Monitoring Cruise at the
Western Long Island Sound Disposal Site,
August 1993

Disposal Area Monitoring System DAMOS

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13. ABSTRACT

The two objectives of the Western Long Island Sound Disposal Site (WLIS) survey conducted 24 to 27 August 1993 by Science Applications International Corporation (SAIC) were to locate a new reference area to replace the existing WLIS-REF reference area, and to monitor ecological conditions at selected stations on the WLIS A and D disposal mounds. This survey was performed as part of the Disposal Area Monitoring System (DAMOS) Program under the auspices of the New England Division (NED) of the US Army Corps of Engineers.

Field monitoring surveys conducted in 1991 and 1992 indicated that, based on sediment chemistry analyses, grain size information, and Remote Ecological Monitoring of the Seafloor (REMOTS®) data, the WLIS-REF reference area did not adequately represent ambient sediments. These reference area characteristics are critical to all dredged material disposal activities as they provide the comparisons needed for all field monitoring surveys conducted at WLIS. Concurrent with these findings, conditions observed at the WLIS A and D mounds from 1990 to 1992 suggested a potential long-term influence of dredged sediments on the benthic habitat in terms of apparent habitat quality and recolonization rates. This has been an area of concern since the 1989/1990 disposal season; as of 1992, several stations did not exhibit the typical temporal infaunal recolonization response expected following disturbance from disposal of dredged material. The 1993 monitoring of these selected stations was conducted in accordance with the DAMOS tiered monitoring program developed in 1989 by scientists at NED and SAIC and by members of a Technical Advisory Committee (TAC).

Pursuant to these objectives, the search in 1993 for an alternative reference area began by visually inspecting reconnaissance sediment sample grabs and measuring water depths at 200 m intervals from the center of the existing SOUTH reference area. These samples were compared to the physical sediment characteristics of reconnaissance grabs and water depth measurements taken in the SW corner of WLIS and to samples taken at the center of the SOUTH reference area. Sediment characteristics obtained from REMOTS® photographs collected at these stations were also used to delineate the newly proposed reference area. Based on the results of the reconnaissance survey, sediment chemistry grab samples were taken at selected stations in the proposed new reference area and the SOUTH reference area to provide the analytical chemical data needed to confirm that the sediments adequately reflected ambient sediment chemical concentrations. Ambient sediments were characterized based on sediment grain size, total organic carbon (TOC), and chemical concentrations of trace metals, polycyclic aromatic hydrocarbons (PAHs), and pesticides and polychlorinated biphenyls (PCBs).

The second objective, the assessment of the benthic recolonization status at selected stations on the WLIS A and D disposal mounds, was accomplished by conducting a REMOTS® monitoring survey at the same station locations in 1993 as were occupied in the 1991 and 1992 surveys. The results of the 1993 REMOTS® data were evaluated independently and then compared to the 1991 and 1992 data to assess the status of benthic habitat and recovery.

The results of this 1993 monitoring survey indicated that, based on reconnaissance sediment grabs, REMOTS® sediment-profile photographs, and sediment chemistry analyses, an area southwest of the disposal site, henceforth, SW-REF, was an acceptable alternate reference area.

Acceptable reference area sediments were observed in an area 600 m to the west and east of the SW-REF center located at 40°58.487' N and 73°29.909' W, and 300 m north and south. Chemistry data showed that the SW-REF sediments were similar in metal and PAH distribution as SOUTH, previous data collected at WLIS reference stations, and regional data as compiled by the National Status and Trends Program.

Analysis of the 1993 REMOTS® photographs from the WLIS A and D mounds indicated benthic conditions improved at WLIS A and ranged from similar to slightly improved at WLIS D from those observed during the July 1992 survey. According to the tiered monitoring protocols, these conditions do not warrant immediate management response. However, considering the historical recolonization response at the selected stations of the A and D mounds, continued monitoring of these stations is recommended during future WLIS monitoring surveys.

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EXECUTIVE SUMMARY

The two objectives of the Western Long Island Sound Disposal Site (WLIS) survey conducted 24 to 27 August 1993 by Science Applications International Corporation (SAIC) were to locate a new reference area to replace the existing WLIS-REF reference area, and to monitor ecological conditions at selected stations on the WLIS A and D disposal mounds. This survey was performed as part of the Disposal Area Monitoring System (DAMOS) Program under the auspices of the New England Division (NED) of the US Army Corps of Engineers.

Field monitoring surveys conducted in 1991 and 1992 indicated that, based on sediment chemistry analyses, grain size information, and Remote Ecological Monitoring of the Seafloor (REMOTS®) data, the WLIS-REF reference area did not adequately represent ambient sediments. These reference area characteristics are critical to all dredged material disposal activities as they provide the comparisons needed for all field monitoring surveys conducted at WLIS. Concurrent with these findings, conditions observed at the WLIS A and D mounds from 1990 to 1992 suggested a potential long-term influence of dredged sediments on the benthic habitat in terms of apparent habitat quality and recolonization rates. This has been an area of concern since the 1989/1990 disposal season; as of 1992, several stations did not exhibit the typical temporal infaunal recolonization response expected following disturbance from disposal of dredged material. The 1993 monitoring of these selected stations was conducted in accordance with the DAMOS tiered monitoring program developed in 1989 by scientists at NED and SAIC and by members of a Technical Advisory Committee (TAC).

Pursuant to these objectives, the search in 1993 for an alternative reference area began by visually inspecting reconnaissance sediment sample grabs and measuring water depths at 200 m intervals from the center of the existing SOUTH reference area. These samples were compared to the physical sediment characteristics of reconnaissance grabs and water depth measurements taken in the SW corner of WLIS and to samples taken at the center of the SOUTH reference area. Sediment characteristics obtained from REMOTS® photographs collected at these stations were also used to delineate the newly proposed reference area. Based on the results of the reconnaissance survey, sediment chemistry grab samples were taken at selected stations in the proposed new reference area and the SOUTH reference area to provide the analytical chemical data needed to confirm that the sediments adequately reflected ambient sediment chemical concentrations. Ambient sediments were characterized based on sediment grain size, total organic carbon (TOC), and chemical concentrations of trace metals, polycyclic aromatic hydrocarbons (PAHs), and pesticides and polychlorinated biphenyls (PCBs).

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The results of this 1993 monitoring survey indicated that, based on reconnaissance sediment grabs, REMOTS® sediment-profile photographs, and sediment chemistry analyses, an area southwest of the disposal site, henceforth, SW-REF, was an acceptable alternate reference area.

Acceptable reference area sediments were observed in an area 600 m to the west and east of the SW-REF center located at 40°58.487' N and 73°29.909' W, and 300 m north and south. Chemistry data showed that the SW-REF sediments were similar in metal and PAH distribution as SOUTH, previous data collected at WLIS reference stations, and regional data as compiled by the National Status and Trends Program.

Analysis of the 1993 REMOTS® photographs from the WLIS A and D mounds indicated benthic conditions improved at WLIS A and ranged from similar to slightly improved at WLIS D from those observed during the July 1992 survey. According to the tiered monitoring protocols, these conditions do not warrant immediate management response. However, considering the historical recolonization response at the selected stations of the A and D mounds, continued monitoring of these stations is recommended during future WLIS monitoring surveys.

1.0 INTRODUCTION

Science Applications International Corporation (SAIC) conducted a monitoring survey at the Western Long Island Sound Disposal Site (WLIS) from 24 to 27 August 1993 with two objectives: 1) to locate a new reference area, and 2) to monitor ecological conditions at two selected historical disposal mounds. WLIS is 5.13 km (2.7 nmi) south of Long Neck Point, Connecticut, and encompasses a 1.852 km^2 (1 nmi^2) area centered at 40°59.400' N and 73°28.700' W (Figure 1-1). The discontinued Eaton's Neck, Stamford, and Norwalk disposal grounds border the disposal site to the east, west, and northeast.

Sediments dredged from nearby harbors and shoreline communities are disposed at WLIS under the auspices of the New England Division (NED) of the US Army Corps of Engineers (USACE), and monitored to investigate the physical, biological, and chemical impacts of ocean disposal of dredged material under the Disposal Area Monitoring System (DAMOS) Program. Disposal operations at WLIS are permitted from October 1 to May 31 and prohibited during the summer months because of the active lobster fishery in the area. Dredged material has been deposited annually at WLIS since disposal first began at the site in March 1982, resulting in the formation of six dredged material disposal mounds named WLIS A-F (Figure 1-2).

1.1 WLIS Reference Area Search

Critical to all DAMOS field monitoring activities are disposal site reference areas. Optimally, three reference areas are maintained for each disposal site. The first objective of the 1993 WLIS monitoring survey, to locate a new reference area, was in response to the results of a series of surveys that suggested that some WLIS reference areas had been affected by historic dredged material disposal (Williams 1995, Eller and Williams 1996). Reference areas should reflect conditions that would exist in the vicinity of the disposal site had no dredged material disposal ever occurred. The search for a new reference area followed the USACE and US Environmental Protection Agency (USEPA) guidelines as detailed in the "Green Book" (EPA/USACE 1991). Reference areas are used as a comparison against which the environmental impact of dredged material disposal is assessed, and are selected based on water depth, proximity to the disposal site, grain size, and sediment chemistry (EPA/USACE 1991). The reference sediments should be substantially free of contaminants (i.e., at "normal" background levels) and as similar to the grain size of the dredged material and the sediment at the disposal site as practical.

In 1991, analyzed Remote Ecological Monitoring of the Seafloor (REMOTS®) data at WLIS-REF and results of REMOTS® and sediment chemistry at the 2000S reference area suggested that WLIS-REF and 2000S did not represent ambient site (reference)

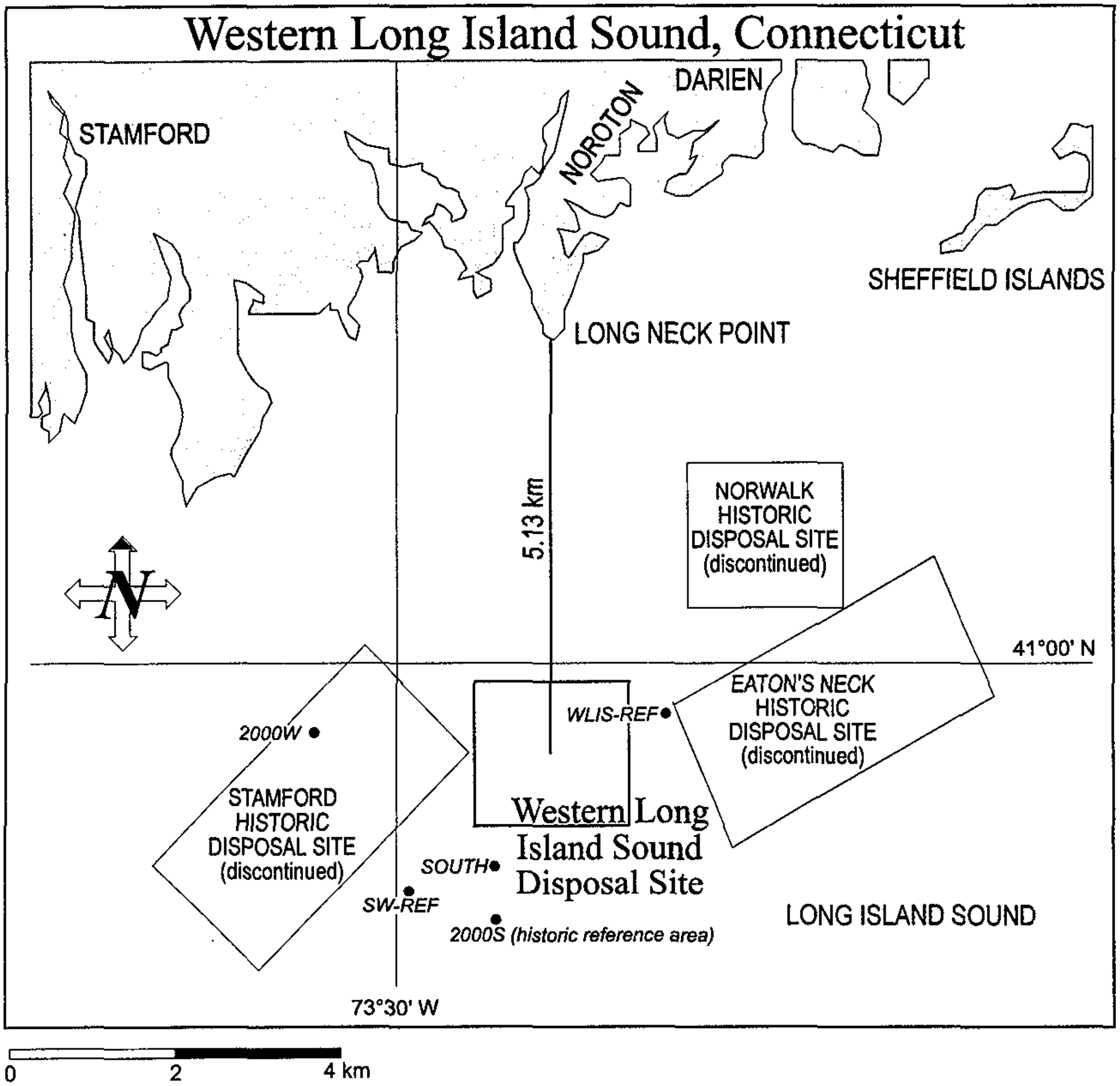


Figure 1-1. Western Long Island Sound Disposal Site location with reference area positions

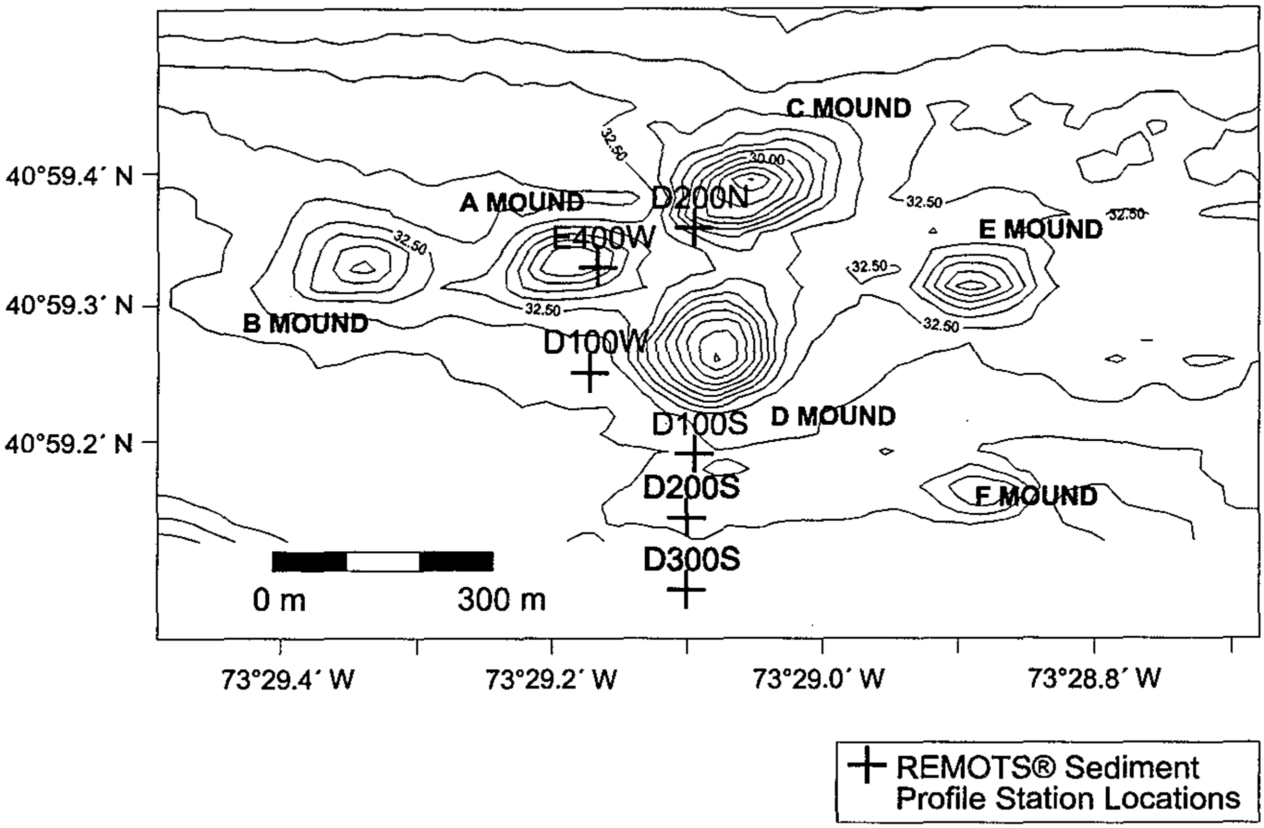


Figure 1-2. REMOTS® sediment profile station locations on the WLIS A and D mounds, August 1993

conditions, and that only 2000W was a suitable reference area (Williams 1995). REMOTS® parameters indicated that 2000S and WLIS-REF had been affected by past dredged material disposal operations, and sediment chemistry analysis indicated that polycyclic aromatic hydrocarbon (PAHs) and metals concentrations exceeded "normal" background concentrations. A suitable replacement for 2000S was located during the 1992 monitoring survey and was named the SOUTH reference (Eller and Williams 1996). The reference area proposed to replace WLIS-REF during the 1992 survey, named EAST, was found not to be a suitable replacement reference area upon analysis, again due to potential historical disposal of dredged material, leading to the continued search for the WLIS-REF replacement during this survey (Eller and Williams 1996).

