2.0 Monitoring Study Design and Data Collection Methods

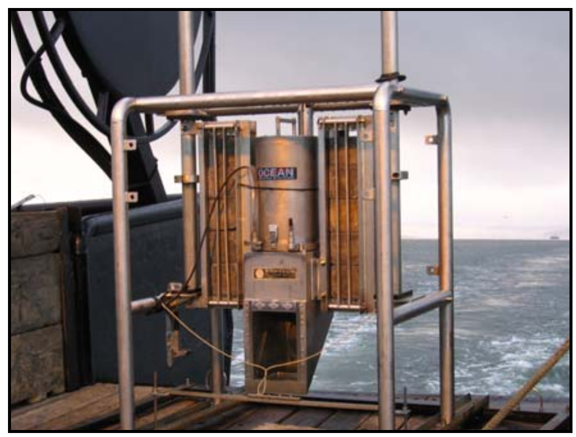
This section provides an overview of the types of data collected for this study and a description of the methods utilized to meet the study objectives. Data collection efforts included sediment profile imaging photography (SPI), sediment grain size distribution, and a multi-beam side-scan sonar survey. The SPI survey and sediment sampling were conducted by Science Applications International Corporation (SAIC). The bathymetric survey was conducted independently by Global Remote Sensing (GRS; Seattle, WA), a subcontractor to Parametrix (Bellevue, WA) under contract with the USACE, Portland District.

2.1 Data Types

The data types collected for this study included still photographs of the sediment-water interface (i.e. sediment profile images) and surface sediment grab samples for analysis of grain size distribution. SPI is a remote photographic method that allows for the visualization of the sediment-water interface and provides a rapid determination of sediment grain size, anaerobic zones, and general biological characteristics. SPI can be deployed at a high sampling density, allowing a more targeted sampling of benthic infauna and conventional parameters. The grain size distribution samples allow for 'ground-truthing' the sediment type seen within the images.

2.1.1 SPI Survey

The SPI survey was conducted using a specially designed, high resolution underwater camera that collects a vertical image of the upper 15-20 cm of the sediment-water interface. A digital-camera equipped Benthos 3731 sediment profile imaging system (Benthos, Inc. North Falmouth, MA) was used to survey the benthic habitat conditions of the study area (Figure 2). The sediment-profile camera consists of a wedge-shaped prism with a Plexiglas face plate and a back mirror mounted at a 45° angle. Light was provided by an internal strobe. The mirror reflects the image of the profile of the sediment-water interface to a digital camera that is mounted horizontally on top of the prism.



Sediment Profile Imaging Camera

The camera prism is mounted on an assembly that can be moved up and down within a stainless steel frame by allowing tension or slack on the winch wire. As the camera is lowered, tension on the winch wire keeps the prism in the up position. Once the camera frame touches the bottom, slack on the winch wire allows the prism to vertically intersect the seafloor. The rate of fall of the prism (6 cm/second) is controlled by an adjustable passive hydraulic piston, which minimizes the disturbance of the sediment-water interface. A trigger is tripped on impact with the bottom, activating a 10 second time-delay on the shutter release; this gives the prism a chance to obtain maximum penetration before a photograph is taken. When the camera is raised from the bottom, a wiper blade automatically cleans off any sediment adhering to the prism faceplate and the strobes are recharged. The camera can then be lowered to collect another replicate image. Due to the predominately sandy conditions at the site, two weight racks, each capable of holding 125 lb. of lead (in 25 lb. increments), were loaded to maximize penetration.

The SPI survey consisted of collecting a total of 149 digital images from the study area (Figure 2). The total images collected included:

- 12 pre-disposal sampling locations (3 reps each)
- 24 post-disposal sampling locations (3 reps each)
- 41 disposal lane transect sampling locations (1 rep each)

The pre-disposal images were collected at two locations along the length of each disposal lane to characterize the native material at the study area prior to the placement of any dredged material. The post-disposal images were collected at four locations per disposal lane, immediately following the placement of the dredged material, with the one exception of Lane Four, which was sampled the morning after the dredged material was placed. The transect sampling locations were collected on an opportunistic basis as time was available. The purpose of the transect locations were to examine a cross-section of the dredged material placement.

