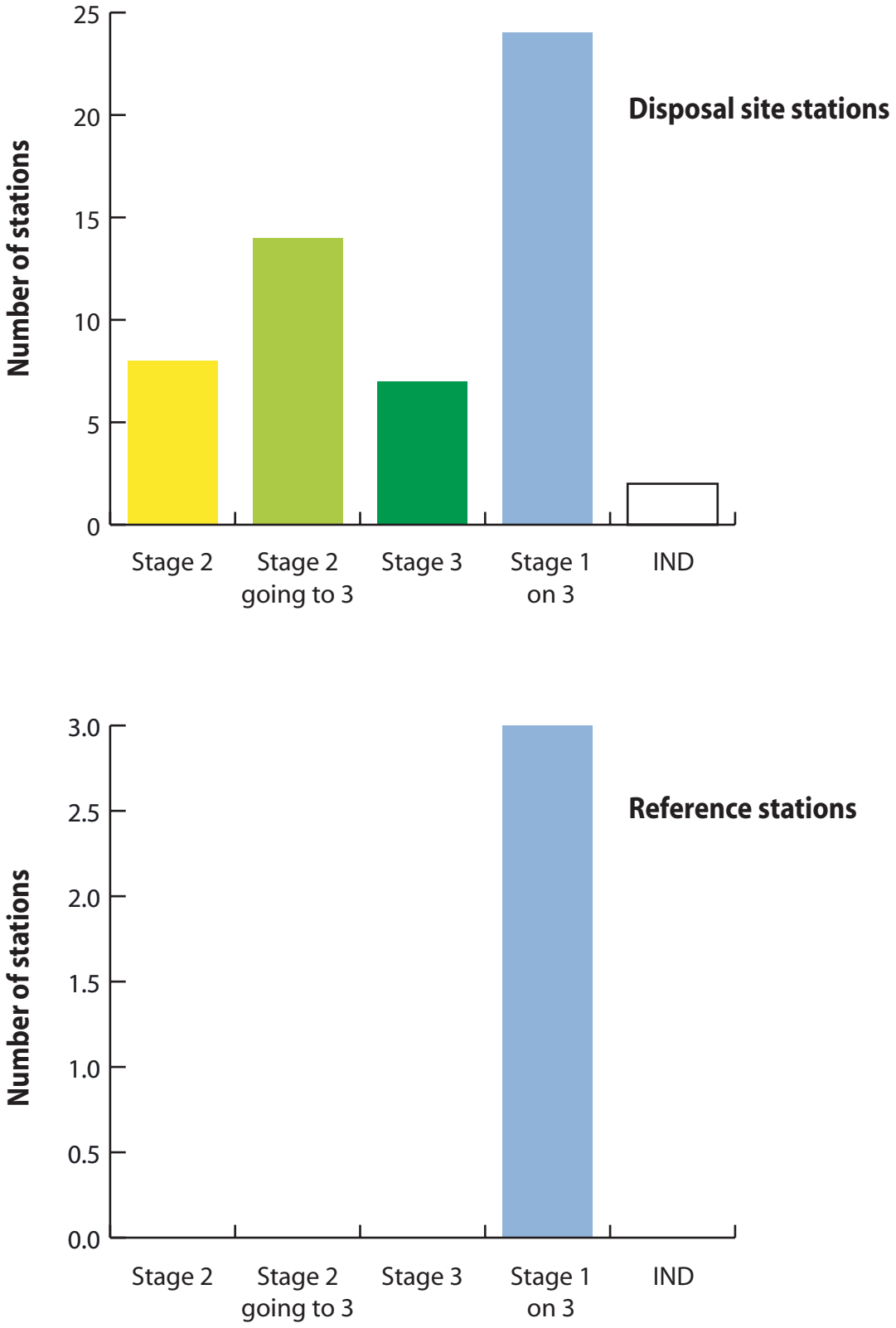

Figure 3-17: Frequency distribution of the highest infaunal successional stage observed at each of the disposal site stations (top) and reference stations (bottom).

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Figure 3-18: SPI image from station C7 illustrating Stage 2 advancing to Stage 3, based on the presence of moderate numbers of different types of tubes at the sediment surface and a small polychaete visible at depth on the lower right (arrow). Scale: actual image width is 14.4 cm.

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A. Station F8 **B. Station E4**

Figure 3-19: SPI images from station F8 (left) and E4 (right) illustrating Stage 1 on 3, based on the observation of low to moderate numbers of small surface tubes, as well as biogenic mounds (arrows) denoting significant bioturbation activity (excavation of subsurface sediment) by deeper-dwelling Stage 3 organisms. Scale: actual image width is 14.4 cm.

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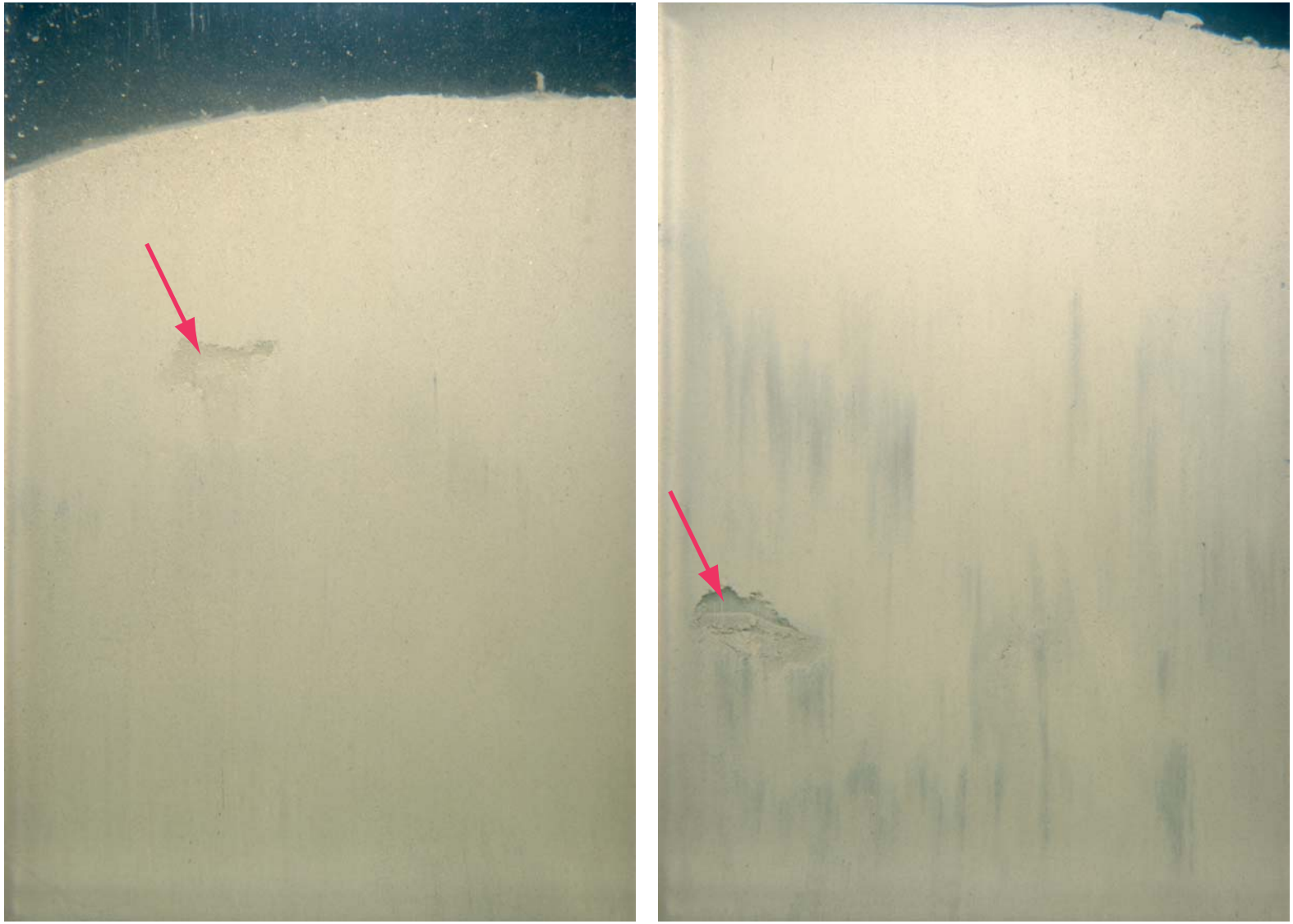

A. Station F4 **B. Station R2**

Figure 3-20: SPI images from station F4 (left) and R2 (right) showing Stage 1 surface tubes and active feeding voids at depth (arrows), providing evidence that Stage 3 subsurface deposit-feeders are present in these relatively soft, fine-grained sediments (Stage 1 on 3). Only part of the sediment surface is visible in the right image; the remainder occurs above the viewing window due to over-penetration of the camera prism in soft sediment. Scale: actual image width is 14.4 cm.

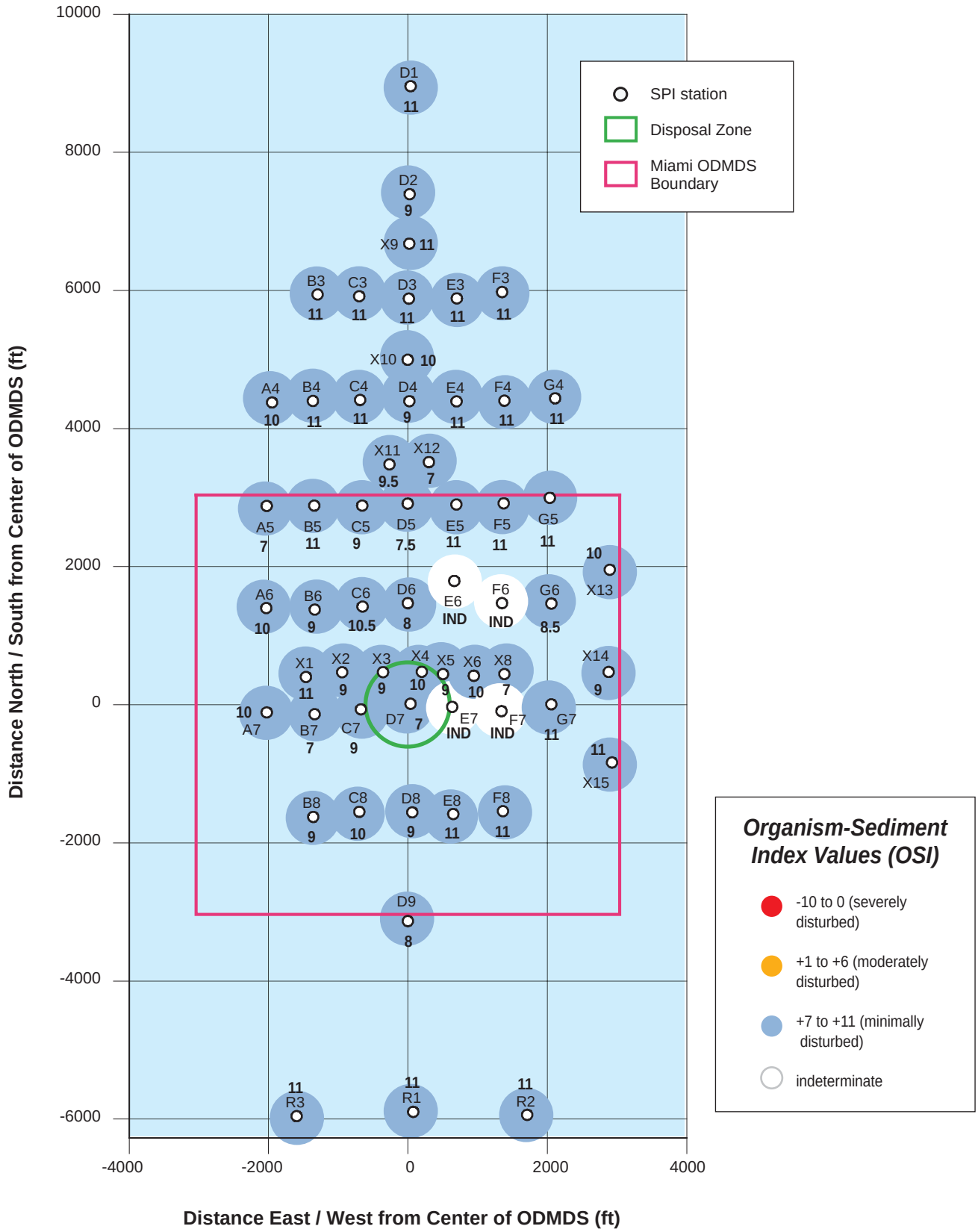

Figure 3-21: Median OSI values at the Miami ODMDS SPI stations.

