Baseline Survey of the
Reconfigured Massachusetts Bay Disposal Site,
14 September 1993

Disposal Area Monitoring System DAMOS

DAMOS
DISPOSAL AREA MONITORING SYSTEM

Contribution 115
February 1997

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New England Division

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6. AUTHORS
ED DeANGELO, PEGGY MURRAY

7. PERFROMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Science Applications Intenational Corporation
221 Thrid Street
Newport, RI 02840

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US Army Corps of Engineers-New England Division
424 Trapelo Road
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13. ABSTRACT

Baseline surveys of the newly designated Massachusetts Bay Disposal Site (MBDS) were conducted in September 1993 to delineate the topography and sediment composition of the site for DAMOS management. This information will enable management to optimize site usage and minimize adverse impact of future disposal projects. MBDS was characterized acoustically through collection of 1) precision bathymetric, 2) side-scan sonar, and 3) Sediment Acoustic Characterization System (SACS) data. In addition, sediments were sampled for grain size analyses to calibrate the acoustic data, and for chemical analyses to map the areal distribution of historically contaminated sediment documented in a prior survey.

MBDS was relocated approximately 1 nmi southwest from the interim MBDS; the interim site was used for the disposal of dredged material from 1977 to 1993. During the 1992/1993 disposal season, the majority of the material disposed at the interim MBDS originated from the Third Harbor Tunnel (THT) project in Boston Harbor. Previous monitoring results obtained through the Disposal Area Monitoring System (DAMOS) Program showed that THT material included fresh blasted rock and large consolidated clasts of Boston blue clay.

Results of the 1993 baseline survey indicated that the new MBDS was composed of two relatively distinct areas: 1) the newly incorporated southwestern area, and 2) the northeastern portion which overlaps the interim MBDS. The southwestern area, where no documented disposal of dredged material has occurred, was topographically featureless and sloped gradually towards the northeast. Sediments in this area were composed predominantly of fine-grained silts and clays. The northeastern region contained two major topographic features: the most recent dredged material disposal mound and a large, shallow basin where, historically, dredged material has been disposed. This shallow basin can be enhanced by management for a potential capping site. The highest topographic peak also was observed in this region, outside of the new site boundary, and interpreted as a remnant glacial outcrop.

Acoustic data suggested that the sediment composition in the northwest region was more heterogeneous than observed in the southwestern area, as would be expected for an area where disposal activity has occurred. The presence of older dredged material in the shallow basin was documented in the SACS data but was not evident in the side-scan mosaic. These results indicated that the high frequency side-scan sonar detected a thin layer of fine-grained sediment deposited on top of dredged material in the basin.

Sediment samples were collected in a 600 m radial grid surrounding an area where polycyclic aromatic hydrocarbons (PAHs) were found to be elevated in a 1989 survey. Results confirmed that the center station of the grid contained higher levels of both metal and organic contaminants than the surrounding sediments. Contaminant concentrations decreased with radial distance away from this station and did not indicate further contamination towards the west as suggested by the previous data.

The integrated acoustic and chemical data proved to be useful in mapping not only the high-reflectance THT material at the most recent dredged material mound, but historical dredged material as well. Comparisons of the SACS and side-scan data indicated that the surface of dredged material disposed less than ten years ago was either covered by ambient sediments or sufficiently reworked to appear uniform to side-scan acoustics. Both the acoustic and chemical data will be used to manage future dredged material disposal and to plan potential *in situ* remediation of historically contaminated sediment.

14. SUBECT TERMS Massachusetts Bay Disposal Site (MBDS), Sediment Acoustic Charecterization System (SACS), Thrid Harbor Tunnel (THT)

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Regulatory Division
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Prepared by:
Ed DeAngelo
Peggy Murray

Submitted by:
Science Applications International Corporation
Admiral's Gate
221 Third Street
Newport, RI 02840
(401) 847-4210

US Army Corps
of Engineers
New England Division

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EXECUTIVE SUMMARY

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1.0 INTRODUCTION

1.1 Objectives of the Survey

Baseline surveys of the newly relocated Massachusetts Bay Disposal Site (MBDS) were conducted by Science Applications International Corporation (SAIC) in July 1993 to characterize the site for DAMOS management, following final designation by the US Environmental Protection Agency (EPA) on July 1993. Baseline information of the site characteristics will enable management to best plan future disposal events to maximize site usage and possible *in situ* remediation of historically contaminated sediment. The boundary of MBDS was relocated approximately 1 nmi west and ½ nmi south of the previously existing interim MBDS (Figure 1-1). The newly designated site is a 2 nmi diameter circular area centered at 42°25.100' N, 70°35.000' W. The interim disposal site was used from 1977 to 1993, and was previously known as the Foul Area Disposal Site (FADS), so named because fishing gear became entangled (fouled) in the area.

The MBDS survey included four major objectives: 1) production of a high-resolution bathymetric chart of the new site; 2) collection of acoustic bottom reverberation data for construction of a sediment characterization map; 3) collection of high-resolution side-scan sonar survey data to provide a digital record capable of cataloging potentially hazardous industrial waste containers and other angular targets; and 4) sediment sampling used to ground-truth acoustic data and provide baseline sediment chemistry and grain size data. Additional objectives of the acoustic surveys were to compare acoustic sediment characterization data with collected grain size samples to produce an integrated acoustic textural map, and to use the side-scan data to identify large-scale geological features such as sand waves, gravel beds, and rock outcrops.

Sediment chemical data were also collected as a response under the DAMOS Tiered Monitoring Protocol (Germano et al. 1994) to recent chemical results of a survey of the interim MBDS in 1989 (Murray 1994). Several stations near the western edge of the interim MBDS (and in the center of the relocated site) indicated that elevated concentrations of PAHs were present in sediment as an apparent result of historical disposal. The highest concentrations were measured at Station 12-3 in the 1989 survey. Sediment samples were collected during the September 1993 survey in a grid around Station 12-3 to determine the localized distribution of these sediment contaminant concentrations within the boundary of the new disposal site.

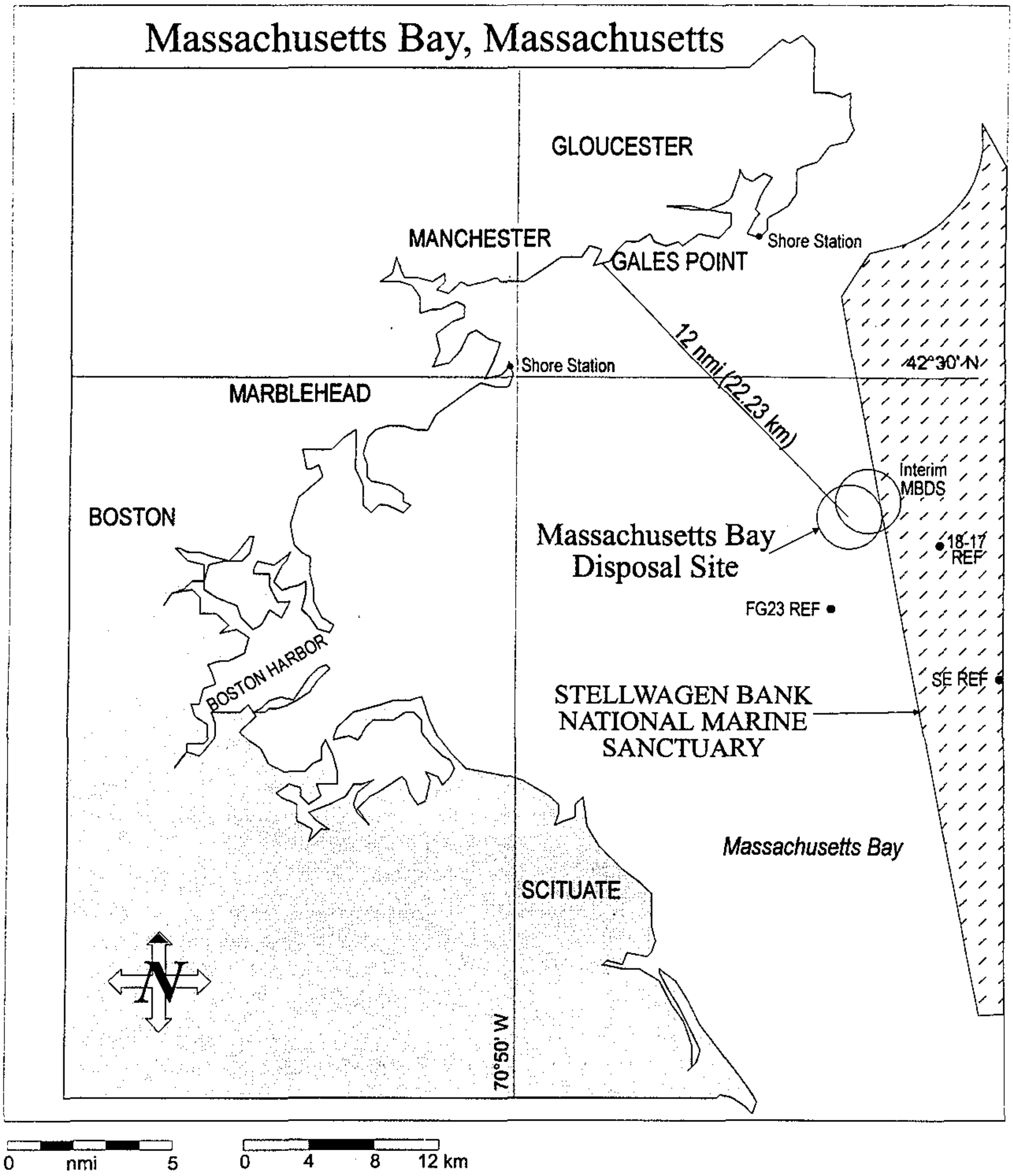

Figure 1-1. Location map of the Massachusetts Bay Disposal Site

1.2 Dredged Material Management at the Massachusetts Bay Disposal Site

MBDS was designated as an Ocean Dredged Material Disposal Site in July 1993 (EPA 1992, 1993). Relocation of the MBDS boundary provided several advantages. First, the relatively pristine eastern portion of the interim MBDS, including the edge that overlaps with the Stellwagen Bank National Marine Sanctuary, is not included in the relocated site. Second, the new site boundary encompasses the area west of the interim MBDS where contaminated sediments, present as a result of historical disposal practices, have been identified. Disposal activities will be avoided in the northern part of the Industrial Waste Site (IWS; closed by the EPA in 1977), where past disposal of waste barrels and other types of debris has occurred. In an EPA-sponsored survey of the IWS in 1991, the International Wildlife Coalition (IWC) identified a specific area, encompassing a significant portion of the IWS, that contained a high density of waste barrels (Wiley et al. 1992). Finally, locating MBDS in Stellwagen Basin, in the lee of the glacial moraine Stellwagen Bank, is advantageous because Stellwagen Basin is a depositional environment, as evidenced by the primarily fine-grained sediments that fill the basin (Oldale et al. 1973).

Disposal of dredged material at MBDS is managed by the New England Division (NED) of the US Army Corps of Engineers (USACE). Monitoring of the disposal of dredged material has been conducted at MBDS through the Disposal Area Monitoring System (DAMOS) Program since 1983. The majority of materials disposed during two years prior to the 1993 survey originated from the Third Harbor Tunnel project; these materials represented a wide variety of lithologies including fresh blasted rock fragments and consolidated clay. The 1993 baseline survey, encompassing the entire new boundary of MBDS, served to characterize baseline conditions against which future impacts of dredged material disposal can be assessed.

An understanding of the nature and distribution of the materials and topography currently present within the new MBDS is needed by management to best plan future use of the site. The data collected during this survey will be used to formulate or adjust guidelines for decisions about future dredged material placement. Dredged material suitable for open ocean disposal may be used for remediation of the historical waste present at the new MBDS.

1.3 Theory of Sonar Operations

The MBDS 1993 survey was conducted using three sound sources simultaneously: a high-frequency (208 kHz) narrow-beam fathometer, a dual-frequency (100/500 kHz) dual-channel side-scan sonar, and a low-frequency (24 kHz) transducer for sediment character. The principle of these acoustic systems is the same: an outgoing pulse is transmitted towards the bottom, the signal is reflected off the bottom, and the return signal is converted into data.

For bathymetry, the high-frequency signal is directed in a narrow beam directly to the bottom; the time delay of the return of this signal is converted into depth, using the measured speed of sound in the water column. The high-frequency signal has a short wavelength to reduce the noise of the returning signal. Side-scan sonar operates by transmitting two channels of sound sideways towards the bottom, producing a composite image by incorporating successive returns from each transducer. The strength (amplitude) of the returning signal traditionally is displayed by making the stronger returns darker on the recording device. In this survey, amplitudes were converted digitally so that the data could be manipulated using SAIC software. The high frequency of the side-scan sonar transducers limits the depth penetration of the sound signal in the sediment.

The low-frequency signal was used, in combination with the fathometer, to characterize the bottom sediments using SAIC's Sediment Acoustic Characterization System (SACS). This system utilizes the high-frequency transducer to define the depth of the sediment/water interface, and the low-frequency transducer for subbottom information. The longer wavelength allows some bottom penetration, which affects the resulting returning signal. The interpretation of the latter signal return is discussed more fully in Section 2.3.

2.0 METHODS

2.1 Navigation

SAIC conducted survey operations at the relocated MBDS from 8 September through 14 September 1993. 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. The INDAS interfaces with a Del Norte Trisponder® system. This microwave-based system operates on a pulsed transmission timing principle and is capable of determining over-water distances to a resolution of 0.1 meter. The actual positional error of the INDAS depends on the accuracy of the Del Norte Trisponder® system and the geometric dilution of precision (GDOP) which is, in turn, a function of the survey vessel's position with respect to the shore-based microwave trisponder (Murray and Selvitelli 1996). For the 1993 field operations, SAIC utilized two shore stations: the Marblehead Neck Light (42°30.320' N, 70°50.051' W) in Marblehead, MA; and the Eastern Point Light (42°34.809' N, 70°39.899' W) in Gloucester, MA. Previous MBDS surveys were also conducted with these shore stations.

During all field operations, the INDAS provided the operator and the helmsman with range and bearing to selected targets (i.e., beginning of a survey lane or sampling station), signal quality, time of day, and selected data from environmental sensors such as the depth sounder. A Hewlett-Packard 7475A plotter recorded the vessel track 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 all position fixes incorporating date and time of day, the ship's position in latitude/longitude and local x/y coordinate system, and the raw Del Norte position ranges.

2.2 Bathymetry

The precision bathymetric survey was conducted with a 25 m lane spacing over a 4000 m × 4075 m area centered at 42°25.100' N, 700°35.000' W, or the center of the newly designated MBDS, resulting in 163 survey lanes (Figure 2-1). The survey area extended beyond the disposal site boundaries, and encompassed significant portions of both the IWS and interim MBDS. The survey orientation was northeast to southwest to take advantage of the predominantly northeast wind direction to reduce ship motion errors. Nine additional tie lanes spaced 400 m apart were run perpendicular to the survey lanes for depth verification.

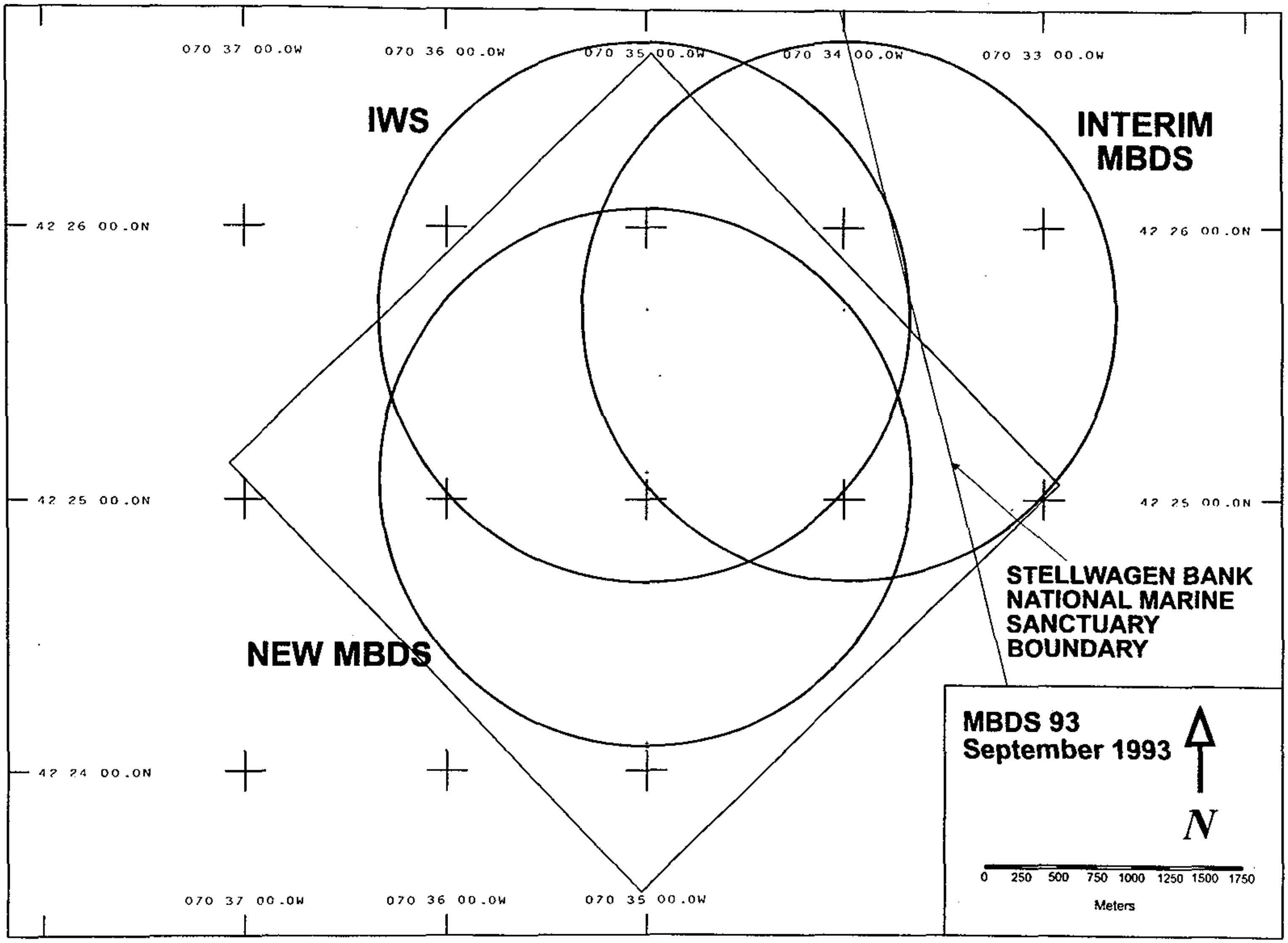

Figure 2-1. Location of the newly designated MBDS in relation to the interim MBDS, the IWS, and the Stellwagen Bank National Marine Sanctuary boundary

An ODOM DF3200 Echotrac® Survey Fathometer with a narrow beam (3°) 208 kHz transducer collected water depth data, simultaneously displaying on a chart recorder and writing data to the INDAS system (Murray and Selvitelli 1996). Water depth data were calibrated to the speed of sound in the water column and tidal variation. The fathometer could reliably detect changes in depth to approximately 20 cm due to the accumulation of errors introduced by the positioning system, calibration (speed of sound and draft of the vessel), slope of the bottom, and vertical motion of the vessel.