A formal analysis of the SPI survey results was conducted to assess the condition of the benthic habitat and determine the physical characteristics of the surface sediment. A single replicate image was selected for analysis from each location (i.e., 12 pre-disposal, 24 post-disposal, and 41 transect images). Parameters assessed from the images include:

- Grain size mode and range
- Prism penetration depth
- Surface boundary roughness
- Benthic habitat classification
- Infaunal successional stage

Analysis of the SPI images was conducted using the REMOTS (Remote Ecological Monitoring Of The Seafloor) system. REMOTS is a formal and standardized technique for SPI image acquisition, image analysis, and interpretation developed by SAIC scientists (Rhoads and Germano, 1982 and 1986; SAIC, 1986a). Physical and biological parameters were measured directly from the SPI digital images using a computer image analysis system. The image analysis system can discriminate up to 256 different tonal scales, so subtle features can be accurately digitized and measured.

The image analysis software allows the measurement and storage of data from up to 21 different variables for each image. All data were edited and verified by a senior-level scientist before final data synthesis, statistical analyses, and interpretation. The specific REMOTS parameters for this survey included: sediment grain size (major mode and range), optical prism penetration depth, dredged material thickness, surface boundary roughness, benthic habitat, and infaunal successional stage.

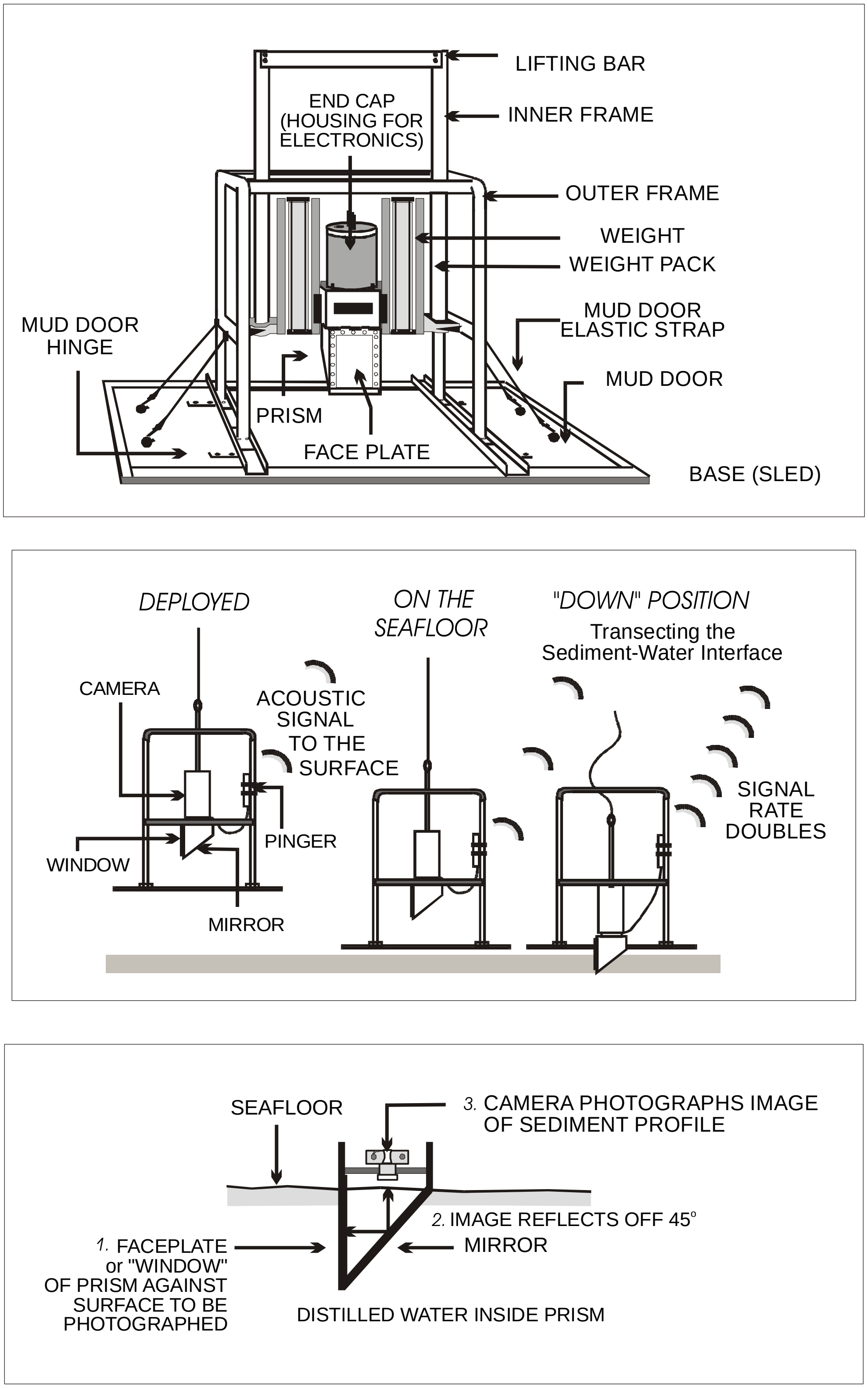


Figure 2. Sediment Profile Imaging Camera

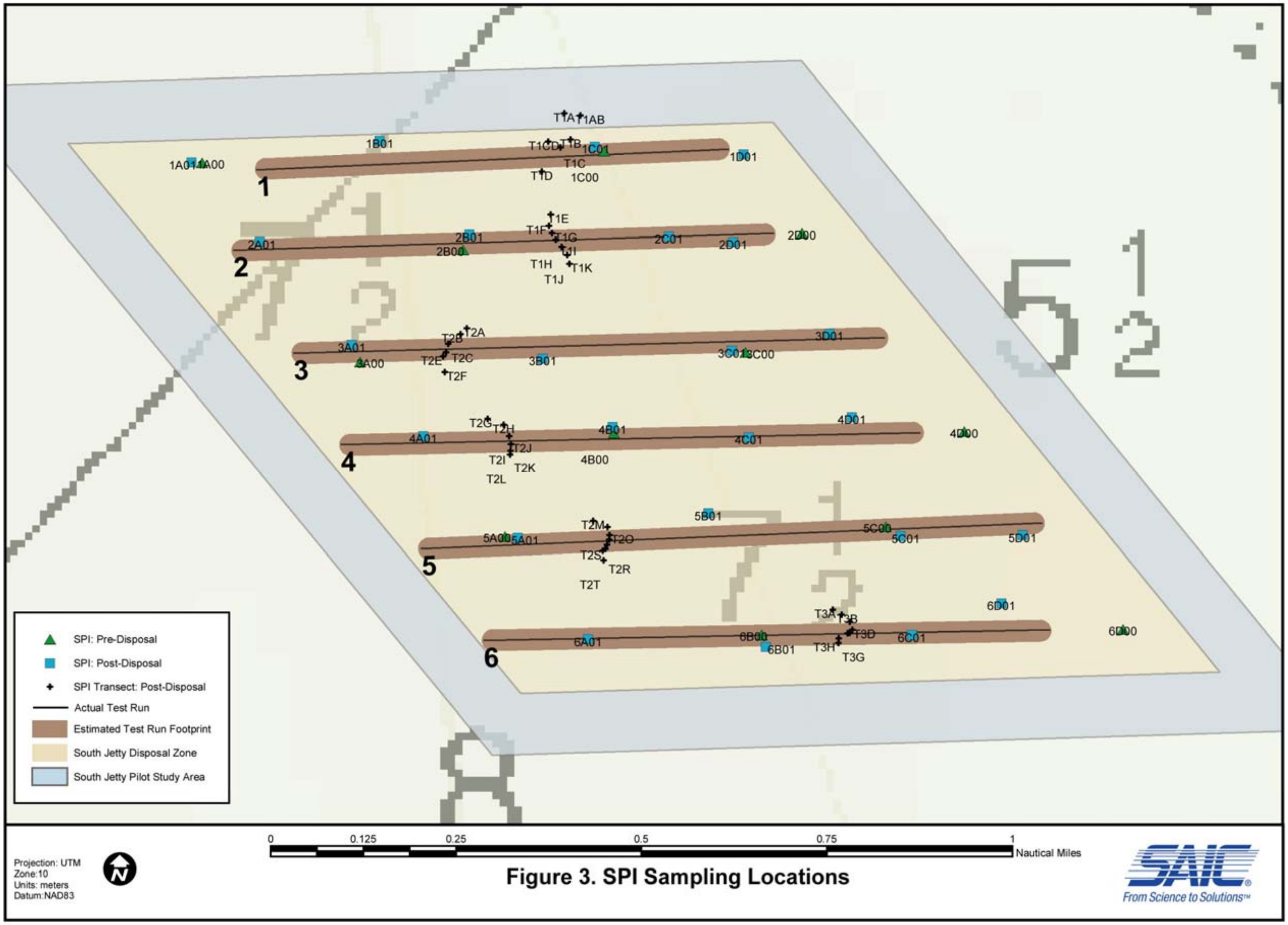


Figure 3. SPI Sampling Locations

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M.Goff, SAIC, October 2005

2.1.1.1 Sediment Grain Size

