INTERPRETING THE PROCESS AND RESULTS OF THE LOWER PASSAIC RIVER PILOT DREDGING STUDY

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ABSTRACT

In December 2005, the New Jersey Department of Transportation – Office of Maritime Resources (NJOMR) implemented a pilot-scale dredging program to remove 3,823 cubic meters (5,000 cubic yards) of sediment from a 0.61-hectare (1.5-acre) area of the Passaic River, New Jersey. The objective of this program, which was conducted as part of the Lower Passaic River Restoration Project (LPRRP), was to study a number of dredging issues, including sediment resuspension, dredging productivity, and material treatability. Another important NJOMR goal was to collect the information necessary to "scale up" to a much larger remedial dredging program – one that would be conducted sometime in the future.

If developed and executed properly, such pilot-scale studies can be very useful in assessing the feasibility of implementing a remedial approach on a larger scale within a specified area of interest. Such programs can also be instrumental in augmenting the nationwide remediation database.

This manuscript evaluates the potential utility of the LPRRP pilot-scale dredging program based on current knowledge of conditions in the lower Passaic River and experience gained from other dredging projects. Specifically, it reviews and discusses localized physical and chemical features of the lower Passaic River system as they pertain to the design and scope of the project and addresses equipment selection, monitoring design and other significant project issues with respect to stated data use and data quality objectives.

Keywords: Sediment removal, decontamination, tidal estuary.

INTRODUCTION

In December 2005, a Dredging Pilot Study (Pilot Study) was implemented within a portion of the lower Passaic River, adjacent to the City of Newark, New Jersey. This project was conducted as part of the Lower Passaic River Restoration Project (LPRRP), which represents a cooperative effort of six federal and state agencies to remediate and restore the lower 27.4 kilometers (km) [17 miles (mi)] of the Passaic River (river). This partnership includes the United States Environmental Protection Agency (USEPA), the United States Army Corps of Engineers (USACE), the New Jersey Department of Transportation (NJDOT), the National Oceanic and Atmospheric Administration (NOAA), the United States Fish and Wildlife Service (USFWS) and the New Jersey Department of Environmental Protection (NJDEP). To advance the LPRRP, these agencies have initiated a Remedial Investigation/Feasibility Study (RI/FS) for the lower 27.4 km of the river, of which the Pilot Study is one component. More information regarding the LPRRP can be found at www.ourpassaic.org.

The Pilot Study, which was sponsored by the New Jersey Office of Maritime Resources (NJOMR, a division of the NJDOT), consisted of the removal and treatment of approximately 3,288 cubic meters (m^3; 4,300 cubic yards [cy]) of sediment (535 m^3 [700 cy] less than targeted) from a 0.61-hectare (ha; 1.5-acre) area within the Harrison Reach of the Passaic River. The primary purpose of the Pilot Study was to evaluate both the feasibility of dredging within the targeted area and the ability to decontaminate the removed sediments. A corollary objective was to collect the

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information necessary to "scale up" to a much larger remedial dredging program that could be considered for future implementation.

This manuscript evaluates the potential utility of the Pilot Study program based on current knowledge of conditions in the lower Passaic River and experience gained from other dredging projects. Specifically, it reviews and discusses localized physical and chemical features of the lower Passaic River system as they pertain to the design and scope of the project, and addresses equipment selection, monitoring design and other significant project issues with respect to stated data use and data quality objectives.

Background and General Description of the Study Area

The Passaic River is a highly industrialized urban river in the northeastern United States. It drains a 2,422-square-km (935-square-mi) watershed in the vicinity of the New York/New Jersey (NY/NJ) Harbor (Figure 1). The lower Passaic River is defined as the 27.4-km (17-mi) tidally influenced portion of the river from its mouth at the confluence with Newark Bay to the Dundee Dam. All or portions of 117 municipalities in eight New Jersey counties, and 15 municipalities in two New York counties, are located within the Passaic watershed (NJOMR 2005b).

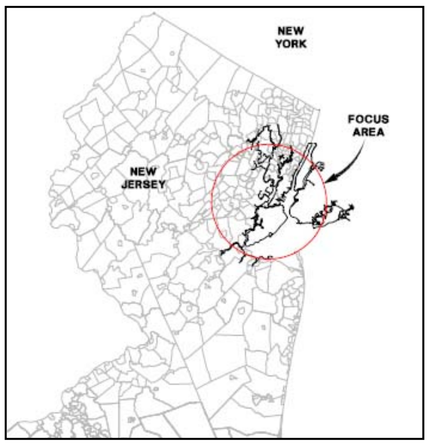

Figure 1. NY/NJ Harbor regional watershed area.