A SeaBird SBE 26-03 Seagauge, Wave, and Tide Recorder was deployed at a tide gauge station before survey operations on 8 September 1993 (42°27.149' N, 70°34.545' W). Tidal data were collected continuously throughout survey operations. Water temperature and salinity data measured by a SeaBird Model 19-01 CTD were used to calculate the speed of sound for use in depth calculations. CTD cast data were collected at the tide gauge station before the survey, and every six hours at the site during each survey day. The CTD was lowered over the side and allowed to equilibrate in ambient seawater for 1-2 minutes prior to initiating the cast.

Analysis of the bathymetric data was conducted using the Hydrographic Data Analysis System (HDAS). All depth values were corrected for speed of sound in seawater, and standardized to Mean Low Water (MLW) by compensating for transducer depth on the vessel and variations in tidal height during the survey. During analysis, position and depth data were checked to identify and eliminate any outlying values before producing the contour plot.

2.3 Sediment Acoustic Characterization System Survey

Bottom reverberation data were collected concurrently with the bathymetric survey using SACS. The SACS utilized dual-beam acoustic bottom reflection data, collected along the same lanes as bathymetry (Section 2.2) using a narrow-beam (19°) 24 kHz transducer for subbottom reflection data, in combination with the high-frequency ODOM Echotrac® fathometer (208 kHz) for precise surface reflection. The acoustic survey was conducted in parallel lanes spaced 25 meters apart across the entire area. The pulse length of the low-frequency (24 kHz) transducer resulted in a minimum subbottom depth resolution of approximately 35 cm. The area sonified, using an average water depth of 90 meters at the MBDS, is a circle with a diameter of approximately 30 meters.

The relative amplitude of the reflected energy between any two layers can be measured by the Rayleigh reflection coefficient (Dobrin 1960). The reflection coefficient (R) is a function of bottom loss of the acoustic signal. Bottom loss (BL) is measured as the strength of the returning signal, in dB, and is mathematically related to the reflection coefficient by the expression: BL = -20logR. Loss of the strength of an acoustic signal at the sediment/water interface can be used to map the character of the sediment. The term "loss" is used to describe the cumulative effect of sound scattering, adsorption in the sediments, and conversion of the acoustic signal at the sediment/water interface into other types of sound waves.

Penetration of sound in sediment is both a function of the system frequency, and of the impedance contrast between the water column and the sediments. Acoustic impedance (vr), the product of the density and the velocity of sound in a layer of sediment, is also affected by differences in porosity, surface "roughness," and grain size, among other factors (LeBlanc et al. 1992). Sound penetrates further into fine-grained sediment since the impedance of high-water content silts and clays is more closely like that of the water column, resulting in an increase in the amount of sound lost and a decrease in the strength of the returning signal. Therefore, a "weaker" signal translates generally as "softer" sediment, and a "stronger" signal return translates into "harder" sediment.

Signal amplitude (dB) data from the 24 kHz transducer were corrected for spherical spreading and adsorption in the water column, both a function of water depth. Relative signal return strength values were gridded so that data could be contoured and displayed. Signal return strength results were also compared with bathymetric and side-scan sonar results.

The precision of the acoustic data was measured by repeating one survey lane (Lane 69) three times over an area of varying sediment densities. Sediment samples were collected along this calibration lane for analysis of sediment density and grain size to ground truth the acoustic data. Ten grab samples were collected and analyzed for density by SAIC and for grain size by the NED laboratory. A representative amplitude was chosen from the geodetic point where a grab sample was collected. A regression correlation was conducted between the ten grain size and amplitude values. After mapping the signal return results, grain sizes were extrapolated from the acoustic map to produce a regional grain size map.

2.4 Side-scan Sonar

A high-resolution side-scan sonar survey was conducted concurrently with the bathymetric and bottom characterization survey at 100 m lane spacing (every fourth lane of the bathymetric survey), providing 150% bottom coverage. The side-scan sonar survey was conducted using a Klein Model 422S dual-frequency (100/500 kHz) towfish, and a Model 595 deck unit equipped with a digital analog tape (DAT) recorder. Data were recorded fully corrected for slant range and speed distortions. Side-scan data were read from DAT tape, gridded, and ported to a Geographic Information System (GIS) raster file using GRASS software. Each lane was individually digitized and filtered. Digitized lanes were compiled into one GRASS raster file to produce a mosaic of the entire area.

2.5 Sediment Sampling

Sediment samples were collected on 14 September 1993 with a 0.1 m^3 van Veen grab sampler. Subsamples were mixed in a plastic container with a solvent-rinsed, teflon-coated spoon. Between stations the subsampling equipment and the van Veen grab were rinsed with seawater. Sediment samples were stored in coolers at approximately 4° C and delivered to the NED laboratory. Proper chain-of-custody procedures were followed.

Sediment grabs were obtained at 26 stations for chemical and grain size analyses, and stored in acid-washed I-CHEM® glass jars, or plastic bags for grain size and total organic carbon (TOC). Chemistry samples were analyzed according to the current guidance (EPA/USACE 1991) including bulk sediment analyses for eight metals (As, Cd, Cr, Cu, Pb, Ni, Hg, and Zn), total polychlorinated biphenyls (PCBs), pesticides, and PAHs according to EPA protocols (EPA 1986; Table 2-1). In addition to grain size and TOC, chemistry samples were analyzed for Al and Fe as a possible method for data normalization.

Of the 26 chemistry samples, 13 were collected from a grid radiating from Station 12-3 (Figure 2-2) to delineate the extent of PAHs measured there in a survey in 1989 (Murray 1994). Samples were collected at 200 m intervals to a maximum of 600 m along the four major compass points with a center sample at Station 12-3 (12-3 Grid). Additionally, seven stations were sampled in the previously uncharacterized southwestern portion of MBDS (MBSW Grid), centered around 42°24.760' N and 70°5.440' W (Figure 2-2). Samples were collected to the northwest, southeast, and east at 600 m intervals to a maximum of 1200 m. Triplicate samples were also collected at two historical MBDS reference areas, FG-23 and 18-17. Samples collected from the 12-3 Grid and the reference areas were analyzed. The remaining samples from the MBSW grid were archived and will be analyzed at a later time.

Table 2-1

Summary of Laboratory Analytical Methods

ANALYTE	SW-846 TEST METHOD NO.		INSTRUMENTATION
Metals	Sample Prep	Analytical	
Aluminum	3051	6010	ICP
Arsenic	3051	206.2	AA
Cadmium	3051	6010	ICP
Chromium	3051	6010	ICP
Copper	3051	6010	ICP
Iron	3051	6010	ICP
Lead	3051	239.2	AA
Mercury	--	7471	CVAA
Nickel	3051	6010	ICP
Zinc	3051	6010	ICP
PAHs	3540	8270	GC/MS
Pesticides	3540	8080	GC/ECD
PCBs	3540	8081	GC/ECD
Total Organic Carbon		9060	

Instrumentation:

ICP	Inductively Coupled Plasma Atomic Emission Spectroscopy
AA	Furnace Technique Atomic Adsorption
CVAA	Cold Vapor Atomic Adsorption
GC	Gas Chromatograph
MS	Mass Spectrometer
ECD	Electron Capture Detector

All Methods from EPA SW-846 (EPA 1986)

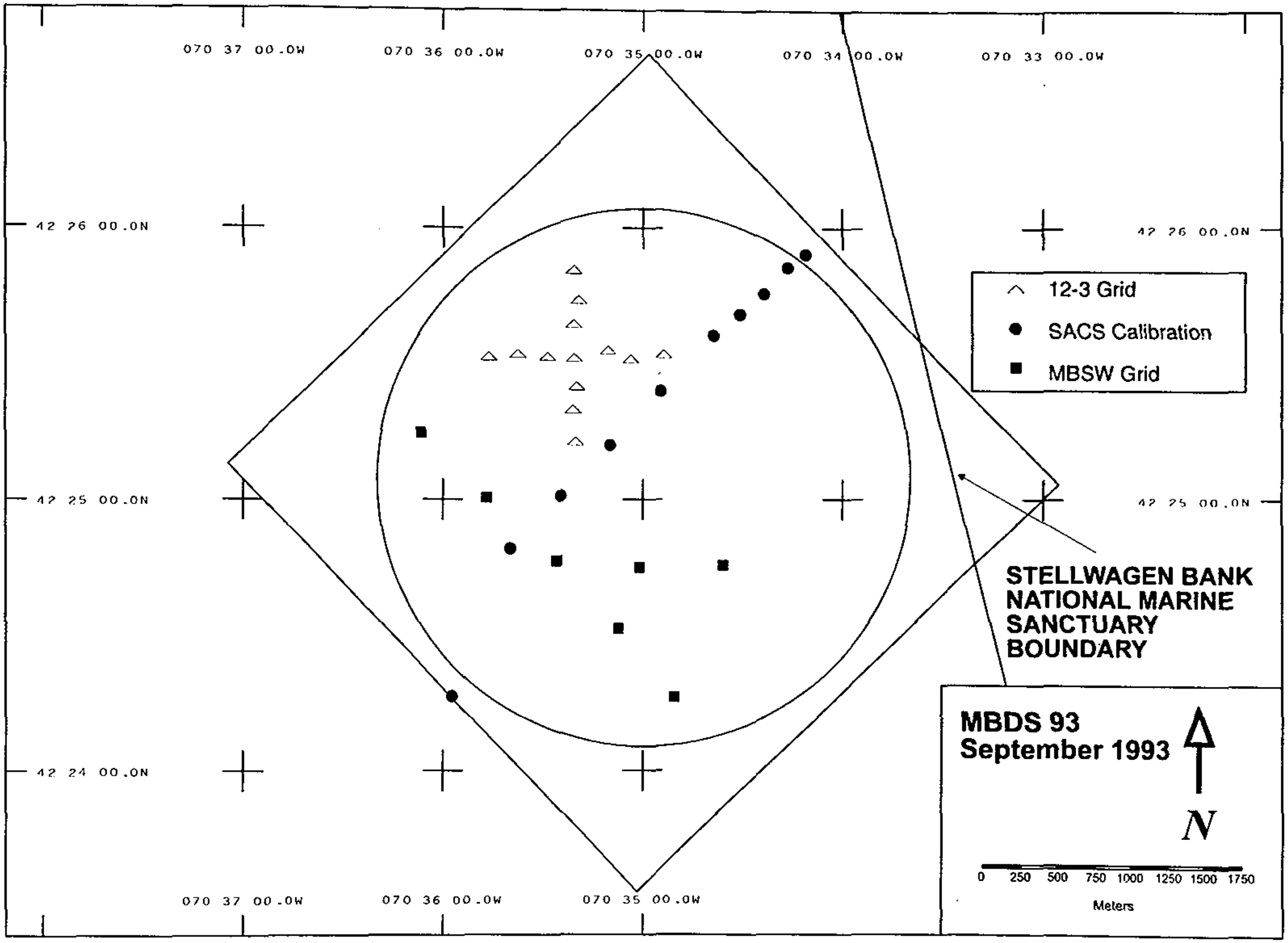

Figure 2-2. Sediment sample locations for the 12-3 Grid, MBSW Grid, and the SACS calibration line

Ten sediment samples were collected along Lane 69 for SACS calibration of density and grain size and stored in sealed plastic bags (CALIB-1 through CALIB-10; Figure 2-2). In addition, grain size was analyzed in the 12-3 Grid samples, and from the three replicates at each reference area. Grain size samples were collected and archived from the seven stations in the southwestern portion of MBDS.

American Society for Testing and Materials (ASTM) Method D422 was used for the analysis of grain size. Grain sizes were classified using the Wentworth classification (phi scale); gravel is classified as phi values between -2 and -1, sand between -1 and +4, silt between +4 and +8, and clays greater than +8. Phi sizes were converted into percentages of each grain size (gravel, sand, silt, and clay) for reporting.

3.0 RESULTS

3.1 Bathymetry

Within the MBDS boundary, depths sloped gradually from 82 m along the southwestern boundary towards a shallow depression (92 m) in the northeast quadrant at the toe of Stellwagen Bank (Figure 3-1). A shallow trough extended northeast from the depression and continued beyond the disposal site boundary. One mound was detected within the site boundary. This mound, associated with the MDA buoy, reached 79.69 m (Figure 3-2) at its shallowest point (42°25.050' N, 70°34.490' W). At the 86 m contour, the mound measured approximately 500 m along the major axis (E-W), and 250 m along the minor axis (N-S; Figure 3-1). The highest topographic feature was observed in the northern corner of the survey area, outside of the disposal site boundary (Figures 3-1 and 3-3). This topographic high extended to 67 m below the sea surface and had a diameter of approximately 500 m.

3.2 Side-scan Sonar

The final mosaic showed several distinctive large-scale features of MBDS (Figure 3-4). In discussing the side-scan results, the terms "strong" and "weak" will be used to describe the relative acoustic return. This usage will be discussed further, in terms of bottom character, in Section 4.2.

A large area of strong acoustic returns spanning several survey lanes was observed near the center of the site (Figure 3-4). Surrounding this large area, the major portion of the site consisted of relatively uniform weak signal return interspersed with several patches of small-scale strong returns, especially in the northern corner of the survey area.

A comparison of bathymetric data and the side-scan mosaic (Figure 3-4) revealed that the large, central area of strong returns is coincident with the mound at the MDA buoy. Additionally, the glacial feature in the northern corner of the survey exhibited a high returning signal strength. In the side-scan mosaic the return strength of the depression north of the MDA mound was not distinguishable from ambient levels.

Lane by lane analysis of the electrostatic paper traces produced in real time during survey operations revealed the presence of several small-scale targets. In the paper traces, individual dredged material dump patterns, including fine- and coarse-grained material, were observed. Other targets in the side-scan record included dragger scars, sunken barges, and, of particular interest, waste barrels. A relatively high density of barrels was observed in the northern corner of the survey. A comprehensive catalogue of side-scan

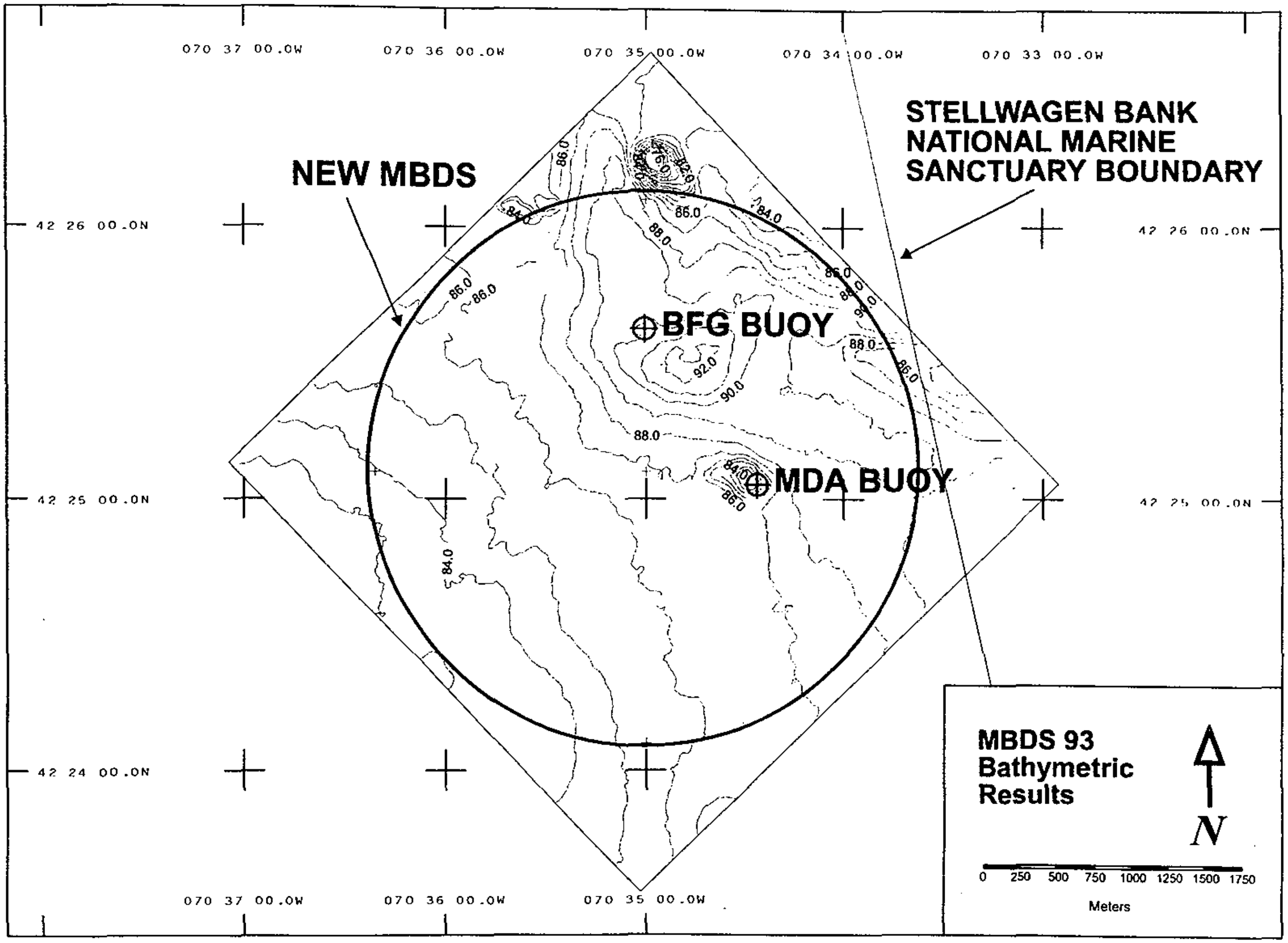

Figure 3-1. Contoured bathymetric chart (depth in meters) of MBDS, September 1993

