

**The 1997 Category II
Capping Project at the New
York Mud Dump Site:
Summary of Geotechnical and
Chemical Analysis From the
April 1998 Postcap
Vibracoring Survey**

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ACKNOWLEDGMENT

This report presents the results of the April 1998 postcap sediment coring survey for the 1997 Category II Capping Project at the New York Mud Dump Site. This survey was conducted by Science Applications International Corporation (SAIC) of Newport, RI, under Delivery Order 11 of SAIC's Indefinite Quantity Contract No. DACW 51-97-D-0014 with the U.S. Army Corps of Engineers (USACE) New York District (NYD). Geotechnical and chemical analyses of the cores, along with the production of this report, were completed under Delivery Order 12 of the same contract. Mr. Brian May is the manager of Technical Activities under the USACE contract. Dr. Scott McDowell is SAIC's Program Manager.

Logistical and planning support for the survey were provided by Mr. May, with assistance from Mr. Tim LaFontaine of the NYD's Caven Point facility.

The following SAIC staff participated in the coring survey: Mr. Ed DeAngelo, Mr. Jason Infantino, Ms. Kate Pickle, and Ms. Melissa Swanson. SAIC staff were responsible for DGPS navigation, selection of coring stations, and handling/custody of core samples.

Ocean Surveys, Inc., under subcontract to SAIC, was responsible for providing vibracoring equipment and an experienced coring technician, Mr. Mike Engels.

Survey operations were conducted aboard the NYD's M/V *Gelberman*. The crew of the M/V *Gelberman* is commended for their skill in vessel handling while conduction coring operations, as well as their dedication during long hours of operation at the Mud Dump Site.

Core processing was conducted at GeoTesting Express' laboratory in Boxborough, MA. SAIC staff responsible for core splitting, descriptions, photography, and chemical sampling were Ms. Pickle and Ms. Swanson. GeoTesting Express, under subcontract to SAIC, was then responsible for the geotechnical analyses of the sediment core samples.

Maxim Technologies, Inc. of St. Paul, MN, (formerly Huntingdon Engineering and Environmental, Inc.) conducted chemical analyses of sediment core samples.

Ms. Pickle and Ms. Swanson prepared this report. Ms. Peggy Murray, Mr. Ray Valente, and Dr. McDowell provided technical review of the report, while Mr. Tom Fox was responsible for report production.

1.0 INTRODUCTION

This report summarizes geotechnical and chemical data from cores collected at the New York Bight dredged material disposal site (Mud Dump Site) in April 1998, as part of a series of postcap surveys for the 1997 Category II Capping Project (Section 1.1). The results represent the fourth geotechnical survey, and the first set of chemical data from sediment cores, for the project. The specific objectives of this coring survey were to evaluate changes in geotechnical properties of the project material since the interim disposal survey, evaluate consolidation of the project dredged material since the placement of cap material at the site, and establish baseline information on chemical concentrations for future monitoring of the project area (Section 1.2).

Following the introduction, methods of data collection, core processing, and laboratory analyses are described in Section 2. Data quality is reviewed in Section 3. Results (Section 4) are summarized for core descriptions, geotechnical, and chemical data. The survey results are discussed in Section 5, followed by a summary in question and answer format in Section 6. Report references are provided in Section 7.

Core locations, core logs and descriptions (Appendix A), discrete geotechnical sample data from GeoTesting Express (Appendix B), and down-core profiles of water content and bulk density (Appendix C), and all chemistry data will be available through the Disposal Area Network - New York (DAN-NY) system.

1.1 Background

Dredged material from the Port of New York and New Jersey historically has been placed at an ocean disposal site in the New York Bight known as the Mud Dump Site (MDS). This site is located six nautical miles off the coast of northern New Jersey and is a 2.2 square mile rectangular area in approximately 12-27 m of water (Figure 1-1). In recent years, there has been growing concern about both the remaining capacity of the site, and the environmental impact of historic and contemporary disposal of dredged material containing elevated concentrations of various organic and inorganic chemical contaminants.

In July 1996, the administrators of the US Environmental Protection Agency (EPA), the US Department of Transportation, and the Secretary of the Army signed a "3-Party" letter of agreement to close the MDS to all levels of contaminated dredged material by September 1, 1997. The planned closure of the MDS left the Port of New York and New Jersey (PANYNJ) with a limited period of time to dispose of a finite volume of partially contaminated (i.e., Category II) dredged material at the site and place a layer of clean (i.e., Category I) sediment over it. Through the collaborative efforts of the US Army Engineer Waterways Experiment Station (WES), Science Applications International Corporation (SAIC), and the US Army Corps of Engineers New York District (NYD), a plan was developed in early 1997 to address dredging, ocean placement, and subsequent capping of the Category II material at the MDS prior to the September 1 closure. This project is herein referred to as the 1997 Category II Capping Project.

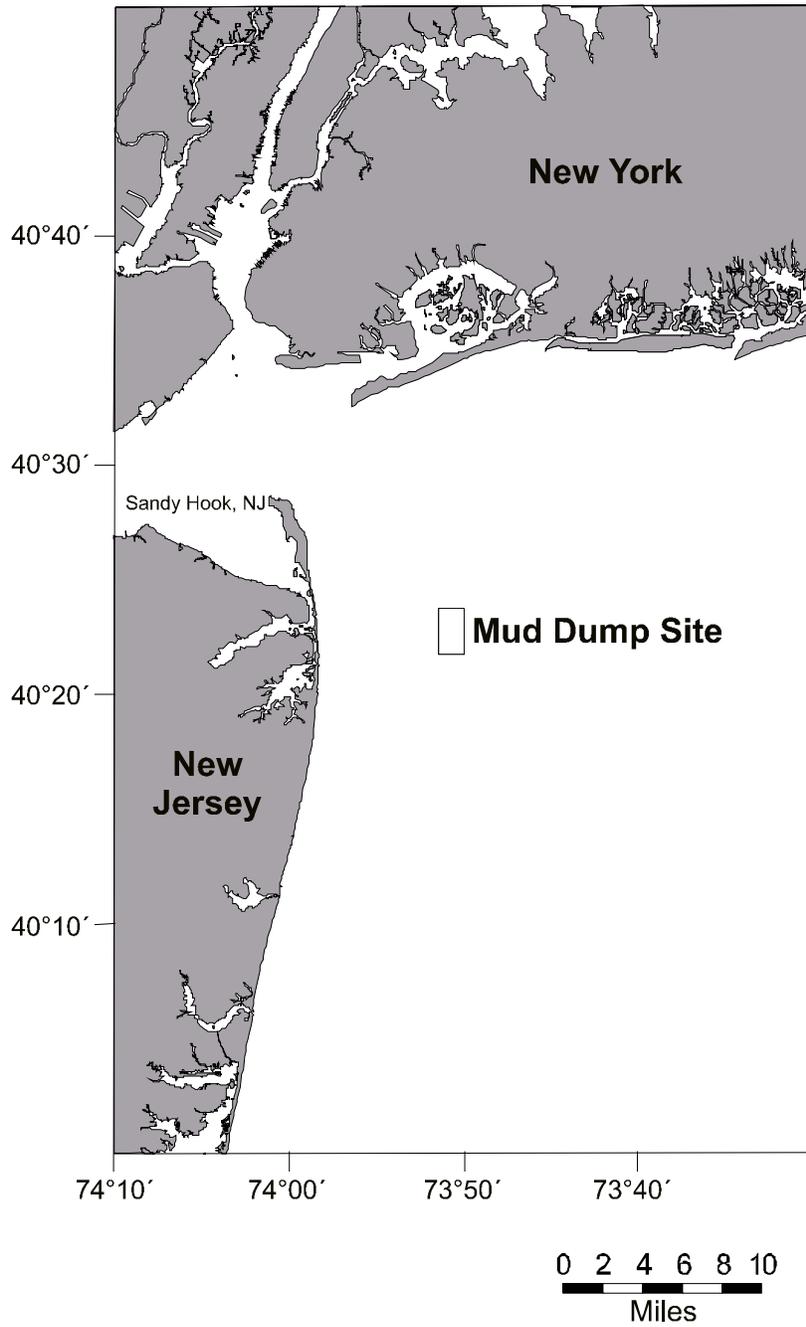


Figure 1-1. Location of the Mud Dump Site in the New York Bight.

The Category II project material was dredged from selected berthing facilities at Port Newark and Elizabeth, New Jersey. Placement of this material in the project area at the Mud Dump Site began in late May 1997, and continued until August 10, 1997 (Figure 1-2). During this period roughly 700,000 yd³ of material were placed, creating a distinct mound on the seafloor.

Following the completion of the dredged material placement operation, capping of the material with clean sand began on August 21, 1997. The capping operation continued intermittently until January 18, 1998, when it was demonstrated that a 1-m thick layer of sand had been placed over the entire project material footprint.

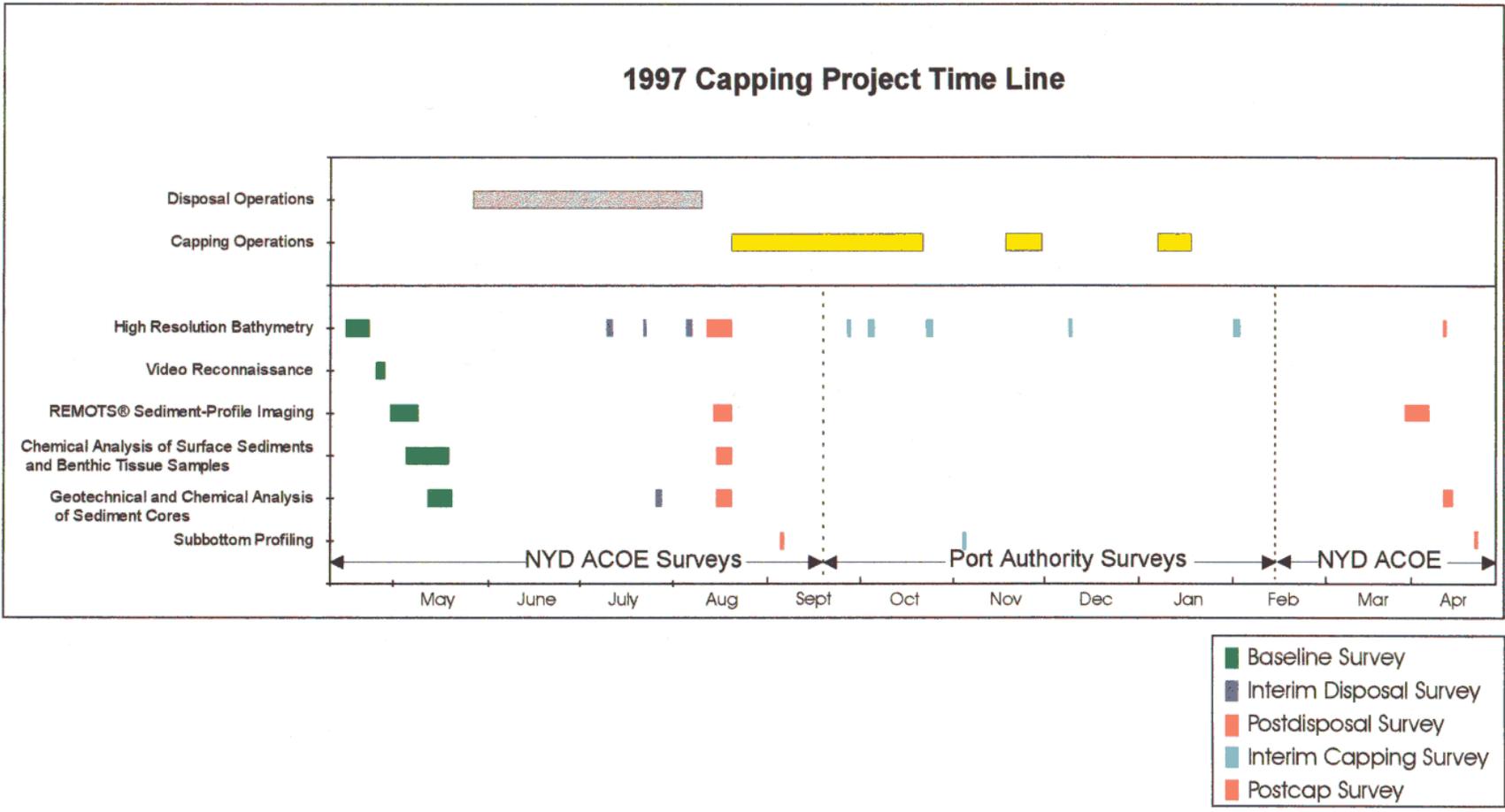
As part of the project, the NYD contracted SAIC to perform a series of oceanographic studies to characterize the seafloor in the area of the MDS selected for placement of the Category II material. Baseline surveys were conducted prior to placement of the dredged material, as well as during and after the disposal and capping operations (Figure 1-2). The following monitoring techniques were utilized: high-resolution bathymetry, seafloor video reconnaissance, chemical analysis of surface sediment and biological tissue samples, sediment coring, subbottom profiling, and REMOTS® sediment-profile imaging. This report presents the results of the first postcap sediment coring survey for the 1997 Category II Capping Project. This survey was conducted aboard the NYD's M/V *Gelberman* in April 1998, three months following the completion of the capping operation. Results from other postcap monitoring surveys, involving high resolution bathymetry, subbottom profiling, and REMOTS® sediment profile imaging, are presented in individual reports under separate delivery orders (SAIC 1998a, 1998b, 1998c).

1.2 Survey Objective

The primary objective of the postcap survey was to acquire sediment vibracores, 6 to 10 feet in length, at each of the 14 stations shown in Figure 1-3. At seven of the stations, a duplicate core was obtained and shipped to WES at the survey's conclusion for analysis of geotechnical and consolidation properties of the in-place sand cap and underlying dredged material. The complete set of 14 cores was analyzed by SAIC, and the results are presented in this report. At a later date, the geotechnical results from the WES cores will be compared with those measured by SAIC to assess laboratory and material variability.

Based on observations from the 1993 Dioxin Capping Project, as consolidation of the project material begins to occur, changes in material properties (e.g., lower water content, increased bulk density, decreased void ratio) are expected (SAIC 1998d). The dataset compiled from this and previous coring surveys for the 1997 Category II Capping Project, therefore, will serve to help monitor physical changes in the 1997 project material, and enhance long-term understanding of the consolidation process. Chemical data collected from this survey's cores will provide baseline information on the material's chemical characteristics, and serve to advance our understanding of the long-term effectiveness of capping with sand as a technique for isolation of dioxin-contaminated sediments.

1997 Capping Project Time Line



1-4

Figure 1-2 1997 Category II Capping Project timeline.

1997 Capping Project
Subbottom Cap Thickness
April 1998

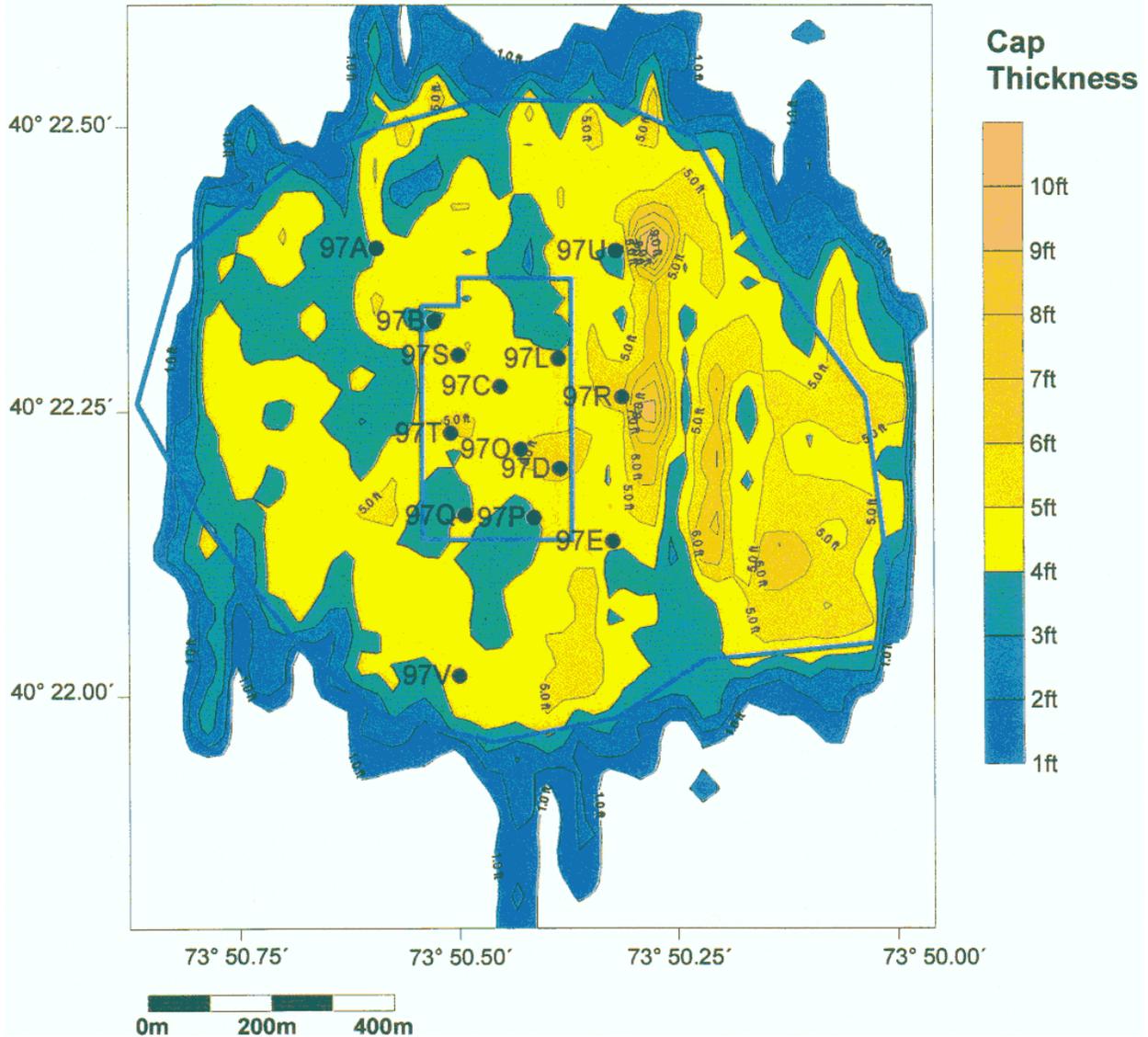


Figure 1-3 Postcap core locations superimposed on contours showing sand cap thickness based on the April 1998 postcap subbottom profiling survey.

2.0 METHODS

2.1 Station Selection and Locations for Geotechnical Surveys

Station selection for the series of geotechnical coring surveys (baseline, interim disposal, postdisposal, and postcap) was designed to optimize sampling of the placed dredged and cap material.

For the baseline coring survey performed in May 1997, 11 stations were located along a northwest-southeast transect crossing the center of the target disposal area (1997 Base Mound Area) to give an overview of pre-disposal conditions in this region (Figure 2-1; SAIC 1998e). Five of these baseline stations (97A-97E) were reoccupied during the interim, postdisposal, and postcap coring surveys.

Based on the results of the first interim disposal bathymetric survey of July 11, 1997 (SAIC 1997a), an additional seven stations were selected for the interim disposal coring survey to sample the apex of the mounds formed by the disposal operations. During the postdisposal coring survey, four of the newly selected interim disposal coring stations (97L, 97O, 97P, and 97Q) were reoccupied, and another three stations added, based on depth differencing results between the third interim (August 6, 1997) and baseline bathymetric surveys (SAIC 1997b). Figure 2-2 shows the location of the 12 stations sampled in the postdisposal coring survey in relation to the dredged material layer thickness as of the August 1997, postdisposal bathymetric survey. One of the three newly added stations for the postdisposal survey (97R) was located outside the Base Mound Area to sample material redistributed by a slope adjustment which had occurred on the mound within the eastern half of the 1997 Base Mound Area (called the eastern mound slope adjustment). The remaining two stations (97S and 97T) were positioned at the apex of the newly formed mounds observed within the western half of the 1997 Base Mound Area.

For the postcap survey, all 12 of the postdisposal coring stations were reoccupied. An additional two stations, 97U and 97V, were added to increase the mound coverage and to better examine areas where material was redistributed during a postdisposal slope adjustment which occurred on the western side of the 1997 Base Mound Area (SAIC 1998f). The locations of all 14 stations occupied during the postcap sediment coring survey are shown in Figure 1-3 in relation to cap material thickness as measured in the April 1998 subbottom profiling survey (SAIC 1998b).

2.2 Field Operations

The postcap sediment coring survey was conducted aboard the NYD's M/V *Gelberman* during April 15-18, 1998. One sediment core was collected at each of the 14 stations shown in Figure 1-3, and later delivered to GeoTesting Express in Boxborough, MA by SAIC. Additionally, a duplicate core was obtained at seven of the stations (Table 2-1) and shipped by the NYD to the WES laboratories in Vicksburg, MS. Table 2-1 presents a complete listing of the 21 cores obtained.

**1997 Capping Project
May 1997 Baseline Vibracore Sampling Stations**

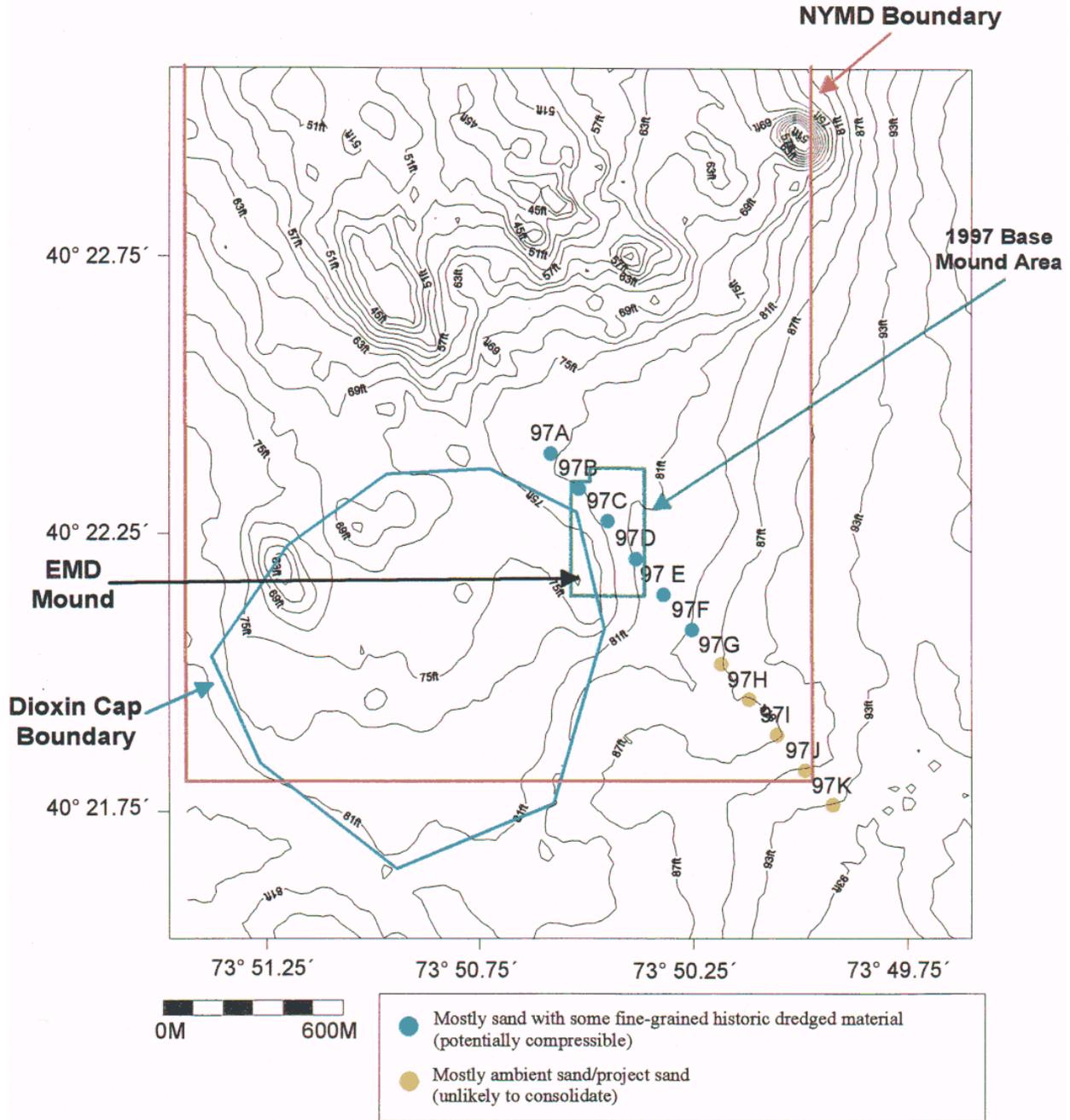


Figure 2-1. Vibracore stations occupied during the May 1997 baseline survey. Water depths (ft, MLLW) were derived from the April 1997 baseline bathymetric survey.

