ENVIRONMENTAL DREDGING PILOT ON THE LOWER PASSAIC RIVER: ONE OF AMERICA'S MOST POLLUTED RIVERS

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ABSTRACT

As part of the Lower Passaic River Restoration Project, an environmental dredging pilot study was implemented in December 2005 to evaluate remedial dredging of contaminated sediments from the Lower Passaic River in New Jersey. The dredging pilot was led by NJDOT along with the USACE and USEPA.

Approximately 5,000 cubic yards (cy) [3,825 m^3] of contaminated sediment were dredged from a 1.5 acre [6,070 m^2] area in 10 to 15 feet [3.0 to 4.6 m] of water at an average rate of 830 cy [635 m^3] per 10-hour workday using an eight (8) cy [6.12 m^3] Cable Arm® mechanical clamshell dredge bucket. The dredge bucket was equipped with sensors for bucket positioning and monitoring bucket closure. The results of a comprehensive monitoring program to evaluate near-field and downstream transport of the contaminated sediment are documented in a separate manuscript (Bilimoria et al., 2006).

One of the pilot study objectives was to determine a reasonable production-rate for remedial dredging. The specifications required a vertical dredging accuracy of +/- 6 inches [15 cm]. Design techniques and other nuances of the dredging design are presented. In general, the average daily cycle times ranged from 1 3/4 to 2 3/4 minutes. A rinse tank was used to clean the dredge bucket between each cycle. Numerous variables, and their effects on sediment resuspension and transport, were tested during the study, including:

- Dredging cycle time;
- Depth positioning technique (depth transducers vs. measuring chain);
- Equilibration holding time (i.e., length of time the bucket was held in position at the water surface to allow for pressure equilibration); and
- Number of lifts per dredging area.

The dredged material was transported to a near shore processing facility for treatment by two innovative decontamination technologies (a sediment washing process and a thermo-chemical destruction process using a rotary kiln) to make beneficial use end products.

Keywords: Dredging productivity, contaminated sediments, Cable Arm, urban river, mechanical dredging

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INTRODUCTION

A pilot study of remedial dredging was conducted in the Lower Passaic River in Newark, New Jersey in December 2005 (Figure 1). The pilot study was performed as part of the Feasibility Study for the Lower Passaic Restoration Project. The U.S Environmental Protection Agency, Region 2 (EPA), the U.S. Army Corps of Engineers, New York District (USACE), and the New Jersey Department of Transportation, Office of Maritime Resources (NJDOT) formed a partnership with U.S. Fish and Wildlife Service (USFWS), National Oceanic Atmospheric Administration (NOAA) and New Jersey Department of Environmental Protection (NJDEP) [Partner Agencies] to carry out the Lower Passaic River Restoration Project. The Lower Passaic River Restoration Project is also being performed as a pilot program under the Urban Rivers Restoration Initiative under joint Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Water Resource Development Act (WRDA) authorities. Funding for the remedial dredging pilot study was provided by the NJDOT as cost-shared funding for the WRDA portion of the project. The Feasibility Study will address remediation and restoration of the 17-mile [27.3 km] tidally influenced Lower Passaic River and its surrounding watershed.