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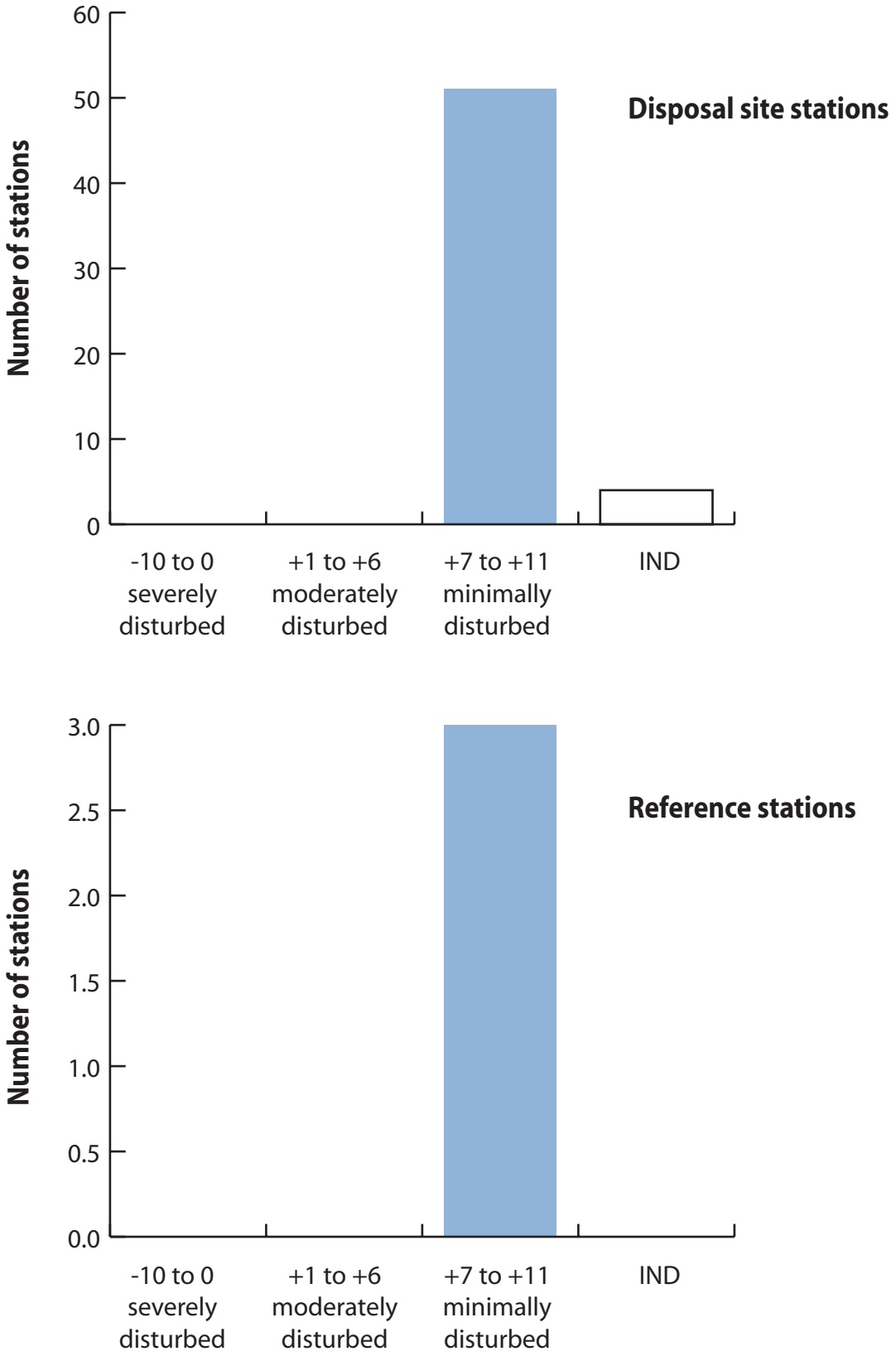

Figure 3-22: Frequency distribution of median OSI values at the disposal site stations (top) and reference stations (bottom).

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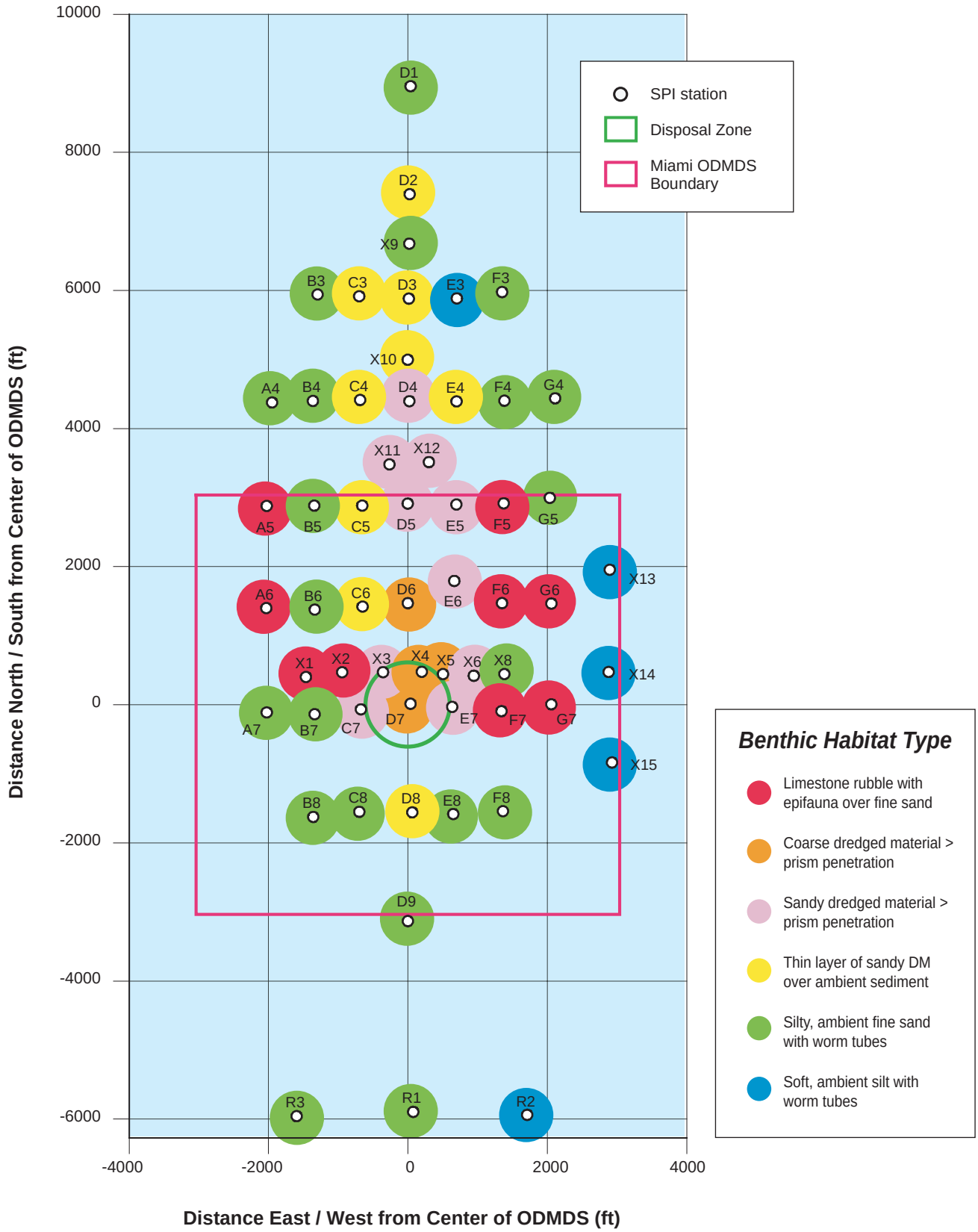

Figure 3-23: Map of benthic habitat types at the Miami ODMDS SPI stations.

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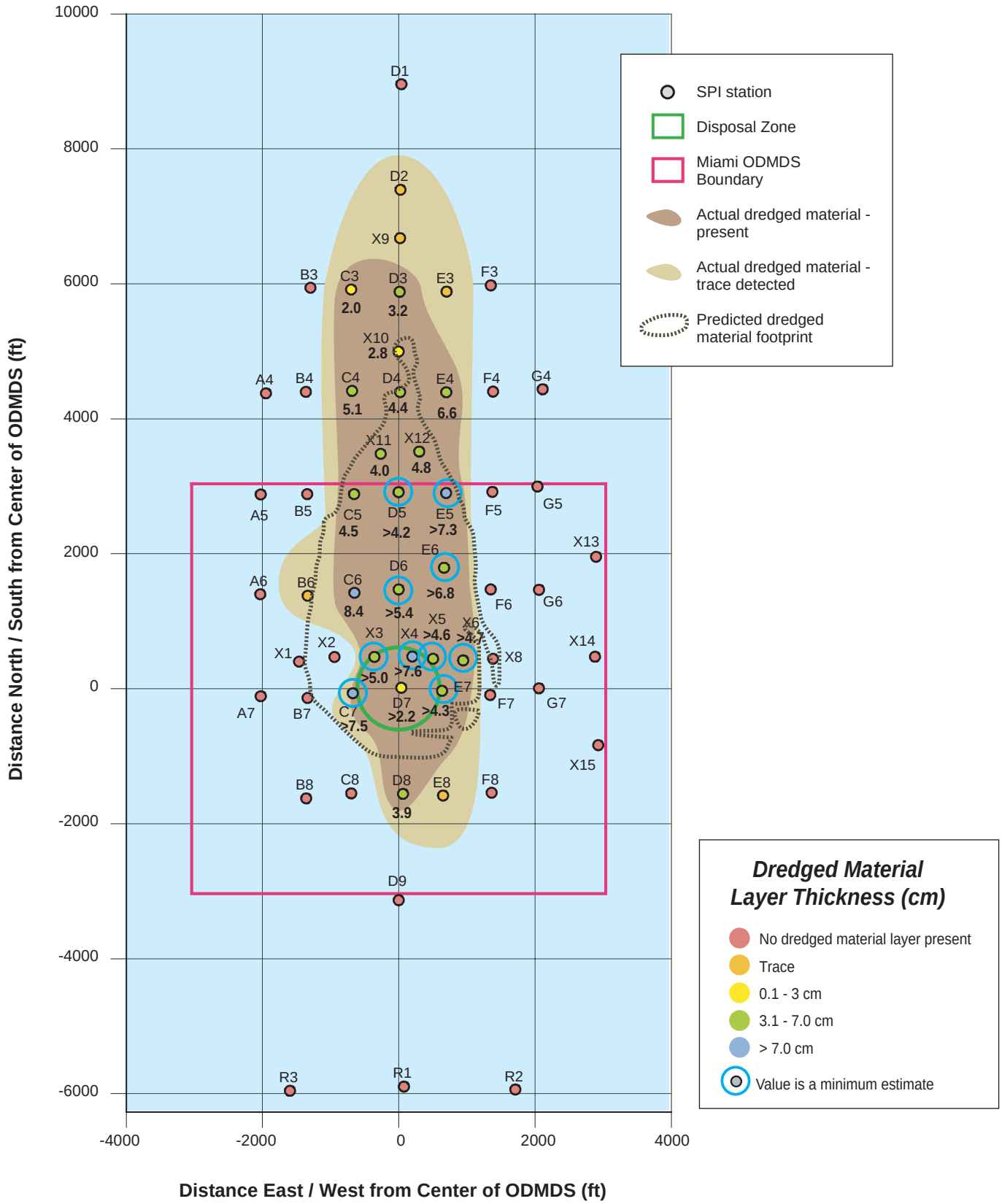

Figure 4-1: Actual distribution of dredged material based on analysis of sediment profile images as compared with modeled results for the Miami Harbor ODMDS.