The sediment grain size major mode and range, in phi (Φ) units, were visually determined from the SPI images by overlaying a grain-size comparator 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) through the SPI optical system. Seven grain-size classes are 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 (gravels). The lower limit of optical resolution is about 62 μm, allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing SPI estimates with grain-size statistics determined from laboratory sieve analyses (SAIC, 1986b).

2.1.1.2 Prism Penetration Depth

The prism penetration depth is determined by measuring both the largest and smallest linear distance between the sediment-water interface and the bottom of the image. Observations regarding the nature and condition of the sediment-water interface are also recorded. Comparative penetration depths from stations of similar grain-size give an indication of relative water content and shear strength of the sediment.

2.1.1.3 Surface Boundary Roughness

Surface boundary roughness was determined by measuring the vertical distance (parallel to the image border) between the highest and lowest points of the sediment-water interface. In addition, the origin (physical or biogenic) of this small-scale topographic relief is sometimes evident and can be recorded. In sandy sediments, boundary roughness can be a measure of ripple height. Depending on the type of disposed dredged material, there is the potential to introduce high surface relief on an otherwise "smooth" bottom. Other surface features are noted where evident, including shell fragments/lag deposits, mud-clay clasts, and wood debris.

2.1.1.4 Benthic Habitat Classification

Based on extensive past sediment-profile imaging surveys (Diaz 1995; SAIC 1997a and b), five basic benthic habitat types have been identified: AM = *Ampelisca* mat, SH = shell bed, SA = hard sand bottom, HR = hard rock/gravel bottom and UN = unconsolidated soft bottom. Several sub-habitat types exist within these major categories. During image analysis, each sediment profile images is assigned one of the habitat categories listed in Table 1.