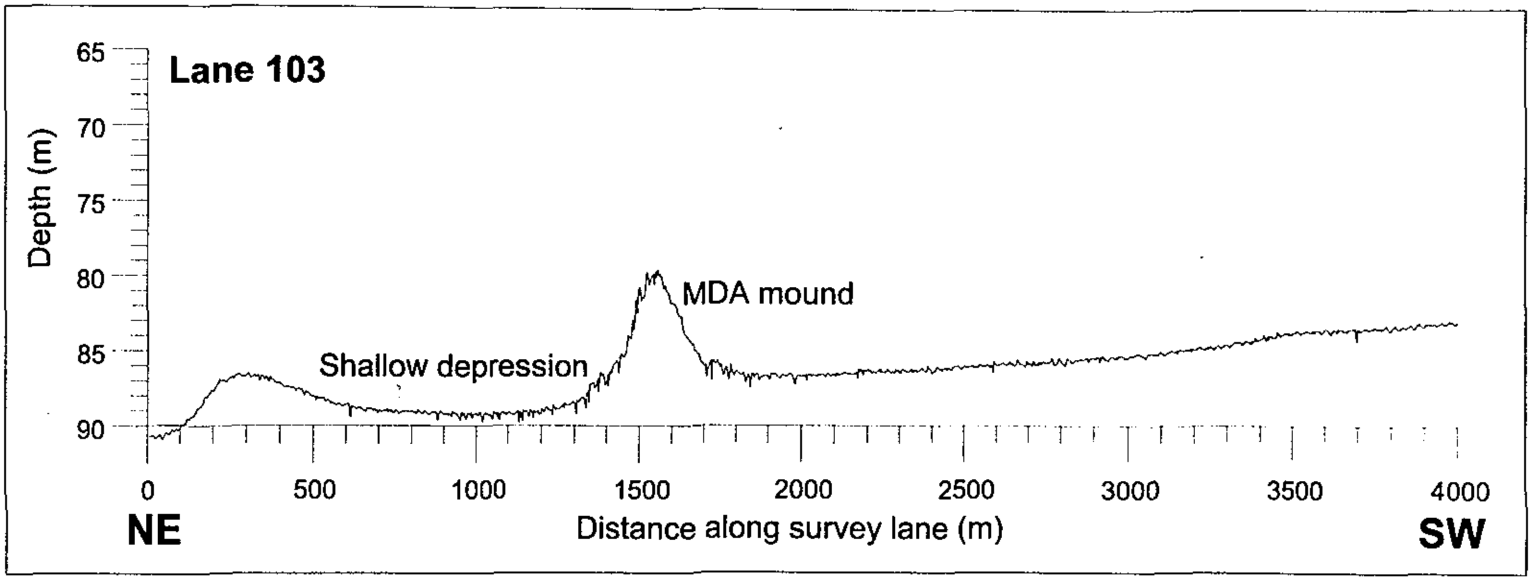

Figure 3-2. Profile plot of survey lane 103 displaying the shallow depressions and the most recent "MDA" mound

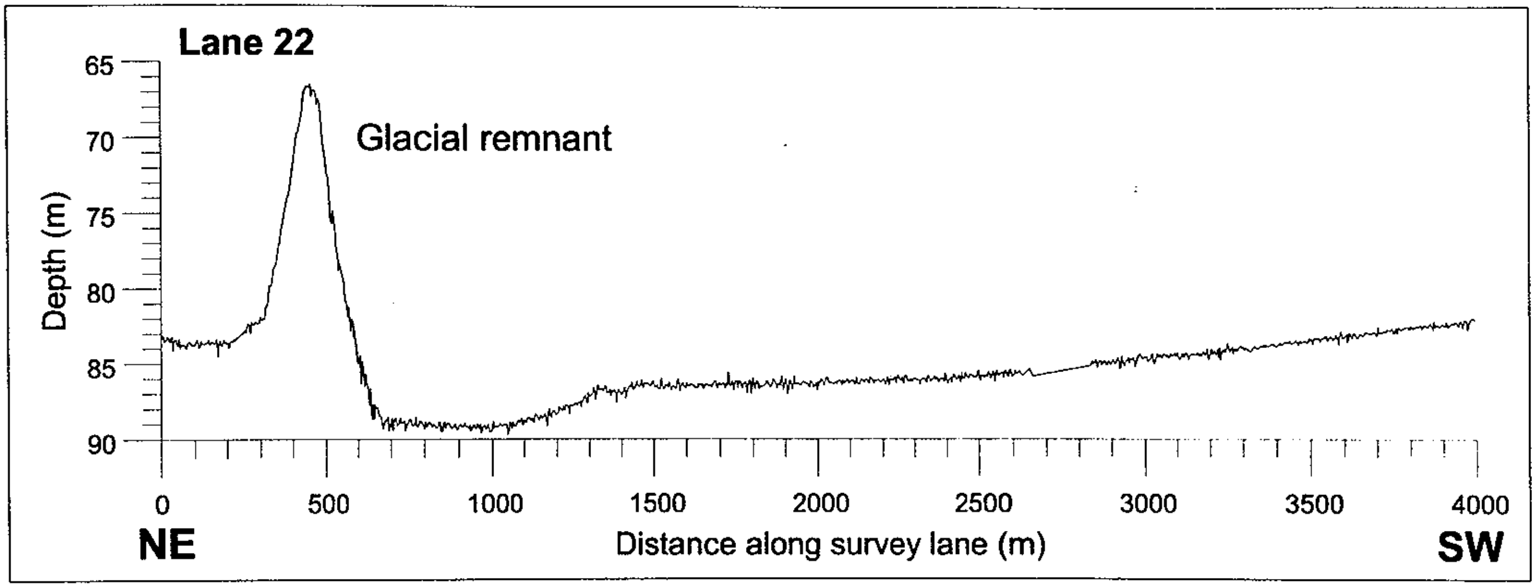

Figure 3-3. Profile plot of survey lane 22 showing the glacial remnant north of the site boundary

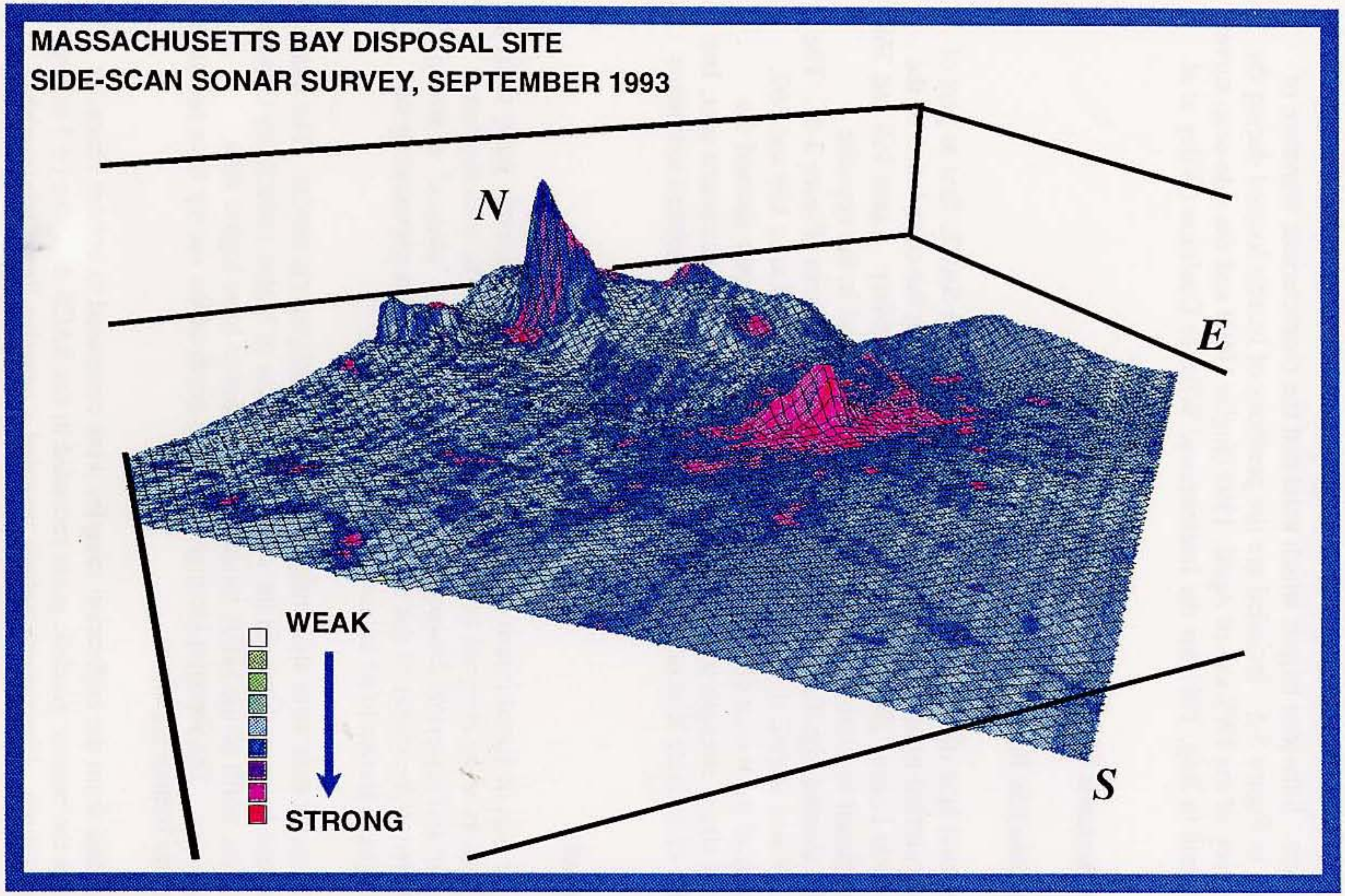

Figure 3-4. Side-scan mosaic draped over a 3-D bathymetric plot

targets from this survey will be produced in a Geographic Information System (GIS) format at a later date. Side-scan targets which exhibited the characteristic signature of barrels are plotted in Figure 3-5. Included are the positions of barrels located during the laser line-scan survey of the IWS site of April, 1993 (Inglin 1994) and the side-scan survey of the IWS conducted in July, 1991 for the International Wildlife Coalition (Wiley et al. 1992).

3.3 Sediment Acoustic Characterization System

3.3.1 Precision Analysis Results

The calibration lane (69) was surveyed three times with the SACS, first as part of the entire survey (referred to as Lane "169"), and twice following the completion of the survey (referred to as Lanes "269" and "369") to test for repeatability. Lanes 169 and 369 were surveyed northeast to southwest, and Lane 269 was surveyed in the opposite direction. Results showed significant agreement among the three lanes (Figure 3-6). The profile of Lane 269 was shifted slightly to the southwest relative to Lanes 169 and 369, probably as a result of the transit direction. The SACS profiles not only showed the relative increase of signal strength over the dredged material in the northeastern area, but also the variability of a single lane of data over dredged material and ambient sediments (Figure 3-6).

3.3.2 SACS Results

The contour plot of signal return strength (in dB) resulted in relatively noisy data; to reduce the noise, colors were assigned to every 5 dB (Figure 3-7). The area that has received both recent and historical dredged material can be seen as a "plateau" of strong signal returns located in the center of the area (Figure 3-7). The area surrounding this higher reflective area is shown to be acoustically featureless.

Bottom character data were also compared with the bathymetric results. The mound at the MDA buoy can be seen clearly in the center of the area of higher reflectivity (Figure 3-8). The depression north of the MDA mound also appears to have higher than background reflectivity. The topographic high at the top north of the survey does not have a distinctive acoustic bottom signature.

Grain size data from the calibration samples were compared to bottom character data (24 kHz) from the nearest geodetic point recorded in the SACS database (±5 m) by linear regression analysis. Regression analysis revealed a negative linear relationship

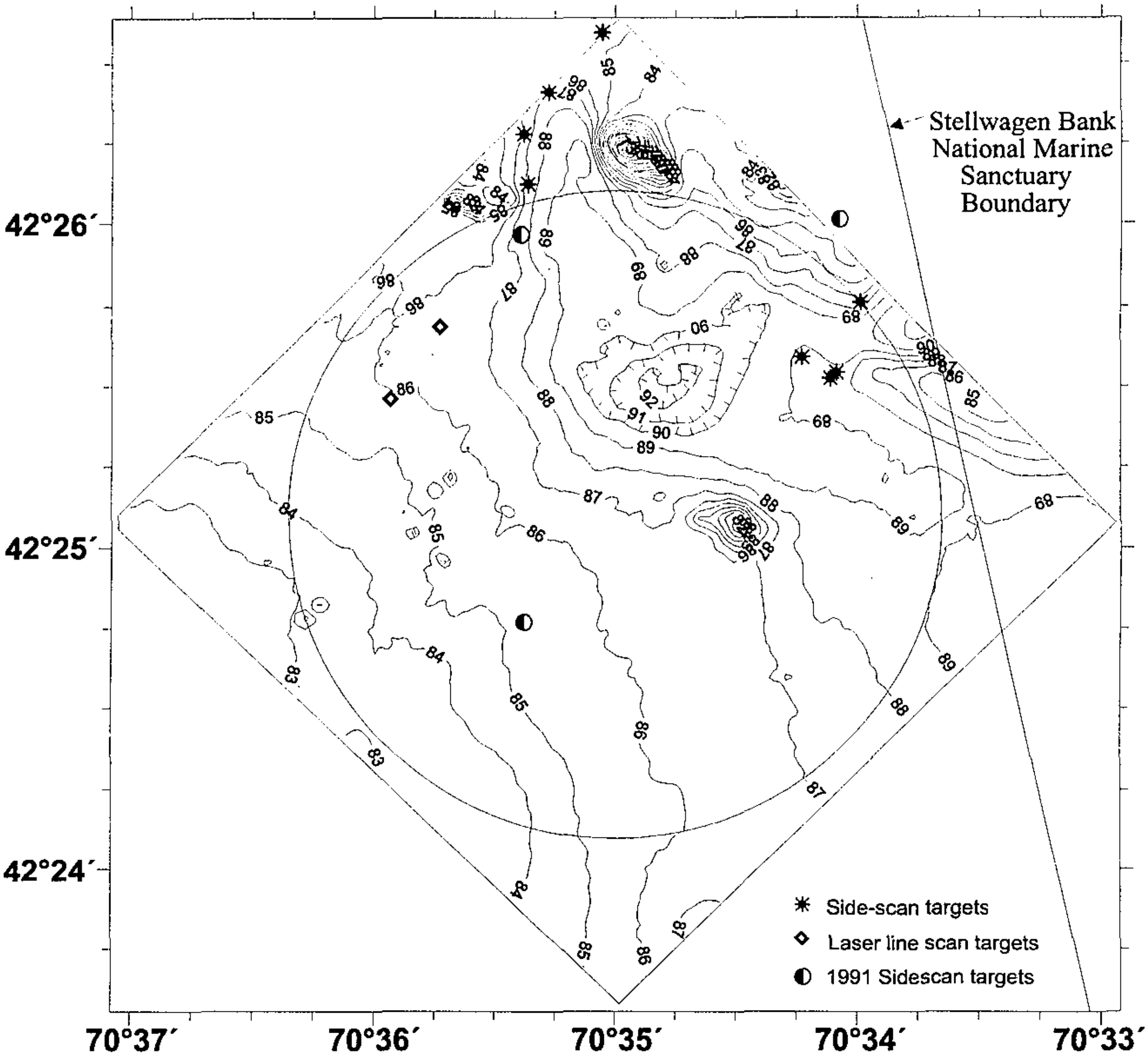

Figure 3-5. Location of acoustic (side-scan sonar) and optical (laser line scan) targets consistent with 55-gallon waste barrels

