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AIMS & SCOPE OF THE JOURNAL

The *Journal of Dredging* is published by the Western Dredging Association (WEDA) to provide dissemination of technical and project information on dredging engineering topics. The peer-reviewed papers in this practice-oriented journal will present engineering solutions to dredging and placement problems, which are not normally available from traditional journals. Topics of interest includes, but is not limited to, dredging techniques, hydrographic surveys, dredge automation, dredge safety a instrumentation, design aspects of dredging projects, dredged material placement, environment and beneficial uses, contaminated sediments, litigation, economic aspects and case studies.

A REVIEW OF THREE RECENT SEDIMENT REMEDIATION PROJECTS

Stephen Garbaciak, Jr.[1] and Daniel Averett[2]

ABSTRACT

Remediation of contaminated sediments has been the subject of extensive investigations and demonstration programs since the Dredged Material Research Program (DMRP) of the 1970's. During the late 1980's and early 1990's, the emphasis of government-directed demonstration programs such as the Assessment and Remediation of Contaminated Sediments (ARCS) Program, Superfund Innovative Technology Evaluation (SITE) Program and the New York & New Jersey Sediment Decontamination Technologies Demonstration Project in the U.S. and the Contaminated Sediment Treatment Technology Evaluation Program (COSTTEP) in Canada switched from testing of treatment technologies to field remediation of contaminated sediments. In recent years, several projects have gone beyond the study/demonstration phase and have been successfully remediated. In this paper, we present an overview of three recently completed projects, discussing the nature of contamination, and the remedial options implemented. The sites discussed are Marathon Battery, New York; Orion Project, New Jersey; and Manistique River and Harbor, Michigan. Technologies implemented at these sites included solidification and stabilization, diver-assisted dredging, nearshore confined disposal and sediment washing.

INTRODUCTION

In recent years, the field of contaminated sediment remediation has advanced rapidly with respect to the number of sites being evaluated under various federal, state and local regulatory authorities, but progress, through actual execution of remedial construction and completion of projects, has been extremely limited. Several authors have presented summaries, overviews and case studies on the various demonstration and limited-scale contaminated sediment remediation projects that have been completed in North America (Cushing, 1997; Mohan, 1997; Romagnoli et al., 1997; Averett and Francingues, 1996; Garbaciak and Miller, 1995; Wardlaw et al., 1995; Miles and Marr, 1994; Murphy et al., 1994; Otis, 1994; Stern et al, 1994; and Wible et al., 1994).

A review of three full-scale sediment remediation projects that were executed in the late 1990's is presented in this paper. The projects represent an interesting cross-section of the variety of remedial alternatives that are "surviving" the remedial investigation, feasibility study and negotiation/settlement stages of project development to be selected for final, detailed design and construction. The availability of appropriately detailed information also varied between these projects, and the authors do not represent these summaries as being the most complete discussions of the individual projects. Any factual errors are unintentional, and the reader is encouraged to contact the original project proponents for further information.

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MARATHON BATTERY PROJECT, NEW YORK

The Marathon Battery Project (Figure 1) involved cleanup of a Superfund site located in the Village of Cold Spring, New York, located upstream of New York City on the Hudson River. Marathon Battery produced nickel-cadmium batteries for the military and for commercial use from 1952 until 1979 (Simmons et al., 1994). During its operation, wastewater was discharged into the Hudson River and into cove and marsh areas hydraulically connected to the Hudson contaminating sediments in these areas with cadmium, nickel, and cobalt. The site was placed on the National Priorities List (NPL) in 1981. Remedial investigations (RI) and feasibility studies (FS) culminated in a plan to dredge the top one foot of sediment to achieve 10 ppm residual cadmium in sediments in the cove and achieving an action level of 100 ppm cadmium in the marsh. Attaining the marsh action level required excavation of 12 to 42 inches of sediment (Nocera and Simmons, 1994). After dredging and excavation, the Record of Decision (ROD) specified that sediments would be dewatered, chemically fixed, and transported to an offsite disposal area.

Remedial design for the Marathon Battery remedial action was originally performed by the U.S. Army Corps of Engineers (USACE) through an interagency agreement with the U.S. Environmental Protection Agency (USEPA). After the project had been advertised for a construction contract, the principal responsible parties (PRP's) agreed with the U.S. District Court to perform the remedial action in accordance with the ROD's and the construction plans and specifications developed by USACE. Cleanup activities began in 1993 and were substantially complete in 1995 (Taylor et al., 1994). Value engineering proposals were successfully made by the PRP contractor modifying some of the original design concepts.

Sediments in shallow, open-water areas (coves/ponds), were removed using a small hydraulic, horizontal auger dredge operated by Aqua Dredge, Inc. The 8-ft wide auger was reported to be capable of a vertical precision control of 0.1 inch (Taylor et al., 1994). Low tides limited daily production times for the dredge, but during optimum conditions, a production rate of 1000 cy/day was reported. Dredged material from the hydraulic dredge was piped to the pre-treatment/dewatering process. Some areas of the site were obstructed with rocks, debris, and other physical limitations to the small hydraulic dredge. These areas were excavated with a clamshell bucket and transported by scow to an off-loading area prior to treatment. Marsh areas of the site were excavated using low ground pressure amphibious excavating equipment with hoppers for transport to the treatment facilities. Project plans called for removing approximately 52,000 cy from the cove and pond areas, 10,000 cy from pier areas, and 14,000 cy from the marsh (Taylor et al., 1994).

Treatment and disposal process for the dredged material consisted of dewatering, solidification/stabilization, and transport by rail to a landfill in Michigan. The PRP contractor originally chose a mechanical dewatering system consisting of screens and centrifuges. The variability of the physical characteristics of the dredged material, rocks, wood, and vegetation, plugged the coarser screens, and the fine silts and clays blinded the finer screens and overloaded the centrifuges (Logigian et al., 1994). To overcome these problems, the dewatering system was