Over the last 20 years, this river system, particularly the lower 9.7 km (6 mi), has been the focus of numerous sediment, biological, surface-water and bathymetry investigations. These programs have been implemented by a number of private and governmental entities in an effort to determine the nature and extent of contamination in the lower Passaic River. Without question, Tierra Solutions, Inc.'s (Tierra's) 1995 RI Sampling Program represents the most comprehensive historical dataset available for sediments within this river segment. Most recently, the USEPA has collected additional cores from a number of locations below Dundee Dam as part of the LPRRP RI/FS. As of the drafting of this manuscript, the latest USEPA data have not yet been released to the public.

From the information gathered from previous investigations, it is known that the geomorphology of the lower Passaic River is influenced by hydrodynamics and sediment supply resulting in channel characteristics that are consistent with the classical geomorphology of meandering river/estuarine channels (e.g., Hager 2003). Sediment is deposited or eroded as a result of estuarine circulation and sediment supply. Point-bar formations with thick accumulated sediment deposits occur along the inside banks of river bends, where flow energy and turbulence are low, while deeper areas characterized by limited sediment deposition that occurs along the outer banks of such bends, where flow energy and turbulence are greater. In straight sections, shallow near-shore areas transition to sloping side channels bounding the deeper center-channel area. Tidal mudflats occur along the channel margins in some areas, although these are limited in scale in the lower Passaic River due to extensive anthropogenic filling and armoring along most of the shoreline (Iannuzzi et al. 2002).

Twelve bridges cross the lower river. At most bridge crossings, flow constriction between abutments or piers results in scour, while shoaling occurs both upstream and downstream of the structures due to lower velocities and reversing tidal flows. In addition, there are 28 combined sewer overflow outfalls and 142 storm sewer outfalls in the lower 9.7 km of the river that may affect local sedimentation patterns.

The Harrison Reach

The Pilot Study was conducted within the Harrison Reach, the portion of the lower Passaic River that extends approximately 3.1 km from the New Jersey Turnpike Bridge (approximately river kilometer 2.4) to the Jackson Street Bridge (approximately river kilometer 5.5). The 0.61-ha (1.5-acre) dredging footprint represents a sub-area of the larger Dredging Pilot Study Area (Figure 2).

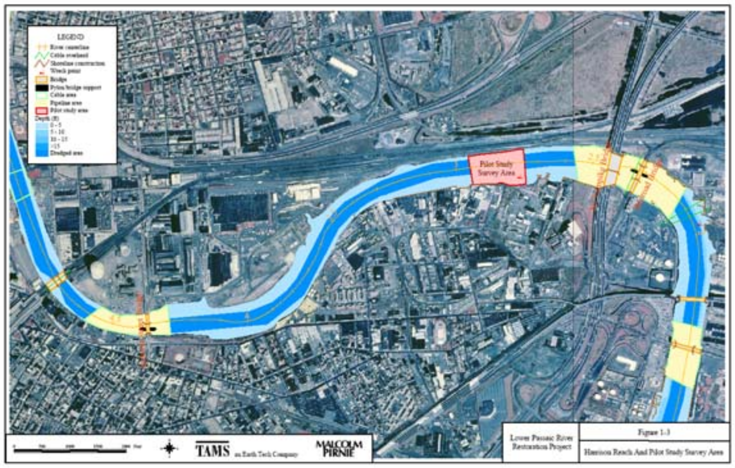

Figure 2. Dredging pilot study area – The Harrison Reach (NJOMR 2005c).

According to the NJOMR (2004), this location was selected based on consideration of in-river conditions, accessibility and concentrations of anthropogenic chemicals in the sediment. The NJOMR determined that the optimal location for the Pilot Study would be a relatively straight section of the river that contained moderately contaminated sediment, allowing for a reasonable assessment of both the selected dredging technology and the available sediment decontamination processes.

The Harrison Reach also fulfilled the NJOMR's requirements for water depth and river velocity. It was expected that scows and towboats would require a minimum of 3 meters (m) of water during low-water conditions to access the Study Area and potential decontamination sites (NJOMR 2005c). Average velocities in the selected Study Area (1 foot per second [fps] and 3 fps due to freshwater and tidal flow, respectively) did not appear to pose a major problem for the dredging operations (NJOMR 2005c). Lastly, it was noted that this section of the Passaic River had relatively light river traffic, which would allow dredging work to proceed largely unimpeded (NJOMR 2005c).

PRE-DREDGE ACTIVITIES

In order to establish baseline conditions and begin the design process, several data collection and assessment activities were performed in the early stages of the Pilot Study. These activities are briefly described below.

Dredging Technology Review

A Dredging Technology Review was conducted to assess conditions within the lower Passaic River and to select the dredging equipment most appropriate to achieving the project goals. Based on an evaluation of the capital investment in infrastructure and land for dewatering and treatment systems, sediment transport and handling requirements, the presence of debris, and potential application to larger-scale river remediation (NJOMR 2004), the NJOMR selected mechanical dredging as the preferred technology for the Pilot Study.