Table 1. Benthic Habitat Categories Assigned to REMOTS Sediment-Profile Images

Habitat AM: *Ampelisca* Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (*Ampelisca* spp.) tube mats at the sediment-water interface. Other species of benthic infauna may also create mats similar to those of *Ampelisca*.
Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: SH.SI: Shell Bed over silty sediment - shell layer overlying sediments ranging from fine sands to silts to silt-clay. SH.SA: Shell Bed over sandy sediment - shell layer overlying sediments ranging from fine to coarse sand.
Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments do not appear to be bioturbated, bed forms common, successional stage mostly indeterminate because of low prism penetration. SA.F: Fine sand - uniform very fine sand (4 to 3 Φ) or fine sand sediments (3 to 2 Φ). SA.M: Medium sand - uniform medium sand sediments (grain size: 2 to 1 Φ). SA.G: Medium sand with gravel – predominately medium to coarse sand with a minor gravel fraction.
Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty-sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates).
Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (I, II and III). Biogenic features may be common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: UN.SS: Fine Sand/Silty - very fine sand mixed with silt (grain size range from 4 to 2 Φ), with little or no shell hash. UN.SI: Silty - homogeneous soft silty sediments (grain size range from >4 to 3 Φ), with little or no shell hash. Generally deep prism penetration. UN.SF: Very Soft Mud - very soft muddy sediments (>4 Φ) of high apparent water content and deep prism penetration.