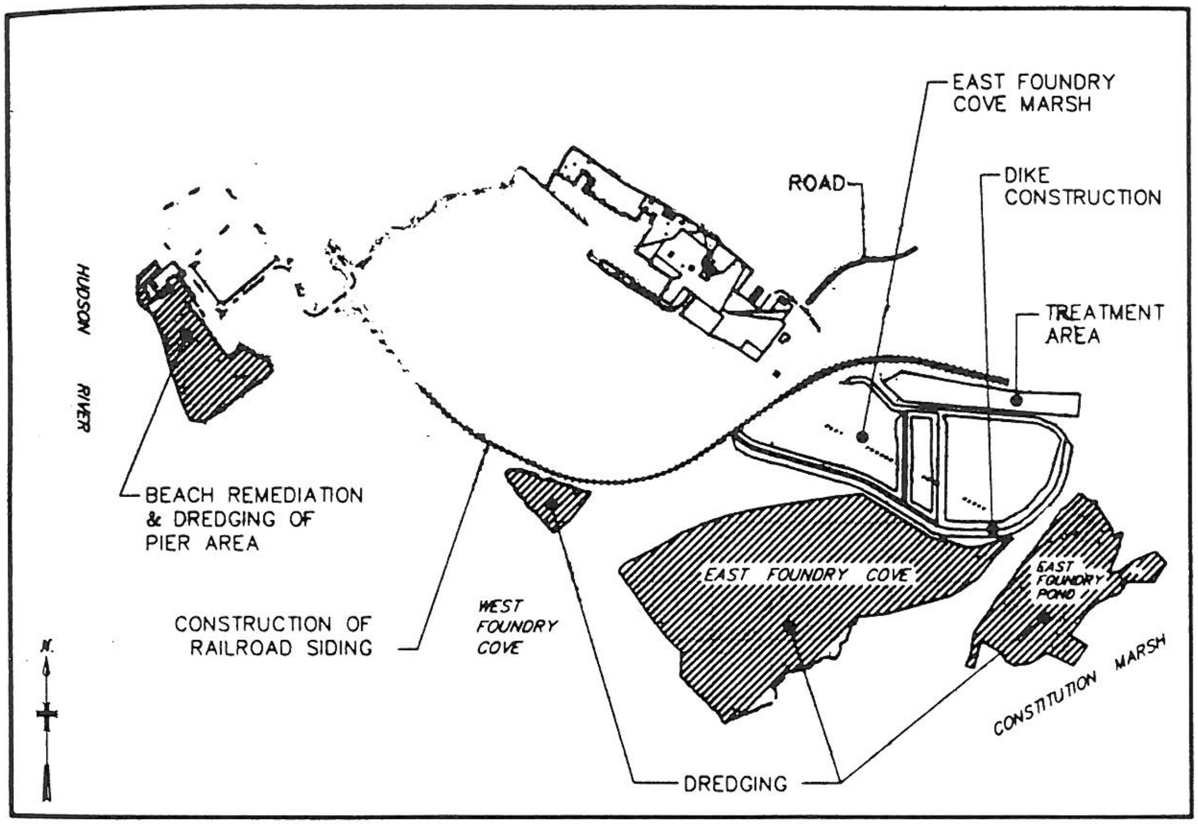

Figure 1- Marathon Battery Project, NY. (from Taylor *et al* 1994)

modified to include settling ponds prior to the mechanical dewatering system to equalize the feed and remove debris. Settled solids were excavated mechanically from the ponds and stockpiled into a paved staging area to await further dewatering using belt filter presses. Excess water from the dredging operation was treated with a polymer and filtered through a sand filter prior to release to the waterway. Dewatered solids were stabilized using the proprietary Maectite process to pass leachate testing, loaded onto rail cars, and transported to an off-site landfill in Michigan (Taylor et al., 1994).

ORION PROJECT, NEW JERSEY

At the Orion Project in Elizabeth, New Jersey (Figure 2), contaminated dredged materials unsuitable for open-ocean disposal are being stabilized and used as structural fill to aid in a landfill closure and redevelopment project (Walsh, 1997). When completed, this project will be one of the two largest examples of the use of stabilized contaminated dredged material as a structural fill in the U.S., with the second project being a similar effort in nearby Kearny, New Jersey.

The Orion Project, a 166-acre privately-owned waterfront property in Elizabeth, New Jersey, is owned by OENJ Corporation. The site is a former municipal solid waste landfill, and is being redeveloped by OENJ in preparation for the construction of 27.5 acre retail mall facility. A total of 2.2 mcy of structural and peripheral fill is needed to complete the project, which includes landfill closure and retail mall site preparation. A joint venture of OENJ, Walsh Remedial Construction Services and Great Lakes Dredge and Dock Company was formed to execute the project, including dredging, amendment of the dredged material to improve physical stability and chemical leaching properties, and placement of the material on site. To date, a 100,000 cy demonstration project has been completed, under contract to the Port Authority of New York and New Jersey, while several hundred thousand cubic yards of additional dredged materials have been and are currently being processed at the site.

The dredged material processed during the demonstration project originated in Reach A of Port Newark, New Jersey. The material was dredged with a closed-bucket clamshell, transported to the disposal site via scow, where it was mechanically unloaded into a vibratory grizzly feed hopper. After debris screening the material was pumped from the offloading facility to the processing plant via a positive displacement pump (Walsh, 1997). Difficulties with debris handling in the early stages of the project were reported to cause excessive pump failures resulting in extensive operational downtime and subsequently greatly reduced processing rates. Refinements to the debris handling operations improved pumping operations and speeded processing throughput times. The dredged material was subjected to a battery of tests, as prescribed by the New Jersey Department of Environmental Protection (NJDEP), focusing on the Toxicity Characteristic Leaching Procedure (TCLP) test as an indicator of leaching characteristics. An unspecified mixture of pozzolanic-based materials was added to the dredged material in a pug-mill centered mixing plant. The amendment mixture varied according to the feed material characteristics, and the final product was suitable for use as structural fill on the site. When completed, the site will be brought to final grade through the placement of up to 15 feet of

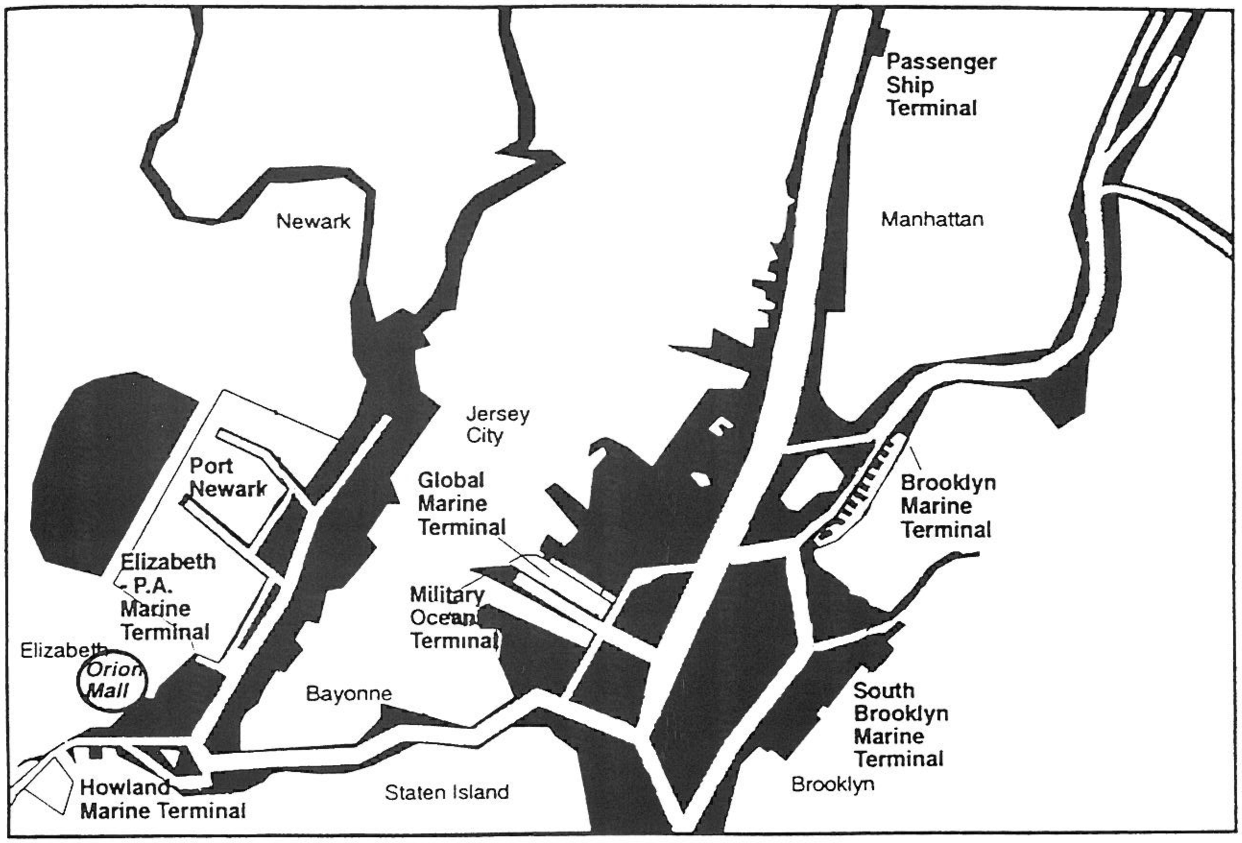

Figure 2- Orion Project, NJ. (from Knoesel *et al* 1998)

additional recyclable and clean fill materials and will eventually be covered by an asphalt parking lot (Walsh, 1997).