Hydrodynamic and Sediment Transport Modeling

The NJOMR developed a three-dimensional hydrodynamic model for the Pilot Study using Computational Fluid Dynamics modeling software Flow3D (NJOMR 2005c). According to NJOMR, the purpose of this model was to:

- Support the placement and positioning of water-column monitoring devices/equipment (both fixed monitoring devices and boats equipped to map the dredge plume)
- Estimate the mass flux of sediment leaving the Study Area
- Evaluate the impact of dredging without the presence of engineering controls

Available hydrodynamic data and other pertinent information from the USACE-NY District; Rutgers University; the United States Geological Survey; Aqua Surveys, Inc.; Tierra; Mike Palermo Consulting; and the University of Utah were evaluated for input into the model (NJOMR 2005c). Following this evaluation, a high-energy case and a low-energy case were evaluated using the model. It was recognized that the hydrodynamics of the Study Area are dominated by tidal energy and, to a lesser extent, freshwater discharges, and that wind and waves also affect sediment transport. However, for purposes of the Pilot Study, it was assumed that dredging would not take place during high-wind or -wave conditions because no engineering controls would be in effect (NJOMR 2005c). Furthermore, because the Study Area is limited by fetch length due to sinuosity of the river, only the effects of the tide and freshwater discharges were considered as hydrodynamic transport forcing mechanisms for the Flow3D model (NJOMR 2005c). Lastly, a very conservative approach to sediment transport was incorporated into the model because the effects of flocculation were not included in the calculations.

Hydrodynamic and sediment transport modeling predicted that concentrations of total suspended solids (TSS) would increase within the plume by 2 to 18 milligrams per liter (mg/L) above background concentrations, with a typical concentration of 7 mg/L above background (NJOMR 2005c). Model predictions also indicated that the plume would align with the navigational channel, biased to the northern bank (NJOMR 2005c). Modeling results suggested that monitoring with fixed moorings at transects located 61 to 91 m [200 to 300 feet (ft)] and 366 to 457 m (1,200 to 1,500 ft) from the dredging activity was necessary to capture the plume and its settling characteristics (NJOMR 2005c).

Geophysical Surveys

Geophysical surveys conducted within the Harrison Reach included a hydrographic survey, a side-scan sonar survey, a magnetometer survey, a sub-bottom profiler survey and a gradiometer survey. The hydrographic survey was performed to develop a bathymetric map of the Passaic River bed along a 305-m (1,000-ft) stretch of the Harrison Reach between the Jackson Street Bridge and the New Jersey Turnpike Bridge. The side-scan sonar survey was conducted to characterize the texture of the sediments and to identify any surficial debris in the Dredging Pilot Study Area. The magnetometer and sub-bottom profiler surveys were performed to detect buried ferrous and non-ferrous debris that may not have been detected in the side-scan sonar survey. The gradiometer survey was intended to further investigate magnetic anomalies in the sediments in the Dredging Pilot Study Area. Major observations resulting from these surveys are outlined below (NJOMR 2005a).

- The hydrographic surveys conducted in 2004 showed that considerable deposition had taken place along the 305-m (1,000-ft) stretch in the Harrison Reach since the March/April 1995 hydrographic surveys conducted by Tierra.
- The side-scan sonar survey outlined large areas of scattered debris (e.g., rocks, poles, tires) along both the northern and southern shorelines, and within shallow ridges in the sediment on the north shore.
- The magnetometer and sub-bottom profiler surveys revealed 12 distinct magnetic anomalies, of which only two could be correlated between the two surveys. These surveys were not able to determine whether the targets identified would pose a hazard to the Pilot Study.
- The gradiometer survey did not identify any targets that would potentially interfere with the proposed Pilot Study dredging activities.

Core Collection and Analysis

Following the geophysical surveys, sediment coring activities were conducted to establish a representative chemical and geotechnical characterization of the sediments in the upper 1.2 m (4 ft) of the Passaic River bed in the Dredging Pilot Study Area (NJOMR 2005a). Specifically, sediment cores with a target depth of 1.2 m (4 ft) were collected from 15 locations in July 2004 (Figure 3).