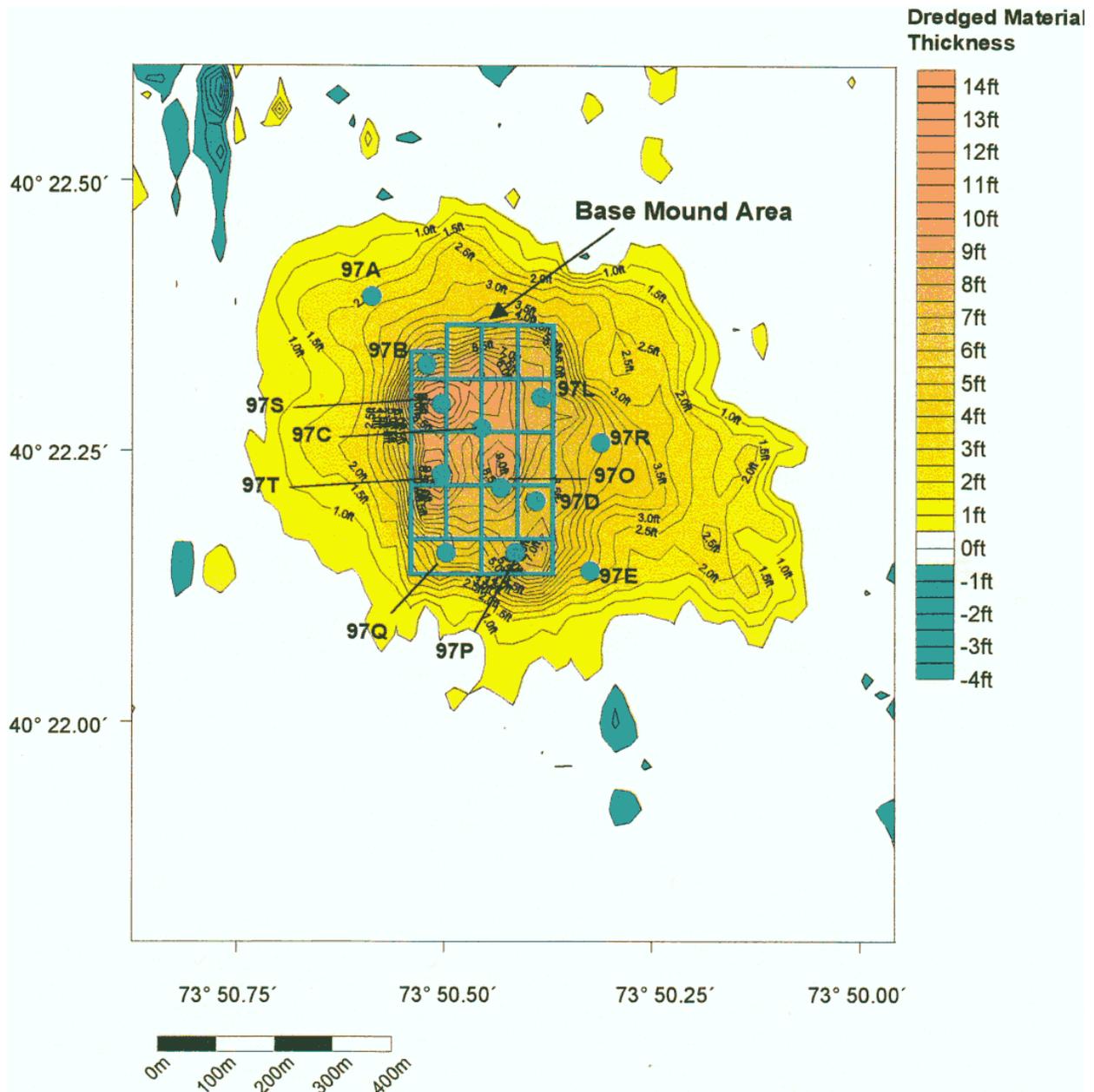


Figure 2-2. Postdisposal core locations superimposed on bathymetric results showing dredged material thickness based on the depth difference between the baseline (April 1997) and postdisposal (August 1997) bathymetric surveys.

Table 2-1**Sediment Cores Acquired During the April 1998 Postcap Coring Survey**

| Cores provided to GeoTesting Express | | | | | | |
|---|----------------|------------------|---------------------|----------------------|----------------------|----------------------|
| Survey Identifier | Station | Replicate | Latitude (N) | Longitude (W) | Date Acquired | Length (cm) |
| 0498 | 97A | A | 40° 22.3956' | 73° 50.5902' | 4/15/98 | 292.1 |
| 0498 | 97B | B | 40° 22.3308' | 73° 50.5254' | 4/15/98 | 279.4 |
| 0498 | 97C | A | 40° 22.2737' | 73° 50.4498' | 4/15/98 | 288.3 |
| 0498 | 97D | B | 40° 22.2018' | 73° 50.3819' | 4/15/98 | 287.0 |
| 0498 | 97E | B | 40° 22.1376' | 73° 50.3220' | 4/18/98 | 256.5 |
| 0498 | 97L | B | 40° 22.2978' | 73° 50.3832' | 4/16/98 | 289.6 |
| 0498 | 97O | A | 40° 22.2186' | 73° 50.4270' | 4/15/98 | 248.9 |
| 0498 | 97P | A | 40° 22.1585' | 73° 50.4114' | 4/16/98 | 285.8 |
| 0498 | 97Q | A | 40° 22.1604' | 73° 50.4899' | 4/18/98 | 283.2 |
| 0498 | 97R | B | 40° 22.2642' | 73° 50.3112' | 4/16/98 | 288.3 |
| 0498 | 97S | B | 40° 22.3007' | 73° 50.4978' | 4/15/98 | 289.6 |
| 0498 | 97T | B | 40° 22.2330' | 73° 50.5068' | 4/18/98 | 284.5 |
| 0498 | 97U | A | 40° 22.3932' | 73° 50.3178' | 4/16/98 | 284.5 |
| 0498 | 97V | A | 40° 22.0194' | 73° 50.4978' | 4/16/98 | 266.7 |
| Core replicates for WES | | | | | | |
| Survey Identifier | Station | Replicate | Latitude (N) | Longitude (W) | Date Acquired | Length (cm) * |
| 0498 | 97B | A | 40° 22.3308' | 73° 50.5260' | 4/15/98 | 276.9 |
| 0498 | 97C | B | 40° 22.2737' | 73° 50.4498' | 4/15/98 | 288.3 |
| 0498 | 97E | A | 40° 22.1388' | 73° 50.3220' | 4/18/98 | 269.2 |
| 0498 | 97Q | B | 40° 22.1609' | 73° 50.4960' | 4/18/98 | 284.5 |
| 0498 | 97R | A | 40° 22.2636' | 73° 50.3112' | 4/16/98 | 170.2 |
| 0498 | 97S | A | 40° 22.3007' | 73° 49.9050' | 4/15/98 | 281.9 |
| 0498 | 97T | A | 40° 22.2330' | 73° 50.5062' | 4/18/98 | 280.7 |

Coordinates in NAD 83

* WES cores greater than 178 cm. were cut into two pieces for shipping purposes (see text).

Vessel positioning and data integration were achieved with SAIC's Portable Integrated Navigation Survey System (PINSS). This PC-based system provides real-time navigation and collection of position, time, and depth soundings for subsequent analysis. Vessel position was determined using a Trimble GPS receiver. One- to five-meter accuracy was achieved by applying differential correction to the GPS signal, which was acquired from the US Coast Guard broadcast station located at Sandy Hook, NJ. The survey vessel was anchored, in a 2-point configuration, during all coring operations.

An Ocean Surveys Inc. vibracorer with an internal liner diameter of 2-5/8 inches was used to acquire the sediment core samples. This device was selected because of its demonstrated ability to acquire sediment core samples of at least 2 m in length on sand-capped mounds within the Mud Dump Site (SAIC 1996). Upon the retrieval of each core, it was carefully capped with a Styrofoam plug and core cap to prevent loss of sediment, and labeled with a unique identifier,

which included the month and year of the survey (e.g., 0498), the station name, and the replicate (e.g., A or B).

2.3 Core Processing

Cores were placed horizontally, due to transportation constraints, in an ice filled cooler and taken to GeoTesting Express on April 21, 1998. In the laboratory, all 14 cores retained by SAIC were split, visually described, photographed, and sampled for chemical analysis. Geotechnical analyses were then performed on all 14 cores by the technicians at GeoTesting Express in Boxborough, MA. Geotechnical analyses included water content, bulk density, grain size, Atterberg limits, shear strength, and specific gravity (described in Section 2.4). Void ratios were calculated from the geotechnical data by SAIC for each sample. Further details on core processing are provided in the following sections.

2.3.1 Core Splitting

Each core tube was scored horizontally using an inverted radial arm saw. Care was taken to cut only the core tube and not the enclosed sediment. The scored core was then transferred to a laboratory bench and the thin layer of remaining core tube cut using a utility knife. Next, a thin piano wire was used to split the sediment axially into two halves. This is a delicate process requiring two people with spatulas to assure that the two halves are maintained in a natural, essentially undisturbed, condition. One half-section was used for detailed visual description, photography, and sampling for chemical analysis, while the other half was processed for geotechnical analyses.

2.3.2 Core Descriptions and Photography

After splitting, each core was carefully examined and described in detail by SAIC personnel. The split cores were photographed with an Olympus D500L digital camera mounted on a copy stand equipped with daylight-balanced lights. The focal distance was kept constant so that individual photographs could be pieced together to form a continuous view of the core. A centimeter scale was affixed to the core crib, which held the core half during photographing, to document core features and penetration depth in successive images. The descriptions and photographs were then combined to create a log for each core, and these are presented in Appendix A of this report.

2.3.3 Core Sampling

Cores were sampled for both geotechnical and chemical analyses beginning on May 5, 1998. Geotechnical analyses consisted of water content, bulk density, grain size (sieve and hydrometer), Atterberg limits, shear strength, and specific gravity. Chemical analyses consisted of PCDD/PCDFs, total organic carbon (TOC), and percent moisture. Specifics on sampling are presented below, and analytical methods are discussed in Sections 2.4 (geotechnical) and 2.5 (chemical). Table 2-2 summarizes the type of analyses performed on each core retained by SAIC.

Table 2-2

Location of Sediment Core Stations, Analyses Performed, and Length of Cores Collected

| Core | Analyses | | | Length (cm) | Latitude (N) | Longitude (W) |
|-------|----------|--------------|----------|----------------|--------------|---------------|
| | visual | geotechnical | chemical | | NAD 83 | |
| 97A-A | x | x | | 292.1 | 40° 22.3956' | 73° 50.5902' |
| 97B-B | x | x | x | 279.4 | 40° 22.3308' | 73° 50.5254' |
| 97C-A | x | x | x | 288.3 | 40° 22.2737' | 73° 50.4498' |
| 97D-B | x | x | | 287.0 | 40° 22.2018' | 73° 50.3819' |
| 97E-B | x | x | x | 256.5 | 40° 22.1376' | 73° 50.3220' |
| 97L-B | x | x | | 289.6 | 40° 22.2978' | 73° 50.3832' |
| 97O-A | x | x | | 248.9 | 40° 22.2186' | 73° 50.4270' |
| 97P-A | x | x | | 285.8 | 40° 22.1585' | 73° 50.4114' |
| 97Q-A | x | x | x | 283.2 | 40° 22.1604' | 73° 50.4899' |
| 97R-B | x | x | x | 288.3 | 40° 22.2642' | 73° 50.3112' |
| 97S-B | x | x | | 289.6 | 40° 22.3007' | 73° 50.4978' |
| 97T-B | x | x | | 284.5 | 40° 22.2330' | 73° 50.5068' |
| 97U-A | x | x | x | 284.5 | 40° 22.3932' | 73° 50.3178' |
| 97V-A | x | x | | 266.7 | 40° 22.0194' | 73° 50.4978' |

2.3.3.1 Geotechnical Sampling

The sample plan was varied according to the amount of material recovered in each core. The numbers listed below indicate the maximum number of samples obtained from each sediment layer (cap and DM) for each of the respective analyses. The actual number of samples it was possible to obtain was left to the discretion of the geotechnical technicians at GeoTesting Express.

A maximum of 20 samples were taken from each core for the determination of water content and an additional 20 samples for the determination of bulk density. The samples were taken side-by-side across the width of the sampled core half, at equidistant intervals based upon the length of each core. Up to five samples for each analysis came from the sand cap, while the remaining 15 were from the underlying, finer-grained dredged material. For quality control of water content analyses, triplicate samples were taken at one sample interval in the sand cap, and one sample interval in the dredged material of core 97C-A (Section 3.1).

Up to two samples were obtained from the sand cap of each core for grain size analysis by sieve (no silt/clay fraction), and up to five samples were obtained from the dredged material unit for analysis by both sieve and hydrometer. Samples were taken at equidistant intervals based on the length of each layer. For the purpose of quality control, triplicate analyses were performed on one section of each layer in core 97C-A (Section 3.1).

Up to three samples for Atterberg limits were obtained from each core for analysis using a wet sample preparation. Samples were collected from homogenous (unmottled) areas of fine-grained

material within the length of the core, at intervals left to the discretion of the geotechnical laboratory technicians. Additionally, a total of five of these samples were duplicated for Atterberg limit analysis using a dry sample preparation. This was done to provide a comparison between the wet and dry sample preparation methods (Section 4.2.4).

Shear strength analysis consisted of performing five Torvane shear strength tests at three depths within the dredged material of each core. The samples were taken from relatively homogenous material, at intervals left to the discretion of the geotechnical technicians.

Three samples were obtained from the dredged material of each core for the analysis of specific gravity. The location of these samples was left to the discretion of the geotechnical technicians.

2.3.3.2 Chemical Sampling

A total of 30 samples were taken from six of the 14 cores for chemical analysis of PCDDs, PCDFs, total organic carbon (TOC), and percent moisture. Within the cap material, samples were extracted 10 cm and 30 cm above the cap/dredged material boundary, with the exception of the cores from Station 97B-B and 97Q-A, which had an additional sample extracted within 2 cm above the interface. Within the dredged material, samples were extracted 10 cm below the interface. Up to three additional samples were taken throughout the length of the fine-grained dredged material at the discretion of SAIC personnel. All of these samples were taken from material that appeared to be relatively homogenous.

In order to obtain a sufficient quantity of sediment to test for PCDD/PCDFs and TOC, samples were taken from an approximate 4-cm thick plug encompassing the desired sample point. Sample locations within each core are noted in Table 4-6 and Appendix D.

Sand cap material samples were removed from the core prior to dredged material sampling to decrease the possibility of contamination. To further minimize contamination, only material not in contact with the core liner was used for the sample. Stainless steel spatulas and mixing bowls were used to remove and homogenize the sediment. Samples were placed into 125-ml pre-cleaned glass jars supplied by the analytical laboratory. PCDD/PCDF samples were placed in amber containers due to the photosensitive nature of these compounds. TOC samples were placed in clear glass containers. The sampling equipment was rinsed with water, followed by acetone between samples. The samples were kept on ice (approximately 4° C) and in the dark, and shipped by air freight in coolers with ice to Maxim Technologies, Inc. located in St. Paul, MN.

2.4 Geotechnical Analysis

2.4.1 Bulk Density and Water Content

Assuming that there is no void space due to air, the wet mass of sediment divided by the volume yields the bulk density. Bulk density for the cores was determined by pushing a cylinder of known volume (39.93 cc) into the sediment surface of the sampled core half, leveling off each end, and then weighing it. Voids or cracks in the sediment, which would affect bulk density measurements, were not noted in this suite of cores.

Water content is defined as the weight of water divided by the dry weight of the sample, and reported as a percentage. Mathematically, it is computed using the following formula:

$$\text{Water Content} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

It should be noted that in geotechnical analysis, it is possible to have water content values greater than 100%. For this analysis, the wet samples were weighed, dried at 110°C for 24 hours, and then reweighed according to the procedures outlined in ASTM method D 2216. Because these samples come from the marine environment, when dried, the salt from the water is left behind, resulting in a higher dry weight (weight of solids) and consequently lower water content. Since geotechnical properties are generally based on sediments saturated with fresh water, the water contents obtained via the above formula were then normalized by an assumed salt content of 35 ppt.

2.4.2 Grain Size

Grain size distributions of representative samples were determined in accordance with ASTM method D 422. Sieve sizes for sand fraction analyses included US standard sieve sizes 10, 20, 40, 60, 100, and 200, to provide coarse (1-0 phi), medium (2-1 phi), fine (3-2 phi), and very fine (4-3 phi) sand fractions, respectively. Clay and silt fractions were measured using a hydrometer. Size classifications are based on the Wentworth (1922) scale (Appendix E).

2.4.3 Atterberg Limits

Atterberg limits are index tests which give an indication of a soil's consistency. They are also used as a part of many soil classification systems, such as the Unified Soils Classification System (USCS). The limits, including liquid, plastic, and shrinkage, are indicators of the changes in consistency of fine-grained materials with changes in water content. The limits are based on the concept that a fine-grained soil can exist in a wide variety of states, ranging from liquid to plastic, semi-solid and solid, depending on its water content. The greater the amount of water a soil contains, the less interaction there will be between adjacent particles, and the more the soil should behave like a liquid. Plastic limit (PL, the water content of soil at the boundary between the plastic and semi-solid states), liquid limit (LL, the water content at the boundary between semi-liquid and plastic states), and the plasticity index (PI, the range of water content over which the soil behaves plastically; mathematically, $PI = LL - PL$) were determined for representative samples of the fine-grained project material (ASTM method D 4318), and corrected for an assumed salt content of 35 ppt. Liquid limit can provide qualitative information on the strength of the sediment.

In previous surveys for the 1997 Capping Project, Atterberg limits were analyzed using the dry preparation procedure outline in ASTM method D 4318. For this project, however, measurement of the sediment behavior at its *in situ* water content is most relevant. By allowing these samples to dry before testing, the liquid and plastic limits may vary considerably from values that would have been obtained from undried samples (ASTM method D 4318). For this suite of cores, therefore, the samples were prepared using the wet preparation procedure outlined in ASTM method D 4318, and LL measured using the multipoint method. To compare the outcome of the

two methods, five duplicate samples were run using both methods. The results are discussed in Section 4.2.4.

2.4.4 Shear Strength

The shear strength of soils is one of the most important engineering properties for predicting soil behavior. It is a complex property influenced by many factors (soil consistency, disturbance, test method, rate of shear, etc.), and is difficult to measure accurately in very soft materials. In some cases, shear strength is not measured directly, but is inferred from some type of index test, such as a CBR, core penetrometer, or Torvane test. GeoTesting Express determined the shear strength using a hand-held Soiltest Torvane with a precision of ± 0.25 ksc (kg/cm^2). The range of shear strength values reported for the project material was relatively narrow (0.05 to 0.20 ksc for this survey), such that differences in the measured shear strength were within the error of the instrument. Also, the precision of the data was questionable; variability of the reported values appeared to be influenced by sampling time and/or personnel. The instrument is designed for qualitative comparisons between end member soil types, so this type of gross index test does not allow evaluation of subtle changes as a single type of material begins to consolidate. Therefore, shear strength is not reported or discussed in this report. It should be noted, however, that WES is performing a more sophisticated shear strength test as part of their geotechnical analyses of the duplicate cores.

2.4.5 Specific Gravity

Specific gravity is defined as the ratio of the mass of a unit volume of material to the same volume of gas-free distilled water at a stated temperature (ASTM D 854), and is represented by the following formula:

$$G_s = \frac{W_s}{V_s \gamma_w} \quad \text{where:} \quad \begin{array}{l} W_s = \text{weight of solids (i.e., dry weight)} \\ V_s = \text{volume of solids} \\ \gamma_w = \text{unit of weight of water} = 1 \text{ g/cc} \end{array}$$

Specific gravity was measured within the dredged material layer of each of the cores, using ASTM method D 854, Method A (procedure for oven dried test specimens).

2.4.6 Void Ratio

Void ratio is a parameter used to help assess the state of consolidation in sediment material. Using the raw data provided by GeoTesting Express, this value was calculated using the following formula:

$$\text{Void Ratio (e)} = \frac{V_v}{V_s} \quad \text{where:} \quad \begin{array}{l} V_v = \text{volume of the voids} \\ V_s = \text{volume of the solids} \end{array}$$

The volume of the voids, V_v , refers to the amount of space occupied by water and air in a sample, and can be calculated as follows:

$$V_v = V_t - V_s \quad \text{where:} \quad \begin{array}{l} V_t = \text{total volume of the sample} \\ V_s = \text{volume of the solids} \end{array}$$

Specific gravity, G_s , is also required as part of the calculations and defined as:

$$G_s = \frac{W_s}{V_s \gamma_w} \quad \text{where:} \quad \begin{array}{l} W_s = \text{weight of solids (i.e., dry weight)} \\ V_s = \text{volume of solids} \\ \gamma_w = \text{unit of weight of water} = 1 \text{ g/cc} \end{array}$$

Rearranging the above equation, the volume of solids, V_s , is calculated as follows:

$$V_s = \frac{W_s}{G_s \gamma_w}$$

2.5 Chemical Analysis

2.5.1 Total Organic Carbon (TOC)

Total organic carbon (TOC) analyses were performed using EPA's SW-846 Method 9060 (USEPA 1997a). In this method, organic carbon is measured using a carbonaceous analyzer that converts the organic carbon in a sample to carbon dioxide (CO_2) by either catalytic combustion or wet chemical oxidation. The CO_2 formed is then either measured directly by an infrared detector or converted to methane (CH_4) and measured by a flame ionization detector. The amount of CO_2 or CH_4 in a sample is directly proportional to the concentration of carbonaceous material in the sample. Results in this report are expressed on a dry weight basis.

2.5.2 PCDD/PCDF Analyses

This section describes the methods used for sample preparation, extraction, and analysis of PCDDs/PCDFs, including QC samples. A detailed discussion was provided in the Quality Assurance Project Plan for Monitoring the Disposal of Dredged Material Containing Dioxin: Laboratory Analysis of Baseline/Post-Storm Samples (SAIC 1993). Results of QA/QC analyses are given in Chapter 3. Samples were analyzed by Maxim Technologies Inc. using EPA Method 8290 (USEPA 1997b), with modifications, such as the levels of the internal standards, recovery standards, and native spiking materials, at the levels described in EPA Method 1613 (USEPA 1994). Following extraction, sample extracts were analyzed for PCDDs/PCDFs using combined capillary column gas chromatography/high resolution mass spectrometry (HRGC/HRMS).

The 30 sediment samples were analyzed for the dioxin and furan compounds (PCDDs/PCDFs) listed below:

Dioxins (PCDDs):

2,3,7,8-TCDD (Dioxin)
1,2,3,7,8-PeCDD
1,2,3,6,7,8-HxCDD
1,2,3,4,7,8-HxCDD
1,2,3,7,8,9-HxCDD
total 2,3,7,8-HpCDD
OCDD

Furans (PCDFs):

2,3,7,8-TCDF (Furan)
1,2,3,7,8-PeCDF
2,3,4,7,8-PeCDF
1,2,3,6,7,8-HxCDF
1,2,3,7,8,9-HxCDF
1,2,3,4,7,8-HxCDF
2,3,4,6,7,8-HxCDF
1,2,3,4,6,7,8-HpCDF
1,2,3,4,7,8,9-HpCDF
OCDF

The 17 PCDDs/PCDFs listed above are the compounds analyzed in Method 8290. Fourteen of these compounds are called "2,3,7,8-substituted PCDDs/PCDFs" and are the PCDDs/PCDFs believed to pose the greatest risks to human health and the environment based on structure activity relationships. The requested laboratory detection limit for both sample groups was 1 ppb for the tetra compounds, 5 ppb for the penta, hexa, and hepta compounds, and 10 ppb for the octa compounds.