MANISTIQUE HARBOR PROJECT, MICHIGAN

Manistique Harbor is located in the Upper Peninsula of the state of Michigan, at the mouth of the Manistique River, a tributary to Lake Michigan (Figure 3). It was the location of lumber mills and logging operations during the heyday of the Midwest logging industry, and continues to be the location of a pulp mill operated by Manistique Papers and a coal-fired power plant operated by Edison Sault Electric Company. USEPA had identified PCB contamination in the sediments of the river and harbor exceeding 1,000 ppm. Through a series of negotiations, the Federal government and the PRP's were able to reach a settlement which involved the dredging, treatment and removal of all sediments contaminated with greater than 10 ppm total PCB's from the system.

Three areas of Manistique River and Harbor are being remediated, Areas B, C and D. Diver-assisted dredging was used beginning in the summer of 1995 to remove soft, silty sediment deposits in Area B. To minimize PCB losses due to sediment resuspension and transport away from the dredging site, the area was surrounded by a sheetpile steel cutoff wall, with floating booms and silt curtains augmenting the sheetpile. USEPA (1996a) reported that "no resuspension of sediments occurred" during the dredging activities, determined through visual observations, surface water analysis and other measurements. Approximately 10,000 cy of sediments were removed prior to the shutdown of operations in November 1995. Dredged materials were processed through a series of settling, particle separation and dewatering steps. An unusually high amount of wood chip and sawdust-like material was present in the dredged material, which in turn served as a strong concentrator of the PCB contamination. Through the screening and separation processes (including hydrocyclones, plate and frame and belt presses), the volume of contaminated material exceeding 50 ppm total PCB's, and therefore requiring disposal in a Toxic Substances Control Act (TSCA) permitted facility, was reduced to 3 percent of the total dredged mass (USEPA, 1996a).

Area B was dredged in 1996 using a "floating hydraulic auger dredge" (USEPA, 1996b). An additional 8,000 cy of sediments were dredged and processed as discussed above. In total, about 3,520 tons of sediment and other waste materials (wood chips) was shipped off site for disposal (USEPA, 1997). These volumes and masses represent clean up of all contaminated sediments in Area B that exceed 10 ppm total PCB's. Confirmatory sampling concluded to USEPA's satisfaction that no residual PCB concentrations above 10 ppm remained in the sediments of Area B. After the completion of dredging activities, a layer of gravel was placed in Area B to improve the fish habitat characteristics of the newly exposed bedrock bottom.

Work completed in 1997 included the removal of a temporary geotextile cap previously placed over Area C, the removal of sediments from the capped area, and the removal of all sediment contaminated with greater than 10 ppm PCB's from Area D. Any areas with residual PCB concentrations over 10 ppm, following dredging, will be covered with clean sand. As of late 1998, dredging at the project site had not been completed, nor had the final sand cap been placed.

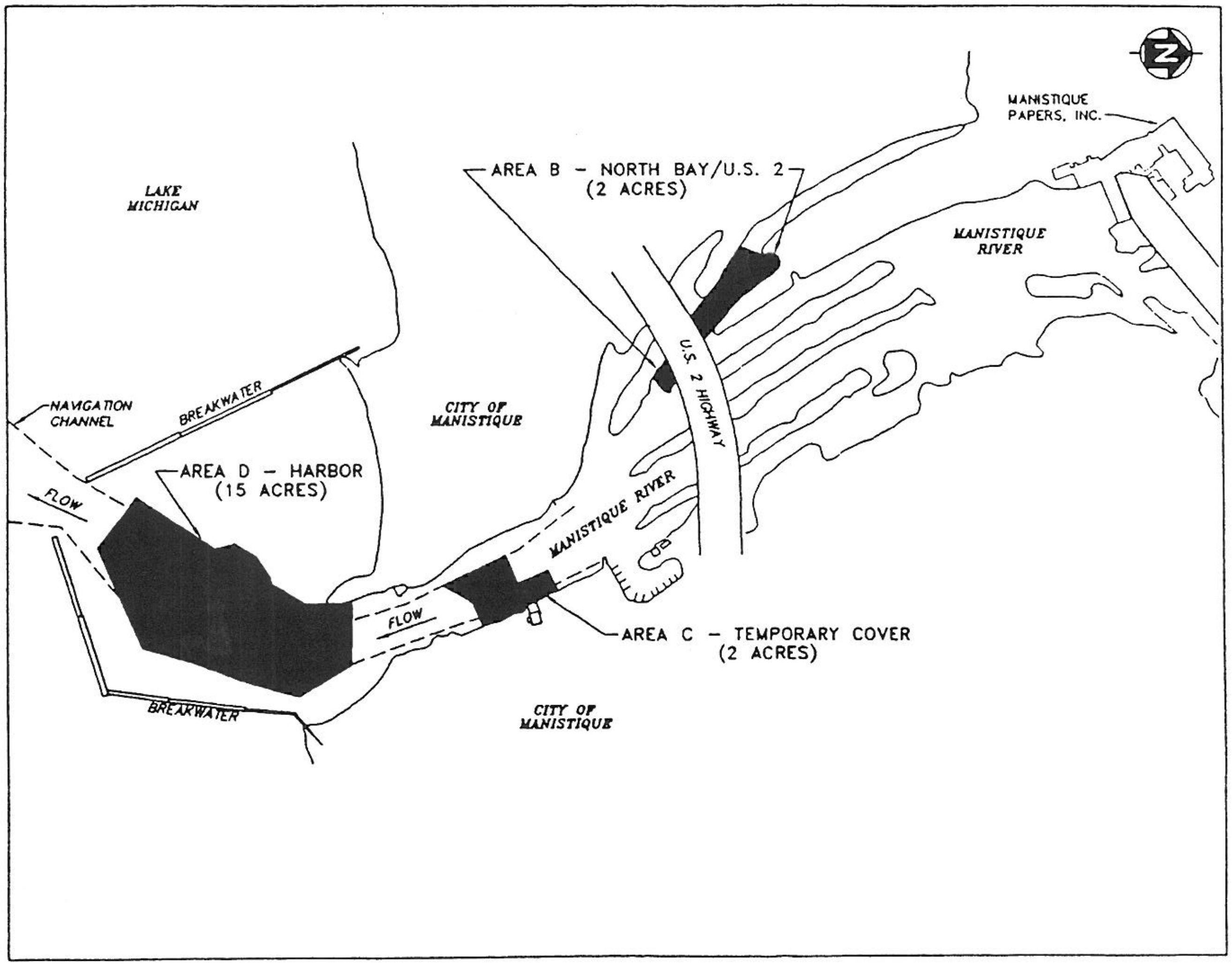

Figure 3- Manistique Harbor Project, MI. (from USEPA 1996b)

Total costs for the project are estimated to range from $6 million to $11 million, with the PRP's providing a cash payment of $6.4 million and additional in-kind services as a final settlement of their liability. USEPA will cover the balance, if any, of the costs incurred in completion of site remediation.

SUMMARY

The three projects discussed in this paper are representative of the still dynamic and unsettled nature of the contaminated sediment remediation field. Although more and more projects are moving into the design and construction stages, no consistent pattern has yet emerged concerning removal, processing or disposal techniques. Site-specificity remains the name of the game, and demonstration projects are still the main avenue through which the application of treatment technologies are being considered. Our ability to adequately capture true costs remains a significant challenge, as the few projects that are completed are often done so under unusual funding circumstances that leave details either sketchy or protected by confidentiality agreements. The next few years promise to continue the rapid expansion in the database of completed sediment remediation projects, through both the advancement of work on several Superfund sites and through the development of large-scale operations for the processing of dredged materials from navigation projects in such areas as New York and Oakland.