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APPENDIX A

Sediment Profile Image Analysis Results

Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles	Low DO?
M-A4	1B	5/23/2006	17:07	14.4	>4 to 3	2	>4	>4 - 2	171.8	11.93	11.64	12.3	0.61	b	80.1	5.56		5.0	5.61	0	None	No
M-A4	2B	5/23/2006	17:08	14.4	>4 to 3	2	>4	>4 - 2	150.3	10.44	10.17	10.9	0.7	b	77.0	5.35		4.1	6.25	0	None	No
M-A4	4B	5/23/2006	17:10	14.42	4 to 3	2	>4	>4 - 2	142.8	9.90	9.36	10.4	1.07	b	72.5	5.03		4.5	5.62	0	None	No
M-A5	1B	5/23/2006	17:29	14.41	4 to 3	2	>4	>4 - 2	15.3	1.06	0	2.7	2.7	b	>15.25	1.06	>	0.0	>2.70	0	None	No
M-A5	2B	5/23/2006	17:30	14.42	ind	ind	ind	ind	0.0	0.00	0	0.0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-A5	4B	5/23/2006	17:32	14.42	ind	ind	ind	ind	0.0	0.00	0	0.0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-A6	2B	5/23/2006	18:23	14.42	ind	ind	ind	ind	0.0	0.00	0	0.0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-A6	3B	5/23/2006	18:25	14.4	ind	ind	ind	ind	0.0	0.00	0	0.0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-A6	4B	5/23/2006	18:26	14.42	>4-3	2	>4	>4 - 2	116.7	8.09	7.36	8.9	1.55	b	100.0	6.93		5.6	7.24	0	None	No
M-A7	1B	5/23/2006	18:44	14.42	>4-3	2	>4	>4 - 2	76.6	5.31	4.56	6.5	1.98	b	>76.63	5.31	>	>4.56	>6.54	0	None	No
M-A7	3B	5/23/2006	18:47	14.4	>4-3	2	>4	>4 - 2	73.5	5.11	3.82	6.3	2.49	p	>73.54	5.11	>	>3.82	>6.31	0	None	No
M-B3	1B	5/23/2006	15:25	14.4	4 to 3	2	>4	>4 - 2	260.6	18.10	17.21	18.6	1.37	b	72.3	5.02		3.5	6.15	0	None	No
M-B3	2B	5/23/2006	15:27	14.4	4 to 3	2	>4	>4 - 2	251.9	17.49	16.69	17.9	1.21	b	66.7	4.63		3.1	6.04	0	None	No
M-B3	3B	5/23/2006	15:28	14.4	4 to 3	2	>4	>4 - 2	218.2	15.15	14.35	15.3	0.96	b	91.3	6.34		4.2	8.22	0	None	No
M-B4	1B	5/24/2006	4:24	14.4	4 to 3	2	>4	>4 - 2	186.1	12.92	11.77	13.7	1.96	b	73.0	5.07		4.0	5.6	0	None	No
M-B4	2B	5/24/2006	4:25	14.4	>4 to 3	2	>4	>4 - 2	194.4	13.50	13.25	13.8	0.51	b	83.8	5.82		3.1	7.22	0	None	No
M-B4	4B	5/24/2006	4:27	14.4	4 to 3	2	>4	>4 - 2	147.8	10.26	9.62	11.3	1.65	b	71.6	4.97		3.1	7.02	0	None	No
M-B5	1B	5/24/2006	4:47	14.42	4 to 3	2	>4	>4 - 2	109.1	7.57	5.79	8.9	3.11	b	54.6	3.78		2.5	5.48	0	None	No
M-B5	3B	5/24/2006	4:48	14.42	4 to 3	2	>4	>4 - 2	151.4	10.50	10.21	10.7	0.44	b	63.3	4.39		3.1	4.85	0	None	No
M-B5	4B	5/24/2006	4:49	14.4	4 to 3	2	>4	>4 - 2	175.6	12.19	10.93	13.6	2.66	b	85.5	5.94		4.2	6.67	0	None	No
M-B6	2B	5/24/2006	5:11	14.42	>4 to 3	2	>4	>4 - 2	113.5	7.87	7.56	8.1	0.52	b	45.3	3.14		2.2	4.33	0	None	No
M-B6	3B	5/24/2006	5:12	14.42	>4 to 3	2	>4	>4 - 2	112.0	7.77	7.38	8.0	0.62	b	47.7	3.31		2.1	4.11	0	None	No
M-B6	4B	5/24/2006	5:13	14.42	>4 to 3	2	>4	>4 - 2	88.1	6.11	5.89	6.3	0.36	b	>88.07	6.11	>	>5.89	>6.25	0	None	No
M-B7	2A	5/24/2006	5:35	14.42	>4 to 3	2	>4	>4 - 2	139.0	9.64	9.4	9.9	0.53	b	37.5	2.60		1.2	4.65	0	None	No
M-B7	3B	5/24/2006	5:36	14.42	4 to 3	2	>4	>4 - 2	39.3	2.72	1.75	3.3	1.52	p	>39.28	2.72	>	>1.75	>3.27	0	None	No

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Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles	Low DO?
M-B7	4B	5/24/2006	5:38	14.4	4 to 3	2	>4	>4 - 2	52.9	3.67	2.92	4.5	1.61	p	>52.89	3.67	>	>2.92	>4.53	0	None	No
M-B8	1B	5/24/2006	5:59	14.4	4 to 3	2	>4	>4 - 2	56.6	3.93	2.96	6.2	3.22	p	>56.64	3.93	>	>2.96	>6.18	0	None	No
M-B8	3B	5/24/2006	6:02	14.4	4 to 3	2	>4	>4 - 2	76.6	5.32	4.66	6.1	1.4	b	>76.63	5.32	>	>4.66	>6.06	0	None	No
M-B8	4B	5/24/2006	6:04	14.42	4 to 3	2	>4	>4 - 2	83.9	5.82	4.58	7.7	3.09	b	>83.92	5.82	>	>4.58	>7.67	0	None	No
M-C3	1B	5/23/2006	22:36	14.42	>4 to 3	2	>4	>4 - 2	262.2	18.18	17.8	18.3	0.54	b	86.3	5.98		4.9	7.04	1	None	No
M-C3	2B	5/23/2006	22:37	14.42	>4 to 3	2	>4	>4 - 2	236.9	16.43	16.14	16.7	0.58	b	77.7	5.39		4.2	6.2	0	None	No
M-C3	4B	5/23/2006	22:40	14.42	>4 to 3	2	>4	>4 - 2	208.2	14.44	13.72	14.9	1.18	b	76.3	5.29		4.1	5.31	0	None	No
M-C4	1B	5/23/2006	23:00	14.4	>4 to 3	2	>4	>4 - 2	164.7	11.44	11.22	11.7	0.52	b	84.3	5.86		5.2	6.58	0	None	No
M-C4	2B	5/23/2006	23:01	14.4	>4 to 3	2	>4	>4 - 2	167.1	11.60	10.95	12.0	1.06	b	75.5	5.24		4.2	6.8	0	None	No
M-C4	4B	5/23/2006	23:03	14.42	>4 to 3	1	>4	>4 - 1	192.9	13.38	12.57	13.8	1.23	b	66.2	4.59		3.5	6.29	0	None	No
M-C5	1B	5/23/2006	23:23	14.4	4 to 3	2	>4	>4 - 2	68.6	4.76	3.86	5.2	1.34	p	>68.56	4.76	>	>3.86	>5.2	0	None	No
M-C5	2B	5/23/2006	23:24	14.42	4 to 3	2	>4	>4 - 2	40.4	2.80	2.57	3.3	0.76	b	>40.41	2.80	>	>2.57	>3.33	0	None	No
M-C5	3B	5/23/2006	23:25	14.42	4 to 3	2	>4	>4 - 2	113.0	7.83	7.48	8.1	0.65	b	66.4	4.61		3.8	4.87	3	None	No
M-C6	1B	5/23/2006	23:49	14.4	4 to 3	2	>4	>4 - 2	154.4	10.72	10.43	11.0	0.55	b	80.4	5.58		5.3	6.43	0	None	No
M-C6	2B	5/23/2006	23:50	14.42	4 to 3	2	>4	>4 - 2	105.1	7.29	6.53	8.1	1.55	p	ind	Indeterminate		ind	ind	0	None	No
M-C6	4B	5/23/2006	23:53	14.4	4 to 3	1	>4	>4 - 1	141.6	9.83	9.62	10.1	0.5	b	80.0	5.55		5.0	5.86	0	None	No
M-C7	1B	5/24/2006	0:30	14.42	3 to 2	1	>4	>4 - 1	117.1	8.12	7.02	9.0	1.98	p	101.7	7.05		5.1	7.06	0	None	No
M-C7	2B	5/24/2006	0:31	14.43	3 to 2	1	>4	>4 - 1	88.1	6.10	5.84	6.5	0.65	p	>88.07	6.10	>	>5.84	>6.49	0	None	No
M-C7	4B	5/24/2006	0:34	14.42	3 to 2	1	>4	>4 - 1	118.0	8.18	8.04	8.5	0.42	p	77.8	5.40		4.5	5.46	0	None	No
M-C8	1B	5/24/2006	1:04	14.41	>4 to 3	2	>4	>4 - 2	190.7	13.24	12.85	13.6	0.73	b	72.8	5.05		4.3	6.33	0	None	No
M-C8	2B	5/24/2006	1:06	14.4	>4 to 3	2	>4	>4 - 2	141.0	9.79	9.43	10.5	1.05	b	64.0	4.45		3.3	4.85	0	None	No
M-C8	3B	5/24/2006	1:07	14.42	>4 to 3	2	>4	>4 - 2	104.2	7.23	6.08	8.5	2.39	b	69.6	4.83		3.9	5.75	0	None	No

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Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles	Low DO?
M-D1	2A	5/23/2006	10:06	14.42	>4	2	>4	>4 - 2	205.6	14.26	13.31	15.9	2.6	b	77.1	5.35		3.6	7.5	0	None	No
M-D1	3B	5/23/2006	10:07	14.42	>4 to 3	2	>4	>4 - 2	144.0	9.99	9.47	11.5	1.99	b	81.6	5.66		4.7	6.89	0	None	No
M-D1	4A	5/23/2006	10:08	14.4	>4 to 3	2	>4	>4 - 2	164.2	11.40	9.76	12.8	3.02	ind	91.1	6.33		4.9	7.19	0	None	No
M-D2	1A	5/23/2006	10:31	14.4	>4 to 3	0	>4	>4 - 0	183.7	12.76	9.64	15.2	5.52	ind	123.9	8.60		6.2	10	0	None	No
M-D2	2A	5/23/2006	10:32	14.4	>4 to 3	2	>4	>4 - 2	188.7	13.10	12.75	13.9	1.12	b	94.5	6.56		5.9	6.67	0	None	No
M-D2	3A	5/23/2006	10:33	14.42	>4 to 3	2	>4	>4 - 2	151.1	10.48	7.38	12.0	4.65	ind	80.8	5.60		3.7	7.43	0	None	No
M-D3	1B	5/23/2006	6:51	14.4	3 to 2/>4	0	>4	>4 - 0	231.9	16.10	15.78	16.4	0.65	p	89.2	6.19		4.3	7.31	0	None	No
M-D3	2B	5/23/2006	6:52	14.4	3 to 2	0	>4	>4 - 0	142.3	9.88	9.41	10.0	0.63	b	101.1	7.02		6.5	8.42	0	None	No
M-D3	4B	5/23/2006	6:54	14.42	3 to 2	1	>4	>4 - 1	179.5	12.45	11.53	13.2	1.64	b	90.6	6.28		3.8	8.01	0	None	No
M-D4	1B	5/23/2006	7:17	14.42	3 to 2	0	>4	>4 - 0	156.4	10.84	10.01	12.3	2.3	b	100.9	7.00		3.9	7.76	0	None	No
M-D4	2A	5/23/2006	7:18	14.42	3 to 2	-1	>4	>4 - -1	52.2	3.62	2.89	4.6	1.69	b	>52.22	3.62	>	>2.89	>4.58	0	None	No
M-D4	4A	5/23/2006	7:20	14.42	3 to 2	-1	>4	>4 - -1	76.4	5.30	4.61	6.1	1.53	b	>76.4	5.30	>	>4.61	>6.14	0	None	No
M-D5	1B	5/23/2006	7:40	14.42	2 to 1	<-1	>4	>4 - <-1	108.4	7.52	7.34	7.7	0.4	p	47.2	3.28		2.0	4.26	0	None	No
M-D5	2B	5/23/2006	7:41	14.42	2 to 1	-1	>4	>4 - -1	47.1	3.26	3.03	3.6	0.54	p	>47.08	3.26	>	>3.03	>3.57	0	None	No
M-D5	4A	5/23/2006	7:43	14.4	2 to 1	<-1	>4	>4 - <-1	26.2	1.82	1.52	2.0	0.5	p	>26.18	1.82	>	>1.52	>2.02	0	None	No
M-D6	1B	5/23/2006	8:05	14.42	0 to -1	<-1	>4	>4 - <-1	91.5	6.35	6.16	6.6	0.39	p	ind	Indeterminate		ind	ind	0	None	No
M-D6	2B	5/23/2006	8:06	14.42	<-1	<-1	>4	>4 - <-1	92.2	6.40	6.12	7.5	1.33	p	ind	Indeterminate		ind	ind	0	None	No
M-D6	4A	5/23/2006	8:08	14.4	<-1	<-1	>4	>4 - <-1	49.3	3.42	3.05	3.8	0.79	p	>49.27	3.42	>	>3.05	>3.84	0	None	No
M-D7	1A	5/23/2006	8:30	14.42	2 to 1	<-1	>4	>4 - <-1	49.1	3.41	1.78	5.5	3.74	p	>49.12	3.41	>	>1.78	>5.52	0	None	No
M-D7	2A	5/23/2006	8:31	14.42	2 to 1	<-1	>4	>4 - <-1	40.8	2.83	2.55	3.2	0.65	p	>40.79	2.83	>	>2.55	>3.2	0	None	No

