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Deep Water Capping

D A M O S

DISPOSAL AREA MONITORING SYSTEM

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Mary Baker Wiley

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Science Applications International Corporation
221 Third Street
Newport, RI 02840

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13. ABSTRACT *(MAXIMUM 200 WORDS)*

The Boston Harbor Navigation Improvement project will generate an estimated 2.2 x$10^6$$m^3$ of dredged material . Approximately 500,000 m^3 of this sediment is expected to be unsuitable for unconfined open water disposal. One alternative proposed was that the unsuitable sediments be deposited at the existing Massachusetts Bay Disposal Site (MBDS), where they would be capped by the remaining 1.7 x 10^6 m^3 of clean dredged material. Successful disposal of contaminated dredged material at open ocean sites requires formation of a distinct dredged material mound, careful placement of capping materials, and bathymetric and environmental monitoring to ensure that the operation is successful initially and effective over the long term.

MBDS is a disposal site approximately 17 nmi east-northeast of Boston Harbor in water depths averaging 90 m. This site is deeper than existing disposal sites in Long Island Sound where capping operations have occurred in a maximum of approximately 25 m water depth. Several concerns have been raised regarding proposals to extend the depth of capped disposal operations to deeper waters (e.g., Dolin and Pederson 1991). Monitoring of disposal at MBDS over the past 7 years has shown that dredged material released at the site does form a distinct disposal mound which can be detected by acoustic bathymetry. The formation of a well-defined disposal mound has been the criterion on which capping decisions have been made at shallower sites.

Such a formation indicates that the dredged material is stable and distinct from the ambient sediment. If the dredged material forms a distinct, stable mound, then the following conditions can be satisfied: the sediment is being contained at the site; the area over which capping material must be placed is known; and the capped mound can be monitored to verify that the cap is isolated the unsuitable sediments effectively. Based on the past disposal at MBDS, as well as deep water sites (>100m) in Puget Sound, we can predict that the dredged material will form a well-defined mound at these depths and that capping can be viable means of containing unsuitable sediments at these sites.

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424 Trapelo Road
Waltham, MA 02254-9149

Prepared by:
Mary Baker Wiley

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

US Army Corps
of Engineers
New England Division

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Boston Harbor Navigation Improvement Project will generate an estimated 2.2×10^6 m^3 of dredged material. Approximately 500,000 m^3 of this sediment is expected to be unsuitable for unconfined open water disposal. One alternative proposed was that the unsuitable sediments be deposited at the existing Massachusetts Bay Disposal Site (MBDS), where they would be capped by the remaining 1.7×10^6 m^3 of clean dredged material. Successful disposal of contaminated dredged material at open ocean sites requires formation of a distinct dredged material mound, careful placement of capping materials, and bathymetric and environmental monitoring to ensure that the operation is successful initially and effective over the long term.

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1.0 INTRODUCTION

Dredged materials unsuitable for unconfined open water disposal have been managed through a variety of confinement techniques. In 1979, the New England Division of the Army Corps of Engineers pioneered an approach to place unsuitable materials on discrete areas of level ocean floor and "cap" these materials with dredged materials suitable for unconfined disposal (for a review see Murray et al. 1992). This approach has been used by other Corps Divisions (Sumeri et al. 1991) and employed with success in water depths up to 60 m.

This paper reviews and summarizes the available information on open water disposal of dredged material that is pertinent to proposed capping projects. This information includes the behavior of the material as it falls through the water and evidence collected from monitoring disposal activities in both shallow water (<25 m) and deeper water (>25 m). The ability to monitor both the formation of the mound and the placement of the cap has been critical in developing successful capping techniques in shallow water (Murray et al. 1992). The experience gained, and the information gathered, in these operations will be applied to an evaluation of the potential for success in deeper water.

While there is no evidence that capping cannot be accomplished in greater depths of water, several concerns have been raised regarding proposals to extend the depth of capped disposal operations (e.g., Dolin and Pederson 1991). There is concern that the increased water depth will present logistical problems, contribute to wider dispersal of unsuitable sediments, and lead to poor control over placement of cap sediments. These issues focus on the apparent lack of experience with dredged material behavior in deeper water and preliminary evidence that disposal activities in deep water failed to produce discrete mounds (SAIC 1984a).

To cap unsuitable sediments effectively, two primary goals must be achieved. First, the unsuitable sediments must be placed in a discrete mound on the ocean floor without extensive spreading or dispersal into the water column. Acceptable limits to spreading of the initial mound are defined by the amount of cap sediments available. Acceptable limits to dispersion in the water column are defined in the United States Ocean Dumping Regulations (Title 40, Code of Federal Regulations, Parts 227-8). Second, the cap sediments must be placed accurately so that they completely cover the mound without disturbing the unsuitable material. There is ample evidence in various open ocean disposal projects that sediment can be placed accurately on the seafloor (e.g., SAIC 1990a, 1991, Murray et al. 1992).

The Massachusetts Bay Disposal Site (MBDS) is primarily where concern regarding depth and the use of capping has been an issue. Specifically, the proposed Boston Harbor Navigation Improvement Project will require the dredging of an estimated 2.2×10^6 m^3 of sediment from the Mystic River, the Chelsea River, and the Reserved Channel. A significant portion of this material (approximately 500,000 m^3) is estimated to be unsuitable for unconfined open water disposal. One alternative the New England Division of the Army Corps of Engineers (NED) has proposed is that the unsuitable sediments be disposed at MBDS and then capped with the remaining suitable dredged materials.

MBDS is a 2 nmi diameter circular area located 17 nmi east-northeast of Boston Harbor and 12 nmi southeast of Gales Point in Gloucester (Figure 1-1). The site was given final designation status in 1993 by the Environmental Protection Agency (EPA) as an Ocean Dredged Material Disposal Site (ODMDS). As part of this designation, the site boundary was shifted 0.95 nmi to the southwest. Water depths at the existing site are a maximum of 92 m (Figure 1-2). The MBDS boundary overlaps a portion of the old Industrial Waste Site which had been in use since the 1940s for the disposal of dredged material as well as other waste. EPA records show no permitted use of the Industrial Waste Site after 1976, and it was formally de-designated on February 2, 1990. The MBDS has been used exclusively for the disposal of dredged material since 1977. The successful use of MBDS for the disposal of contaminated dredged material requires the formation of a stable disposal mound that can be capped and monitored.

Initial capping attempts at MBDS (formerly known as the Boston Foul Ground, BFG, and the Foul Area Disposal Site, FADS) in the summer/winter of 1982/1983 were problematic. Positioning problems during the disposal operation may have caused inaccurate and widely spaced placement of dredged material, hindering the formation of a dredged material mound.

The project design called for sediment from Boston Harbor to be dredged mechanically using a clamshell dredge and transported to MBDS where it was to be point dumped at a taut-wired buoy during the summer of 1982 (SAIC 1984a). However, a bathymetry survey conducted after the disposal operation did not detect a mound of dredged material below the location of the buoy. A side-scan survey of the area did detect scattered patches of highly reflective sediment, usually indicative of dredged material. Sediment samples containing the contaminated dredged material were collected at locations 500 m south and 700 m north and west of the disposal location. After these surveys were concluded, it was suggested that increased disposal accuracy would occur by shortening the hawser, slowing the tug, and opening the barge doors only when close aboard the buoy.

In January 1983, cleaner cap material was placed at the site by a hopper dredge using LORAN-C coordinates. Because the contaminated dredged material did not form a mound, the capping sediment released by the hopper dredge was effective in capping only that portion of the contaminated dredged material that was deposited at the correct disposal location. Where patches of contaminated dredged material were found at the buoy location, contaminant levels in that sediment decreased after the cap material was released (SAIC 1984a).

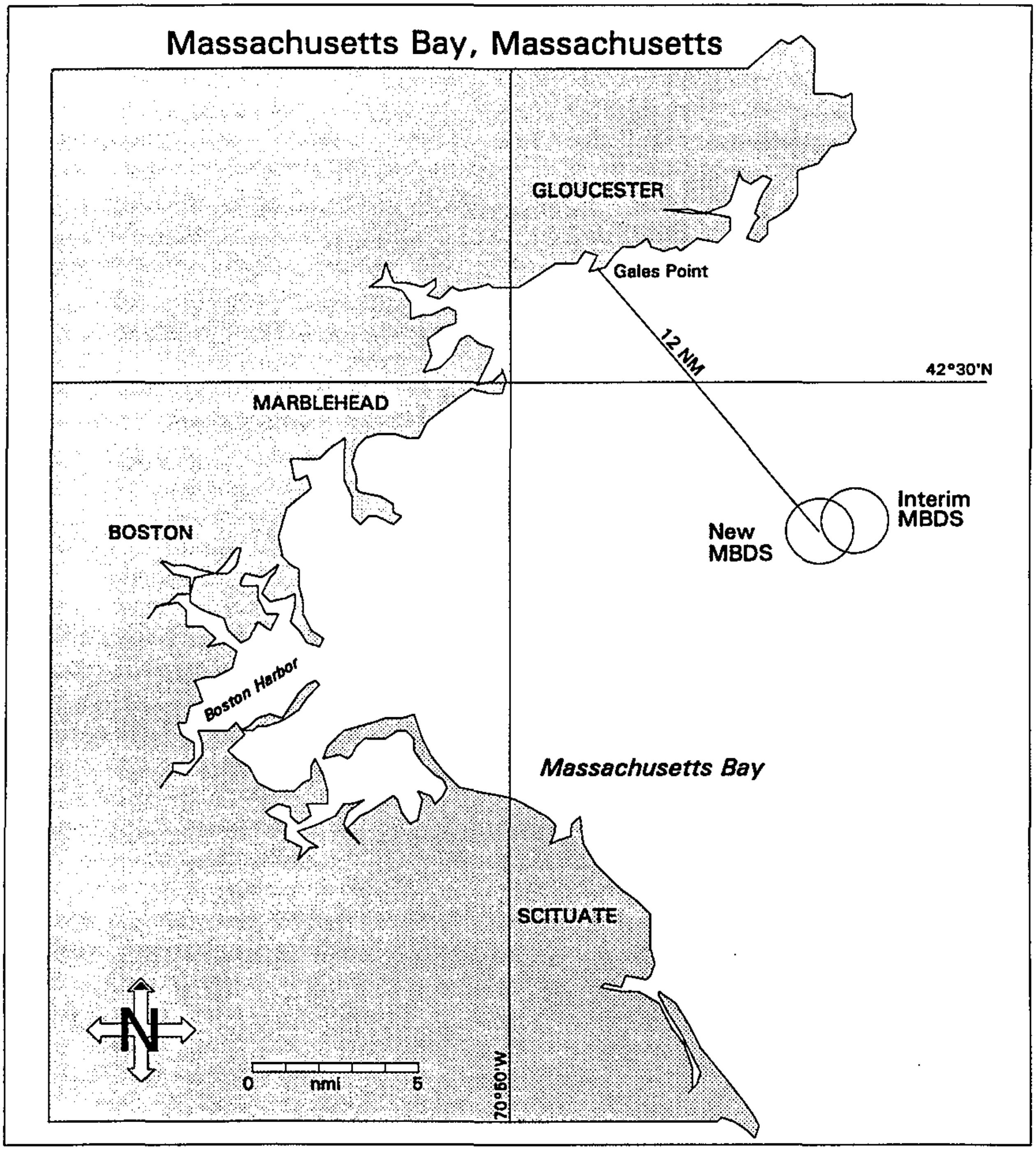

Figure 1-1. Location of Massachusetts Bay Disposal Site (MBDS) in relation to Boston Harbor and Gloucester, MA