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OPTIMIZATION OF DREDGED MATERIAL PLACEMENT NEEDS USING THE SUB-CHANNEL PLACEMENT CELL CONCEPT

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ABSTRACT

In order to provide optimal placement of contaminated dredged material from the New York and New Jersey shipping channels and berths, the Port Authority of New York & New Jersey (PA) conducted a study of the Sub-channel Placement Cell (SPC) concept. Areas studied included the Howland Hook Marine Terminal, the Port Jersey Channel, the Brooklyn Marine Terminal, South Elizabeth Channel, Elizabeth Pierhead Channel, Port Elizabeth Channel, Port Newark Pierhead Channel and Port Newark Channel. The study evaluated the feasibility and cost of providing dredged material storage capacity below the channel depth for dredged material at these sites as well as creating cells suitable for trapping the contaminated sediments. It was found that SPC's could be used at select locations along the New York and New Jersey Harbor to provide cost effective and environmentally attractive placement of dredged material.

INTRODUCTION

Sub-channel Placement Cells (SPC's) consists of deepening sections of the berth and channel area into the underlying in-situ soils. This is an environmentally beneficial technique that can trap contaminated sediments and prevent their migration to other areas. Contaminants moving through the channel and berth areas are deposited into SPC's due to the low velocity created by their hydraulics, which enhances sedimentation. There is no subsequent need for dredging since the deposited materials are below the channel depth, which reduces the potential for resuspension. Sediments deposited in the berth areas may also be removed and transferred into adjacent SPC's, thus keeping any contaminated sediment in the vicinity of the deposition zone.

Faced with expensive options for disposal of contaminated sediments ($56 to $117/cy), the Port Authority of New York & New Jersey (PA) have been studying various innovative and cost-effective placement options (PA, 1996a; Wakeman, 1997; Wakeman et al, 1997; Knoesel et al; 1998). The PA (1996a) study looked at advance maintenance dredging (AMD), which simultaneously provides contaminated sediment traps at the Port Newark and Port Elizabeth Channels. By dredging deeper traps, the volume of contaminated material requiring special placement is minimized. Further, the cleaner in-situ materials that lie beneath the contaminated sediments can be disposed quite cost-effectively.

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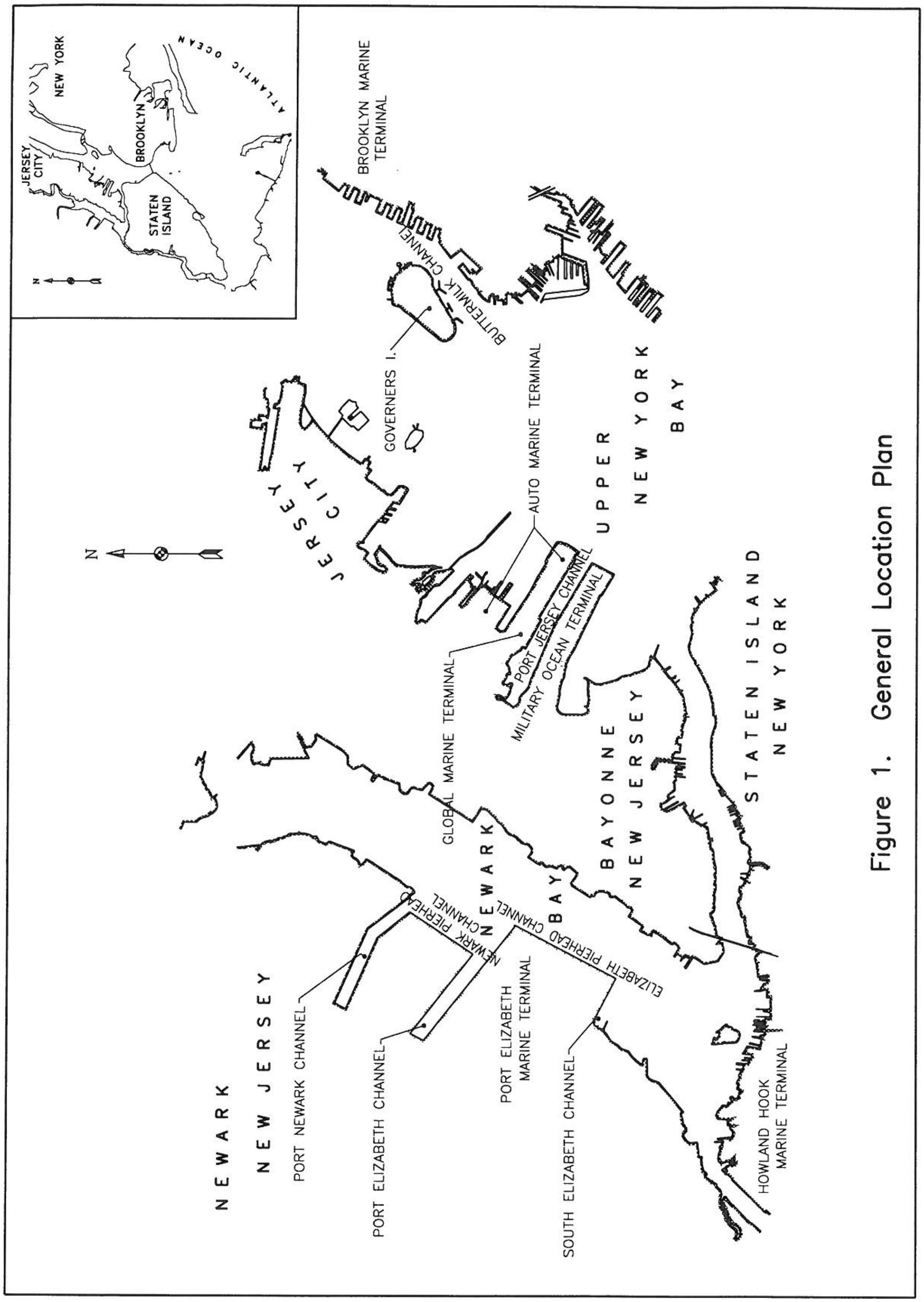

Figure 1. General Location Plan

The deepened/widened channel creates a basin that acts as a sediment trap by enhancing sedimentation in the water column and by sequestering sediment relocated from adjacent areas. Also, from an environmental perspective, it is generally preferred that the contaminated sediment is kept within an area that is already contaminated (i.e., the sediment is contained in a newly constructed "cell"), rather than existing borrow pits, which are viewed as fish habitat. AMD has been used by the U.S. Army Corps of Engineers (USACE) for many years in order to achieve the following:

- Reduce dredging frequency (savings in mobilization and demobilization)
- Increase dredging production (by increasing the dredging face/bank)
- Reduce dredging cost (since clean sediments are dredged to provide cell capacity)
- Control shoaling patterns.

Gahagan & Bryant Associates, Inc. (GBA, 1997) expanded the PA (1996a) study to include Howland Hook Marine Terminal (HHMT), the Port Jersey Channel (PJC), the Brooklyn Marine Terminal (BMT), South Elizabeth Channel (SEC), Elizabeth Pierhead Channel (EPC), Port Elizabeth Channel (PEC), Port Newark Pierhead Channel (PNPC) and Port Newark Channel (PNC). These are shown in Figure 1.

GEOTECHNICAL ANALYSIS

Geotechnical profiles were developed using boring logs and the thicknesses of various material types were estimated for the sites. Note that individual material layers vary considerably and the stratigraphy described below is a very approximate estimate for the entire area within each site.