2.1.1.5 Infaunal Successional Stage

The mapping of infaunal successional stages from SPI images is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor perturbation. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance and these invertebrates interact with sediments in specific ways. Moreover, functional types are the biological units of interest and by definition do not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982).

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

Infaunal succession following a major seafloor disturbance initially involves pioneering populations (Primary or Stage I succession) of very small organisms that live at or near the sediment/water interface (Pearson and Rosenberg 1978; Rhoads and Germano 1986). In the absence of further disturbance, infaunal deposit feeders eventually replace these early successional assemblages. The start of this "infaunalization" process is designated as Stage II. Large, deep-burrowing infauna (Stage III taxa) represents a high order successional stage typically found in areas of low disturbance.

Pioneering assemblages (Stage I assemblages) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes (Figure 3); alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary; bioturbation depths are shallow, particularly in the earliest stages of colonization (Figure 3).

Many deep-burrowing infauna feed at depth in a head-down orientation. This localized feeding activity results in distinctive excavations called feeding voids. Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. The relatively coarse-grained material represents particles rejected by head-down deposit-feeders, as this deep-dwelling infauna preferentially ingest the finer sediment particles. Other subsurface structures, including burrows or methane bubbles, do not exhibit these characteristics. The bioturbation activities of these deposit-feeders are responsible for aerating the sediment and causing the redox horizon to be located several centimeters below the sediment-water interface. The presence of feeding voids indicates the presence of Stage III organisms.

In sandy, dynamic environments such as those found at the MCR, the climax communities may consist primarily of surface dwellers (e.g., *Amphiodia*) that reside in the upper cm of the sediment surface and have few, if any, naturally burrowing community members. These type communities are classified as Stage I communities by REMOTS analysis, reflective of an area influenced by physical factors (e.g., higher energy) and the presence of a sandy substrate. This contrasts to a higher order successional stage that would typically be assigned a climax community (as described above) in a depositional environment dominated by a silt/clay substrate.