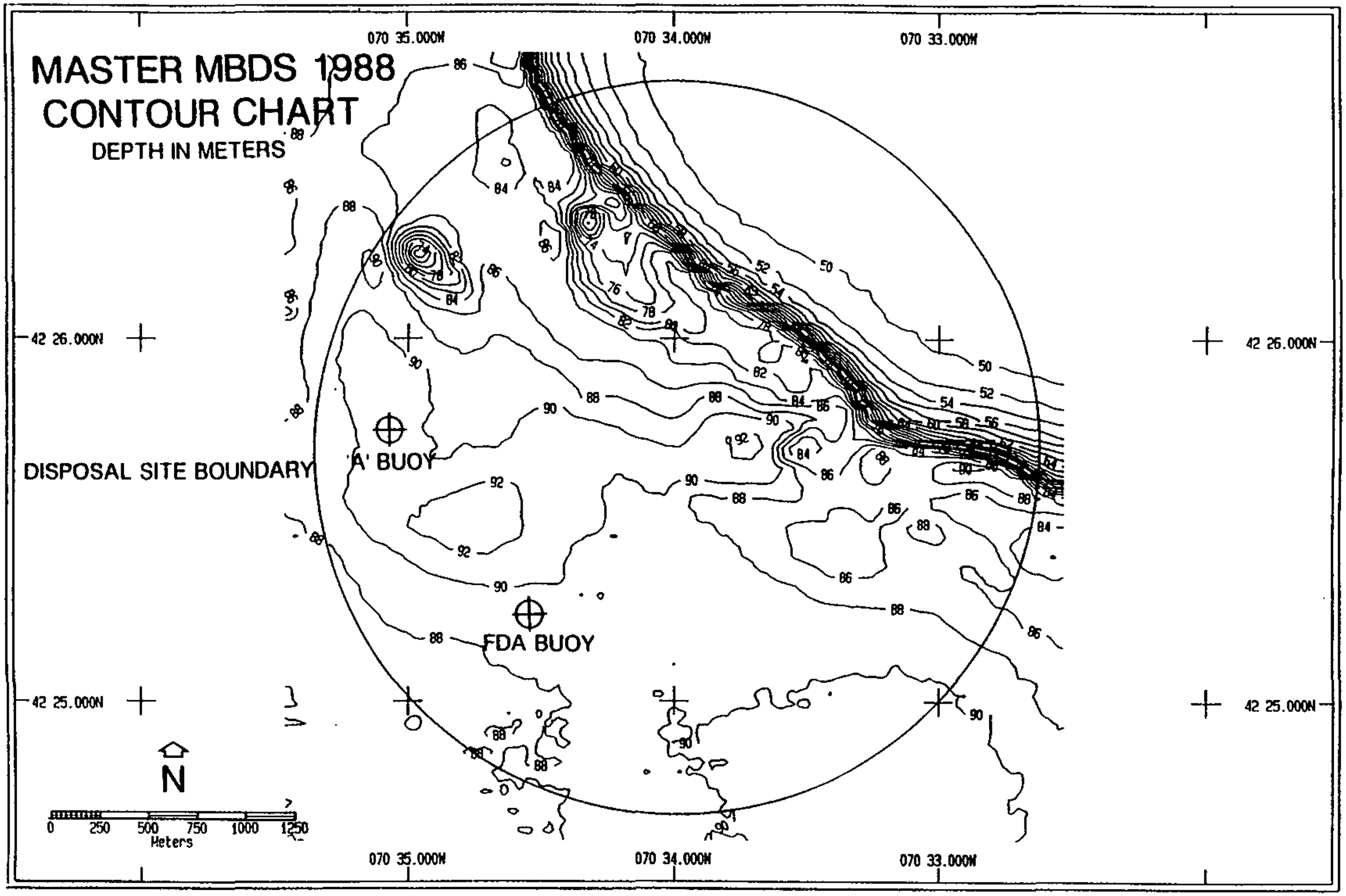

Figure 1-2. Bathymetric contour chart (depth in meters) of MBDS, November 1988

Under the DAMOS (Disposal Area Monitoring System) Program, successful capping has been conducted in water depths less than 60 m (196′). With tightly controlled disposal operations, accurate placement of both the material deemed unsuitable for unconfined ocean disposal and the cap material has resulted in a well-defined dredged material mound. The formation of a well-defined dredged material mound, as illustrated by capping operations at the Central Long Island Sound Disposal Site (CLIS), is the primary determinant of successful capping operations (e.g., SAIC 1984b). The dredged material disposal mounds formed at MBDS, Port Gardner, WA, and Elliott Bay, WA disposal sites support the feasibility of capping operations in deeper water. Because of our understanding of the behavior of material as it travels through the water column (based on empirical results of other disposal operations and verified modeling results), we feel confident that similar operational control over the disposal of dredged material in deeper water should result in successful capping.

The results from monitoring recent disposal operations at MBDS show that a distinct mound was formed at this site during these disposal operations. From 1987 to 1992, approximately 836,148 m^3 of material dredged from the Boston area was deposited at the "MDA" (formerly the "FDA") buoy (SAIC 1990b, Germano et al. 1993). A bathymetric survey conducted in 1992 detected a mound over a 400 by 200 m area (Figure 1-3). From 1987 to 1990, a maximum of 0.8 m of material had accumulated to the east of the buoy location (Figure 1-4). From 1990 to 1992, up to 2.0 m of dredged material had accumulated west of the buoy location (Figure 1-5). The successful formation of a mound from these disposal activities suggests that the Boston Harbor material will also form a distinct dredged material mound at this site provided that tight control is exercised over disposal operations. Routine monitoring techniques (bathymetry and REMOTS® sediment- profile photography) can determine the areal extent of a discrete, stable deposit quite accurately, thereby allowing NED managers to direct subsequent disposal operations to form a cap over the initial mound.

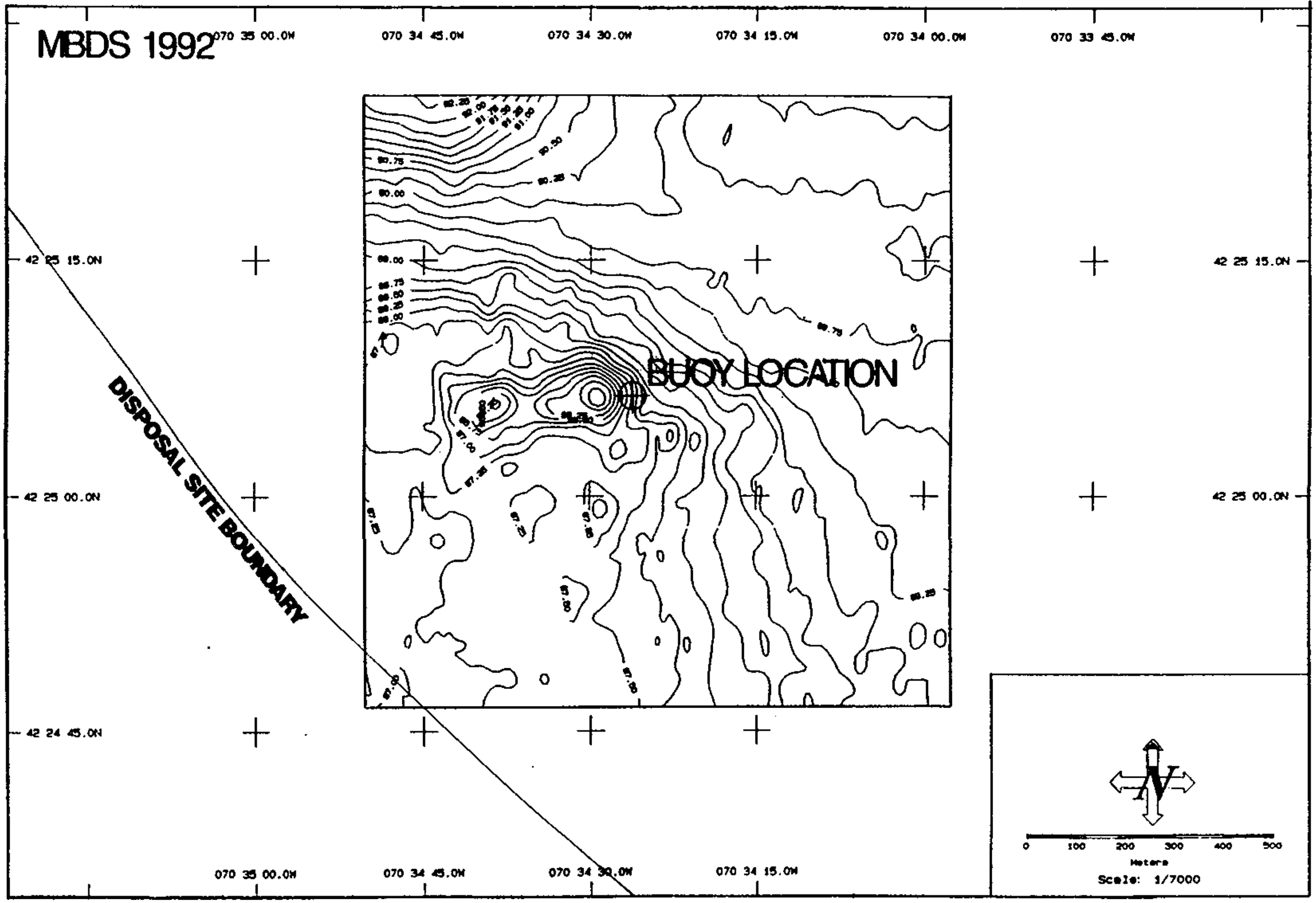

Figure 1-3. Bathymetric contour chart (depth in meters) of active disposal point at MBDS, 31 March 1992

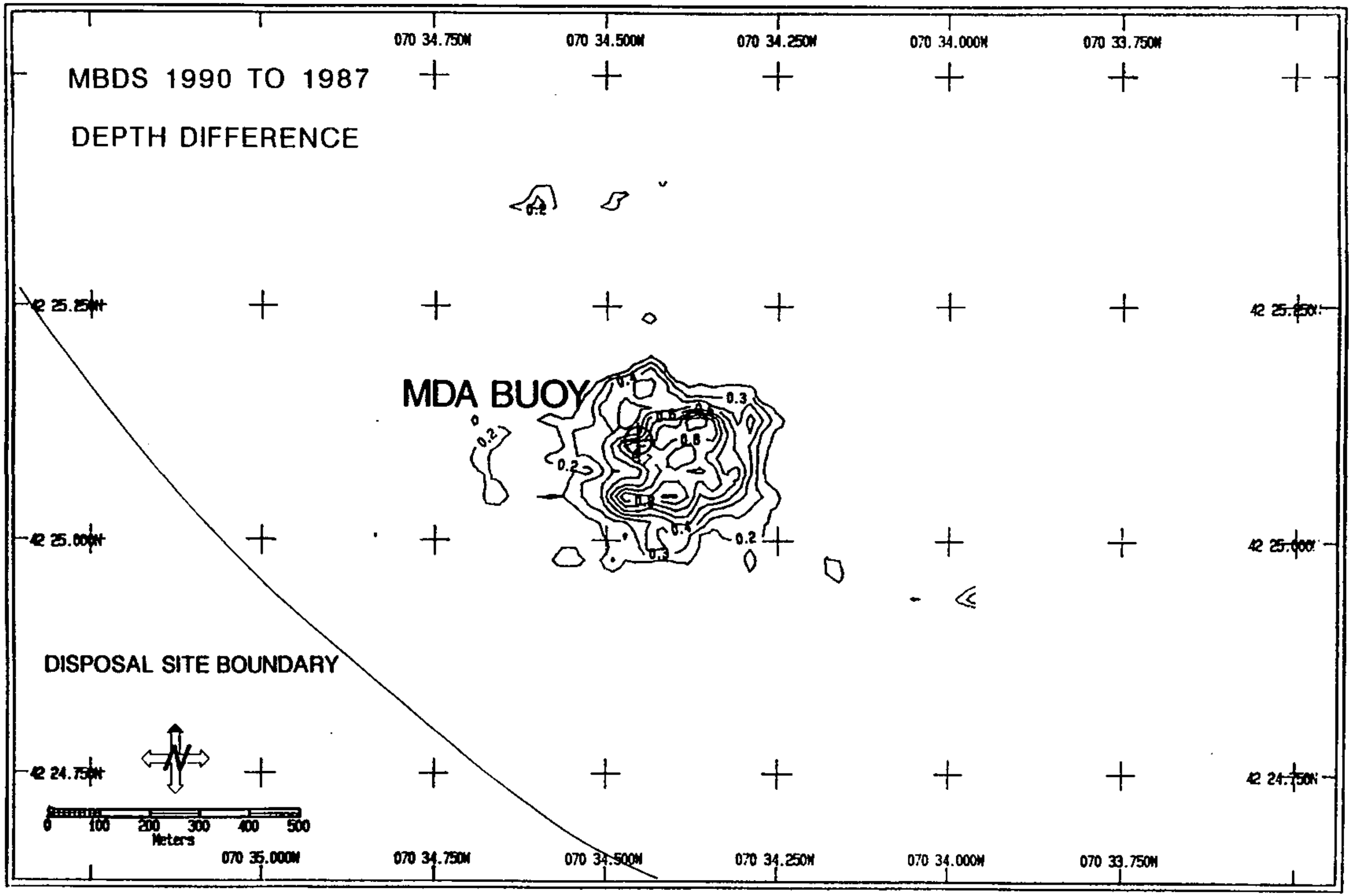

Figure 1-4. Depth difference contour chart (in meters) based on the comparison of 1990 and 1987 MBDS bathymetry