Sediment Extraction. An aliquot of each sample was spiked with a ^{13}C -labeled internal standard solution and extracted for 18 hours using toluene in a Soxhlet extractor. The extracts were quantitatively transferred to Kuderna Danish concentrators, concentrated, and solvent exchanged to hexane. The hexane extracts were processed through the analyte enrichment procedures described below. One method blank and one laboratory spike sample was prepared with each group of up to 20 samples. Method blanks were used to identify any contamination that may be contributed by the laboratory during the preparation of samples for instrumental analysis. The laboratory quality control spike was prepared by extracting clean sand that had been fortified with unlabeled target PCDDs/PCDFs. Moisture content of the sediments was determined by oven drying separate aliquots of the samples until a constant dry weight was achieved.

Analyte Enrichment. In addition to the PCDDs/PCDFs, the extraction procedure often removes other compounds from the sample matrix. PCDDs/PCDFs are frequently associated with other chlorinated compounds such as polychlorinated biphenyls (PCBs) and polychlorinated diphenyl ethers (PCDPEs). PCBs can directly interfere with the analyses while other compounds can overload the capillary column, causing a degradation in chromatographic resolution or sensitivity. Because this method measures very low levels of PCDDs/PCDFs, the elimination of interferences is essential. The analyte enrichment (clean up) steps described below were used to remove interferences from the extracts.

Immediately prior to clean-up, extracts were spiked with a 2,3,7,8-TCDD- $^{37}\text{Cl}_4$ enrichment efficiency standard. The recovery of this standard can be used to differentiate between losses of

analytes or internal standards during extraction and losses that occur during the various cleanup procedures. Each extract was diluted to 100 ml with hexane, transferred to a separatory funnel and washed with 1N sodium hydroxide, concentrated sulfuric acid, and aqueous sodium chloride (5% w/v) as needed. The hexane extract was then quantitatively transferred to a liquid chromatography column containing alternating layers of silica gel, 40% concentrated sulfuric acid on silica gel, and 33% 1 N sodium hydroxide on silica gel. During this step, the acidic and basic compounds and easily oxidized materials were removed from the sample extract. The column was eluted with 90 ml of hexane and the entire extract collected and concentrated, under ambient conditions, to a volume of 1 ml.

Each extract was then fractionated on a liquid chromatography column by elution using a series of organic solvents with toluene being the final elutant. The toluene fraction was collected, spiked with two recovery standards (1,2,3,4-TCDD- $^{13}\text{C}_{12}$ and 1,2,3,7,8,9-HxCDD- $^{13}\text{C}_{12}$), and concentrated to a final volume of 20 μl . The 1,2,3,4-TCDD- $^{13}\text{C}_{12}$ is used to determine the percent recoveries of the tetra and penta chlorinated congeners, while the 1,2,3,7,8,9-HxCDD- $^{13}\text{C}_{12}$ recovery standard is used to determine the percent recoveries of the hexa, hepta, and octa chlorinated congeners.

PCDD/PCDF Analyses and Identification using HRGC/HRMS. Sample extracts were analyzed for the PCDDs/PCDFs using combined capillary column gas chromatography/high resolution mass spectrometry (HRGC/HRMS). Each 2,3,7,8-substituted PCDD/PCDF, with the exception of OCDF, was identified based on its retention time relative to the corresponding $^{13}\text{C}_{12}$ -labeled isomer. A labeled OCDF standard was not used due to the associated interference with the determination of the native OCDD. The OCDF was identified by its retention time relative to $^{13}\text{C}_{12}$ -labeled OCDD as determined from the daily calibration standard. The identification of all other PCDD/PCDF isomers was based on their retention times falling within their respective PCDD/PCDF retention time windows as established by a window defining mix.

Relative response factors were calculated from analyses of standard mixtures containing representatives of each of the PCDD/PCDF congener classes at five concentration levels, and each of the internal standards at one concentration level. The PCDD/PCDF isomers were quantified by comparing the sum of the responses from the two ions monitored for each class to the sum of the responses from the two ion masses of the isotopically labeled internal standard. The quantitative results for the unlabeled isomers were corrected for the recovery of the internal standards, based on the assumption that losses of internal standards during sample preparation and analysis are equal to the losses of the unlabeled PCDDs/PCDFs. The recovery of the internal standard was determined by comparing the response of the internal standard to the response of the appropriate recovery standard.

2.5.3 2,3,7,8-TCDD Toxic Equivalent Concentrations (TECs)

Method 8290 requires the calculation of the 2,3,7,8-TCDD Toxic Equivalent Concentration (TEC) to aid in the assessment of risks associated with exposure to these compounds. A 2,3,7,8-TCDD Toxicity Equivalence Factor (TEF; Safe 1990) is assigned to each of the 2,3,7,8-

Table 2-3

2,3,7,8-TCDD Toxicity Equivalence Factors (TEFs)
for Polychlorinated Dibenzodioxins and Dibenzofurans

| Number | Compound(s) | TEF (pptr) |
|------------------|---------------------|------------|
| DIOXIN COMPOUNDS | | |
| 1 | 2,3,7,8-TCDD | 1.0 |
| 2 | 1,2,3,7,8-PeCDD | 0.5 |
| 3 | 1,2,3,6,7,8-HxCDD | 0.1 |
| 4 | 1,2,3,7,8,9-HxCDD | 0.1 |
| 5 | 1,2,3,4,7,8-HxCDD | 0.1 |
| 6 | 1,2,3,4,6,7,8-HpCDD | 0.01 |
| 7 | OCDD | 0.001 |
| 8 | * Total - TCDD | 0.0 |
| 9 | * Total - PeCDD | 0.0 |
| 10 | * Total - HxCDD | 0.0 |
| 11 | * Total - HpCDD | 0.0 |
| FURAN COMPOUNDS | | |
| 12 | 2,3,7,8-TCDF | 0.1 |
| 13 | 1,2,3,7,8-PeCDF | 0.05 |
| 14 | 2,3,4,7,8-PeCDF | 0.5 |
| 15 | 1,2,3,6,7,8-HxCDF | 0.1 |
| 16 | 1,2,3,7,8,9-HxCDF | 0.1 |
| 17 | 1,2,3,4,7,8-HxCDF | 0.1 |
| 18 | 2,3,4,6,7,8-HxCDF | 0.1 |
| 19 | 1,2,3,4,6,7,8-HpCDF | 0.01 |
| 20 | 1,2,3,4,7,8,9-HpCDF | 0.01 |
| 21 | OCDF | 0.001 |
| 22 | * Total - TCDF | 0.0 |
| 23 | * Total - PeCDF | 0.0 |
| 24 | * Total - HxCDF | 0.0 |
| 25 | * Total - HpCDF | 0.0 |

* Excluding the 2,3,7,8-substituted congeners.

Reference: USEPA 1989

substituted PCDDs/PCDFs (Table 2-3). A TEF relates the toxicity of that congener to an equivalent concentration of the most toxic congener, 2,3,7,8-TCDD or dioxin. TEFs were defined by a 1989 international scheme (I-TEFs/89, NATO-CCMS 1988a, 1988b) and have been adopted by EPA (USEPA 1989). TEFs are different for each congener. The concentrations of congeners detected in environmental samples are multiplied by their respective TEF, and the products are summed over all congeners, yielding a concentration with the same toxicity as an equivalent amount of 2,3,7,8-TCDD. This concentration is variously referred to as a TCDD-Equivalent (TCDD-EQ), a TEQ (Toxic Equivalent), and, in this report, a Toxic Equivalent Concentration (TEC), expressed in units of ng/kg or ppt. The TECs were calculated using a value of one-half the LOD for values below detection (Clarke 1994; McFarland et al. 1994).

2.5.4 Normalization of PCDDs/PCDFs

Normalization is the process of relating the whole body or whole sediment concentration of a contaminant to a specific phase of the sediment. The normalized concentration then represents the concentration of the contaminant per unit of that phase of sediment. Normalization of contaminant concentrations is done when there is a significant body of evidence to suggest that the tissue or sediment phase that is used to normalize is the most important bulk phase that controls the behavior of a contaminant (Lake et al. 1990; O'Connor 1990). Normalization allows comparison of chemical concentrations when the controlling phase is variable in each sample. For organic compounds in tissues, the relevant controlling phase is usually the lipid content of the organism, as organic compounds segregate into lipids. For sediments, phases which are important for contaminants include fine-grained sediments (silts and clays) and organic matter, or TOC as measured here. In addition, the TOC concentration is an indicator of potential contaminant bioavailability. For neutral organic chemicals, TOC is the primary controlling phase; sorption to specific particle size fractions has been shown to be due largely to organic carbon content (Karickhoff et al. 1979). In sediments that have been influenced by anthropogenic activity, however, TOC is found to covary with contaminant concentrations because TOC itself is high around urban areas (NOAA 1991). Therefore, PCDDs/PCDFs are normalized both to TOC and the fine-grained sediment fraction for comparison. Sediment PCDDs/PCDFs are normalized by dividing the measured reported sediment concentration of PCDDs/PCDFs by the fraction of TOC or by the fraction of fine-grained sediments present in the sediment sample. Normalization can be done using either wet weight or dry weight data; in this report sediment dry weight data were normalized. The data are presented as ng contaminant per kg TOC or fine-grained sediment.

2.6 Statistical Analysis

Descriptive statistics calculated for the geotechnical and chemical data included average, standard deviation, coefficient of variation, minimum, and maximum for each of the physical and chemical properties reported, grouped by unit (e.g., cap material and dredged material). For calculation of geochemical statistics, where concentrations were below detectable limits, one-half the Limit Of Detection (LOD) was used (Clarke 1994).

The coefficient of variation (CV) is a measure of the amount of variability within a set of data. It is calculated using the following formula:

$$\text{Coefficient of Variation (CV)} = \frac{\text{standard deviation}}{\text{average}} \times 100$$

3.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

3.1 Geotechnical QC Data

All analyses were completed in accordance with the project objectives, and data were fully documented. Geotechnical data were received from GeoTesting Express in both hard copy and electronic formats.

All geotechnical analyses were conducted using standard ASTM methods. As part of these methods, associated QA/QC procedures were followed. Other QC procedures in the analysis of geotechnical data include triplicate analysis of water content and grain size, which were performed on core 97C-A for this project.

The coefficient of variation (CV) was used to evaluate the precision of these data. In Table 3-1, QA/QC measurements and calculations are provided. Water content triplicates had a CV of 4.5% and 1.4% for the sand cap and dredged material layers, respectively. For the major grain size components, defined as being $\geq 20\%$, CVs were less than 9.1%. When the CV is calculated for small numbers, particularly with a large range, the values tend to be skewed towards the high end. For this reason, the CV was calculated only for grain sizes comprising $\geq 20\%$ of the sample. Overall, the CVs in Table 3-1 indicate very good precision for these analyses.

3.2 Chemical QC Data

Data quality is typically assessed in relation to specified criteria for precision, accuracy, representativeness, comparability, and completeness (PARCC). Analytical precision is expressed as the percent difference between results of replicate samples (Relative Percent Difference [RPD] or Coefficient of Variation [CV]). Analytical accuracy of the laboratory is evaluated quantitatively as the percent recovery of a spiked standard compound added at a known concentration to the sample before analysis. When spiked duplicates are run, the results can be expressed as an RPD to evaluate precision of the analysis of the spiked compounds. By inference, the precision of analysis of other related compounds should be similar. Laboratory accuracy also is evaluated qualitatively by evaluating the laboratory QC information on sample holding times, method blank results, tuning and mass calibration, recovery of internal standards, laboratory quality control samples, and initial and continuing calibration checks. The following section defines the various QA/QC requirements and summarizes the data quality objectives for this project.

3.2.1 Sample Tracking Procedures

SAIC Standard Operating Procedures for sample tracking and custody were followed. In preparation for the field survey, a checklist of all samples to be collected was prepared. Sample containers were chemically-cleaned I-Chem® jars, and the labels were completed in indelible ink. After samples were placed inside, the jars were sealed with waterproof tape. Label information included the date, sample location, station number, replicate number, and type of

Table 3-1
 Triplicate Analysis Values for QA/QC
 (Core 97C-A)

| | Water Content* (%) | Percent | | | | Sand Components | | | |
|-------------------|--------------------|-------------|----------|----------|----------|-----------------|------------|----------|---------------|
| | | >Coarse (%) | Sand (%) | Silt (%) | Clay (%) | Coarse (%) | Medium (%) | Fine (%) | Very Fine (%) |
| Sand Cap Material | 18.7 | 14.5 | 83.5 | 3.0 | | 27.5 | 39.0 | 16.0 | 1.0 |
| | 18.1 | 14.5 | 83.5 | 3.0 | | 25.5 | 42.0 | 15.0 | 1.0 |
| | 17.1 | 19.5 | 79.5 | 2.0 | | 27.5 | 35.0 | 16.0 | 1.0 |
| S.D. | 0.8 | 2.9 | 2.3 | 0.6 | | 1.2 | 3.5 | 0.6 | 0.0 |
| AVG. | 18.0 | 16.2 | 82.2 | 2.7 | | 26.8 | 38.7 | 15.7 | 1.0 |
| CV (%) | 4.5 | ** | 2.8 | ** | ** | 4.3 | 9.1 | ** | ** |
| Dredged Material | 59.7 | 1.0 | 26.0 | 55.0 | 18.0 | 2.0 | 6.0 | 8.5 | 9.5 |
| | 58.4 | 0.5 | 28.5 | 53.0 | 18.0 | 2.0 | 7.5 | 7.0 | 12.0 |
| | 58.1 | 1.0 | 29.0 | 50.0 | 20.0 | 2.5 | 8.5 | 9.0 | 9.0 |
| S.D. | 0.9 | 0.3 | 1.6 | 2.5 | 1.2 | 0.3 | 1.3 | 1.0 | 1.6 |
| AVG. | 58.7 | 0.8 | 27.8 | 52.7 | 18.7 | 2.2 | 7.3 | 8.2 | 10.2 |
| CV (%) | 1.4 | ** | 5.8 | 4.8 | ** | ** | ** | ** | ** |

S.D = Standard Deviation

CV = Coefficient of Variation (see Section 2.6)

A legend for grain sizes can be found in Appendix C

*Corrected for 35ppt salinity

**CVs were only calculated for major grain size components (>20%)

analysis. All sediment chemistry samples were stored at 0-4° C. Chain-of-custody records were maintained for all samples.

3.2.2 Sample Holding Times

The sediment samples were collected on May 5 through May 7, 1998. They were stored under refrigeration and in the dark until they could be shipped to the laboratory on May 11, 1998. The laboratory received the samples on May 12, 1998. Extraction of sediment samples was undertaken from May 15 to 19, 1998, and the samples were analyzed from May 27 to June 12, 1998.

The recommended maximum holding time for dioxin/furan samples is 30 days from sample collection to extraction, and 45 days from collection to analysis, as specified in Method 8290 (USEPA 1997b). The more recent Method 1613 states, however, that there are no demonstrated

maximum holding times associated with PCDDs/PCDFs in aqueous, solid, semi-solid, tissues, or other sample matrixes, as well as extracts, and samples may be stored up to one year (USEPA 1994). Samples were held for a maximum of 14 days between collection and extraction and 38 days between collection and analysis. These samples were stored for less than the one year recommendation of Method 1613 and the data, therefore, are considered valid with respect to sample holding time requirements.

3.2.3 Method Blanks

Data from three method blanks were submitted for the 30 analyzed samples, meeting the requirement of one blank for every 10 samples of sediment. The method blanks were free of PCDDs and PCDFs, with the exceptions of trace background levels (0.12 ng/kg, or pptr) of TCDF and (0.20 pptr) 1,2,3,4,6,7,8-HpCDF, and slightly higher levels (1.1 pptr) of OCDD. These measured background levels were all below the instrument calibration ranges. In the data report supplied by the laboratory, samples containing the above listed compounds within five times the associated blank level were flagged. Sample values that are less than five times the associated method blank cannot be distinguished from background.

3.2.4 Assessment of Analytical Accuracy

Analytical accuracy is evaluated by examining the percent recovery of a known concentration of a compound spiked to the environmental sample before analysis. The closer that the numerical value of the measurement approaches the actual concentration of the compound, the more accurate the measurement. The percent recovery values are calculated using the following equation:

$$\frac{A_r - A_o}{A_f} \times 100$$

where: A_r = Total compound concentration detected in the spiked sample
 A_o = Concentration of the compound detected in the unspiked sample
 A_f = Concentration of the spike added to the sample

Internal standards, consisting of $^{13}\text{C}_{12}$ -labeled PCDD/PCDFs, were added as spikes to each sample prior to extraction in order to determine the percent recovery of the spike, and to evaluate overall accuracy of the analysis for each individual spike. Recoveries of isotopically-labeled PCDD/PCDF internal standards used as spikes must fall within the range of 40 to 135% as stated in EPA Method 8290 (USEPA 1997b). Measured recoveries of spiked internal standards for this data set generally ranged from 40 to 131%, indicating a level of efficiency in the extraction and enrichment steps that is considered typical for this matrix. Slightly lower recoveries (28-38%) were obtained for the labeled TCDD and/or TCDF internal standards in samples 97E-B-86, 97E-B-106, and 97R-B-176. Detection limits were not impacted in any of these cases as the quantification of the native 2378-substituted isomers was based on isotope dilution. The data were automatically corrected for variation in recovery.

In addition to internal isotopically-labeled standards, matrix spike (MS) and matrix spike duplicate (MSD) samples were prepared from three of the submitted samples: 97B-B (103 cm), 97Q-A (116 cm), and 97U-A (146 cm). Matrix spike (MS) and matrix spike duplicates (MSD)

are prepared by dividing a sample into multiple aliquots and spiking an aliquot with a known concentration of analyte and finally proceeding with the analysis as though the spike was a sample. The laboratory standard operating procedure targets a range of 75 to 125% recovery. The MS/MSD recoveries indicated acceptable accuracy; recovery rates ranged from 81 to 117%.

A laboratory QC spike sample was also prepared with each sample batch by extracting clean sand that had been fortified with native standards. Recoveries of spiked native compounds must fall within the range of 70 to 130% as defined by the laboratory standard operating procedure. The recoveries of the analytes from the spiked samples ranged from 73 to 118%, indicating acceptable accuracy.

3.2.5 Assessment of Analytical Precision

Analytical precision is expressed as the relative percent difference (RPD) between two results or the coefficient of variation (CV) between three or more results. Three types of replicate samples were examined for precision analysis: matrix spike duplicates (MS/MSD), laboratory spike samples, and three samples that were homogenized by the laboratory and then divided into triplicate subsamples. The triplicates were analyzed independently. The closer the numerical values of the measurements are to each other, the lower the RPD or CV. Low RPD or CV values indicate a high degree of analytical precision.

The relative percent difference (RPD) between two sample results was calculated using the following equation:

$$\text{RPD} = \frac{(\text{sample result} - \text{duplicate result})}{(\text{sample result} + \text{duplicate result}) / 2} \times 100$$

The RPD for the matrix spike duplicates should be 20 percent or less for a high degree of precision. The CV values for the laboratory triplicates should equal 25% or less (USEPA 1997b).

The RPD values obtained for the recovery of the spiked compounds in the MS/MSD samples ranged from 0.2-16.3%, indicating a high degree of precision. The CV for the laboratory spike samples ranged from 5.7 to 20.3%, indicating acceptable precision. Three samples (97R-B [96 cm], 97R-B [116 cm], and 97U-A [166 cm]) were each split into three aliquots to be analyzed as triplicates. Precision calculations could not be made for these triplicates as dioxin and furan were not detected in any of these samples.

3.2.6 2,3,7,8-TCDF Confirmation

Confirmation of 2,3,7,8-TCDF was performed on all samples having detected concentrations of this isomer. On the initial DB-5 capillary gas chromatographic column, other isomers can coelute with furan. Historically, problems have been associated with the separation of 2,3,7,8-TCDF and 2,3,4,7-TCDF. Therefore, these samples were re-run on a second, DB-DIOXIN

column in order to confirm the presence of the 2,3,7,8-TCDF isomer. In this instance, samples from cores 97B-B (103, 131, and 143 cm), 97C-A (108 and 148 cm), 97Q-A (116 and 128 cm), 97R-B (96, 116, 136, 176, and 196 cm), and 97U-A (146, 166, 186, 206, and 239 cm) also had interferences using the DB-DIOXIN column. Therefore, for these samples, 2,3,7,8-TCDF values have been flagged as having possible contributions from other TCDF isomers.

Interferences from polychlorinated diphenylethers (PCDPEs) were found in many of the samples. PCDPEs can give false positive responses for PCDFs. Therefore, any PCDF response exhibiting a simultaneous response in the PCDPE channel was omitted from the calculations; as a result, the limits of detection (LODs) for affected isomers were elevated. The degree of elevation of LODs tends to increase as the degree of chlorination of the compound increases.

3.2.7 Instrument Performance

Continuing calibration checks of the instrument must show a response deviation within $\pm 25\%$ RPD for the 17 PCDD/PCDF compounds of interest and within $\pm 35\%$ RPD for the nine isotopically-labeled PCDD/PCDF internal standards (USEPA 1997b). Daily instrument calibration checks showed response factor deviations within these specified limits.

3.2.8 Total Organic Carbon

A total of 30 sediment core samples were analyzed for total organic carbon (TOC) according to EPA Method SW846 9060. Analyses were carried out on June 2, 1998. Triplicates were taken from three sediment core samples, 97B-B (103 cm), 97E-B (86 cm), and 97R-B (96 cm) which yielded CVs of 8.9%, 8.3% and 20.1%, respectively. Analyses of TOC are typically subject to a high degree of variation. This high variation combined with the low TOC values found in the cap material caused the higher CV value of 20.1%. These CV values generally indicate acceptable precision. There were two laboratory control samples analyzed with recoveries of 109%, well within the 75-125% acceptable accuracy range.

3.2.9 Representativeness, Completeness, and Comparability

Sample representativeness was ensured during the sampling survey by collecting a sufficient number of sediment samples from the cap (14 samples) and dredged material (16 samples) portions of the cores. All samples were collected in a uniform manner and are considered to be representative (see Methods).

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Comparability is based in large part on the other PARCC parameters because precision and accuracy must be known to compare one data set with another. To optimize comparability, sampling stations and sampling procedures used in the April 1998 survey were consistent with those employed in previous surveys of the New York Mud Dump Site in which chemistry samples were collected (1993 Dioxin Capping Project baseline and postcap surveys). Analytical methods and protocols were also the same for this and past surveys, and the same laboratory (Maxim Technologies Inc.) performed the analyses for all surveys.

4.0 RESULTS

4.1 Core Descriptions and Photography

This section presents descriptions of the cores based on visual observations and photographs. Core photographs with detailed descriptions are provided in Appendix A.

Material observed in this suite of cores was classified as either sand cap material (cap), project dredged material (DM), or pre-project material (PP). The specific characteristics of each of these material units are discussed in detail below. Visual observations made by SAIC and GeoTesting Express, discrete core data collected by GeoTesting (Appendix B), down-core geotechnical profiles of water content and bulk density (Appendix C), and postcap bathymetric results all were consulted in order to arrive at the material type classifications presented.

4.1.1 Sand Cap (Cap)

The sand cap material was a mix of fine, medium, and coarse sand that ranged from dark gray to grayish brown and brownish gray in color. Shell fragments were observed within the sand cap layer of all the cores. The transition between the cap and dredged material units was clearly evident, as seen in the core photographs (Appendix A) and the geotechnical profiles (Appendix C). Sand from the cap often was observed along the outer edge of the dredged material in the core liner for the first few centimeters. This is due to drag-down during the coring process (e.g., Appendix A, Core 97C-A).

All 14 cores were collected within the cap boundary footprint (Figure 4-1). All cores contained a sand cap layer greater than one meter, ranging from 116 to 257 cm (Table 4-1). Coring surveys from the 1993 Dioxin Capping Project have shown high spatial variability of cap thickness measurements, both among replicate cores and at similar locations through time (SAIC 1995a, 1995b). The sand cap thicknesses measured in the cores of the present survey are consistent with postcap bathymetric (SAIC 1998a) and sub-bottom (SAIC 1998b) survey data.