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Station	REP	DATE	TIME	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Source	RPD Area (sq.cm)	Mean RPD (cm)	RPD>pen?	RPD Minimum (cm)	RPD Maximum (cm)	Mud Clast Number	# of Methane Bubbles	Low DO?
M-D7	3A	5/23/2006	8:32	14.4	<-1	<-1	>4	>4 - <-1	6.2	0.43	0	0.9	0.93	p	ind	Indeterminate		ind	ind	0	None	No
M-D8	1B	5/23/2006	8:54	14.4	4 to 3	2	>4	>4 - 2	106.6	7.40	6.95	8.3	1.34	b	65.5	4.55		4.4	5	0	None	No
M-D8	3B	5/23/2006	8:56	14.42	4 to 3	2	>4	>4 - 2	85.1	5.90	5.59	6.5	0.94	b	62.5	4.33		2.2	5.18	0	None	No
M-D8	4B	5/23/2006	8:58	14.42	4 to 3	2	>4	>4 - 2	107.7	7.47	7.21	8.0	0.77	b	69.9	4.85		4.1	4.95	0	None	No
M-D9	2B	5/24/2006	6:30	14.42	>4 to 3	2	>4	>4 - 2	73.1	5.07	4.71	5.6	0.84	b	>73.13	5.07	>	>4.71	>5.55	0	None	No
M-D9	3B	5/24/2006	6:31	14.42	4 to 3	2	>4	>4 - 2	43.7	3.03	2.78	3.3	0.47	b	>43.65	3.03	>	>2.78	>3.25	0	None	No
M-D9	4B	5/24/2006	6:33	14.42	4 to 3	2	>4	>4 - 2	73.1	5.07	4.43	5.7	1.27	b	>73.12	5.07	>	>4.43	>5.7	0	None	No
M-E3	1A	5/23/2006	19:43	14.43	>4 to 3	2	>4	>4 - 2	145.9	10.11	9.01	10.7	1.64	ind	80.4	5.57		2.9	6.97	0	None	No
M-E3	3B	5/23/2006	19:46	14.42	>4	2	>4	>4 - 2	227.8	15.80	15.25	16.5	1.27	b	89.7	6.22		6.1	7.1	0	None	No
M-E3	4B	5/23/2006	19:47	14.42	>4	2	>4	>4 - 2	245.6	17.03	15.27	18.9	3.61	ind	73.8	5.12		3.8	6.02	0	None	No
M-E4	1B	5/23/2006	20:10	14.4	>4 to 3	2	>4	>4 - 2	236.5	16.42	15.92	17.0	1.04	b	84.3	5.86		4.8	6.67	0	None	No
M-E4	3B	5/23/2006	20:13	14.42	>4 to 3	2	>4	>4 - 2	182.8	12.67	11.86	13.9	1.99	b	95.9	6.65		5.3	7.61	0	None	No
M-E4	4B	5/23/2006	20:14	14.4	>4 to 3	2	>4	>4 - 2	210.9	14.65	13.48	15.7	2.2	b	87.8	6.10		4.1	8.16	0	None	No
M-E5	1B	5/23/2006	20:35	14.42	3 to 2	1	>4	>4 - 1	99.6	6.90	6.07	7.8	1.73	b	>99.57	6.90	>	>6.07	>7.8	0	None	No
M-E5	2B	5/23/2006	20:36	14.4	3 to 2	1	>4	>4 - 1	60.6	4.21	3.9	5.5	1.6	b	ind	Indeterminate		ind	ind	0	None	No
M-E5	3B	5/23/2006	20:37	14.42	3 to 2	1	>4	>4 - 1	155.6	10.79	10.21	11.2	1.01	b	ind	Indeterminate		ind	ind	0	None	No
M-E6	2B	5/23/2006	21:01	14.42	3 to 2	<-1	>4	>4 - <-1	75.7	5.25	4.65	6.5	1.86	p	ind	Indeterminate		ind	ind	0	None	No
M-E6	3B	5/23/2006	21:02	14.4	3 to 2	<-1	>4	>4 - <-1	108.5	7.53	7.14	8.0	0.83	p	ind	Indeterminate		ind	ind	0	None	No
M-E6	4B	5/23/2006	21:04	14.42	3 to 2	-1	>4	>4 - -1	110.1	7.63	7.61	7.8	0.23	p	ind	Indeterminate		ind	ind	0	None	No
M-E7	1B	5/23/2006	21:25	14.4	0 to -1	<-1	>4	>4 - <-1	70.0	4.86	4.58	5.7	1.07	p	ind	Indeterminate		ind	ind	0	None	No

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M-E7	2B	5/23/2006	21:26	14.42	3 to 2	-1	>4	>4 - -1	42.7	2.96	2.61	3.4	0.81	p	ind	Indeterminate		ind	ind	0	None	No
M-E7	4B	5/23/2006	21:28	14.4	2 to 1	<-1	>4	>4 - <-1	74.1	5.15	4.67	5.3	0.59	p	ind	Indeterminate		ind	ind	0	None	No
M-E8	1B	5/23/2006	21:49	14.4	4 to 3	2	>4	>4 - 2	146.9	10.20	9.07	11.5	2.41	p	69.0	4.79		3.5	5.66	0	None	No
M-E8	2B	5/23/2006	21:50	14.42	4 to 3	2	>4	>4 - 2	134.8	9.35	8.97	9.5	0.54	b	78.7	5.46		4.7	5.62	0	None	No
M-E8	3B	5/23/2006	21:51	14.42	4 to 3	2	>4	>4 - 2	126.2	8.75	8.24	9.4	1.16	b	81.8	5.67		3.6	7.32	0	None	No
M-F3	1B	5/23/2006	11:04	14.42	>4	2	>4	>4 - 2	250.5	17.37	17.02	17.66	0.64	b	133.0	9.22		4.54	13.87	0	None	No
M-F3	2B	5/23/2006	11:06	14.4	>4	2	>4	>4 - 2	230.5	16.00	14.76	16.43	1.67	b	90.9	6.31		3.97	8.84	0	None	No
M-F3	3A	5/23/2006	11:07	14.42	>4	2	>4	>4 - 2	124.1	8.60	8.39	8.81	0.42	b	>124.06	8.60	>	>8.39	>8.81	0	None	No
M-F4	2B	5/24/2006	1:53	14.42	>4	2	>4	>4 - 2	265.1	18.38	17.88	19	1.12	b	120.1	8.33		7.4	10.16	0	None	No
M-F4	3B	5/24/2006	1:54	14.42	>4	2	>4	>4 - 2	263.7	18.29	16.93	18.91	1.98	b	108.7	7.54		6.8	8.69	0	None	No
M-F4	4B	5/24/2006	1:55	14.4	>4	2	>4	>4 - 2	215.7	14.98	14.1	16.36	2.26	b	98.0	6.81		4.09	9.05	0	None	No
M-F5	1B	5/24/2006	2:32	14.4	>4 to 3	<-1	>4	>4 - <-1	8.2	0.57	0	1.41	1.41	p	>8.19	0.57	>	>0	>1.4	0	None	No
M-F5	2B	5/24/2006	2:33	14.42	>4 to 3	<-1	>4	>4 - <-1	111.3	7.72	7.21	8.57	1.36	b	>111.28	7.72	>	>7.21	>8.57	0	None	No
M-F6	3B	5/24/2006	3:14	14.4	>4 to 3	2	>4	>4 - 2	39.5	2.75	0	4.74	4.74	p	>39.5	2.74	>	0	>4.7	0	None	No
M-F6	4B	5/24/2006	3:15	14.42	ind	ind	ind	ind	0.0	0.00	0	0	0	p	ind	Indeterminate		ind	ind	ind	None	No
M-F7A	1B	5/24/2006	10:42	14.42	4 to 3	2	>4	>4 - 2	29.0	2.01	0.99	3.07	2.08	ind	>28.9	2.004160888	>	>1.0	>3.1	0	None	No
M-F7A	3B	5/24/2006	10:45	14.42	ind	ind	ind	ind	0.0	0.00	0	0	0	ind	ind	Indeterminate		ind	ind	ind	None	No
M-F7A	4B	5/24/2006	10:46	14.4	4 to 3	2	>4	>4 - 2	5.9	0.41	0	0.94	0.94	ind	ind	Indeterminate		ind	ind	0	None	No
M-F8	1B	5/23/2006	14:15	14.42	>4 to 3	2	>4	>4 - 2	219.3	15.21	14.5	16.6	2.1	b	116.9	8.10		4.53	9.55	0	None	No
M-F8	2B	5/23/2006	14:17	14.4	>4 to 3	1	>4	>4 - 1	222.3	15.43	14.16	16.23	2.07	b	87.5	6.08		3.12	7.4	0	None	No

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M-F8	4B	5/23/2006	14:21	14.4	4 to 3	2	>4	>4 - 2	133.1	9.24	8.83	9.55	0.72	b	>133.07	9.24	>	>8.83	>9.55	0	None	No
M-G4	1A	5/23/2006	11:32	14.42	>4	2	>4	>4 - 2	73.5	5.09	4.43	6.71	2.28	b	>73.45	5.09	>	>4.43	>6.71	0	None	No
M-G4	2A	5/23/2006	11:33	14.4	>4	2	>4	>4 - 2	109.5	7.60	7.4	7.73	0.33	b	>109.45	7.60	>	>7.4	>7.73	0	None	No
M-G4	4A	5/23/2006	11:35	14.42	>4	2	>4	>4 - 2	109.0	7.56	7.37	7.71	0.34	b	>108.99	7.56	>	>7.37	>7.71	0	None	No
M-G5	2A	5/23/2006	12:08	14.4	>4 to 3	2	>4	>4 - 2	96.3	6.69	5.89	7.67	1.78	b	>96.32	6.69	>	>5.89	>7.67	0	None	No
M-G5	3A	5/23/2006	12:09	14.42	>4 to 3	2	>4	>4 - 2	87.7	6.08	5.72	6.62	0.9	b	>87.65	6.08	>	>5.72	>6.62	0	None	No
M-G5	4B	5/23/2006	12:10	14.42	>4 to 3	2	>4	>4 - 2	150.7	10.45	10.17	10.85	0.68	b	81.1	5.63		4.58	6.57	0	None	No
M-G6	1B	5/23/2006	12:43	14.4	>4 to 3	2	>4	>4 - 2	49.6	3.45	1.5	4.4	2.9	ind	>49.64	3.45	>	>1.50	>4.4	0	None	No
M-G6	3B	5/23/2006	12:46	14.4	<-1	<-1	>4	>4 - <-1	0.0	0.00	0	0	0	p	ind	Indeterminate		ind	ind	0	None	No
M-G6	4B	5/23/2006	12:48	14.42	>4 to 3	2	>4	>4 - 2	57.1	3.96	3.09	4.91	1.82	b	>57.1	3.96	>	>3,1	>4.9	0	None	No
M-G7	1B	5/23/2006	13:25	14.42	>4 to 3	1	>4	>4 - 1	80.7	5.60	0.38	8.52	8.14	b	>80.69	5.60	>	>0.38	>8.52	0	None	No
M-G7	3B	5/23/2006	13:30	14.42	4 to 3	1	>4	>4 - 1	75.5	5.24	4.12	6.14	2.02	p	>75.5	5.24	>	>4.1	>6.1	0	None	No
M-G7	4B	5/23/2006	13:32	14.42	>4 to 3	1	>4	>4 - 1	130.4	9.04	8.31	10.25	1.94	b	>130.37	9.04	>	>8.31	>10.25	0	None	No
M-X1	1B	5/24/2006	8:13	14.42	<-1	<-1	>4	>4 - <-1	0.0	0.00	0	0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-X1	2B	5/24/2006	8:14	14.42	<-1	<-1	ind	ind - <-1	0.0	0.00	0	0	0	ind	ind	Indeterminate		ind	ind	0	None	No
M-X1	4B	5/24/2006	8:17	14.42	>4 to 3	2	>4	>4 - 2	90.2	6.25	5.63	7.23	1.6	b	>90.18	6.25	>	>5.63	>7.23	0	None	No
M-X2	1B	5/24/2006	8:41	14.4	4 to 3	2	>4	>4 - 2	101.2	7.03	6.07	7.82	1.75	p	>101.16	7.03	>	>6.07	>7.82	0	None	No
M-X2	3B	5/24/2006	8:44	14.42	<-1	<-1	<-1	<-1 - <-1	0.0	0.00	0	0	0	p	ind	Indeterminate		ind	ind	0	None	No
M-X2	4B	5/24/2006	8:46	14.42	3 to 2	1	>4	>4 - 1	13.3	0.92	0	1.45	1.45	b	>13.2	0.92	>	ind	>1.4	0	None	No
M-X3	2B	5/24/2006	9:09	14.42	2 to 1	-1	>4	>4 - -1	65.9	4.57	4.19	4.78	0.59	p	>65.9	4.57	>	>4.2	>4.8	0	None	No
M-X3	3B	5/24/2006	9:11	14.42	2 to 1	<-1	>4	>4 - <-1	80.3	5.57	5.37	5.91	0.54	p	>80.3	5.57	>	>5.4	>5.9	0	None	No
M-X3	4B	5/24/2006	9:12	14.42	2 to 1	<-1	>4	>4 - <-1	70.5	4.89	4.54	5.22	0.68	p	>70.5	4.89	>	>4.5	>5.2	0	None	No
M-X4	1B	5/24/2006	9:35	14.42	2 to 1	<-1	>4	>4 - <-1	118.2	8.20	7.56	8.57	1.01	p	>118.2	8.20	>	>7.6	>8.6	0	None	No
M-X4	2B	5/24/2006	9:36	14.42	2 to 1	<-1	>4	>4 - <-1	93.7	6.50	6.1	7.01	0.91	p	>93.7	6.50	>	>6.1	>7.0	0	None	No