1.2 Monitoring at the WLIS A and D Disposal Mounds

Monitoring surveys have normally been conducted on an annual basis at WLIS to determine the distribution of recently disposed dredged material and assess the effects of each season's disposal on the benthic habitat and water column. The second major objective of the WLIS 1993 survey, to monitor conditions at two selected WLIS disposal mounds, resulted from several prior surveys at the WLIS disposal mounds A and D, which indicated that further investigation was required (Williams 1995, Eller and Williams 1996). These recommendations were based on the tiered monitoring protocols developed by scientists at NED and SAIC, and by members of a Technical Advisory Committee (TAC) for the DAMOS Program (Germano et al. 1994). The tiered monitoring protocols were developed to provide guidelines and a logical structure to establish a system of disposal decision and action criteria based on management objectives. They include responsive measures to minimize any possible environmental impacts that may be associated with the disposal of dredged material.

One objective of field monitoring surveys is to assess the infaunal recolonization rate of benthic invertebrates on dredged material deposits. These benthic communities are used as biological indicators and reflect the quality of habitat (dredged material) and site conditions of the disposal project area (Germano et al. 1994). Conditions observed at the A and D mounds from 1990 to 1992 suggested a potential long-term influence of dredged sediments on the benthic habitat in terms of apparent habitat quality and recolonization rates (Williams 1995, Eller and Williams 1996). Several stations at the A and D disposal mounds exhibited shallow redox potential discontinuity depths (RPD) and reduced sediments in all 1990—1992 surveys (Figure 1-2). These conditions are indicative of a high sulfide content and a high sediment oxygen demand (SOD). This has been an area of concern because these sediments were deposited prior to 1990, and as of 1992 did not exhibit the typical temporal infaunal recolonization responses expected following disturbance from disposal of dredged material (Rhoads and Germano 1982).

REMOTS® sediment-profile photography and sediment toxicity testing were used to provide data for the assessment of current habitat conditions for 1992 in accordance with the tiered monitoring protocols. Data from the toxicity testing demonstrated no statistical difference between the WLIS A and D mounds and reference stations (Eller and Williams 1996). Results of the July 1992 REMOTS® survey, however, were similar to those of the 1991 survey (little temporal change) with regard to the depth of the RPD, successional stages, and values for the Organism-Sediment Index (OSI), with the exception of two stations on the D mound which showed lower values for the OSI. Under tiered monitoring protocols (Germano et al. 1994), the possible deleterious effects of prior disposal at the WLIS A and D mounds warranted continued monitoring in 1993.

The August 1993 survey was conducted to define an alternative reference area to replace WLIS-REF, and to monitor the ecological conditions at the WLIS A and D mounds. Investigation of these objectives resulted in two recommendations:

- Reconnaissance sediment grabs, REMOTS® sediment-profile photographs, and sediment chemistry analyses indicated an acceptable alternate reference area for WLIS-REF;

- Analysis of the 1993 REMOTS® photographs from selected stations at the WLIS A and D mounds indicated some improvements in benthic conditions.

2.0 METHODS

2.1 Navigation

The SAIC Integrated Navigation and Data Acquisition System (INDAS) provided the precision navigation required for all field operations. This system uses a Hewlett-Packard 9920® series computer to collect position, depth, and time data for subsequent analysis and to provide real-time navigation. A Del Norte Trisponder® system provided positioning to an accuracy of ±3 meters. The actual positional error of the INDAS depends on the accuracy of the Del Norte Trisponder® system and the geometric dilution of precision which is, in turn, a function of the survey vessel's position with respect to the shore-based microwave trisponder. Shore stations were established in Connecticut at known benchmarks at Greenwich Point, Old Greenwich, CT, and the Norwalk Harbor Power Plant, Norwalk, CT. Survey work was completed aboard the *R/V UCONN*. A detailed description of the navigation system and its operation can be found in the DAMOS QA/QC Plan (Browning et al. 1990).

During all field operations, the INDAS provided the operator and the helmsman with range and bearing to a selected target (i.e., REMOTS® stations and sediment sampling stations), signal quality, and time of day. A Hewlett Packard 7475A plotter tracked the vessel's position during survey operations allowing the navigator to assess the ship's location relative to other targets in the area. A printer generated a hard copy of these position fixes. Each fix incorporated date and time of day, the ship's position in latitude/longitude and local x/y coordinate system, and raw Del Norte position ranges.

2.2 Reference Area Sediment Sampling

2.2.1 Reconnaissance Reference Area Sampling

The selection criteria for choosing an alternate reference area included (1) depth comparable to the disposal site; (2) location outside of the active and discontinued disposal sites; (3) relative proximity to the SOUTH and the previously utilized 2000S reference areas; and (4) the physical and chemical similarities (substantially free from contaminants) between sediments at the SOUTH reference area, southwestern corner of WLIS, and the proposed new reference area. The data needed to assess these criteria were collected from reconnaissance sediment grabs, followed by sediment chemistry analyses, and REMOTS® sediment-profile photographs.

Reconnaissance sediment samples were obtained with the 0.1 m^2 van Veen grab, and provided visual and textural characteristics for the initial screening of potential reference areas (Appendix A). On 25 August 1993, three reconnaissance sediment grabs were obtained near the southwestern corner of the disposal site, and three at the center of the SOUTH reference area (Figure 2-1). These grabs were used for comparison for the initial screening of potential reference areas. The grabs obtained in the southwestern corner of the disposal area represented ambient sediment conditions that had not yet been affected by disposal operations. Reconnaissance sediment grabs were then obtained immediately west of the SOUTH reference area along a similar latitude (40°58.700' N) (SW1-3 and SW3A; Figure 2-1). Visual inspection of reconnaissance grabs obtained at Stations SW2 and SW3 showed dark gray silt/clay sediments with an olive brown oxidized layer, approximately ½ cm in thickness. These preliminary results indicated that the sediments were sufficiently similar to the disposal site and SOUTH reference sediments.

On the following day, 26 August 1993, the area east of the SOUTH reference area was surveyed and grabs obtained immediately east (EG4-5) and southeast (EG6-8) of the reference area (Figure 2-1). Additional grabs were taken in an east, northeast direction as far north as Eaton's Neck Historic Disposal Site (EG9 to EG14) (Figures 1-1 and 2-1). Sediments in this area proved to be too different from the disposal site and SOUTH reference area sediments based on visual inspection of grabs (Appendix B). Shell debris and sandy sediments excluded some areas from consideration; other sediments were very dark and composed largely of silt. These characteristics are commonly associated with dredged or introduced sediments, or are indicative of a type of a current regime not found at WLIS. Therefore, these sediments were evaluated as not representing ambient conditions.

Based on the above results, it was concluded that the area west of the SOUTH reference area (named SW-REF) showed the best potential as an alternative reference area and was further investigated by obtaining additional reconnaissance grab samples (Stations SW15-24). Using the location of SW16 as a center reference point, additional reconnaissance grabs were collected at 200 m intervals to the north (SW17-20), 600 m west (SW21), and 300 m south (SW22) of center (Figure 2-1). Reconnaissance grabs SW23 and SW24 were located 600 m southeast and 600 m east of SW18. In total, fourteen reconnaissance grabs were taken to delineate the potential SW reference area. The results obtained through reconnaissance grabs at the SW-REF area in comparison to the SOUTH area warranted further investigation of the surrounding area by sampling for sediment chemistry analysis and REMOTS® sediment-profile photography.

2.2.2 Sediment Chemistry Sampling

Sediment chemistry samples were collected in triplicate at the SOUTH reference area, and one composite sample was collected at each of the SW-REF stations SW16,

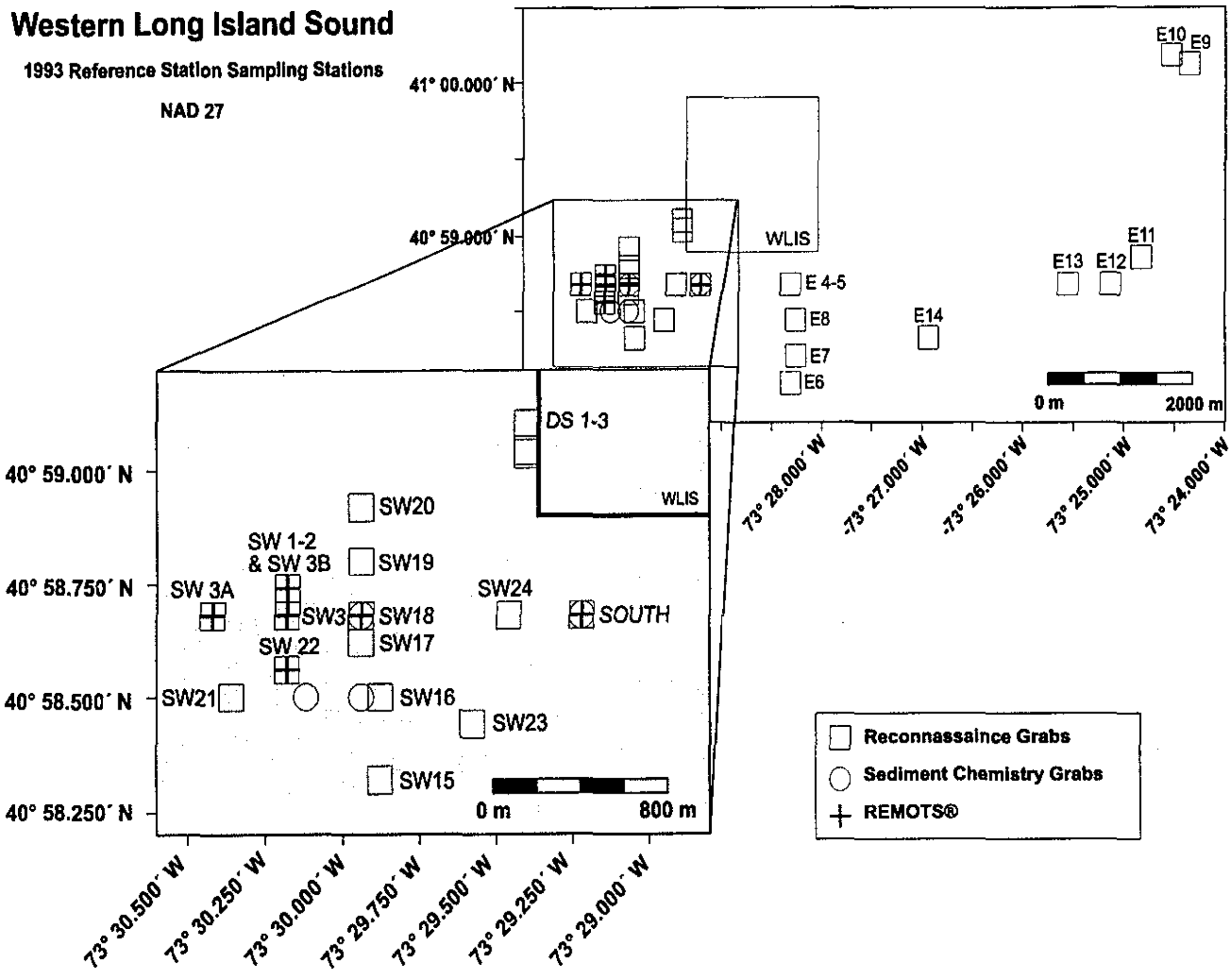


Figure 2-1. Location of reconnaissance grabs, sediment chemistry grabs, and REMOTS® stations at WLIS, August 1993

SW18, and SW22 following completion of reconnaissance grab sampling. Samples were collected with a 0.1 m^2 van Veen sampler and subsamples extracted with 10-cm-long polycarbonate cores (3.7 cm diameter). The subsamples were mixed in a plastic container with a teflon-coated spoon until no color or textural changes were discernible. Between stations the subsampling equipment was solvent rinsed with acetone and the van Veen rinsed with seawater. Sediment samples were stored in coolers at approximately 4° C and delivered to the NED laboratory on 31 August 1993. The samples were analyzed for grain size, total organic carbon (TOC), percent moisture, metals, polychlorinated biphenyls (PCBs), pesticides, and polycyclic aromatic hydrocarbons (PAHs) using approved EPA analytical methods (EPA 1986).

2.3 Laboratory Analyses

2.3.1 Grain Size and Total Organic Carbon Analyses

Grain size analyses were performed using the American Society for Testing and Materials (ASTM) Method D422 (sieve and hydrometer; Table 2-1) (ASTM 1990). A detailed explanation of this method is provided in DAMOS Contribution 102 (Eller and Williams 1996).

Total organic carbon (TOC) was measured using the EPA's *Manual of Test Methods for Evaluating Solid Waste* (SW-846) Method 9060 (EPA 1986). Organic carbon in the samples was converted by the analyzer to carbon dioxide (CO_2), which was subsequently measured by an infrared detector. The amount of CO_2 is directly proportional to the concentration of carbonaceous material in the sample. Inorganic forms of carbon (carbonate and bicarbonate) were not included as part of the reported TOC value. Total organic carbon is a measurement of organic matter (both labile and refractory) in sediments.

2.3.2 Metal Analyses

A total of ten metals were analyzed for this survey, using standard SW-846 procedures for metals analysis (Table 2-1).

Results of metals analyses were compared to the data compiled by the New England River Basin Commission (NERBC 1980) as a reference to evaluate the level of metals contamination. The NERBC values traditionally have been used to classify sediments into low, moderate, and highly contaminated categories, due to the lack of other approved standards. Reference values for metals and PAHs are currently being assessed using compiled disposal site reference area data from the USACE and USEPA; these data are intended to serve as a guideline for evaluating sediment chemistry data (SAIC 1994).

Table 2-1

Methods of Physical and Chemical Analyses
for Sediment Samples Collected at WLIS 1993

Analysis	**Method**	**Instrumentation**
Grain Size	ASTM D422	Sieve/Hydrometer
Analysis	**SW846 Method*** (EPA 1986)	**Instrumentation**
Total Organic Carbon	NA/9060	
PAHs	3540/8270	GC/MS
PCBs	3540/8080	GC/MS
Pesticides	3540/8080	GC/MS
Metals:		
Aluminum	3051/6010	ICP
Arsenic	3051/206.2	GFAA
Cadmium	3051/6010	ICP
Chromium	3051/6010	ICP
Copper	3051/6010	ICP
Iron	3051/6010	ICP
Lead	3051/239.2	GFAA
Mercury	NA/7471	CVAA
Nickel	3051/6010	ICP
Zinc	3051/6010	ICP

* First value refers to extraction method, second value refers to analysis method.
NA = Not applicable.

GC/MS = Gas Chromatograph/Mass Spectrometer
ICP = Inductively Coupled Argon Plasma Emission Spectrometry
GFAA = Graphite Furnace Atomic Absorption
CVAA = Cold Vapor Atomic Absorption
PCB = Polychlorinated biphenyl
PAH = Polycyclic aromatic hydrocarbon

2.3.3 Organic Analyses

PAHs were analyzed using EPA SW-846 Method 8270 (Table 2-1); chlorinated pesticides and PCBs were analyzed using SW-846 Method 8080 (EPA 1986). Both methods utilize gas chromatography/mass spectrophotometry (GC/MS).