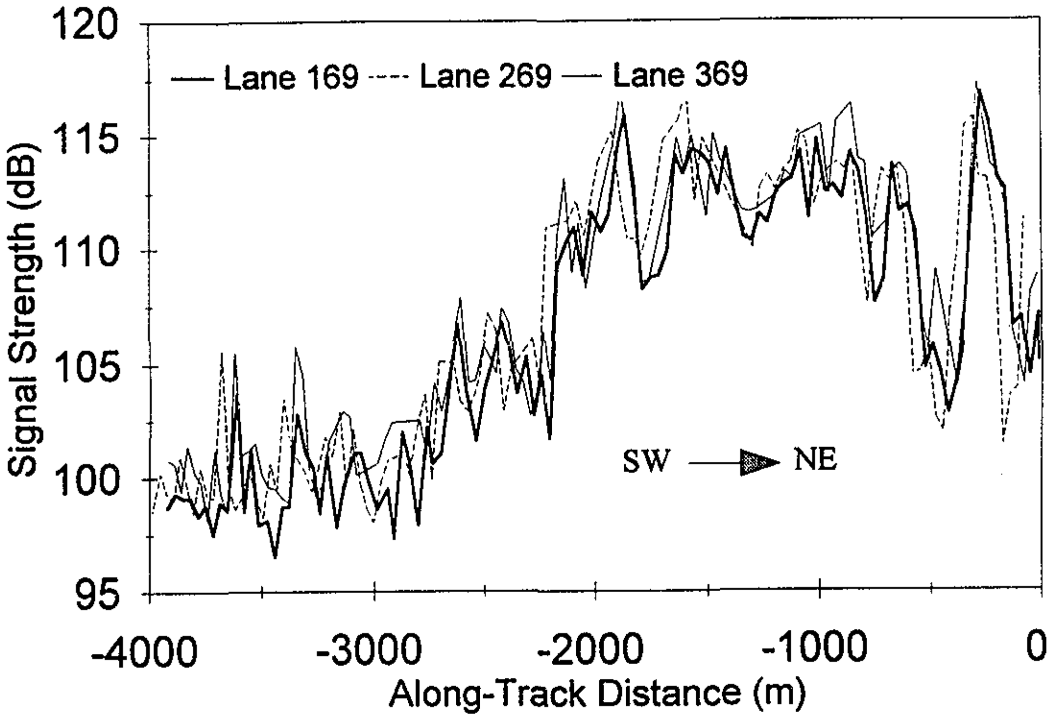

Figure 3-6. Results of SACS precision analysis

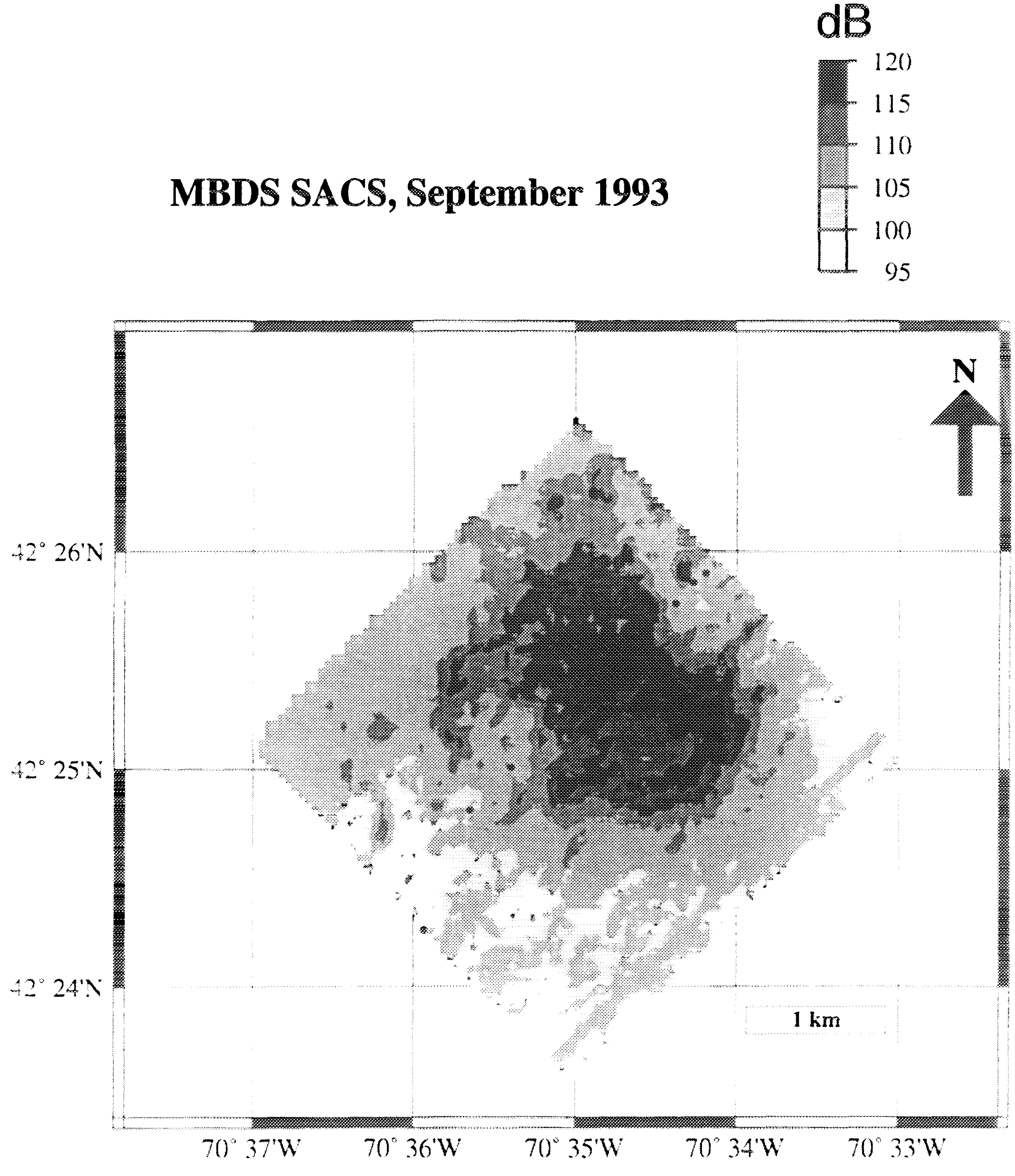

Figure 3-7. SACS signal return strength results

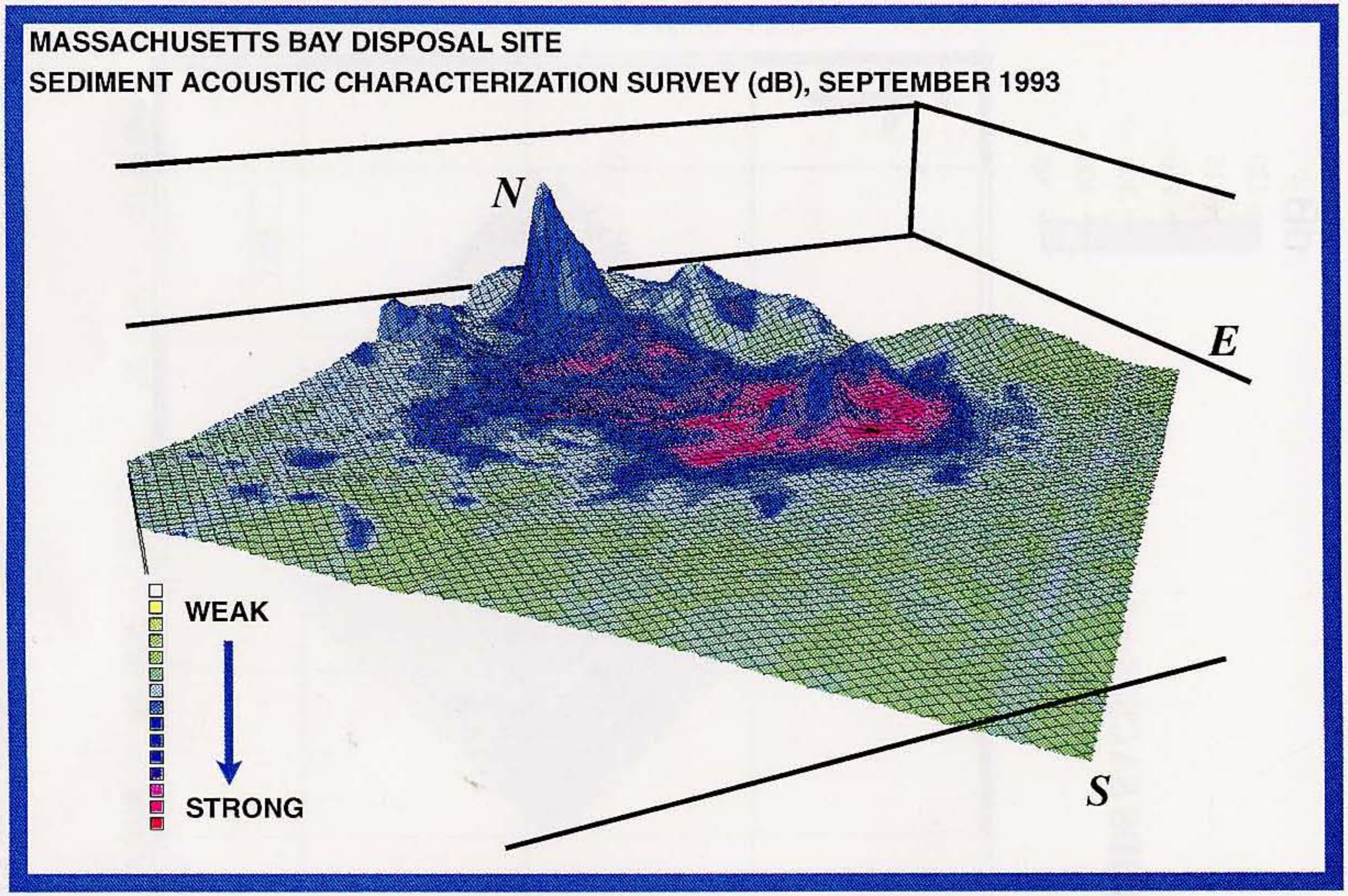

Figure 3-8. SACS contours draped over a 3-D bathymetric plot

between signal strength and percentage of total fines (silts and clay; Figure 3-9). The R^2 value for the correlation was relatively low (0.64). The low R^2 value for correlation of acoustic response and grain size was not unexpected because signal strength is not simply a function of grain size.

The linear equations derived from the regression analyses were applied to the gridded signal strength data in order to provide a qualitative estimate of the percentage of fines and/or sands over the entire survey area. A contour map of the acoustically estimated grain size (percent fines; Figure 3-10) correlated roughly with features observed in the SACS data. The most noticeable feature observed in the grain size map was the MDA mound, marked by sediments that consisted of ~85% fine-grained sediment (Figure 3-10) and ~15% sand, while the surrounding ambient sediments were 90-95% fine grained.

3.4 Sediment Chemistry

For this report, MBDS chemistry data have been reported as both raw and normalized concentrations. Natural variations in sediment parameters can influence the concentration of trace metals and organics. Two such parameters that affect contaminant levels are grain size distribution (Förstner 1989) and TOC content (NOAA 1991). Because contaminants adhere to surfaces, they tend to be associated with the fine-grained fraction of sediment particles which offer more available surface area than do larger particles. In addition, the TOC content affects the adhesiveness of sediment particles which often influences levels of organic contaminants. Trace metals were normalized by dividing the raw concentration by the fraction (by weight) of fine-grained sediment particles, the same method used by the National Status and Trends Program (NS&T; NOAA 1991). Values of Al and Fe are reported, but were not used as a means of normalization, as this method has a lower correlation to trace metals than the NS&T method (NOAA 1991). Organic contaminants were normalized to the percent (by weight) of TOC.

3.4.1 Chemistry Data Quality Assessment

Results submitted by the NED laboratory were accompanied by appropriate documentation of quality control (QC) information, instrument detection limits (IDL), dilution factors, and explanations of data qualification. QC samples consisted of method blanks, surrogates, and matrix spikes. Results of metals, total PCBs, and TOC analyses were found to be acceptable, as indicated by low method blanks and high surrogate spike recoveries, with the exception of a few samples. These exceptions included three Hg, four Cd, and three total PCB measurements which were qualified by the NED laboratory as "J" (above IDL but below practical quantification limits [PQL]). PQLs were defined as the estimated lowest level of measurement that can be reliably achieved within the specified

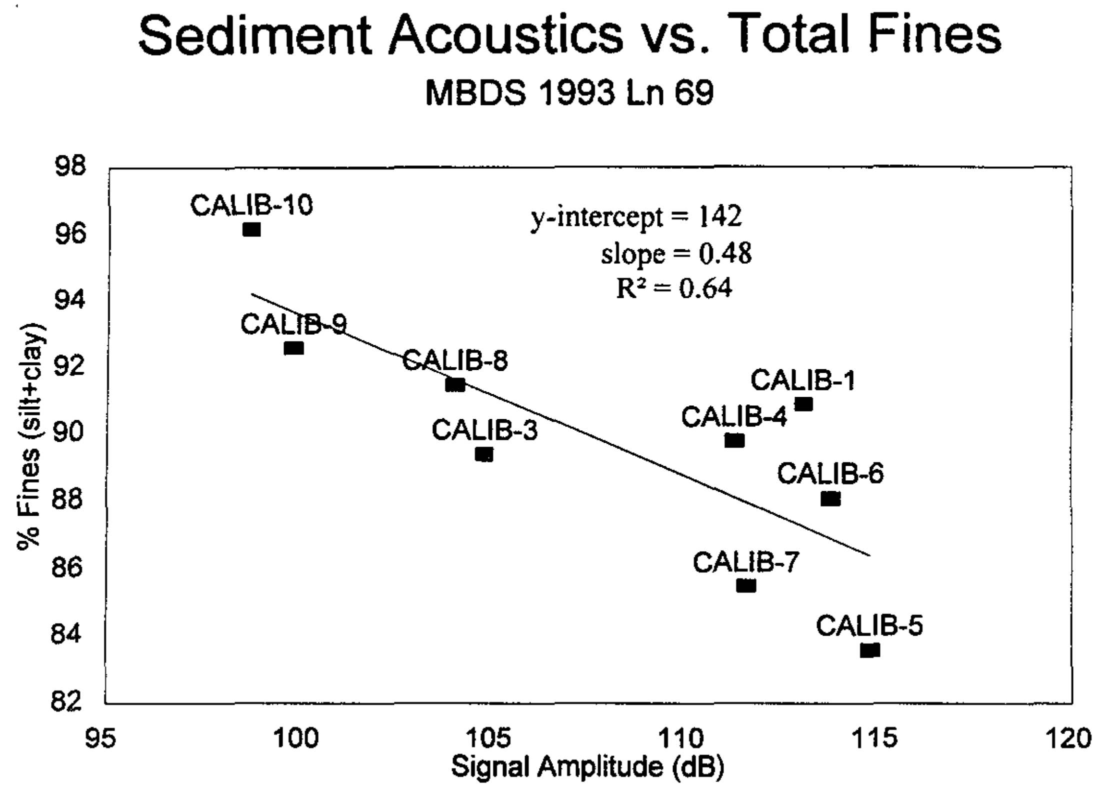

Figure 3-9. Sediment acoustics vs. total fines

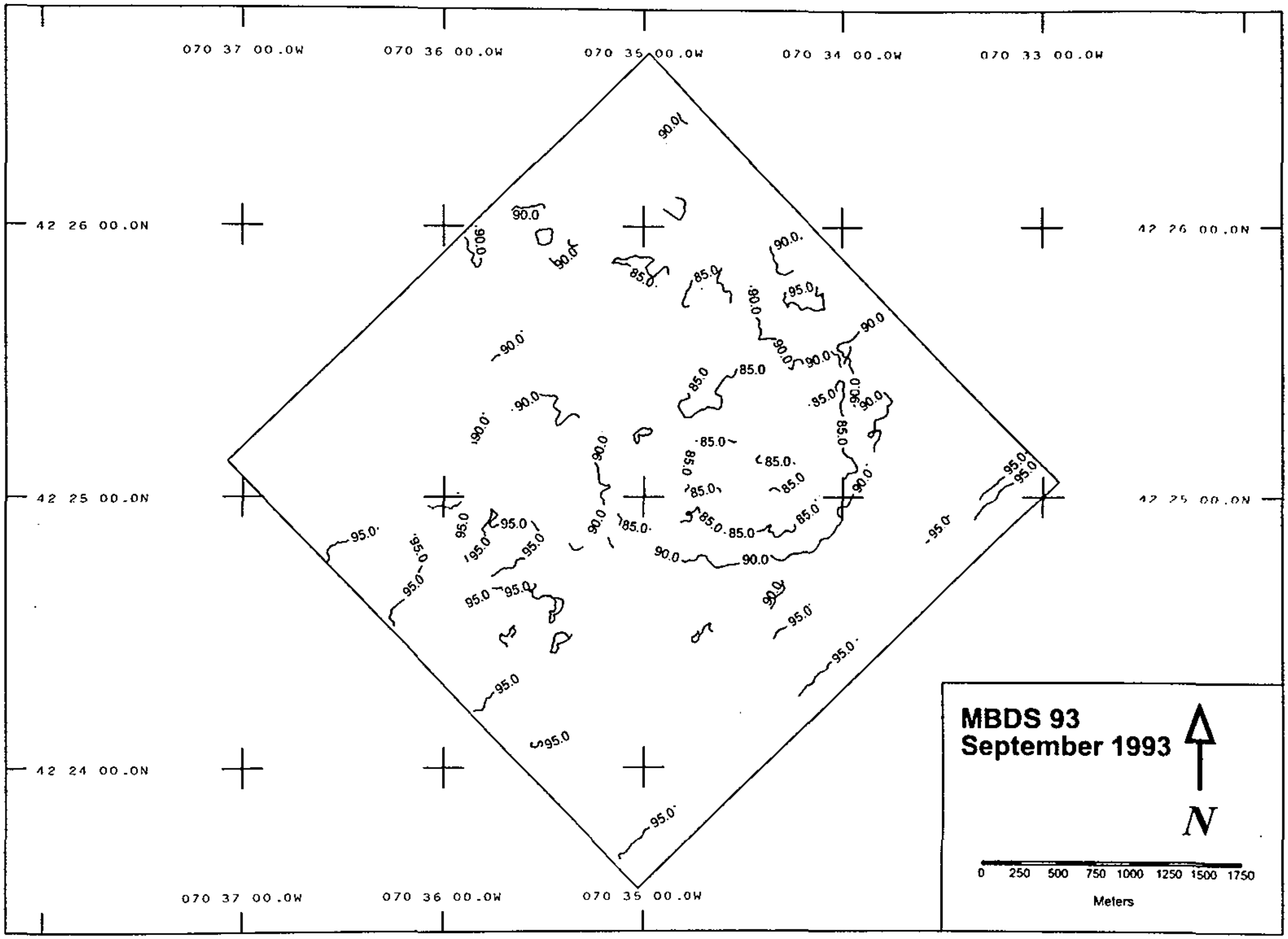

Figure 3-10. Contour plot of estimated fine grain size distribution (%) over MBDS

limits of precision and accuracy during routine laboratory operating conditions for a sample of a particular matrix.