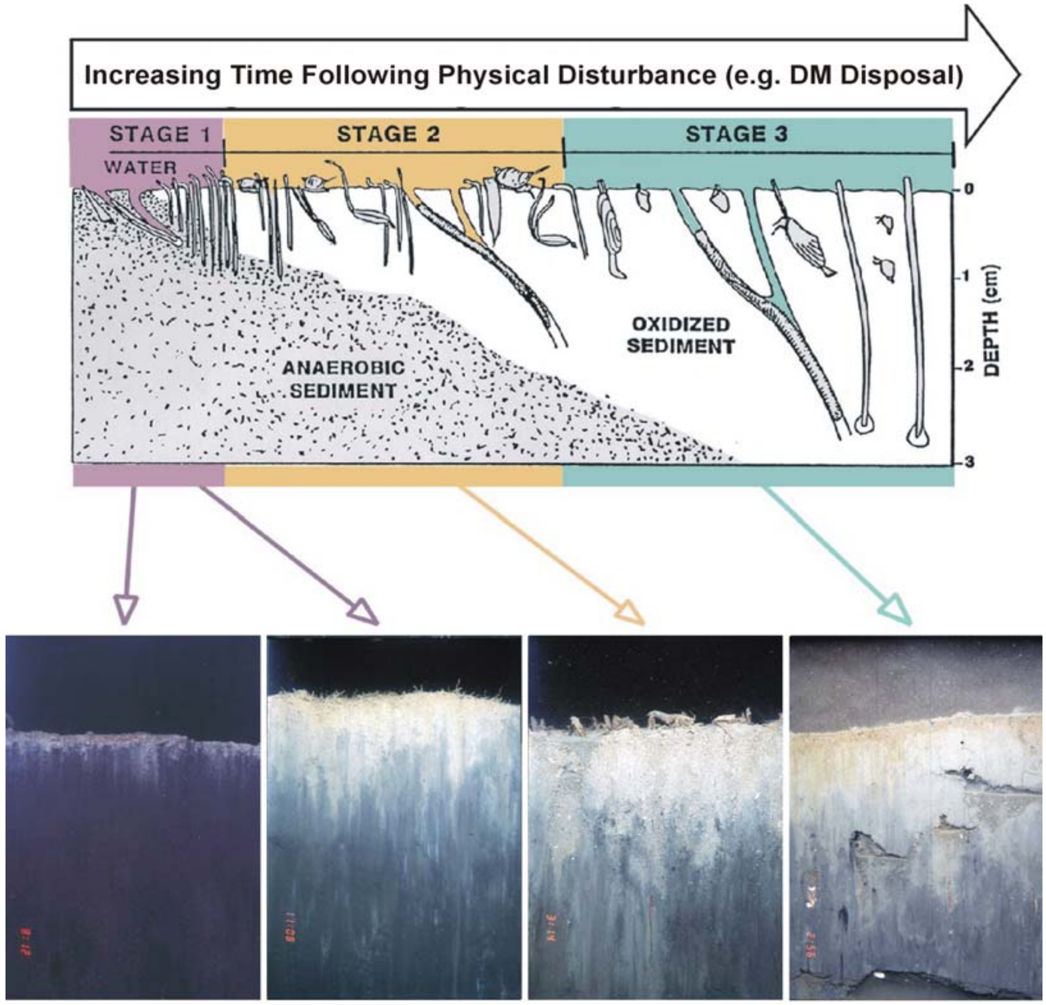

Figure 4. Successional Assemblages and Relationship to SPI Imagery

The drawing at the top illustrates the development of infaunal successional stages over time following a physical disturbance or with distance from an organic loading source (from Rhoads and Germano 1986). The REMOTS images below the drawing provide examples of the different successional stages.

Image A: Image A shows highly reduced sediment with a very shallow redox layer (contrast between light colored surface sediments and dark underlying sediments) and little evidence of infauna.

Image B: Numerous small polychaete tubes are visible at the sediment surface in image B (Stage I), and the redox depth is deeper than in image A.

Image C: A mixture of polychaete and amphipod tubes occurs at the sediment surface in image C (Stage II).

Image D: Image D shows numerous burrow openings and feeding pockets (voids) at depth within the sediment; these are evidence of deposit-feeding, Stage III infauna. Note the RPD is relatively deep in this image, as bioturbation by the Stage III organisms has resulted in increased sediment aeration and causing the redox horizon to be located several centimeters below the sediment-water interface.

2.1.2 Grain Size Analysis

Grain size distributions were characterized by the percent fractions of gravel, sand, silt, and clay comprising the substrate material. Surface sediment (0 to 10 cm) sampling was conducted at 10 locations following the placement of dredged material and completion of the SPI survey (Figure 5). The samples were collected at six locations (one per disposal lane) where dredged material was placed and four locations outside of the disposal lanes where native material was present. A 0.1 m^2 modified Young's van Veen grab sampler was used to collect the surface sediment for grain size distribution analysis. Acceptable grab samples were determined by meeting the following criteria (PSEP 1986):

- Sampler is not overfilled,
- Overlying water is present,
- No leakage of water during recovery,
- Sediment surface is relatively flat with no evidence of disturbance or winnowing, and
- A minimum penetration depth of 10 cm.

Once a sample was accepted, a description of the collected material was then recorded in logbooks including such information as color, texture, odor, presence of biological structures or any other notable observations.

The sediment from each grab was processed in the field. After characterizing the sediment as described above, the sub-samples were collected from the grab and homogenized. An aliquot of the homogenate was then placed in a pre-cleaned glass sample container and kept cool at approximately 4°C during transport and storage. Sample descriptions were recorded and chain-of-custody procedures were used to document the number and location of the grab samples collected. The sediment samples were stored and shipped for analysis to AMTEST Laboratories of Redmond, WA, a Washington State certified analytical laboratory. The analytical method used for determination of grain size distribution was ASTM D-422.

2.1.3 Bathymetric Survey

A multibeam bathymetric survey was conducted by GRS immediately following the placement of dredged material for the pilot study. Backscatter information derived from the multibeam survey was used for further classification of the seafloor at the disposal site. A detailed description of the multibeam investigation methodology is provided in Appendix C.