2.4 Laboratory Quality Assurance/Quality Control (QA/QC)

Quality control was determined by evaluating holding times from collection to extraction and extraction to analysis, method blank results (for all analyses except PAHs), blank spikes and duplicate blank spikes (metals and pesticides analyses), recovery of surrogate compounds for all organic analyses, and a laboratory control sample for TOC analysis.

2.4.1 Holding Times

The maximum holding times between sample collection and analysis were not exceeded for all metals analyses except for Hg which was exceeded by 24 days. The 14-day maximum recommended holding time between sample collection and extraction for the PCBs, pesticides, and PAHs was exceeded by 62 to 84 days. The 40-day maximum recommended holding time between extraction and analysis was met for the PCBs and pesticides. Analyses of PAHs were originally performed by an outside laboratory and then rerun by the NED laboratory. Samples were rerun in-house due to high detection limits submitted by the outside laboratory. When the PAH extracts were received by the NED laboratory for reanalysis, 50 days had passed since the extraction date of 12 February 1994, which exceeded the maximum holding time by 10 days.

2.4.2 Method Blanks

Method blanks are laboratory QC samples processed with the samples but containing only reagents. Method blanks test for contamination which may have been contributed by the laboratory during sample preparation. The metals blank showed Al (7.0 ppm), Cu (2.4 ppm), Fe (1.8 ppm), Pb (0.80 ppm), and Zn (0.96 ppm) (Appendix A Table 1). Sediment concentrations of the metals which had detected values in the blank were sufficiently high so that any positive bias was minimal. The method blanks for TOC, PCBs, and pesticides were free from contamination.

2.4.3 Blank Spike/Duplicate Blank Spike

Blank spikes were used to measure accuracy, and duplicate blank spikes were used to measure precision (relative percent difference). Analytical accuracy is expressed as the percent recovery of the spiked compound that is added to the environmental sample at a known concentration before analysis. The closer the numerical value of the measurement approaches the actual concentration of the spike, the more accurate the measurement. Accuracy was measured for the metal and pesticide analyses. Accuracy for the metal analyses with the exception of As and Pb ranged from 86 to 94% and fell well within the control limits of 75–125% (Appendix A Table 2). The blank spike for Pb was just below the control limit (70%), and the duplicate blank spike for As was barely above the upper limit of the acceptable range (126%). Accuracy values for pesticides ranged from 88 to 92% and were within the acceptable ranges for each spiking compound (Appendix A Table 2).

Analytical precision for metals was expressed as the percentage of the difference between results of the duplicate blank spikes. The maximum acceptable value for the relative percent difference for metals was 30%, and actual values ranged from less than or equal to 8% with the exception of As which was 25%.

2.4.4 Surrogate Recovery

Each sediment sample for pesticide, PCB, and PAH analyses was spiked with surrogate compounds as a measure of accuracy. Surrogate samples are analyzed as a check on the laboratory's ability to extract known concentrations of compounds not normally found in the sample, but having similar characteristics. Surrogate compounds (generally compounds labeled with stable isotopes) are the only means of checking method performance on a sample by sample basis. Recoveries for the pesticides were in control with the exception of three out of seven instances for decachlorobiphenyl (Appendix A Table 2). However, for each sample and the method blank, one of the two surrogate compounds was consistently in control. The surrogate recoveries for PCB analyses ranged from 90 to 97% and were well within the control limits of 60–150% (Appendix A Table 2).

The PAH surrogates were in control in 12 out of 18 instances (Appendix A Table 3). Recovery for the surrogate terphenyl-d14 (acceptable range of 18–137%) was exceeded five times in a range of 15–47% while nitrobenzene-d5 was recovered once in an amount barely outside the maximum range (recovered at 121% with a range of 23–120%). The high surrogate recoveries were potentially caused by matrix interferences. The acceptable recoveries of two out of three surrogate compounds for each sample indicate no laboratory extraction problem (EPA 1991).

2.4.5 Laboratory Control Sample

One laboratory control sample (LCS) was analyzed for the TOC analysis. The LCS was analyzed using identical procedures as samples. The percent TOC recovered from the LCS was 104% and was well within the acceptable range of recovery of 80–120%.

2.4.6 Data Qualification

Results for Hg were qualified as J due to the violations in recommended holding times from collection to analysis. Results for Al, Cu, Fe, Pb, and Zn were qualified with a B because of the detection of these metals in the method blank. Results for organic analyses were qualified as UJ for non-detects and J for detects due to extended holding times between collection and analysis and for PAHs because of the holding time between extraction and analysis. Further explanations of qualification codes can be found in *Laboratory Data Validation: Functional Guidelines for Evaluating Inorganic and Organic Analyses* (EPA 1988a and 1988b).

2.5 REMOTS® Sediment-Profile Photography

The REMOTS® System utilizes a Benthos Model 3731 Sediment Profile Camera, combined with a computerized image analysis system to digitize and analyze photographs. REMOTS® is a formal and standardized technique for sediment-profile imaging and analysis. Designed to obtain *in situ* images of the top 0.1 cm to 20 cm of sediment, REMOTS® photography has been used to detect and map the distribution of thin (0.1–20 cm) dredged material layers. In addition, REMOTS® is used to map benthic disturbance gradients, and monitor infaunal recolonization on and adjacent to disposal mounds (Rhoads and Germano 1982).

In general, triplicate REMOTS® photographs were collected at each station to account for the variability of benthic habitat parameters at each station. Between stations, the camera was raised on deck to check camera penetration depth, and the camera frame count via the digital readout on the camera. If the digital readout did not advance by at least three numbers, the camera was re-deployed at that station for additional pictures.

Measurements of all physical parameters and some biological parameters are obtained directly from film slides using a video digitizer and computer image analysis system. Specific measurement/observational techniques of REMOTS® parameters typically obtained for the DAMOS Program include sediment grain size major mode and range, prism penetration depth, surface boundary roughness, presence/absence and size of mud clasts, apparent redox potential discontinuity (RPD) depth, apparent presence/absence of sedimentary methane, estimate of infaunal successional stage, and calculation of the REMOTS® OSI. Automatic disc storage of all parameters measured allows data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. A detailed description of REMOTS® image acquisition, analysis, and interpretive rationale is given in the DAMOS SOP Manual (SAIC 1985) and QA/QC Plan (Browning et al. 1990).

2.5.1 Reference Areas

Following reconnaissance grabs, REMOTS® sediment-profile photographs were obtained at several locations in the area of SW-REF (Stations SW3, SW3A, SW3B, SW18, and SW22), and three replicate photos at SOUTH (Figure 2-1). REMOTS® photographs obtained at SW3A showed possible dredged material. These photographs were taken in the vicinity of the discontinued Stamford Historic Disposal Site and indicated that additional reference grabs should not be taken this far west. Other REMOTS® photographs were not obtained during the survey because of operation problems with the camera.

2.5.2 REMOTS® Sediment-Profile Photography: A and D Mounds

In total, REMOTS® sediment-profile photographs were obtained at six stations on the A and D mounds (Figure 1-2). Triplicate photographs were generated for Station E400W at the WLIS A mound and Stations D100W, D100S, D200S, D300S, and D200N at the WLIS D mound.

3.0 RESULTS

3.1 Reconnaissance Sediment Grabs/Depth Measurement

Sediments in the southwest corner of the disposal site represented base or ambient sediments. The three replicate reconnaissance grabs showed an olive gray/brown oxidized layer approximately 1 mm in thickness (Appendix B). This surface sediment had a high water content, some very small shell fragments, and a few pebbles. A small shrimp and polychaete worm were also observed. The underlying sediments consisted of dark gray to black silt/clay with some fine sands. No noticeable odors were associated with the grab.

Sediments from the SOUTH reference area were dark gray to black sandy silt and sandy silty clay with an olive gray/brown organic layer (Table 3-1 and Appendix B). The areas to the east, southeast, and northeast of the SOUTH reference were eliminated because of water depth or different sediment characteristics (Appendix B). Many of the reconnaissance grabs in these areas consisted of dark gray silts with a very high moisture content and very thin oxidized olive layer (< 1 mm), often accompanied by an anoxic (sulfur) smell. Other sediments contained shellhash or consisted of sands. These characteristics are commonly associated with dredged or introduced sediments or are indicative of more energetic current regimes not normally found at WLIS.

Sediments of the SW-REF showed characteristics similar to those at the disposal site and SOUTH (Appendix B). The olive gray/brown oxidized layers of the first four replicate grabs (SW1-3 and SW3A) contained a small shrimp and crab, a flabelligerid polychaete, and some shell fragments. Other than a marine mud odor there were no discernible hydrocarbon or anoxic odors. Sediment samples collected from SW16 (SW-REF CTR), SW22, and SW18 were medium gray to black sandy silts and silty sand (Figure 2-1 and Table 3-1).

Acceptable reference sediments based on the appearance of reconnaissance grabs were apparent at Stations SW1, SW2, SW3, SW3A, SW15, SW16, SW17, and SW18. Station SW19 indicated an area of transition from silt/clay sediments mixed with sand to sediments with a higher moisture content and higher percentages of silt (Appendix B). At Station SW20, an additional 200 m north of SW19, surface sediments consisted of soft medium gray silt. At the western edge of the proposed alternate area, sediments from Station SW21 were similar to those at SW19 and SW20 with a slightly higher clay content.

Table 3-1

Results of Sediment Grain Size Analyses and Percent Total Organic Carbon (TOC) at the SW-REF and SOUTH Reference Areas for WLIS, August 1993

	SW-REF CTR (SW16)	SW-REF 300W (SW22)	SW-REF 400 N (SW18)	SW-REF AVERAGE	SOUTH-REF REP-1	SOUTH-REF REP-2	SOUTH-REF REP-3	SOUTH-REF AVERAGE
DESCRIPTION	Dark gray to black silty sand	Dark gray to black sandy silt	Dark gray to black sandy silt		Dark gray to black sandy silt	Dark gray to black sandy silty clay	Dark gray to black sandy silty clay	
GRAIN SIZE								
% Gravel	<1	<1	<1	**0 +/- 0**	<1	<1	<1	**0 +/- 0**
% Coarse sand	1	2	1	**1 +/- 0**	3	3	3	**3 +/- 0**
% Medium sand	17	13	11	**14 +/- 2**	14	12	11	**12 +/- 1**
% Fine sand	44	26	22	**31 +/- 10**	22	33	22	**26 +/- 5**
% Silt/clay	38	59	66	**54 +/- 12**	61	54	64	**60 +/- 4**
(% Silt)	26.7	39.9	52.4	**40 +/- 10**	43.4	26	33.5	**34 +/- 7**
(% Clay)	10.7	19.3	13.9	**15 +/- 4**	17.2	26.1	30.1	**24 +/- 5**
TOC (% w/w dry)	1.5	0.68	0.84	**1 +/- 0**	3.3	1.3	1.7	**2 +/- 1**

Water depths in the WLIS area increase towards the south and west. The water depths at the southwest corner of the disposal site averaged approximately 33 meters. At the SOUTH reference area, depths ranged from approximately 26 to 27 meters. Water depths in the SW-REF area ranged from 20 meters at SW15 to 30 meters at SW20 (Appendix B).

3.2 Reference Area Sediment Grain Size and TOC

Grain size analyses of the triplicate samples obtained from the SOUTH reference area contained an average of 60% silt/clay, 26% fine sand, and 12% medium sand (Table 3-1). Grain size analyses for sediments collected at Stations SW18 and SW22 were similar to those collected at the SOUTH reference, with an average of 62.5% silt/clay, 24% fine sand, and 13% medium sand. Sediments collected from SW16 (the center of the SW-REF), however, were sandier with 61% fine and medium sand and 38% silt/clay (Table 3-1).

The higher percentage of sand at SW16 relative to the other sampled stations was not reflected in TOC concentrations; typically, sandier sediments have relatively lower TOC values. TOC values measured at the SOUTH reference area ranged from 1.3 to 3.3%, with an average of 2.0% (Table 3-1). The third replicate at SOUTH (3.3%) was unusually high unusually high relative to the other two replicates (1.3% and 1.7%), indicating a patchy distribution at the center of the SOUTH reference area. The three stations sampled at the SW-REF area were less variable, ranging from 0.68 to 1.5% with an average of 1.0% (Table 3-1). SW22 and SW18 were most similar in TOC percentage (0.68% and 0.84%, respectively), and SW16 was highest with a TOC concentration of 1.5%.

3.3 Sediment Chemistry

3.3.1 Metal Analyses

Sediment samples collected from the SOUTH and SW-REF reference areas showed low levels of all contaminant metals measured (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) compared with the "low" category established by the New England River Basins Commission (NERBC; Table 3-2 and Appendix A Table 1). No metal concentrations were below the detection limit. Metal concentrations were overall lower at the three SW-REF stations as compared to the SOUTH replicates. Comparing the averages at SW-REF and SOUTH, however, shows that the variability of each (as measured by the standard deviation) indicated no significant difference in metals concentrations between the two reference areas. Additionally, the Al and Fe concentrations were lower overall for SW-REF (Appendix A Table 1), indicating that the fraction of the sediment made up of aluminisilicate minerals (clay minerals) was lower for SW-REF. The average clay-sized fraction for SW-REF was, indeed, less than SOUTH (14.6% vs. 24.5%, Table 3-1). Clay particles have a higher surface area and therefore will tend to absorb more contaminants relative to quartz or other silt- or sand-sized minerals.

Table 3-2

Average Metals Analyses (ppm Dry Weight) for SW-REF and SOUTH Reference Areas, WLIS 1993, compared to Low Limits for New England River Basins Commission (NERBC 1980)

	SW-REF	SOUTH	NERBC LOW
As	3.3±0.6	4.6±0.86	<10
Cd	0.99±0.18	1.4±0.17	<3
Cr	26±7.5	38±3.8	<100
Cu	32.3±10.7	47±4.2	<200
Hg	0.07±0.02	0.12±0.02	<0.5
Ni	11.1±2.5	15±0.58	<50
Pb	19±5.6	29±2.6	<100
Zn	72±21.7	105±13	<200

3.3.2 Organic Analyses

Both low molecular weight polycyclic aromatic hydrocarbon (LMW PAH) compounds and high molecular weight polycyclic aromatic hydrocarbon (HMW PAH) compounds were detected in sediments collected from the SW-REF and SOUTH area. Average PAH concentrations were lower for SW-REF, but the overlapping ranges among SW-REF stations and SOUTH replicates indicate no significant difference (Appendix A Table 2). Values for the LMW PAH compounds at SW-REF ranged from 127 to 380 ppb, and at the SOUTH reference area ranged from 318 to 464 ppb. Values for HMW PAH compounds ranged from 834 to 3069 at the SW-REF and 2547 to 3594 ppb at the SOUTH reference area. PAH concentrations at SW18 were higher than both the other SW-REF stations and at least two of the SOUTH replicates in a sediment with relatively low organic carbon (Table 3-1). The implications of this result will be discussed below.

In total, six sediment samples (three from SOUTH and three from SW-REF) were analyzed for 20 individual pesticides and total PCBs. Both pesticides and PCBs were below the detection limit for all compounds measured (Appendix A Table 3).