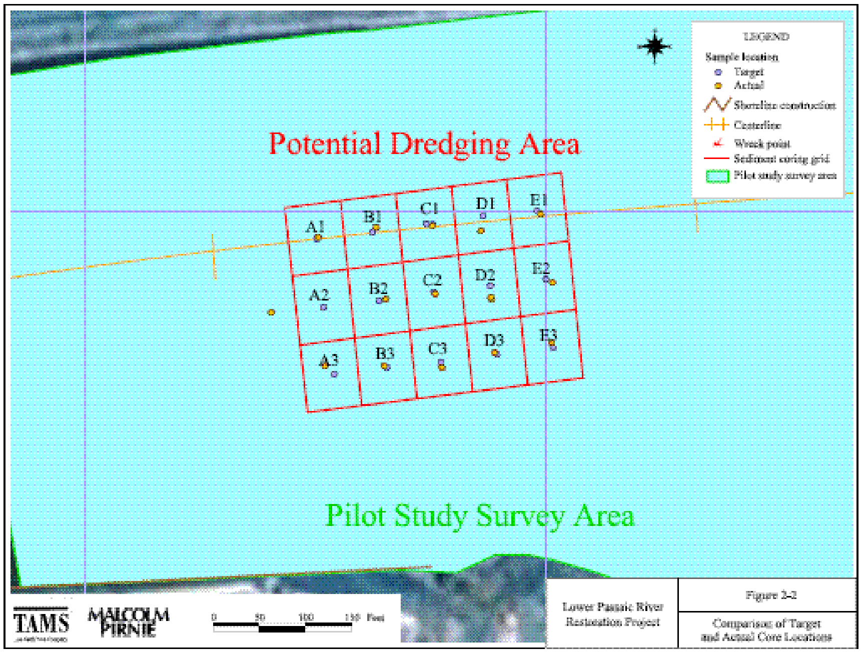

Figure 3. Pre-dredge sediment coring locations (NJOMR 2005a).

Once cores were collected and transported to the processing facility, they were sliced into 0.3-m (1-ft) sections (0 to 0.3, 0.3 to 0.6, 0.6 to 0.9, and 0.9 to 1.2 m), weighed for bulk density determinations, and then homogenized, subsampled, and shipped to the designated laboratories for analysis. A total of 45 discrete sediment samples (one sample from each of the top three segmented depth intervals), as well as quality control samples, were submitted for analysis. The 15 samples collected from the bottom interval (0.9 to 1.2 m) were shipped to laboratories for archiving and were later analyzed. Each sample was analyzed for volatile organic compounds (VOCs); semivolatile organic compounds (SVOCs), including polyaromatic hydrocarbons (PAHs); pesticides; aroclor polychlorinated bipheyls (PCBs); PCB congeners; herbicides; dioxins/furans; metals; total organic carbon (TOC); and geotechnical parameters (percent solids, moisture content, Atterberg Limits, specific gravity and grain size) (NJOMR 2005a).

In addition to the discrete samples discussed above, horizontal composite samples from each of five rows (A through E, shown on Figure 3) were submitted for analysis. Sub-samples from the same depth interval of all three cores within a row were combined to create composite samples (i.e., sub-samples from A1, A2 and A3 were combined to create composite samples of row A for each of the top three depth intervals) (NJOMR 2005a). In addition, the USEPA also collected one bulk drum sample for use in treatability studies conducted by potential sediment decontamination technology vendors (NJOMR 2005c). The NJOMR detailed the results of the sediment analyses (NJOMR 2005a); major observations are outlined below.

- VOCs were detected in less than one-third of the discrete samples and at low concentrations. Chlorobenzene was the most frequently detected VOC, with a maximum concentration of 12 micrograms per kilogram (µg/kg).
- Total PAHs were detected in all sample intervals, with concentrations generally highest in the 0.6- to 0.9-m interval, and lowest in the 0.9- to 1.2-m interval. Total PAH concentrations ranged from 7,312 to 96,100 µg/kg.

- 4,4'-DDT and related pesticide compounds (4,4'-DDD and 4,4'-DDE) were detected in all samples. Total DDT concentrations ranged from 30 to 1,100 µg/kg, with concentrations from the 0.9- to 1.2-m interval lower than those found in the top three intervals.
- Aroclor PCBs were detected in approximately 60 percent of the samples analyzed. Total PCB concentrations in discrete samples from the 0- to 0.9-m intervals ranged from 230 to 3,800 µg/kg, concentrations from the 0.9- to 1.2-m interval ranged from 8,400 to 12,200 µg/kg, and concentrations in row composite samples ranged from 1,220 to 7,400 µg/kg. Herbicides were detected infrequently. No herbicides were detected in any samples from the 0- to 0.3-m or 0.9- to 1.2-m intervals. Detected concentrations ranged from 40 to 750 µg/kg.
- Dioxins, specifically Total TCDD and 2,3,7,8-TCDD, were detected in all sediment samples analyzed. Data showed a general trend of increasing concentration with depth, although there were exceptions in individual cores. Total TCDD concentrations ranged from 290 to 3,800 nanograms per kilogram (ng/kg), and 2,3,7,8-TCDD concentrations ranged from 200 to 3,400 ng/kg.
- Mercury and lead were detected in every sample analyzed. A general trend of increasing concentration with depth was observed for both analytes. Mercury was detected at concentrations ranging from 1.4 to 12 milligrams per kilogram (mg/kg), and lead was detected at concentrations ranging from 210 to 1,100 mg/kg.
- Percent solids data and moisture content data show the expected trend of increased solids content with depth; however, no discernible trend of TOC concentration with depth was observed. TOC values ranged from 46,000 mg/kg (4.6 percent) to 81,000 mg/kg (8.1 percent).
- Silt was the predominant grain-size fraction, typically representing 70 to 80 percent of the sample; it was the dominant fraction in all but one of the samples analyzed. The sand fraction was highly variable, ranging from 5 percent to a maximum of 50 percent. The clay fraction was generally low, with a maximum value of less than 10 percent.