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M-X4	3B	5/24/2006	9:38	14.42	2 to 1	<-1	>4	>4 - <-1	115.0	7.97	7.63	8.64	1.01	p	>115	7.98	>	>7.6	>8.6	0	None	No
M-X5	2B	5/24/2006	9:53	14.42	2 to 1	<-1	>4	>4 - <-1	96.7	6.71	6.23	6.98	0.75	p	>96.7	6.71	>	>6.2	>7.0	0	None	No
M-X5	3A	5/24/2006	9:54	14.42	2 to 1	<-1	>4	>4 - <-1	40.9	2.84	2.24	3.01	0.77	p	>40.9	2.84	>	>2,2	>3.0	0	None	No
M-X5	4B	5/24/2006	9:55	14.4	1 to 0	<-1	>4	>4 - <-1	60.9	4.23	2.22	4.74	2.52	p	>60.9	4.23	>	>2,2	>4.7	0	None	No
M-X6	1B	5/24/2006	10:05	14.42	3 to 2	1	>4	>4 - 1	71.6	4.97	4.52	5.46	0.94	p	>71.6	4.97	>	>4.5	>5.5	0	None	No
M-X6	2B	5/24/2006	10:06	14.42	3 to 2	<-1	>4	>4 - <-1	62.6	4.34	3.55	5.02	1.47	b	>62.6	4.34	>	>3.6	>5.0	0	None	No
M-X8	1B	5/24/2006	10:17	14.42	4 to 3	2	>4	>4 - 2	29.6	2.05	0.77	2.61	1.84	b	>29.6	2.05	>	>0.8	>2.6	0	None	No
M-X8	2B	5/24/2006	10:18	14.42	4 to 3	2	>4	>4 - 2	21.6	1.50	0.97	2.2	1.23	b	>21.6	1.50	>	>1.0	>2.2	0	None	No
M-X8	4A	5/24/2006	10:21	14.42	4 to 3	2	>4	>4 - 2	0.0	0.00	0	0	0	b	ind	Indeterminate		ind	ind	ind	None	No
M-X9	2B	5/24/2006	12:47	14.4	4 to 3	2	>4	>4 - 2	157.5	10.94	9.88	11.97	2.09	ind	71.2	4.94		4.45	4.95	0	None	No
M-X9	3B	5/24/2006	12:49	14.41	>4	1	>4	>4 - 1	281.6	19.54	17.72	20.49	2.77	ind	95.4	6.62		6.05	7.47	0	None	No
M-X9	4B	5/24/2006	12:50	14.41	>4	1	>4	>4 - 1	291.6	20.23	18.5	20.74	2.24	ind	104.3	7.24		6.42	8.74	0	None	No
M-X10	1B	5/24/2006	13:26	14.41	4 to 3	-1	>4	>4 - -1	199.1	13.82	13.49	14.34	0.85	b	100.0	6.94		4.32	7.71	0	None	No
M-X10	2B	5/24/2006	13:27	14.42	4 to 3	-1	>4	>4 - -1	187.4	12.99	12.33	13.91	1.58	b	79.0	5.48		3.51	7.41	0	None	No
M-X10	4B	5/24/2006	13:30	14.4	4 to 3	-1	>4	>4 - -1	98.0	6.80	6.68	7.21	0.53	b	>98.0	6.81	>	>6.7	>7.2	0	None	No
M-X11	1B	5/24/2006	14:05	14.42	3 to 2	-1	>4	>4 - -1	16.9	1.17	0	2.57	2.57	p	>16.9	1.17	>	ind	>2.6	0	None	No
M-X11	2B	5/24/2006	14:06	14.4	3 to 2/4 to 3	-1	>4	>4 - -1	96.7	6.71	6.55	6.96	0.41	b	>96.6	6.71	>	>6.6	>7.0	0	None	No
M-X11	4B	5/24/2006	14:09	14.42	3 to 2/4 to 3	-1	>4	>4 - -1	92.2	6.39	5.94	6.8	0.86	b	>92.2	6.39	>	>5.9	>6.8	0	None	No
M-X12	1B	5/24/2006	14:27	14.42	2 to 1/4 to 3	-1	>4	>4 - -1	96.7	6.71	6.29	7.14	0.85	p	>96.7	6.71	>	>6.3	>7.1	0	None	No
M-X12	2A	5/24/2006	14:28	14.42	3 to 2	<-1	>4	>4 - <-1	40.2	2.79	2.24	3.14	0.9	b	>40.2	2.79	>	>2.2	>3.1	0	None	No
M-X12	4A	5/24/2006	14:31	14.42	3 to 2	1	>4	>4 - 1	39.4	2.73	2.37	3.53	1.16	b	>39.4	2.73	>	>2.4	>3.5	0	None	No
M-X13	1B	5/24/2006	15:09	14.42	>4	2	>4	>4 - 2	217.2	15.06	14.7	15.53	0.83	b	70.0	4.85		3.56	5.53	0	None	No
M-X13	2B	5/24/2006	15:11	14.42	>4	2	>4	>4 - 2	193.4	13.41	13.08	13.67	0.59	b	109.1	7.57		6.68	7.82	0	None	No

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M-X13	4B	5/24/2006	15:13	14.42	>4	2	>4	>4 - 2	180.9	12.54	12.05	12.93	0.88	b	99.2	6.88		5.11	8.07	0	None	No
M-X14	1B	5/24/2006	15:45	14.42	>4	1	>4	>4 - 1	236.8	16.42	16.23	16.77	0.54	b	100.7	6.98		6.4	7.5	0	None	No
M-X14	2B	5/24/2006	15:47	14.4	>4	2	>4	>4 - 2	127.6	8.86	8.26	9.18	0.92	b	73.6	5.11		2.22	6.1	0	None	No
M-X14	3B	5/24/2006	15:48	14.4	>4	1	>4	>4 - 1	193.6	13.44	13.19	13.82	0.63	b	81.1	5.63		4.26	6.49	0	None	No
M-X15	1A	5/24/2006	16:14	14.42	>4	2	>4	>4 - 2	93.5	6.49	6.09	7.08	0.99	b	>93.5	6.48	>	>6.1	>7.1	0	None	No
M-X15	2B	5/24/2006	16:15	14.42	>4	2	>4	>4 - 2	229.8	15.93	14.33	16.87	2.54	b	90.8	6.29		5.22	7.74	0	None	No
M-X15	4B	5/24/2006	16:17	14.42	>4	2	>4	>4 - 2	180.0	12.48	12.34	12.89	0.55	b	77.6	5.38		3.87	6.24	0	None	No
M-R1	1B	5/23/2006	5:09	14.42	>4 to 3	2	>4	>4 - 2	179.8	12.47	11.92	13.34	1.42	b	99.7	6.92		4.66	8.65	0	None	No
M-R1	2B	5/23/2006	5:10	14.42	>4 to 3	2	>4	>4 - 2	192.8	13.37	13.19	13.59	0.4	b	70.6	4.90		2.43	6.8	0	None	No
M-R1	3B	5/23/2006	5:11	14.42	>4 to 3	2	>4	>4 - 2	160.9	11.15	10.82	11.29	0.47	b	74.5	5.16		3.23	6.64	0	None	No
M-R1	4B	5/23/2006	5:13	14.41	>4 to 3	1	>4	>4 - 1	293.4	20.36	20.21	20.43	0.22	b	75.0	5.21		3.63	7.77	0	None	No
M-R2	1B	5/23/2006	4:35	14.41	>4	3	>4	>4 - 3	>303.28	>21.1	>21.1	>21.1	ind	ind	ind	Indeterminate		ind	ind	ind	None	No
M-R2	2B	5/23/2006	4:35	14.39	>4	2	>4	>4 - 2	>303.3	>21.1	>21.1	>21.1	ind	ind	92.8	6.45		2.49	9.49	ind	None	No
M-R2	3B	5/23/2006	4:35	14.41	>4	2	>4	>4 - 2	299.9	20.81	19.89	>21.1	ind	ind	103.0	7.15		4.61	8.89	ind	None	No
M-R2	4A	5/23/2006	4:35	14.41	>4	2	>4	>4 - 2	265.2	18.40	12.25	>21.1	ind	ind	102.7	7.13		3.75	7.85	0	None	No
M-R3	1B	5/23/2006	5:35	14.42	4 to 3	1	>4	>4 - 1	115.9	8.04	7.56	8.81	1.25	b	>115.89	8.04	>	>7.56	>8.81	0	None	No
M-R3	2B	5/23/2006	5:36	14.42	4 to 3	0	>4	>4 - 0	91.2	6.33	5.72	6.86	1.14	b	>91.2	6.32	>	>5.7	>6.9	0	None	No
M-R3	3B	5/23/2006	5:37	14.42	4 to 3	1	>4	>4 - 1	91.6	6.35	5.59	7.12	1.53	b	>91.63	6.35	>	>5.59	>7.12	0	None	No
M-R3	4B	5/23/2006	5:38	14.42	4 to 3	1	>4	>4 - 1	63.1	4.37	4.01	4.76	0.75	b	>63.1	4.38	>	>4.0	>4.8	0	None	No

Station	REP	DM?	DM lyr thickness	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	SUCCESS. STAGE	OSI	COMMENT
M-A4	1B			0			0.0	Stage 3	11	Ambient muddy fine sand>pen; low redox contrast; v. homogenous sed texture; small surf tubes
M-A4	2B			0			0.0	Stage 2 -> 3	10	Ambient muddy fine sand>pen; low redox contrast; v. homogenous texture; small surf tubes
M-A4	4B			0			0.0	Stage 2 -> 3	10	Ambient muddy fine sand>pen; low redox contrast; v. homogenous texture; one or two small surf tubes
M-A5	1B			0			0.0	Stage 3	7	Underpen; firm ambient muddy fine sand>pen; rpd>pen; one or two tubes in farfield; homogenous sed texture
M-A5	2B			ind			0.0	Indeterminate	Indeterminate	No penetration; encrusted rocks/cobbles over fine sand; old DM??; rocks thickly encrusted w/ hydroids=not newly disposed
M-A5	4B			ind			0.0	Indeterminate	Indeterminate	No penetration; most likely similar to other rep: encrusted rocks/cobbles over fine sand; old DM??
M-A6	2B			ind			0.0	Indeterminate	Indeterminate	No penetration; most likely similar to other station rep (3B): encrusted rocks/cobbles over fine sand; old DM??
M-A6	3B			ind			0.0	Indeterminate	Indeterminate	No penetration; encrusted rocks/cobbles over muddy fine sand; rocks=old DM?? or ambient corraline rock?
M-A6	4B			0			0.0	Stage 2 -> 3	10	Ambient soft sandy mud>pen; homogenous light color and texture; v. low contrast redox; multiple small surface tubes
M-A7	1B			0			0.0	Stage 2	9	Ambient sandy mud>pen; winch wire in farfield; homogenous light color+texture; low contrast rpd; v. small tubes@surf=upright+recumbent
M-A7	3B			0			0.0	Stage 3	11	Ambient sandy-silty mud>pen; homogenous color+texture; low constrast rpd; small tubes@surf=recumbent+upright
M-B3	1B			1	5.7	6.03	5.9	Stage 1 on 3	11	Ambient very silty f. sand>pen; deep pen= relatively soft; subtle layering of silt/sand or layering effect due to silt dragdown?; low constrast rpd; active biogenic reworking of SWI=pits+burrows+many tubes; active void
M-B3	2B			0			0.0	Stage 1 on 3	11	Ambient very silty f. sand>pen; deep pen= relatively soft; subtle layering of silt/sand or layering effect due to silt dragdown?; only a few small worms visible due to descending farfield; 1 or 2 small worms@depth?
M-B3	3B			0			0.0	Stage 1 on 3	11	Ambient very silty f. sand>pen; deep pen=relatively soft; several tubes@swi+v. small worms(?)@depth; biogenic pit@left=feeding pit or burrow opening?; active bio reworking of SWI
M-B4	1B			0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; relatively soft; distinct filamentous tubes=??; prominent long thin polychaete@depth; bio reworking of SWI
M-B4	2B			0			0.0	Stage 1 on 3	11	Ambient silty f. sand>pen; homogenous color+texture; low contrast rpd; biogenic working of surf; filamentous/floccy "tubes"??
M-B4	4B			0			0.0	Stage 1 on 3	11	Ambient silty f. sand>pen; roughness=transect of "mud clast" like structure=clast or biogenic mound? camera artifact? but more in farfield; one prominent tube;
M-B5	1B			0			0.0	Stage 2 -> 3	10	Ambient silty f. sand>pen; roughness=biogenic mound??; small tubes@right; homogenous color+texture=low contrast rpd
M-B5	3B			0			0.0	Stage 3	11	Ambient silty f. sand>pen; 1 or 2 larger tubes w/ rust colored halos@subsurface; black(=reduced) tube coloration@depth; homogenous sed color/texture; low contrast rpd
M-B5	4B			0			0.0	Stage 3	11	Ambient silty f. sand>pen; homogenous color+texture; faint reduced patches@depth; low contrast rpd; a few small subsurface worms; mound=biogenic??
M-B6	2B	Trace	NA	0			0.0	Stage 2 -> 3	9	Ambient silty very fine sand>pen; upper 1.5 cm=horizon of faintly darker sed=deposition of floccy fines from nearby disposal; faintly reduced patches@depth; surface tubes+subsurface worms
M-B6	3B	Trace	NA	0			0.0	Stage 2 -> 3	9	Ambient silty very fine sand>pen; upper 1.5 cm=horizon of faintly darker sed=deposition of floccy fines from nearby disposal; faintly reduced patches@depth; surface tubes+subsurface worms
M-B6	4B	Trace	NA	0			0.0	Stage 2	9	Ambient silty very fine sand>pen; RPD>pen; upper 2.5 cm=horizon of faintly lighter sed=deposition of floccy fines from nearby disposal; many small surface tubes (many in farfield)
M-B7	2A			0			0.0	Stage 3	9	Ambient silty very fine sand>pen; faint rpd contrast; small surface tubes=mostly in farfield; farfield mound=biogenic??; v. small and few subsurface worms
M-B7	3B			0			0.0	Stage 1 -> 2	6	Ambient silty fine sand>pen; numerous firm clay clasts(?)@SWI=relic DM??; small tubes?; low penetration=firm clay or mud clasts