3.4 REMOTS® Sediment-Profile

3.4.1 Reference Areas

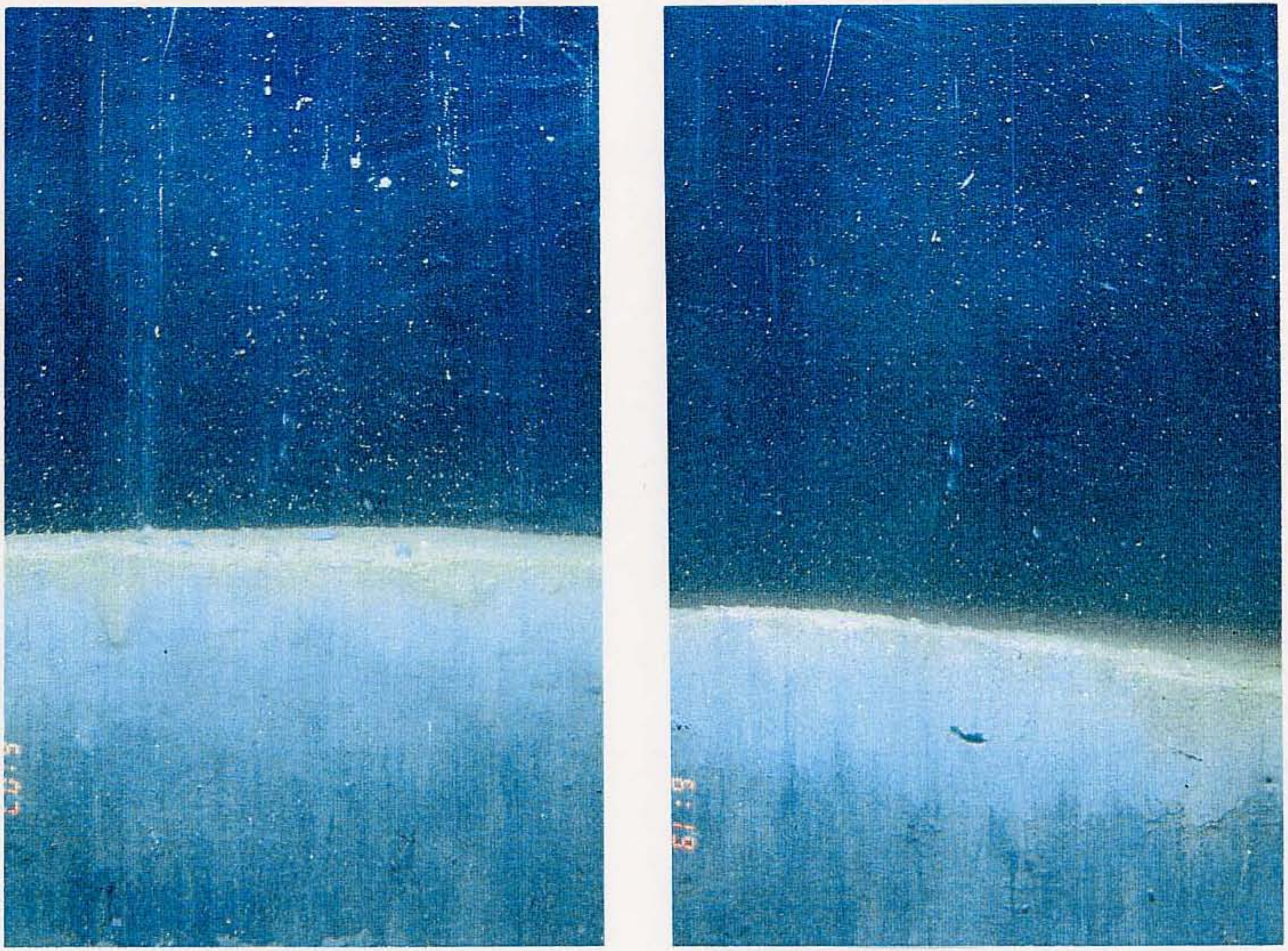
To assist in the selection of a new reference area, three replicate REMOTS® photographs were obtained at the SOUTH reference area for comparison with those obtained from the SW-REF area Stations SW3, SW3A, SW3B, SW18, and SW22 (Figure 2-1). Results of the REMOTS® analyses can be found in Appendix C Table 1.

Grain sizes as estimated from the REMOTS® photographs showed a major mode of >4 phi (silt/clay) at all SOUTH and SW-REF reference stations except Station SW18 which showed a major mode of 4-3 phi (very fine sands) (Appendix C Table 1). The range in grain size was 2 to >4 phi for the majority of REMOTS® stations (medium sand to silt/clay). These results are generally consistent with the laboratory grain size analyses (Figure 2-1 and Table 3-1). Photographs from every station showed evidence of a layer of sand over mud (Figure 3-1).

The prism penetration depth is an indicator of how "soft" the sediment is; generally fine-grained material has a higher prism penetration depth than coarse, more compact sediment. The prism penetration depth at the SOUTH reference area was 7.5 cm (Appendix C Table 1). The SW-REF area ranged from 4.79 to 12.05 cm with an average of 7.8 cm, indicating no significant difference between SW-REF and SOUTH. The deepest prism penetration depths were measured at Station SW3A, an area suspected of being located on historic dredged material and consisting of a thin layer of sand over silt/clay (Figure 3-2). Dredged material at REMOTS® Station SW3A was suspected because of the presence of sedimentary layers (Figure 3-2).

Boundary roughness values (measured as the difference between the maximum and minimum depth of the sediment/water interface) at the SOUTH reference ranged from 0.08 to 2.50 cm and averaged 1.39 cm. The origin of the boundary roughness was classified as primarily physical in origin, indicating more active disturbance than biological reworking of the surface by Stage I organisms (Appendix C Table 1). Boundary roughness values were less variable at SW-REF, ranging from 0.25 to 1.62 cm with an average of 0.83 cm. The origin of boundary roughness at the SW-REF stations was due to both physical and biological mechanisms.

The RPD values at the SOUTH reference area ranged from 0.77 to 1.25 cm with an average of 0.93 cm. The SW-REF area ranged from 0.62 to 3.00 cm and averaged 1.33 cm. Overall the RPDs for SW-REF and SOUTH were comparable, except for a high RPD of 3.0 at one of the replicates at SW3.



A B

Figure 3-1. REMOTS® sediment-profile photographs of Stations SW18 (A) and SW22 (B) showing sand-over-mud layering. Prism penetration depth averaged 6.7 and 5.7 cm at these stations because of the thickness of the sand layer. The successional stages were Stage I and Stage I on III, and the OSI values were 3 and 9.

Figure 3-2. REMOTS® photograph of Station SW3A located on historic dredged material. The average prism penetration depth was 10.5 cm, the successional stage was Stage I on III, and the OSI was 8. Layers of historic dredged material were apparent in the photograph.

All of the replicates at SOUTH demonstrated mature Stage I on III benthic communities (Figures 3-1, 3-2, Appendix C Table 1). The successional stages were more variable among the SW-REF replicates. Of five stations analyzed, three had Stage III organisms in at least two of the replicate photographs. Stage III was present in only one replicate at SW18 and SW22, Stage I dominated in two of three replicates at SW18, and two of the SW22 replicates had indeterminate successional stages.

OSI values ranged from 7 to 9 at most stations in the SOUTH and SW-REF areas (Appendix C Table 1), indicating that, overall, REMOTS® data indicate comparability of the two areas. The exception was REMOTS® Station SW18 which showed an OSI value of 5 due to the presence of Stage I organisms and the absence, in two out of three photographs, of Stage III organisms.

3.4.2 WLIS A and D Mounds

Results of REMOTS® sediment-profile photography at Station E400W on the A mound showed a successional stage of Stage I on III, an average RPD of 1.20 cm, and an average OSI value of 7 (Appendix C Table 2). These results are consistent with a healthy benthic recovery following disturbance from disposal of dredged material.

The results of the RPD and OSI REMOTS® data on the WLIS D mound were quite variable (Appendix C Table 2). Stations D100W and D200N showed median OSI values above 6 and the presence of Stage III taxa. The average depth of the RPD at Station D200N was less than 1 cm because of an organic matter layer present in one replicate photograph (Appendix C Table 3). Below the RPD layer at Station D200N, very dark sediments were layered over beige clay.

Station D100S had an average RPD of 1.4 cm, a successional stage of I on III, and a median OSI of 5.0 (Appendix C Table 2). All of these parameters show increases in values from the 1991 and 1992 surveys. Station D200S showed a decline in the average RPD from 2.2 cm (1992) to 0.2 cm (1993). The median OSI remained a value of 6 from 1992 to 1993, and the successional stage remained Stage I taxa on III.

Station D300S had an average RPD depth of almost 2 cm, but the OSI value calculated was indeterminate because of indeterminate successional stages. Replicate photographs from this station indicated various surface layers: (a) shell hash over sand, (b) sand over mud, and (c) an organic surface layer. Sediments in all of these replicate photographs were dark with the exception of the oxidized RPD layer in two of the photographs.

4.0 DISCUSSION

4.1 Selection of a Reference Area

Due to the presence of dredged sediments to the north, east, and west of the disposal site as determined in the 1992 monitoring survey and confirmed with the reconnaissance grabs during this survey, the area south of the site was the focus for an alternate reference area. The area designated SW-REF was evaluated to replace the existing WLIS-REF reference area. This evaluation consisted of visual inspection of reconnaissance sediment grabs, comparison of water depths, analysis of REMOTS® data, and chemical and physical analyses of sediment grab samples. Preliminary results from this survey indicate that SW-REF is a suitable replacement for WLIS-REF.

Because a primary consideration of a DAMOS disposal site reference area is a comparable water depth to the disposal site itself, the water depth was measured at each of the grab stations. The water depth at the center of the newly proposed SW-REF area, Station SW16, was 22 meters in comparison to 33 meters at the SW corner of WLIS. Although there is a difference of 11 meters between the two sites, this difference most likely will not affect the sediment properties of SW-REF due to wave actions or currents. Studies conducted in Long Island Sound immediately following Hurricane Gloria in September 1985 showed no indication of any storm-induced disturbance at depths greater than 21 meters (68.9 feet) (SAIC 1989).

REMOTS® analyses from the reference areas, as discussed below, were consistent with the visual grab descriptions and laboratory grain size data. More detailed reference data chemistry analyses, discussed in the following section, include a comparison of the metals and PAH sediment data from the SW-REF area with the SOUTH area, historical WLIS reference area data, and regional data provided by NOAA's National Status and Trends Program. Data for pesticides and PCBs were not compared because results were less than detection limits.

REMOTS® sediment-profile photographs indicated that the visual estimations of grain sizes were similar for the two areas and also corresponded with the results of the laboratory analyses. The photographs showed no evidence of previous dredged material disposal except at Station SW3A. The presence of dredged material at the one station is not surprising considering that much of the area surrounding WLIS received dredged material in the past. Historic disposal operations were not controlled and monitored in the manner they are today, and this material was disposed across a wide area. This complicated the search for appropriate reference areas.

Based on the preliminary grab and REMOTS® survey, the SW-REF was selected because it (a) was outside historic disposal site boundaries, (b) was of a similar depth to the disposal site, (c) appeared to have similar grain sizes to the disposal site, and (d) showed minimal evidence of past dredged material deposition.

4.2 Reference Area Sediment Chemistry Analysis

Chemical data presented in Section 3 indicated that the range of concentrations of PAHs overlapped between the SW-REF and SOUTH reference areas. Station SW16 had the lowest PAH concentrations, potentially because of the higher sand content and lower percentage of silt/clay. Natural variations in sedimentary parameters can influence the concentration of organic constituents and trace metals measured in the laboratory; for example, an increase in both the fine-grained fraction and in TOC usually can be positively correlated with metal and organic concentrations. Of the three stations sampled at SW-REF, however, SW 16 had the highest TOC concentration (1.5% vs. 0.68 and 0.84% for the other two stations) yet the lowest fine-grained fraction (37% vs. 59 and 66%). The implication of this is discussed further below. For comparison purposes, PAH values were normalized to TOC for the following discussion.

The TOC-normalized concentrations of selected LMW PAH and HMW PAH compounds for the three individual replicates and the average at SW-REF and SOUTH from this survey, and pooled historical WLIS reference station values, are presented in Appendix A Table 4. The pooled data consist of the most applicable historical data for PAHs; detection limits for PAH analyses have been too high to be useful for comparison purposes up until the 1991 chemistry survey (Eller and Williams 1996). In 1991, of the three reference areas sampled (2000W, WLIS-REF, and 2000S), 2000S was considered to be not representative of ambient conditions because of the high PAH values, and therefore not included in the pooled dataset. In 1992, two reference stations were analyzed: EAST and SOUTH. Data from EAST were discarded again due to PAH concentrations, and not included in the pooled dataset. Therefore, the pooled data set that is presented in Appendix A Table 4 consists of PAH data from WLIS-REF and 2000W from the 1991 survey, and SOUTH from the 1992 survey. Only comparably measured PAH compounds were included in the table. Normalized values were calculated by dividing the dry weight concentration of PAHs by the percent value of TOC.

Average total PAHs normalized to TOC were slightly higher at SW-REF in comparison to SOUTH (Appendix A Table 4), but not significantly different when evaluating the variability expressed as one standard deviation from the mean. As mentioned previously, Station SW16 was somewhat anomalous as it had the lowest PAH values of the three SW-REF stations sampled, while at the same time possessing the highest concentration of TOC, resulting in very low normalized PAH values. The range of TOC concentrations measured at the SOUTH replicates was also variable (1.3, 1.7, and 3.3%), indicating a high variability over a small sampled area. The presence of this variable, or patchy, distribution is discussed further below.

Similar results were found between replicates at SOUTH. Replicate one contained a high concentration of TOC (3.3%) in relation to the other two replicates and had the lowest raw concentration of LMW PAHs, resulting in the lowest normalized value within the three replicates.

Selected LMW and HMW PAHs (PAH compounds that were measured for all three datasets) were compared to normalized values calculated from pooled WLIS reference area data. These data indicate that the samples collected from the SW-REF and SOUTH reference areas had lower concentrations of TOC-normalized LMW PAHs in relation to the pooled set of data. Average normalized HMW PAH data, however, were highest at SW-REF in relation to SOUTH and the pooled data set. These differences in total LMW and HMW PAH concentrations among the three areas indicate different sources of PAHs to each area. The variability (again measured as one standard deviation from the mean) among all three datasets, however, indicate no significant difference.

PAH data were also compared to regional data collected by the NOAA National Status and Trends (NS&T) Program. The NS&T Program has collected and analyzed coastal and estuarine sediment data from three hundred sites since 1984. Several stations in Western Long Island Sound were sampled over the period 1984–1989 (NOAA 1991), but only one station was considered comparable to the proposed SW-REF reference area. Most of the NS&T stations are coastal (north shore of Long Island or south shore of Connecticut) except for the Western Long Island station (NS&T code WLI) which is located approximately 5 km west of WLIS, and was therefore used for the comparison.

In comparing the WLIS results with the NS&T data, several qualifications should be made. The analytical methods used vary somewhat between the two datasets because the NS&T methods were developed for very low detection limits. All NS&T data were normalized to the fine-grained fraction since the correlation between the percentage of silt and clay and trace chemical constituents was higher than between Al or TOC (NOAA 1991). Therefore, the 1993 WLIS data were also normalized to the fine-grained fraction for comparison purposes to the NS&T data (Appendix A Table 5 and Appendix A Table 6).

Normalizing PAH values to the fine-grained fraction reflected the trend observed for non-normalized dry weight values; values for LMW PAH and HMW PAH were lower at the SW-REF than the SOUTH reference areas. Grain size normalized LMW PAH WLIS 1993 values were lower than the values measured at the NS&T WLI station (Appendix A Table 5). High molecular weight PAHs were generally lower at the reference areas in relation to WLI. The exceptions to this were for three select compounds, benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(g,h,i)perylene, which were considerably higher at SW-REF and SOUTH (Appendix A Table 5). As with TOC, grain size data and therefore normalized values were variable between individual stations at SW-REF as well as between replicates at SOUTH. This issue is discussed further below.

As mentioned previously, the concentrations of metals were low for the two reference areas when compared with the guidelines established by the NERBC. Metal data also were compared to the regional NS&T data, by normalizing metals data to the percent silt/clay (Appendix A Table 6). Values for all metals were lower at the SW-REF when compared to SOUTH, and both SW-REF and SOUTH were lower than the values for the NS&T station WLI.

The results above exemplify the complexity of locating a reference area in Western Long Island Sound that reflects "ambient" conditions. Sediment data used to characterize reference area sediments, including TOC and grain size, have shown a high degree of variability; for example, the three individual replicates taken at SOUTH show that TOC values range considerably. This variability cannot be attributed to dredged material as REMOTS® data have not indicated the presence of historical dredged material. Other potential sources of small-scale variability, or patchiness, in the environment around WLIS include other anthropogenic sources (e.g., outflow from industrialized harbors).