Instrument detection limits for the preliminary analysis of PAHs and pesticides were much higher than the requested levels. Only a few samples had organic concentrations that were measured above detection. During analysis, samples were diluted to varying degrees which affected the IDL. Three PAH samples contained high boiling point nontarget compounds and required dilutions of a factor of 23-28. Consequently, IDLs for these three samples were an order of magnitude greater than the high IDLs for the remaining samples. All samples were reanalyzed by the NED laboratory, with dilution factors ranging from 0.45 to 0.07. In the 12-3 Grid, this reanalysis resulted in all values but one above the IDL.

3.4.2 Grain Size and TOC

MBDS sediments primarily consisted of medium olive-gray silty clay with slightly varying amounts of sand and shell fragments. Grain size analyses showed only small variation between samples and sampling sites. The average percentage (±1s) of total silt and clay for the SACS calibration samples, 12-3 Grid samples, and the combined reference area samples were 89.7% ±3.5%; 84.3% ±1.6%; and 86.8% ±1.6%, respectively (Table 3-1).

With the exception of the SACS "CALIB-2" sample, sediments from the MBDS varied only slightly and were predominately silt and clay with a small percentage of sandy material. Sample "CALIB-2" contained a large proportion (61%) of gravel. As the only sample containing any gravel, CALIB-2 is a statistical outlier and was not included in the statistical values listed in Table 3-1.

Total organic carbon (TOC) was very similar as measured at the 12-3 Grid and the reference areas. Mean TOC at the 12-3 Grid was 2.7% (w/w dry) and ranged less than ±1% from the mean (Table 3-1). The mean reference area TOC value was slightly lower at 2.4% (w/w dry).

3.4.3 PAHs

All PAHs were measured above the IDL in samples from both the 18-17 and FG-23 reference areas with the exceptions of acenaphthylene at Stations 18-17B and 18-17C and the FG-23 REF area; 2,3,5-tri-methylnapthalene at Stations 18-17C; and dibenzo(a,h)-anthracene at Station FG-23A (Table 3-2). At the 12-3 Grid all PAHs were measured

Table 3-1

Grain Size and TOC Results

Grain Size (%)									
STATION	GRAVEL	SAND				SILT	CLAY	FINES	TOC
		COARSE	MEDIUM	FINE	(TOTAL)			(TOTAL)	% (w/w dry)
SACS Calibration									
CALIB-1	0.0	0.2	1.6	7.3	9.1	54.4	36.5	90.9	N
CALIB-2	61.0	0.8	2.6	2.9	6.3	23.9	8.8	32.7	O
CALIB-3	0.0	0.2	1.5	8.9	10.6	46.6	42.8	89.4	T
CALIB-4	0.0	0.4	1.3	8.6	10.3	53.5	36.3	89.8	
CALIB-5	0.0	0.6	1.9	13.9	16.4	46.6	37.0	83.6	A
CALIB-6	0.0	0.5	1.7	9.6	11.8	62.2	25.9	88.1	N
CALIB-7	0.0	0.7	2.5	11.4	14.6	54.7	30.8	85.5	A
CALIB-8	0.0	0.4	2.1	6.0	8.5	56.9	34.6	91.5	L
CALIB-9	0.0	0.6	1.9	4.9	7.4	54.8	37.8	92.6	Y
CALIB-10	0.0	0.2	1.1	2.5	3.8	57.0	39.2	96.2	Z
Minimum*	0.0	0.2	1.1	2.5	3.8	46.6	25.9	83.6	E
Maximum*	0.0	0.7	2.5	13.9	16.4	62.2	42.8	96.2	D
Average*	0.0	0.4	1.7	8.1	10.3	54.1	35.7	89.7	
Standard Deviation*	0.0	0.2	0.4	3.2	3.5	4.7	4.6	3.5	
* Statistical values DO NOT include CALIB-2									
12-3 Grid									
12-3 600N	0.0	2.4	6.0	9.0	17.4	51.2	31.4	82.6	2.5
12-3 400N	0.0	2.4	5.7	8.0	16.1	49.7	34.2	83.9	3
12-3 200N	0.0	2.0	5.1	8.8	15.9	53.7	30.4	84.1	2.5
12-3	0.0	2.0	4.9	10.6	17.5	59.9	22.6	82.5	2.8
12- 3 200S	0.0	2.3	5.2	10.7	18.2	41.8	40.0	81.8	2.6
12-3 400S	0.0	1.9	4.5	9.3	15.7	46.6	37.7	84.3	2.6
12-3 600S	0.0	1.5	4.0	8.9	14.4	44.8	40.8	85.6	2.1
12-3 600W	0.0	2.2	5.2	8.3	15.7	41.8	42.5	84.3	2.8
12-3 400W	0.0	1.2	4.0	8.6	13.8	51.9	34.3	86.2	3.7
12-3 200W	0.0	1.6	3.8	7.4	12.8	50.8	36.4	87.2	2.7
12-3 200E	0.0	1.8	4.5	8.7	15.0	48.3	36.7	85.0	2.7
12-3 400E	0.0	1.7	4.4	8.9	15.0	51.6	33.4	85.0	3
12-3 600E	0.0	1.3	4.1	8.6	14.0	48.3	37.7	86.0	2.9
Minimum	0.0	1.2	3.8	7.4	12.8	41.8	22.6	81.8	2.1
Maximum	0.0	2.4	6.0	10.7	18.2	59.9	42.5	87.2	3.7
Average	0.0	2.0	4.8	9.0	15.8	49.2	35.0	84.3	2.7
Standard Deviation	0.0	0.4	0.7	1.0	1.6	5.3	5.6	1.6	0.4
Reference									
18-17A	0.0	1.8	4.5	9.0	15.3	43.6	41.1	84.7	2.7
18-17B	0.0	1.4	4.2	6.8	12.4	48.0	39.6	87.6	2.0
18-17C	0.0	1.5	4.0	8.4	13.9	43.5	42.6	86.1	2.5
FG-23A	0.0	1.3	3.6	6.7	11.6	45.7	42.6	88.3	2.6
FG-23B	0.0	1.0	3.3	6.9	11.2	49.6	39.2	88.8	2.4
FG-23C	0.0	1.8	4.6	8.5	14.9	43.3	41.8	85.1	2.3
Minimum	0.0	1.0	3.3	6.7	11.2	43.3	39.2	84.7	2.0
Maximum	0.0	1.8	4.6	9.0	15.3	49.6	42.6	88.8	2.7
Average	0.0	1.5	4.0	7.7	13.2	45.6	41.2	86.8	2.4
Standard Deviation	0.0	0.3	0.5	0.9	1.6	2.4	1.3	1.6	0.2

TOC = Total Organic Carbon (percent dry weight)

Table 3-2

Polycyclic Aromatic Hydrocarbon (PAH) Results

	12-3 Grid													
PAH Compound (ppb)	600W	400W	200W	12-3	200E	400E	600E	600N	400N	200N	200S	400S	600S
Low Molecular Weight													
napthalene	860	690	570	1700	220	120	140	130	310	390	260	380	69
2-methyl napthalene	170	150	120	170	57	45	48	41	81	110	76	75	J 23
acenaphthylene	310	160	130	1300	68	42	51	74	120	99	100	170	38
acenaphthene	110	73	88	770	61	J 30	42	J 22	68	150	62	62	J 17
biphenyl	65	42	46	400	26	22	23	20	42	45	33	38	14
2-6 dimethylnapththalene	77	51	45	530	32	27	30	20	46	46	39	43	13
1-methylphenanthrene	78	100	120	320	77	50	44	36	82	82	66	82	23
1-methylnapthalene	83	60	57	1200	32	22	26	21	40	60	65	42	11
2,3,5-tri-methylnaphthalene	33	10	32	180	21	19	20	10	22	23	14	19	6
High Molecular Weight													
fluorene	170	120	170	2200	88	55	71	J 36	100	210	87	100	J 31
phenanthrene	890	770	680	6300	540	340	420	220	520	960	530	510	190
anthracene	480	430	560	2100	160	120	120	85	300	360	210	250	63
fluoranthene	1600	1500	2400	3900	870	610	650	390	880	1200	820	1100	350
pyrene	4900	2300	2900	10000	1400	1000	1100	1000	1900	2300	2100	2700	640
benzo(a)anthracene	1600	880	1300	2700	470	360	370	320	580	740	590	880	220
chrysene	1200	880	1200	2100	430	350	370	290	580	680	530	750	210
benzo(b)fluoranthene	3100	1400	2600	3500	890	690	790	610	1100	1400	1300	1700	470
benzo(k)fluoranthene	2600	1400	2100	4100	910	650	660	560	920	1200	1100	1500	440
benzo(a)pyrene	3000	1400	2500	4000	950	690	730	670	1100	1300	1200	1700	470
indeno(1,2,3-cd)pyrene	1200	620	900	1400	410	340	330	240	390	590	550	630	170
dibenzo(a,h)anthracene	370	190	260	380	120	100	100	56	140	180	160	200	< 10
benzo(g,h,i)perylene	1000	550	680	1200	370	290	300	210	390	530	500	570	150
benzo(e)pyrene	510	260	390	530	170	120	130	94	180	240	200	260	69
perylene	280	130	210	330	87	62	68	76	110	120	110	150	40

	18-17 REF			FG-23 REF		
PAH Compound (ppb)	18-17 A	18-17 B	18-17 C	FG-23 A	FG-23 B	FG-23 C
Low Molecular Weight						
napthalene	44	50	42	27	35	63
2-methyl napthalene	J 22	J 21	J 19	J 16	J 19	J 16
acenaphthylene	J 27	J 28	J 33	J 24	J 24	J 24
acenaphthene	12	< 13	< 13	< 12	< 12	< 11
biphenyl	16	17	15	15	14	12
2-6 dimethylnapththalene	13	13	13	10	11	9.3
1-methylphenanthrene	59	40	23	33	24	25
1-methylnapthalene	10	12	8.8	8.2	12	10
2,3,5-tri-methylnaphthalene	7	4.9	< 19	7.3	4.6	5.9
High Molecular Weight						
fluorene	J 21	J 21	J 20	J 16	J 20	J 18
phenanthrene	160	170	140	140	170	160
anthracene	J 31	J 36	J 31	J 27	J 33	J 37
fluoranthene	290	290	280	280	320	320
pyrene	470	490	360	410	420	360
benzo(a)anthracene	150	150	130	130	150	140
chrysene	160	160	140	150	160	150
benzo(b)fluoranthene	310	390	310	360	350	300
benzo(k)fluoranthene	330	380	270	310	370	290
benzo(a)pyrene	290	350	280	300	310	270
indeno(1,2,3-cd)pyrene	140	190	170	140	140	120
dibenzo(a,h)anthracene	J 18	J 16	49	< 12	40	40
benzo(g,h,i)perylene	140	150	160	140	140	120
benzo(e)pyrene	29	62	71	62	60	66
perylene	31	37	31	33	31	28

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL
Values detected below the instrument detection limit (IDL) are shown as (J)

above the IDL except for dibenzo(a,h)anthracene at Station 600S (Table 3-2). The highest level measured was pyrene; elevated values relative to the other compounds were found at all thirteen 12-3 Grid stations. The maximum concentration, 10000 ppb, was measured at the center station (12-3), and the minimum value, 640 ppb, was measured at 600S. The center station of the 12-3 Grid had the highest levels of all PAH compounds, with levels generally decreasing at the 200 m stations and leveling off with increasing distance. Levels of PAH decreased slightly less at the stations to the west, and levels at 600W were higher than at 400W (Table 3-2).

High molecular weight polycyclic aromatic hydrocarbon (HMW PAH) data from the 12-3 Grid and the 18-17 and FG-23 reference areas were normalized to TOC. Normalized values for the 12-13 Grid samples that contained HMW PAH concentrations above IDL are tabulated in Table 3-3 with normalized 1989 data from Station 12-3 (Murray 1994). Normalized HMW PAH values observed at Station 12-3 in the 1993 survey followed a pattern similar to the unnormalized concentrations. Values for pyrene are plotted for 12-3 station locations in Figure 3-11. Normalized HMW PAH concentrations measured at the 12-3 station in 1989 generally were consistent with the 1993 values, in that five of the eight compounds were higher at 12-3 in both 1989 and 1993 than at all of the surrounding stations. Some variability between sampling years in individual compound concentrations is expected, typical of the spatially patchy character of dredged material. Three of the HMW PAH compounds measured in 1989 including benzo(s)pyrene, indeno(1,2,3-cd)pyrene, and benzo(g,h,i)perylene, had measured levels from half to a third of the 1993 levels, and were exceeded by several of the 1993 stations.

3.4.4 Pesticides and Total PCBs

Three pesticide compounds were measured above detection limits at the 12-3 Grid: 4,4'-DDD (DDD); 4,4'-DDE (DDE); and 4,4'-DDT (DDT). DDE and DDT were each found at only one station: 12-3 and 200S, respectively (Table 3-4). DDD concentrations were measured above detection at seven stations and covered a range of values from 8.4 ppb at 200E to 22 ppb at 400N. Pesticides measured above detection limits at the reference areas were limited to 4,4'-DDD at Stations FG-23A and FG-23B, as well as 4,4'-DDE at Station FG-23 A.

DDE was also the only pesticide measured at MBDS in the 1989 survey (Murray 1994). The measured DDE concentration, normalized to TOC, was 3.7 ppb (Table 3-5). The TOC-normalized concentration of DDE in 1993 was essentially unchanged (3.1 ppb).

Total PCB concentrations were well above the detection limit of 2.5 ppb. PCBs at the 12-3 Grid ranged from 99 ppb at 600S to 810 ppb at 12-3 (Table 3-4). PCB concentrations were also normalized to TOC and showed similar patterns (Table 3-5). Reference area total PCB concentrations varied over a smaller range: 57 ppb (FG-23A) to 120 ppb (18-17C; Table 3-4). Reference area normalized PCBs were generally several times less than MBDS concentrations.

Table 3-3

TOC-normalized PAH Results

	12-3 Grid													
														12-3
PAH Compound (ppb)	600W	400W	200W	200E	400E	600E	12-3	600N	400N	200N	200S	400S	600S	(1989)
High Molecular Weight														
fluorene	61	32	63	33	18	24	786	14	33	84	33	38	15	
phenanthrene	318	208	252	200	113	145	2250	88	173	384	204	196	90	
anthracene	171	116	207	59	40	41	750	34	100	144	81	96	30	
fluoranthene	571	405	889	322	203	224	1393	156	293	480	315	423	167	1375
pyrene	1750	622	1074	519	333	379	3571	400	633	920	808	1038	305	2250
benzo(a)anthracene	571	238	481	174	120	128	964	128	193	296	227	338	105	1088
chrysene	429	238	444	159	117	128	750	116	193	272	204	288	100	1150
benzo(b)fluoranthene	1107	378	963	330	230	272	1250	244	367	560	500	654	224	1200
benzo(k)fluoranthene	929	378	778	337	217	228	1464	224	307	480	423	577	210	
benzo(a)pyrene	1071	378	926	352	230	252	1429	268	367	520	462	654	224	588
indeno(1,2,3-cd)pyrene	429	168	333	152	113	114	500	96	130	236	212	242	81	238
dibenzo(a,h)anthracene	132	51	96	44	33	34	135	22	47	72	62	77	5*	
benzo(g,h,i)perylene	357	149	252	137	97	103	429	84	130	212	192	219	71	263
benzo(e)pyrene	182	70	144	63	40	45	189	38	60	96	77	100	33	
perylene	100	35	78	32	21	23	118	30	37	48	42	58	19	

* Value calculated based on PAH concentration below instrument detection limit (IDL).
Units= PAH (ppb)/TOC (%)

	18-17 REFERENCE AREA			FG-23 REFERENCE AREA		
High Molecular Weight	18-17 A	18-17 B	18-17 C	FG-23 A	FG-23 B	FG-23 C
fluorene	8	11	8	6	8	8
phenanthrene	59	85	56	54	71	70
anthracene	11	18	12	10	14	16
fluoranthene	107	145	112	108	133	139
pyrene	174	245	144	158	175	157
benzo(a)anthracene	56	75	52	50	63	61
chrysene	59	80	56	58	67	65
benzo(b)fluoranthene	115	195	124	138	146	130
benzo(k)fluoranthene	122	190	108	119	154	126
benzo(a)pyrene	107	175	112	115	129	117
indeno(1,2,3-cd)pyrene	52	95	68	54	58	52
dibenzo(a,h)anthracene	7	8	20	5	17	17
benzo(g,h,i)perylene	52	75	64	54	58	52
benzo(e)pyrene	11	31	28	24	25	29
perylene	11	19	12	13	13	12