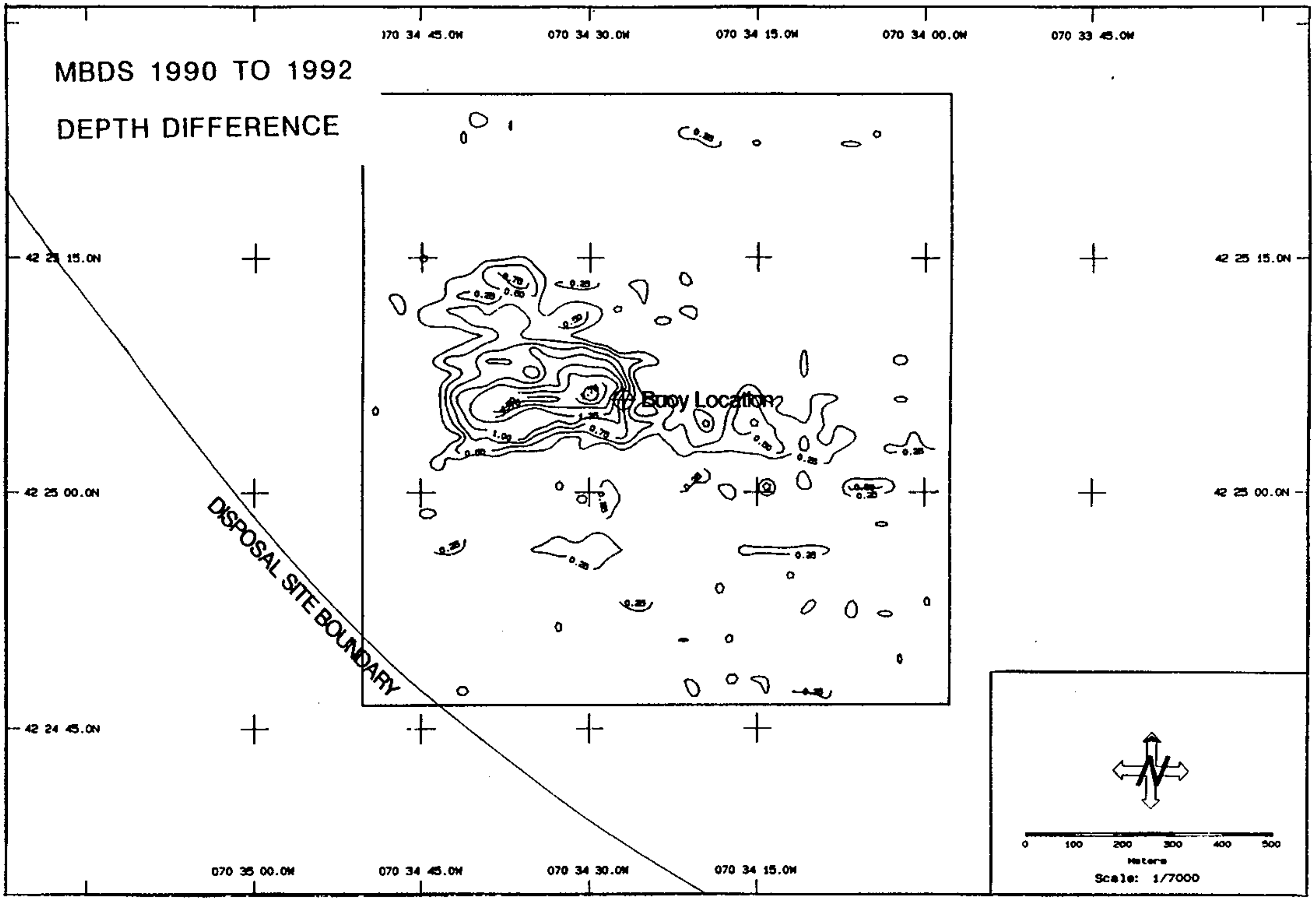

Figure 1-5. Depth difference contour chart (in meters) based on the comparison of 1990 and 1992 MBDS bathymetry

2.0 OPEN WATER DISPOSAL AND CAPPING OF DREDGED MATERIAL

The increased use of open water sites for confined aquatic disposal, or capping, of contaminated dredged material is due to a decrease in the availability of upland or wetland areas for the disposal of dredged material, associated costs, and concerns over disposal of contaminated material near freshwater aquifers. Successful disposal of contaminated dredged material at open water sites requires formation of a distinct dredged material mound, careful placement of capping materials, and concurrent bathymetric and environmental monitoring to ensure that the operation is successful initially and effective over the long term. This has been accomplished at several locations within the CLIS Disposal Site (e.g., Morton 1979, Morton and Miller 1980, SAIC 1984b, Murray et al. 1992).

The formation of a dredged material mound requires good navigational control during disposal operations and a disposal method that contributes to the formation of a mound. There is a wealth of experience in the DAMOS Program to demonstrate that point dumping of the dredged material using LORAN-C coordinates and a taut-wired buoy will provide accurate placement of the dredged material (e.g., SAIC 1990a, 1991, Murray et al. 1992). Point dumping requires that the disposal barge pull up close to the buoy and slow or stop before opening the barge doors rather than opening the doors underway. The taut-wired buoy design incorporates a hang weight between the anchor and the surface buoy. This hang weight keeps the wire vertical between it and the surface, reducing the watch circle of the buoy at the surface. When accurate navigation and a taut-wired buoy are used, the onboard inspection/control must also guarantee that the instructions are followed.

Dredging and disposal of subtidal sediments are accomplished with either a hopper dredge for dredging and disposal or a clamshell dredge with barge disposal. The majority of dredging projects in New England are accomplished with a clamshell dredge. During dredging, a hopper dredge entrains water and breaks down the cohesiveness of the sediments. If sediments are dredged with a clamshell dredge, however, the sediments will maintain most of their cohesiveness. Therefore, the combination of clamshell dredging and a split-hull or pocket barge is the most efficient method to form a mound. This method keeps the dredged sediment's water content at a minimum and helps control the dispersion of dredged material following release.

Field data has indicated that 80% of the dredged material released from a stationary barge and detectable by acoustic methods should be deposited within a 30 m radius of the release point in water depths < 50 m. A total of 90% of the material detectable by acoustic methods will settle within a 120 m radius under most conditions (Bokuniewicz et al. 1975).

Once a stable dredged material mound has formed in deep water, it can be capped. To isolate contaminated dredged material, a sediment cap must be of sufficient thickness and density to contain the contaminants effectively. In order to remain stable, the cap material should be denser than the underlying contaminated material (Shields and Montgomery 1984). The cap must be thick enough to isolate the contaminated sediments from the water column, biota, and erosive forces. In general, the thickness required for a biological seal is greater than for a chemical seal in the absence of biological activity. Results from lab experiments on contaminated dredged material from Long Island Sound have been used to calculate a minimum cap thickness on the order of 50 cm (Gunnison et al. 1987, Brannon et al. 1987). To accommodate irregularities in the placement of cap material and in the topography of the dredged material mound, the COE/NED generally recommends a minimum cap thickness of 50 cm (T. Fredette pers. comm.).

Placement control for the capped material will be as important as control for the placement of the contaminated dredged material. To contain contaminated sediments successfully, both the contaminated dredged material and the cap must be placed without excess dispersion and spread. The placement procedures of cap material must insure that the contaminated material mound is covered completely. The DAMOS capping model is used to predict the thickness and lateral extent of the cap based on the amount of material and a random distribution pattern of disposal locations within a predefined radius of operations (Wiley 1994). For the placement of contaminated dredged material, point dumping will maintain control over the mound formation, but it can result in uneven coverage when used to place the cap. Hopper dredge pumpdown, sand spray systems, and submerged diffusers are some of the ways proposed in various projects to ensure adequate cap coverage (Shields and Montgomery 1984, Palermo 1991, Sumeri 1989). However, these methods are more expensive due to the cost for new equipment and increased time for disposal operations. Therefore, cap placement is also likely to be by disposal barge. Choosing multiple LORAN-C locations for the disposal of cap material on a mound is cost-effective and has been successfully used for several previous projects. Surveying the capped mound by acoustic bathymetry after the cap material has been deposited is critical to monitoring the actual location of the cap material and to verify that management objectives have been achieved.

Long-term monitoring of capped dredged material mounds within the DAMOS Program has helped to verify the long-term stability of the mounds and the ability of the cap to contain contaminants effectively (SAIC 1989a, Murray et al. 1992). Survey techniques that have been used to investigate long-term stability of the cap include: acoustic bathymetry, subbottom profiling, side-scan sonar, and REMOTS® sediment-profile photography. These techniques have been used to document the presence of the cap either through changes in mound height, differing acoustic densities between the mound and the cap, or photographs of the cap material. Comparison of these surveys over time has been used to document any changes in the dimensions of the cap. The ability of the cap to isolate dredged material contaminants from overlying waters and biota has been documented over time by observing the recolonization rate of the cap by infauna, analyzing bulk sediment chemistry from surface grab samples as well as vertical core profiles, and measuring contaminant body burden levels from resident infauna. REMOTS® sediment-profile photography has been used to characterize the rate of infaunal recolonization to provide information on the health of the benthic community on the cap (SAIC 1989b). Analyses of bulk sediment chemistry and body burden of infauna have given more detailed information on changes in contaminant levels at capped mounds and their availability to the biotic community. To date, the monitoring of capped mounds has given no indication of any perceived problems. Changes in recolonization rates or increases in containment levels in sediments or infauna would have warranted further investigation to determine the source of contamination (Germano et al. 1994).

Three examples of effective and one example of ineffective cap coverage can be seen in results from experimental capping operations at CLIS; the mounds capped at CLIS include Stamford-New Haven North (STNH-N), Stamford-New Haven South (STNH-S), Cap Site 1 (CS-1), and Cap Site 2 (CS-2). Both STNH-N and STNH-S mounds were capped successfully due to interim monitoring during the disposal operation and control over the placement of cap material (e.g., Morton 1979, Morton and Miller 1980, SAIC 1984b, Murray et al. 1992). At STNH-N, cap material completely covered the peak and flanks of the mound, extending its areal extent as well as its height (Figure 2-1). Cap coverage at STNH-S extended over most of the contaminated material (Figure 2-2). At CS-1 and CS-2, a LORAN-C fix was used as a location point for the disposal of cap material, and it was assumed that random error in placement would result in the correct distribution of the cap over the contaminated dredged material. At CS-2, the cap disposal points were concentrated to the west of the mound (Figure 2-3). Because a buoy existed as a stationary reference point, the cap material disposal points were close enough to the mound to cover it adequately. At CS-1 there was no buoy, and the barge operators relied only on LORAN-C coordinates to locate the cap material disposal location. As a result, the cap material at CS-1 was spread southwest of the disposal point by barges passing the release point as they steamed in from the northeast (Figure 2-4; SAIC 1987). These examples illustrate the importance of placement control for the contaminated dredged material and the cleaner cap material. Operational control over dredged material placement must be consistently applied to projects at all water depths to cap contaminated dredged material successfully.

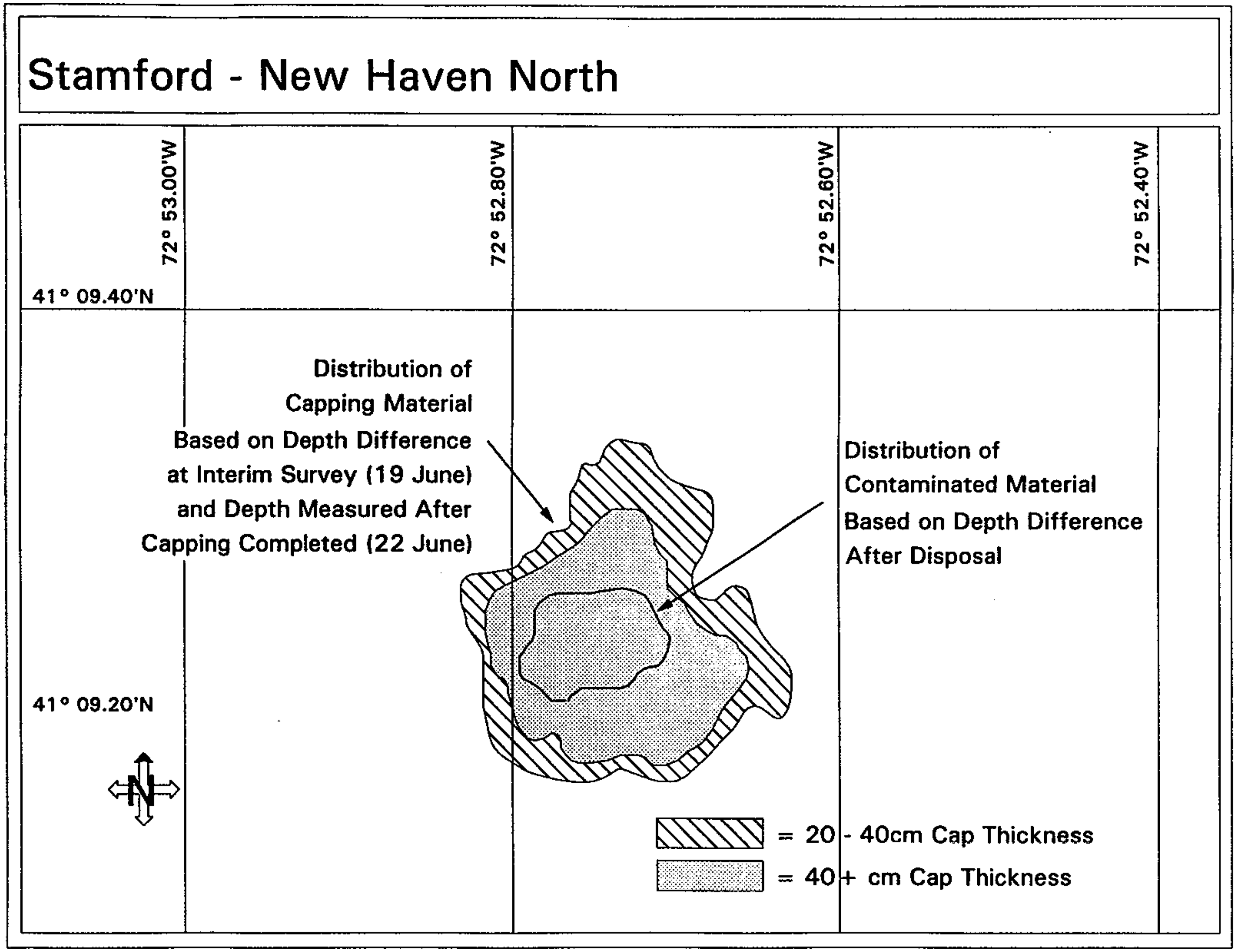

Figure 2-1. Distribution of dredged material at STNH-N (adapted from Fredette et al. 1992)