In Table 4-2, the average sand size fractions of the 1993 Dioxin Capping Project cap and the 1997 Category II Capping Project cap are presented. Although the sand cap material for both projects was obtained from Ambrose Channel, the 1993 cap was dominated by medium to fine sand. The 1997 sand cap is composed primarily of medium sand, with high amounts of fine (25.7%) and coarse (19.6%) sand also present. These differences, as discussed in the following sections, were used in the classification of material types to help track and differentiate the 1993 cap within the pre-project (PP) material unit.

4.1.2 Project Dredged Material (DM)

In general, the DM unit was composed of a fine-grained, black, silty clay material. A 20 cm interval of fine to medium, very dark gray sand was observed in Core 97A-A at 190

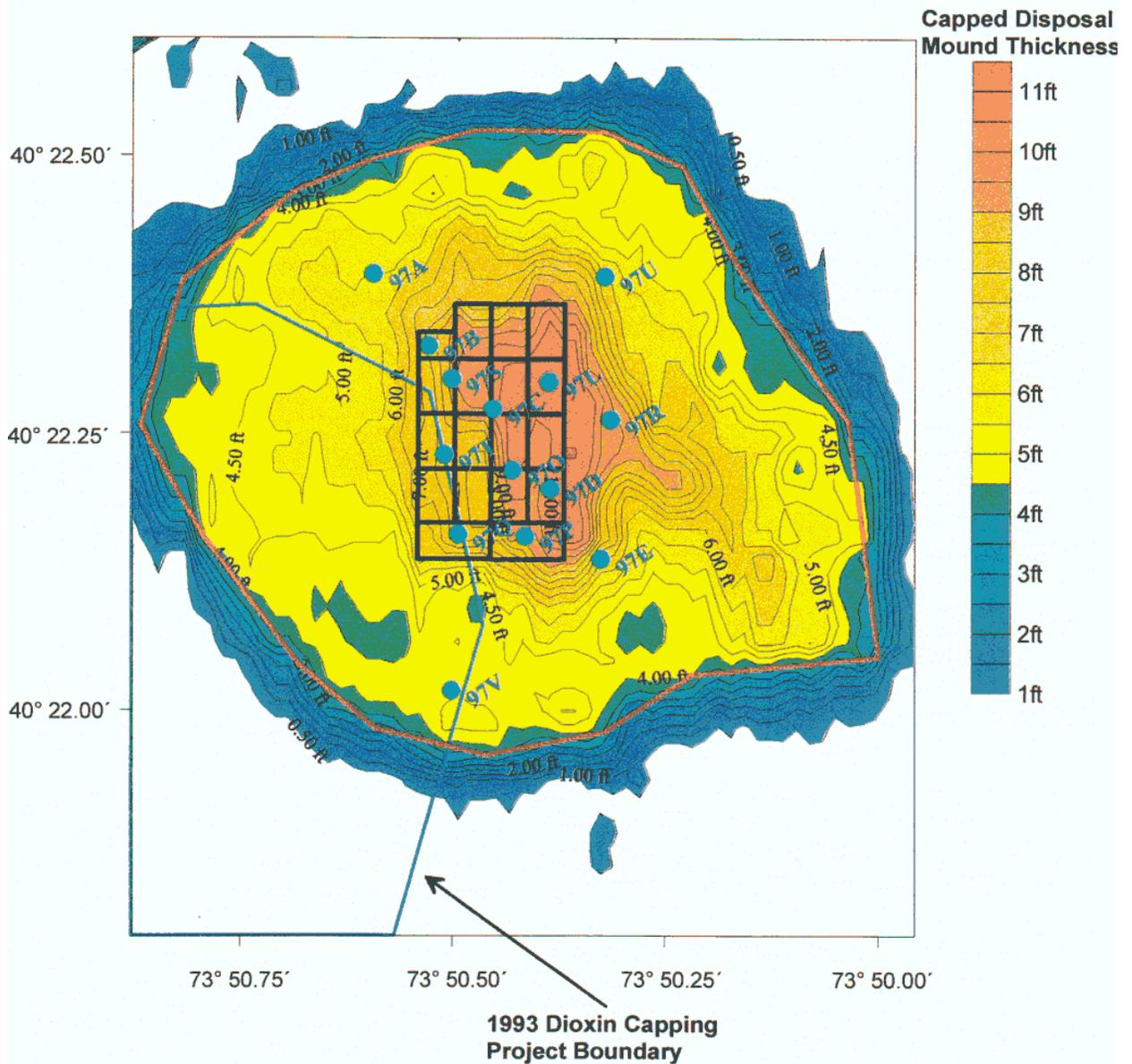


Figure 4-1. Postcap core locations superimposed on bathymetric results showing capped mound thickness based on the depth difference between the baseline (April 1997) and postcap (April 1998) bathymetric surveys.

Table 4-1

Thickness of Sand Cap as Measured in the Collected Sediment Cores

| Core | Cap Thickness (cm) |
|-------------|---------------------------|
| 97A-A | 167 |
| 97B-B | 133 |
| 97C-A | 146 |
| 97D-B | 225 |
| 97E-B | 116 |
| 97L-B | 228 |
| 97O-A | 245 |
| 97P-A | 257 |
| 97Q-A | 120 |
| 97R-B | 126 |
| 97S-B | 194 |
| 97T-B | 229 |
| 97U-A | 176 |
| 97V-A | 150 |

Table 4-2

Average Sand Fraction Components for the 1993 Dioxin Capping Project and 1997 Category II Capping Project Sand Caps

| | Coarse (%) | Medium (%) | Fine (%) | Very Fine (%) |
|-----------------|-------------------|-------------------|-----------------|----------------------|
| 1993 Cap | 5.8 | 34.2 | 48.5 | 7.8 |
| 1997 Cap | 19.6 | 44.3 | 25.7 | 2.5 |

cm depth, and a 5 cm band of medium dark gray sand was seen in Core 97U-A at 235 cm (Appendix A). Due to the fact that the sand band in 97A-A was composed of fine to medium sand instead of the dominant medium to coarse sand generally seen in this cap (Table 4-2), and that only one core exhibited a sand band so near the cap/dredged material interface (~25 cm below interface), it most likely was a result of natural variation within the deposited project dredged material. Postcap bathymetric results indicated a total material thickness (cap plus DM) of 6 to 7 ft in the vicinity of station 97U. The sand that was seen within this core, therefore, was also most likely a function of the dredged material's natural variability. Core 97B-B contained various intervals of brown gray and very dark gray clay and silty clay. Various shades of gray silty clay also were observed throughout cores 97D-B, 97E-B, 97Q-A, 97S-B, 97T-B, and 97U-A.

These observed variations in color and texture are typical of dredged material and a testament to its natural variability.

Overall, the grain size was relatively uniform throughout the DM layer, and the material appeared much more cohesive or “sticky” than in the previous interim disposal (July 1997, SAIC 1998g) and postdisposal (August 1997, SAIC 1998g) surveys. This observed change is likely a function of the consolidation processes that have begun to take place prior to and since the placement of the sand cap material (Section 5).

4.1.3 Pre-Project Material (PP)

In three of the collected cores (97A-A, 97E-B, and 97V-A), it appears that pre-project material was recovered. In core 97A-A, a 20 cm layer of sand was observed at ~230 cm. Beneath this sand was an apparent dredged material layer (Appendix B) which was interpreted as being historical material. In 97E-B, very sandy material was observed from 180 to 250 cm. This sand interval may be from the fringe of the 1993 Dioxin Capping Project cap (Figure 4-1) or the earlier EMD project sand cap (Parker and Valente 1988). In core 97V-A, an apparent change from '97 to '93 cap material was observed at ~165 cm where the sand changed to a finer texture. Cap material from this project was generally a medium- to coarse-grained sand (Table 4-2). Additionally, silty black bands were observed near the cap-dredged material interface located at ~252cm. This type of banding was a typically seen feature within the 1993 Dioxin Capping Project capping material (SAIC 1998d).

4.2 Geotechnical Analyses

Geotechnical data for the discrete samples taken within each core are presented in Appendix B. Summary statistics for the cap and DM material units are presented in Tables 4-3a-b. These data are discussed within subsequent sections.

4.2.1 Water Content

The water content of the cap material was relatively uniform throughout all of the cores, ranging from 17.1 to 26.3%. The average water content was 20.8% \pm a standard deviation of 1.6% (Table 4-3a). This uniformity reflects the consistency of the source area (Ambrose Channel).

Water content in the DM unit ranged from 21.5 to 85.3%, and had an average of 59.7% \pm 13.1% (CV = 21.9%; Table 4-3b). In general, a linear relationship is expected between water content and bulk density. A plot of all the water content and bulk density values obtained in the 1997 Category II Capping Project coring surveys serves to confirm this (Figure 4-2). This plot shows that the majority of bulk density values fall within a water content range of 40% to 80%. For the postcap coring survey, several DM values were plotted in the vicinity of cap material values, and represented dredged material samples with high sand content (Appendix B, Cores 97A-A and 97B-B). Due to its mineral structure, sand is a poor retainer of water, and therefore tends to have lower water content

Table 4-3a

Summary of Physical Properties for Sand Cap Material

| | Sand Cap Material (C) | | | | | |
|-----------------------------|-----------------------|-----------|--------------------------|------|------|--------------|
| | Average | Std. Dev. | Coefficient of Variation | Min | Max | Sample Count |
| Water Content (%) | 20.8 | 1.6 | 7.7 | 17.1 | 26.3 | 68 |
| Bulk Density (g/cc) | 1.96 | 0.05 | 2.55 | 1.81 | 2.07 | 68 |
| > Coarse (%) | 6.1 | 5.1 | 83.6 | 1.0 | 19.5 | 29 |
| Sand (%) | 90.1 | 4.6 | 5.1 | 78.5 | 95.5 | 29 |
| Coarse (%) | 19.6 | 7.1 | 36.2 | 7.0 | 30.0 | 29 |
| Medium (%) | 44.3 | 5.8 | 13.1 | 35.0 | 55.5 | 29 |
| Fine (%) | 25.7 | 10.9 | 42.4 | 10.0 | 47.0 | 29 |
| Very Fine (%) | 2.5 | 2.0 | 80.0 | 0.0 | 7.0 | 29 |
| Silt & Clay (%) | 3.7 | 2.2 | 59.5 | 1.0 | 10.0 | 29 |
| Liquid Limit (%) | --- | --- | --- | --- | --- | --- |
| Plasticity Index (%) | --- | --- | --- | --- | --- | --- |
| Specific Gravity | --- | --- | --- | --- | --- | --- |
| Void Ratio | 0.71 | 0.3 | 40.9 | 0.5 | 2.1 | 68 |
| USCS Symbol(s)* | SP | | | | | 28 |

Table 4-3b

Summary of Physical Properties for Dredged Material

| | Dredged Material (DM) | | | | | |
|-----------------------------|-------------------------|-----------|--------------------------|------|------|--------------|
| | Average | Std. Dev. | Coefficient of Variation | Min | Max | Sample Count |
| Water Content (%) | 59.7 | 13.1 | 21.9 | 21.5 | 85.3 | 98 |
| Bulk Density (g/cc) | 1.67 | 0.10 | 6.0 | 1.51 | 2.05 | 96 |
| > Coarse (%) | 1.8 | 2.4 | 133.3 | 0.0 | 14.0 | 44 |
| Sand (%) | 16.4 | 9.5 | 57.9 | 3.0 | 42.5 | 44 |
| Coarse (%) | 2.6 | 1.9 | 73.1 | 0.5 | 9.5 | 44 |
| Medium (%) | 5.7 | 3.5 | 61.4 | 0.5 | 14.5 | 44 |
| Fine (%) | 6.8 | 4.8 | 70.6 | 1.5 | 25.0 | 44 |
| Very Fine (%) | 9.0 | 3.0 | 33.3 | 2.5 | 15.0 | 44 |
| Silt (%) | 62.4 | 8.5 | 13.6 | 37.0 | 78.0 | 44 |
| Clay (%) | 19.4 | 4.5 | 23.2 | 12.0 | 32.0 | 44 |
| Liquid Limit (%) | 65.0 | 11.1 | 17.1 | 34.5 | 82.5 | 31 |
| Plasticity Index (%) | 40.0 | 9.0 | 22.5 | 16.8 | 59.1 | 31 |
| Specific Gravity | 2.64 | 0.05 | 1.9 | 2.52 | 2.73 | 31 |
| Void Ratio | 1.56 | 0.31 | 19.9 | 0.59 | 2.21 | 96 |
| USCS Symbol(s)* | CH (27), CL (3), SC (1) | | | | | 31 |

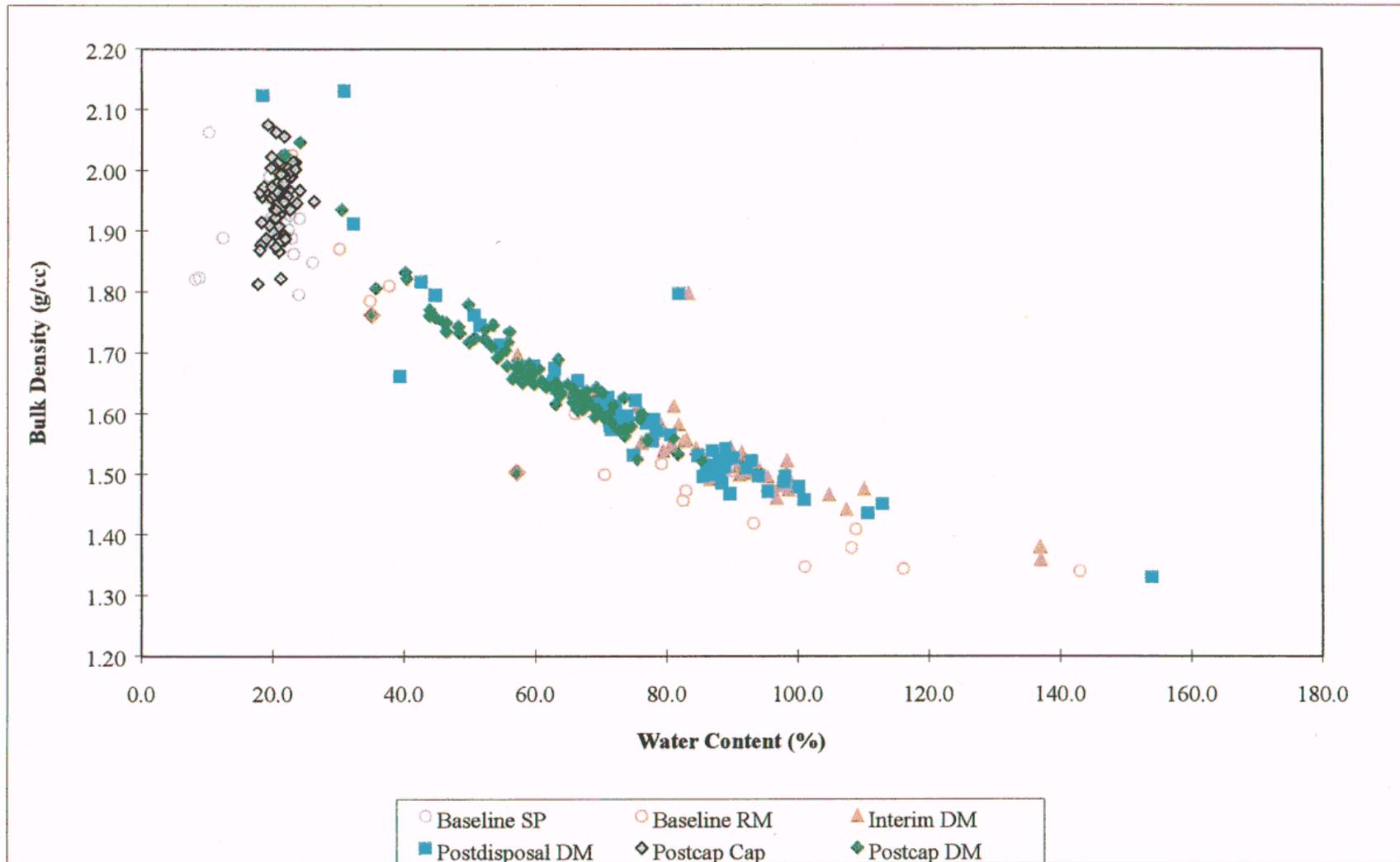


Figure 4-2. Plot of water content versus bulk density for datasets collected during the baseline (RM and SP), interim disposal (DM), postdisposal (DM), and postcap (cap and DM) sediment coring surveys.

values compared to silt and clay. Two additional points also are observed which do not really fit the general curve of the data (Figure 4-2; Appendix B, Core 97U-A). These samples had a higher percentage of coarse-grained sand (6.5%), resulting in a lower water content. These few outliers attest to the natural “patchiness” of the project material with respect to texture and water content. The average water content value for the DM unit observed during this survey (59.7% \pm 13; Table 4-3b) was slightly lower than that observed in the postdisposal coring data (77.1% \pm 22.0; Table 4-4). Statistically, a two-tailed t-test for samples with unequal variance indicated that the observed difference in the means was significant (P<0.001). This suggested that statistically significant consolidation of the dredged material had occurred since the placement of the sand cap (Section 5.1.2).

Table 4-4

Summary of Physical Properties for Postdisposal (August 1997) Dredged Material

| | Dredged Material (DM) | | | | | |
|-----------------------------|---|-----------|--------------------------|------|-------|--------------|
| | Average | Std. Dev. | Coefficient of Variation | Min | Max | Sample Count |
| Water Content (%) | 77.1 | 22.0 | 28.6 | 18.4 | 154.0 | 60 |
| Bulk Density (g/cc) | 1.60 | 0.15 | 9.1 | 1.33 | 2.13 | 60 |
| > Coarse (%) | 2.7 | 4.6 | 166.7 | 0.0 | 34.0 | 60 |
| Sand (%) | 17.5 | 11.9 | 68.2 | 2.5 | 69.0 | 60 |
| Coarse (%) | 1.9 | 2.7 | 140.8 | 0.0 | 15.0 | 60 |
| Medium (%) | 5.2 | 5.3 | 101.3 | 0.0 | 31.0 | 60 |
| Fine (%) | 5.6 | 4.1 | 72.5 | 0.5 | 21.0 | 60 |
| Very Fine (%) | 4.8 | 2.5 | 52.8 | 0.5 | 12.0 | 60 |
| Silt (%) | 52.4 | 11.9 | 22.8 | 14.0 | 77.0 | 60 |
| Clay (%) | 27.4 | 5.9 | 21.5 | 7.0 | 38.0 | 60 |
| Liquid Limit (%) | 49.0 | 7.8 | 15.8 | 30.5 | 74.6 | 58 |
| Plasticity Index (%) | 21.0 | 5.2 | 24.9 | 9.0 | 37.2 | 58 |
| Void Ratio | 2.0 | 0.6 | 30.1 | 0.5 | 4.2 | 60 |
| USCS Symbol(s)* | CL (20), MH (17), ML (13), SM (1), CH (7), SC (2) | | | | | |

4.2.2 Bulk Density

In general, bulk density is inversely proportional to water content (e.g., Figure 4-2). During the process of consolidation, water is removed from pore spaces and that volume is then generally replaced by sediment (solids). This results in more sediment being present within an equal sample volume, thereby increasing the material’s bulk density. Within the cap material, the average bulk density was 1.96 \pm 0.05 g/cc, with a range of 1.80 to 2.07 g/cc. Within the DM unit, the average bulk density value was 1.67 \pm 0.10g/cc, and had a range of 1.51 to 2.05 g/cc.

In comparison to the postdisposal DM data, the average bulk density value observed here was slightly higher (1.60 verses 1.67 g/cc). This is consistent with the general increase in

values expected over time. Statistically, however, a t-test showed that no significant difference existed between the postdisposal and postcap bulk density values. This appears to be inconsistent with the statistical change observed in the water content values between the two surveys. However, the relative magnitude of the change in bulk density was much smaller than that observed for water content.

4.2.3 Grain Size

The grain size measurements indicated a sharp distinction between the sand cap and finer-grained DM (Appendix B). Within the cap material, medium sand was the most dominant component (average of 44.3%) and showed the least variation (CV = 13.1%; Table 4-3a). Coarse (average of 19.6%) and fine (average of 25.7%) fractions also were significant components. Very little silt and clay (average of 3.7%) was present within the cap material.

Silt was the dominant grain size within the DM unit (average of 62.4±8.5%). Clay-sized particles, with an average of 19.4±4.5%, were the secondary component within this material. This is consistent with observed values for both the interim (averages of 51.8% for silt, 30.5% for clay; SAIC 1998g) and postdisposal (averages of 52.4% for silt, 27.4% for clay; Table 4-4) datasets. Within all three datasets, sand was observed as a patchy and variable component.

Table 4-5 presents the average sediment fraction components of the dredged material from the interim disposal, postdisposal, and postcap sediment coring surveys. A single factor ANOVA test indicated that no significant difference existed between the observed percent sand in the three surveys (P=0.8). It did, however, indicate a significant difference in the observed silt and clay percentages over time (P<0.001). This change may be an artifact related to coring techniques (gravity versus vibracore), or variability in laboratory data (though this is believed to be minimal). The grain size distribution could also reflect the natural variation of the DM. The process of consolidation, however, might affect the relative distribution of silt and clay-sized particles because of the physical compaction of pore spaces between particles (i.e., clay-sized particles aggregating into larger particles). The trend will continue to be monitored in upcoming surveys.

Table 4-5

Average Sediment Fraction Components for DM Collected during the Interim Disposal, Postdisposal, and Postcap Coring Surveys

| Average Percent | Interim Disposal | Postdisposal | Postcap |
|-----------------|------------------|--------------|---------|
| Sand | 15.3 | 17.5 | 16.4 |
| Silt | 51.8 | 52.4 | 62.4 |
| Clay | 30.5 | 27.4 | 19.4 |

NOTE: Because average values are used, sums may not equal 100%

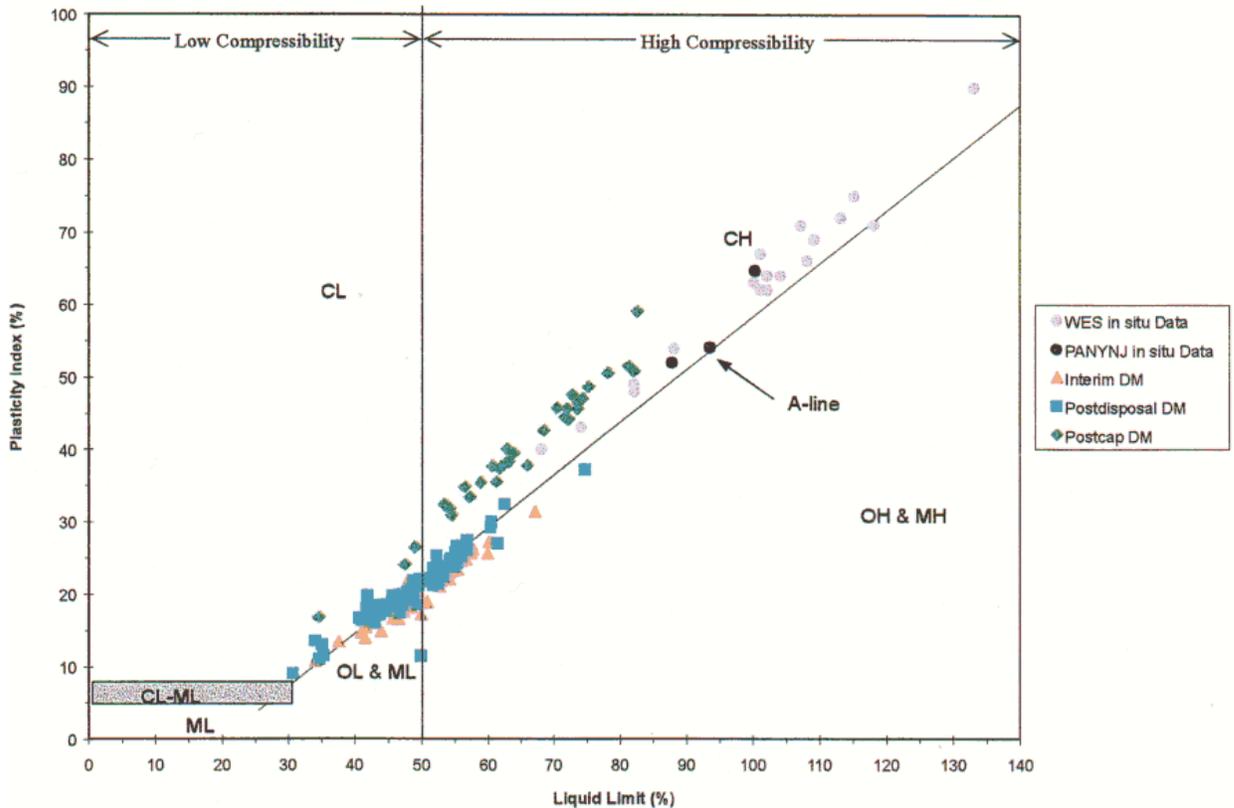
4.2.4 Atterberg Limits

Atterberg limits were only measured within the fine-grained sediment fractions (i.e., silt and clay). Within the fine-grained DM unit, average values for liquid limit and plasticity index were $65.0 \pm 11.1\%$ and $40.0 \pm 9.0\%$, respectively (Table 4-3b). The Atterberg limits were not distinct enough to differentiate changes within the dredged material texture. In general, water content values were observed to be lower than measured liquid limits (Appendix B), indicating increased material stability as consolidation had begun to occur (Section 5.1.2).