Howland Hook Marine Terminal

The stratigraphy at Howland Hook Marine Terminal consists of a 3.0 to 14.0 ft. (10.4 ft., on average) thick "mud" layer, underlain typically by a 0.1 to 9.5 ft. (1.6 ft., on average) thick very stiff clay layer, or a 6.0 to 10.0 ft. soft clay layer. This layer is underlain by bedrock. At certain locations, the mud layer is underlain by bedrock; while at certain other areas, a 2.0 ft. medium to stiff clay layer is present in between. The bedrock is at -40 to -45 ft. MLW.

Port Jersey Channel

The stratigraphy for the three reaches of the Port Jersey Channel (Figure 2) is described below:

- *Reach 1*: The bed consists of a 5.0 ft. mud layer underlain by a 10.0 ft. dense sand layer. At certain locations thin lenses of loose sand, medium to stiff clay, and very stiff clay exist between the mud and dense sand layers. At the southern portion of the channel, the bed consists of a 8.0 ft. mud layer, underlain either by an 8.0 ft. dense sand layer, or by an 8.0 ft. very stiff clay layer. At other locations, thin intermittent lenses of medium sand or soft clay are present. The bedrock is at -60 to -80 ft. MLW (average of -65 ft. MLW).

- *Reach 2*: The bed consists of a 6.0 ft. mud layer, underlain by a 5.0 ft. layer of dense sand, followed by a 4.0 ft. layer of very stiff clay. At the north edge of the channel, the bed consists of a 3.0 ft. mud layer underlain by a 7.0 ft. dense sand layer. At the south edge of the channel, stratigraphy varies with location and consists of either a 5.0 ft. mud layer followed by a 9.0 ft. layer of dense sand (western section), or a 9.0 ft. layer of very stiff clay (eastern section). The bedrock is at -60 to -70 ft. MLW (-65 ft. MLW, on average).

- *Reach 3*: The bed consists of a 2.0 ft. mud layer, followed by a 12.0 ft. layer of very stiff clay with silt. A 2.0 to 4.0 ft. medium to dense sand lens is present along channel edges between the mud and clay layers. The bedrock elevation is approximately -70 ft. MLW.

Brooklyn Marine Terminal

The stratigraphy at Brooklyn Marine Terminal consists of a 1.3 to 9.1 ft. (2.3 ft., on average) thick mud layer, followed by intermittent layers of sand (varying thickness and density, depending upon location of boring), and clay (varying thickness and stiffness, depending upon location of boring). At certain locations, the top mud layer is absent and is instead either a loose sand layer, or a medium to dense sand layer. It is estimated that the bedrock elevation at the site exceeds -80 ft. MLW.

South Elizabeth Channel

In general, the channel bed consists of a 10-12 ft layer of medium to stiff clay with silt, followed by a 10-20 ft layer of very stiff clay with silt. At some locations, a 1-3 ft layer of very stiff silty clay overlies the medium silty clay layer. Bedrock elevation varies from -50 to -65 ft (-60 ft, on average).

Elizabeth Pierhead Channel

The stratigraphy at Elizabeth Pierhead Channel consists of a 1-2 ft layer of medium to stiff clay with silt followed by a 4-6 ft layer of very stiff clay with silt at some locations. At other locations, the bed consists of a 1-2 ft layer of very stiff clay with silt followed by a 7-9 ft layer of medium to stiff clay with silt. The bedrock elevation varies from -70 to -95 ft.

Port Elizabeth Channel

The stratigraphy at Port Elizabeth Channel consists of a 5-30 ft layer of medium to stiff clay with silt, underlain by a 1-20 ft layer of very stiff clay with silt. At some locations, either a 1-6 ft layer of soft clay with silt or a 2-13 ft layer of very stiff clay with silt overlies the medium silty clay layer. The bedrock elevation varies from -45 (west channel section) to -90 ft, and typically exceeds -75 ft.

Port Newark Pierhead Channel

The channel bed typically consists of a 7-17 ft layer of medium to stiff clay with silt, followed by either a 3-9 ft layer of very stiff clay with silt or a 1-6 ft layer of medium to dense sand. The bedrock elevations were estimated to range from -50 to -65 ft, with an average value of -60 ft., using the bedrock contours presented in the rock contour plots supplied by the Port Authority (PA, 1996d). There was no data available in the borings from elevation –57 ft. to the bedrock layer. Information from the boring logs at the proposed Newark Bay CDF (that lie closest to the Port Newark Pierhead Channel) were used to reduce the above mentioned data gap. At these locations, the sediment stratigraphy (deeper than approximately 42 ft) consists of a 3-28 ft layer of very stiff silty clay followed by either a 16 ft layer of very stiff clay with silt or a 16 ft layer of medium to stiff clay with silt. The bedrock elevation at this location exceeds -75 ft.

Port Newark Channel

The channel bed consists of a 10-23 ft layer of medium to stiff clay with silt, followed by a 3-7 ft layer of very stiff clay with silt. At some locations, a 5-12 ft layer of very stiff silty clay overlies the medium silty clay layer. The bedrock elevation varies from -40 to below -75 ft.

POTENTIAL SPC LAYOUTS

Several potential layouts for SPC's were considered to evaluate the effectiveness and economics of the sites. Sites with effective sediment trapping capability, high site life, and low construction costs were considered "attractive" for SPC construction. The analysis for these sites was based on the following assumptions.

- An offset distance of 100 ft. was maintained from the wharf structure.
- The following bedrock elevations (ft-MLW) were used: -35 to -45 ft (HHMT); -60 to -80 (PJC); -80 (BMT); -50 to -60 (SEC); -70 to -95 (EPC); -45 to -90 (PEC); -50 to -65 (PNPC); and -40 to -50(PNC).
- The final filling elevation of the SPC was assumed to be -45 ft. MLW, which is the study depth for this investigation.

Howland Hook Marine Terminal

A review of the material borings supplied by PA (1996b) shows bedrock to be at elevation -40 to -45 ft., indicating that construction of sediment traps for a final filling elevation of -45 ft. MLW would require excavation of bedrock. Excavation of bedrock for this purpose is neither considered practical nor cost effective. Furthermore, the sediment rate at Howland Hook could rapidly fill excavated cells. Because of the above limitations, advance maintenance of sufficient depth to create SPC's was considered not economically feasible at this site. It was therefore determined that SPC's would not be feasible at HHMT due to the shallow bedrock elevations at this site and associated practical and economic reasons.

Port Jersey Channel

Based on bathymetry, boring log data and sedimentation data it was determined that SPC's are feasible in the Port Jersey Channel. Selection of the configuration of SPC's in the Port Jersey Channel is a function of several factors including site capacities and operational life, initial dredging volumes, construction costs, operation and maintenance, and environmental factors. Four SPC configurations were laid out for the PJC as shown in Figure 2 and Table 1. Note that the average