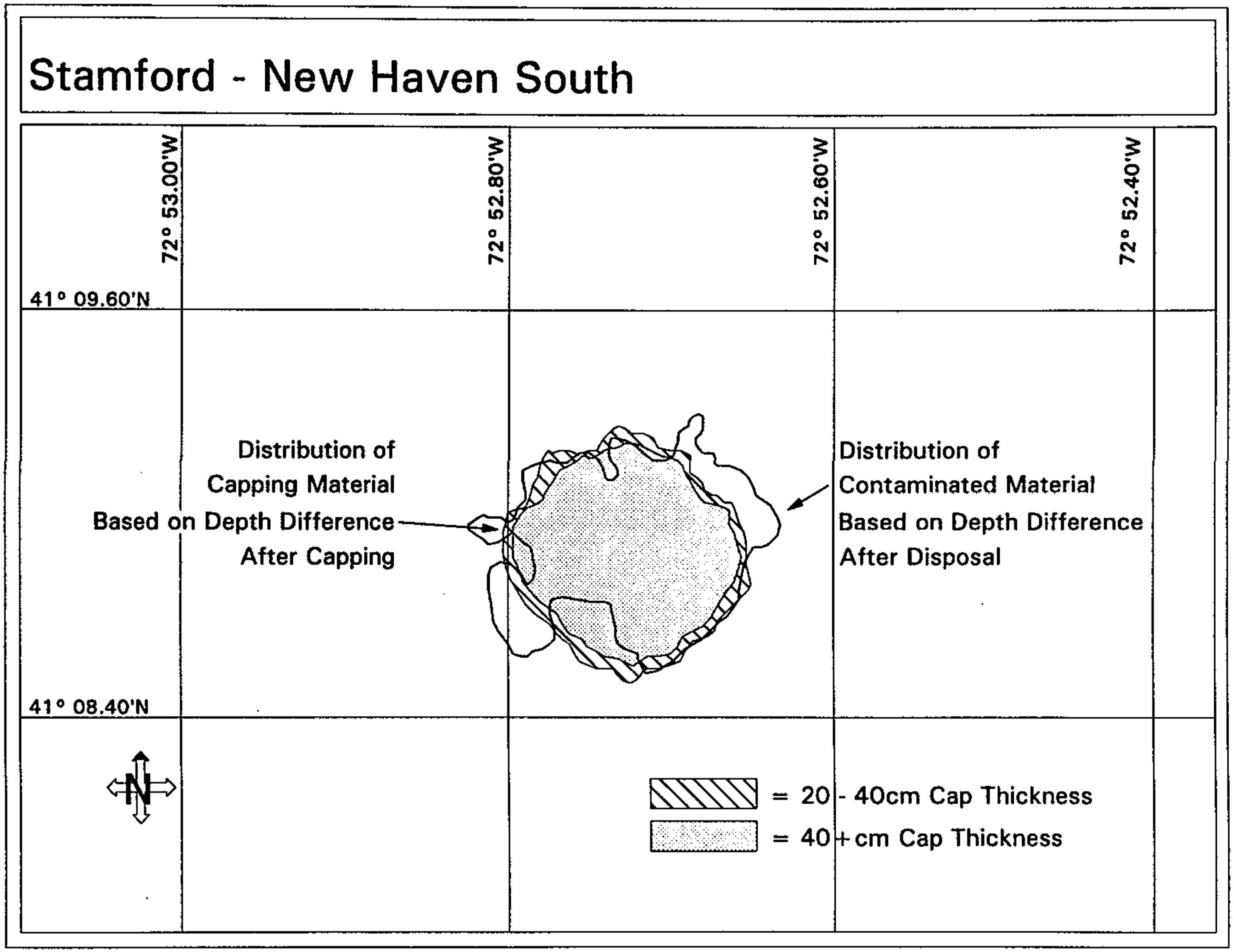

Figure 2-2. Distribution of dredged material at STNH-S (adapted from Fredette et al. 1992)

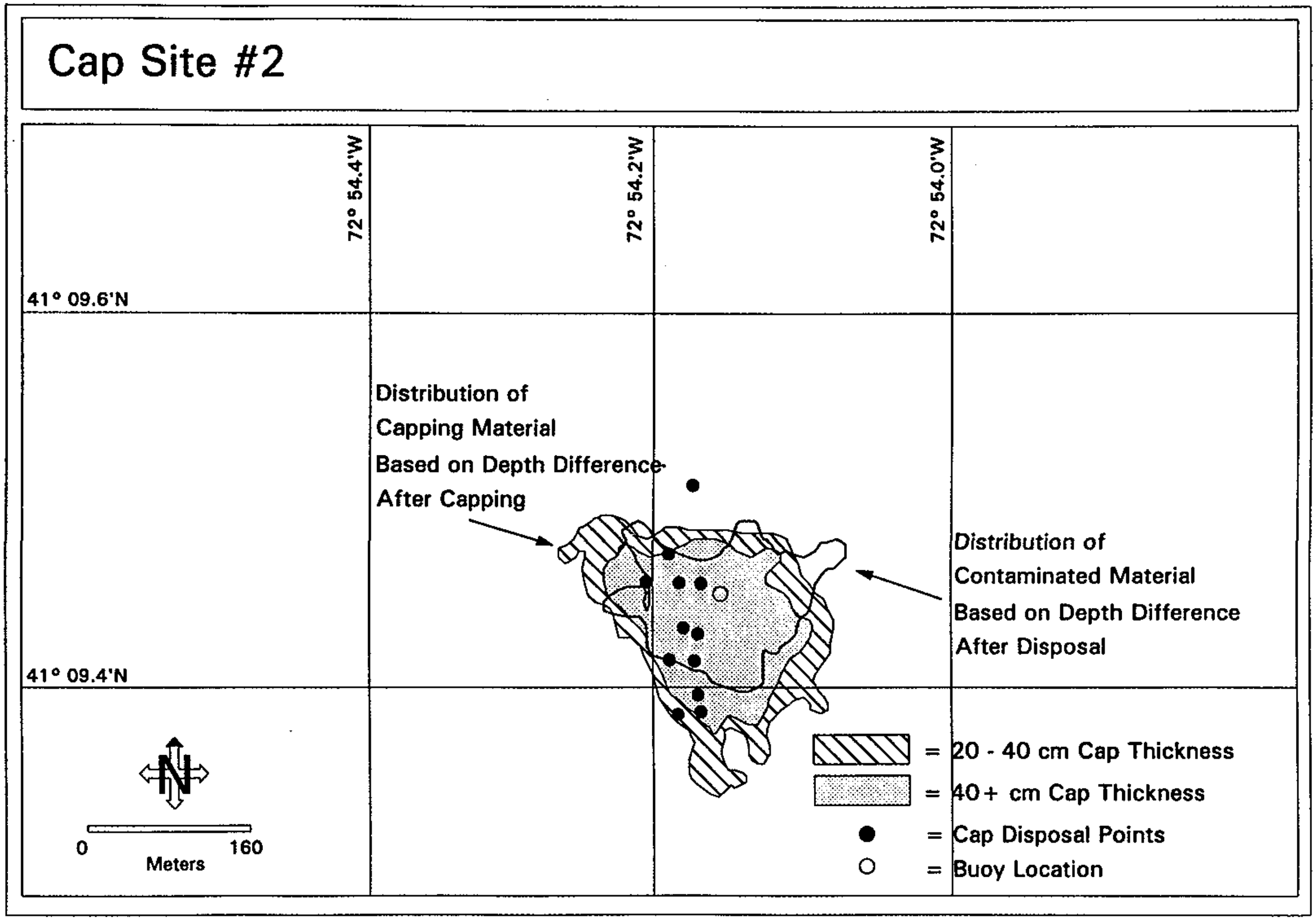

Figure 2-3. Disposal points for cap material at CS-2 with distribution of dredged material (adapted from Fredette et al. 1992)

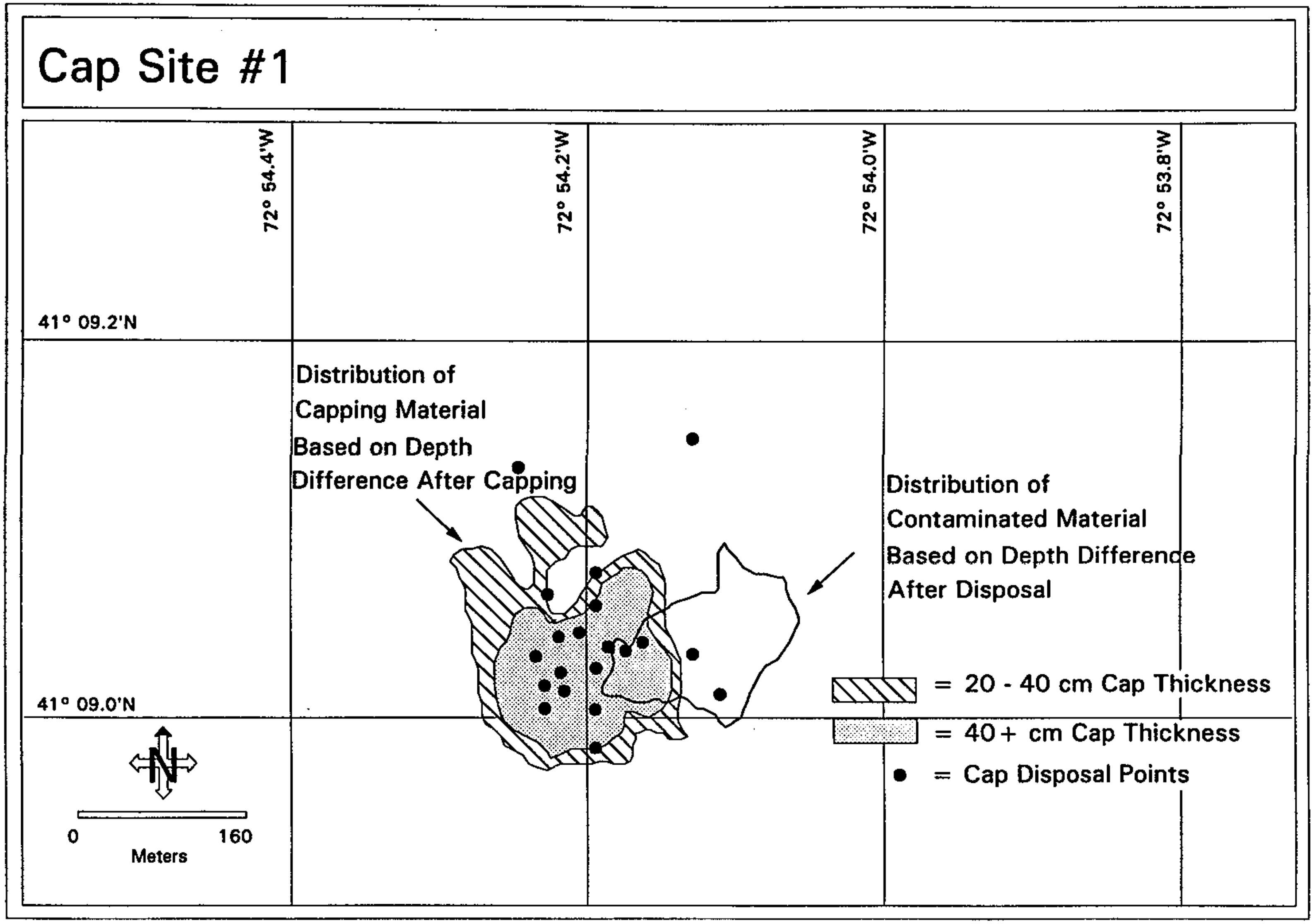

Figure 2-4. Disposal points for cap material at CS-1 with distribution of dredged material

3.0 DEEP WATER DISPOSAL AND DEEP WATER CAPPING

The results from mathematical modeling predictions and from monitoring actual capping operations in up to 60 m water depth form the basis for evaluating the feasibility of capping dredged material in deeper water. Studies have shown that the crucial steps in successful capping are the initial formation of a distinct dredged material mound and the subsequent accurate placement of cap material. Disposal operations conducted at depths greater than 60 m (MBDS, Port Gardner, WA, and Elliott Bay, WA) have formed distinct mounds that were mapped by postdisposal monitoring. Once the areal extent of a mound is mapped, cap material can then be placed over the mound accurately.