In December 1996, WES took core samples of the pre-dredged material in both Port Newark and Port Elizabeth. These data were used to model and help design the 1997 Category II Capping Project (Rollings and Rollings 1998a). Within the same time frame, the Port Authority of New York and New Jersey (PANYNJ) collected samples within Port Elizabeth as part of a study to look at maintenance dredged material properties in the area (PANYNJ 1996). These *in situ* values were plotted on a plasticity chart along with Atterberg limits measured for the interim disposal, postdisposal, and postcap datasets (Figure 4-3). Plasticity charts are used to help classify silt and clay into the various subdivisions described by the USCS criteria (Section 4.2.5). The “A-line” (Figure 4-3) indicates the boundary between inorganic clay (symbols CH and CL, above the line) and the inorganic silt and organic clay (symbols ML, MH, OL, and OH) sediments. In such a chart, any data points that fall within the shaded box have characteristics of both inorganic silt and clay, and therefore carry a double classification. Also, sediments with a liquid limit of greater than 50% are generally considered to be highly compressible. Further details of this classification system can be found in standard soil classification texts (e.g., Wu 1976).

When plotted, the postcap data generally fell above the A-line, indicating a homogenous mixture of inorganic clay. In general, the Atterberg limits observed in the DM unit of the postcap cores overlap with the range of the *in situ* values observed by WES and PANYNJ in December 1996 (Figure 4-3). The observed variability is attributed to the natural heterogeneity of the dredged material. Preliminary analysis of cores analyzed by WES showed that considerable variability in material type and density was apparent throughout the sampling site and even within duplicate cores (Rollings and Rollings 1998a). It is also important to note that the project material came from several different sites and that geological variation within and among sites is expected. By nature, dredged materials tend to be highly patchy and heterogeneous (Rollings and Rollings 1998a).

The postcap data also showed a marked shift towards higher plasticity index and liquid limit values compared to the interim disposal and postdisposal datasets. This shift can be explained by the change in testing procedures used to measure the Atterberg limits. In previous surveys, a dry sample preparation was used. In this survey, however, the protocol was changed to use the wet sample preparation techniques presented in ASTM method D 4318 (Section 2.4.3). A comparison of duplicate samples tested each way (Appendix B, core 97D-B and 97E-B) showed that while the plastic limit was not affected, the liquid limit was 5 to 20% lower in samples prepared using the dry preparation technique. Because the plasticity index is calculated by subtracting the



| | |
|----|--|
| ML | inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity |
| CL | inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays |
| OL | organic silts and organic silt-clays of low plasticity |
| MH | inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| CH | inorganic clays of high plasticity, organic silts |
| OH | organic clays of medium to high plasticity |

Figure 4-3. Plasticity chart for DM from the interim disposal, postdisposal, and postcap datasets. *In situ* data collected by WES and PANYNJ fort Port Newark and Port Elizabeth in December 1996 is also included.

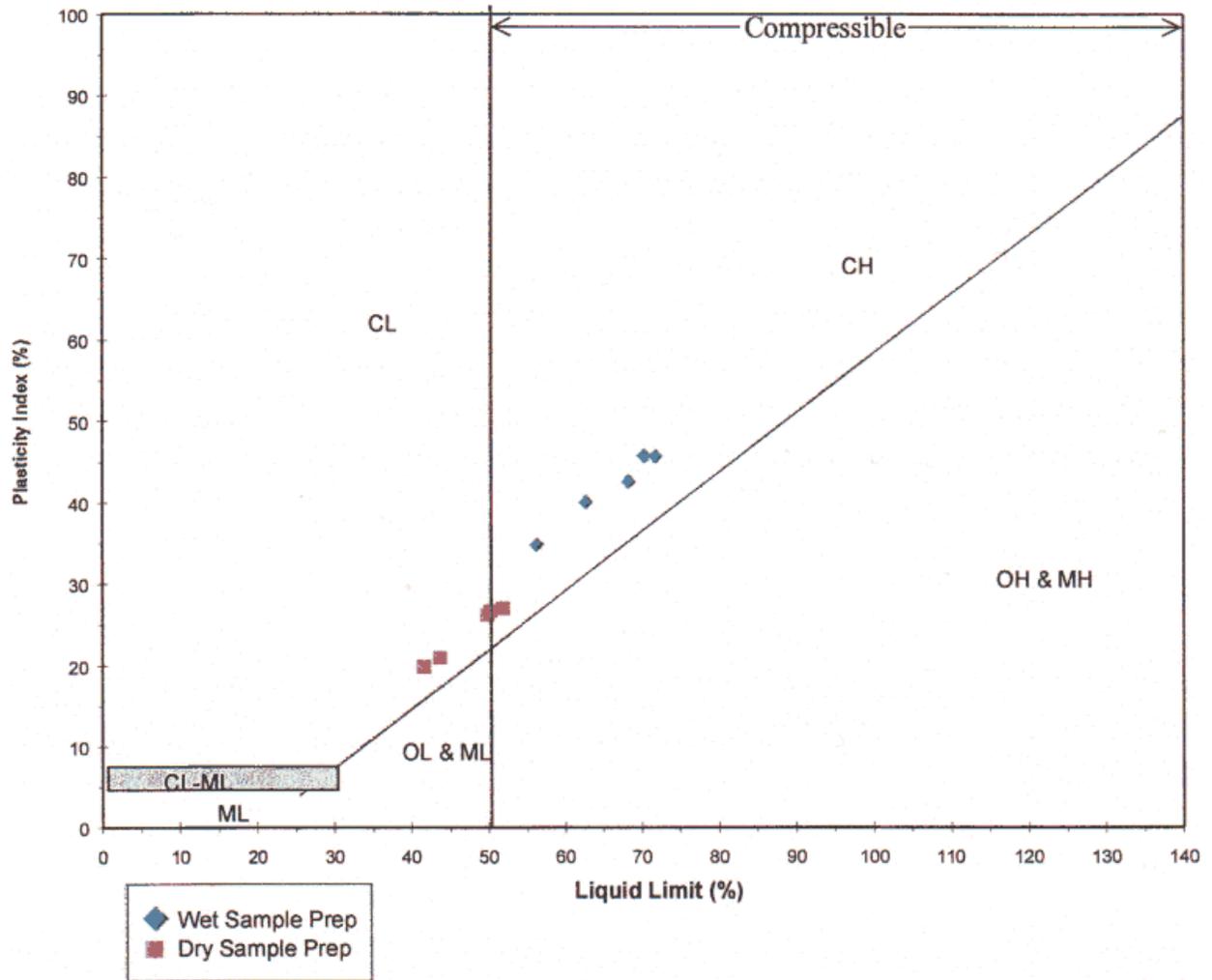


Figure 4-4. Plasticity chart comparing wet versus dry sample preparation techniques.

plastic limit from the liquid limit, it shows a similar decrease in samples tested using dry preparation. In Figure 4-4, data points for the duplicate samples tested each way were plotted, showing a shift similar to that seen in Figure 4-3.

4.2.5 USCS Classification

The Unified Soil Classification System (USCS) is used to help provide consistent soil type descriptions using visual observations and geotechnical characteristics. The system was developed in 1948 for primary use in airfield construction, and later modified in 1952 for use in other types of construction (Bowles 1979). The classification system is useful to categorize the saturated marine sediments from this project. Classification of the cap material was uniformly SP (poorly graded sand). The preponderance of samples from the DM unit were classified as CH (inorganic clays of high plasticity, organic silts). Three of 31 samples were classified as CL (inorganic clays of low to medium plasticity,

sandy clays, and silty clays) and the remaining sample was classified as SC (clayey sands, poorly graded sand-clay mixtures).

A shift in the classifications derived from Atterberg limits between this survey and the interim and postdisposal surveys can be seen in Figure 4-3. This shift is artificial due to the change from dry sample preparation to wet sample preparation for Atterberg limit testing (Section 4.2.4).

4.2.6 Specific Gravity

Specific gravity measurements were made for the DM unit for the first time in the 1997 Category II Capping Project. Values ranged from 2.52 to 2.73, and had an average of 2.64. This value is similar to the literature-derived value of 2.7 assumed in the previous interim disposal and postdisposal reports. No specific gravity measurements were made within the cap material, so an assumed value of 2.67 was derived from the literature for sand (Das 1983).

4.2.7 Void Ratio

Void ratio is a calculated value (Section 2.4.6) used to help assess a material's state of consolidation. Void ratio values for the cap material ranged from 0.5 to 2.1, with an average of 0.71 ± 0.3 (Table 4-3a). As the material consolidates, the void ratio values will decrease over time. Sand is considered to be relatively incompressible, however, so that changes in void ratio should be negligible as time progresses.

Void ratio values for the DM unit averaged 1.56 ± 0.31 for this survey. Even when the effect of using the new measured specific gravity value over the previously used theoretical value is taken into consideration, this was a decrease over the postdisposal average of 2.0 ± 0.6 . A two-tailed t-test conducted on the two datasets, assuming unequal variances, indicated a significant difference to exist ($P < 0.001$).

4.3 Chemical Analysis

Results are presented for the April 1998 postcap coring survey. Samples for TOC, dioxin and furan analyses were collected from both the sand cap and underlying black clayey-silt dredged material found in the cores.

4.3.1 Total Organic Carbon

Total organic carbon (TOC) concentrations in the core samples ranged from 0.07% to 2.40% (Table 4-6). The cap material had the lowest TOC concentrations, ranging from 0.07% to 0.28%, with an overall average value of 0.13%. The black clayey-silt dredged material had TOC values ranging from 1.63% to 2.40%, with an overall average value of 1.96%.

Table 4-6

Total Organic Carbon Results from Postcap Core Samples

| Core | Core Depth* (cm) | Relative Sample Location** (cm) | TOC (% , dry wt.) | Material Type |
|-------|------------------|---------------------------------|--------------------|------------------|
| 97B-B | 103 | (+) 30 | 0.150 [§] | sand |
| | 123 | (+) 10 | 0.140 | sand |
| | 131 | (+) 2 | 0.278 | sand |
| | 143 | (-) 10 | 1.930 | dredged material |
| | 163 | (-) 30 | 1.970 | dredged material |
| 97C-A | 108 | (+) 30 | 0.118 | sand |
| | 128 | (+) 10 | 0.116 | sand |
| | 148 | (-) 10 | 1.630 | dredged material |
| | 168 | (-) 30 | 2.030 | dredged material |
| | 188 | (-) 50 | 1.800 | dredged material |
| 97E-B | 86 | (+) 30 | 0.172 [§] | sand |
| | 106 | (+) 10 | 0.165 | sand |
| | 126 | (-) 10 | 1.840 | dredged material |
| | 146 | (-) 30 | 2.130 | dredged material |
| 97Q-A | 90 | (+) 30 | 0.102 | sand |
| | 110 | (+) 10 | 0.097 | sand |
| | 117 | (+) 3 | 0.072 | sand |
| | 130 | (-) 10 | 1.820 | dredged material |
| | 150 | (-) 30 | 2.010 | dredged material |
| 97R-B | 96 | (+) 30 | 0.112 [§] | sand |
| | 116 | (+) 10 | 0.083 | sand |
| | 136 | (-) 10 | 1.900 | dredged material |
| | 156 | (-) 30 | 1.960 | dredged material |
| | 176 | (-) 50 | 1.930 | dredged material |
| | 196 | (-) 70 | 1.810 | dredged material |
| 97U-A | 146 | (+) 30 | 0.079 | sand |
| | 166 | (+) 10 | 0.101 | sand |
| | 186 | (-) 10 | 1.970 | dredged material |
| | 206 | (-) 30 | 2.400 | dredged material |
| | 239 | (-) 63 | 2.280 | dredged material |

* Samples collected from a 4 cm band surrounding the desired sample depth.

** Distance above (+) or below (-) the sand cap-dredged material interface within the core.

§ Values represent average concentration based on triplicate analysis.

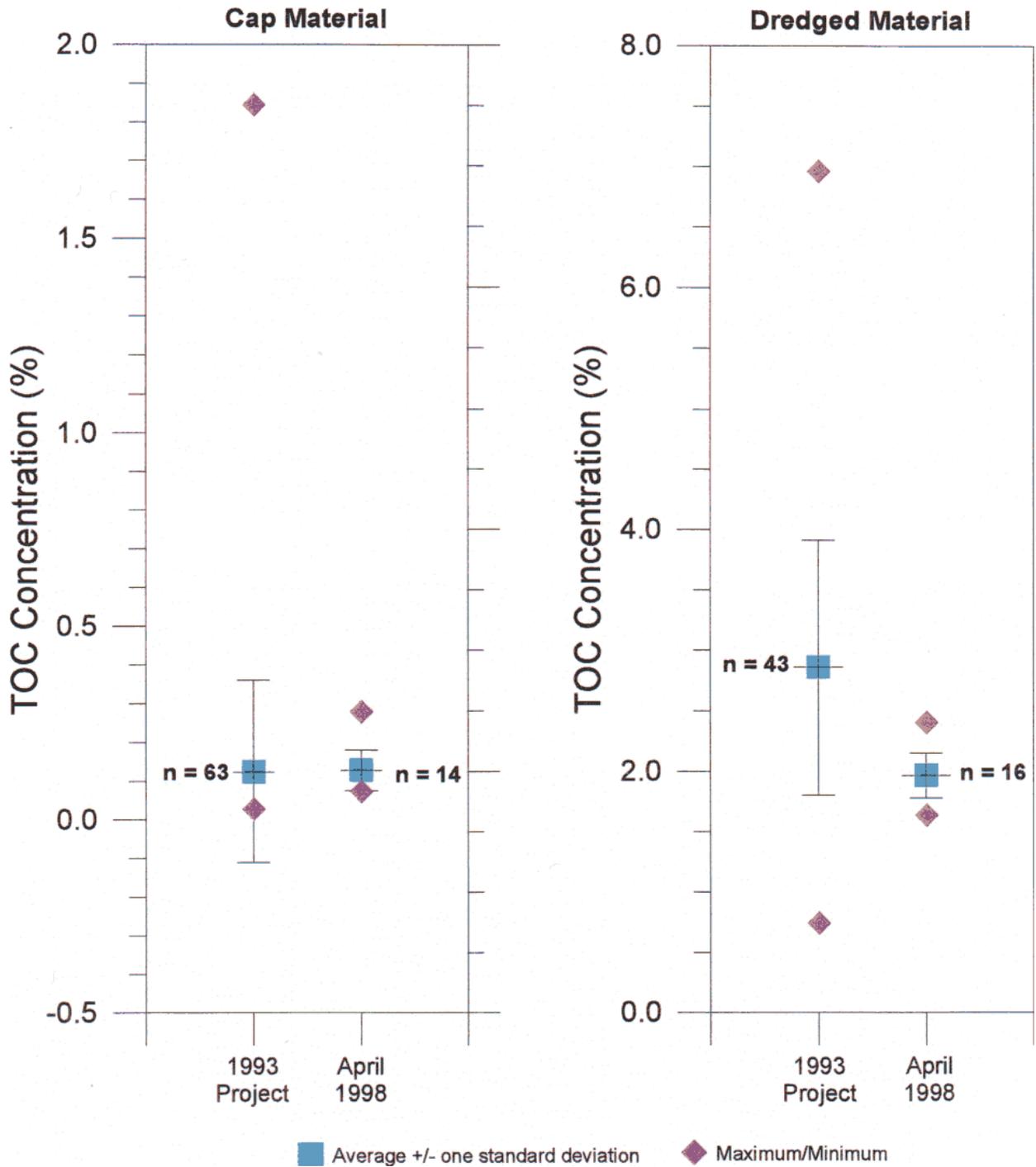


Figure 4-5. Comparison of average total organic carbon concentration in cap material (left graph) and dredged material (right graph) between the April 1998 postcap coring survey of the 1997 Category II Capping Project and the 1993 Dioxin Capping Monitoring Project. Note the difference in scale between the two graphs.

Values for all four postcap surveys for the 1993 Dioxin Project were averaged and then compared to the results from the April 1998 postcap survey (Figure 4-5). The average TOC concentrations in the cap material were roughly comparable for the 1993 Dioxin Project and the 1997 Capping Project (Figure 4-5). The black clayey-silt dredged material consistently had a higher average and range of TOC concentrations than the cap material for both the 1993 Dioxin Project and 1997 Capping Project. The dredged material from the April 1998 postcap survey showed a narrower range of values and lower average concentration than the 1993 Dioxin Project; however, the 1998 TOC concentrations were within the statistical range of values measured in the 1993 project material (Figure 4-5).

4.3.2 Unnormalized Concentrations of Dioxin and Furan

Unnormalized sediment concentrations of all measured PCDDs/PCDFs, including congener data, are presented on a dry weight basis for the 6 cores in Appendix D. All 14 samples of the cap material had dioxin values below the Level of Detection (LOD), but 8 of the 14 samples had detectable levels of furan. However, none of the cap material samples had furan detected at greater than the 1.0 pptr minimum LOD. A total of 16 samples were taken from the underlying black dredged material and analyzed for PCDDs/PCDFs. Twelve samples had detectable levels of dioxin and nine samples had detectable levels of furan. Values for dioxin ranged from 0.20 to 6.8 pptr and furan values ranged from 0.36 to 3.1 pptr.

4.3.3 Average Dioxin/Furan Concentrations for Cap and Dredged Material Units

Dioxin and furan values were averaged for the cap and the black dredged material using one-half of the detection limit for data below detection (Table 4-7). The average value of dioxin in the cap material was 0.19 ± 0.075 pptr, and the average value in the underlying dredged material was 1.5 ± 1.6 pptr. The average furan value in the cap material was 0.26 ± 0.11 pptr, compared with an average of 1.0 ± 0.70 pptr in the underlying dredged material.

As with the TOC data, dioxin and furan values from the four 1993 Dioxin Project postcap surveys were combined and compared with data from this survey (Figures 4-6 and 4-7, respectively). The average dioxin value for cap material for the April 1998 survey was 0.19 ± 0.075 pptr, less than half of the average value for the 1993 Dioxin Project (0.47 ± 0.75 pptr). The average furan value for the April 1998 cap material was 0.26 ± 0.11 pptr, while the average furan value for the 1993 Dioxin Project was 0.52 ± 1.0 pptr. Thus, while the overall levels of dioxin and furan in the sand cap were negligible (i.e., less than 1 pptr) for both the 1993 and 1997 projects, it appears the 1997 project had even lower average levels (based on a single postcap survey) than those observed in multiple postcap surveys for the 1993 project.

Within the black clayey-silt dredged material, the average April 1998 dioxin concentration (1.5 ± 1.6 pptr) was much lower than the 1993 Dioxin Project average value (56 ± 41 pptr; Figure 4-6). The average value of furan (1.0 ± 0.70 pptr) also was much

Table 4-7. PCDD/PCDF Summary Statistics for Cap and Dredged Material.

| NATIVE ISOMERS | Cap Material | | | | | Dredged Material | | | | |
|--------------------|--------------|--------------------|---------|---------|--------------|------------------|--------------------|---------|---------|--------------|
| | Average | Standard Deviation | Maximum | Minimum | Sample Count | Average | Standard Deviation | Maximum | Minimum | Sample Count |
| 2378-TCDF (Furan) | 0.26 | 0.11 | 0.52 | 0.14 | 14 | 1.0 | 0.70 | 3.1 | 0.36 | 16 |
| 2378-TCDD (Dioxin) | 0.19 | 0.075 | 0.32 | 0.090 | 14 | 1.5 | 1.6 | 6.8 | 0.20 | 16 |
| 12378-PeCDF | 0.15 | 0.087 | 0.40 | 0.046 | 14 | 1.4 | 3.3 | 14 | 0.12 | 16 |
| 23478-PeCDF | 0.18 | 0.12 | 0.56 | 0.075 | 14 | 0.69 | 0.44 | 1.9 | 0.24 | 16 |
| 12378-PeCDD | 0.33 | 0.21 | 1.0 | 0.15 | 14 | 0.84 | 0.94 | 4.1 | 0.36 | 16 |
| 123478-HxCDF | 0.23 | 0.094 | 0.48 | 0.11 | 14 | 1.5 | 1.3 | 4.4 | 0.22 | 16 |
| 123678-HxCDF | 0.17 | 0.074 | 0.30 | 0.075 | 14 | 0.90 | 1.2 | 4.9 | 0.12 | 16 |
| 234678-HxCDF | 0.26 | 0.067 | 0.36 | 0.15 | 14 | 0.78 | 0.54 | 2.3 | 0.22 | 16 |
| 123789-HxCDF | 0.29 | 0.13 | 0.50 | 0.12 | 14 | 0.81 | 0.97 | 4.3 | 0.24 | 16 |
| 123478-HxCDD | 0.20 | 0.072 | 0.34 | 0.090 | 14 | 0.62 | 0.56 | 2.6 | 0.32 | 16 |
| 123678-HxCDD | 0.23 | 0.10 | 0.44 | 0.12 | 14 | 1.9 | 4.6 | 19 | 0.24 | 16 |
| 123789-HxCDD | 0.24 | 0.072 | 0.37 | 0.14 | 14 | 1.1 | 1.7 | 7.5 | 0.19 | 16 |
| 1234678-HpCDF | 0.32 | 0.18 | 0.75 | 0.15 | 14 | 7.2 | 9.4 | 34 | 0.63 | 16 |
| 1234789-HpCDF | 0.27 | 0.11 | 0.43 | 0.11 | 14 | 1.2 | 1.6 | 7.0 | 0.19 | 16 |
| 1234678-HpCDD | 0.85 | 0.72 | 3.2 | 0.29 | 14 | 38 | 86 | 360 | 9.3 | 16 |
| OCDF | 0.51 | 0.38 | 1.6 | 0.15 | 14 | 17 | 24 | 95 | 1.3 | 16 |
| OCDD | 11 | 10 | 45 | 5.0 | 14 | 679 | 555 | 2700 | 390 | 16 |
| TEC | 0.67 | 0.19 | 1.08 | 0.46 | 14 | 4.4 | 3.7 | 15 | 1.6 | 16 |

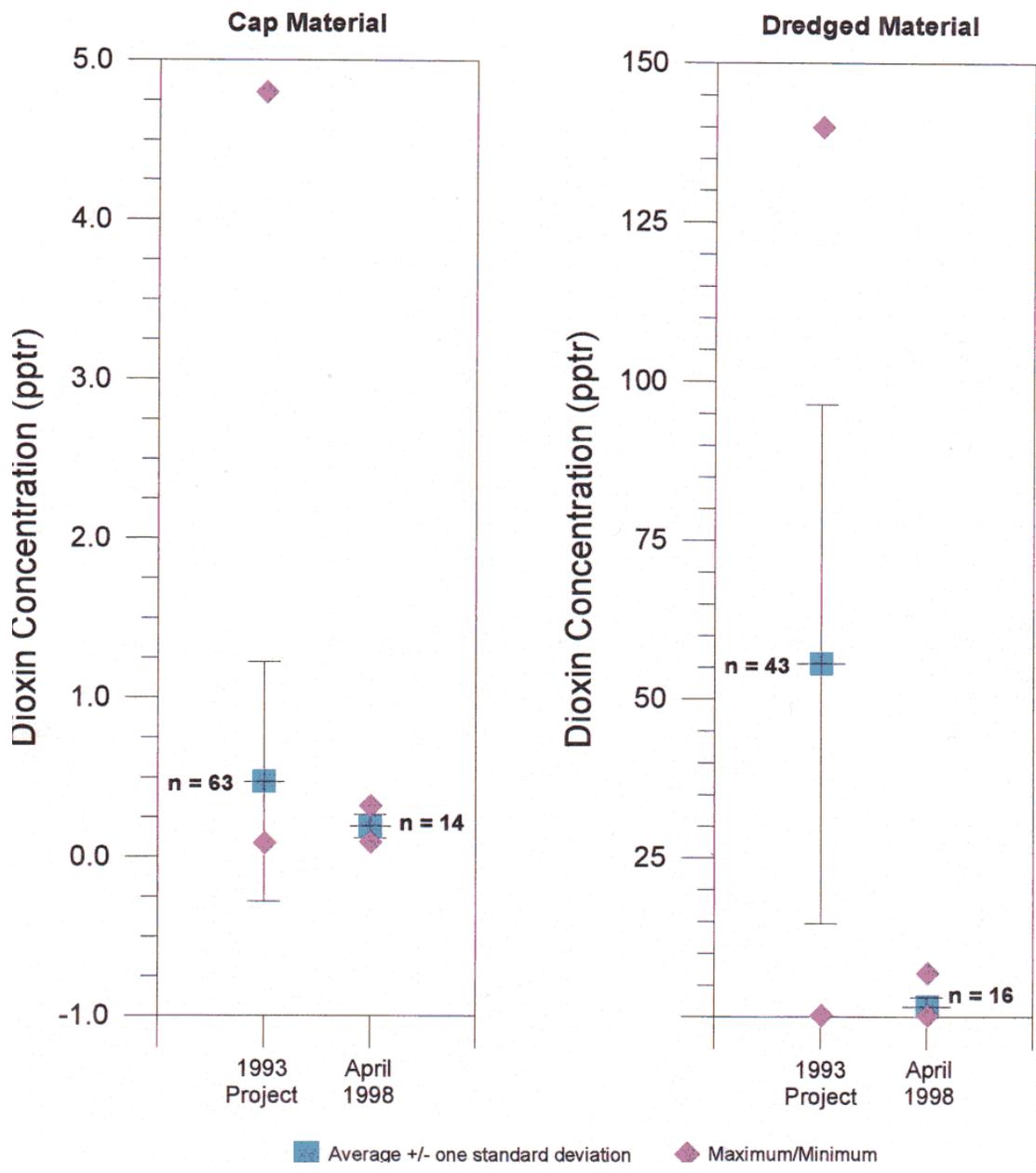


Figure 4-6. Comparison of average dioxin concentration in cap material (left graph) and dredged material (right graph) between the April 1998 postcap coring survey of the 1997 Category II Capping Project and the 1993 Dioxin Capping Monitoring Project. Note the difference in scale between the two graphs.