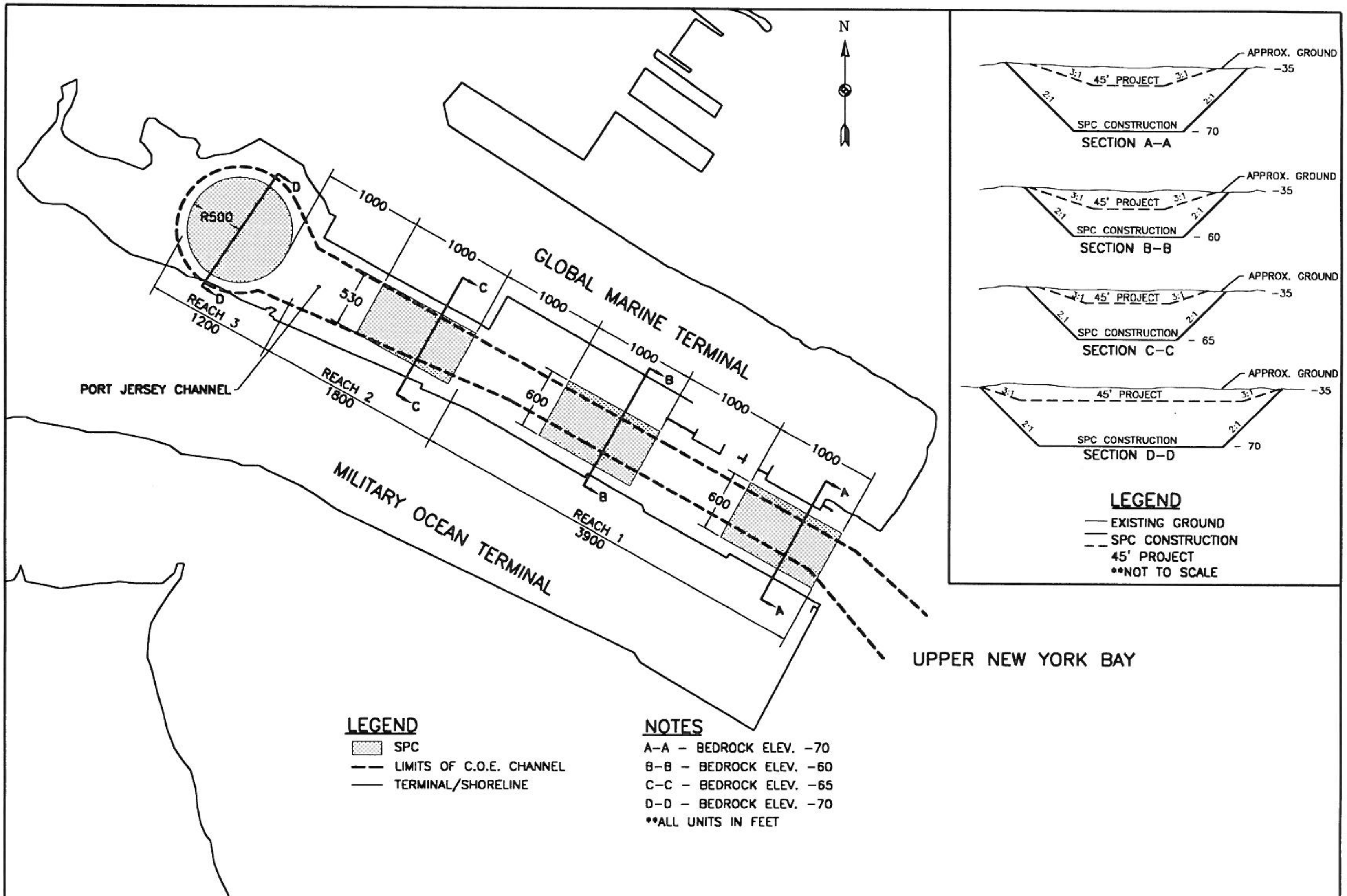

Figure 2. SPC Layout for Port Jersey Channel

bedrock elevations in Table 1 are based on the USACE (1996a) bedrock contours applied to the specific configuration.

Brooklyn Marine Terminal

It was determined that SPC construction with sufficient depth to create sediment traps along the berths between the piers was primarily restricted by the limited geometry available for construction of efficient cells (i.e., only limited widths are permissible due to slopes and offset distance requirements from piers). Therefore, it was determined that SPC's within the BMT would not be practical or efficient.

SPC was also reviewed outside and along the Brooklyn Marine Terminal. However, data from the U.S. Army Corps of Engineers (USACE, 1996b) indicated that the flow velocities along the Buttermilk Channel (in front of the Brooklyn Marine Terminal) far exceeds the threshold velocity for deposition of suspended sediments. Therefore, it was determined that SPC's along the Buttermilk Channel would not be efficient. Further, if any material were placed in these areas it would be dispersed to downstream sources during high river flows. Because of the above limitations, the SPC concept was considered not technically feasible.

South Elizabeth Channel

Based on bathymetry, boring log data and sedimentation data it was determined that SPC is implementable in the South Elizabeth Channel. The bedrock elevations and sedimentation rates provide adequate conditions for SPC. Selection of the configuration of SPC's in the South Elizabeth Channel is a function of several factors including site capacities and operational life, initial dredging volumes, construction costs, operation and maintenance, and environmental factors. Three SPC configurations were found to be possible for the SEC (see Figure 3 and Table 1).

Elizabeth Pierhead Channel

Based on bathymetry, boring log data and sedimentation data it was determined that SPC is implementable in the Elizabeth Pierhead Channel. The bedrock elevations and sedimentation rates provide adequate conditions for SPC. Selection of the configuration of SPC's in the EPC is a function of several factors including site capacities and operational life, initial dredging volumes, construction costs, operation and maintenance, and environmental factors. Three modified SPC configurations were laid out for the EPC as described in Table 1 and shown in Figure 3.

Port Elizabeth Channel

Based on bathymetry, boring log data and sedimentation data it was determined that SPC is implementable in the Port Elizabeth Channel. The bedrock elevations and sedimentation rates provide adequate conditions for SPC. Selection of the configuration of SPC's in the PEC is a function of several factors including site capacities and operational life, initial dredging volumes, construction costs, operation and maintenance, and environmental factors. Three modified SPC configurations were laid out for the PEC as described in Table 1 and shown in Figure 3.