The transfer of capping technology to areas where the water depth is greater than 60 m requires an understanding of how dredged material acts as it travels through the water column. Any change in the behavior of the descending dredged material as water depth increases will indicate the need for a change in the design of the capping operation. Fortunately, empirical and theoretical information on the fate of dredged material disposed in deep water is available.

Dredged materials go through three phases of descent independent of the water depth at the disposal site: convective descent, dynamic collapse, and passive dispersion (SAIC 1987; Figure 3-1). During convective descent, the material is transported to the bottom under the influence of gravity. Sediments dredged with a clamshell dredge retain most of their consolidated nature during descent. At dynamic collapse, which occurs when the dredged material reaches the bottom (or a level of neutral buoyancy), the vertical momentum is transferred to horizontal spreading. The loss of momentum from the disposal operation initiates the passive dispersion phase where ambient currents and turbulence determine the transport and spread of material.

As the water depth increases, the time the material spends in the convective descent phase in the water column increases. A model of dredged material disposal at the New London Disposal Site, 20 m depth, calculates the material remaining in convective descent for 12 seconds. If the water depth is increased to 100 m, convective descent time increases to 102 seconds. Even with dredged material reaching bottom during the convective descent phase for the deeper water disposal sites, the time that the material spends in the water column during descent can affect disposal design and operation. At the 90 m depths found at MBDS, the material will take 90 seconds to reach bottom based on a descent velocity of 1 m/sec (Bokuniewicz et al. 1978). An increase in descent time can increase water entrainment. Due to the entrainment of water and the residual dispersal of sediment washing out of the disposal vessel, some dredged material will remain in suspension in the water column. Estimates of the amount of dredged material remaining in suspension range from 3 to 5% (dry mass basis based on *in situ* observation or modeling;

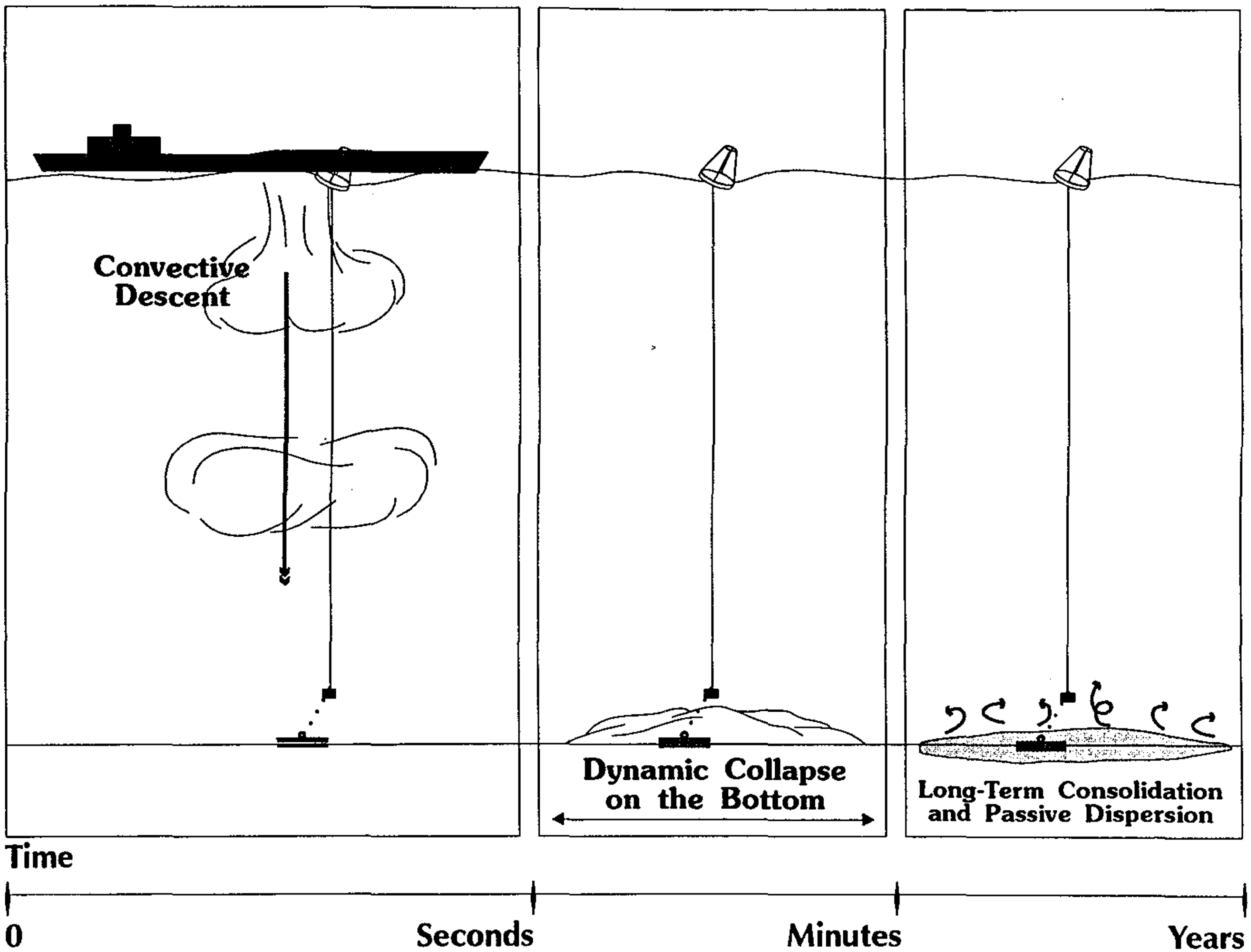

Figure 3-1. Schematic diagram of the phases encountered during a disposal event

SAIC 1987). If a hopper dredge is used, slightly more sediment will be dispersed or suspended. The 3 to 5% of dredged material in suspension will eventually settle or be transported by currents. At 90 m water depth, this sediment will settle in at least four hours.

The increased water entrainment for the dredged material traveling through the water column may also affect mound height. Increased water content in the dredged sediment, either through water entrainment or dredging methods, may alter the form of the dredged material from a peaked mound to a flat deposit. The lateral extent will be the same as a more peaked mound, but the height will be more uniform across the deposit. A pancake-like mound can be more difficult to detect acoustically if the overall height of the mound is less than the resolution of the fathometer.

While disposal and capping of dredged material in deeper water may require tighter control during the disposal operation, greater disposal depth has an advantage for the stability of the mound. The increased water depth can act as a buffer from wave action. During major storm events, such as Hurricanes David and Gloria, some erosional effects were noted at the Long Island Sound disposal sites on recently completed caps in the early stages of consolidation (Fredette et al. 1992). At the depths found at MBDS, there will be a minimal effect from storm waves (SAIC 1987).

Once the dredged material mound and cap have been formed in deep water, the effectiveness of the cap has to be monitored. As in shallow water, monitoring of the capped mound should verify the thickness and areal extent of the cap and confirm that recolonization by benthic infauna has occurred within 4 to 12 weeks after capping (Germano et al. 1994). When acoustic bathymetric surveys are used to monitor the capped mound in deeper water, a higher resolution fathometer than is used in shallower water is needed. Small changes in bathymetry, indicating the presence of dredged material or cap, may be missed using acoustic bathymetry if they are smaller than the resolution of the fathometer. The dredged material deposits causing the small bathymetric changes, generally less than 20 cm, usually can be detected during a REMOTS® sediment profiling survey where the distinctive character of the dredged material will contrast with the underlying ambient sediment.

3.1 Deep Water Disposal Operations

Distinct dredged material mounds have been mapped at five dredged material disposal sites where the water depth is greater than 25 m: Massachusetts Bay Disposal Site (MBDS; 90 m), Elliott Bay (108 m), in Seattle, WA, Port Gardner (132 m), in Everett, WA, Portland Disposal Site (60 m), and Rockland Disposal Site (65-80 m). MBDS, Elliott Bay, and Port Gardner have been proposed as possible locations for the capping of contaminated dredged material. The observation of well-defined dredged material mounds at these locations supports the feasibility of capping at sites ranging as deep as 130 m (Figure 3-2).

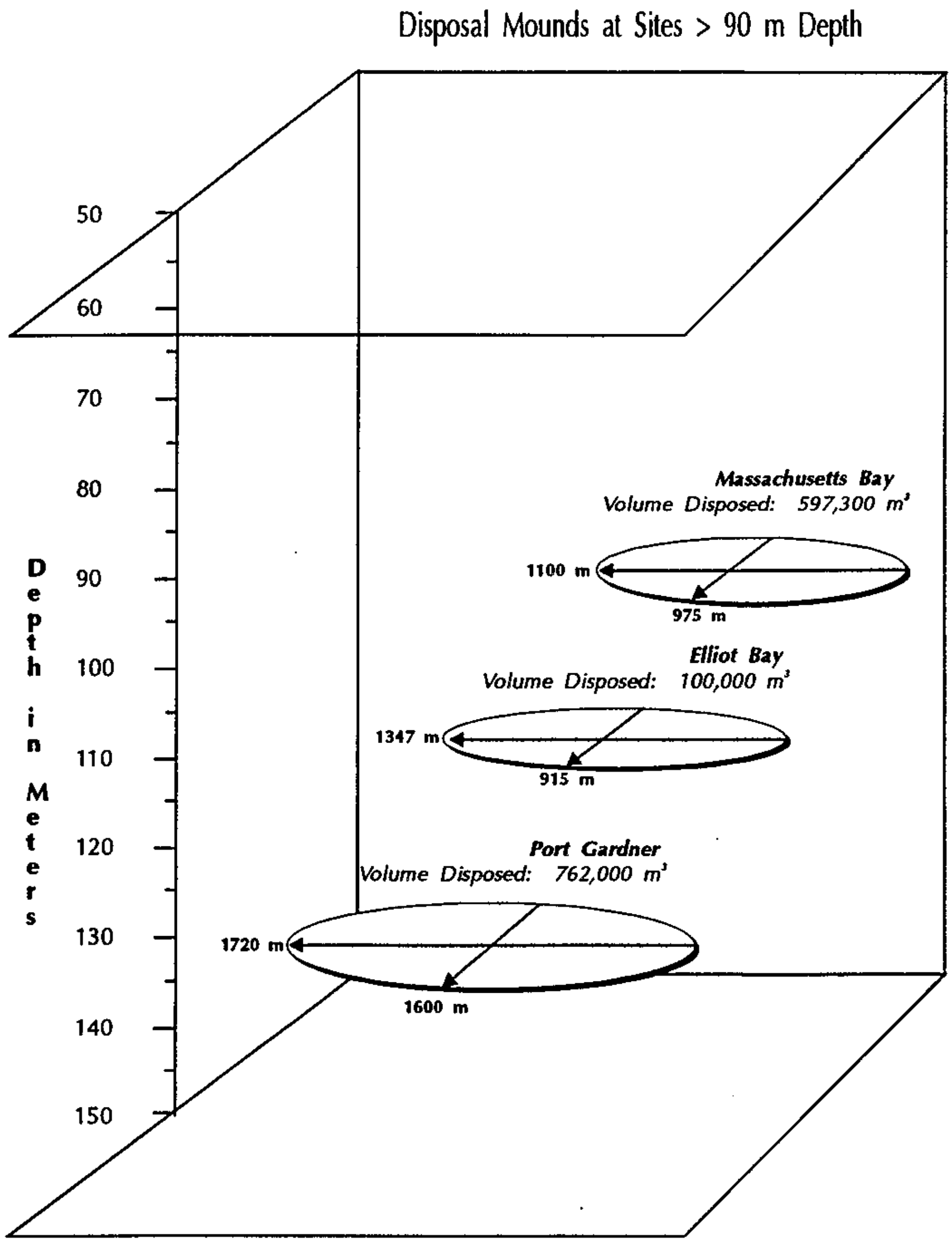

Figure 3-2. Area of dredged material mounds formed at Massachusetts Bay, Elliott Bay, and Port Gardner Disposal Sites

The areal extent of the deposits at MBDS, Elliott Bay, and Port Gardner, although well defined, is larger than deposits measured at shallower sites. Deposits at WLIS and CLIS, formed at less than 30 m depth, measured approximately 200 meters in diameter for disposal volumes of 128,000 m^3 and 62,624 m^3, respectively.