The issue of patchiness around the WLIS area makes definitive comparison of contaminant values between reference areas with relatively small data sets problematic. The concerns of data variability within reference areas, and the need for accurate descriptive statistics of background levels of contaminant concentrations at these reference areas, are currently being addressed in a comprehensive report for Western Long Island Sound and other DAMOS disposal areas (SAIC 1994). This large, statistically derived chemistry data set will provide a better means of comparison for reference area values. The results of this 1993 survey provide a valuable data set to this compilation, as well as accurately reflecting that SW-REF is suitable as a reference area in the context of WLIS and Western Long Island Sound.

4.3 Benthic Habitat Progression at the A and D Mounds

A review of the historical record of monitoring at the two questionable D mound stations suggests a history of conflicting benthic habitat data. In 1992, bioassay testing was conducted on composites from a reference station, the A mound, and several stations from the D mound (D200N, D100S, D300S, and D100W). Survival rates for the reference station, A mound, and the control were 94%, 93%, and 89%, respectively. The average survival rate for the composite sample from D was 71%, and considered not to be statistically different. One of the individual tests from sample D, however, had only a 25% survival rate. REMOTS® results from this survey were compared more closely with results from prior surveys in order to assess the implication of this year's monitoring data.

Selected REMOTS® results from the 1993 survey were compared to the data collected at the same stations in 1992 (Table 4-1). REMOTS® data from the 1993 WLIS survey showed that the OSI value at the WLIS A mound (E400W) improved significantly since 1992. Several stations surveyed in 1993 on the WLIS D mound showed similar OSI values to the 1992 survey (D200N, D200S) or higher OSI values relative to 1992 (D100W, D100S) (Table 4-1 and Figure 4-1).

Station D200S showed a decline in the average RPD from 2.2 (1992) to 0.2 cm (1993) although the median OSI value of 6 remained unchanged from 1992 to 1993 (Table 4-1 and Figure 4-2). One photograph at this station was azoic in 1993. The two other replicate photographs indicated a healthier environment with evidence of Stage III taxa and OSI values of 6. At Station D100S, however, the 1993 median OSI value of 5 indicated improved benthic conditions since the 1991 and 1992 median OSIs of 3 (Table 4-1). The depth of the average RPD improved significantly since 1992 from 0.7 cm to 1.4 cm in 1993.

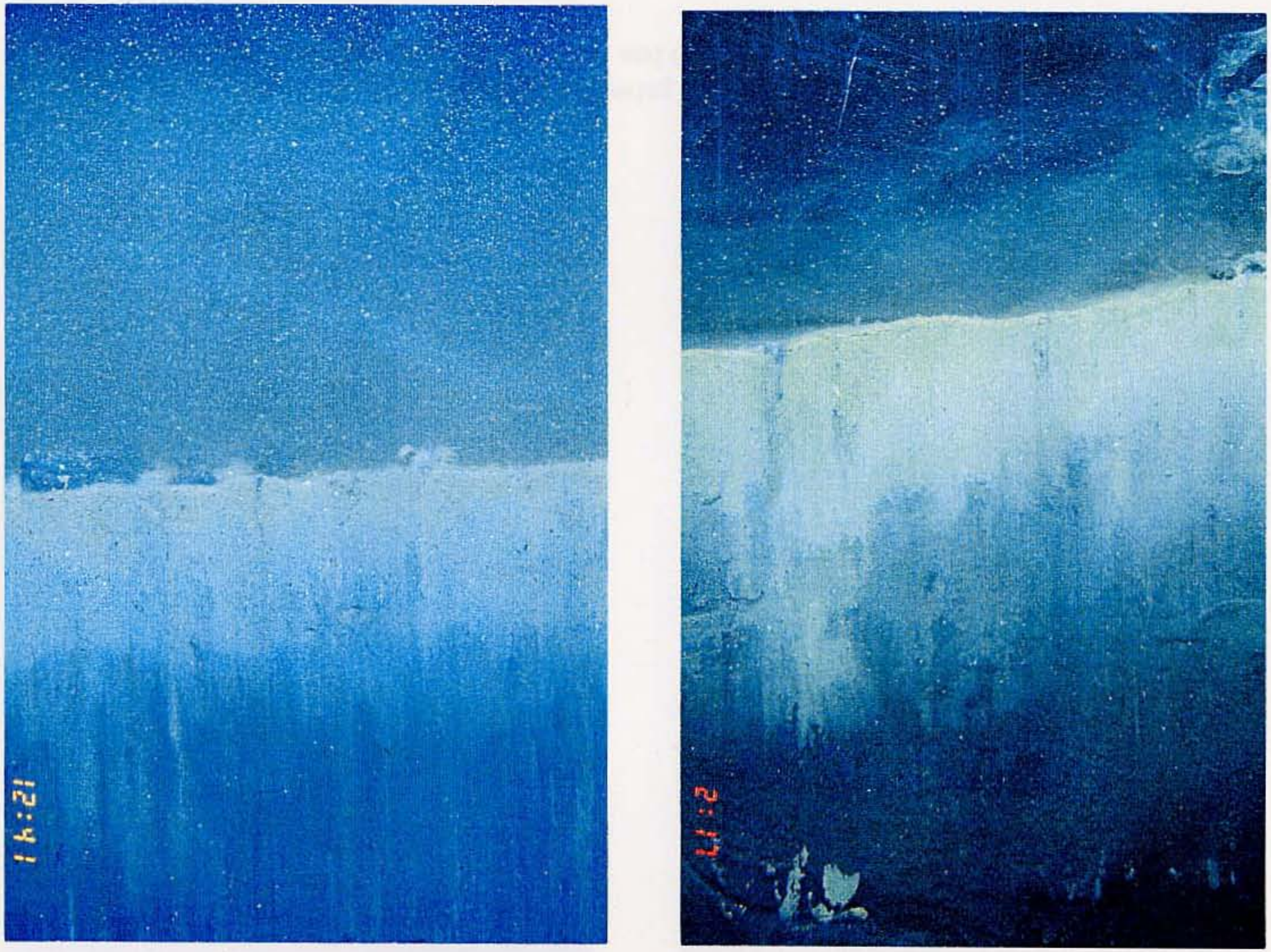
At Station D200S, the presence of dark, potentially anoxic subsurface sediments was the primary cause of a lower average RPD between 1992 and 1993. The low RPD, in combination with one azoic replicate photograph, resulted in a lower OSI than seen in 1991. Stage III infaunal activity was evident at all stations except D300S. Station D300S also showed evidence of dark sediments, but overall had an improved RPD relative to 1992. The low resultant OSIs at D300S were primarily due to indeterminate successional stages.

The REMOTS® results of the 1993 survey do not warrant, according to tiered monitoring protocols, immediate management response. Based on the inconclusiveness of the combination of results of the 1993 survey (only one out of three photos at D200S was azoic; D300S had an indeterminate successional stage), no remedial action is necessary at the WLIS D and A stations. Considering the historical record of questionable recolonization at the D mound stations, however, continued monitoring at the WLIS D stations are recommended during future WLIS monitoring surveys.

Table 4-1

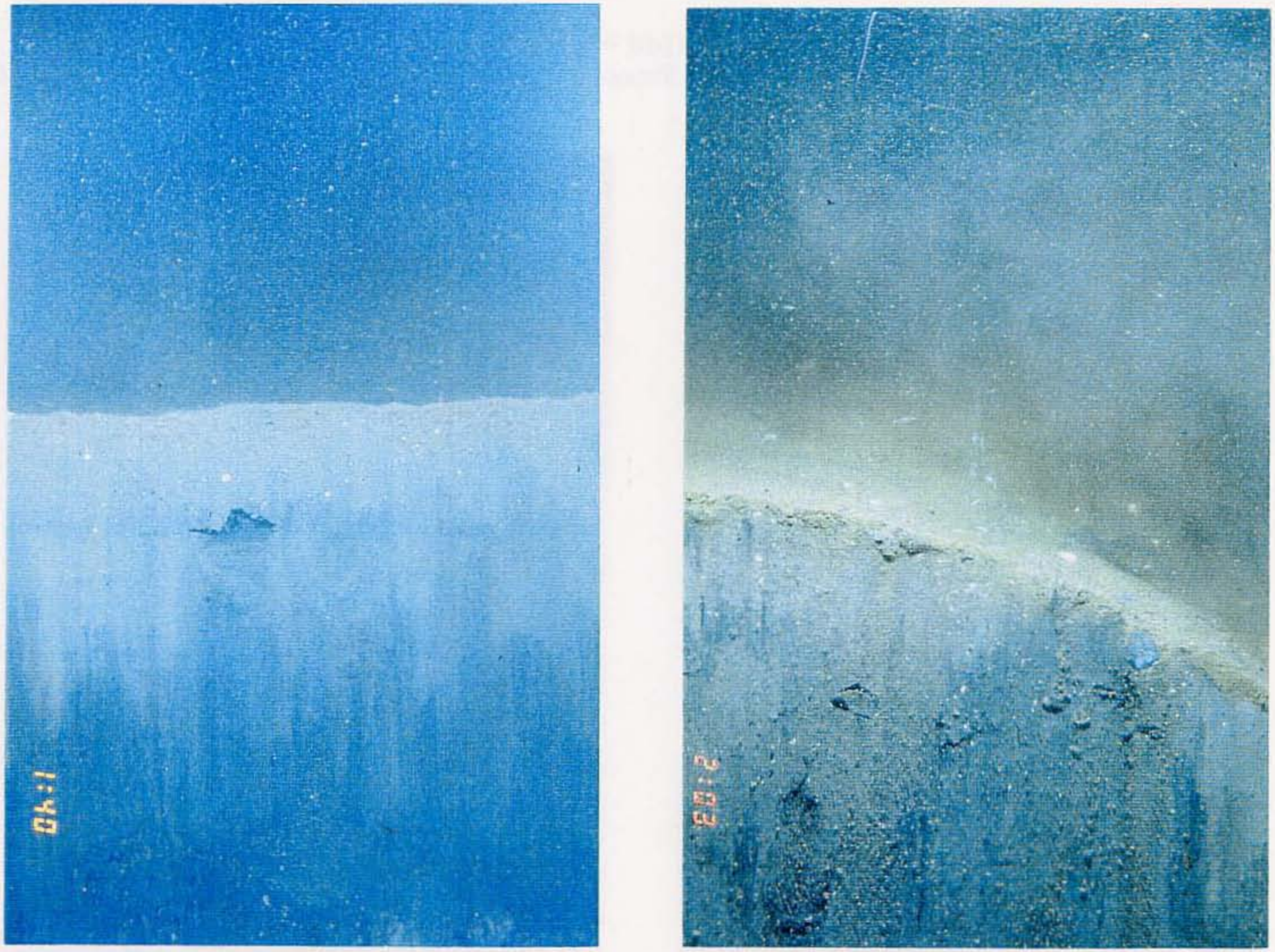
Summary of REMOTS® Analyses for Stations Occupied at the WLIS A and D mounds, 1990–1993

Station	Average Prism Penetration Depth	Average RPD	Successional Stage	Median OSI	Grain Size
A Mound E400W					
1991	11	1.4	III	4.0	4-3
1992	10.6	1.7	III	4.0	>4
1993	12.6	1.2	I on III	7.0	>4
D Mound D100W					
1991	11.4	1.1	I on III	7.0	4-3
1992	17.4	1.7	I on III	7.0	>4
1993	13.2	2.2	I on III	8.0	>4
D Mound D100S					
1991	12.9	1.2	I on III	3.0	>4
1992	16.4	0.7	I	3.0	4-3
1993	17.3	1.4	I on III	5.0	4-3
D Mound D200S					
1991	13.4	1.9	I on III	8.0	4-3
1992		2.2	III	6.0	4-3
1993	10.2	0.2	I on III	6.0	>4
D Mound D300S					
1991	11.5	1.2	I	3.0	4-3
1992	14.7	1.5	I	3.0	4-3
1993	11.8	1.7	IND	IND	>4
D Mound D200N					
1991	13.9	2.2	I on III	5.0	4-3
1992	17.1	2.4	I on III	7.0	4-3
1993	11.9	0.7	III	7.0	>4



A B

Figure 4-1. REMOTS® photographs of Station D100W showing Stage I on III communities and OSI values of 7 in 1991 (A) and 8 in 1993 (B). The depths of the RPDs were 1.1 cm (A) and 2.2 cm (B).



A B

Figure 4-2. REMOTS® photographs of Station D200S showing a decrease in the RPD and OSI values since 1991. The average OSI values were 8.0 in 1991 (A) and 6.0 in 1993 (B). The successional stage during both surveys showed evidence of Stage III taxa.

5.0 CONCLUSIONS

The objectives of the WLIS 1993 survey were to investigate areas south of the disposal site for a new reference area, and to evaluate ecological conditions at selected REMOTS® stations on the A and D mounds. A new alternative reference area, the SW-REF, was found to be a suitable replacement for WLIS-REF. This recommendation is based on the visual grab descriptions, REMOTS® results, and sediment chemistry. A further analysis of sediment chemistry data showed that SW-REF sediments were similar in metal and PAH distribution to SOUTH, previous data collected at WLIS reference stations, and regional data as compiled by the National Status and Trends Program.

Of the six stations monitored using the REMOTS® camera, the data from four showed similar or improved benthic conditions from 1992. Results of two stations from the WLIS D disposal mound showed the continued presence of dark, anoxic sediments and inconclusive successional stage information. One replicate at Station D200S was classified as azoic, and all of the replicates at Station D300S had successional stages that were indeterminate. Based on the historical concern at these stations, and the inconclusiveness of the 1993 survey results (only one out of three photos at D200S was azoic; D300S was indeterminate), it was concluded that no remedial action was necessary at the WLIS A and D mounds. Continued monitoring at Stations D200S and D300S during routine WLIS monitoring surveys is recommended as a conservative management measure.

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APPENDIX A

Chemistry Data for WLIS 1993

Appendix A - Chemistry Data for WLIS 1993

Appendix A Table 1.	Results of Metal Analyses (ppm Dry Weight) at the SW-REF and SOUTH Reference Areas, WLIS 1993
Appendix A Table 2.	PAH (ppb Dry Weight) Results at the SW-REF and SOUTH Reference Areas, WLIS 1993
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Appendix A Table 1

Results of Metal Analyses (ppm Dry Weight) at the SW-REF and SOUTH Reference Areas, WLIS 1993

METALS	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF 400N (SW18)	**SW REF AVERAGE**	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	**SOUTH REF AVERAGE**
Al	B 5400	B 8700	B 7300	**7133 +/- 1656**	B 9800	B 10000	B 13000	**10933 +/- 1793**
As	2.7	3.8	3.3	**3.3 +/- 0.6**	3.7	4.8	5.4	**4.6 +/- 0.86**
Cd	0.84	1.2	0.95	**0.99 +/- 0.18**	1.3	1.3	1.6	**1.4 +/- 0.17**
Cr	18	33	27	**26 +/- 7.5**	36	35	42	**38 +/- 3.8**
Cu	B 23	B 44	B 30	**32.3 +/- 10.7**	B 46	B 44	B 52	**47 +/- 4.2**
Fe	B 11000	B 15000	B 13000	**13000 +/- 2000**	B 17000	B 16000	B 18000	**17000 +/- 1000**
Hg	J 0.048	J 0.091	J 0.061	**0.07 +/- 0.02**	J 0.12	J 0.11	J 0.14	**0.12 +/- 0.02**
Ni	9.3	14	10	**11.1 +/- 2.5**	15	15	16	**15 +/- 0.58**
Pb	14	25	18	**19 +/- 5.6**	28	27	32	**29 +/- 2.6**
Zn	B 52	B 95	B 69	**72 +/- 21.7**	B 97	B 98	B 120	**105 +/- 13**

METALS	Method Blank	Spike recovery %		RPD (30% limit)	Accuracy Limits (%)
		Blank	Dup.* Blank		
Al	7.0	87	88	1	75-125
As	<0.002	98	126	25	75-125
Cd	<0.17	90	91	1	75-125
Cr	<0.72	92	94	2	75-125
Cu	2.4	87	93	6	75-125
Fe	1.8	86	88	2	75-125
Hg	<0.02	93	92	2	75-125
Ni	<0.56	88	90	2	75-125
Pb	0.8	70	76	8	75-125
Zn	0.96	88	89	1	75-125