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M-B7	4B			0			0.0	Stage 1 -> 2	7	Ambient firm silty fine sand>pen; 2 small tunicates(??)@SWI in center nearfield; numerous small tubes; mostly nearfield; small rocks or clasts W/ encrusting epifauna; rpd>pen
M-B8	1B			0			0.0	Stage 2	9	Ambient firm silty fine sand>pen; numerous small tubes or other biogenic structures@swi but indistinct(?); low pen=firm sand; rpd>pen
M-B8	3B			0			0.0	Stage 1 -> 2	8	Ambient firm silty fine sand>pen; clay clumps or rocks in farfield; no redox contrast; rpd>pen; numerous small tubes@surf; one visible thin small worm@depth; biogenic roughness?
M-B8	4B			0			0.0	Stage 2	9	Ambient firm silty fine sand>pen; RPD>pen; moderately dense surface tubes in nearfield and farfield; biogenic roughness=feeding pits or mounds??; one small thin worm@depth
M-C3	1B	Y	2.3	0			0.0	Stage 1 on 3	11	Thin surface lyr of recent DM light-colored fine sand over sandy older DM layer(?) over ambient soft sandy silt>pen; underlying silt has reduced patches; point of contact between layers very subtle; weak rpd contrast; a few small worms@depth
M-C3	2B	Y	1.8	0			0.0	Stage 1 on 3	11	Thin surface layer of recent DM (light-colored fine sand) over older sandy DM lyr(?) over ambient soft sandy silt>pen; reduced patches@depth coincide w/ ambient silt lyr; faint alternating silt+sand layers@depth=multiple DM lyrs?; several small thin polychaetes@depth; abundant surface tubes
M-C3	4B	Y	1.8	0			0.0	Stage 1 on 3	11	Surface DM lyr over ambient soft sandy silt>pen; reduced patch@depth; faint alternating silt+sand layers; faint horizon of reduced fines 2-3 cm deep=surface DM lyr?; 1-2 small thin polychaetes@depth; a few surface tubes
M-C4	1B	Y	6.8	0			0.0	Stage 2 to 3	10	Surface DM layer of light-colored sand w/ reddish tint over ambient soft sandy silt>pen; reduced patch@depth; faint alternating silt+sand layers; faint horizon of slightly darker fines 2-3 cm deep=trace DM; several small thin polychaetes@depth; many surface tubes=mostly in farfield
M-C4	2B	Y	6.2	0			0.0	Stage 1 on 3	11	Surface DM layer of light-colored sand w/ reddish streaks over ambient soft sandy silt>pen; slightly more reduced@depth; faint alternating silt+sand layers; several small polychaetes@depth; many surface tubes=mostly in farfield
M-C4	4B	Y	2.3	0			0.0	Stage 1 on 3	11	Surface DM lyr over ambient moderately soft sandy silt>pen; faint horizon of darker fines in upper 2-3 cm=measured as thin DM lyr; small worms@depth; surf tubes mostly recumbent
M-C5	1B	Y	>5.13	0			0.0	Stage 2	9	Sandy DM w/ faint reddish streaks>pen; upright and recumbent surface tubes
M-C5	2B	Y	>2.87	0			0.0	Stage 1 -> 2	6	Sandy DM w/ faint reddish tint>pen; DM has slightly darker horizon in upper 1 to 2 cm=recent fine-grained organic deposition?; patches of organic floc @ surface; very few distinct tubes
M-C5	3B	Y	4.5	0			0.0	Stage 2 to 3	10	Surface layer of sandy DM w/ reddish tint over ambient silty sand; Layering very faint=DM layer is slightly darker w/ rust color@depth; reduced patches@depth; a few distinct surf tubes
M-C6	1B	Y	8.4	0			0.0	Stage 1 on 3	11	Surface layer of sandy DM over ambient silt; point of contract visible @ lower left; DM is darker/more reduced near SWI=shallow rpd; brittle star@swi+a few tubes
M-C6	2B	Y	>pen	0			0.0	Stage 2	Indeterminate	Sandy DM>pen; reddish/rust patches=diagnostic of DM at this site; no rpd contrast but dm is relatively dark@SWI=reduced=0 rpd; few visible worm tubes=v. early recolonization=fresh dm??
M-C6	4B	Y	>pen	0			0.0	Stage 2 to 3	10	Sandy DM>pen; point of contact w/ ambient sed near bottom of image??: horizon of fines in upper 2-3 cm; vertical streaks of reduced sed.@depth; small surface tubes
M-C7	1B	Y	>pen	0			0.0	Stage 2	9	Sandy DM>pen; small patches of reddish/rust sed@depth; difficult rpd measurement=very low contrast=indeterminate??; small tubes and/or small clumps of organis detritus@surface
M-C7	2B	Y	>pen	0			0.0	Stage 2 to 3	10	Clean fine homogenous sand =DM)>pen; v. difficult rpd measurement=indeterminate?; very few worm tubes@swi; more in farfield??
M-C7	4B	Y	>pen	0			0.0	Stage 2	9	Clean fine homogenous sand (=DM)>pen; difficult rpd measurement=low contrast=indeterminate?; very few worm tubes@swi; many small brown rocks or mud clasts? one larger white rock
M-C8	1B			0			0.0	Stage 2 to 3	10	Ambient soft sandy silt>pen; reduced patches@depth; faintly alternating sand and silty/muddy layers; red patch@right but not DM; very few small worms@SWI
M-C8	2B			0			0.0	Stage 2	9	Ambient moderately soft sandy silt>pen; vertical streaks of reduced sed@depth; biogenic reworking of sed surface; many surface tubes, esp. in farfield
M-C8	3B			0			0.0	Stage 1 on 3	11	Ambient moderately soft sandy silt>pen; sed appears to have slightly higher fines in upper 5 cm or so=DM influence??: low contrast rpd=difficult measurement; surface tubes+whip-like structure in farfield

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M-D1	2A			0			0.0	Stage 1 on 3	11	Ambient soft mostly silty sed>pen; minor fine sand fraction; homogenous texture+color; slightly more sand in upper 2-3 cm; streaks of reduced sed@depth; small surface tubes
M-D1	3B			0			0.0	Stage 1 on 3	11	Ambient moderately soft and sandy silt>pen; slightly higher fine sand fraction in upper 8-10 cm?; small biogenic mound in farfield; numerous small tubes on sed surface=many recumbent
M-D1	4A			0			0.0	Stage 1 on 3	11	Ambient moderately soft and sandy silt>pen; sandier near SWI=winnowing effect?; patches of moderately reduced sed@depth; a few small tubes
M-D2	1A	Trace	NA	0			0.0	Stage 2	9	Trace of sandy DM over softer ambient silt; contact between layers very subtle; DM=very fine silty sand and color very similar to ambient silt; a few small shell frags=somewhat diagnostic; a few small tubes; origin of boundary roughness unknown=large ripples?
M-D2	2A	Trace	NA	0			0.0	Stage 2	9	Trace of sandy DM over softer ambient silt-clay; contact between layers subtle but more pronounced than previous rep; streaks of reduced sed@depth; only 2 surface tubes
M-D2	3A	Trace	NA	0			0.0	Stage 2 to 3	10	Trace of sandy DM over ambient sandy silt; difficult to see contact between layers; high boundary roughness=mega-ripples??; numerous very small surf tubes
M-D3	1B	Y	3.3	0			0.0	Stage 1 on 3	11	Thin surface layer of recent sandy DM w/ silt over older DM layer over ambient silt-clay; clear points of contact between layers; DM has subtle sand over mud over sand layering=multiple layers; small surface tubes
M-D3	2B	Y	3.3	0			0.0	Stage 1 on 3	11	Thin surface lyr of recent sandy DM w/ silt over older DM layer over ambient silt-clay; point of contact between DM and ambient layers near bottom of image=guesstimate based on previous rep; one worm@depth; sandy DM w/ small shells or carbonate frags
M-D3	4B	Y	3.1	0			0.0	Stage 1 on 3	11	Thin surface layer of recent sandy DM w/ silt over older DM layer(s)? Over ambient sandy silt; no clear point of contact between layers; DM measured to top of vertical reduced streak; older DM>pen??; small surf tubes
M-D4	1B	Y	4.5	0			0.0	Stage 2 to 3	10	Sandy DM w/ small shell frags over ambient sandy silt or older sandy DM layer(?); DM measured to top of reduced patch; DM>pen?; many small surf tubes, mainly in farfield
M-D4	2A	Y	>pen	0			0.0	Stage 2	8	Sandy DM (fine sand) w/ small shell frags>pen; patch of fines in upper sed column but DM mostly fine sand; small surface tubes; RPD>pen (no obvious contrast)
M-D4	4A	Y	>pen	0			0.0	Stage 2	9	Sandy DM (fine sand) with small shell frags>pen; some fines in sand; faint reduced layer@depth; boundary roughness=assymetrical ripples??; very few tubes
M-D5	1B	Y	>pen	0			0.0	Stage 2 to 3	9	Sandy DM (medium sand) w/ small shell frags>pen; appears slightly coarser in upper 6-8 cm compared to underlying layers=layering of DM?; a few small surf tubes; slight reduced horizon@depth
M-D5	2B	Y	>pen	0			0.0	Indeterminate	Indeterminate	Firm sandy DM (fine to medium sand) w/ silt, small shell frags, and small pieces of carbonate(?); sed surface draped with silt-clay; no visible worm tubes=fresh DM?
M-D5	4A	Y	>pen	0			0.0	Stage 2	6	Firm sandy DM (fine to medium sand) w/ some silt+small shell frags; a few small pebbles or carbonate rock; rust spot on sed surface in farfield; mud drape on sand surface; no visible tubes=recent DM(?)
M-D6	1B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	Firm sandy DM (coarse to very coarse) w/ numerous shell frags+small chunks of carbonate/calcareous rock; coarser near surface grading to coarse to medium sand@depth; mud drape@sed surf; few/no tubes=recent DM
M-D6	2B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	Loose gravelly DM comprised of small rocks, shell frags, and larger calcareous rock; coarser texture in upper 2-4 cm compared to underlying sed; few or no worm tubes=recent DM(?); RPD=????
M-D6	4A	Y	>pen	0			0.0	Stage 2	8	Loose gravelly DM comprised of small rocks, shell frags, pieces of coral and coralline rock; light drape of mud at sed surface; few or no tubes=recent DM
M-D7	1A	Y	>pen	0			0.0	Indeterminate	Indeterminate	Firm DM comprised mostly of coarse sand w/ shell frags, large mud clasts and/or sandstone, and corraline rock; few or no surface tubes=recent DM; station at center of disposal zone=coarsest material
M-D7	2A	Y	>pen	0			0.0	Stage 2	7	Firm DM comprised of mostly medium to coarse sand w/ shells and shell fragments and pebbles; large chunk of limestone in farfield; no visible tubes=recent DM?