Based on a comparison of the pre-dredge sampling data to available historical data (i.e., Tierra's 1995 RI data), the more highly contaminated sediment is located deeper than the 1.2-m (4-ft) core depth. As a result, it is reasonable to assume that the 1-m (3.5-ft) dredging depth utilized for this Pilot Study did not reach the more contaminated sediment within this portion of the Harrison Reach.

PROJECT GOALS

An important goal of the Pilot Study was to collect the information necessary to "scale up" to a much larger remedial dredging program that could be considered for future implementation in the lower Passaic River. The Pilot Study consisted of two components: an environmental dredging demonstration (an evaluation of which is the focus of this manuscript) and a sediment decontamination technology demonstration. The objectives of the Pilot Study (NJOMR 2005b) were to:

- Evaluate dredging productivity and sediment resuspension
- Evaluate equipment performance, turbidity levels and engineering controls
- Evaluate lower Passaic River sediments, demonstrating they can be treated to meet applicable criteria for the designated beneficial use end product

The general scope and components of the Pilot Study are discussed below.

GENERAL SCOPE AND COMPONENTS

The Pilot Study utilized the data and information obtained as part of the pre-dredging activities and consisted of three general components:

1. Dredging/handling
2. Resuspension control/monitoring
3. Decontamination

Because this manuscript does not focus on treatment of the removed sediments, only the dredging and monitoring components are discussed in further detail. It should be noted, however, that the dredged sediments were scheduled to undergo testing at two separate decontamination facilities: Endesco/GTI for thermal treatment and Biogenesis for sediment washing. The results of this testing were not available at the time of this writing.

Similarly, it is important to note that, as of this writing, a construction documentation report had not yet been released to the public. As such, most of the discussion provided below is based on the project plans and public presentations.

Dredging/Handling

The Pilot Study design targeted the removal of 3,823 m^3 (5,000 cy) of sediment over a 5-day period. In order to meet this objective, the contractor was required to remove sediment at a rate not to exceed 765 m^3 (1,000 cy) per 12-hour work day (NJOMR 2005c). According to Ms. Lisa Baron of the NJDOT (February 1, 2006 Project Delivery Team [PDT] Meeting), Jay Cashman, Inc. (Cashman; Quincy, MA, USA) and Cable Arm, Inc. (Cable Arm; Trenton, MI, USA) actually dredged approximately 3,288 m^3 (4,300 cy) of sediments over the course of the Pilot Study. A 6.1-m^3 (8-cy) mechanical bucket was used for the dredging operation. River bottom material was removed to a depth of approximately 0.9 m (3 ft), and no greater than 1 m (3.5 ft), and was placed on a barge for dewatering and transport to the designated treatment vendors (NJOMR 2005c). At the decontamination facility, the material was unloaded onto a floating storage barge to await treatment.

Bathymetric information was obtained on a daily basis (as well as at the end of the Pilot Study) to estimate removal quantities and to determine final depths. Sediment profile images were also collected in and around the dredge area once the project was completed. According to Ms. Lisa Baron of the NJDOT (February 1, 2006 PDT Meeting), these images showed a thin layer of newly deposited sediment outside the dredge area and approximately 5 centimeters (2 inches) of newly deposited sediment inside the dredge area. Residual chemical sediment sampling was not conducted, nor was the dredge area backfilled/capped.

Resuspension Control/Monitoring

An integral part of this dredging study consisted of the measurement of sediment resuspension utilizing both fixed and mobile reference frames. The monitoring program was designed using results of the hydrodynamic and sediment transport model described previously. A stated objective of the Pilot Study was not only to track and quantify the sediments released during dredging operations, but also identify the type of monitoring necessary for a much larger operation (Bilimoria et al. undated).

It is important to recognize that the Pilot Study was conducted without any type of silt containment. The design was developed with the intention of accurately identifying and tracking the released and resuspended sediments without such controls. It was thought that such a program would help to identify the containment system(s) that would be required for a much larger operation.

The monitoring program involved a combination of six fixed locations and four monitoring areas covered by four boats, that extended no farther than 300 m from the dredging location (Figure 3). Three fixed moorings were located both upstream and downstream of the dredging area, with sensors placed 1 m below the water surface and 1 m above the sediment surface. The moorings were designed to monitor water column stratification and stability, particle concentration, and size distribution on a 24-hour basis throughout the Pilot Study (Bilimoria et al., undated). No chemical analyses were performed at these locations. Each mooring was equipped with two Conductivity-Temperature-Depth (CTD) probes, two Optical Back Scatter (OBS) sensors, and an Acoustic Doppler Current Profiler (ADCP) (Bilimoria et al. undated). The two moorings located along the centerline and closest to the targeted dredging area (at approximately 120 m) were additionally equipped with a Laser In-Situ Scattering and Transmissometry (LISST) probe (Figure 4).