Appendix A Table 2

PAH (ppb Dry Weight) Results at the SW-REF and SOUTH Reference Areas, WLIS 1993

PAHs	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF +400N (SW18)	SW REF AVERAGE	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	SOUTH REF AVERAGE
Low Molecular Weight								
naphthalene	J 15.0	J 22.0	J 23.0	**J 20 +/- 4.4**	J 27.0	J 28.0	J 62.0	**J 39 +/- 19.9**
1-methylnapththelene	J 4.7	J 8.2	J 8.2	**J 7 +/- 2.0**	J 8.3	J 11.0	J 15.0	**J 11.4 +/- 3.4**
2-methylnaphthalene	J 11.0	J 17.0	J 17.0	**J 15 +/- 3.5**	J 20.0	J 22.0	J 32.0	**J 24.7 +/- 6.4**
2-6 dimethylnapththalene	J 4.3	J 10.0	J 9.2	**J 7.8 +/- 3.1**	J 14.0	J 14.0	J 19.0	**J 15.7 +/- 2.9**
2,3,5-tri-methylnapthalene	J 4.3	J 4.4	J 6.3	**J 5 +/- 1.1**	J 4.7	J 6.1	J 7.1	**J 6 +/- 1.2**
biphenyl	J 5.1	J 8.8	J 7.8	**J 7.2 +/- 1.9**	J 8.9	J 10.0	J 14.0	**J 11 +/- 2.7**
acenaphthylene	J 13.0	J 26.0	J 28.0	**J 22.3 +/- 8.1**	J 34.0	J 34.0	J 45.0	**J 37.7 +/- 6.4**
acenaphthene	UJ 5.6	J 8.2	J 13.0	**J 8.9 +/- 3.8**	J 13.0	J 22.0	J 21.0	**J 18.7 +/- 4.9**
flourene	UJ 6.9	J 12.0	J 21.0	**J 13.3 +/- 7.1**	J 20.0	J 28.0	J 24.0	**J 24 +/- 4.0**
phenanthrene	J 34.0	J 82.0	J 170.0	**J 95.3 +/- 69.0**	J 110.0	J 190.0	J 140.0	**J 146.7 +/- 40.4**
1-methylphenanthrene	J 9.4	J 9.3	J 25.0	**J 14.6 +/- 9.0**	J 19.0	J 22.0	J 22.0	**J 21 +/- 1.7**
anthracene	J 14.0	J 26.0	J 52.0	**J 30.7 +/- 19.4**	J 40.0	J 38.0	J 63.0	**J 47 +/- 13.9**
Total LMWpah*	J 127	J 233	J 380	**J 246.7 +/- 127**	J 318	J 425	J 464	**J 402.3 +/- 75.6**
High Molecular Weight								
fluoranthene	J 79	J 160	J 290	**J 176.3 +/- 106.4**	J 170	J 250	J 250	**J 223.3 +/- 46.2**
pyrene	J 140	J 400	J 500	**J 346.7 +/- 185.8**	J 550	J 630	J 690	**J 623.3 +/- 70.2**
benzo(a)anthracene	J 56	J 110	J 190	**J 118.7 +/- 67.4**	J 160	J 170	J 200	**J 176.7 +/- 20.8**
chrysene	J 58	J 110	J 190	**J 119.3 +/- 66.5**	J 160	J 180	J 210	**J 183.3 +/- 25.2**
benzo(b)fluoranthene	J 110	J 290	J 320	**J 240 +/- 113.6**	J 350	J 380	J 500	**J 410 +/- 79.4**
benzo(k)fluoranthene	J 120	J 270	J 790	**J 393.3 +/- 351.6**	J 350	J 360	J 490	**J 400 +/- 78.1**
benzo(a)pyrene	J 130	J 270	J 380	**J 260 +/- 125.3**	J 400	J 430	J 580	**J 470 +/- 96.4**
benzo(e)pyrene	J 22	J 41	J 60	**J 41 +/- 19.0**	J 49	J 61	J 87	**J 65.7 +/- 19.4**
indeno(1,2,3-cd)pyrene	J 49	J 120	J 140	**J 103 +/- 47.8**	J 150	J 160	J 250	**J 186.7 +/- 55.1**
dibenz(a,h)anthracene	J 12	J 36	J 44	**J 30.7 +/- 16.7**	J 40	J 56	J 80	**J 58.7 +/- 20.1**
benzo(g,h,i)perylene	J 47	J 100	J 140	**J 95.7 +/- 46.7**	J 140	J 160	J 210	**J 170 +/- 36.1**
perylene	J 11	J 26	J 25	**J 20.7 +/- 8.4**	J 28	J 31	J 47	**J 35.3 +/- 10.2**
Total HMWpah*	J 834	J 1933	J 3069	**J 1945.3 +/- 1117.6**	J 2547	J 2868	J 3594	**J 3003 +/- 536.4**
Total PAHs	J 961	J 2166	J 3449	**J 2192 +/- 1244.2**	J 2865	J 3293	J 4058	**J 3405 +/- 604.4**
Surrogate recoveries*								
nitrobenzene-d5 (23-130%)	121	108	117	115 %	118	106	115	113 %
2-fluorobiphenyl (30-115%)	92	87	92	90 %	94	68	88	83 %
terphenyl-d14 (18-137%)	129	187	157	158 %	202	186	171	186 %

* Numbers in parentheses are acceptable ranges.

Appendix A Table 3

Results of Pesticide and PCB Analyses (ppb Dry Weight)
at the SW-REF and SOUTH Reference Areas, WLIS 1993

PESTICIDES	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF +400N (SW18)	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	METHOD BLANK
alpha-BHC	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
gamma-BHC (Lindane)	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
beta-BHC	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
delta-BHC	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
heptachlor	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
aldrin	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
heptachlor epoxide	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
endosulfan I	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
endosulfan II	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
4,4'-DDE	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
4,4'-DDD	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
4,4'-DDT	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
dieldrin	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
endrin	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
endrin aldehyde	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
endosulfan sulfate	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
methoxychlor	UJ <22	UJ <27	UJ <24	UJ <31	UJ <31	UJ <41	UJ <17
endrin ketone	UJ <4.3	UJ <5.3	UJ <4.6	UJ <5.9	UJ <5.9	UJ <7.9	UJ <3.3
chlordane	UJ <2.2	UJ <2.7	UJ <2.4	UJ <3.1	UJ <3.1	UJ <4.1	UJ <1.7
toxaphene	UJ <221	UJ <272	UJ <238	UJ <306	UJ <306	UJ <408	UJ <170
Surrogate recovery*							
tetrachloro-m-xylene (60-150)	93	93	96	90	97	96	95
decachlorobiphenyl (60-150)	49	51	105	52	104	98	52
TOTAL PCBs	UJ <87	UJ <107	UJ <94	UJ <121	UJ <121	UJ <161	UJ <67
Surrogate recovery							
tetrachloro-m-xylene (60-150)	93	93	96	90	97	96	105

Pesticide	Blank spike % Recovery	Accuracy %
gamma-BHC (Lindane)	88	56-123
aldrin	91	40-120
heptachlor	92	40-131
dieldrin	87	52-126
endrin	91	56-121
4,4'-DDT	92	38-127

* Surrogate recoveries reported in percent; numbers in parentheses are acceptable ranges.

Appendix A Table 4

PAH Data Normalized to TOC for WLIS Reference Station Data (ppb Dry Weight)

PAHs	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF +400N (SW18)	SW REF AVERAGE	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	SOUTH REF AVERAGE	WLIS REF AREAS *
Low Molecular Weight									
naphthalene	10.0	32.4	27.4	**23.2 +/- 9.6**	8.2	21.5	36.5	**22.1 +/- 11.6**	**64.1**
1-methylnapththelene	3.1	12.1	9.8	**8.3 +/- 4.6**	2.5	8.5	8.8	**6.6 +/- 3.5**	
2-methylnaphthalene	7.3	25.0	20.2	**17.5 +/- 9.1**	6.1	16.9	18.8	**13.9 +/- 6.9**	
2-6 dimethylnapththalene	2.9	14.7	11.0	**9.5 +/- 6.1**	4.2	10.8	11.2	**8.7 +/- 3.9**	
2,3,5-tri-methylnapthalene	2.9	6.5	7.5	**5.6 +/- 2.4**	1.4	4.7	4.2	**3.4 +/- 1.8**	
biphenyl	3.4	12.9	9.3	**8.5 +/- 4.8**	2.7	7.7	8.2	**6.2 +/- 3.1**	
acenaphthylene	8.7	38.2	33.3	**26.7 +/- 12.9**	10.3	26.2	26.5	**21.0 +/- 7.5**	**29.7**
acenaphthene	3.7	12.1	15.5	**10.4 +/- 4.9**	3.9	16.9	12.4	**11.1 +/- 5.4**	**17.5**
flourene	4.6	17.6	25.0	**15.7 +/- 8.4**	6.1	21.5	14.1	**13.9 +/- 6.3**	**27.7**
phenanthrene	22.7	120.6	202.4	**115.2 +/- 73.5**	33.3	146.2	82.4	**87.3 +/- 46.2**	**175.8**
1-methylphenanthrene	6.3	13.7	29.8	**16.6 +/- 12.0**	5.8	16.9	12.9	**11.9 +/- 5.7**	
anthracene	9.3	38.2	61.9	**36.5 +/- 21.5**	12.1	29.2	37.1	**26.1 +/- 10.4**	**69.8**
Total LMW PAH	84.9	344.0	453.0	**293.9 +/- 29.9**	96.6	327.0	273.0	**232.2 +/- 22.5**	
Total Selected LMW PAH	59	259	366	**228.0 +/- 38.9**	74	261	209	**181.3 +/- 28.5**	**383**
High Molecular Weight									
fluoranthene	52.7	235.3	345.2	**211.1 +/- 120.7**	51.5	192.3	147.1	**130.3 +/- 58.7**	**275.9**
pyrene	93.3	588.2	595.2	**425.6 +/- 235.0**	166.7	484.6	405.9	**352.4 +/- 135.2**	**560.4**
benzo(a)anthracene	37.3	161.8	226.2	**141.8 +/- 78.4**	48.5	130.8	117.6	**99.0 +/- 36.1**	**198.9**
chrysene	38.7	161.8	226.2	**142.2 +/- 77.8**	48.5	138.5	123.5	**103.5 +/- 39.4**	**221**
benzo(b)fluoranthene	73.3	426.5	381.0	**293.6 +/- 156.8**	106.1	292.3	294.1	**230.8 +/- 88.2**	**186.8**
benzo(k)fluoranthene	80.0	397.1	940.5	**472.5 +/- 355.3**	106.1	276.9	288.2	**223.7 +/- 83.3**	**188.7**
benzo(a)pyrene	86.7	397.1	452.4	**312.0 +/- 161.0**	121.2	330.8	341.2	**264.4 +/- 101.3**	**222.7**
benzo(e)pyrene	14.7	60.3	71.4	**48.8 +/- 30.1**	14.8	46.9	51.2	**37.6 +/- 19.9**	
indeno(1,2,3-cd)pyrene	32.7	176.5	166.7	**125.3 +/- 65.6**	45.5	123.1	147.1	**105.2 +/- 43.4**	**12.2**
dibenz(a,h)anthracene	8.0	52.9	52.4	**37.8 +/- 21.1**	12.1	43.1	47.1	**34.1 +/- 15.6**	**12.2**
benzo(g,h,i)perylene	31.3	147.1	166.7	**115.0 +/- 59.7**	42.4	123.1	123.5	**96.3 +/- 38.1**	**112.3**
perylene	7.3	38.2	29.8	**25.1 +/- 16.0**	8.5	23.8	27.6	**20.0 +/- 10.1**	
Total HMW PAH	556.0	2842.6	3653.6	**2350.7 +/- 149.5**	771.8	2206.2	2114.1	**1697.3 +/- 103.6**	
Total Selected HMW PAH	534	2744.3	3552.5	**2276.9 +/- 143.3**	748.6	2135.5	2035.3	**1639.8 +/- 98.6**	**1991.1**

* Pooled value for SOUTH (1992), WLIS-REF (1991), and 2000W (1991).

Appendix A Table 5

Results of PAH Data Normalized to Grain Size for the SW-REF and SOUTH Reference Areas

PAHs	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF +400N (SW18)	SW REF AVERAGE	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	SOUTH REF AVERAGE	WLI
Low Molecular Weight									
naphthalene	0.39	0.37	0.35	**0.37 +/- 0.02**	0.44	0.52	0.97	**0.64 +/- 0.23**	**1.79**
1-methylnapththelene	0.12	0.14	0.12	**0.13 +/- 0.01**	0.14	0.20	0.23	**0.19 +/- 0.04**	
2-methylnaphthalene	0.29	0.29	0.26	**0.28 +/- 0.01**	0.33	0.41	0.50	**0.41 +/- 0.07**	**1.24**
2-6 dimethylnapththalene	0.11	0.17	0.14	**0.14 +/- 0.02**	0.23	0.26	0.30	**0.26 +/- 0.03**	
2,3,5-tri-methylnapthalene	0.11	0.07	0.10	**0.09 +/- 0.02**	0.08	0.11	0.11	**0.10 +/- 0.02**	
biphenyl	0.13	0.15	0.12	**0.13 +/- 0.01**	0.15	0.19	0.22	**0.18 +/- 0.03**	
acenaphthylene	0.34	0.44	0.42	**0.40 +/- 0.04**	0.56	0.63	0.70	**0.63 +/- 0.06**	**0.73**
acenaphthene	0.15	0.14	0.20	**0.16 +/- 0.03**	0.21	0.41	0.33	**0.32 +/- 0.08**	**0.35**
flourene	0.18	0.20	0.32	**0.23 +/- 0.06**	0.33	0.52	0.38	**0.41 +/- 0.08**	**0.57**
phenanthrene	0.89	1.39	2.58	**1.62 +/- 0.71**	1.80	3.52	2.19	**2.50 +/- 0.73**	**5.19**
1-methylphenanthrene	0.25	0.16	0.38	**0.26 +/- 0.09**	0.31	0.41	0.34	**0.35 +/- 0.04**	
anthracene	0.37	0.44	0.79	**0.53 +/- 0.18**	0.66	0.70	0.98	**0.78 +/- 0.14**	**6.00**
Total Selected LMW PAHs	2.62	3.27	4.91	**3.59 +/- 0.50**	4.33	6.70	6.05	**5.69 +/- 0.76**	**16.00**
Total LMW PAHs	3.35	3.96	5.77	**4.36 +/- 0.42**	5.23	7.87	7.25	**6.78 +/- 0.64**	
High Molecular Weight									
fluoranthene	2.08	2.71	4.39	**3.06 +/- 0.98**	2.79	4.63	3.91	**3.77 +/- 0.76**	**10.46**
pyrene	3.68	6.78	7.58	**6.01 +/- 1.68**	9.02	11.67	10.78	**10.49 +/- 1.10**	**9.86**
benzo(a)anthracene	1.47	1.86	2.88	**2.07 +/- 0.59**	2.62	3.15	3.13	**2.97 +/- 0.24**	**6.81**
chrysene	1.53	1.86	2.88	**2.09 +/- 0.57**	2.62	3.33	3.28	**3.08 +/- 0.32**	**7.28**
benzo(b)fluoranthene	2.89	4.92	4.85	**4.22 +/- 0.94**	5.74	7.04	7.81	**6.86 +/- 0.86**	**0.81**
benzo(k)fluoranthene	3.16	4.58	11.97	**6.57 +/- 3.86**	5.74	6.67	7.66	**6.69 +/- 0.78**	**1.54**
benzo(a)pyrene	3.42	4.58	5.76	**4.58 +/- 0.95**	6.56	7.96	9.06	**7.86 +/- 1.03**	**4.87**
benzo(e)pyrene	0.58	0.69	0.91	**0.73 +/- 0.14**	0.80	1.13	1.36	**1.10 +/- 0.23**	
indeno(1,2,3-cd)pyrene	1.29	2.03	2.12	**1.81 +/- 0.37**	2.46	2.96	3.91	**3.11 +/- 0.60**	
dibenz(a,h)anthracene	0.32	0.61	0.67	**0.53 +/- 0.15**	0.66	1.04	1.25	**0.98 +/- 0.25**	**1.82**
benzo(g,h,i)perylene	1.24	1.69	2.12	**1.68 +/- 0.36**	2.30	2.96	3.28	**2.85 +/- 0.41**	**0.80**
perylene	0.29	0.44	0.38	**0.37 +/- 0.06**	0.46	0.57	0.73	**0.59 +/- 0.11**	
Total Selected HMW PAHs	19.79	29.59	43.09	**30.81 +/- 2.05**	38.03	48.44	50.16	**45.53 +/- 3.06**	**45**
Total HMW PAHs	21.95	32.76	46.50	**33.74 +/- 10.05**	41.75	53.11	56.16	**50.34 +/- 6.20**	