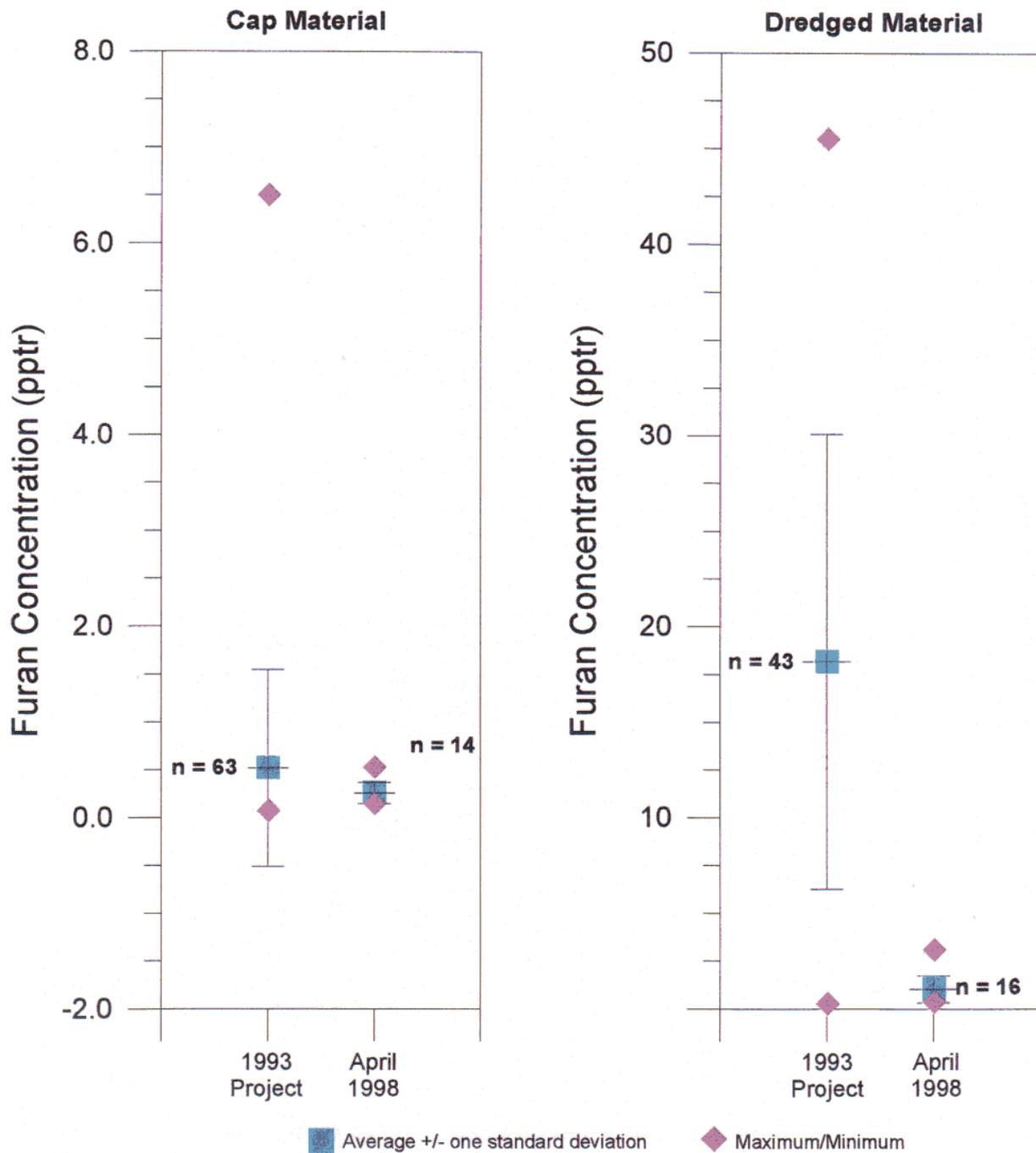


Figure 4-7. Comparison of average furan concentration in cap material (left graph) and dredged material (right graph) between the April 1998 postcap coring survey of the 1997 Category II Capping Project and the 1993 Dioxin Capping Monitoring Project. Note the difference in scale between the two graphs.

Table 4-8. PCDD/PCDF Concentrations Normalized to Total Organic Carbon (Dry Weight for a) Cap Material and b) Dredged Material.

| Sample Depth (cm) | 97B-B | | | 97C-A | | 97E-B | | 97Q-A | | | 97R-B | | 97U-A | |
|--------------------|-------|------|-------|-------|------|-------|------|-------|------|------|-------|------|-------|------|
| | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap | Cap |
| 103 | 123 | 131 | 108 | 128 | 86 | 106 | 88 | 108 | 116 | 96 | 116 | 146 | 166 | |
| 2378-TCDF (Furan) | 187 | | 144 | 136 | | | 4303 | | | 222 | 232 | 313 | 266 | 515 |
| 2378-TCDD (Dioxin) | | | | | | | | | | | | | | |
| 12378-PeCDF | | | | | | | | | | | | | | |
| 23478-PeCDF | | | | | | | 339 | | | | | | | |
| 12378-PeCDD | | | | | | | | | | | | | | |
| 123478-HxCDF | 94 | | 122 | | | | | | | | | | | |
| 123678-HxCDF | | | | | | | | | | | | | | |
| 234678-HxCDF | 200 | 221 | 115 | | 276 | | | 314 | | | | | 456 | |
| 123789-HxCDF | | 193 | | | | | | | | | | | | |
| 123478-HxCDD | | | | | | | | | | | | | | |
| 123678-HxCDD | | | | | | | | | | | | | | |
| 123789-HxCDD | | | | | | | | | | | | | | |
| 1234678-HpCDF | | | 270 | | | 128 | | | | | 268 | | | |
| 1234789-HpCDF | | | | | | | | | | | | | | |
| 1234678-HpCDD | 454 | 600 | 1151 | 517 | | 384 | 418 | 588 | 835 | 542 | 893 | 1325 | 861 | |
| OCDF | | | 576 | | 190 | 326 | | | | | | | | |
| OCDD | 5010 | 6643 | 16187 | 6949 | 5517 | 3669 | 5939 | 9706 | 8454 | 6944 | 10714 | 8795 | 7975 | 6733 |
| TEC | 534 | 336 | 259 | 458 | 397 | 274 | 1170 | 892 | 711 | 875 | 473 | 578 | 975 | 782 |

Note: Values were not calculated for results below detection. Data are provided on a dry weight basis and are given in terms of ng congener/kg TOC.

b) PCDD/PCDF Concentrations Normalized to Total Organic Carbon (Dry Weight) for Dredged Material.

| Sample Depth (cm) | 97B-B | | 97C-A | | | 97E-B | | 97Q-A | | 97R-B | | | | 97U-A | | |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | DM |
| 143 | 163 | 148 | 168 | 188 | 126 | 146 | 128 | 148 | 136 | 156 | 176 | 196 | 186 | 206 | 239 | |
| 2378-TCDF (Furan) | 32 | | 67 | | | | | 35 | | 53 | | 78 | 72 | 19 | 71 | 36 |
| 2378-TCDD (Dioxin) | | 345 | 74 | 89 | 161 | 39 | 47 | 82 | 42 | 74 | | 44 | 77 | | 31 | 88 |
| 12378-PeCDF | | | | | | | | | | | | | | | | |
| 23478-PeCDF | | | | 24 | 47 | | | | | | | 37 | | | 50 | 43 |
| 12378-PeCDD | | | | | | | | | | | | | | | | |
| 123478-HxCDF | 37 | 223 | | | | | | | | | | 173 | | | 175 | |
| 123678-HxCDF | | 249 | | | | | | | | | | | 38 | | 71 | |
| 234678-HxCDF | | | 33 | 34 | | | | | 29 | 30 | | 40 | 61 | 22 | 58 | 53 |
| 123789-HxCDF | | | | | | | | | | | | | | | 38 | |
| 123478-HxCDD | | | 20 | | | 17 | | | 31 | | | | | | 29 | 26 |
| 123678-HxCDD | | 81 | 37 | | 40 | | | 28 | 35 | | 969 | 32 | 77 | 12 | 67 | 57 |
| 123789-HxCDD | | | | 33 | 41 | 32 | | | 49 | 19 | 383 | 35 | | 28 | 46 | 53 |
| 1234678-HpCDF | 88 | 1320 | 264 | 212 | 356 | 92 | 108 | 198 | 104 | 126 | 1735 | 130 | 348 | 32 | 500 | 228 |
| 1234789-HpCDF | | | | | | | | | | | | | | | | |
| 1234678-HpCDD | 482 | 1320 | 920 | 788 | 1111 | 652 | 516 | 604 | 1095 | 684 | 18367 | 570 | 1436 | 558 | 1167 | 1009 |
| OCDF | 155 | 2335 | 736 | 690 | 778 | 245 | 155 | 1099 | 164 | 295 | 4847 | 238 | 718 | 66 | 917 | 360 |
| OCDD | 22280 | 30964 | 27607 | 24138 | 28889 | 26630 | 20657 | 21429 | 36816 | 21579 | 13775 | 20207 | 33702 | 34518 | 32500 | 32018 |
| TEC | 82 | 627 | 171 | 170 | 269 | 123 | 120 | 165 | 146 | 157 | 751 | 135 | 220 | 79 | 175 | 200 |

Note: Values were not calculated for results below detection. Data are provided on a dry weight basis and are given in terms of ng congener/kg TOC.

lower than the 1993 Dioxin Project value (18 ± 12 pptr; Figure 4-7). Thus, it appears based on the April 1998 postcap survey results that the 1997 Category II Capping Project material was significantly less contaminated, on average, than the 1993 project material.

4.3.4 Normalized Concentrations of Dioxin and Furan

Dioxin and furan data for each sediment sample were normalized to TOC because of the different characteristics of each material type. TOC was significantly higher in the black clayey-silt dredged material compared to the cap material (Figure 4-5).

Results of normalization of dioxin (ng/kg) to TOC (mg/kg) on a dry weight basis are provided in Table 4-8. Values below detection were not included in this table. Where the unnormalized results were divided by small fractions of TOC, the normalized values are high.

Dioxin in the cap material sampled in April 1998 was not detected above the required LOD of 1 pptr. Therefore, normalized values were not calculated. Furan was detected in nine samples. Normalized furan concentrations ranged from 135 pptr (97C-A, 108 cm) to 4303 pptr (97E-B, 106 cm). The minimum value of TOC-normalized dioxin in the black clayey-silt was measured in core 97U-A at 206 cm (31 pptr). The highest value of TOC-normalized dioxin was in the black clayey-silt within core 97B-B at 163 cm (345 pptr). TOC-normalized furan values in the black clayey-silt material ranged from 19 pptr in sample 97U-A (186 cm) to 78 pptr in sample 97R-B (176 cm).

4.3.5 2,3,7,8-TCDD Toxic Equivalent Concentrations in Sediments

The concentrations of congeners in sediments have been expressed in terms of 2,3,7,8-TCDD Toxic Equivalents Concentration (TECs; Safe 1990) for each sediment sample (Appendix D). In general, the TEC values mimic those of the raw (i.e., unnormalized) dioxin values. This is not surprising because the TEF (Table 2-3) for 2,3,7,8-TCDD is 1, giving it a larger proportion of the TEC than any of the other congeners, whose TEFs range from 0.001 to 0.5. TECs are summarized for both material units in Table 4-7. The cap material had the lowest average TEC (0.67 ± 0.19 pptr). The black clayey-silt dredged material had the highest average TEC, but with high variability (4.4 ± 3.7 pptr).

5.0 DISCUSSION

5.1 Discussion of the Geotechnical Data

5.1.1 Chronology of Geotechnical Studies

The geotechnical investigation of the 1997 Category II Capping Project began in December 1996, when WES obtained measurements of the pre-dredged *in situ* geotechnical properties of material from Port Newark and Port Elizabeth. The information was collected in order to aid in the project design (Rollings and Rollings 1998a). Ultimately, the material dredged originated from three separate locations: Reach “D” for Sealand Shipping; the loading facility in Tremley Point Reach for Citgo Oil Company; and the Newark Bay Contaminated Disposal Facility (CDF; Figure 5-1, SAIC 1997c). The data still provide a relative baseline for the project.

In May 1997, a baseline sediment coring survey was conducted to provide a description of the seafloor material within the proposed disposal location (SAIC 1998e). The most common material observed was a medium- to fine-grained gray sand, with relatively low water content (average 19.4%). Some silt and clay was noted in cores collected at stations along the northwest half of the sampling transect (Figure 2-1, cores 97A-97F), where historical dredged material had been disposed (e.g., Williams and Duane 1974). In fact, Category I material was disposed to the north of the 1997 Category II Capping Project area within two years prior to the disposal phase of this project. The average water content value for the pre-project silty material (63.4%) was higher than that of the sandier material, a result which was consistent both with the dominant fine grain size, and the potential presence of recently disposed Category I dredged material to the north of the project area.

Cores collected during the baseline survey at stations along the southeast half of the transect (Figure 2-1, cores 97G-97K) were more consistent in size and texture, being comprised almost entirely of sand throughout the core profile. In 1980, an experimental capping study took place in the southeast quadrant of the Mud Dump Site, referred to as the Experimental Mud Dump (EMD). The study involved capping contaminated dredged material with a layer of clean sand from Ambrose Channel. It is possible that some of the sand presently found in the vicinity of the EMD mound (see Figure 2-1) is the result of this 1980 capping project. It is more likely, however, that the yellowish sand found in the cores at stations comprising the southeast half of the transect (Figure 2-1) is of natural origin, given its similarity in color and texture to the ambient sandy sediments found throughout the New York Bight region (Dayal et al. 1983).

Analysis of geotechnical data throughout disposal operations was aided by data from SAIC’s New York Disposal Surveillance System (NYDISS) units. The units were installed on each of the scows to record the beginning and end points of each disposal event through the use of a GPS positioning system with applied differential corrections to provide 1 to 5 m accuracy (SAIC 1998i). These data were recorded and later used to create track plots (Figure 5-2) that illustrated the location of individual disposal events within the rectangular target area known as the 1997 Base Mound Area (SAIC 1997c). Of the 251 logged disposal events for this project, 169 are presented in Figure 5-2. Details of the data recorded and missed can be found in SAIC 1997c.

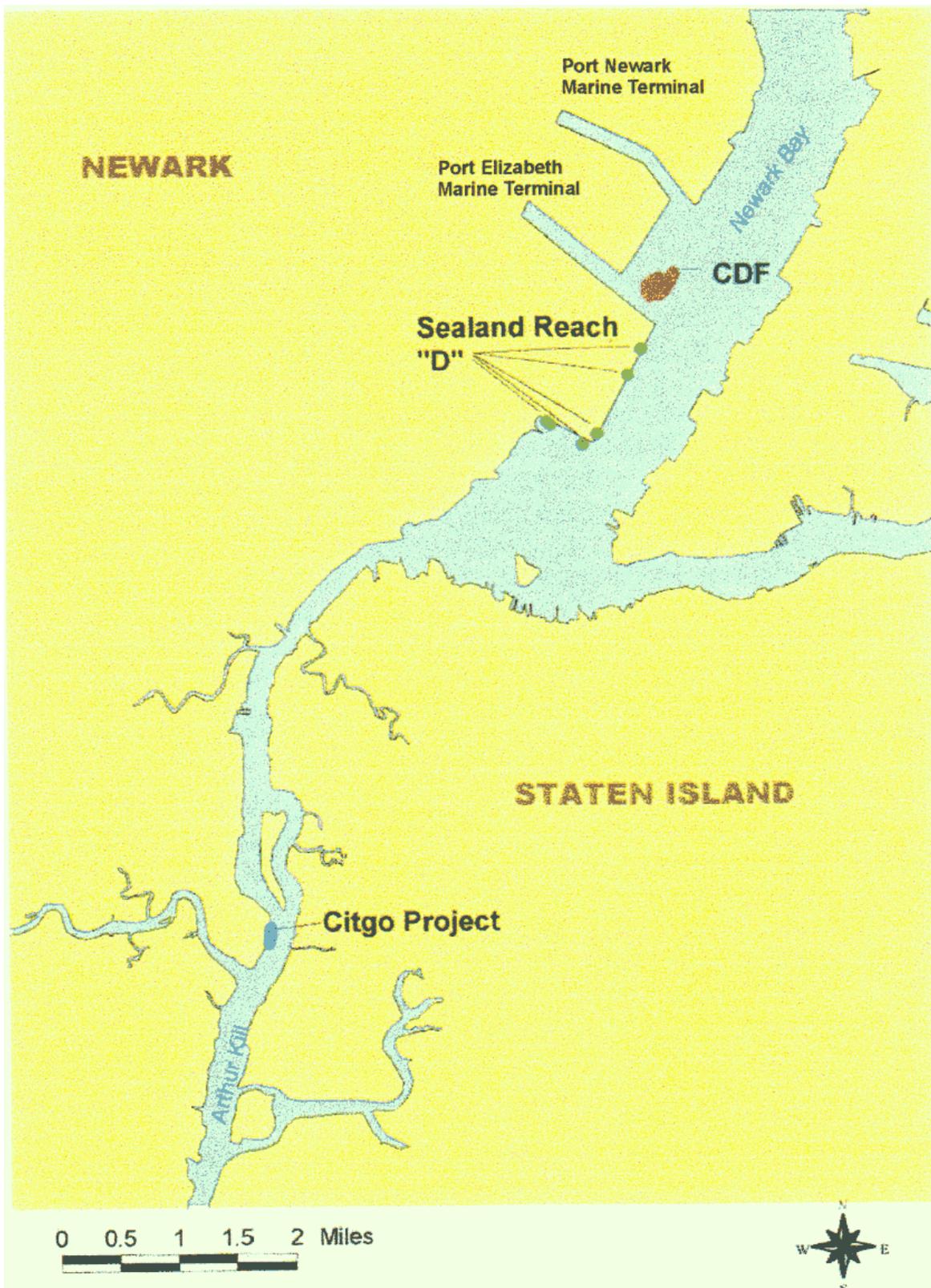


Figure 5-1. Scow loading positions for the three Category II dredging projects as determined by NYDISS.

NYDISS Data from the Mud Dump Site

169 of 251 Disposal Events

May 27 Through August 10, 1997

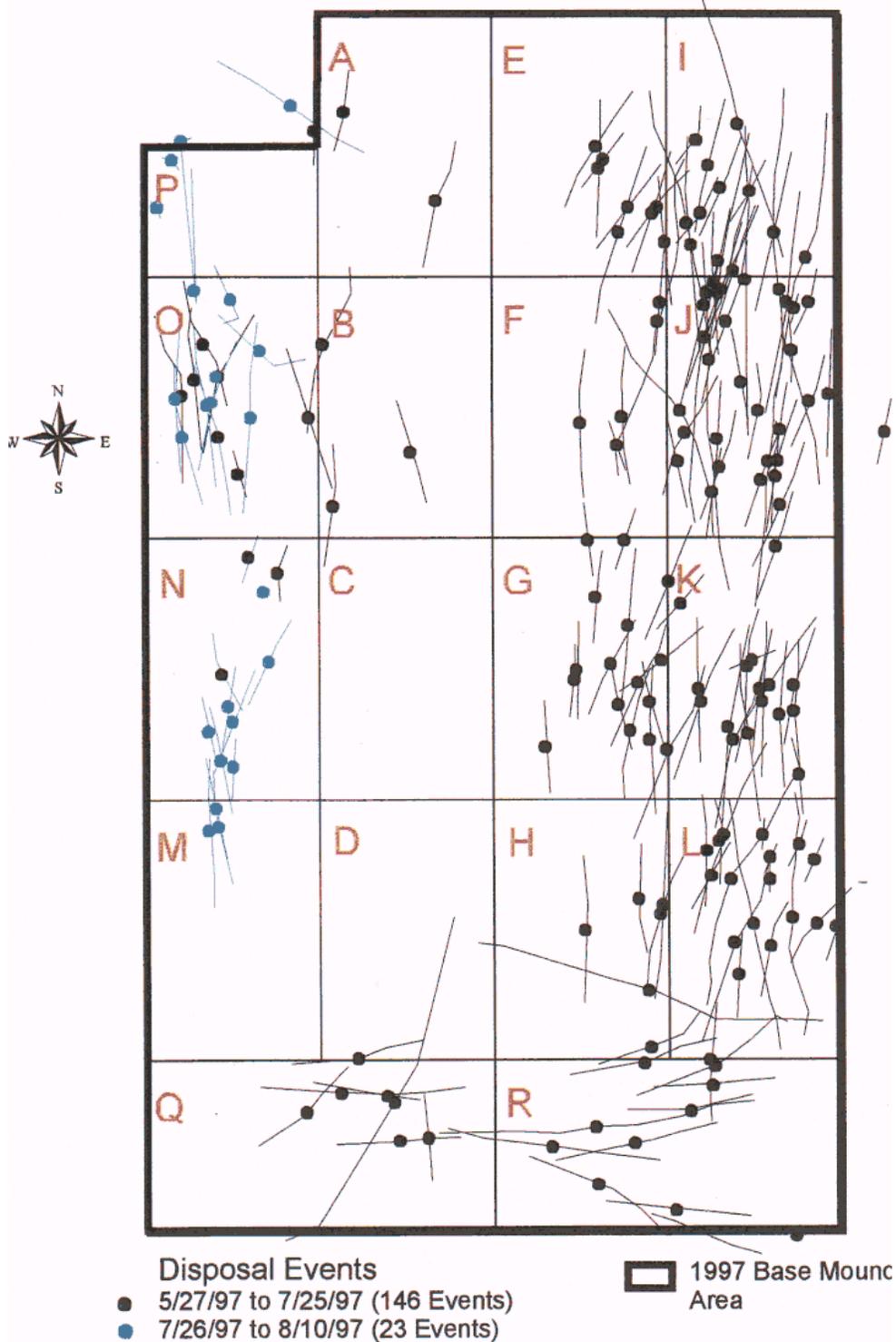


Figure 5-2. NYDISS track plot of the 1997 Capping Project disposal operations, May 27, to August 10, 1997.