3.1.1 Massachusetts Bay Disposal Site

Sequential surveys conducted from 1985 to 1992 have documented the development of a distinct disposal mound at MBDS. The volumes of dredged material released at MBDS annually since 1985 are listed in Table 3-1. Prior to 1985, disposal operations at MBDS were conducted using a conventionally moored buoy with a wide scope or only LORAN-C navigation. Acoustic bathymetric surveys at that time were unable to detect any dredged material mound (Bajek et al. 1987). In November 1985, a taut-wired buoy was deployed at a previously unused location in MBDS. An acoustic bathymetric survey conducted at the same area in 1987 still did not indicate any topographic features related to disposal. The REMOTS® sediment-profiling system, however, showed a large pancake-like deposit of dredged material (SAIC 1988). In 1988, a comparison of the 1988 and the 1987 bathymetric surveys was able to discern a layer of dredged material 0.3 m thick and 150 m in diameter (Figure 3-3). The REMOTS® survey detected flank deposits less than 20 cm thick at the edges and up to 900 m in diameter. A comparison of the 1990 bathymetry and the 1988 data indicated an additional thickness of 0.8 m and a diameter of 420 m (Figure 3-4). The REMOTS® survey in 1990 recorded fresh dredged material up to 800 m west of the buoy location (Germano et al. 1993). The barge release locations from 1987 to 1990 indicated that most disposal points were 400 m from the buoy (Figure 3-5). From 1990 to 1992 the dredged material thickness increased by 2 m west of the buoy and covered an area 200 by 400 m (Figure 1-5). The barge release locations from 1990 to 1992 indicated that disposal locations again were within 400 m of the buoy location (Figure 3-6).

The SAIC DAMOS capping model was used to predict the height and lateral extent of a mound that would be formed under the disposal conditions that have existed at MBDS since 1987. Based on REMOTS® observations, the MBDS dredged material was estimated to be silty clay with some sand (30% sand, 35% silt, and 35% clay). The amount of material deposited at MBDS from 1987 to 1992 was approximately 836,148 m^3 over a 450 meter radius. The mound that the model predicted for these parameters was 4.22 m high and 600 m in radius. The actual mound formed at MBDS between 1987 and 1992 was approximately 2.4 m high just west of the buoy location. Because the location of the peak of the dredged material mound varied slightly from 1987 to 1992, the cumulative amount of material at any one location was less than that predicted by the model. The excess mound height predicted by the model is due to the random distribution pattern inherent in the model. Excess height in the modeled dredged material mound may also be due to overestimation of the amount of

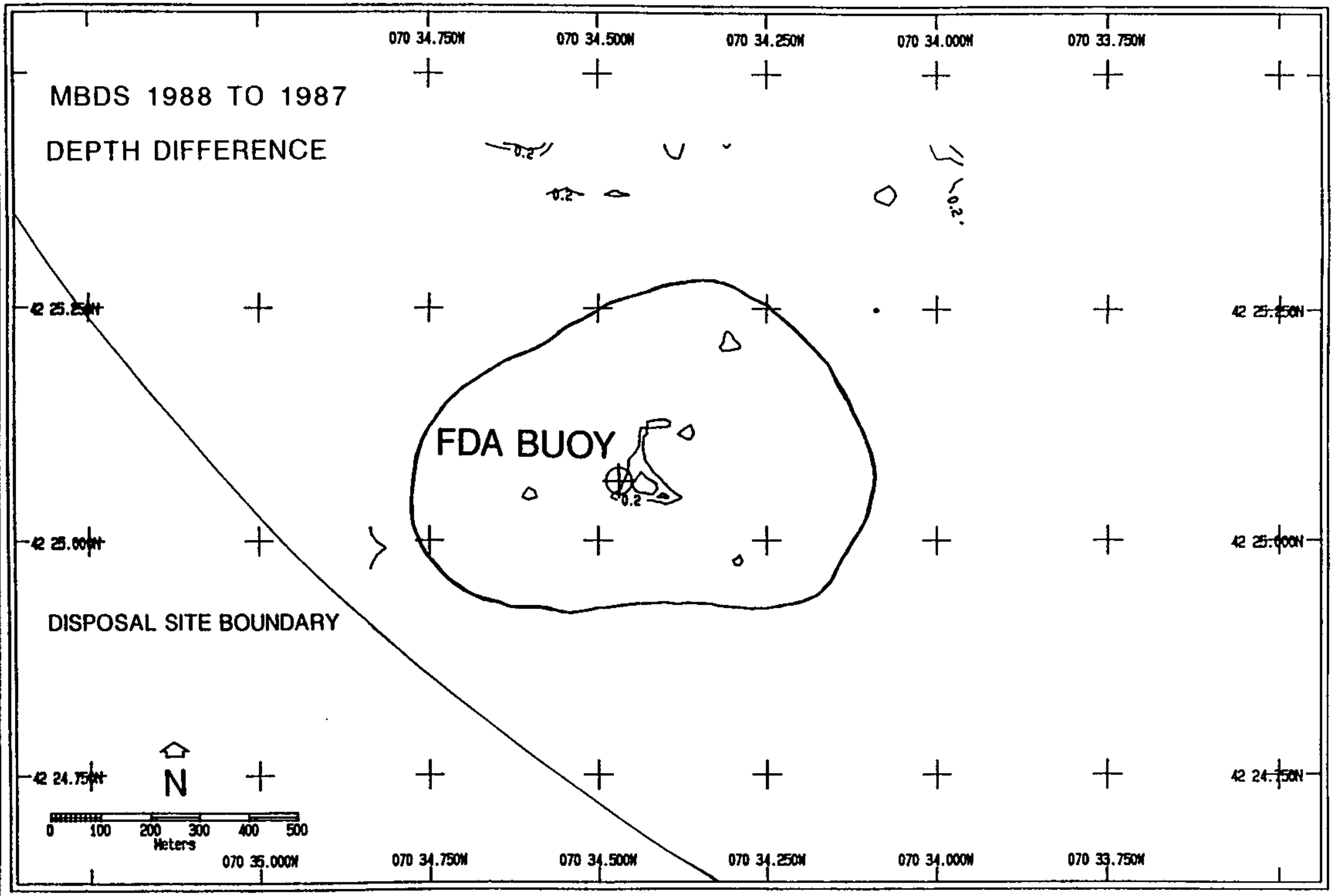

Figure 3-3. Depth difference (in meters) contour chart based on a comparison of 1988 and 1987 MBDS bathymetry. The area outlined indicated the extent of dredged material detected by REMOTS®.

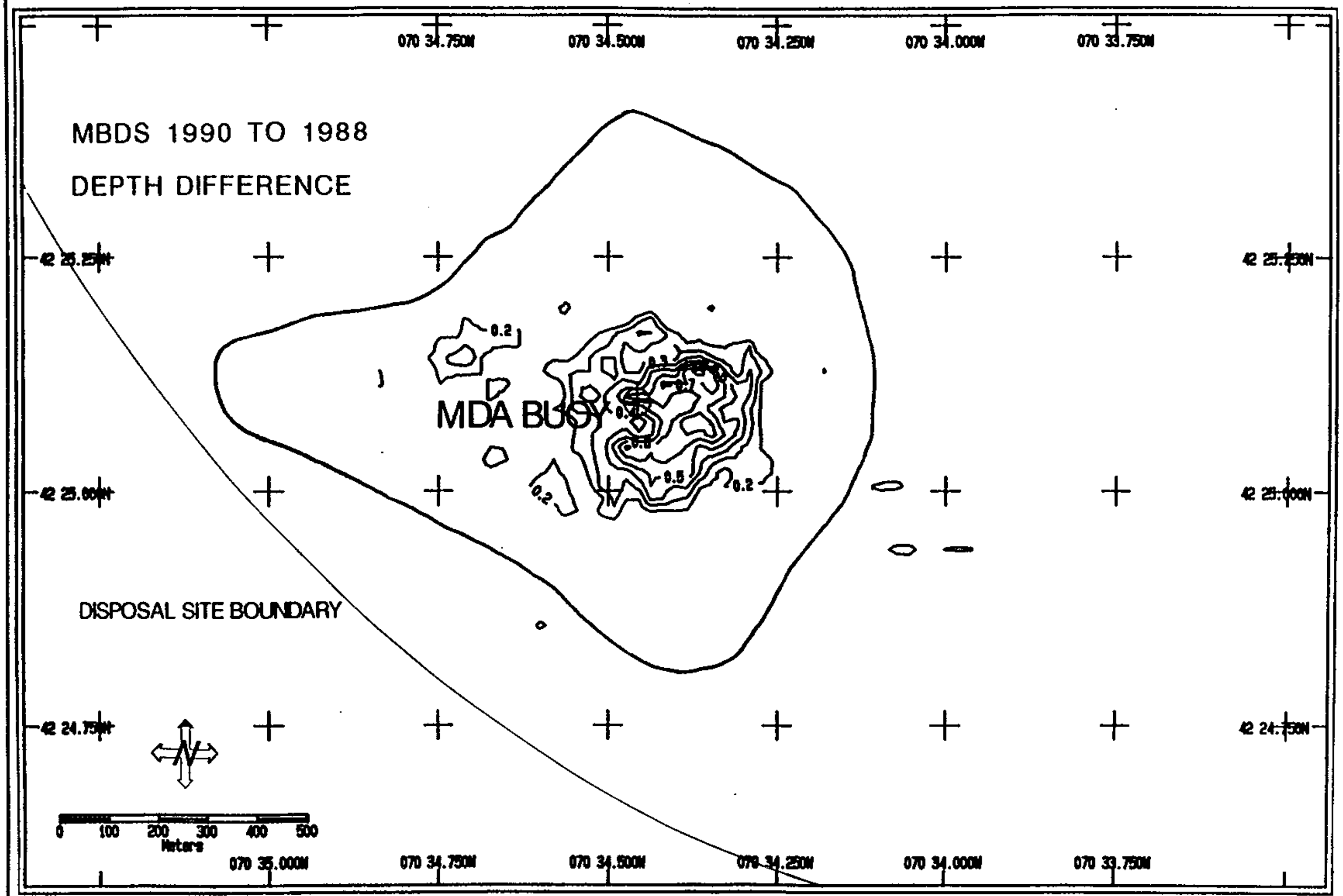

Figure 3-4. Depth difference (in meters) contour chart based on a comparison of 1990 and 1988 MBDS bathymetry. The area outlined indicates the extent of dredged material detected by REMOTS®.

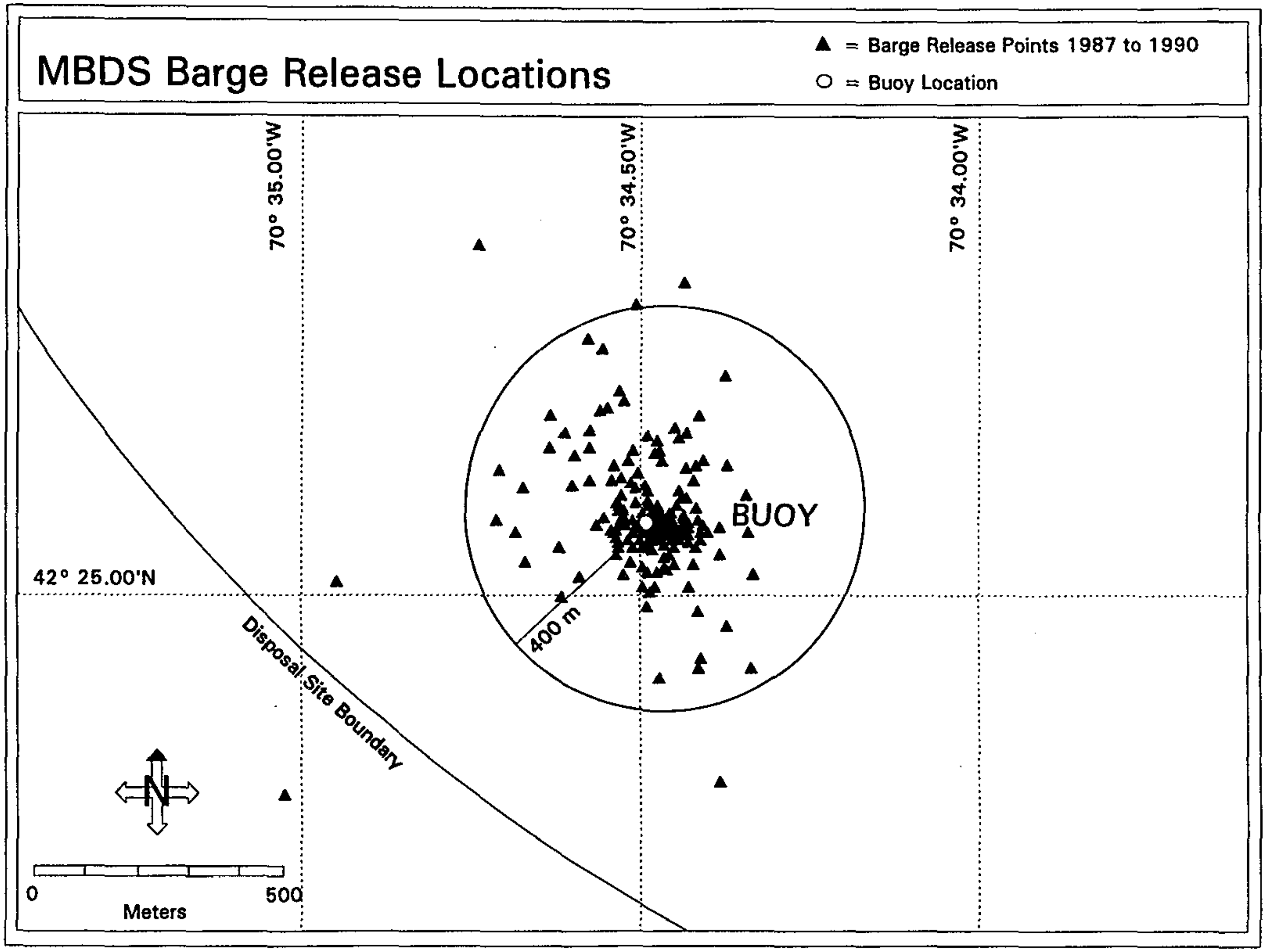

Figure 3-5. A plot of the barge release points indicating that the majority of barges released dredged sediment within 400 m of the buoy location from 1987 to 1990