Table 3-4

Pesticide and PCB Results

	12-3 Grid												
Analyte (ppb)	600W	400W	200W	12-3	200E	400E	600E	600N	400N	200N	200S	400S	600S
Pesticides													
4,4'-DDD	10	< 8.9	< 8.6	14	8.4	< 8.3	< 8.6	9.6	22	9.2	13	< 8.3	< 7.3
4,4'-DDE	< 8.9	< 8.9	< 8.6	8.7	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
4,4'DDT	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	12	< 8.3	< 7.3
aldrin	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
alpha-BHC	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
beta-BHC	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
chlordane	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
delta-BHC	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
dieldrin	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
endosulfan sulfate	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
endosulfan I	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
endosulfan II	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
endrin	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
endrin aldehyde	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.3	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
endrin ketone	< 8.9	< 8.9	< 8.6	< 7.9	< 7.9	< 8.4	< 8.6	< 6.9	< 8.6	< 7.9	< 8.3	< 8.3	< 7.3
gamma-BHC	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
heptachlor	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
heptachlor epoxide	< 4.6	< 4.6	< 4.4	< 4.1	< 4.1	< 4.3	< 4.4	< 3.6	< 4.4	< 4.1	< 4.3	< 4.3	< 3.7
methoxychlor	< 46	< 46	< 44	< 41	< 41	< 43	< 44	< 36	< 44	< 41	< 43	< 43	< 37
toxaphene	< 459	< 459	< 442	< 408	< 408	< 425	< 442	< 357	< 442	< 408	< 425	< 425	< 374
Total PCBs	680	380	260	810	190	180	250	260	290	540	540	360	99

	18-17 REF			FG-23 REF		
Analyte (ppb)	18-17 A	18-17 B	18-17 C	FG-23 A	FG-23 B	FG-23 C
Pesticides						
4,4'-DDD	< 9.2	< 9.6	< 9.6	9.2	9.2	< 8.6
4,4'-DDE	< 9.2	< 9.6	< 9.6	4.8	< 9.2	< 8.6
4,4'DDT	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
aldrin	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
alpha-BHC	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
beta-BHC	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
chlordane	< 4.8	< 4.9	< 4.9	< 5	< 4.8	< 4.4
delta-BHC	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
dieldrin	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
endosulfan sulfate	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
endosulfan I	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
endosulfan II	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
endrin	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
endrin aldehyde	< 9.2	< 9.6	< 9.6	< 9.2	< 9.2	< 8.6
endrin ketone	< 9.2	< 9.6	< 9.6	< 9	< 9.2	< 8.6
gamma-BHC	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
heptachlor	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
heptachlor epoxide	< 4.8	< 4.9	< 4.9	< 4.8	< 4.8	< 4.4
methoxychlor	< 48	< 49	< 49	< 48	< 48	< 44
toxaphene	< 476	< 493	< 493	< 476	< 476	< 442
Total PCBs	96	110	120	57	61	59

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.

PCBs = Polychlorinated Biphenyls

Table 3-5

TOC-normalized Pesticide and PCB Results

Station	Pesticides (ppb)			Total PCBs (ppb)	TOC (% w/w dry)
	4,4'-DDD	4,4'-DDE	4,4'-DDT		
600W	3.6			243	2.8
400W				103	3.7
200W				96	2.7
12-3	5.0	3.1		289	2.8
200E	3.1			70	2.7
400E				60	3.0
600E				250	2.9
600N	2.6			70	2.5
400N	8.1			107	3.0
200N	3.3			193	2.5
200S	4.8		4.4	200	2.6
400S				120	2.6
600S				34	2.1
12-3 (1989)		3.7			
Reference Areas					
18-17 A				35.6	2.7
B				55	2.0
C				48	2.5
FG-23 A				21.9	2.6
B				25.4	2.4
C				25.7	2.3

Values below the instrument detection limit (IDL) are shown as less than (<) the IDL.
PCBs = Polychlorinated Biphenyls
TOC = Total Organic Carbon (percent dry weight)

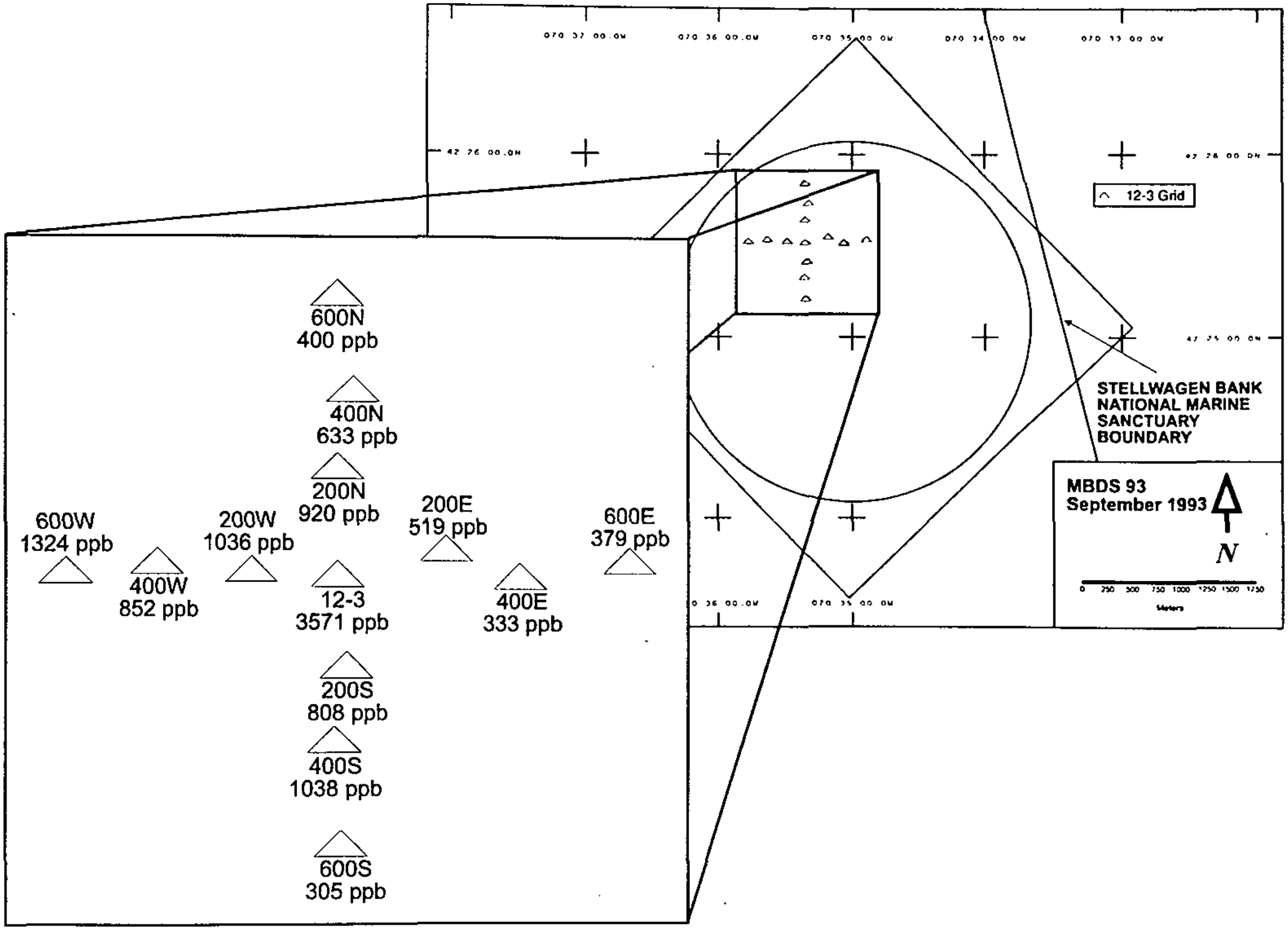

Figure 3-11. Distribution of pyrene values at 12-3 stations in 1993

3.4.5 Trace Metals

Ten trace metals (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, and Zn) were analyzed (Table 3-6); metals concentrations generally were consistent between stations. Station 12-3 contained the highest concentrations of Cd, Cr, Cu, Hg, Ni, and Zn (2.9, 150, 62, 0.13, 30, and 160 ppm, respectively; Table 3-6). The maximum As concentration, 18 ppm, was measured at Station 400W, and the Pb maximum, 180 ppm, was found at Station 600N. Pb concentrations displayed the largest range of values observed at the 12-3 Grid, ranging from a maximum of 180 ppm at Station 600N to 3.5 ppm at Station 400W. The lowest Cd concentration was an estimated value of 0.81 ppm at Station 400N. Concentration minima for As, Cu, and Hg (9.2, 34, and 0.037 ppm, respectively) were measured at Station 600N. Minimum concentrations of Cr and Ni were observed at Stations 400E and 200E, respectively. Comparison of trace metal concentrations between 1989 and 1993 at Station 12-3 (Table 3-6) revealed only minor differences. Chromium and Ni were slightly elevated in 1993, while Cu, Hg, Pb, and Zn were all slightly lower.

Metals concentrations were also normalized for the fraction of fine-grained material (Table 3-7). Normalized concentrations showed the same patterns as the unnormalized concentrations. Comparisons of the 1989 and 1993 normalized metals concentrations were also similar, except that the normalized value of Cu remained unchanged at 75.

Almost all of the metals concentrations at both the disposal site and the two reference areas were within the "low" category of contaminated sediments as classified by the New England River Basins Commission (NERBC 1980). Exceptions which fell in the "moderate" category included thirteen (out of nineteen) As results (10–20 ppm), two Cr results (100–300 ppm), and one Pb result (100–200 ppm). Two reference samples, 18-17A and 18-17B, had "moderate" contaminant levels of As (15 ppm and 11 ppm, respectively; Table 3-8).

The two reference areas were also sampled in 1989 (Table 3-8). Comparing both unnormalized and normalized metal concentrations, values did not change significantly for any metal except for Hg. Mercury is consistently higher in samples collected in 1989. The difference may be due to the sample preparation or analyses method, as the data from 1989 and 1993 were analyzed by two separate laboratories.

In addition to the eight trace metals required by the current guidance (EPA/USACE 1991), Al and Fe were also analyzed by the NED laboratory for use as a possible means of normalization against other data sets. It was decided after analysis that normalization should follow NS&T methods, and the data was normalized to percent fines. Al concentrations ranged from a minimum concentration of 17,000 ppm at Station 200E to a

Table 3-6

Metal Results

Station Name	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Al	Fe
600W	14	0.96	100	42	0.043	28	79	140	29000	29000
400W	18	1.9	84	45	0.11	27	3.5	150	19000	28000
200W	9.4	1.8	88	44	0.11	27	71	150	18000	25000
200E	11	1.7	81	45	0.093	23	77	110	17000	24000
400E	12	2	77	40	0.07	25	72	110	18000	27000
600E	13	1.9	82	38	0.076	26	52	110	19000	26000
600N	9.2	0.94 J	95	34	0.037	26	180	110	28000	28000
400N	11	0.81 J	99	38	0.049	28	58	120	24000	30000
200N	12	1	86	40	0.064	25	70	110	21000	27000
200S	12	2	88	41	0.067	27	57	110	19000	27000
400S	10	1.7	89	37	0.053	26	42	100	19000	26000
600S	12	2.1	77	37	0.04	29	42	100	22000	31000
12-3 (1993)	13	2.9	150	62	0.13	30	84	160	20000	28000
12-3 (1989)	na	na	139	74	0.47	16	110	221	na	na
Minimum	9.2	0.81	77	34	0.037	23	3.5	100	17000	24000
Maximum	18	2.9	150	62	0.13	30	180	160	29000	31000
Mean	12	1.7	95	44	0.101	26	71	129	21000	27385
Std. Dev.	2	0.6	22	11	0.110	3	40	33	3808	1938

J = Value is estimated (above the IDL but below the practical quantification limit).

na = Not Analyzed.

All units are ppm.

Statistical values are calculated only on 1993 data.

Table 3-7

Grain Size-normalized Metal Results

Station Name	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	Al	Fe
600W	17	1.1	119	50	0.05	33	94	167	34524	34524
400W	21	2.2	98	52	0.13	31	4	174	22093	32558
200W	11	2.1	101	51	0.13	31	82	172	20690	28736
200E	13	2.0	95	53	0.11	27	91	129	20000	28235
400E	14	2.4	91	47	0.08	29	85	129	21176	31765
600E	15	2.2	95	44	0.09	30	60	128	22093	30233
600N	11	1.1	114	41	0.04	31	217	133	33735	33735
400N	13	1.0	118	45	0.06	33	69	143	28571	35714
200N	14	1.2	102	48	0.08	30	83	131	25000	32143
200S	15	2.4	107	50	0.08	33	70	134	23171	32927
400S	12	2.0	106	44	0.06	31	50	119	22619	30952
600S	14	2.4	90	43	0.05	34	49	116	25581	36047
12-3 (1993)	16	3.5	181	75	0.16	36	101	193	24096	33735
12-3 (1989)	na	na	140	75	0.47	16	111	223	na	na
Minimum	11	1.0	90	41	0.04	27	4	116	20000	28235
Maximum	21	3.5	181	75	0.16	36	217	223	34524	36047
Mean	14	2.0	111	51	0	30	83	149	24873	32408
Std. Dev.	3	0.7	24	11	0	5	47	32	4698	2427

na = Not Analyzed.

Corrected for fine-grained fraction (by weight).

Statistical values are calculated only on 1993 data.

Table 3-8a

Reference Area Metal Results

	18-17 Reference					FG-23 Reference				
Metals (ppm)	A	B	C	Mean	(1989)	A	B	C	Mean	(1989)
Arsenic	15	11	7.0	11	na	5.3	8.2	5.7	6.4	na
Cadmium	0.72 J	0.66 J	2.0	1.1	na	1.9	1.6	1.7	1.7	na
Chromium	90	97	96	94	83	96	83	87	89	64
Copper	21	22	29	24	37	25	23	24	24	21
Mercury	0.017 J	0.018 J	0.035	0.023	0.21	0.036	0.036	0.017 J	0.030	0.19
Nickel	27	28	30	28	26	31	27	28	29	21
Lead	41	46	52	46	62	47	41	41	43	38
Zinc	97	100	110	102	135	100	92	98	97	97
Aluminum	31000	32000	24000	29000	na	23000	20000	22000	21667	na
Iron	29000	31000	31000	30333	na	30000	25000	29000	28000	na

J = Value is estimated (above the IDL but below the practical quantification limit).

na = Not Analyzed.

Table 3-8b

Reference Area Grain Size-normalized Metal Results

	18-17 Reference					FG-23 Reference				
Metals (ppm)	A	B	C	Mean	(1989)	A	B	C	Mean	(1989)
Arsenic	18	13	8	13	na	6	9	7	7	na
Cadmium	0.8	0.8	2.3	1.3	na	2.2	1.8	2.0	2.0	na
Chromium	106	110	112	109	85	109	93	102	102	66
Copper	25	25	34	28	38	28	26	28	27	22
Mercury	0.02	0.02	0.04	0.03	0.21	0.04	0.04	0.02	0.03	0.20
Nickel	32	32	35	33	27	35	30	33	33	22
Lead	48	52	60	54	63	53	46	48	49	39
Zinc	114	114	128	119	138	114	103	115	111	100
Aluminum	36471	36364	27907	33580	na	26136	22472	25882	24830	na
Iron	34118	35227	36047	35130	na	34091	28090	34118	32099	na

na = Not Analyzed.

Corrected for fine-grained fraction (by weight).

maximum of 32,000 ppm at 18-17B. The minimum Fe concentration, 24,000 ppm, was also found at Station 200E while the maximum value, 31,000 ppm, was found at Stations 600S and 18-17B and C (Table 3-6).

4.0 DISCUSSION

4.1 Bathymetry

The topography of the new site offers two distinctly different areas, each with features relevant for site management. The southwestern half of the disposal site was relatively flat and featureless; over the 1 nmi radius of the site, the water depth increased by only four meters (Figure 3-1). Outside of the IWS and Interim Site boundaries and less impacted by historic disposal, this flat topography allows more accurate tracking of the mounds created by future disposal events. The northeastern half of the disposal site, however, included several bathymetric features. The most recent MDA mound was located 700 m east of the site center. A plot of disposal log coordinates (Figure 4-1) from 1992 and 1993 showed a high level of disposal activity at the MDA buoy directly over this mound. The disposal mound rose approximately seven meters above the surrounding ambient seafloor and covered an approximate area of 125,000 m^2. Due to the geographic location and survey orientation of this baseline study, volume calculations cannot be obtained by direct depth-differencing with bathymetric models produced from prior surveys of the interim MBDS.

A prominent bathymetric feature located in the northeastern half of the disposal site was a large shallow depression centered approximately 800 m northeast of the site center. This basin can be enhanced by management of future disposal events to create a potential capping site. The depth increased from the site center at 87 m to 92 m at the center of the basin. Three arms radiated from the center of the basin in northerly, northeasterly, and southeasterly directions. Finally, north of the shallow depression and outside of the new disposal site boundary, the distinct topographic high was mapped. This feature lies at the foot of the Stellwagen Bank terminal moraine and is thought to be a remnant glacial outcrop (Oldale et al. 1973).

4.2 Bottom Characterization

Two methods were used to acoustically characterize MBDS sediments: dual side-scan sonar and the SACS. Both systems provide information about bottom "hardness" by measuring the strength of the returning acoustic signal. The low-frequency transducer of the SACS data, however, should result in reflection of a composite of the upper sediment layer, rather than a strict surface return as with the higher frequency side-scan system.