The NYDISS data plot shown in Figure 5-2 illustrates that the dredged material disposal for the 1997 Category II Capping Project was focused in two primary locations within the 1997 Base Mound Area. From the beginning of the disposal operations until the first interim disposal coring survey, performed July 26–27, the focus was on the eastern side of the site. The results of this July 1997 interim disposal coring survey, therefore, provided baseline geotechnical data for the project material following the first two months of disposal (0 to 61 days; SAIC 1998g). The dredged material collected in the 12 cores from the July survey consisted of black, dark gray, and dark brown elastic and sandy silt, with an average water content of 87.6%. Void ratio values, which are an indication of the state of consolidation (Section 2.4.6), ranged from 1.5 to 3.7, with an average of 2.3. In four of the cores, it was possible to differentiate pre-project material, which, as expected, had properties similar to the units seen in the baseline coring survey.

In the 19-day period between the interim and postdisposal coring surveys, the focus of the disposal operations changed to the western side of the Base Mound Area (Figure 5-2). This pattern of disposal allowed for two separate time series of data to be collected within the site (t_{west} and t_{east}). Data from the postdisposal coring survey (SAIC 1998h), conducted following the completion of disposal operations, indicated that while decreases of up to 30% in parameters such as void ratio and water content were evident between the $t_{\text{0-east/west}}$ and $t_{\text{1-east}}$ datasets, statistically, the changes were not significant. It was therefore concluded that no statistically significant consolidation occurred within the eastern project mounds as a result of self-weight consolidation. Because of this result, the $t_{\text{west}}/t_{\text{east}}$ comparison was discontinued.

This, the first postcap coring survey, is the first to look at the sediment properties since final placement of sand cap material occurred. The data collected in this survey provides the foundation for future monitoring to ensure cap effectiveness and allows evaluation of the changes in the capped dredged material's physical properties over time.

5.1.2 Cap Stability

Often, the possibility of mixing between the higher density sand cap and the lower density fine-grained dredged material is a concern. The cores collected in this survey showed a distinct sand cap/dredged material interface. Some cores exhibited sand along the core edge within the first few centimeters of the DM unit as a result of the coring device dragging down some material as it penetrated the sediment. This is not an indication of cap instability. The DM in the cores also was noted as being firmer in texture, and exhibited lower water content and liquid limit values, compared to previous surveys. These changes were a result of the compaction and consolidation of the DM from the load of the sand cap (see Section 5.1.3). Consolidation results in greater material stability, so it is unlikely that mixing of the cap and DM will be observed in any future monitoring surveys.

5.1.3 Evaluation of Material Properties Following Sand Cap Placement

In both the interim disposal and postdisposal coring surveys, the goal was to look at the changes in the geotechnical properties of the project dredged material from the time it was disposed until the cap material was put into place. When sediments are dredged and re-deposited, they are initially bulked due to the entrainment of water during the process (SAIC 1997e, Rollings and

Rollings 1998b). In the time period between the dredged material's initial deposition at the site and the placement of capping material, self-weight consolidation begins to occur, though at a much slower rate than consolidation under overburden conditions. The results of the interim disposal (SAIC 1998g) and the postdisposal (SAIC 1998h) coring surveys indicated that no statistically significant consolidation of the project DM occurred due to self-weight consolidation.

The lack of statistically significant changes in physical properties does not prove that self-weight consolidation was not an active process at the dredged material mound. Rather, it is indicative of the difficulties inherent in measuring geotechnical properties of disposed dredged material immediately after deposition. The initial void ratio measurements were made on dredged material placed anytime between 0 and 61 days of the beginning of disposal operations. This suggests the samples were collected from sediment in variable phases of self-weight consolidation.

Ten days following the conclusion of disposal operations, the project's capping phase began. Sand was slowly distributed across the project area by hopper dredges running along a system of grid lanes (Figure 5-3 a-b). This resulted in the sand cap material being evenly distributed across the project area, and should, theoretically, have resulted in the project dredged material consolidating similarly throughout the area over time. The data collected in this, the first postcap sediment coring survey, provides baseline postcap information for the sand cap and capped dredged material.

Past studies have shown that consolidation due to overburden conditions (i.e., placement of sand cap material) starts out very rapidly and then slows to an almost undetectable rate as time progresses (Poindexter-Rollings 1990). A smaller scale capping project in Long Island Sound showed that 90% of the dredged material consolidation occurred within the first 100 days following the sand cap placement (Poindexter-Rollings 1990). In the 1997 Category II Capping Project, the dredged material capping began in August 1997 and concluded on January 18, 1998, about 3 months prior to this survey. Therefore, the time period over which postcap consolidation had occurred prior to sample collection was at least 3 months, suggesting the most rapid phase of consolidation already had taken place. Theoretically, this consolidation is detectable through changes in geotechnical properties such as water content, bulk density, and void ratio. As material begins to consolidate, water is forced out from the compacting pore spaces, decreasing both the material's water content and void ratio and increasing the bulk density. The average values for water content, bulk density, and void ratio are presented in Table 5-1 for the interim disposal, postdisposal, and postcap sediment coring surveys.

Table 5-1

Average Water Content, Bulk Density, and Void Ratio Values for the DM Unit of the three 1997 Category II Capping Project Sediment Coring Surveys

| | Interim Disposal | Postdisposal | Postcap |
|----------------------------|-------------------------|---------------------|----------------|
| Water Content (%) | 87.6 | 77.1 | 59.7 |
| Bulk Density (g/cc) | 1.54 | 1.60 | 1.67 |
| Void Ratio | 2.30 | 2.00 | 1.56 |

1997 Category II Project NYDISS Sand Dispersal Tracks

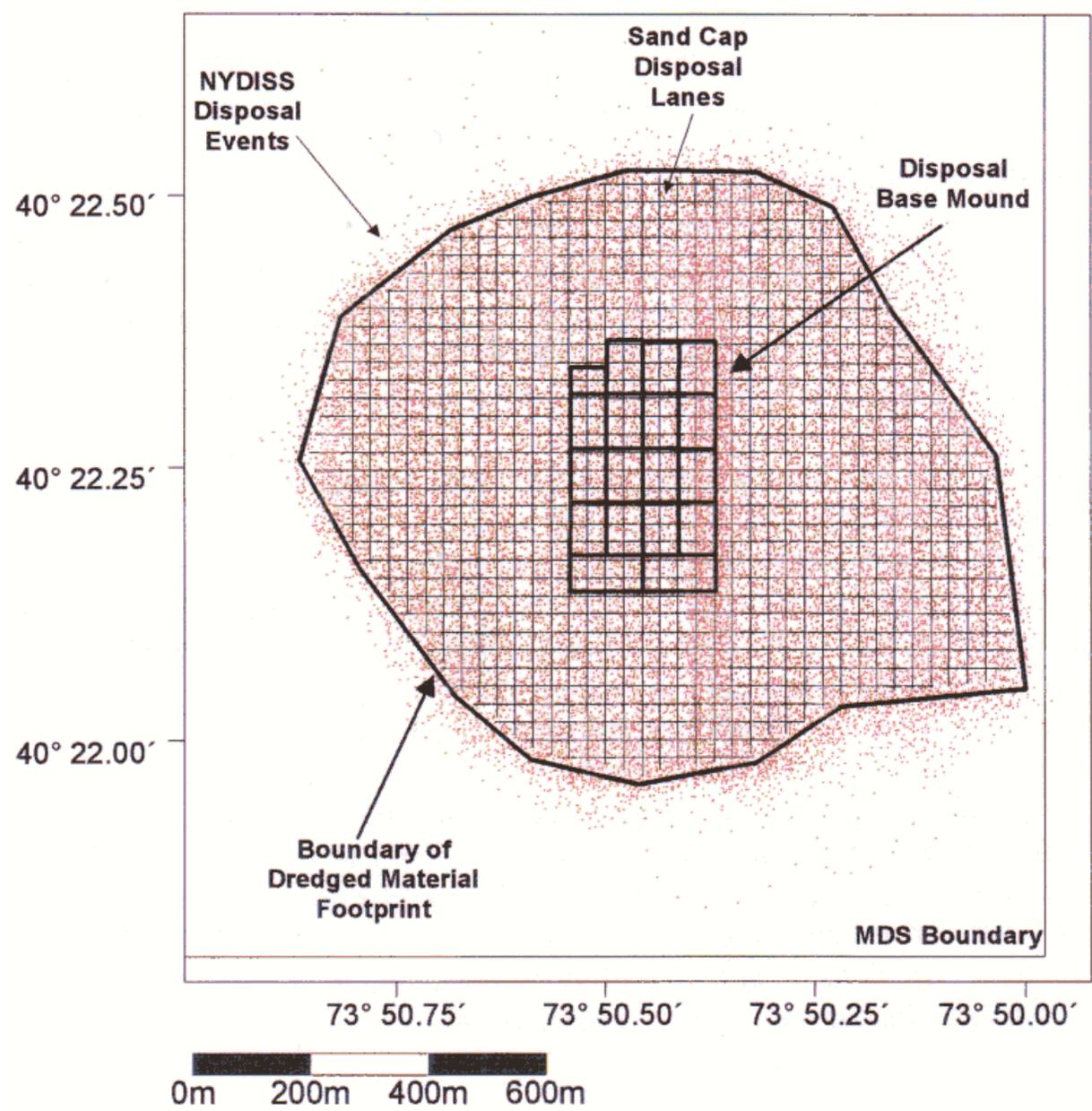


Figure 5-3a. The cumulative number of DGPS fixes recorded by NYDISS systems installed aboard hopper dredges during cap placement operations from August 20 to October 21, 1997, at the New York Mud Dump Site.

Capping Transects of the Dodge Island 8 Trips on 10/17/97

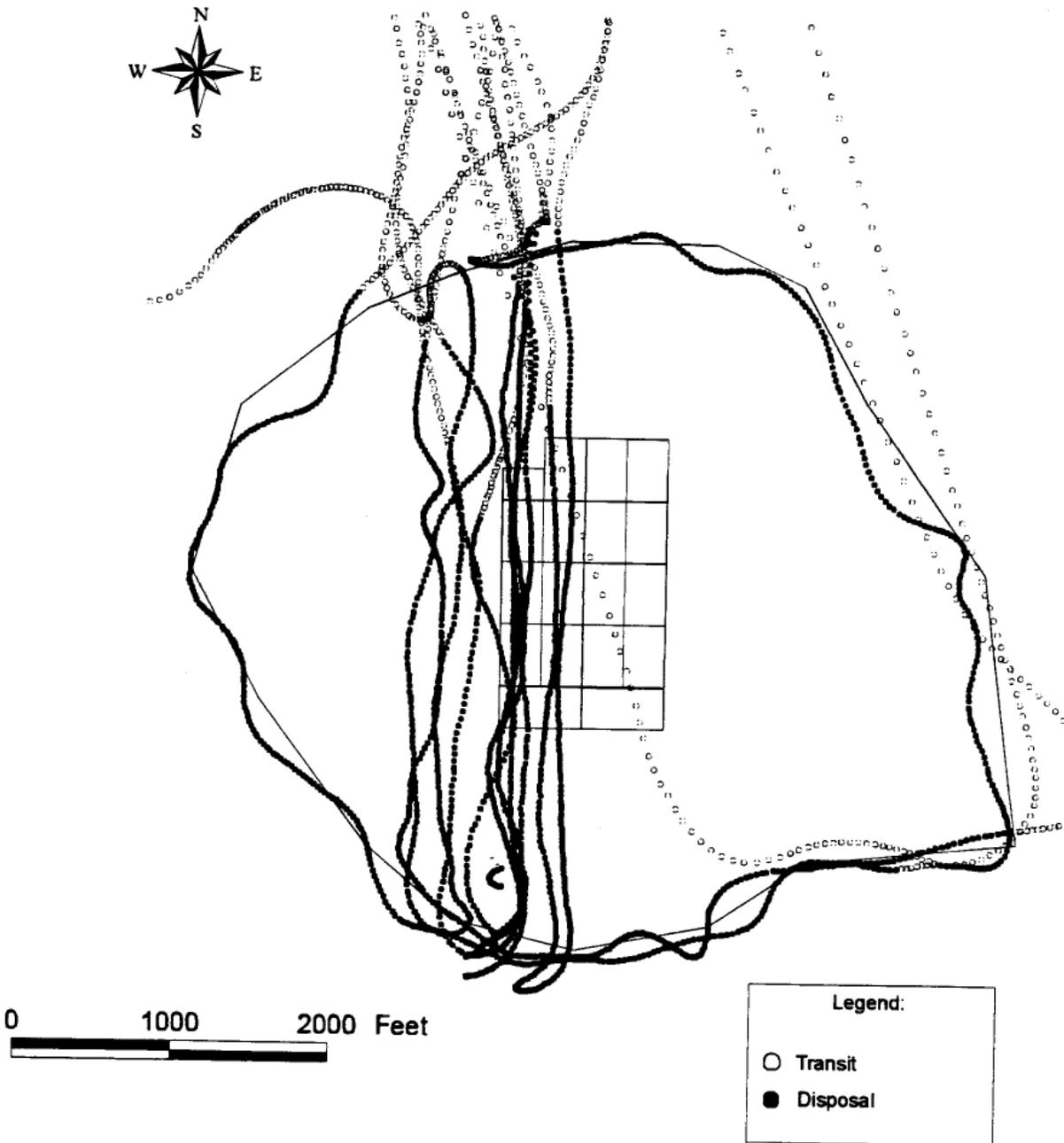


Figure 5-3b. Sequential DGPS positions occupied by hopper dredge *Dodge Island* during 8 capping trips to the 1997 Category II Capping Project Area.

When plotted, as in Figure 5-4, the above mentioned trends become evident. Statistically, a two-tailed t-test indicated a significant difference between the postdisposal and postcap water content and void ratio values. The same statistical test showed, however, that no difference existed between the bulk density values for the two surveys. As future monitoring surveys take place, it is expected that much smaller changes in these values will be observed.

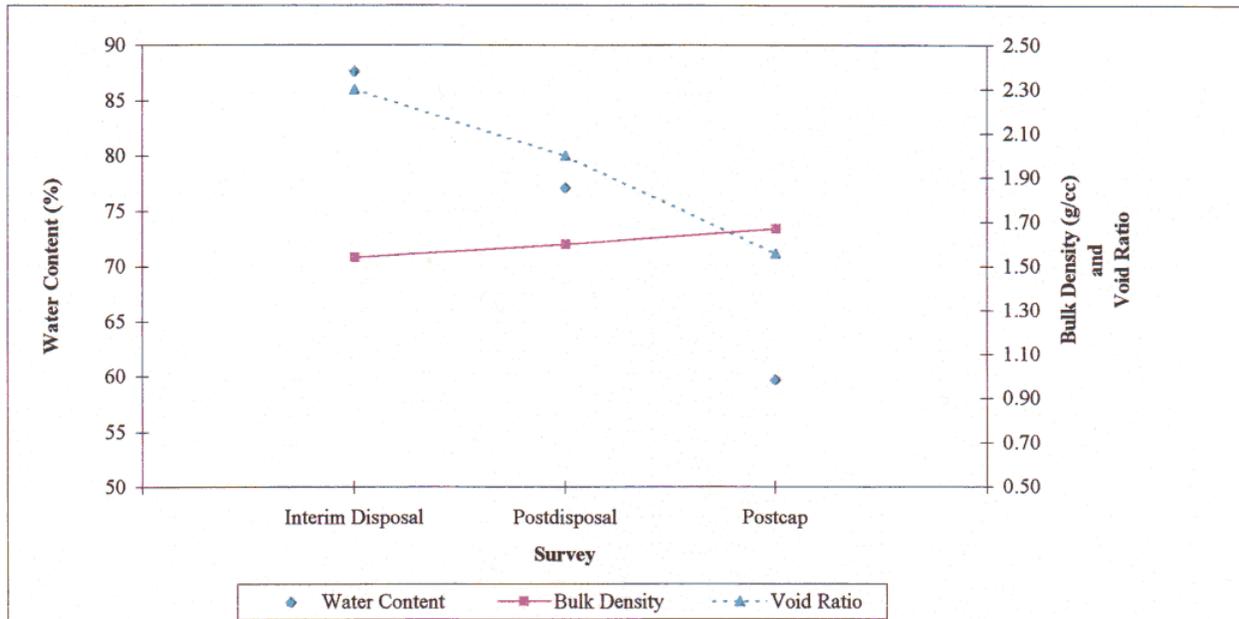


Figure 5-4. Change in average water content, bulk density, and void ratio values for the dredged material unit throughout the 1997 Category II Capping Project sediment coring surveys.

5.1.4 Comparison of Data with *in situ* Properties

In December of 1996, both WES and PANYNJ collected cores from Port Elizabeth and Port Newark, which provided data on the pre-dredged properties of potential material to be deposited during the 1997 Category II Capping Project. The cores collected by PANYNJ came from Port Elizabeth and had an average water content of 167.4% (PANYNJ 1996). Data obtained by WES was used to model and aid in the project’s design, and showed *in situ* void ratio values for Port Newark and Port Elizabeth to range from 2.9 to 4.8, with an average of 3.25 (Rollings and Rollings 1998a). WES predicted the initial void ratio of the disposal mound to be around 3.7. These values are high compared to values obtained since the material placement at the MDS. It is hypothesized that differences between the source material tested and that actually dredged for the 1997 project are the main cause for the observed discrepancy (Rollings and Rollings 1998a). Further evaluation of the results, including a review of testing methods and material sources, is currently under investigation.

5.2 Discussion of Chemical Analysis Results

5.2.1 Total Organic Carbon

Total organic carbon values for the April 1998 survey generally are consistent with expectations for this project. The average values for both cap and dredged material units are consistent with and within one standard deviation of values from the 1993 Dioxin Capping Project (Figure 4-5). In addition, values for the dredged material sampled 10 cm below the sand cap-dredged material interface within the cores are comparable to surface sediment TOC values from the August 1997 postdisposal sediment/tissue survey for stations from each survey in close proximity to each other (Figure 5-5; SAIC 1998j). Samples from the August 1997 postdisposal sediment/tissue survey had more variation (average = 2.25 ± 0.70) than the samples from the April 1998 coring survey (average = 1.85 ± 0.12).

5.2.2 Dioxin and Furan

The purpose of the sand cap is to provide a relatively clean (i.e., Category I) containment method for the underlying Category II disposed material. The sand used for capping of both the 1997 Category II Capping Project and the earlier 1993 Dioxin Capping Project was dredged from Ambrose Channel after first having been characterized as Category I; therefore, dioxin and furan are not expected to be detected within the cap material. Figures 4-6 and 4-7 illustrate the negligible concentrations of dioxin and furan within the cap material during both the 1993 Dioxin Capping Project and 1997 Category II Capping Project. For the 1997 Category II Capping Project, therefore, these results support the conclusion that the newly-placed cap was effectively isolating underlying contaminants known to be present, albeit at low concentrations, in the underlying material.

Based on the pre-dredging characterization of the 1997 project material as Category II, it is reasonable to expect that elevated concentrations of dioxin and furan would be measured in the samples of this material obtained during the April 1998 coring survey. However, the concentrations detected in the postcap core samples were quite low, particularly in comparison to the 1993 Dioxin Capping Project. As illustrated in Figure 4-6, the average value of dioxin measured in the 1997 project material was 1.5 ppt, which is significantly lower than the overall average of 56 ppt for the 1993 project material. Likewise, there is a large difference in average measured furan values between the 1997 and 1993 projects, with the 1997 average value being significantly lower (Figure 4-7). For the 1997 project material sampled in the April 1998 cores, the standard deviation was roughly equal to the mean for both dioxin (1.5 ± 1.6 ppt) and furan (0.70 ± 1.0 ppt). This suggests high variability in the distribution of these contaminants within the material. Overall, these results indicate that the 1997 project material had relatively low and highly variable levels of both dioxin and furan, particularly compared to the 1993 project material. Given these relatively low concentrations, it will be surprising if future monitoring reveals appreciable levels of either contaminant in the overlying cap.

To determine whether the dioxin and furan values measured in the April 1998 survey are anomalously low, a comparison can be made between the “surface-most” dredged material samples from the April 1998 cores (at a depth of 10 cm below the sand cap-dredged material

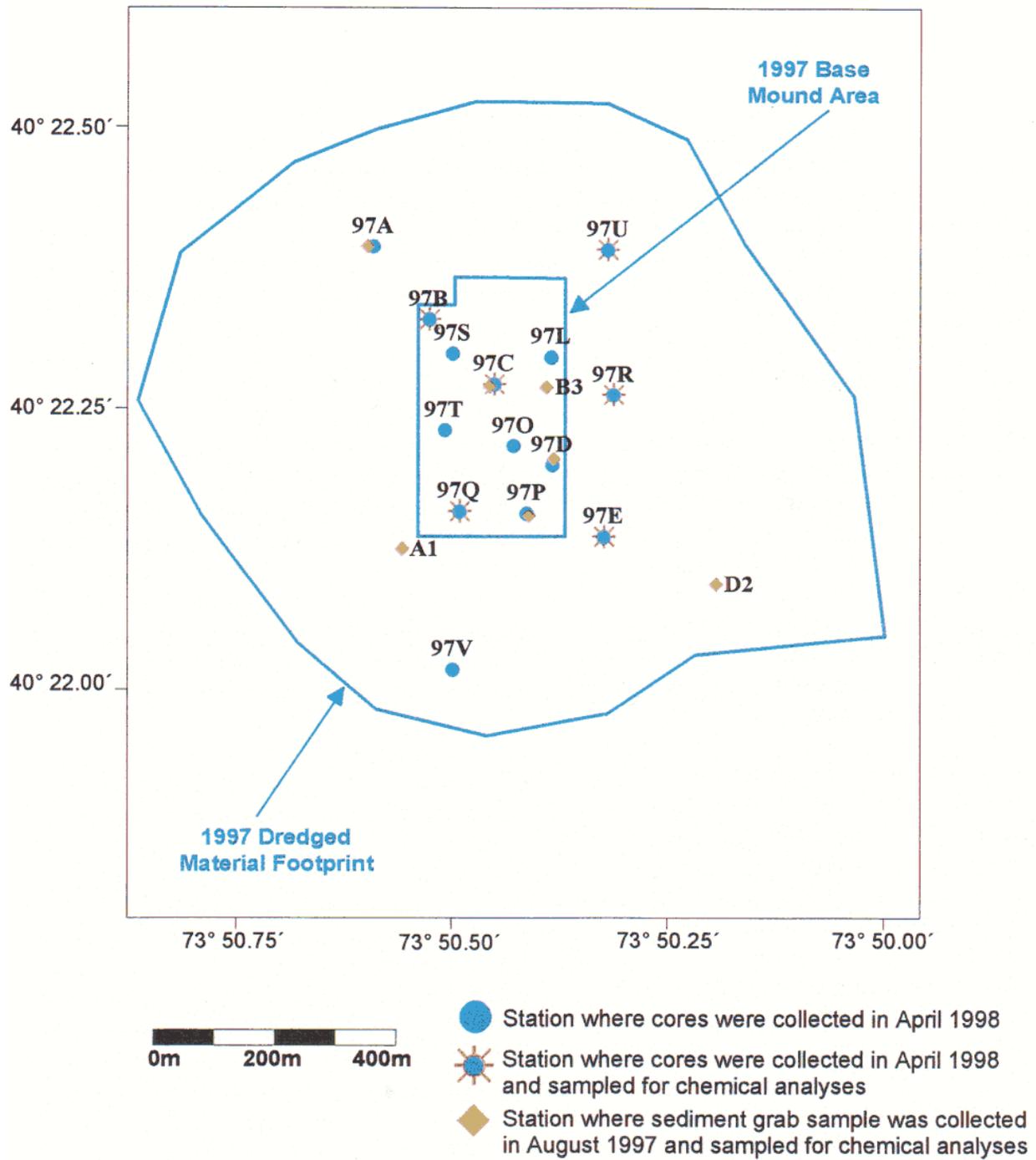


Figure 5-5. Map showing the location of both the August 1997 postdisposal sediment/tissue grabs and the April 1998 sediment coring stations.

interface) and surface sediment grab samples collected during the postdisposal sediment/tissue survey of August 1997. Figure 5-5 illustrates the location of the postdisposal sediment grab stations relative to the postcap coring stations.