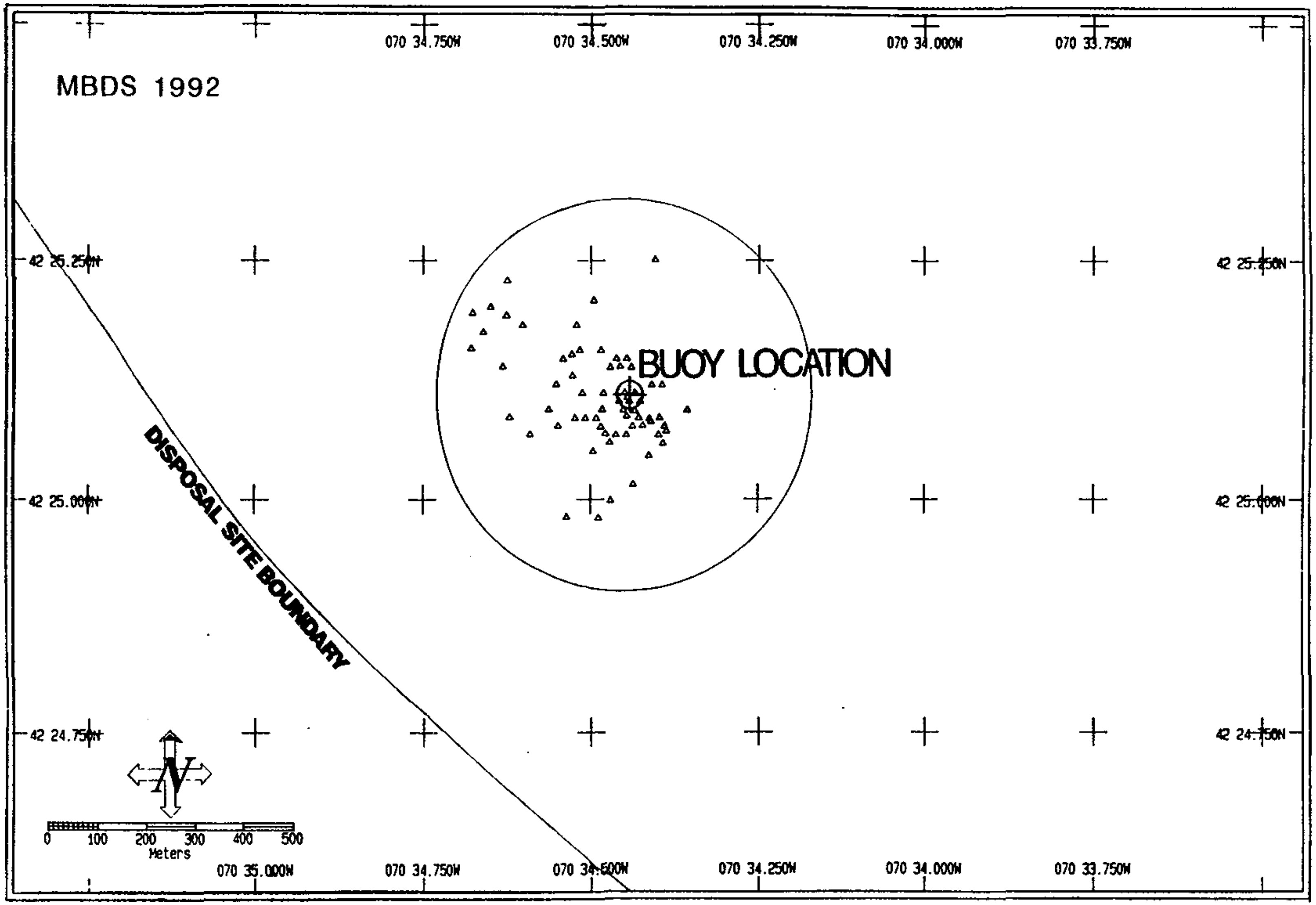

Figure 3-6. Barge release locations, September 1990 to March 1992

Table 3-1 Annual Disposal History Massachusetts Bay Disposal Site	
Year	Disposal Volume
1985	72,114 m^3
1986	141,895 m^3
1987	82,439 m^3
1988	94,415 m^3
1989	156,803 m^3
1990	217,081 m^3
1991	173,506 m^3
1992	194,343 m^3

material by the barge logs or the failure of the model to take consolidation or dewatering into consideration once the material has been deposited (Wiley 1994).

3.1.2 Elliott Bay and Port Gardner

Elliott Bay, located off Seattle, WA and Port Gardner, located at Everett, WA are two nondispersive sites used in the Puget Sound Dredged Disposal Analysis (PSDDA) Program (Revelas et al. 1991). Water depths exceed 132 m (440′) at Port Gardner and 108 m (360′) at Elliott Bay. Both sites were monitored after the 1989/1990 disposal season to determine if the dredged material was located within the designated site boundaries.

At Elliott Bay, 100,000 m^3 of dredged material were released within a 183 m radius target zone at the center of the site. A REMOTS® survey was conducted which included stations within the boundary of the disposal site and in the perimeter (a buffer zone surrounding the disposal site). The survey showed that dredged material distribution mirrored the shape of the disposal site boundary with no evidence of dredged material in any of the perimeter stations (Figure 3-7). At Port Gardner, approximately 762,000 m^3 of dredged material were released in the winter of 1989/1990. As at Elliott Bay, barges were allowed to open their doors in a 183 m radius target zone at the center of the site. The REMOTS® survey at Port Gardner showed dredged material at all stations within the boundary and eight stations outside the boundary (Figure 3-8). Prior to disposal, Port Gardner was modeled using the DIFID (Disposal From Instantaneous Dump) model from the US Army Engineer Waterways Experiment Station (WES) to predict the distribution of dredged material. The model correctly predicted areas of thick deposits but did not predict areas of thin cover to the west (Figure 3-9). The thin cover is >3 cm thick at the perimeter stations.

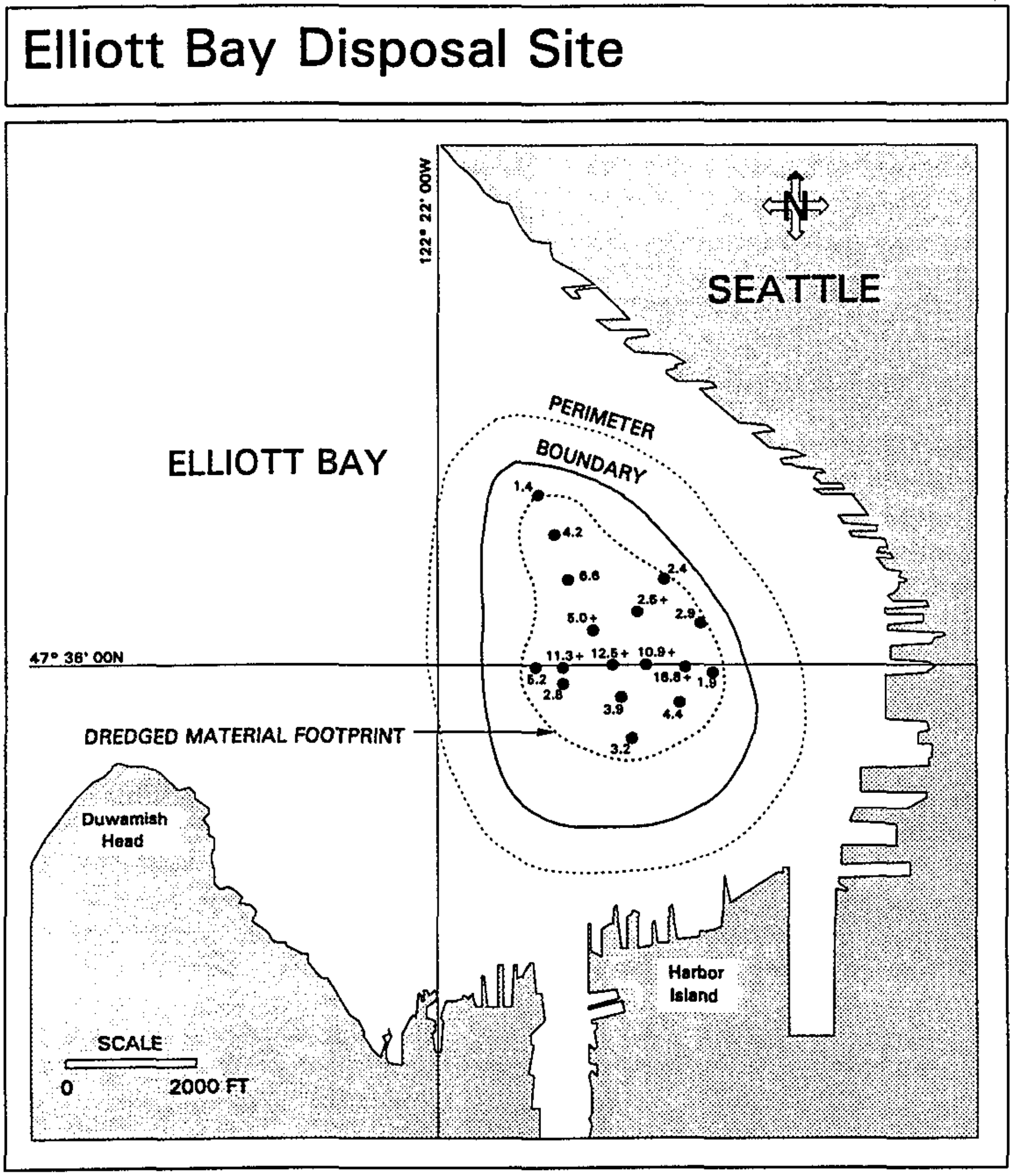

Figure 3-7. The distribution of dredged material (cm) at the Elliott Bay disposal site as detected by REMOTS®. The solid line is the site boundary; the dashed line is the site perimeter. The "+" indicates dredged material greater than penetration.