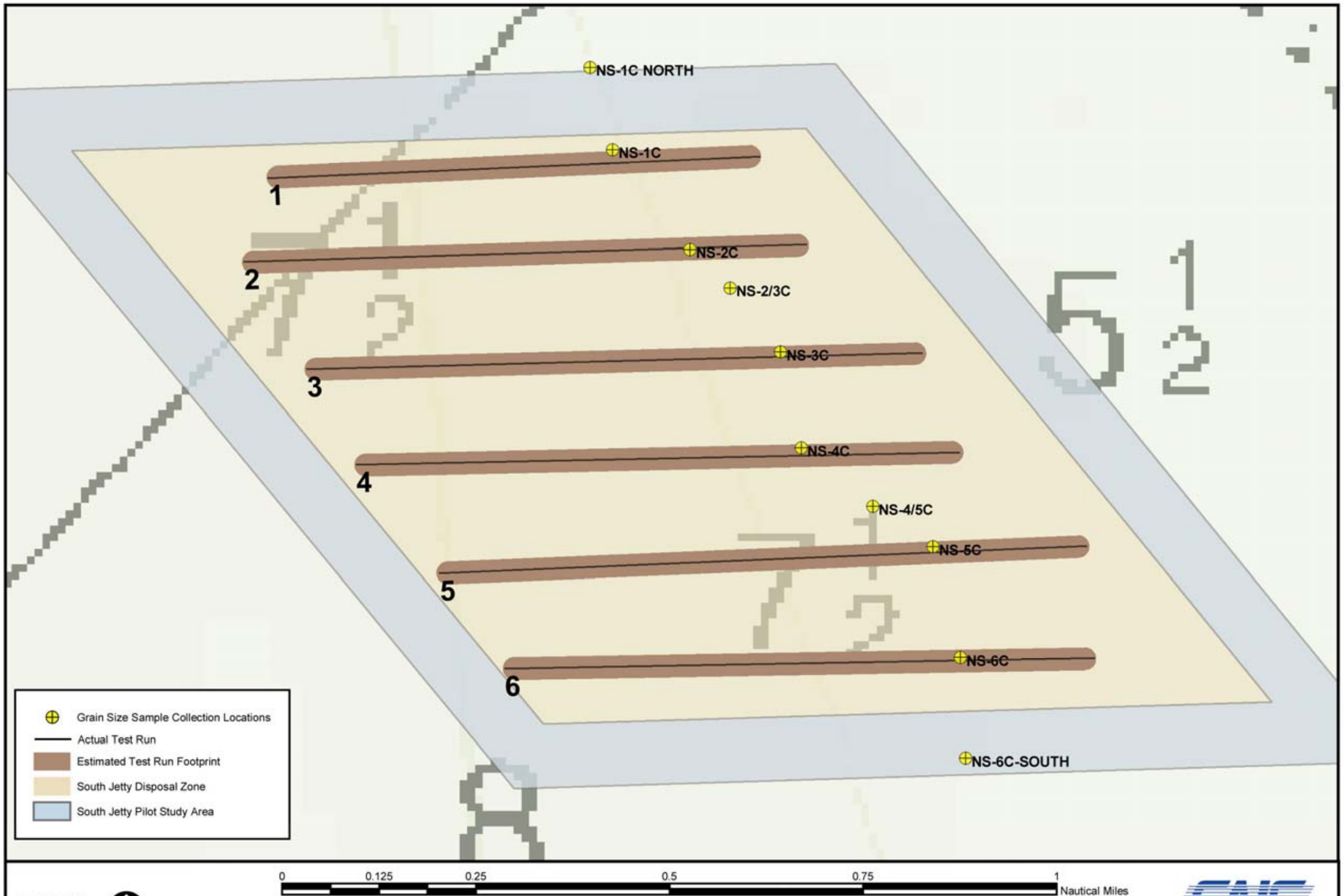

Figure 5. Sediment Sampling Locations

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M Goff, SAIC, October 2005

2.2 Sampling Platform

Sampling Vessel F/V Iron Lady

The F/V Iron Lady, an 81-ft commercial bottom trawler stationed in Warrenton, Oregon, was used for the SPI and sediment sampling activities. This vessel was outfitted to accommodate both commercial otter trawl demersal fish trawling, as well as scientific and engineering consulting services off the coasts of Washington and Oregon. The F/V Iron Lady is owned by Ms. Trisha Bisby, and registered in South Bend, WA. The vessel is operated by Captain Kevin Dunn, a skipper with more than 20 years of experience in Oregon and Washington coastal waters, including the Columbia River Bar and environs. The vessel is equipped with winches, davits, and an A-frame to accommodate the various sampling instruments. The back deck provided extensive open area to accommodate the sampling gear and operations conducted for this investigation.

2.3 Station Positioning

Prior to field operations, Coastal Oceanographic's HYPACK® Max was used to establish the planned survey lines and stations that were occupied in the survey. Navigation and positioning was accomplished using a differential global positioning system (DGPS) integrated with a computerized navigation system. The use of U.S. Coast Guard differential corrections and a Trimble DSM212L DGPS receiver provided positional accuracy of ± 3 meters. Vessel coordinates were updated every two seconds and transmitted directly to the onboard system. The HYPACK® Max survey and data acquisition software provided real-time data display and a plan-view chart display to aid the helmsman, as well as logged the vessel position and associated data. All station coordinates were reported in latitude and longitude using decimal minutes, accurate to 1/1000 of a minute.

3.0 Results

This section provides a summary of the results of the dredged material placement, SPI image analysis, and grain size distribution analysis. The information for the dredge material placement was provided by the Dredge Essayons via the USACE Portland District. The SPI images that were analyzed are presented in Appendix A. The coordinates for the SPI and sediment sampling locations are provided in Appendix B. A copy of the Parametrix bathymetric report is provided in Appendix C.

3.1 Dredged Material Placement