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M-D7	3A	Y	>pen	0			0.0	Indeterminate	Indeterminate	Underpen=very coarse DM consisting mostly of larger pebbles, shell frags, and calcareous rock; fine to medium sand mixed in; no visible surf tubes=recent DM(?)
M-D8	1B	Y	3.8	0			0.0	Stage 2	9	Surface DM lyr of silty fine sand over ambient silty fine sand; bottom of DM layer has slight reddish tint; not a strong DM signal; small surface tubes
M-D8	3B	Y	3.8	0			0.0	Stage 1 -> 2	8	Surface DM lyr of silty fine sand over ambient silty fine sand; bottom of DM layer has slight reddish tint; not a strong DM signal; small surface tubes; reduced patch@depth appears to have been buried by DM
M-D8	4B	Y	4.0	0			0.0	Stage 2	9	Surface DM lyr of silty fine sand over ambient silty fine sand; bottom of DM layer has slight reddish tint; not a strong DM signal; a few recumbent tubes(?)
M-D9	2B	N		0			0.0	Stage 2	9	Ambient silty fine sand>pen; increased fines in upper 4 cm=minor influence of farfield transport of finest sed fractions from DM disposal???; unlikely because it is upcurrent and not a discrete DM lyr; sed darker@surf=indeterminate RPD; muddy surface tubes
M-D9	3B	N		0			0.0	Stage 1 -> 2	7	Ambient firm silty fine sand>pen; slightly darker in upper 2-3 cm from minor DM influence??; RPD=indeterminate; general trend that ambient seds are firmer from N to S at this site; some muddy surface tubes(?)
M-D9	4B	N		0			0.0	Stage 1 -> 2	8	Ambient firm silty fine sand>pen; finer texture and slightly darker in upper 2 cm=??; faint reddish/rust color at depth=faint DM influence?; many small mud tubes@sed surf
M-E3	1A	Trace		2	6.4	9.02	7.7	Stage 1 on 3	11	Ambient moderately soft muddy fine sand/sandy mud>pen; very small feeding voids(?) at depth near patches of reduced sed; slight reddish tint 3-5 cm horizon=trace DM; homogenous color=tricky RPD measurement
M-E3	3B	Trace		0			0.0	Stage 1 on 3	11	Ambient soft sandy silt>pen; higher sand fraction in upper 5 to 10 cm=trace DM, softer at depth; patches of reduced sed@depth; numerous larger surface tubes
M-E3	4B	Trace		0			0.0	Stage 2 to 3	10	Ambient soft sandy silt>pen; higher sand fraction in upper 5 to 10 cm=trace DM (does not appear as a discrete layer); vertical reduced patches@depth; partial pull-away in upper left of image; at least one worm@depth
M-E4	1B	Y	6.3	0			0.0	Stage 1 on 3	11	Surface DM lyr of silty fine sand w/ reddish tint over slightly muddier ambient fine sand; very subtle contact between layers; DM is more corraline sand; reduced streaks in underlying ambient sed layer; one surf tube=farfield
M-E4	3B	Y	7.0	0			0.0	Stage 1 on 3	11	Surface DM lyr of silty fine sand w. faint reddish patches over slightly muddier ambient sandy silt; subtle contact between layers; DM has more light-colored sand grains-corraline sand?; small surface tubes
M-E4	4B	Y	6.5	0			0.0	Stage 1 on 3	11	Surface DM lyr of silty fine sand over muddier ambient silt; DM is clearly sandier and lighter color; very low contrast=RPD???; red streaks=two organisms@depth; fecal mound@surface@left
M-E5	1B	Y	>pen	0			0.0	Stage 1 on 3	11	DM>pen; DM is muddy light-colored fine sand; horizontal "line" at bottom of image is lighting artifact and not layering; several surface tubes and flocculant muddy structures (biogenic?) at sed surface
M-E5	2B	Y	>pen	0			0.0	Stage 1 on 3	Indeterminate	DM>pen; DM is muddy light-colored fine sand w/ reddish patches@depth; muddy/floccy structures@sed surface=??; biogenic mound in nearfield @ left; contrast-adjusted image suggests zero RPD?
M-E5	3B	Y	>pen	0			0.0	Stage 1 on 3	Indeterminate	DM>pen; DM is muddy light-colored fine sand w/ reddish patches; fines within sand matrix obscure the RPD measurement=indeterminate; several larger tubes@SWI
M-E6	2B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	DM>pen; DM is fine and w/ small shell frags; lack of contrast=indeterminate RPD in sand; winch wire on sed surface in farfield; one surface tube in nearfield??
M-E6	3B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	DM>pen; Dm is medium to fine sand w/ small shell frages; upper 4-6 of DM has reddish tint; one surface tube in neafield=very early recolonization of recent DM; no clear RPD contrast=indeterminate
M-E6	4B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	DM>pen; Dm is medium to fine sand w/ small shell frages+reddish/rust colored patches; faint layering=multiple DM layers?; no clear tubes or infauna=recent DM not yet colonized?
M-E7	1B	Y	>pen	0			0.0	Stage 2	Indeterminate	DM>pen; DM is poorly sorted mix of gravel w/ coarse, medim and fine sand; larger rock=limestone?; prominent red color from rust or red clay particles?; no visible infauna=Stage 0=recent DM? winch wire on sed surface

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M-E7	2B	Y	>pen	0			0.0	Stage 2	Indeterminate	DM>pen; DM is homogenous brown fine sand w/ strong reddish/rust color+a moderate number of small shell frags; different from previous rep=variability in DM; no visible infauna=Stage 0=recent DM?
M-E7	4B	Y	>pen	0			0.0	Stage 2 to 3	Indeterminate	DM>pen; DM is mix of fine shell hash and fine-to-medium brown sand; distinct reddish-rust color=clay or rust particles?; no visible infauna=recent DM?; different from other 2 reps
M-E8	1B	Trace	NA	0			0.0	Stage 1 on 3	11	Ambient light-colored sediment consisting of silty very fine sand>pen; fines have been dragged down in upper sed column-rpd measured behind fines as a guesstimate; faint reddish horizon=trace DM?; numerous larger surf tubes; winch wire across sed surf
M-E8	2B	Trace	NA	0			0.0	Stage 1 on 3	11	Ambient light-colored silty very fine sand>pen; faint horizon of reddish sed@depth=trace DM influence??: small surface tubes in nearfield; larger tubes in farfield?? v. difficult RPD measurement
M-E8	3B	Trace	NA	0			0.0	Stage 1 on 3	11	Ambient light-colored silty very fine sand>pen; faint horizon of reddish sed@depth=trace DM influence??; small surface tubes at SWI on right; tricky RPD measurement; reduced patches@depth
M-F3	1B	n		0			0.0	Stage 1 on 3	11	Ambient soft silt>pen; minor amounts of very fine sand; partial pull-away at SWI; very homogenous color and texture; subtle rpd contrast; small surface tubes; 2 long thin worms@depth
M-F3	2B	n		0			0.0	Stage 1 on 3	11	Ambient soft silt>pen; minor amounts of very fine sand; homogenous texture+color=low contrast rpd; streaks+patches of reduced sed@depth; two small worms@depth; indistinct surface tubes (?)
M-F3	3A	n		1	5.7	5.92	5.8	Stage 2 to 3	10	Ambient moderately soft sandy silt>pen; small indistinct surface tubes+possible ophiouroid at right?; several small+thin polychaetes@depth; indistinct feeding void; minor fine sand fraction
M-F4	2B	n		1	15.0	15.03	15.0	Stage 1 on 3	11	Ambient v. soft silt>pen; minor fraction of very fine sand; very homogenous color+texture; one very deep+small feeding void; small worm tubes+worms@depth
M-F4	3B	n		1	5.2	5.41	5.3	Stage 1 on 3	11	Ambient v. soft silt>pen; homogenous color+texture; low rpd contrast; one feeding void+one thin polychaete@depth; moderate number of surface tubes
M-F4	4B	n		0			0.0	Stage 1 on 3	11	Ambient soft silt>pen; homogenous color+texture=low RPD contrast; very small surface tubes+one thin worm@depth; patches/streaks of reduced sed@depth
M-F5	1B	n		ind			0.0	Indeterminate	Indeterminate	Underpen; pebble to cobble-sized rocks (calcareous rocks?) over silty fine sand; rocks encrusted w/ epifauna (hydrozoans, white calcareous worm tube); possible
M-F5	2B	n		2	5.0	6.84	5.9	Stage 1 on 3	11	Ambient silty very fine sand>pen; v. homogenous color+texture=RPD is guesstimate; large cobble-sized rocks w/ thick encrusting epifauna=rubble from past DM disposal?; numerous surface tubes+subsurface void/burrow
M-F6	3B	n		0			0.0	Indeterminate	Indeterminate	Ambient silty very fine sand>pen; RPD>pen(?); homogenous color+texture; cobble-size rocks in farfield=rubble from past DM disposal(?); white calcareous worm tubes+epifauna on rocks; high boundary roughness=rubble field(?)
M-F6	4B	n		ind			0.0	Indeterminate	Indeterminate	Underpen; pebble to cobble-sized rocks (limestone?) prevent prism penetration; dense epifaunal growth on rocks, including one prominent anemone=rubble from past DM disposal
M-F7A	1B	n		0			0.0	Indeterminate	Indeterminate	Minimal penetration; silty very fine sand>pen; mound-like structures=biogenic or physical??; RPD>pen; very firm ambient sand=minimal pen; few or no visible tubes or other infauna
M-F7A	3B	n		ind			0.0	Indeterminate	Indeterminate	Underpen; pebble to cobble-sized rocks (limestone?) prevent prism penetration; dense epifaunal growth on rocks=rubble from past DM disposal(?)
M-F7A	4B	n		ind			0.0	Indeterminate	Indeterminate	Underpenetration; silty very fine sand w/ rocks in farfield+numerous mounds (sand covered rocks?); very firm ambient sand=minimal pen; anemones on rocks=older rocks=rubble from old DM(?)
M-F8	1B	n		0			0.0	Stage 1 on 3	11	Ambient moderately soft silt w/ very fine sand>pen; homogenous color and texture, but more sand in upper 10 cm of sed column; numerous larger surface tubes but little/no evidence of subsurface activity
M-F8	2B	n		0			0.0	Stage 1 on 3	11	Ambient moderately soft silt w/ significant very fine sand fraction>pen; homogenous color+texture=tricky RPD measurement; several large tubes@surface but little/no evidence of subsurface activity