Dioxin concentrations for the April 1998 coring and August 1997 sediment grab samples were all generally below 4 ppt (Figure 5-6), with the exception of sediment grab samples at stations 97A (21 ppt) and D2 (23 ppt). These results help to illustrate the non-homogeneity of the dredged material. A sample was collected at station 97C in both surveys, and the RPD for those samples was 22%. Furan concentrations followed a similar pattern as that for dioxin, with samples for both surveys generally below 2 ppt (Figure 5-6), however, concentrations in three of the seven samples from the August 1997 survey were greater than 8 ppt. Thus, the low concentrations of dioxin and furan observed in the April 1998 coring samples are not considered anomalous in light of the equally low concentrations of dioxin and furan observed in the sediment grab samples from the August 1997 sediment/tissue survey.

It is interesting to examine how the concentrations of dioxin and furan vary with core depth, particularly with respect to the sand cap-dredged material interface (Figure 5-7). This figure provides a visual example of the non-homogeneity of the project material both within individual cores and among cores. It is apparent that the concentrations of both dioxin and furan increase below the sand cap-dredged material interface. Four of the six cores show an increase in both dioxin (97B, 97C, 97Q, and 97U) and furan (97B, 97E, 97R, and 97U) concentration between the 10 cm and 30 cm below interface samples. Dioxin concentrations continue to increase with depth in cores 97C and 97U. There is no consistent trend in furan concentration with core depth below the sand cap-dredged material interface.

In conclusion, the chemistry results for the April 1998 coring survey appear to show that the sand cap has been effective in containing the underlying dioxin and furan contaminated Category II dredged material. There was no dioxin detected within the cap material and no appreciable amount (less than 1 ppt) of furan detected within the cap material. Dioxin and furan were detected within the dredged material but at concentrations of less than seven parts per trillion. At such low concentrations in the underlying material, it seems unlikely that appreciable concentrations of either dioxin or furan will be observed in the sand cap in future monitoring efforts.

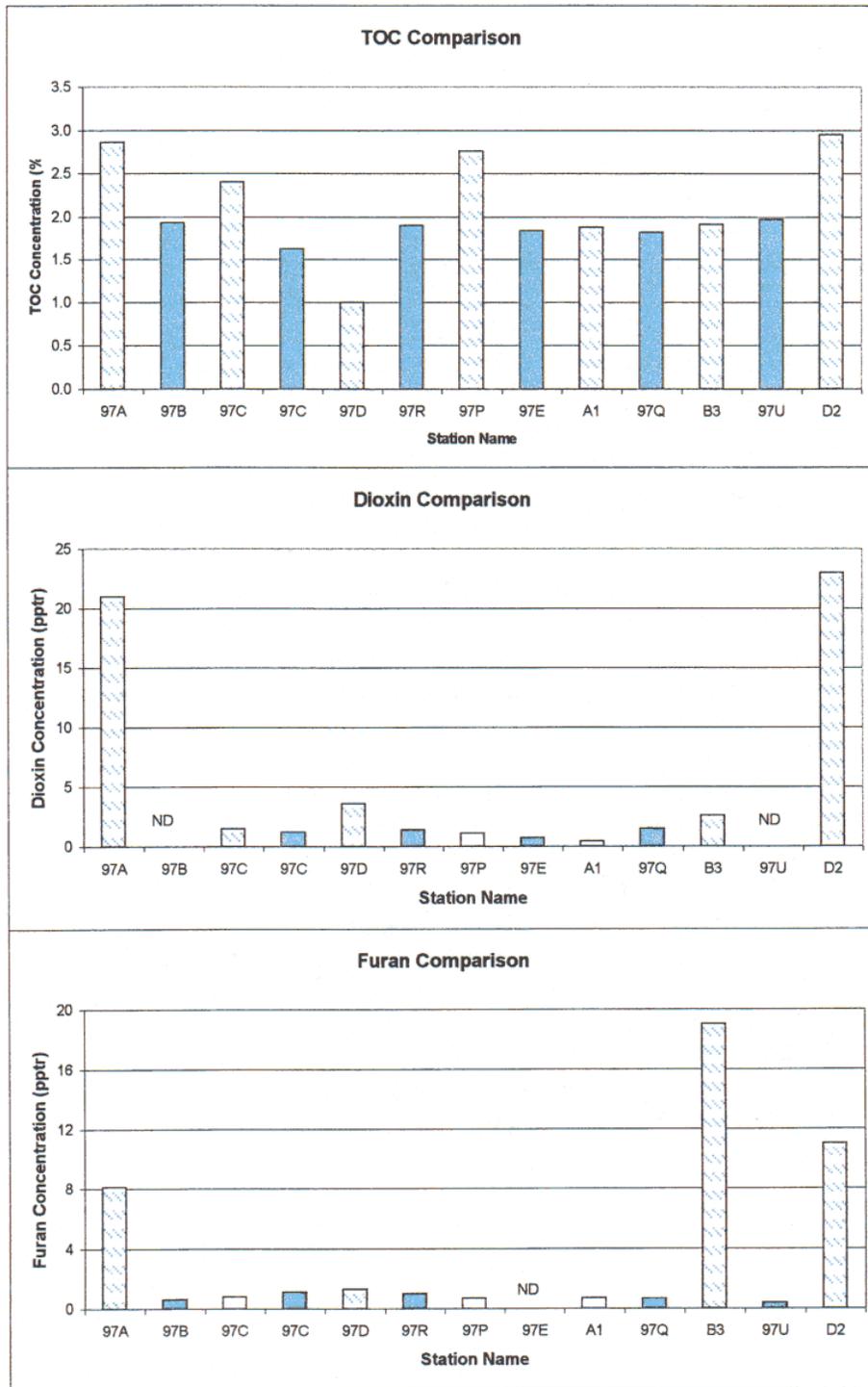


Figure 5-6. Comparison of TOC, dioxin, and furan concentrations between the August 1997 postdisposal sediment/tissue samples and the April 1998 sediment coring samples. Solid bars are values from the April 1998 postcap coring survey. Hatched bars are from the August 1997 postdisposal sediment/tissue survey. The proximity of the compared stations is shown in Figure 5-5.

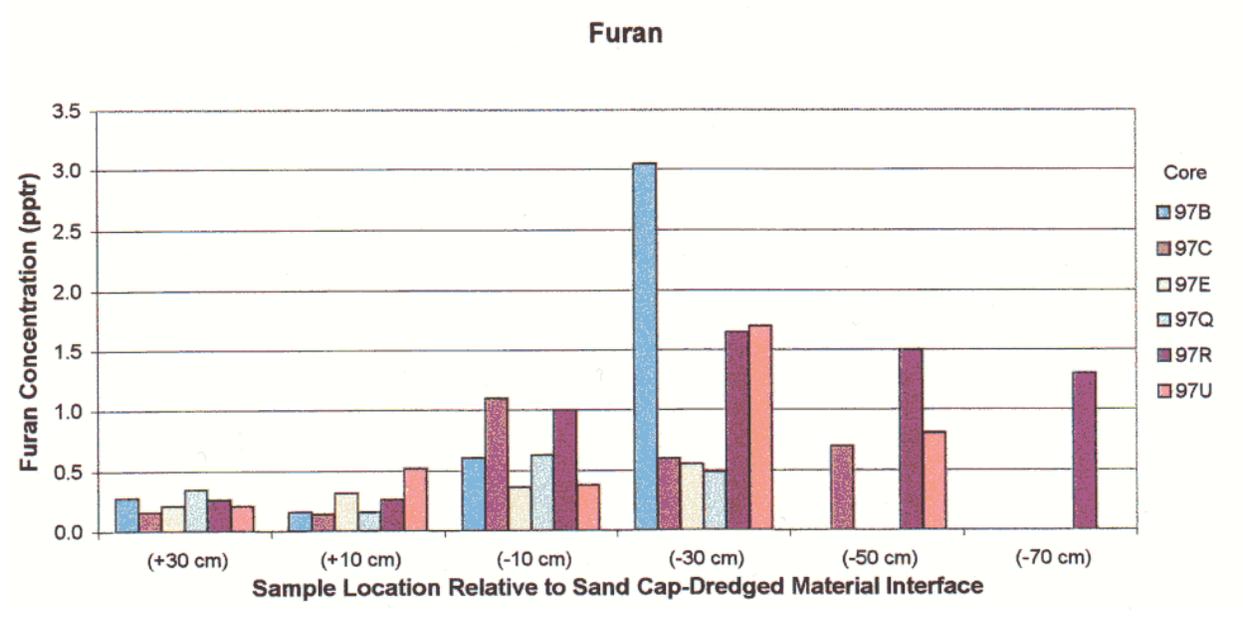
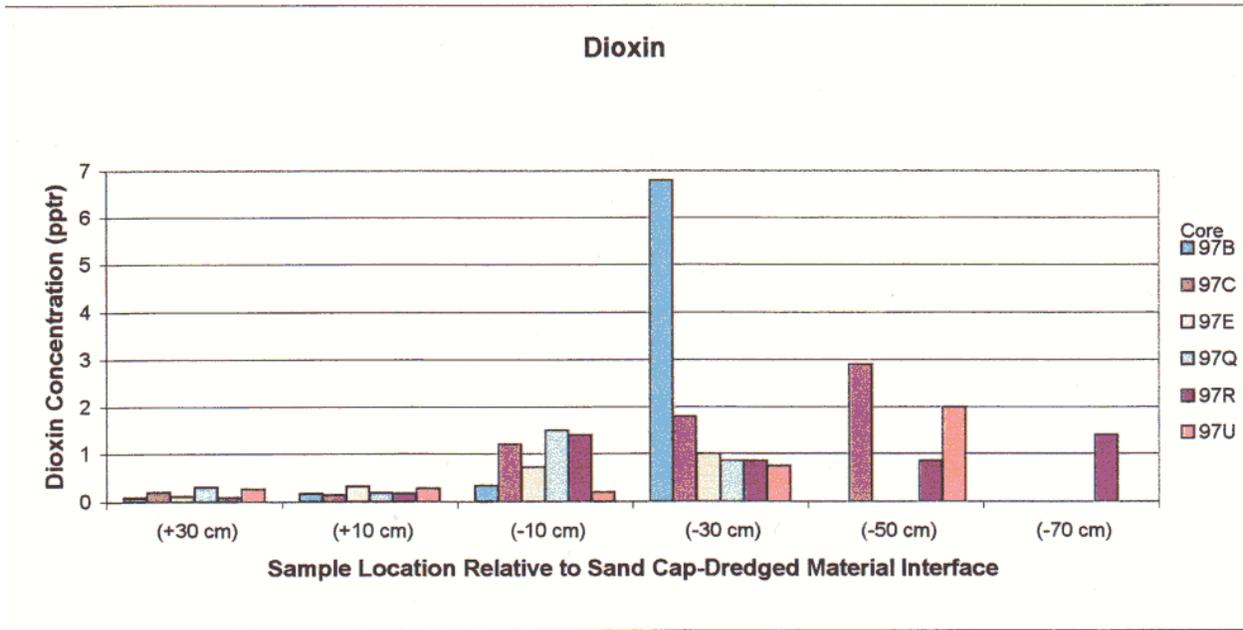


Figure 5-7. Intercore comparison of dioxin and furan concentrations.

6.0 SUMMARY

Material Units from Postcap Cores

- **Was it possible to distinguish project material from pre-project material?**

Based on core location, material depth, and material properties, it was possible to distinguish pre-project material in three of the collected cores (97A-A, 97E-B, and 97V-A). These three stations were located on the outskirts of the 1997 project, where project material is thinner and the sand caps from this and historical capping projects begin to merge (Section 4.1.1).

- **Was it possible to identify an interface between the sand cap and the underlying dredged material in the cores?**

Based on grain size as well as color and texture, the transition from cap to dredged material was clearly visible in all cores for which DM was penetrated. In most cases, this was a very distinct, sharp boundary, however sand was noted along the outer edge of the dredged material for the first few centimeters for several of the cores. This is attributed to drag-down during the coring process rather than reflecting instability at the cap-dredged material boundary.

- **Was there variability in either the cap or the underlying dredged material?**

Overall, both the cap and DM layers were composed of relatively homogenous material types. The sand cap was comprised of medium to coarse sand ranging from dark gray to grayish brown and brownish gray in color. The DM unit had a wide range of physical properties, but could not be categorized into distinct sub-categories. In general, the DM unit consisted of fine-grained black silty clay with some patches of clay and medium sand.

Physical Stability: Analysis of Potential Mixing Processes

- **Were there any visual indications of mixing (instability) between the sand cap and dredged material?**

The possibility of mixing between the higher density sand of the cap and the lower density, fine-grained dredged material has been a concern of this and other capping projects. The cores from the April 1998 project showed an undisturbed boundary between the sand and finer-grained project material, with no obvious indications of mixing between the two layers. In several cores, there was sand along the sides of the top layer of dredged material in the core liner. This is attributed to drag-down during the coring process.

- **Do the geotechnical properties of the in-place cap material and the underlying dredged material suggest that these materials are internally stable?**

There was no geotechnical evidence of instability across the cap/dredged material interface due to either consolidation or loading of the higher density sand cap over lower density dredged material. The core profiles of density and water content all showed a distinct difference between the cap and dredged material. Within the cores, there was no evidence of mixing between the layers which would be seen if the sand had collapsed into the underlying, more fluid, fine grained material. Large-scale deformations caused by loading sand over silty and clay could not, however, be measured by the limited horizontal resolution of the relatively narrow cores.

- **Is there evidence of dredged material consolidation?**

As sediment consolidates, water is extruded from the compacting pore spaces, resulting in decreased water content and void ratio values, and increased bulk density values, over time. The data from the postdisposal and postcap surveys were compared, showing a trend towards lower water content and void ratio values. A statistically significant difference in the mean water content and void ratio values was found.

After an initial steep rate of change in consolidation after capping, the rate of consolidation slows dramatically until the change is below the resolution of measurement techniques (Poindexter-Rollings 1990). The observed change in water content and void ratio values between the postdisposal and postcap coring surveys was evidence of consolidation that had occurred since the loading of the sand cap material. As monitoring of this site continues, it is expected that this observed trend in consolidation will continue, though at a slower rate.

Chemical Stability: Analysis of Potential Migration Processes

- **Was there any dioxin or furan present in the cap material?**

Dioxin was consistently below detection in all cap sediment samples in April 1998. Eight cap samples had trace (<1.0 pptr) concentrations of furan detected. The lack of any dioxin or furan above the required detection limit of 1.0 pptr in the sand cap suggests that this newly-placed cap was being effective in isolating the underlying contaminated dredged material at the time of the April 1998 postcap coring survey.

7.0 REFERENCES

- ASTM. 1993. *1993 Annual Book of ASTM Standards*, Section 4, Construction, Volume 4.08, Soil and Rock; Dimension Stone; Geosynthetics, American Society for Testing and Materials, Philadelphia, PA.
- Bowles, J. E., (1979). *Physical and Geotechnical Properties of Soils*. McGraw-Hill, New York.
- Clarke, J.U. (1994). Evaluating methods for statistical analysis of less than detection limit data using simulated small samples. (2. General results). In: McNair, E.C., Jr. (ed.), *Dredging '94*, Vol. 1, Proceedings of the Second International Conference on Dredging and Dredged Material Placement, pp. 747-755.
- Das, B.H. (1983). *Advanced Soil Mechanics*. Taylor & Francis.
- Dayal, R., Heaton, M.G., Fuhrmann, M., Duedall, I.W. (1983). A geochemical study of the dredged material deposit in the New York Bight. In: Kester, P.R., Ketchum, B.H., Duedall, I.W., and Park, P.K. (eds.), *Wastes in the Ocean Vol. 2*. John Wiley and Sons, NY, pp.123-149.
- Karickhoff, S. W., Brown, D. S., and Scott, T. A. (1979). Sorption of hydrophobic pollutants on natural sediments. *Water Research*, 13: 241-248.
- Krumbein, W. C., and Sloss, L. L. 1963. *Stratigraphy and Sedimentation*, 2nd Ed., W. H. Freeman and Company, San Francisco, CA.
- Lake, J. L., Rubinstein, N. I., Lee, H., Lake, C. A., Heltsche, J., and Pavignano, S. (1990). Equilibrium partitioning and bioaccumulation of sediment-associated contaminants by infaunal organisms. *Environ. Toxicol. Chem.* 9:1095-1106.
- McFarland, V. A., Lutz, C. H., and Reilly, F. J. (1994). Bioaccumulation data and analysis for selected contaminants in sediments and biota of the New York Bight Apex Mud Dump Reference Site. Final report to the U.S. Army Corps of Engineers, New York District, New York, NY.
- NATO-CCMS (North Atlantic Treaty Organization, Committee on the Challenges of Modern Society). (1988a). International toxicity equivalency factor (I-TEF) method of risk assessment for complex mixtures of dioxins and related compounds. Report No. 176.
- NATO-CCMS (North Atlantic Treaty Organization, Committee on the Challenges of Modern Society). (1988b). Scientific basis for the development of international toxicity equivalency (I-TEF) factor method of risk assessment for complex mixtures of dioxins and related compounds. Report No. 178.

- NOAA. (1991). Second summary of data on chemical contaminants in sediments from the National Status and Trends Program. National Oceanographic Atmospheric Administration Tech. Mem. NOS OMA 59. Rockville, MD. 29 pp. + 4 appendices.
- O'Connor, T. (1990). Coastal environmental quality in the United States, 1990: Chemical contamination in sediment and tissues. NOAA 20th Anniversary Report, U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, 34 pp.
- PANYNJ. (1996). Summary report of maintenance dredge material properties: NY/NJ Harbor region.
- Parker, J. P. and Valente, R. M. (1988). Long-term sand cap stability: New York dredged material disposal site. Contract Report CERC-88-2, U.S. Army Engineer District, New York, NY.
- Poindexter-Rollings, M.E. (1990). Methodology for Analysis of Subaqueous Sediment Mounds. Technical Report D-90-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Rollings, M. P. and R. S. Rollings. (1998a). Consolidation and related geotechnical issues at the 1997 New York Mud Dump site. Proceedings, XVth World Dredging Congress, WEDA, Las Vegas, NV.
- Rollings, M. P. and R. S. Rollings. (1998b). Shear Failures in the New York Harbor Disposal Mound and Implications for Design of Sand Caps. Proceedings, XVth World Dredging Congress, WEDA, Las Vegas, NV.
- Safe, S. (1990). Polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), and related compounds: environmental and mechanistic considerations which support the development of toxicity equivalency factors (TEFs). Crit. Rev. Toxicol. 21: 51-88.
- SAIC. (1993). Monitoring of the disposal of dredged material containing dioxin: Laboratory analysis of baseline/post-storm samples. Report #5 of the New York Mud Dump Site Studies. EPA Contract No. 68-W2-0026. SAIC Report No. 286.
- SAIC. (1995a). The Dioxin Capping Monitoring Program at the New York Mud Dump Site: summary of geotechnical and chemical analyses of cores from the May 1994 postcap survey. Report #19 of the Dioxin Capping Monitoring Program. U.S. Army Corps of Engineers, Waterways Experiment Station (WES) Contract No. DACW33-94-C-0117. SAIC Report No. 341.
- SAIC. (1995b). The Dioxin Capping Monitoring Program at the New York Mud Dump Site: summary of geotechnical and chemical analyses of cores from the December 1994 postcap survey. Report #21 of the Dioxin Capping Monitoring

- Program. U.S. Army Corps of Engineers, Waterways Experiment Station (WES) Contract No. DACW33-94-C-0117. SAIC Report No. 348.
- SAIC. (1996). The Dioxin Capping Monitoring Program at the New York Mud Dump Site: Summary of Geotechnical and Chemical Analyses of Cores from the August 1995 Postcap Survey. Report #30 of the New York Mud Dump Site Studies. U.S. Army Corps of Engineers, Waterways Experiment Station, Contract USACE-WES DACW33-94-C-0117. SAIC Report No. 359.
- SAIC. (1997a). Results from the First Interim Disposal Bathymetry Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #59 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-97-0014. SAIC Report No. 403.
- SAIC. (1997b). Results from the Third Interim Disposal Bathymetry Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #61 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-97-0014. SAIC Report No. 406.
- SAIC. (1997c). Automated Surveillance of Disposal Operations during the 1997 Category II Capping Project at the New York Mud Dump Site. Report #63 of the New York Mud Dump Site Studies. USACE-CENAN, Contract No. DACW51-95-D-0027. SAIC Report No. 409.
- SAIC. (1997d). A consolidation monitoring plan for dredged material mounds at the New York Mud Dump Site. Report #40 of the New York Mud Dump Site Studies. U.S. Army Corps of Engineers, Waterways Experiment Station (WES) Contract No. DACW39-94-C-0117. SAIC Report No. 375.
- SAIC. (1998a). Results from the April 1998 Postcap Bathymetry Survey for the 1997 Category II Capping Project at the Mud Dump Site. Report #83 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-97-D-0014. SAIC Report No. 438.
- SAIC. (1998b). The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the April 1998 Postcap Subbottom Survey. Report #87 of the New York Mud Dump Site Studies. USACE CENAN, Contract No. DACW51-97-D-0014. SAIC Report No. 450.
- SAIC. (1998c). The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the First Postcap REMOTS® Survey of April 1998. Report #88 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-97-D-0014. SAIC Report No. 451.

- SAIC. (1998d). Synthesis of Monitoring Results for the 1993 Dioxin Capping Project at the New York Mud Dump Site. Report #79 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-95-D-0027. SAIC Report #430.
- SAIC. (1998e). The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the May 1997 Baseline Coring Survey. Report #68 of the New York Mud Dump Site Studies. USACE Contract No. DACW51-95-D-0027. SAIC Report No. 416.
- SAIC. (1998f). The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the September 1997 Postdisposal Subbottom Profile Survey. Report #75 of the New York Mud dump Site Studies. USACE Contract No. DACW51-97-D-0014. SAIC Report No. 424.
- SAIC. (1998g). The 1997 Category II Capping Project at the Mud Dump Site: Results from the July 1997 Interim Disposal Coring Survey. Report #76 of the New York Mud dump Site Studies. USACE Contract No. DACW51-97-D-0014. SAIC Report No. 425.
- SAIC. (1998h). The 1997 Category II Capping Project at the New York Mud Dump Site: Results from the August 1997 Postdisposal Coring Survey. Report #68 of the New York Mud Dump Site Studies.
- SAIC. (1998i). New York Disposal Surveillance System: Prototype Description. Report #72 of the New York Mud Dump Site Studies. USACE-WES Contract No. DACW39-94-C-0117. SAIC Report #421.
- SAIC. (1998j). The 1997 Category II Capping Project at the Mud Dump Site: Chemical analysis of sediment and tissue samples for the August 1997 postdisposal survey. Report #78 of the New York Mud Dump Site Studies. USACE-CENAN Contract No. DACW51-97-D-0014. SAIC Report No. 427.
- USEPA. (1989). Interim procedures for estimating risks associated with exposures to mixtures of chlorinated dibenzo-p-dioxins and -dibenzofurans (CDDs and CDFs) and 1989 update. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC. EPA/625/3-89/016.
- USEPA. (1994). Tetra- through octa-chlorinated dioxins and furans by isotope dilution HRGS/HRMS. Method 1613, Revision A, pp. 1-42.
- USEPA. (1997a). Method 9060 – Total organic carbon. In: USEPA. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846 Third Edition, Update 3. Method 9060.
- USEPA. (1997b). Method 8290 - Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) by high resolution gas

chromotography/high resolution mass spectrometry (HRGC/HRMS). In: USEPA. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846 Third Edition, Update 3. Method 8290. Revision O.

Wentworth, C.K. (1922). A scale of grade and class terms of clastic sediments. *J. Geo.* 30:377-390.

Williams, S. J., Duane, D. B. (1974). Geomorphology and sediments of the inner New York Bight continental shelf. U.S. Army Corps of Engineers, Coastal Engineering Research Center Technical Memorandum No. 45.

Wu, T.H. (1976). *Soil Mechanics*. 2nd ed. Allyn and Bacon, Inc., Boston.