Appendix A Table 6

Metal Data Normalized to Grain Size for the SW-REF and SOUTH Reference Areas

METAL	SW REF CTR 1 (SW16)	SW REF 300W (SW22)	SW REF 400N (SW18)	SW REF AVERAGE	SOUTH REF Rep 1	SOUTH REF Rep 2	SOUTH REF Rep 3	SOUTH REF AVERAGE	WLI
Al	142.1	147.5	110.6	**133.39 +/- 16.26**	160.7	185.2	203.1	**182.99 +/- 17.41**	**801**
As	0.07	0.06	0.05	**0.06 +/- 0.01**	0.06	0.09	0.08	**0.08 +/- 0.01**	**0.112**
Cd	0.02	0.02	0.01	**0.02 +/- 0.00**	0.02	0.02	0.03	**0.02 +/- 0.00**	**0.012**
Cr	0.47	0.56	0.41	**0.48 +/- 0.06**	0.59	0.65	0.66	**0.63 +/- 0.03**	**1.68**
Cu	0.61	0.75	0.45	**0.60 +/- 0.12**	0.75	0.81	0.81	**0.79 +/- 0.03**	**1.6**
Fe	289.5	254.24	196.97	**246.89 +/- 38.12**	278.69	296.30	281.25	**285.41 +/- 7.77**	**499**
Hg	0.0013	0.0015	0.0009	**0.00 +/- 0.00**	0.002	0.002	0.002	**0.00 +/- 0.00**	**0.007**
Ni	0.24	0.24	0.15	**0.21 +/- 0.04**	0.25	0.28	0.25	**0.26 +/- 0.01**	**0.45**
Pb	0.37	0.42	0.27	**0.35 +/- 0.06**	0.46	0.50	0.50	**0.49 +/- 0.02**	**1.09**
Zn	1.37	1.61	1.05	**1.34 +/- 0.23**	1.59	1.81	1.88	**1.76 +/- 0.12**	**3.22**

APPENDIX B

Description of Reconnaissance Grabs for WLIS 1993

WLIS/Southwest Corner

		Latitude	Longitude
DS1	Depth 103′	40°59.058′ N	73°29.373′ W

- olive brown oxidized surface (~1 mm in thickness) with very small shell fragments, watery, no active biological life readily apparent on surface
- gray/black silt/clay with some very fine sand, 1 worm, a scallop shell
- clay content increased at bottom of grab, rock with encrusted bryozoans
- no odors in grab

DS2 40°59.057′ N 73°29.377′ W

- olive gray oxidized surface (~1 mm thick), watery, small shrimp on top, a little shellhash, some pebbles
- dark gray silt/clay with fine sand (not as black as grab 1)
- no odors

DS3 Depth 111′ 40°59.120′ N 73°29.370′ W

- olive gray oxidized layer (~1 mm thick), *Nereis* or *Nephtys*
- dark gray silt/clay, some black streaks in it
- clay increased with depth - more compact
- grab 3 finer then grab 2

SOUTH Reference

1 Depth 86′ 40°58.699′ N 73°29.197′ W

- Big rock, very sandy - repeated grab

2 Depth 87′ 40°58.700′ N 73°29.198′ W

- olive gray/brown organic layer, very soft, maybe some biological holes
- gray/brown very fine sands with some silt, not much clay

3 40°58.698′ N 73°29.204′ W

- olive gray surface layer with dark very fine sand particles, reddish cast, some worm tubes, a rock
- very fine sand with silt, dark gray-green color, live *Mercenaria* 1½"
- no odors

West of SOUTH Reference/SW-REF Area

SW1 (EG1) Depth 86′ 40°58.704′ N 73°29.915′ W (400 m N of SW16)

- olive gray, sandy, oxidized layer, a snail, some shell fragments, a flabelligerid at surface
- medium gray very fine sands with silt
- increase in clay content - more compact - silt/clay at bottom of grab
- no odors

SW2 (EG2) Depth 91′ 40°58.700′ N 73°30.201′ W (600 m NW of SW16)

- olive gray/brown oxidized layer - very soft
- dark brown sediments with a lot of clay, silt/clay content greater than EG1
- no tubemats, a few worms
- some marine mud odor
- REMOTS® sediment-profile station EG3

SW3 (EG3) Depth 91′ 40°58.692′ N 73°30.200′ W (600 m NW of SW16)

- olive gray surface sediments (~½ cm), a little more sand
- dark gray silt sand with some very fine sands
- dark gray silt/clay at bottom of grab
- REMOTS® sediment profile station EG3

SW3A (EG3A) 40°58.697′ N 73°30.412′ W (800 m NW of SW16)

- olive brown oxidized layer, (~½ cm thick), small shrimp and crab on surface
- dark gray very fine sands with silt
- silt/clay and very fine sand at bottom of grab
- looks similar to EG3
- marine mud odor
- REMOTS® sediment profile station EG3/300w

SW15 (EG15) Depth 66′ 40°58.315′ N 73°29.860′ W (300 m S of SW16)

- oxidized olive layer with some very tiny black sand fragments, a few shells, live gastropods
- medium gray very fine sand with silt all the way through the grab
- not highly bioturbated

SW16 (EG16) Depth 73′ 40°58.487′ N 73°29.909′ W (approximate center for SW-REF)

- oxidized medium brown layer (2-3 mm), *Mercenaria*
- very fine sands with some silt, medium gray/green color
- no odor

SW17 (EG17) 40°58.599′ N 73°29.914′ W (200 m N of SW16)

- olive brown oxidized layer with some very dark sand grains
- gray silt/clay with some sand, some black streaks further down in grab
- anemone shell

SW18 (EG18) Depth 82′ 40°58.700′ N73°29.928′ W (400 m N of SW16)

- olive oxidized layer (2-3 mm depth), some worms, few rocks and small stones, some small shells
- gray silt/clay at bottom of grab with some very fine sand mixed in, clay content increased with depth
- no odors
- REMOTS® sediment-profile photographs

SW19 (EG19) Depth 92′ 40°58.810′ N 73°29.918′ W (600 m N of SW16)

- light brown oxidized layer with very fine black sand particles mixed in
- dark gray silt/clay sediments, silt content and percent moisture higher than EG18
- softer sediment than station EG18
- appearance of transitional sediment from EG18

SW20 (EG20) Depth 97′ 40°58.916′ N 73°29.910′ W (800 m N of SW16)

- muddy soup on a soft, fluffy oxidized layer
- soft, medium gray silt with medium to fine sands, a large worm (not chocolate mousse)

SW21 (EG21) Depth 81′ 40°58.477′ N 73°30.343′ W (600 m W of SW16)

- olive gray oxidized layer, a little soupy (1 worm tube)
- dark gray silt/clay sediment
- clay increased with depth
- marine mud odor
- similar to grabs 19 and 20

SW22 (EG22) Depth 80′ 40°58.481′ N 73°30.133′ W (300 m W of SW16)

- olive gray oxidized layer with some shell fragments and scallop shell
- brown gray silt/clay sediments
- sandier than EG21 with some fine, very fine sands
- slight marine mud odor
- REMOTS® sediment-profile station EG3/300S

SW23 (EG23) 40°58.465′ N 73°29.608′ W (425 m E of SW16)
600 m southeast of EG18

- olive brown oxidized layer (~2 mm thick), reddish cast, bits of tiny shell fragments, grass shrimp, one rock
- gray/brown silt with some very fine sand, some shells scattered in
- increase in clay content at bottom of grab
- slight marine mud odor

SW24 (EG24) Depth 76′ 40°58.698′ N 73°29.488′ W (700 m NE of SW16)
600 m east of EG18

- oxidized olive brown layer, a few shell fragments, *Mercenaria* shell
- gray/brown silt with some medium/fine sands, some silt/clay with an increase in clay at the bottom of the grab
- slight marine mud odor

East of SOUTH Reference Area

EG4 40°58.699′ N 73°28.325′ W

- very thin oxidized olive layer (< 1 mm), very little grit
- dark gray silt/clay, soupy, a small amount very fine sand, 1 rock, 1 worm - flabelligerid
- "chocolate mousse" type sediment

EG5 40°58.695′ N 73°28.341′ W

- Same as EG4

EG6 Depth 62′ 40°58.011′ N 73°28.291′ W

- olive oxidized layer with small shell fragments, very fine dark sand particles
- dark gray, very fine sands
- no odors
- shallow area

EG7 Depth 70′ 40°58.224′ N 73°28.282′ W

- olive brown oxidized layer, very thin <1 mm thick, 1 worm
- very dark soupy sediment (mousse), no grit
- very strong odor (anoxic, sulfur smell)

G8 Depth 72′ 40°58.445′ N 73°28.288′ W

- soft soupy thin oxidized layer, some *Nucula annulatum*
- less moisture in grab than EG7
- dark gray silt/clay, small amount of very fine sands
- strong odor

EG9 Depth 156′ 41°00.110′ N 73°24.330′ W

- shellhash with some small rocks
- gray sand with fine, very fine silt/clay patches
- lots of rocks
- too deep, wrong sediment type for reference area

EG10 Depth 101′ 41° 00.174′ N 73°24.546′ W

- olive brown surface, coarse sand with pebbles and a razor clam
- medium to coarse gray sand with some silt, an increase in clay at bottom of grab
- *Ensis* (razor clam) and *Astarte* (bivalve)
- sediments too sandy

EG11 Depth 93′ 40°58.873′ N 73°24.833′ W

- very soft thin olive brown surface, some shells and pebbles on top (very few)
- dark gray silt/clay with some grit

EG12 40°58.697′ N 73°25.119′ W

- light olive brown layer, reddish cast, some *Yoldia litmatula*
- dark gray silt, some *Mulinia*
- odor (looks like dredged material)

EG13 40°58.698′ N 73°25.550′ W

- light brown soft sediments, 1 worm, lots of *Mulinia*
- very dark gray silt, some increase in clay at bottom of grab
- strong odor
- looks like New Haven Harbor sediments

EG14 Depth 58′ 40°58.309′ N 73°26.917′ W

- thin brown oxidized layer (<1 mm thick)
- very silty with little grit
- dark gray silt/clay
- *Nephtys*

CHEMISTRY GRABS

Area West of SOUTH Reference/SW-REF

SW16 (EG16) 40°58.484′ N 73°29.914′ W (approximate center of SW-REF)

- olive brown oxidized layer
- gray/green silt with fine sand, small shrimp, little crab, 2 snails
- no odor

SW18 (EG18) 40°58.700′ N 73°29.914′ W (400 m N of SW16)

- olive brown layer, worm tubes, couple shell fragments
- very fine sand with silt/clay, gray color

SW22 (EG22B) 40°58.475′ N 73°30.130′ W (300 m W of SW16)

- olive gray oxidized layer with some shell fragments and scallop shell
- brown gray silt/clay sediments
- slight marine mud odor

South Reference Area

Rep1 40°58.712′ N 73°29.207′ W

- olive brown oxidized layer about 1 mm in thickness many small snails
- medium gray/green silt with some very fine sand some clay
- very slight marine mud odor

Rep2 40°58.711′ N 73°29.186′ W

- olive brown oxidized layer
- medium gray/green silt clay with some fine sands

Rep3 40° 58.694′ N 73°29.196′ W

- light olive brown layer
- gray/green silt/clay-silt content higher than Rep2
- slight marine mud odor

APPENDIX C

REMOTS® Data for WLIS 1993

Appendix C - REMOTS® Data for WLIS 1993

Appendix C Table 1. Results of REMOTS® Analyses for the SW-REF and SOUTH Reference Areas, WLIS 1993

Appendix C Table 2. Results of REMOTS® Analyses for the Stations Occupied at the A and D Mounds, WLIS 1993

Appendix C Table 1

Results of REMOTS® Analyses for the SW-REF and SOUTH Reference Areas, WLIS 1993

LOCATION	STATION	REP	POSITION	AVERAGE PENETRATION	MAXIMUM PENETRATION	MINIMUM PENETRATION	DM PENETRATION	BOUNDARY ROUGHNESS	BOUNDARY TYPE	GRAIN SIZE MAJOR MODE	GRAIN SIZE RANGE
SOUTH Reference	g1	a	40 58.688N 73 29.201W	7.37	8.62	6.12	0	2.50	Physical	> 4	2 to > 4
SOUTH Reference	g1	b	40 58.692N 73 29.199W	7.33	8.12	6.54	0	1.58	Physical	> 4	2 to > 4
SOUTH Reference	g1	c	40 58.688N 73 29.212W	7.75	7.79	7.7	0	0.08	Indeterminate	> 4	2 to > 4
SW-REF Area	sw3/eg3	a	40 58.695N 73 30.189W	7.12	7.29	6.95	0	0.33	Indeterminate	> 4	3 to > 4
SW-REF Area	sw3/eg3	b	40 58.704N 73 30.199W	8.47	8.62	8.33	0	0.29	Biological	> 4	2 to > 4
SW-REF Area	sw3/eg3	c	40 58.705N 73 30.201W	7.02	7.25	6.79	0	0.46	Physical	> 4	3 to > 4
SW-REF Area	sw3/100n (SW3B)	a	40 58.756N 73 30.195W	7.18	7.87	6.5	0	1.37	Biological	> 4	2 to > 4
SW-REF Area	sw3/100n (SW3B)	b	40 58.753N 73 30.195W	8.79	9.29	8.29	0	1.00	Biological	> 4	3 to > 4
SW-REF Area	sw3/100n (SW3B)	c	40 58.752N 73 30.195W	10.04	10.45	9.62	0	0.83	Indeterminate	> 4	1 to > 4
SW-REF Area	sw3/300e (SW18)	a	40 58.695N 73 29.980W	8.08	8.2	7.95	0	0.25	Biological	3 to 4	3 to > 4
SW-REF Area	sw3/300e (SW18)	b	40 58.700N 73 29.986W	6.35	6.7	6	0	0.71	Biological	> 4	2 to > 4
SW-REF Area	sw3/300e (SW18)	c	40 58.697N 73 29.991W	5.81	6.2	5.41	0	0.79	Physical	3 to 4	2 to > 4
SW-REF Area	sw3/300s (SW22)	a	40 58.534N 73 30.205W	6.02	6.33	5.7	0	0.62	Biological	> 4	2 to > 4
SW-REF Area	sw3/300s (SW22)	b	40 58.536N 73 30.201W	6.39	7.2	5.58	0	1.62	Physical	> 4	2 to > 4
SW-REF Area	sw3/300s (SW22)	c	40 58.535N 73 30.188W	4.79	5.41	4.16	0	1.25	Physical	> 4	2 to > 4
SW-REF Area	sw3/300w (SW3A)	a	40 58.696N 73 30.418W	12.05	12.87	11.24	0	1.62	Physical	> 4	2 to > 4
SW-REF Area	sw3/300w (SW3A)	b	40 58.704N 73 30.417W	10.31	10.66	9.95	0	0.71	Biological	> 4	2 to > 4
SW-REF Area	sw3/300w (SW3A)	c	40 58.705N 73 30.414W	9.20	9.49	8.91	0	0.58	Biological	> 4	2 to > 4

Appendix C Table 1 (cont.)