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M-F8	4B	n		0			0.0	Stage 1 on 3	11	Ambient silty very fine sand>pen; mid-penetration=moderately soft; distinctive tubes; both large and small tubes present; little evidence of subsurface activity
M-G4	1A	n		0			0.0	Stage 1 on 3	11	Ambient mostly silty sediment w/ minor very fine sand>pen; homogenous color+texture=tricky RPD measurement; many distinctive surface tubes; also distinct biogenic mounds@sed surface=but little evidence of subsurface activity in profile(?)
M-G4	2A	n		0			0.0	Stage 1 on 3	11	Ambient mostly silty sediment w/ minor v. fine sand>pen; homogenous color+texture; v. low RPD contrast=estimate; numerous larger surface tubes but no or little subsurface infauna; mounds in farfield=origin unknown
M-G4	4A	n		0			0.0	Stage 2	9	Ambient mostly silty sediment w/ minor very fine sand>pen; v. homogenous color+texture; low RPD contrast=estimate; many larger surface tubes; a few small thin worms@depth
M-G5	2A	n		2	3.2	4.04	3.6	Stage 1 on 3	11	Ambient mostly silty sediment w/ minor fine sand>pen; homogenous color+texture; 2 indistinct feeding voids(??); numerous large+small surface tubes; biogenic mound in nearfield
M-G5	3A	n		0			0.0	Stage 1 on 3	11	Ambient mostly silty sediment w/ minor fine sand>pen; homogenous color+texture+low contrast RPD; little evidence of subsurface activity but numerous surface tubes
M-G5	4B	n		1	3.0	3.01	3.0	Stage 1 on 3	11	Ambient mostly silty sediment w/ minor fine sand>pen; one prominent feeding void and several larger surf tubes; well-oxidized sed=deep rpd; homogenous color+texture
M-G6	1B	n		0			0.0	Stage 1	6	Ambient very silty sediment w/ minor very fine sand>pen; large rock/cobble in farfield=rubble from past DM disposal?; "crack" in sed surface=rocks covered by silt?
M-G6	3B	n		0			0.0	Indeterminate	Indeterminate	Underpen; cobbles/rocks>pen; rubble from past DM disposal; silty sand has filled in among rocks; dense epifaunal growth on rocks=tubes, hyroids+prominent anemone
M-G6	4B	n		0			0.0	Stage 3	11	Ambient very silty fine sand>pen; fecal mound in nearfield w/ intact fecal casts; rock in farfield with anemone; rocks=silt-draped old DM; surface worm tubes
M-G7	1B	n		0			0.0	Stage 1 on 3	11	Ambient silty sediment w/ minor fine to medium sand fraction>pen; small whitish rocks on sed surf=limestone rubble from old DM disposal?; rocks heavily encrusted w/ tubes; burrow opening@left
M-G7	3B	n		0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; numerous pebble- to cobble-sized limestone rocks@sed surface=old DM rubble?; rocks are heavily encrusted w/ epifauna; numerous hydroids; burrow opening@left
M-G7	4B	n		2	7.0	8.31	7.6	Stage 1 on 3	11	Ambient silty fine sand>pen; homogenous color and texture; many small surf tubes; two feeding voids@lower right; small shell frags near surface@upper left=trace DM influence??
M-X1	1B	n		ind			0.0	Indeterminate	Indeterminate	Underpenetration=ambient firm/hard bottom>pen; bottom consists of limestone/corraline rocks w/ encrusting epifauna on top of silty fine sand; old DM rubble??
M-X1	2B	n		ind			0.0	Indeterminate	Indeterminate	No pen=hard bottom; relatively large rock w/ encrusting epifauna=old DM rubble??
M-X1	4B	n		0			0.0	Stage 1 on 3	11	Ambient silty very fine sand>pen; very low RPD contrast=used adjusted image for measurement; no subsurface bio activity; small worm tubes; homogenous sed color+texture
M-X2	1B	n		0			0.0	Stage 2	9	Ambient firm silty fine sand>pen; homogenous color and texture; low contrast RPD=used adjusted image; large ornate worm tubes(?)@sed surface; smaller tubes also present; no subsurface activity
M-X2	3B	n		0			0.0	Indeterminate	Indeterminate	No pen=hard bottom; pebble to cobble size rocks w/ dense encrusting epifauna=old DM rubble??
M-X2	4B	n		0			0.0	Indeterminate	Indeterminate	Underpen=firm fine sand>pen; numerous floccy tubes on sed surface; RPD>pen (minimum estimate of RPD); different from other 2 reps=small-scale variabillity at this station
M-X3	2B	y	>4.74	0			0.0	Stage 2	9	DM>pen; dm is fine to medium sand w/ shell frags; RPD>pen; very minor amount of silt; small numbers of surf tubes=early colonization of recent DM?
M-X3	3B	Y	>5.97	0			0.0	Stage 2 to 3	10	DM>pen; DM is medium to coarse sand w/ shell frags; RPD>pen; no subsurface biological activity; a few small surface tubes=early colonization of recent DM?
M-X3	4B	Y	>5.42	0			0.0	Stage 2	9	DM>pen; DM is fine to medium sand w/ shell frags; RPD>pen; small numbers of surf tubes=early colonization of recent DM?
M-X4	1B	Y	>8.48	0			0.0	Stage 2 to 3	10	DM>pen; DM is medium to coarse sand w/ shell hash and gravel; RPD>pen; few tubes=early colonization of recent DM?; no evidence of subsurface biological activity
M-X4	2B	Y	>7.08	0			0.0	Stage 2 to 3	10	DM>pen; DM is medium to coarse sand w/ shell hash and gravel; RPD>pen; no visible tubes or subsurface bio=early colonization of recent DM?

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M-X4	3B	Y	>8.63	0			0.0	Stage 2	9	DM>pen; DM is medium to coarse sand w/ significant gravel and shell frags; RPD>pen; no visible tube or subsurface bio activity=recent DM?; larger gravel pieces@sed surface
M-X5	2B	Y	>7.04	0			0.0	Stage 2	9	DM>pen; DM is medium to coarse sand w/ gravel and shell frags; sand has reddish hue=iron oxides?; one surface tube in farfield=early colonization of recent DM; RPD>pen
M-X5	3A	Y	>3.33	0			0.0	Stage 2	7	DM>pen; DM is fine to medium sand w/ gravel and shell frags; strong reddish tint; few tubes=early colonization; RPD>pen
M-X5	4B	Y	>4.7	0			0.0	Stage 2	9	DM>pen; DM is medium to coarse sand w/ gravel and shell frags; reddish tint; gravel on sed surface w/ encrusting epifauna; RPD>pen; moderate colonization of DM
M-X6	1B	Y	>5.5	0			0.0	Stage 2 to 3	10	DM>pen; DM is fine sand w/ some shell frags; slight layering of brown sand over sand w/ reddish tint=multiple DM layers; very few small tubes@surface=early colonization; RPD>pen
M-X6	2B	Y	>5.0	0			0.0	Stage 2 to 3	10	DM>pen; DM is fine sand w/ some shell frags; slight layering of brown sand over sand w/ reddish tint=multiple DM layers; RPD>pen; a few small tubes
M-X8	1B	n		0			0.0	Indeterminate	Indeterminate	Ambient firm fine sand>pen; sand is silty w/ uniform color and texture; RPD>pen=minimal RPD estimate; a few small surface tubes
M-X8	2B	n		0			0.0	Stage 3	7	Ambient firm fine sand>pen; sand is silty w/ uniform color and texture; RPD>pen=mimimum RPD estimate; fecal mound w/ fecal casts@left?; a few small tubes
M-X8	4A	n		0			0.0	Stage 3	Indeterminate	No penetration, but appears to be ambient firm fine sand>pen; sand is light-colored and silty w/ uniform color/texture; scattered larger worm tubes
M-X9	2B	n		0			0.0	Stage 3	11	Ambient light-colored+very homogenous fine sand>pen; one larger worm@depth=Stage 2; no visible surface tubes; low RPD contrast=estimated rpd from hi contrast image
M-X9	3B	Trace	NA	0			0.0	Stage 1 on 3	11	Ambient soft sandy silt-clay>pen; higher sand content in upper 4-5 cm w/ shell frags=trace DM; larger-bodied worm@depth=Stage 3; very small surface tubes; low contrast rpd; very homogenous texture+color
M-X9	4B	Trace	NA	0			0.0	Stage 1	7	Ambient soft sandy silt-clay>pen; higher sand content in upper 2-4 cm w/ shell frags=trace DM; very small surface tubes; low contrast rpd; very homogenous texture+color
M-X10	1B	Y	2.7	0			0.0	Stage 2 to 3	10	DM layer of fine sand w/ shell frags over ambient silty fine sand; point of contact between layers is subtle; several small surface tubes; no obvious subsurface bio activity
M-X10	2B	Y	2.7	0			0.0	Stage 1 on 3	11	DM layer of silty fine sand w/ medium sand+shell frags over ambient silty fine sand; subtle contact between layers; surface mound=biogenic??; one subsurface worm+several surface tubes
M-X10	4B	Y	2.9	0			0.0	Stage 2 to 3	10	DM layer of silty fine sand w/ medium sand+shell frags over ambient sitly fine sand; very subtle contact between layers; clump of decayed eelgrass(?); small surface tubes
M-X11	1B	Y	>2.6	0			0.0	Indeterminate	Indeterminate	Minimal pen; DM>pen; DM is firm fine sand w/ shell frags; clumps of large tubes(??) in farfield
M-X11	2B	Y	3.9	0			0.0	Stage 2 to 3	10	DM layer of 3-2 phi fine sand w/ shell frags+reddish streaks+reduced silty patches over ambient silty very fine sand (4-3 phi); subtle point of contact between layers; several surface tubes
M-X11	4B	Y	4.1	0			0.0	Stage 2	9	DM layer of 3-2 phi fine sand w/ shell frags+reddish streaks+reduced silty patches over ambient silty very fine sand (4-3 phi); subtle contact between layers; several surface tubes
M-X12	1B	Y	4.8	0			0.0	Stage 2	9	DM layer of 3-2 phi fine sand w/ shell frags+reddish streaks+reduced silty patches over ambient silty very fine sand (4-3 phi); subtle contact between layers; several surface tubes
M-X12	2A	Y	>3.1	0			0.0	Stage 2	7	DM>pen; RPD>pen; DM is silty fine to medium sand w/ shell fragments; underpenetration; a few small worm tubes
M-X12	4A	Y	>3.5	0			0.0	Stage 2	7	DM>pen; RPd>pen; underpenetration; DM is silty fine sand w/ shell frags+reddish/orange tint in places
M-X13	1B	n		0			0.0	Stage 1 on 3	11	Ambient soft silty sediment>pen; homogenous texture+light color=low rpd contrast; minor fraction of fine sand; one larger surf tube and 2 or 3 small thin worms@depth; dragdown of dark piece of vegetation
M-X13	2B	n		0			0.0	Stage 2 to 3	10	Pull-away artifact, measurements made from SWI; ambient soft silt-clay>pen; very homogenous texture+color; RPD is a conservative estimate, probably deeper; minor sand fraction; very little evidence of biology=organic poor sed

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M-X13	4B	n		0			0.0	Stage 2 to 3	10	Ambient soft silt-clay>pen; very homogenous texture+color; RPD is a conservative estimate, probably deeper; minor sand fraction; at least two small thin worms@depth+a few surface tubes=organic-poor sediment
M-X14	1B	n		0			0.0	Stage 2	9	Ambient soft silt-clay w/ patches of fine sand>pen; very homogenous color=RPD is conservative estimate, probably deeper; uniform light color=low organics; a few small worms@depth
M-X14	2B	n		0			0.0	Indeterminate	Indeterminate	Pull-away artifact, measurements made from SWI; ambient moderately soft silt>pen; some fine to medium sand appears to be present; RPD is minimum estimate; low organic sed; 1-2 worms@depth
M-X14	3B	n		1	3.3	3.56	3.4	Stage 2	9	Pull-away artifact, measurements made from SWI; ambient soft silt >pen; patches/horizons of fine sand@depth; prominent shallow feeding void; several larger tubes@surf
M-X15	1A	n		1	4.0	4.9	4.4	Stage 1 on 3	11	Ambient moderately soft silt>pen; RPD>pen; homogenous color+texture; biogenic reworking of SWI; numerous surface tubes+one prominent subsurface void
M-X15	2B	n		0			0.0	Stage 1 on 3	11	Ambient very soft silt-clay>pen; homogenous color+texture; very faint reduced patches@depth=measureable RPD; slight pull-away near SWI; small surface tubes
M-X15	4B	n		1	4.8	4.94	4.9	Stage 1 on 3	11	Ambient moderately soft silt>pen; homogenous color+texture; RPD is minimum estimate, probably deeper; partial pull-away in upper 2-4 cm; small tubes; one void/burrow+1 subsurface worm
M-R1	1B	n		2	10.2	11.65	10.9	Stage 1 on 3	11	Ambient silty sediment w/ very fine sand>pen; reduced patches@depth=measureable rpd; feeding voids (?) or buried rocks or sand (?); small surface tubes
M-R1	2B	n		0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; deep pen=moderately soft; horizon of reduced sed@depth=measureable rpd; biogenic reworking@SWI; small worms@depth?; v. small surf tubes; indistinct f. void@far right?
M-R1	3B	n		0			0.0	Stage 2 to 3	10	Ambient silty very fine sand>pen; faintly reduced@depth=measureable rpd; small worms@depth?; numerous small surface tubes; vertical streak w/ reddish tint in center of profile
M-R1	4B	n		3	11.8	16.26	14.0	Stage 1 on 3	11	Ambient silty fine sand>pen; deep penetration=very soft; faint layering of fine sand over silt over fine-to-medium sand; several voids@depth; worms@depth; reduced horizon=measureable rpd
M-R2	1B	n		0			0.0	Indeterminate	Indeterminate	Overpenetration=ambient very soft silt-clay>pen; very homogenous texture+color; horizon of reduced sed@depth=rpd at least 5 cm; one small worm@depth
M-R2	2B	n		1	1.8	2.64	2.2	Stage 1 on 3	11	Overpenetration=ambient very soft silt-clay>pen; homogenous texture+color; faint reduced sed@depth=measured rpd; one prominent active feeding void
M-R2	3B	n		1	13.5	14.22	13.9	Stage 1 on 3	11	Partial overpenetration=ambient very soft silt-clay>pen; homogenous texture+color; faint reduced sed@depth=measured rpd; one prominent active feeding void
M-R2	4A	n		1	5.0	5.57	5.3	Stage 1 on 3	11	Partial overpenetration=ambient very soft silt-clay>pen; homogenous texture+color; high boundary roughness+"cracks" in sed surface=burrows? fractures? artifacts? one opening looks like a void
M-R3	1B	n		0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; moderate degree of boundary roughness=biogenic mounds??; little or not subsurface activity; very small surface tubes; low contrast rpd
M-R3	2B	n		0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; rocks or hard bottom in farfield encrusted w/ epifauna; small surface tubes; RPD>pen=no contrast; little or no subsurface biology
M-R3	3B	n		0			0.0	Stage 1 on 3	11	Ambient silty fine sand>pen; low rpd contrast in adjusted image=measured; many small surface tubes; little or no subsurface biological activity
M-R3	4B	n		0			0.0	Stage 2	9	Ambient silty fine sand>pen; RPD>pen; numerous larger tubes@sed surface; little or no subsurface biological activity