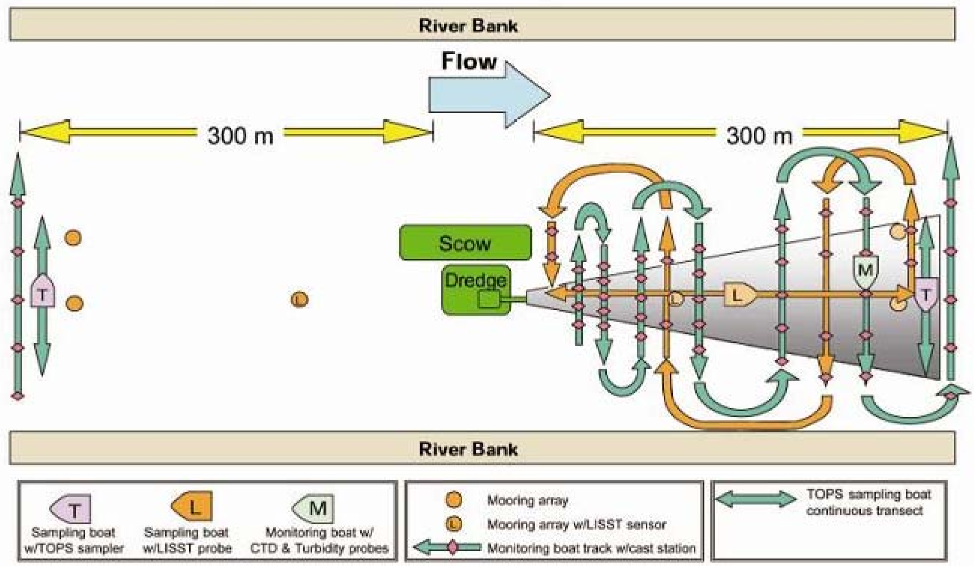

Figure 4. Pilot Study monitoring plan view (ebb tide) – mooring arrangement and boat track (NJOMR 2005b).

As described by Bilimoria et al. (undated), the mobile monitoring boats varied in equipment and purpose. Two of the four boats were equipped with a global positioning system, a depth profiler, a Trace Organic Platform Sampler (TOPS) apparatus, and two ISCO automatic samplers. These boats ("T-boats") performed continuous traverses perpendicular to the river flow at half-hour intervals along the 300-m transects: one up-river and the other down-river from the dredge site (Figure 4). They collected water samples for TSS, particulate and dissolved organic carbon (POC and DOC), chloride/bromide, filtered and unfiltered metals, low-level mercury, dioxins/furans, PCB congeners and pesticide analyses. The other two boats did not collect samples for analyses. The third mobile monitoring boat was equipped with a CTD probe, an OBS sensor, and an ADCP. Identified as the "M-boat," it traveled across the dredging plume in a zigzag pattern approximately seven times in one hour (Figure 4). The final boat ("L-boat") was similar to the "M-boat," but carried a LISST probe in lieu of the ADCP and traveled parallel to the river flow (Figure 4). To a lesser extent, it was planned that this "L-boat" would also travel in a non-linear manner to identify the edges of the plume (Bilimoria et al. undated).

The monitoring schedule consisted of 1 day of pre-dredge background monitoring, 5 days of during-dredge monitoring and 1 day of post-dredge monitoring (Bilimoria et al. undated). Pre-dredge background monitoring was performed by the two "T-boats" 4 days before the dredging activities were to commence. These "T-boats" conducted the during-dredge monitoring, as well, which was performed during all 5 days of construction. Two days after the conclusion of dredging, one "T-boat" was deployed to conduct the post-dredge monitoring.

EVALUATION OF STUDY DESIGN

The objectives of the Pilot Study were to study a number of dredging issues and to collect the information necessary to "scale up" to a much larger remedial dredging program that could be considered for future implementation. However, the manner in which the Pilot Study was designed and implemented raises questions about its usefulness for future decision-making. According to the USEPA Office of Solid Waste and Emergency Response Directive (1988), the purpose of a pilot study should be to "simulate the physical as well as chemical parameters…and accurately simulate the performance of the full-scale process," and should be "operated in a manner as similar as possible to the operation of the full-scale system." The design of the Pilot Study falls short of meeting these purposes. The operational components of this study appear to have been set up for "success" by utilizing artificial constraints and idealized situations. It is, therefore, highly questionable that this Pilot Study is adequately predictive of a larger-scale operation. The following discussion highlights some of the more significant issues.

Project Location

The location of the Pilot Study was not representative of river conditions that would be encountered during a full-scale dredging program. For example, dredging operations were conducted in a relatively straight portion of the river to reduce the complexity of estimating and evaluating water quality impacts (NJOMR 2005b). In a full-scale dredging operation, such complexities cannot be avoided. The lower Passaic River contains numerous bends that are known to collect and trap sediments along their inner channels, and to produce complex circulation patterns and higher flow velocities. The significant challenges of dredging within these more complex conditions cannot be assessed through this Pilot Study, especially if a dredge plume containment system were required to mitigate dredging impacts.