Results from the SACS and side-scan systems generally were in good agreement. Data collected from both systems indicated that the majority of the disposal site was characterized by relatively soft surface sediments. The acoustic results supported the

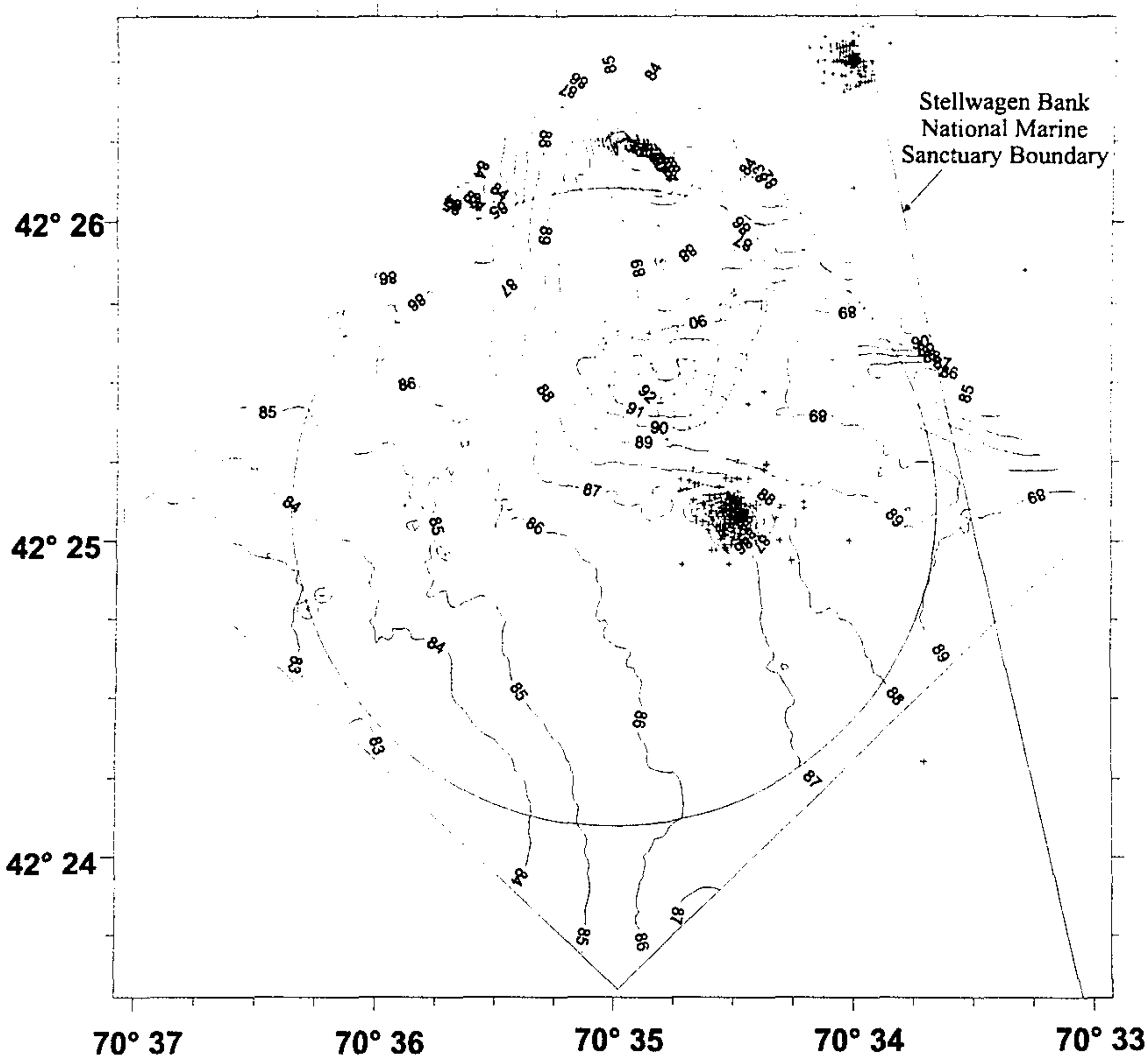

Figure 4-1. Barge disposal points from 1992 and 1993

conclusion that the ambient sediments of Stellwagen Basin are fine-grained silts and clays. These results indicated that the upper sediment layer is homogeneous throughout most of the area, relatively unaffected by anthropogenic influence.

Both data sets indicated that the MDA mound and the area immediately surrounding the mound were distinctively more reflective than ambient sediments. The most recently disposed material from the Third Harbor Tunnel project in Boston Harbor contained both rock fragments from tunnel blasting and large consolidated blocks of Boston blue clay (Wiley 1993). The acoustic reflection from both of these materials should be stronger than the ambient silts and clays, as supported by both the side-scan and SACS results.

The two most significant differences between the two data sets were associated with the large depression and the glacial knoll. Both the side-scan paper traces and the mosaic suggested that the glacial knoll was covered with rubble and debris and relatively hard bottom. But this geological feature had less uniformly hard returns in the SACS data, although the area does have higher reflectivity than ambient. In comparing the SACS results with bathymetry (Figure 3-8), however, it appears that the flat top of the knoll has lower reflectivity, and is potentially covered with ambient fine-grained material. The differences between the two data sets may be largely operational, with at least two factors at work. The bottom coverage of the side-scan system is greater as it integrates over a large linear swath (~150 m), whereas the SACS data is contoured over a series of discrete points (received from a circular area ~30 m in diameter). Also, the effect of slope influences side-scan data more severely because the first returns will be from the shallowest areas and therefore the wider swath of the side-scan data will be more distorted than that collected by the narrow-beam SACS transducer.

The opposite situation held for the basin north of the MDA mound. This area appeared harder than ambient in the SACS data (Figure 3-8), but was indistinguishable from ambient in the side-scan mosaic (Figure 3-4). Barge logs and historic buoy positions indicate that disposal activity had occurred within the basin from 1984 to 1985 (Figure 4-2). We interpret the difference in the acoustic reflection data as a difference in the depth interval over which both instruments are measuring. The pulse width of the low-frequency SACS transducer limits the depth resolution of the first subbottom acoustic return to a minimum of 35 cm in the study area. With time, in the depositional regime of Stellwagen Basin, the dredged material will be biologically reworked and covered with ambient silts and clays, resulting in a surficial layer that resembles ambient sediment. The resolution of the SACS low-frequency transducer indicated only that this interval is <35 cm thick. By contrast, the underlying layer presumably still contains somewhat coarser grained, more chaotic dredged material that has a harder acoustic return than the surface. Later surveys at other sites have demonstrated a depth dependent correlation with signal return in SACS

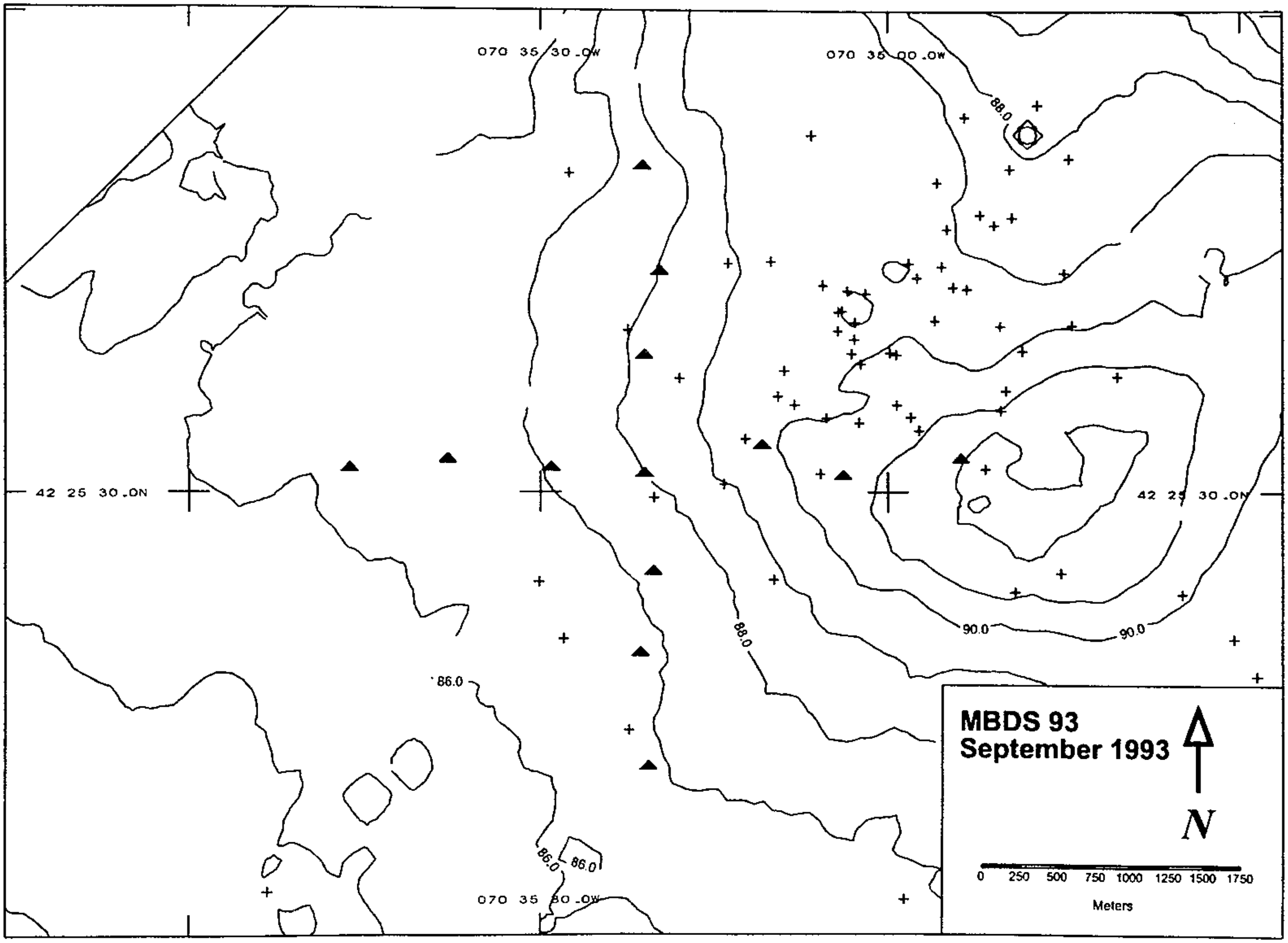

Figure 4-2. Barge disposal points from 1984 and 1985 relative to 12-3 sample grid

data; when relative depth at the site increases, signal return tends to increase, while an decrease in depth tends to decrease signal return. On a relatively flat site such as MBDS, this effect is minimized, but would explain the differences in the acoustic records for the relative decrease in return for the glacial knoll, and the relative increase in return for the depression.

Recent work has attempted to relate the surficial reflection coefficient to surface sediment characteristics such as density, porosity, and grain size (e.g., LeBlanc et al. 1992). Models that predict sediment characteristics based on acoustic reflectivity generally rely on relatively homogeneous sediments. A dredged material deposit is heterogeneous by nature because of its formation by successive disposal episodes from potentially different areas representing different types of material. Factors such as dredged material heterogeneity and bottom roughness certainly influenced the resultant high variability of the surface R values.

4.3 Sediment Chemistry

4.3.1 The 12-3 Grid

The 12-3 Grid was sampled in response to questions raised from the results of sediment sampling conducted in the interim MBDS in 1989 (Murray 1994). Results from 1989 indicated that the maximum concentration for several metals (i.e., Cr, Cu, Zn, and Hg) was measured at Station 12-3, and the trend of total HMW PAHs indicated a general increase towards Station 12-3. Because Station 12-3 was located on the far western edge of the interim MBDS, no samples were collected west of this station, and information concerning metals and/or PAHs ended abruptly at the site border.

With the relocation of the disposal site, Station 12-3 was located approximately 750 m northwest of center of the new MBDS. Chemical data were collected in the 1993 survey in order to determine the extent of this area of elevated PAHs and metals. The 12-3 Grid was centered at Station 12-3 with sampling stations radiating along the four major compass points, spaced at 200 m increments.

As with the 1989 data, Station 12-3 represented the highest measured concentration for several of the metals analyzed. Six (Cd, Cr, Cu, Hg, Ni, and Zn) of the eight metals usually required by current EPA/USACE guidance had concentration maxima located at the 12-3 station. The concentration of Cu, for example, reached a peak value of 62 ppm (Figures 4-3 and 4-4) at Station 12-3. Two hundred meters to the north, south, east, and west, Cu concentrations decreased to 18–22 ppm.

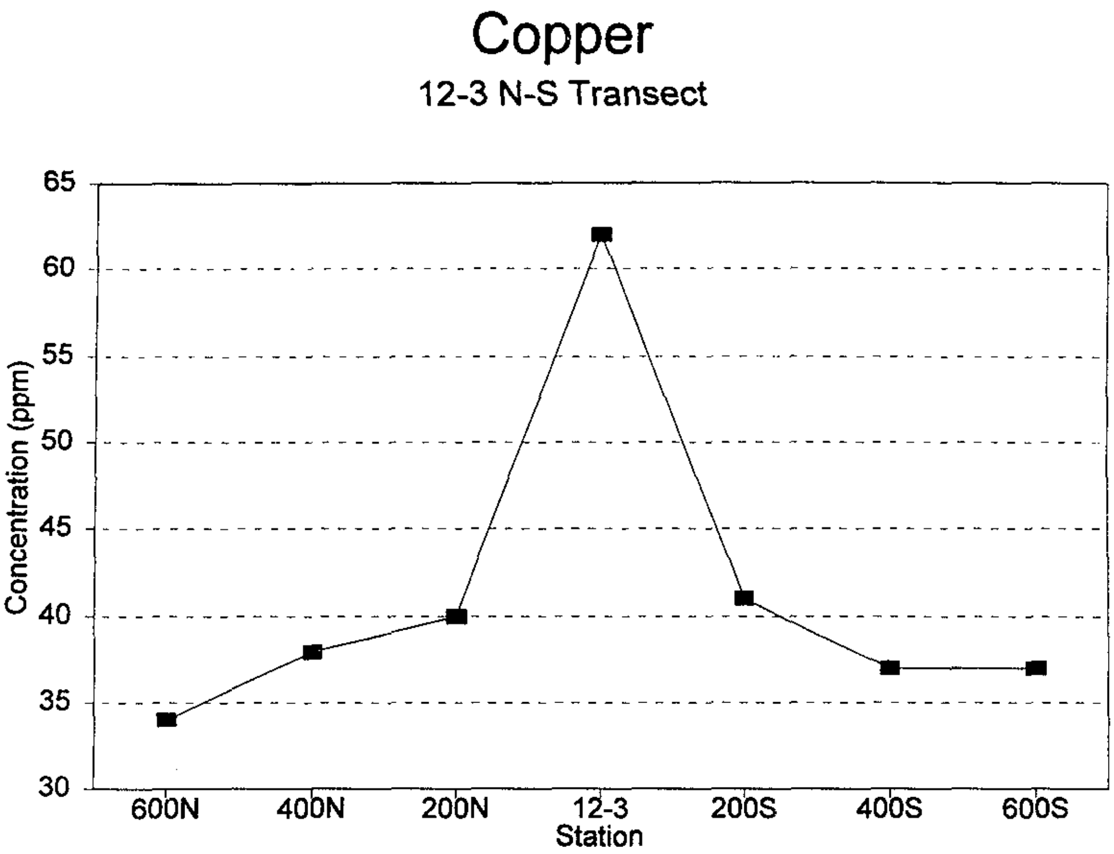

Figure 4-3. Copper concentration along 12-3 north-south transect

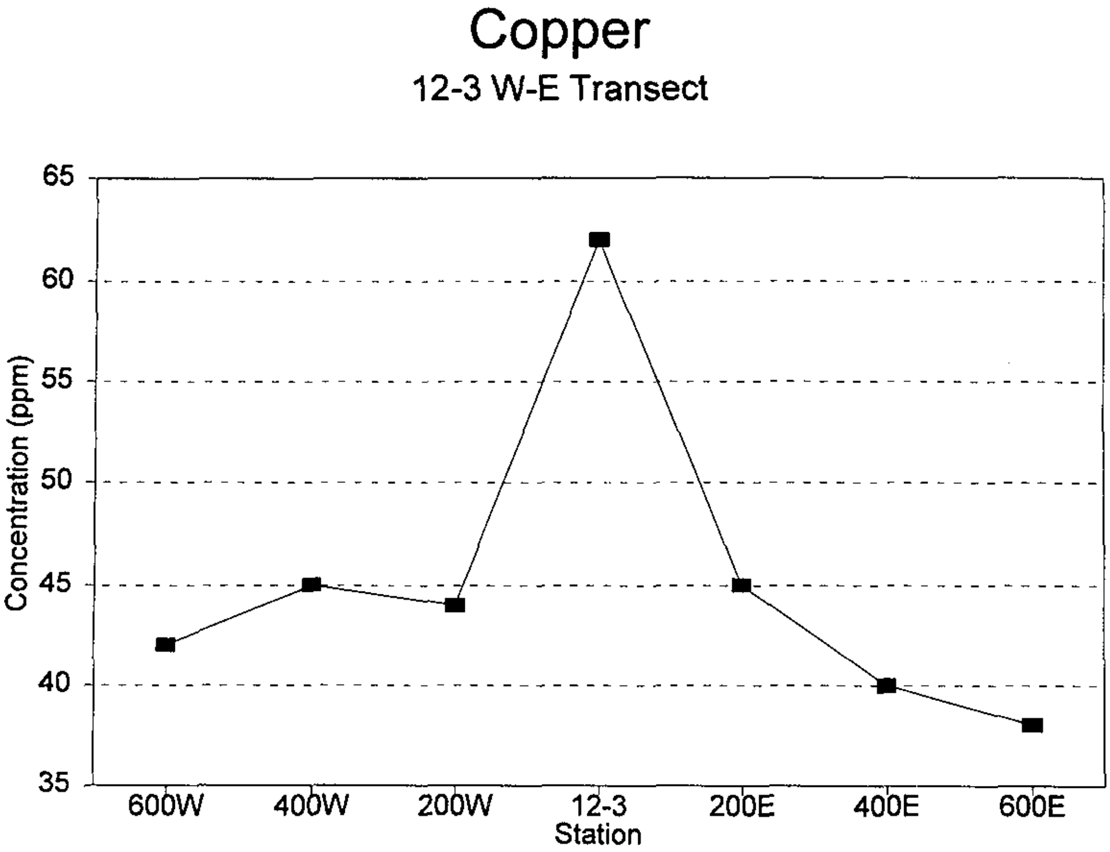

Figure 4-4. Copper concentration along 12-3 west-east transect

Spatial patterns of organic compounds, including total PCBs and PAHs, displayed a similar radial concentration decrease away from 12-3. The 12-3 station was the center of highest concentration for all LMW PAH and HMW PAH compounds (Table 3-2). PAH concentrations, like the metals, decreased sharply within a 200 m radius of 12-3. Beyond 200 m, PAH concentration values tended to level off. Stations to the west had somewhat higher concentrations of PAHs, and PAHs increased at 600W from the 400W levels, although not to the level seen at 200W.