The placement of dredged material at the near shore site was conducted over a two day period (September 14th and 15th, 2005). The Essayons was commanded by Chief Mate Jeffrey S. McDonald during the pilot study. The weather and sea conditions were favorable during the study with light winds, temperatures between 55° and 60° F, with overcast skies and light drizzle on the 14th, and sunshine on the 15th. Wave conditions consisted of a modest swell between 2 to 3 feet with a long period. The tidal currents were moderated by a relatively small tidal exchange of -1 to +7.5 feet MLLW between lower low and higher high tides.

Data recorded during the disposal runs are presented in the Figures 6 through 11, which graphically displays the displacement and speed profiles of the dredge Essayons during each placement. Table 2 summarizes details of the enhanced disposal effort. The Essayons offloaded material in single continuous run along each disposal lane. The dredge displacement profiles show relatively constant disposal of material over the length of each run. Each disposal run took 8 to 10 minutes, with a ship speed ranging from 2 to 7.5 knots during the placement activities. The dredge turn-around-time was approximately 2.5 to 3.0 hours between dredging at Quadrant 4 in the navigational channel to disposal at the nearshore site. The length of each disposal ranged from 1183 to 1554.8 meter. The volume of dredged material per disposal run ranged from 5520 to 5810 cubic yards.

The average thickness of dredged material could be estimated using the dredged material volumes, the apparent footprint of dredged material using the recorded disposal lane lengths and average width of 180 feet. The estimate of average dredge material deposition ranged from 2.03 to 2.69 inches thick was based on volumetric calculations. The USACE, Portland District estimate a maximum simulated bottom accumulation of 4.8 inches using the MDFATE model of dredged material distribution at the South Jetty (Moritz 2005). The USACE model simulated ocean conditions during the pilot study using field data measured in September 2003 that matched the 2005 tide and wave conditions. These data were used for FATE model simulation of dredged material deposition on the seabed at the South Jetty Site. The parameters utilized in the model simulation included: wave height and direction, depth averaged current direction and velocity, and observed tides. Graphics depicting the model parameters and model simulation results are presented in Appendix D. These estimates are consistent with the goals of the enhanced disposal target depths of 2 to 4 inches identified in the research permit (USEPA 2005).