Port Gardner Disposal Site

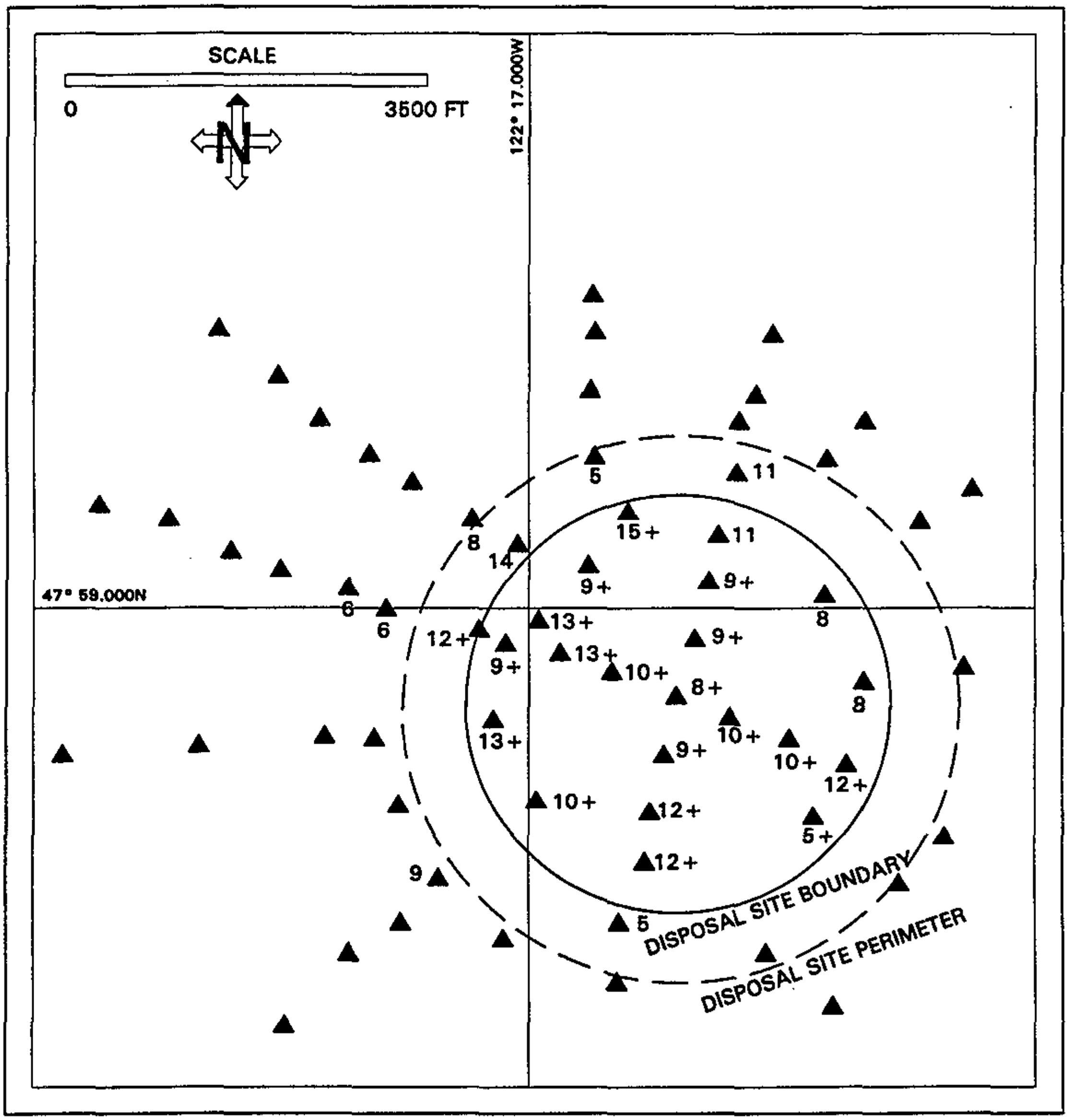

Figure 3-8. The distribution of dredged material (cm) at Port Gardner disposal site as detected by REMOTS® survey. The solid line is the site boundary; the dashed line is the site perimeter. The "+" indicates dredged material greater than penetration.

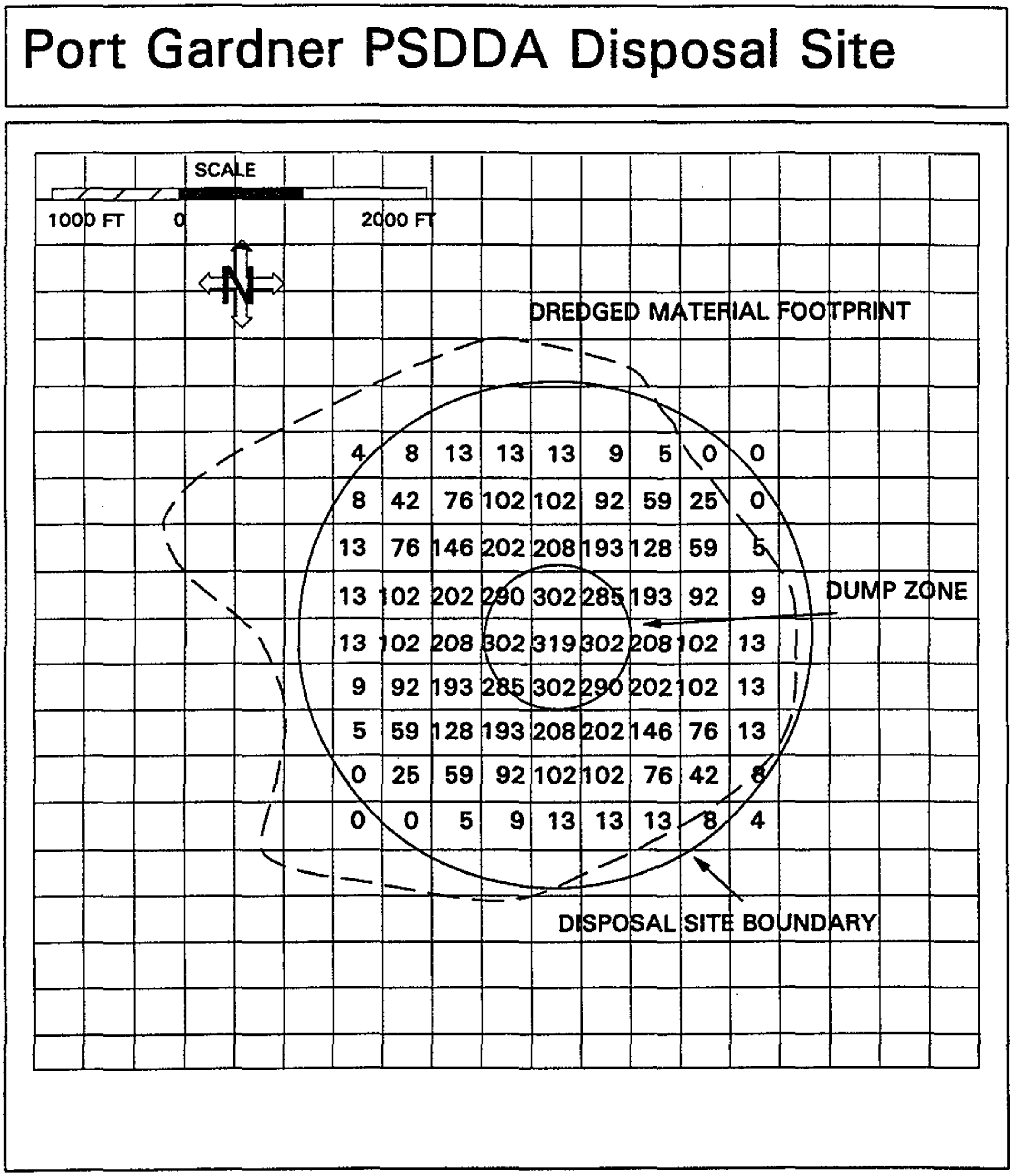

Figure 3-9. DIFID model prediction of dredged material distribution (cm) at Port Gardner

4.0 DISCUSSION

Open water disposal of contaminated dredged material followed by "capping" with cleaner dredged materials has been employed successfully in water depths ranging from approximately 20 to 60 m. Proposals to extend the depth of capped disposal operations up to about 150 m have raised several concerns, although there is no evidence that capping cannot be accomplished at these depths. In fact, all the available theory and empirical evidence supports its feasibility. Successful capping of contaminated dredged material requires the disposal of dredged material in a discrete mound without extensive spreading or dispersal into the water column. The cap material must then be placed accurately onto the mound without disturbing the contaminants. There is concern that the increased water depth will contribute to wider dispersal and spreading of contaminated material and poor control over cap placement. These concerns focus on the apparent lack of knowledge of dredged material behavior in deeper water and the 1982 attempt to form a dredged material mound at MBDS which failed to produce an acoustically discernable mound.

The behavior of dredged material as it descends through the water column was discussed earlier. For the capped mounds in Long Island Sound, a barge load of dredged material reaches the seafloor while in the convective descent phase and then undergoes dynamic collapse and passive dispersion. The effect of increasing water depth on the descent of the dredged material was investigated by modeling the behavior of a 4000 m^3 barge load of dredged material as it descended through water depths ranging from 377 m to 914 m (Stoddard et al. 1985). The model results indicated that dredged material should reach neutral buoyancy and go from convective descent to dynamic collapse between 340 and 390 m. Therefore, dredged material deposited at MBDS (90 m), Elliott Bay (132 m), and Port Gardner (108 m) should behave the same as dredged material deposited in Long Island Sound, reaching the seafloor during convective descent without achieving neutral buoyancy.

The height and lateral extent of a mound that would be formed by dredged material disposal was modeled for MBDS and for the Port Gardner Disposal Site. For the approximately 836,148 m^3 of silty dredged material deposited at MBDS from 1987 to 1992, the DAMOS capping model predicted a mound height of 4.22 m and a radius of 600 m. At Port Gardner, the model incorporated a 10 $cm \cdot s^{-1}$ NW/SE bottom current and predicted a dredged material footprint of 2000 m radius and 3.19 m mound height for the 762,000 m^3 of dredged material released within a 183 m radius target zone.

Investigations of dredged material disposal at MBDS, Port Gardner, and Elliott Bay by bathymetry and/or REMOTS® surveys determined that the dredged material at these sites had mounding characteristics very similar to those predicted by the model. Where both REMOTS® and bathymetric surveys were conducted, the REMOTS® survey, due to its finer resolution, mapped a larger areal extent for the deposit. At MBDS, the larger area of dredged material detected by the REMOTS® survey could be due to the release of dredged material at a distance from the disposal point or to the spread of dredged material in deeper water depths. The cohesive nature of the dredged material found away from the disposal location and the reported location of barge release points indicate that the large area of dredged material may be due to releasing material away from the buoy. A plot of the barge release locations, which were LORAN-C positions reported in the barge logs rather than actual positions printed out on the tug, showed dredged material released at a distance from the disposal point up to 400 m from the buoy (Figure 3-5).

The acoustic detection of dredged material at MBDS, which delineated a smaller area of dredged material than detected by REMOTS®, was apparent for the first time after a taut-wired buoy and LORAN-C navigation were used to mark the disposal point in 1987. Consecutive bathymetric surveys revealed a distinct dredged material mound that increased in height as the amount of dredged material increased. For both the Port Gardner and Elliott Bay disposal operations, navigation equipment on the tugs guaranteed that all release points were within the 183 m radius target zone. The footprint of the 762,000 m^3 of material released at Port Gardner extended northwest and southwest of that predicted by the model (Figure 3-9). Because dredged material placement was tightly controlled, the deposition of material away from the target zone would have been due to the transport of material after it was released by the barge. The release of a smaller amount of dredged material within an identical target area at the Elliott Bay disposal site produced a dredged material deposit over a smaller area (1347 m by 915 m). These examples illustrate the importance of placement control during the disposal operation and of an understanding, prior to modeling the predicted mound configuration, of any conditions unique to the disposal area.

Early capping operations in Long Island Sound demonstrated that operational control over the placement of the contaminated dredged material and the cap material is the prime determinant in the success of the capping operation. A lack of operational control in the placement of cap material at CS-1 resulted in cap coverage that was less than 50 cm on portions of the mound. Similar lack of emphasis on placement of dredged material at MBDS in 1982/1983 resulted in unfocused disposal of dredged material and the lack of any mound formation. As demonstrated by all successful capping operations conducted so far, tight operational control during disposal is of primary importance in the success of capping regardless of the water depth. This holds true for all sites above the depth of neutral buoyancy (approximately 350 m). No information is available on mound formation from dredged material disposed in waters of greater depths.

When there has been tight operational control during the disposal operation, a distinct dredged material mound can be detected by bathymetry and REMOTS® sediment-profile photography. The bathymetric survey delineates the height of the mound and the optimum location for the placement of cap material, while the REMOTS® survey delineates the true areal extent of the deposit. Once the spatial extent of the mound is known, the success of the capping operation can be defined with postdisposal bathymetric surveys.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The success of capped dredged material mounds in Long Island Sound and elsewhere was based on the initial formation of a well-defined mound of contaminated dredged material followed by controlled placement of cap material to cover the underlying material. These capped sites were at a maximum water depth of 60 m. The question of extending capping operations to greater depths has been addressed in the analysis of results from disposal operations at sites in deeper water, such as MBDS, Port Gardner, Portland, and Elliott Bay. It has been shown that controlled placement of dredged material at these sites results in well-defined dredged material mounds.

The formation of a well-defined mound at MBDS supports the use of capping as an effective management option at this site to deal with the volume and type of dredged material resulting from proposed projects in the Boston Harbor area. The depth at MBDS is greater than the maximum depth at other disposal sites in New England where capping has been employed successfully. However, this increase in water depth has not hindered the formation of a well-defined dredged material deposit, nor is there any suggested effect on the behavior of the dredged material. Postdisposal monitoring by bathymetry and REMOTS® is as effective in defining the dredged material mound at this site as it has proven to be in Long Island Sound.

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INDEX