LOCATION	STATION	REP	RPD AVERAGE	RPD MAXIMUM	RPD MINIMUM	RPD WIDE	RPD AREA	RR AVG	RR TOP	RR BOTTOM	MC COUNT	MC DIAMETER	MC STATUS
SOUTH Reference	g1	a	1.25	1.54	0.96	12.99	16.23	0	0	0	7	0.46	Both
SOUTH Reference	g1	b	0.77	1.21	0.33	12.78	9.85	0	0	0	0	0	
SOUTH Reference	g1	c	0.77	1.17	0.37	12.78	9.85	0	0	0	0	0	
SW-REF Area	sw3/eg3	a	0.85	1.29	0.42	12.87	10.98	0	0	0	0	0	
SW-REF Area	sw3/eg3	b	1.02	1.67	0.37	12.91	13.17	0	0	0	0	0	
SW-REF Area	sw3/eg3	c	0.96	1.29	0.62	12.99	12.44	0	0	0	9	0.34	Reduced
SW-REF Area	sw3/100n (SW3B)	a	1.21	1.75	0.67	13.03	15.74	0	0	0	2	0.12	Reduced
SW-REF Area	sw3/100n (SW3B)	b	3.00	4.12	1.87	12.87	38.58	0	0	0	0	0	
SW-REF Area	sw3/100n (SW3B)	c	1.62	2.66	0.58	12.66	20.56	0	0	0	4	0.46	Reduced
SW-REF Area	sw3/300e (SW18)	a	1.04	1.54	0.54	12.66	13.18	0	0	0	4	0.21	Reduced
SW-REF Area	sw3/300e (SW18)	b	1.69	2.12	1.25	12.7	21.42	0	0	0	0	0	
SW-REF Area	sw3/300e (SW18)	c	1.00	1.5	0.5	12.66	12.65	0	0	0	5	0.37	Reduced
SW-REF Area	sw3/300s (SW22)	a	0.62	1.25	0	12.74	7.96	0	0	0	0	0	
SW-REF Area	sw3/300s (SW22)	b	2.37	2.79	1.96	12.58	29.85	0	0	0	0	0	
SW-REF Area	sw3/300s (SW22)	c	0.65	1.29	0	12.87	8.3	0	0	0	6	0.29	Reduced
SW-REF Area	sw3/300w (SW3A)	a	1.52	1.96	1.08	12.62	19.18	0	0	0	0	0	
SW-REF Area	sw3/300w (SW3A)	b	1.15	1.79	0.5	12.58	14.4	0	0	0	0	0	
SW-REF Area	sw3/300w (SW3A)	c	1.33	1.87	0.79	12.49	16.65	0	0	0	0	0	

Appendix C Table 1 (cont.)

LOCATION	STATION	REP	LOW DO	METHANE PRESENT	METHANE AVERAGE	METHANE COUNT	METHANE MINIMUM	METHANE MAXIMUM	METHANE DIAMETER	SUCCESSIONAL STAGE	OSI
SOUTH Reference	g1	a	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SOUTH Reference	g1	b	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SOUTH Reference	g1	c	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SW-REF Area	sw3/eg3	a	NO	0	0	0	0	0	0	Stage III	7
SW-REF Area	sw3/eg3	b	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SW-REF Area	sw3/eg3	c	NO	0	0	0	0	0	0	Stage III	7
SW-REF Area	sw3/100n (SW3B)	a	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SW-REF Area	sw3/100n (SW3B)	b	NO	0	0	0	0	0	0	Stage I ON Stage III	9
SW-REF Area	sw3/100n (SW3B)	c	NO	0	0	0	0	0	0	Indeterminate	IND
SW-REF Area	sw3/300e (SW18)	a	NO	0	0	0	0	0	0	Stage I	3
SW-REF Area	sw3/300e (SW18)	b	NO	0	0	0	0	0	0	Stage I	4
SW-REF Area	sw3/300e (SW18)	c	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SW-REF Area	sw3/300s (SW22)	a	NO	0	0	0	0	0	0	Indeterminate	IND
SW-REF Area	sw3/300s (SW22)	b	NO	0	0	0	0	0	0	Stage I ON Stage III	9
SW-REF Area	sw3/300s (SW22)	c	NO	0	0	0	0	0	0	Indeterminate	IND
SW-REF Area	sw3/300w (SW3A)	a	NO	0	0	0	0	0	0	Stage I ON Stage III	8
SW-REF Area	sw3/300w (SW3A)	b	NO	0	0	0	0	0	0	Stage I ON Stage III	7
SW-REF Area	sw3/300w (SW3A)	c	NO	0	0	0	0	0	0	Stage I ON Stage III	7

Appendix C Table 1 (cont.)

LOCATION	STATION	REP	RPD > PENETRATION	DM > PENETRATION	LOW PENETRATION	COBBLE	SAND OVER MUD	BED FORMS	MUD OVER SAND	FRESH DM	POOR SORT	CHAOTIC FABRIC
SOUTH Reference	g1	a	0	0	0	0	Sand/Mud	0	0	0	Poor Sort	0
SOUTH Reference	g1	b	0	0	0	0	Sand/Mud	Bed Forms	0	0	0	0
SOUTH Reference	g1	c	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/eg3	a	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/eg3	b	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/eg3	c	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/100n (SW3B)	a	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/100n (SW3B)	b	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/100n (SW3B)	c	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/300e (SW18)	a	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/300e (SW18)	b	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/300e (SW18)	c	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/300s (SW22)	a	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/300s (SW22)	b	0	0	0	0	Sand/Mud	Bed Forms	0	0	0	0
SW-REF Area	sw3/300s (SW22)	c	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/300w (SW3A)	a	0	0	0	0	Sand/Mud	0	0	0	0	0
SW-REF Area	sw3/300w (SW3A)	b	0	0	0	0	0	0	0	0	0	0
SW-REF Area	sw3/300w (SW3A)	c	0	0	0	0	Sand/Mud	0	0	0	0	0

Appendix C Table 1 (cont.)

LOCATION	STATION	REP	SHELL LAG	MUSSEL BED	AMPHIPODS	HYDROIDS	ADDITIONAL MEASURE	ADDITIONAL COMMENT	GENERAL COMMENTS
SOUTH Reference	g1	a	0	0	0	0	0		
SOUTH Reference	g1	b	0	0	0	0	0		a few shell frags
SOUTH Reference	g1	c	0	0	0	0	0		
SW-REF Area	sw3/eg3	a	0	0	0	0	0		similar to South ref relic voids?
SW-REF Area	sw3/eg3	b	0	0	0	0	0		
SW-REF Area	sw3/eg3	c	0	0	0	0	0		wiper smearing at interface
SW-REF Area	sw3/100n (SW3B)	a	0	0	0	0	0		
SW-REF Area	sw3/100n (SW3B)	b	0	0	0	0	0		deeper rpd here
SW-REF Area	sw3/100n (SW3B)	c	0	0	0	0	0		pull away
SW-REF Area	sw3/300e (SW18)	a	0	0	0	0	0		
SW-REF Area	sw3/300e (SW18)	b	0	0	0	0	2.83	sand layer	
SW-REF Area	sw3/300e (SW18)	c	0	0	0	0	0		
SW-REF Area	sw3/300s (SW22)	a	0	0	0	0	0		
SW-REF Area	sw3/300s (SW22)	b	0	0	0	0	0		
SW-REF Area	sw3/300s (SW22)	c	0	0	0	0	0		encrusted cinder
SW-REF Area	sw3/300w (SW3A)	a	0	0	0	0	0		dm present
SW-REF Area	sw3/300w (SW3A)	b	0	0	0	0	0		dm?
SW-REF Area	sw3/300w (SW3A)	c	0	0	0	0	0		

Appendix C Table 2

Results of REMOTS® Analyses for the Stations Occupied
at the A and D Mounds, WLIS 1993

LOCATION	STATION	REP	AVERAGE PENETRATION	MAXIMUM PENETRATION	MINIMUM PENETRATION	DM PENETRATION	BOUNDARY ROUGHNESS	BOUNDARY TYPE	GRAIN SIZE MAJOR MODE	GRAIN SIZE RANGE
WLIS D Mound	d100s	a	18.95	19.15	18.74	19.15	0.42	Biological	3 to 4	1 to > 4
WLIS D Mound	d100s	b	15.70	16.95	14.45	16.91	2.50	Physical	3 to 4	2 to > 4
WLIS D Mound	d100s	c	17.20	17.36	17.03	17.36	0.33	Indeterminate	3 to 4	2 to > 4
WLIS D Mound	d100w	b	13.18	14.20	12.16	14.20	2.04	Physical	> 4	2 to > 4
WLIS D Mound	d200n	a	3.94	6.61	1.27	6.61	5.34	Physical	3 to 4	2 to > 4
WLIS D Mound	d200n	b	16.24	16.45	16.03	16.45	0.42	Indeterminate	> 4	2 to > 4
WLIS D Mound	d200n	c	15.63	16.11	15.15	16.11	0.96	Indeterminate	> 4	2 to > 4
WLIS D Mound	d200s	a	7.75	9.99	5.50	9.99	4.50	Physical	3 to 4	2 to > 4
WLIS D Mound	d200s	b	8.77	11.83	5.70	11.83	6.12	Physical	> 4	2 to > 4
WLIS D Mound	d200s	c	11.72	13.99	9.45	13.99	4.54	Physical	> 4	3 to > 4
WLIS D Mound	d300s	a	7.72	10.49	4.96	10.49	5.54	Physical	> 4	2 to > 4
WLIS D Mound	d300s	b	12.74	13.03	12.45	13.03	0.58	Indeterminate	> 4	2 to > 4
WLIS D Mound	d300s	c	14.97	15.28	14.66	15.28	0.62	Physical	> 4	2 to > 4
WLIS A Mound	e400w	a	17.63	18.07	17.20	18.07	0.87	Physical	> 4	2 to > 4
WLIS A Mound	e400w	b	7.97	8.20	7.75	8.20	0.46	Biological	> 4	2 to > 4
WLIS A Mound	e400w	c	12.10	12.24	11.95	12.24	0.29	Indeterminate	> 4	2 to > 4

Appendix C Table 2 (cont.)

LOCATION	STATION	REP	RPD AVERAGE	RPD MAXIMUM	RPD MINIMUM	RPD WIDE	RPD AREA	RR AVG	RR TOP	RR BOTTOM	MC COUNT	MC DIAMETER	MC STATUS
WLIS D Mound	d100s	a	1.33	2.12	0.54	13.03	17.37	0	0	0	0	0	
WLIS D Mound	d100s	b	2.04	2.71	1.37	12.78	26.08	0	0	0	0	0	
WLIS D Mound	d100s	c	0.85	1.37	0.33	12.83	10.95	0	0	0	0	0	
WLIS D Mound	d100w	b	2.21	2.96	1.46	12.83	28.30	0	0	0	2	0.38	Reduced
WLIS D Mound	d200n	a	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	
WLIS D Mound	d200n	b	1.19	1.58	0.79	12.91	15.32	0	0	0	0	0	
WLIS D Mound	d200n	c	0.94	1.27	0.61	13.44	12.66	0	0	0	0	0	
WLIS D Mound	d200s	a	0.58	0.62	0.54	13.03	7.60	0	0	0	0	0	
WLIS D Mound	d200s	b	0.48	0.96	0.00	0.00	0.00	0	0	0	0	0	
WLIS D Mound	d200s	c	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	
WLIS D Mound	d300s	a	1.50	2.54	0.46	12.91	19.35	0	0	0	0	0	
WLIS D Mound	d300s	b	2.25	2.75	1.75	12.87	28.93	0	0	0	0	0	
WLIS D Mound	d300s	c	1.31	1.75	0.87	4.12	5.41	0	0	0	0	0	
WLIS A Mound	e400w	a	1.27	2.00	0.54	12.95	16.45	0	0	0	2	0.38	Reduced
WLIS A Mound	e400w	b	1.12	1.75	0.50	13.03	14.65	0	0	0	2	0.46	Reduced
WLIS A Mound	e400w	c	1.12	1.62	0.62	12.87	14.47	0	0	0	0	0	

Appendix C Table 2 (cont.)

LOCATION	STATION	REP	LOW DO	METHANE PRESENT	METHANE AVERAGE	METHANE COUNT	METHANE MINIMUM	METHANE MAXIMUM	METHANE DIAMETER	SUCCESSIONAL STAGE	OSI
WLIS D Mound	d100s	a	NO	0	0	0	0	0	0	Stage I	3
WLIS D Mound	d100s	b	NO	0	0	0	0	0	0	Stage I	4
WLIS D Mound	d100s	c	NO	0	0	0	0	0	0	Stage I ON Stage III	7
WLIS D Mound	d100w	b	NO	0	0	0	0	0	0	Stage I ON Stage III	8
WLIS D Mound	d200n	a	YES	0	0	0	0	0	0	Indeterminate	99
WLIS D Mound	d200n	b	NO	0	0	0	0	0	0	Stage III	7
WLIS D Mound	d200n	c	NO	0	0	0	0	0	0	Stage I ON Stage III	7
WLIS D Mound	d200s	a	NO	0	0	0	0	0	0	Stage III	6
WLIS D Mound	d200s	b	NO	0	0	0	0	0	0	Stage I ON Stage III	6
WLIS D Mound	d200s	c	YES	0	0	0	0	0	0	AZOIC	-8
WLIS D Mound	d300s	a	NO	0	0	0	0	0	0	Indeterminate	99
WLIS D Mound	d300s	b	NO	0	0	0	0	0	0	Indeterminate	99
WLIS D Mound	d300s	c	NO	0	0	0	0	0	0	Indeterminate	99
WLIS A Mound	e400w	a	NO	0	0	0	0	0	0	Stage I ON Stage III	7
WLIS A Mound	e400w	b	NO	0	0	0	0	0	0	Stage I ON Stage III	7
WLIS A Mound	e400w	c	NO	0	0	0	0	0	0	Stage III	7

Appendix C Table 2 (cont.)

LOCATION	STATION	REP	RPD > PENETRATION	DM > PENETRATION	LOW PENETRATION	COBBLE	SAND OVER MUD	BED FORMS	MUD OVER SAND	FRESH DM	POOR SORT	CHAOTIC FABRIC
WLIS D Mound	d100s	a	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS D Mound	d100s	b	0	DM > Pen	0	0	0	Bed Forms	0	0	0	0
WLIS D Mound	d100s	c	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS D Mound	d100w	b	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS D Mound	d200n	a	0	DM > Pen	0	0	Sand/Mud	0	0	0	0	0
WLIS D Mound	d200n	b	0	DM > Pen	0	0	0	0	0	0	0	Chaotic Fabric
WLIS D Mound	d200n	c	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS D Mound	d200s	a	0	DM > Pen	0	0	0	Bed Forms	0	0	0	0
WLIS D Mound	d200s	b	0	DM > Pen	0	0	0	Bed Forms	0	0	0	0
WLIS D Mound	d200s	c	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS D Mound	d300s	a	0	DM > Pen	0	0	Sand/Mud	Bed Forms	0	0	0	0
WLIS D Mound	d300s	b	0	DM > Pen	0	0	Sand/Mud	0	0	0	0	0
WLIS D Mound	d300s	c	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS A Mound	e400w	a	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS A Mound	e400w	b	0	DM > Pen	0	0	0	0	0	0	0	0
WLIS A Mound	e400w	c	0	DM > Pen	0	0	0	0	0	0	0	0

Appendix C Table 2 (cont.)

LOCATION	STATION	REP	SHELL LAG	MUSSEL BED	AMPHIPODS	HYDROIDS	ADDITIONAL MEASURE	ADDITIONAL COMMENT	GENERAL COMMENTS
WLIS D Mound	d100s	a	0	0	0	0	0		multiple dm layers, looks like fresh dm
WLIS D Mound	d100s	b	0	0	0	0	0		deeper rpd very dark sediment, looks like fresh dm
WLIS D Mound	d100s	c	0	0	0	0	0		shrimp at surface, looks like fresh dm
WLIS D Mound	d100w	b	0	0	0	0	0		deeper rpd here dark sediment
WLIS D Mound	d200n	a	0	0	0	0	0		erosional
WLIS D Mound	d200n	b	0	0	0	0	0		layers dm
WLIS D Mound	d200n	c	0	0	0	0	0		multiple dm layers and relic rpds
WLIS D Mound	d200s	a	0	0	0	0	0		organic surface layer
WLIS D Mound	d200s	b	0	0	0	0	0		camera disturbed surface
WLIS D Mound	d200s	c	0	0	0	0	0		
WLIS D Mound	d300s	a	Shell Lag	0	0	0	0		
WLIS D Mound	d300s	b	0	0	0	0	0		Stage III?
WLIS D Mound	d300s	c	0	0	0	0	0		Stage III? organic surface layer
WLIS A Mound	e400w	a	0	0	0	0	0		very dark sediment relic Stage III?
WLIS A Mound	e400w	b	0	0	0	0	0		very dark sediment relic Stage III?
WLIS A Mound	e400w	c	0	0	0	0	0		layers of sediment feeding void?