In addition, as described in the Dredging Pilot Project Plans (NJOMR 2005b), "Targeted sediments should have moderately elevated contamination levels…though not levels that would create major handling problems…This reach provides an opportunity to handle and process the widest range of contaminated sediments and, therefore, the results obtained from the pilot program can be expected to have the broadest applicability to ultimate remediation of the river system." Therefore, it is clear that the Pilot Study design sought to minimize handling problems associated with removal and transport of the sediments and to minimize the challenges associated with treatment. In fact, by limiting the dredging depth to less than 1 meter (3.5 ft), the Pilot Study intentionally avoided some of the more highly contaminated material present at depth. This restriction has major implications for decontamination and for resuspension and residuals management.

Dredging Design

For this Pilot Study, the NJOMR utilized a single Cable Arm clamshell bucket to dredge the targeted sediments from the Study Area. This technology was designed to provide a relatively flat cut and a watertight seal for the dredging of contaminated sediments. While this approach and design may be adequate for removing the rather limited (and shallow) sediments targeted under this Pilot Study, this technology may not be effective for larger-scale remediation. The effectiveness of the Cable Arm system at more significant sediment depths and in sediment with different grain-size distributions and debris content is unclear.

At a minimum, different bucket types and sizes should have been tested during the Pilot Study for performance comparisons, especially considering the presence of debris (discussed below). In addition, an assessment of the relative performance of other dredging (e.g., hydraulic) technologies and a limited site-specific comparison of mechanical versus hydraulic dredging (within the budget constraints of the Pilot Study) would have provided valuable information. It is far too early in the LPRRP RI/FS process to eliminate technology options, especially one of the potential importance and utility of hydraulic dredging.

Debris is present throughout the lower Passaic River, and it is likely that a dedicated debris extraction operation will be necessary for a larger-scale operation. In addition, debris extraction can be even more disruptive to native sediments than actual dredging operations. However, the Cable Arm clamshell bucket typically does not perform well in the presence of debris (as demonstrated during the Pilot Study, when debris broke the bucket's watertight seal, resulting in significant releases of sediment). The Pilot Study could have provided a valuable opportunity to determine the most effective technology for debris removal and to evaluate the impacts of the sediment releases on the surrounding water column and benthos.

In addition, the Pilot Study failed to establish or enforce water quality performance standards. Therefore, it did not provide essential information that must be taken into account to meet those standards when designing a larger-scale dredging operation for the lower Passaic River (e.g., the speed of the dredgehead, the cycle time of the bucket).

Ironically, although one of the project goals was to identify the type of containment system that would be required for a large-scale dredging operation, the NJOMR decided not to test containment systems during the Pilot Study. This appears to have had a major limiting effect on the overall utility of the study. The presence or lack of a containment system dramatically affects the manner in which work is conducted and the environmental impacts of the dredging operation. Typically, containment systems require significant attention/maintenance throughout a project and, therefore, can detract from productivity and add to costs. However, this information was not obtained, thus precluding the Pilot Study's ability to support decision-making regarding the need for, performance of, and cost of a containment system for dredging operations in the Passaic River.

Constraints were also placed on dredging production, which is counter-intuitive to a pilot study of this sort. As indicated, a dredging rate of approximately 765 m^3 (1,000 cy) per day was dictated in the project specifications, with no more than 3,823 m^3 (5,000 cy) of sediments to be removed over the 5-day period (NJDOT 2005). In addition, on at least one day, dredging operations ceased early to ensure that material would be available for removal on the following day (according to Ms. Lisa Baron [NJDOT] at the February 1, 2006 PDT Meeting). To truly understand production rates that might be achieved on a larger scale, such constraints cannot be imposed, as they clearly eliminate this variable from consideration.

Results from the Pilot Study must be used and applied with great caution when one considers the limited depth to which the bucket was allowed to penetrate. As called for in the specifications (NJDOT 2005), dredging was to proceed to a depth not greater than 1 m (3.5 ft), which has several implications. First, as shown in previous sections of this manuscript, significantly higher constituent concentrations are generally found below this one meter (3.5 ft) elevation in the lower Passaic River. In the case of any larger-scale program, such deeper sediments likely would be targeted for removal as well. Consequently, a number of unknowns still exist, even after the Dredge Pilot Study, including:

- How would water quality conditions be impacted at full-scale?
- What type and volume of residuals would be left behind at full scale?
- Will side slope stability and/or sediment sloughing be an issue, and if so, how would it be addressed?

Thus, this Study provides no guidance or evaluation concerning such impacts in connection with any dredging that may be proposed to a depth greater than 1 meter.