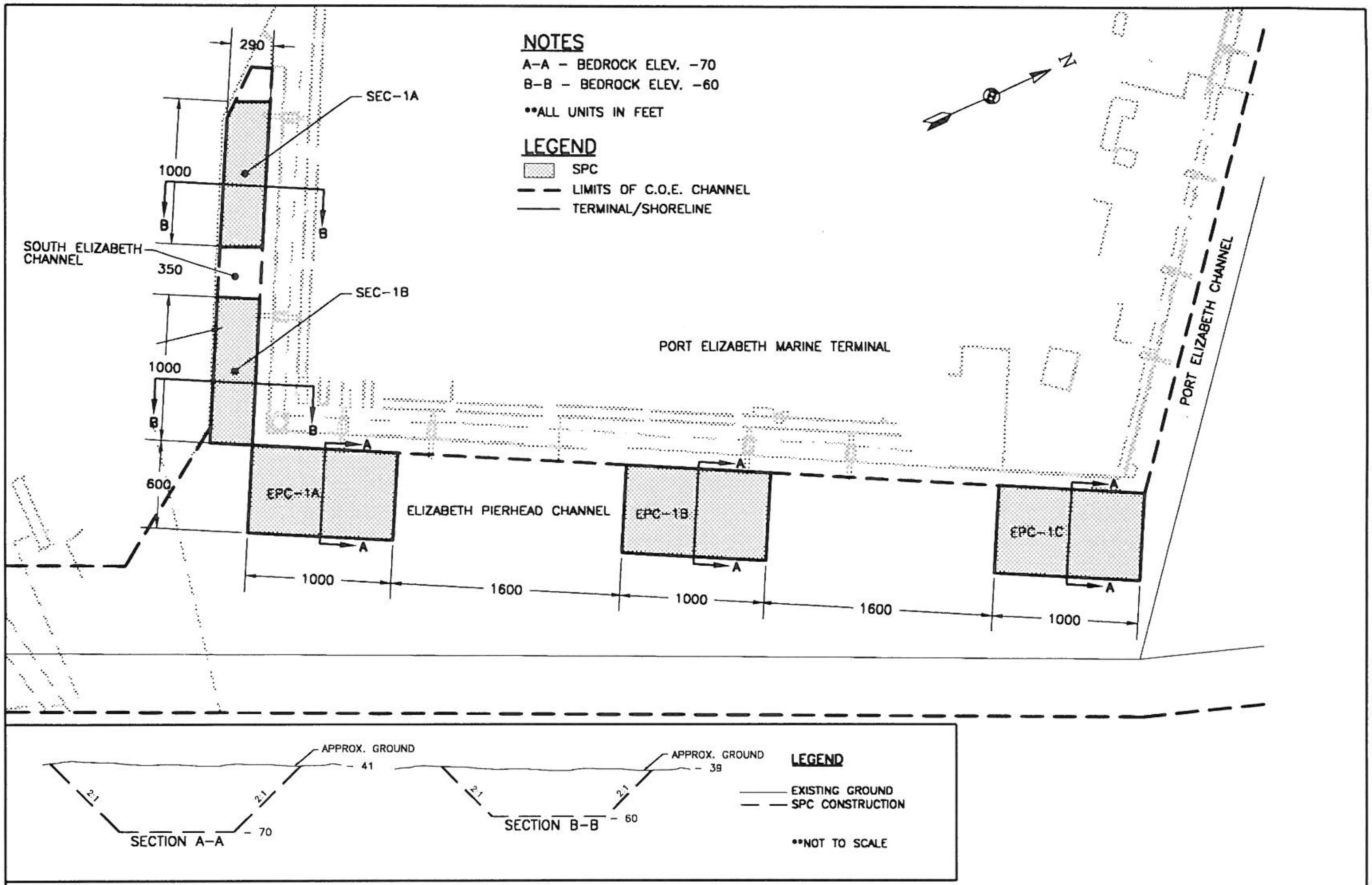

Figure 3. SPC Layouts for South Elizabeth Channel, Port Elizabeth, and Elizabeth Pierhead Channel

Port Newark Pierhead Channel

Based on bathymetry, boring log data and sedimentation data it was determined that SPC is implementable in the Port Newark Pierhead Channel. Although the bedrock elevations are somewhat shallow, the low sedimentation volumes provide adequate conditions for SPC. Selection of the configuration of SPC's in the PNPC is a function of several factors including site capacities and operational life, initial dredging volumes, construction costs, operation and maintenance, and environmental factors. Three modified SPC configurations were laid out for the PNPC as described in Table 1 and shown graphically in Figure 4.

Port Newark Channel

Based on bathymetry, boring log data and sedimentation data, it was determined that SPC is not implementable in the Port Newark Channel. The shallow bedrock elevations and the expected sedimentation rates do not provide adequate conditions for sub channel placement. Construction of SPC's to a deeper elevation would require excavation of bedrock, which is neither considered practical nor cost effective. Because of the above limitations SPC was considered not economically feasible at this site.

DREDGING VOLUMES

Based on the SPC layouts discussed above, the required dredging volumes for construction of the basins were estimated. The projects were analyzed in two stages: (1) assumed channel deepening, to -45 ft. MLW; and (2) further deepening to create sediment storage capacity (SPC construction).

Dredging volumes were separated into contaminated and clean sediment volumes. The estimated dredging volumes were based on the following assumptions:

- Top 2 ft of the in-channel sediments were considered to be contaminated (PA, 1996a-c).
- Volume computations were based on average widths for the section.

The dredging volumes for the various sites are summarized in Table 1.

ESTIMATED SPC FILLING RATES

Estimated SPC filling rates were determined using the shoaling rates supplied by USACE (1996a) and PA (1996a-d). These sources determined the shoaling rate for the existing configuration by standard methods and used a linear extrapolation of the shoaling rates based on increase in water column depth due to the modified configuration. This method has been shown to provide relatively good agreement with numerical modeling (M&N, 1997).

The following values were assumed for the shoaling rates.

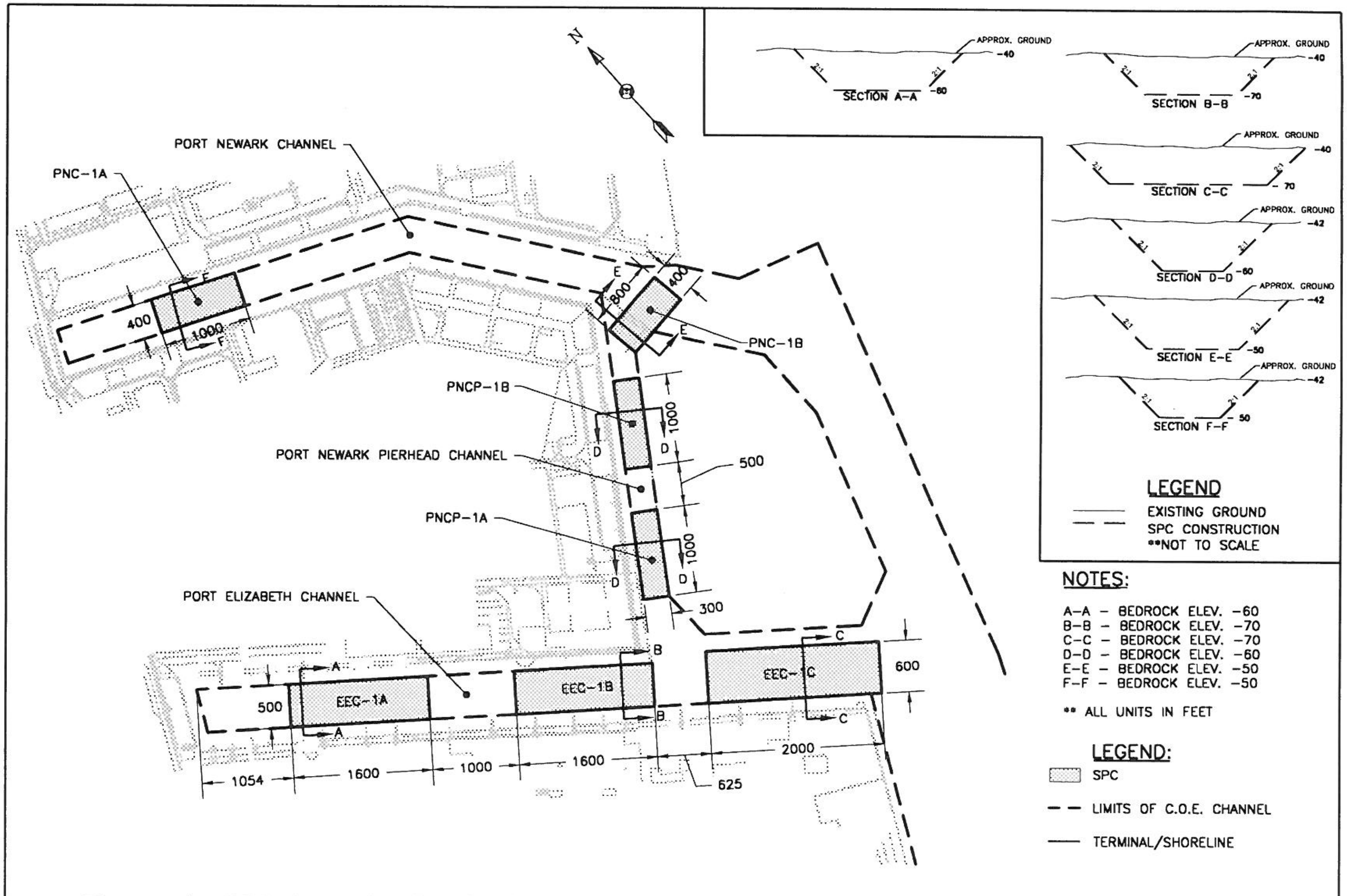

Figure 4. SPC Layouts for Port Newark PierHead Channel and Port Newark Channel

- Port Jersey Channel: 0.25 ft/yr for the -40 ft. channel.
- South Elizabeth Channel: 0.42 ft/yr for the -39 ft channel.
- Elizabeth Pierhead Channel: 0.42 ft/yr for the -41 ft channel.
- Port Elizabeth Channel: 0.42 ft/yr for the -42 ft channel.
- Port Newark Pierhead Channel: 0.42 ft/yr for the -42 ft channel.