Prior to 1986, a conventionally moored disposal buoy was located north of the present disposal mound; disposal points from the 1985–1986 time frame show a widely scattered pattern over the basin (Figure 4-2). Station 12-3 was located among these disposal points; in fact, the station is approximately 50 m from a barge disposal point (Figure 4-2). The contaminants in the area of 12-3 may be related to that particular barge load, which originated from Port Norfolk (1985), but also may be a remnant of historical waste disposal in the IWS.

4.3.2 Reference Area Chemical Trends

Three reference areas have been sampled periodically since monitoring activities at MBDS. In 1994, a new reference area was designated by the EPA as a replacement of the 18-17 reference area thought to be not representative of control conditions. Two historical reference areas (FG-23 and 18-17) have been chemically characterized primarily for metals and PCBs since 1985. These data, in comparison with the 1993 sampling, are discussed here. (Because grain size data were not available prior to 1987, non-normalized data are discussed.)

Comparison of reference area data for five metals (Cr, Cu, Ni, Pb, and Zn) for FG-23 (Figure 4-5) and 18-17 (Figure 4-6) revealed that metal concentrations have not varied consistently since 1987 at Station FG-23, or since 1985 at Station 18-17. On average, trace metal concentrations from MBDS are only slightly elevated above reference area data, and have remained nearly constant since 1989 (Table 4-1). Chromium has risen consistently at both reference areas since 1987 and at MBDS since 1989; however, this rise of Cr levels was within the variability of the data.

Total PCB concentrations measured in 1993 were elevated in samples from both the reference areas and at MBDS as compared to samples collected in 1989. All but one sample from 1989 had total PCB levels below the detection limit (<20 ppb); the one detected value was at FG-23 (23 ppb; qualified as estimated; Murray 1994). In 1993, total PCB levels were much higher, ranging from 99 to 810 ppb (Table 3-4). While these PCB concentrations greatly exceed levels measured in 1989, they are more comparable to data

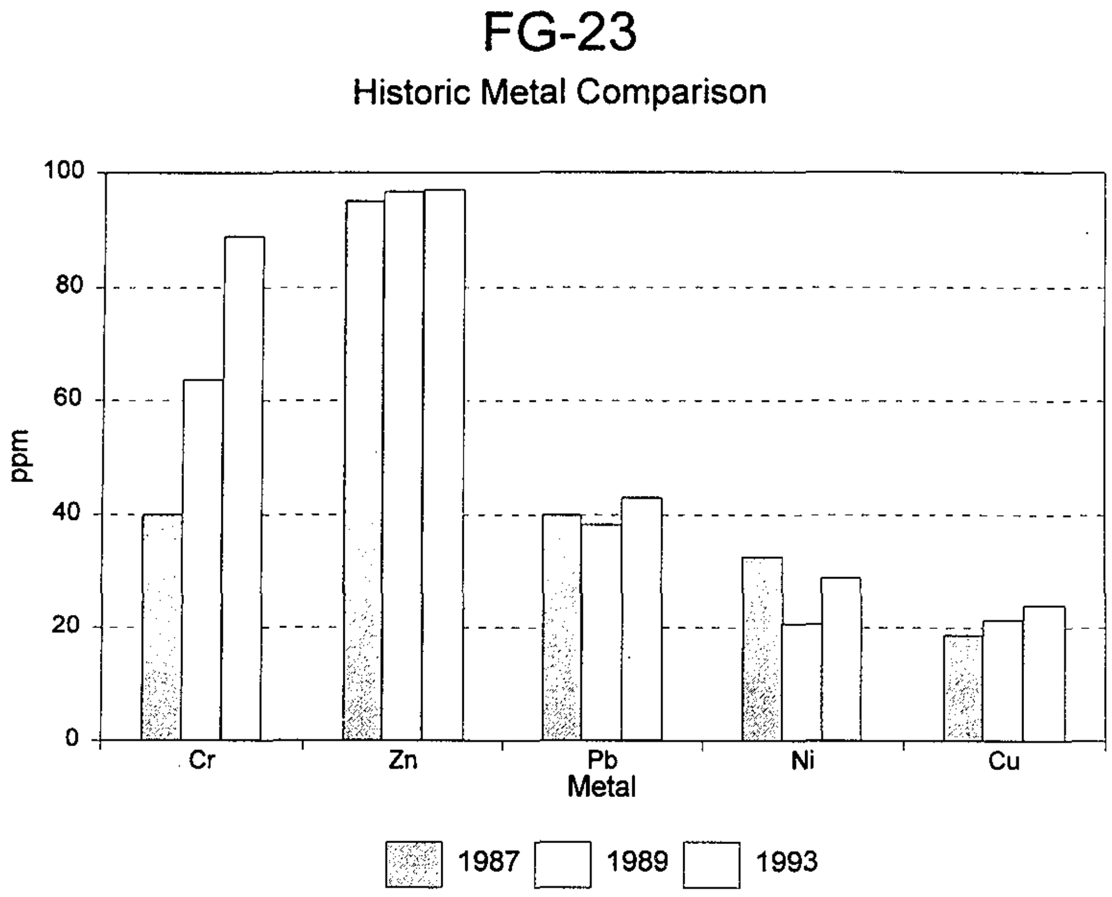

Figure 4-5. Station FG-23 historic metal comparison (1987–1993)

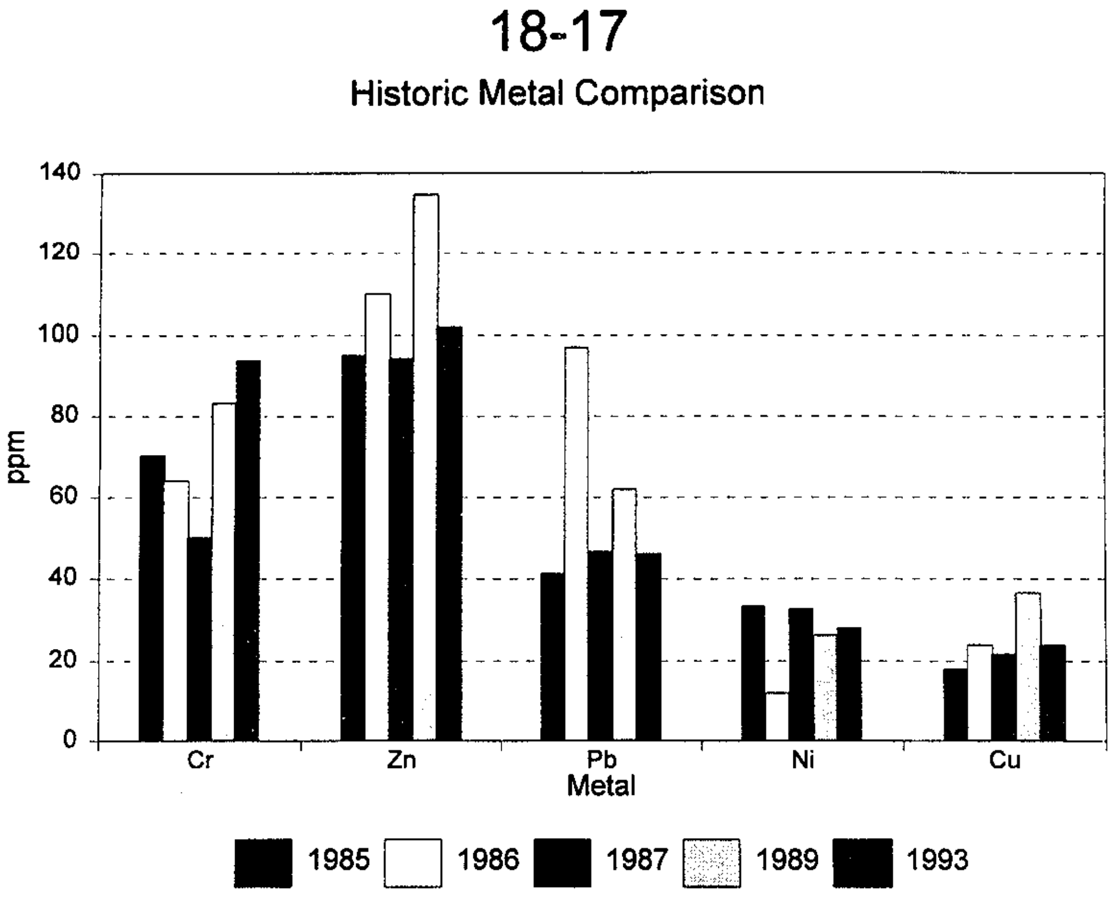

Figure 4-6. Station 18-17 historic metal comparison (1985–1993)

Table 4-1

MBDS Reference Area Historic Metal Concentrations

Reference Station	Date	Cr	Zn	Pb	Ni	Cu	Hg
				(all ppm)			
18-17	June 85	70	95	41	33	18	-
18-17	January 86	64	110	97	12	24	-
18-17	October 87	50	95	47	33	22	-
18-17	June 89	83	135	62	26	37	0.21
18-17	September 93	94	102	46	28	24	0.02
	Mean	72	107	59	26	25	0.05
	Standard Deviation	15	15	20	8	6	0.08
FG-23	October 87	40	95	40	33	19	-
FG-23	June 89	64	97	38	21	21	0.19
FG-23	September 93	89	97	43	29	24	0.03
	Mean	64	96	40	27	21	0.07
	Standard Deviation	20	1	2	5	2	0.08
Mean MBDS*	June 89	70	127	72	21	44	0.22
Standard Deviation		28	35	31	6	15	0.10
Mean 12-3	September 93	96	124	69	27	43	0.10
Standard Deviation		23	22	37	2	8	0.03

* Excludes reference area data

Historic data taken from Murray 1994; SAIC 1987, 1990 collected in 1985 and 1986 (SAIC 1987; Figure 4-7). Figure 4-7 illustrates the variability of the mean total PCB levels for samples collected at MBDS and Station 18-17 recorded since 1985. Mean total PCBs for samples collected at the disposal site decreased steadily by two orders of magnitude from 1985 to 1989, and increased by an order of magnitude from 1989 to 1993. However, concentrations at the reference station 18-17 remained relatively constant over the entire period time from 1985 to 1993.

Because all of the data sets were accompanied with analytical QC support, it is difficult to discard any one data set. To explain the decrease of PCBs (which are stable in sediment) noted in samples collected in 1989, it was postulated that sediment deposition and/or dilution through mixing had occurred (Murray 1994). If sediment deposition and mixing were the dominant processes affecting PCB levels, rather than disposal events, one would expect to find 1) a similar trend at the reference station, which was not the case; and 2) low levels of PCBs in the 1993 data, not higher. The wide range of detected PCBs at the MBDS site could be a function of the natural patchiness of sediments influenced by anthropogenic material.

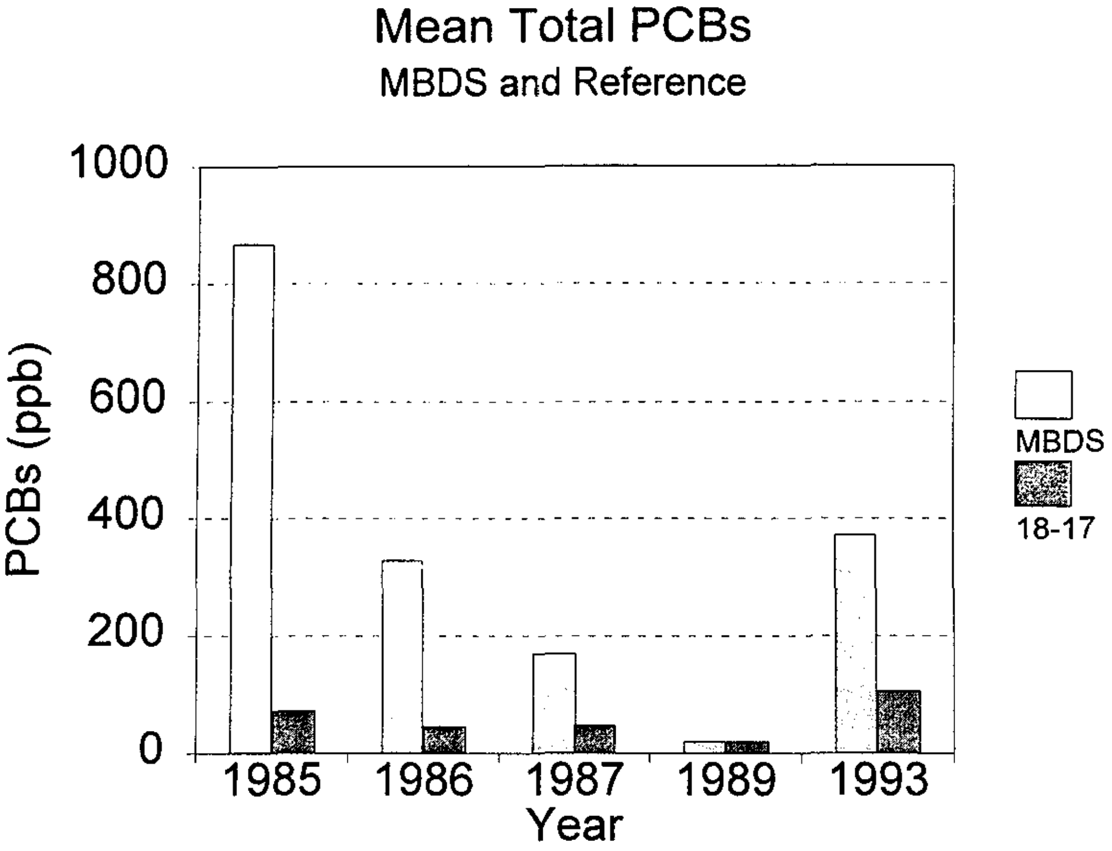

Figure 4-7. Mean total PCB concentrations measured in 1993 in comparison to historical data at MBDS and the 18-17 reference area

5.0 CONCLUSIONS

The 1993 survey results indicated that the newly designated MBDS was comprised of two topographically and acoustically distinct areas, each with different implications for management: 1) the recently incorporated southwestern area where little to no documented disposal has occurred; and 2) the northeastern portion which overlaps the IWS and interim MBDS. The southwestern portion was topographically featureless and consisted of a gradual slope towards the northeast. Sediments in this region were characterized by weak signal returns by both the side-scan sonar and SACS. From the relationship between SACS acoustic data and sediment grain size distribution, it was estimated that sediments in the southwest portion were comprised of at least 95% silt and clay.

The northeastern portion of the new disposal site contained two major topographical features: a large shallow basin which can be enhanced by management as a potential capping site, and the most recent dredged material disposal mound. Grain size estimates from the SACS analysis indicated that the sediment composition of the MDA mound and the shallow basin was more heterogeneous than the sediments of the southwestern portion of MBDS. Both the SACS and side-scan results showed that the most recently disposed material from the THT project had much higher reflectivity than the surrounding sediment.

Differences between the SACS and side-scan sonar data in this region were consistent with the Stellwagen Basin as a depositional environment. The large basin, which has not received dredged material in at least eight years, was characterized by "hard" signal returns by SACS but not by side-scan sonar. Aside from a depth-correlated bias in SACS, it is possible that the SACS low-frequency transducer, which penetrates the sediment surface, was reflected off a subbottom dredged material layer, whereas the side-scan sonar was reflected off a surficial fine-grained, depositional layer. Samplings of the upper sediment layer, including the use of the REMOTS® sediment-profile camera, could test this hypothesis. Because the MDA mound has been the recipient of recently disposed dredged material, there has been insufficient time for accumulation of fine-grained material at this location.

Chemical analyses of sediment samples collected from the 12-3 sampling grid were consistent with the 1989 data that indicated Station 12-3 contains relatively higher levels of contaminants than surrounding sediments. Both the 1989 and 1993 data suggested a general westward contaminant level increase; the survey results revealed that contaminant levels decrease rapidly in a radial pattern north, east, and south of Station 12-3. Although contaminant levels were higher than surrounding sediments, no metals measured fell within the "high" category defined by the NERBC (1980). The majority of the trace metals were defined in the "low" category with the exception of a few As, Cr, and Pb results which were described in the "moderate" category. Normalized contaminant levels were consistent with levels measured in 1989 showing no significant change over time.

Results of the 1993 survey can provide guidance for future disposal of dredged material at MBDS. The new site has several factors that should be considered when selecting new disposal points, including

- a relatively pristine southwestern area where future disposal of dredged material can be carefully monitored;
- sediments that contain evidence of chemical contaminants, present because of past disposal practices, that may be suitable for remediation;
- a large depositional basin where data indicate that historically deposited dredged material has been reworked or covered by ambient sediments.

The presence of a large depositional basin and evidence from successful long-term site management at the Central Long Island Sound Disposal Site (Morris et al. 1996, Morris 1996) suggest that appropriate site management may include provision of a circle of mounds to accommodate potential capping operations.

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