Finally, residuals are known to be an issue for most, if not all, sediment dredging projects. Residuals are defined as sediment (and associated contamination) that is left behind following removal operations and, typically, cannot be practicably removed, even following multiple clean-up dredging passes. Residuals can be generated by the resuspension and resettling of targeted sediments, sloughing from un-dredged side-slopes, or the exposure of contaminated sediments that, prior to dredging, were buried deeper beneath the surface. In the case of this Pilot Study, it would seem prudent, if not critical, to understand this specific phenomenon in the Passaic River. However, as noted previously, the Pilot Study did not include a post-dredging residuals sampling program. This represents one of the more critical data gaps of the overall program.

Resuspension Monitoring Design

A key aspect to the overall Pilot Study was the resuspension monitoring program. Proper design and implementation is essential to accurate data collection to inform regarding sediment releases during dredging operations. The following discussion outlines the intended monitoring program (based on NJOMR's project plans), and highlights significant shortcomings.

The monitoring program was not sufficient to identify and fully track any plume that was generated by the dredging operations. According to the Final Dredging Pilot Study Project Plans (NJOMR 2005c), attempts to track the dredge plume were confined to a 300-meter threshold – a threshold which is generally considered unacceptable as most of the sands may have settled out by this point. Although it is widely recognized that the finer particles adsorb most constituents, and therefore have the greatest impact on contaminant redistribution, the Dredging Pilot Study should have attempted at least to determine where such fines are no longer in suspension.

Furthermore, the project plans do not explain how, or if, the boats monitoring the dredge plume first identified the point closest to the source (within safe operations), and then tracked the plume down-current of the source. Ideally, once the plume is identified, the boats performing the monitoring should have mapped the extent of the plume (top and bottom edges, side edges, and location of maximum TSS concentration) as a function of distance down-current from the dredge area. This information is critical for proper monitoring of the plume and understanding the impact from dredging operations.

Similarly, once the plume is mapped after the start of each dredging event, it should be monitored to ensure that samples are collected from within the plume over the duration of the sampling event. Such monitoring is important to support accurate characterization of plume intensity (as a function of TSS, OBS, LISST, etc). In addition, attempts should be have been made to evaluate the distribution of chemical compounds from the dredge area.

As indicated previously, the fixed monitoring locations established for this Pilot Study were determined based on the results of the hydrodynamic and sediment transport model. Whether or not these fixed devices actually detected the plume in a meaningful way is unknown. It is highly unlikely that such fixed stations as used in this Study could identify and characterize a plume that, in itself, is dynamic in time and space.

Lastly, given the myriad water-born vehicles that were associated with this project, it will likely be very difficult to interpret the resuspension data once it is received. There were numerous indications of localized sediment resuspension occurring throughout the program, much of which was not directly associated with the actual dredging apparatus. As mentioned by Ms. Lisa Baron (NJDOT) at the February 1, 2006 PDT Meeting, such examples include the multiple sampling/monitoring boats and rinse tank movement on the water.

CONCLUSIONS

The artificial constraints placed on the Dredging Pilot Study violate the fundamental tenets of a properly designed pilot study. Such constraints make it unreliable, if not impossible, to extrapolate the results for larger dredging applications in this system. A number of examples can be cited to support this conclusion, one of which includes the identification of the project location. The NJOMR acknowledges that the area was selected based on its relatively optimal setting when considering river configuration, access characteristics, sediment contamination, and river velocity. These selection criteria alone suggest that the project (and the associated information obtained) is biased to simplicity and not representative of conditions that will more likely be encountered during larger operations. Furthermore, the Pilot Study targeted only the top 1 m (3.5 ft) of sediment material in this discrete region. The material in this area, and at this limited depth, has been shown to contain low-to-moderate levels of contamination relative to deeper sediments and/or sediments in some other areas of the lower Passaic River. Therefore, should future assessments indicate the need to excavate deeper, where contaminant levels are shown to be much higher, the Pilot Study will be of limited use. Such significantly different conditions will introduce significant new problems (e.g., sediment sloughing), unaddressed by this highly constrained pilot study.

Another fundamental, related concern regarding this Pilot Study centers on its lack of clearly established data use and data quality objectives. For example, the project aims to show that Passaic River sediments can be "successfully dredged," however, criteria for success are never clearly defined (NJOMR 2005b). Successful pilot projects are designed to answer very specific and critical questions related to a given technology, and should establish performance metrics in advance to support the interpretation of the data collected.

It should be clear that while the 2005 Passaic River Dredging Pilot Study produced some information that was not previously known, little can be said for its utility in "scaling up" to a larger-scale dredging operation. The only true statement that can be made at this point is that, under optimal environmental and operational conditions, low- to moderately-contaminated sediments at shallow depths can be removed (and likely treated) from relatively straight segments of the lower Passaic River using a mechanical bucket. There are still myriad questions and unknowns related to the feasibility and ultimate "success" of any significantly larger-scale dredging program in this system, including (but not limited to) unknowns as to proper equipment type, residual concentrations, debris removal, production rates, sediment releases/containment, and costs. As a result, additional studies must be conducted, and/or greater consideration given to these issues before a large-scale program can be contemplated within this river system.

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