Shoaling rates for the modified channel/berth (SR_m) were estimated as follows:

$$SR_m = SR_e\,[(D_e+\Delta D)/D_e]$$

where, SR_e is the shoaling rate of the existing channel/berth, D_e is the existing channel/berth depth, and ΔD is the difference between the depth of the existing and modified channels/berths.

SPC CAPACITY & LIFE

SPC capacity is the volume of in-situ (cut) material that it can accommodate, over its operational life. The operational life is measured in years. Capacity and life depends on the following:

- Geometry of the site,
- Rate of shoaling and type of shoaled material (ie: fine grained or granular),
- Final permitted elevation of the site (function of the required channel depth),
- Site surface area and configuration, and
- Site management plan (operation and management of settled material, including transfer to other placement cells or locations).

The estimated site capacities and operational lives for the various SPC options are summarized in Table 1. The computations were based on the following information and assumptions.

- Capacity computations are based on average widths for the section.
- Site capacity was assumed to be equal to site volume since both sediment bulking (during dredging) and sediment consolidation (after placement) were assumed to neutralize the effects of each other.
- Site life indicates the number of years the SPC's would remain functional without maintenance (i.e., transfer or diversion of material from one SPC to another).

ESTIMATED PROJECT COSTS

Estimated construction costs, site capacities and the cost per cubic yard for the various channels and SPC configurations are summarized in Table 1. The estimates were based on the following assumptions.

Table 1. Summary of SPC Evaluations

	Port Jersey Channel			
	PJC-1	PJC-2	PJC-3	PJC-4
Configuration & Volumes:				
Total Site Area (Acres)	58	52	28	91
Weighted Average Bedrock Elev. (Ft. MLW)	- 67	- 68	- 60	- 66
Average Site Depth (Ft.)	21	23	15	22
Required Dredging Volume (Million CY)	2.71	2.62	1.61	3.74
Contaminated Sediment Volume (Million CY)	0.29	0.29	0.29	0.31
Clean Sediment Volume (Million CY)	2.42	2.33	1.32	3.44
Capacity & Life:				
Site Capacity (Million CY)	1.8	1.7	0.6	2.8
Average Site Life (Years)	31	19	7	46
Site Costs:				
Site Construction Costs (Million $)	33.2	32.4	25.4	41.2
Average Construction Unit Cost ($/CY)	12	12	16	11
Cost per Cubic Yard Capacity ($/CY)	18	19	41	15

	South Elizabeth Channel			Elizabeth Pierhead Channel		
	SEC-1	SEC-2	SEC-3	EPC-1	EPC-2	EPC-3
Configuration & Volumes:						
Total Site Area (Acres)	13	12	15	41	44	84
Weighted Average Bedrock Elev. (Ft. MLW)	- 60	- 57	- 57	- 70	- 70	- 70
Average Site Depth (Ft.)	15	12	12	25	25	25
Required Dredging Volume (Million CY)	0.41	0.33	0.38	1.93	2.06	3.53
Contaminated Sediment Volume (Million CY)	0.06	0.06	0.06	0.27	0.27	0.27
Clean Sediment Volume (Million CY)	0.35	0.28	0.32	1.66	1.79	3.25
Capacity & Life:						
Site Capacity (Million CY)	0.3	0.2	0.3	1.5	1.6	3.1
Average Site Life (Years)	17	13	15	20	22	37
Site Costs:						
Site Construction Costs (Million $)	5.5	5.0	5.3	26.9	27.5	38.1
Average Construction Unit Cost ($/CY)	14	15	14	14	13	11
Cost per Cubic Yard Capacity ($/CY)	19	24	21	18	17	12

	Port Elizabeth Channel			Port Newark Pierhead Channel		
	EEC-1	EEC-2	EEC-3	PNPC-1	PNPC-2	PNPC-3
Configuration & Volumes:						
Total Site Area (Acres)	64	62	90	14	14	24
Weighted Average Bedrock Elev. (Ft. MLW)	- 68	- 70	- 66	- 60	- 60	- 60
Average Site Depth (Ft.)	22	25	18	15	15	15
Required Dredging Volume (Million CY)	2.50	2.23	3.12	0.41	0.42	0.64
Contaminated Sediment Volume (Million CY)	0.34	0.34	0.34	0.09	0.09	0.09
Clean Sediment Volume (Million CY)	2.15	1.89	2.78	0.32	0.33	0.54
Capacity & Life:						
Site Capacity (Million CY)	2.1	1.8	2.7	0.3	0.3	0.5
Average Site Life (Years)	20	17	21	15	17	19
Site Costs:						
Site Construction Costs (Million $)	34.2	32.1	38.5	7.5	7.6	9.0
Average Construction Unit Cost ($/CY)	14	14	12	18	18	14
Cost per Cubic Yard Capacity ($/CY)	16	18	14	25	25	17

- Estimated quantities of contaminated, clean soft, and clean stiff materials were based on best available information at the time of the study.
- The costs for dredging and placing contaminated, clean soft, and deeper clean stiff materials during the SPC construction were estimated to be \$56/cy, \$4/cy and \$10/cy, respectively.
- It was assumed that the contaminated sediments will be placed off site.
- The cost estimates do not include environmental monitoring, testing and analysis.
- Costs for permits, engineering design, project management, and operation and maintenance are not included.

As shown in Table 1, the estimated unit cost of material placement in SPC's vary from \$7 to \$11/cy, depending on the geometry and bedrock depth. This is significantly less than other currently available methods of disposal of dredged material unsuitable for placement at the Historic Area Remediation Site (HARS), the cost of which vary from \$56/cy to \$117/cy.

CONCLUSIONS

Our study revealed the following - SPC's were not cost-effective at Howland Hook Marine Terminal due to shallow bedrock elevation and low site life. SPC's were not efficient at Brooklyn Marine Terminal due to high flow velocities and limited geometry. SPC's were designed for the Port Jersey Channel, South Elizabeth Channel, Elizabeth Pierhead Channel, Port Elizabeth Channel and Port Newark Pierhead Channel, yielding a cost-effective and environmentally attractive dredged material placement methodology. The unit cost of material placement in SPC's was estimated to vary from \$7 to \$11/cy. These costs do not include environmental monitoring, engineering design and maintenance. Even so, these costs are much lower than the \$56 to \$117/cy costs for the currently available options for placing contaminated dredged material from New York and New Jersey. Therefore, SPC's provide a cost-effective and environmentally attractive placement method for contaminated dredged material, plus the added benefit of advance maintenace for those portions of the deepened channels and berths.

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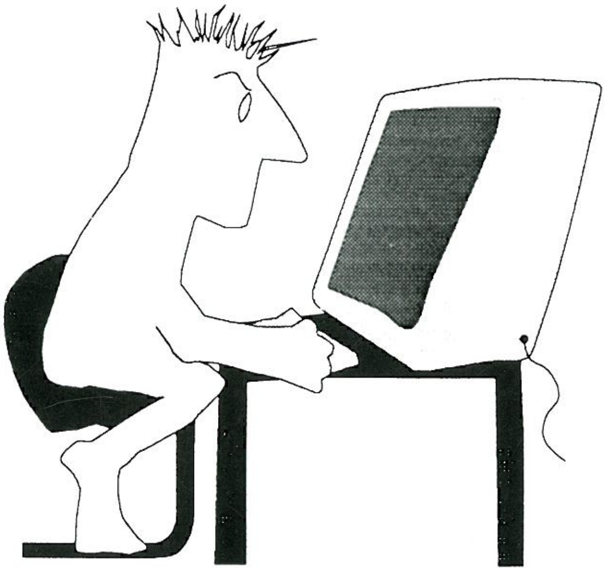

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