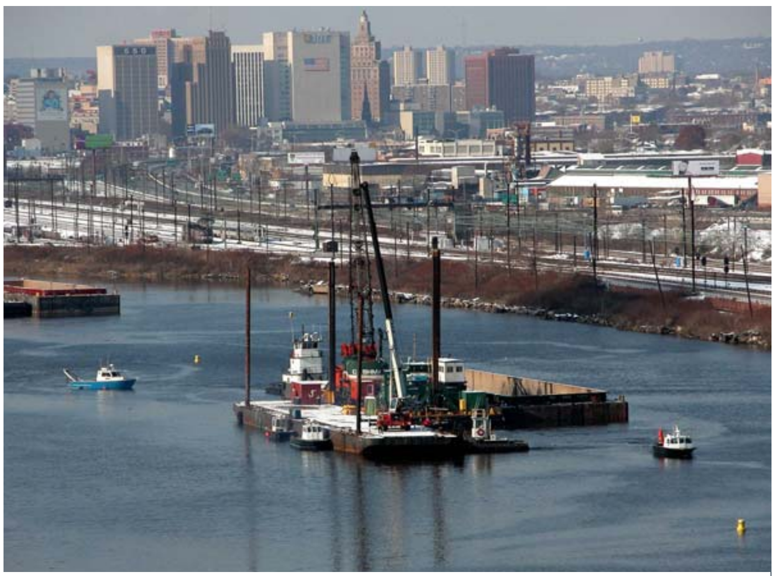

Figure 1. Environmental Dredging Pilot on the Passaic River

Site Background

The Lower Passaic River is a highly degraded urban waterway. The project study area begins at the Dundee Dam in Clifton, NJ and proceeds 17 miles [27.3 km] through four counties in New Jersey to its confluence with Newark Bay (Figure 2). The river is contaminated as a result of more than a century of heavy industrial use. Pollutants in sediment include dioxin, DDT, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), mercury, arsenic, lead, cadmium, and other organic and inorganic chemicals. Currently, fishing advisories are maintained by the State of New Jersey as a result of the bioaccumulation of dioxin, PCBs, and mercury into fish tissue. The Lower Passaic River is an estuarine river and is tidally influenced for all or nearly all of its length. The upper 1-2 miles [1.6 – 3.2 km] of the river are dominated by freshwater inputs from flows over the Dundee Dam. At its confluence with Newark Bay, the river is brackish in nature, with typical bottom salinities of 14-23 parts per thousand. A Federal navigation channel is authorized in the Lower Passaic River. Because of the contamination in the sediments, the navigation channel has not been adequately maintained for decades; as a result, significant shoaling (up to 15 ft [4.6 m]) exists in the channel. Furthermore, contaminants from the Lower Passaic River impact the quality of the sediment in Newark Bay, which is the location of critical navigation channels in the Port of New York and New Jersey. For more detailed site background, see **http://www.ourpassaic.org**.

Figure 2. Project Location Map

Pilot Study Overview

The dredging pilot study targeted approximately 5,000 cy [3,825 m^3] of sediment in the Federal channel and adjacent areas. Dredging was performed over an approximately 1.5 acre [6,070 m^2] area to depths of approximately 3 feet [0.91 m]. The dredged material was transported to a near shore processing facility for treatment by two innovative decontamination technologies. These technologies are expected to process the dredged material into beneficial use end products. A portion of the Lower Passaic River sediment has been dewatered and 300 cy [230 m^3] of the dewatered material will undergo treatment with a thermo-chemical destruction process using a rotary kiln. Construction-grade cement will be produced during the treatment process, which could be used in the construction of sidewalks, parking lots, and driveways. The remaining sediment is being treated using a sediment washing process to produce a manufactured soil product. The decontaminated soil could be used in a number of land-based applications, such as upland remediation and landscaping.

The major objectives of the pilot study included:

- Evaluate dredging equipment performance. This includes productivity, precision (achieving targeted dredging depth and cut lines), turbidity levels, and operational controls.
- Monitor sediment resuspension. This includes determining how much sediment is released from the dredging activity and where that sediment is transported. The monitoring program will help determine what kind of engineering controls would be required for a full-scale sediment removal action.
- Evaluate sediment decontamination and treatability. The pilot will evaluate the technical feasibility and economic viability of two decontamination technologies to treat contaminated Lower Passaic River sediments and determine whether a valuable product, such as manufactured soil or construction-grade cement, can be produced at full scale.

This paper provides the preliminary results of the Pilot Study for the following aspects of the work:

- Study Design
- Dredging Performance (volumes and accuracy)
- Dredging Productivity (including working time analysis)

The preliminary results for the resuspension evaluation are presented in a separate paper (Bilimoria et al., 2006). The final results for all aspects of the pilot study will be presented in a report anticipated to be released in the summer of 2006.

Pilot Study Design

The Partner Agencies conducted an extensive data collection effort in preparation for the pilot study. Studies included: environmental dredging technology review, hydrographic surveys, side-scan sonar, sub-bottom profiles, magnetometry and gradiometry surveys, sediment coring (to characterize chemical and geotechnical properties of the sediment), hydrodynamic studies, and predictive plume modeling. Detailed Project Plans for implementation including a Work Plan, a Quality Assurance Project Plan, and Health and Safety Plans were also prepared. All activities conducted in support of the environmental dredging pilot study are posted on **http://www.ourpassaic.org**.

Design plans and specifications were prepared for procurement of a dredging contractor by NJDOT. Elements of the design rationale conveyed in the bidding documents are as follows:

Limits of Dredge Prism

In order to avoid the underlying highly contaminated materials, the design called for a shallow excavation (maximum depth of –3.5 ft [-1.1 m]). The area to be dredged was divided into cells, the widths of which mimic the topography of the bottom surface to minimize overall cut depths, and the lengths of which are consistent with the length of the area that has been characterized (see Figure 3). In order to estimate the total volume of material to be removed, a side slope of 3:1 was assumed, which has also been calculated to be a theoretically stable slope. However, while small portions of sand are present in the targeted sediments, much of the targeted materials are soft estuarine silt deposits. It was recognized that sloughing may occur at the edges of the excavation, which the contractor had to consider in executing the work.

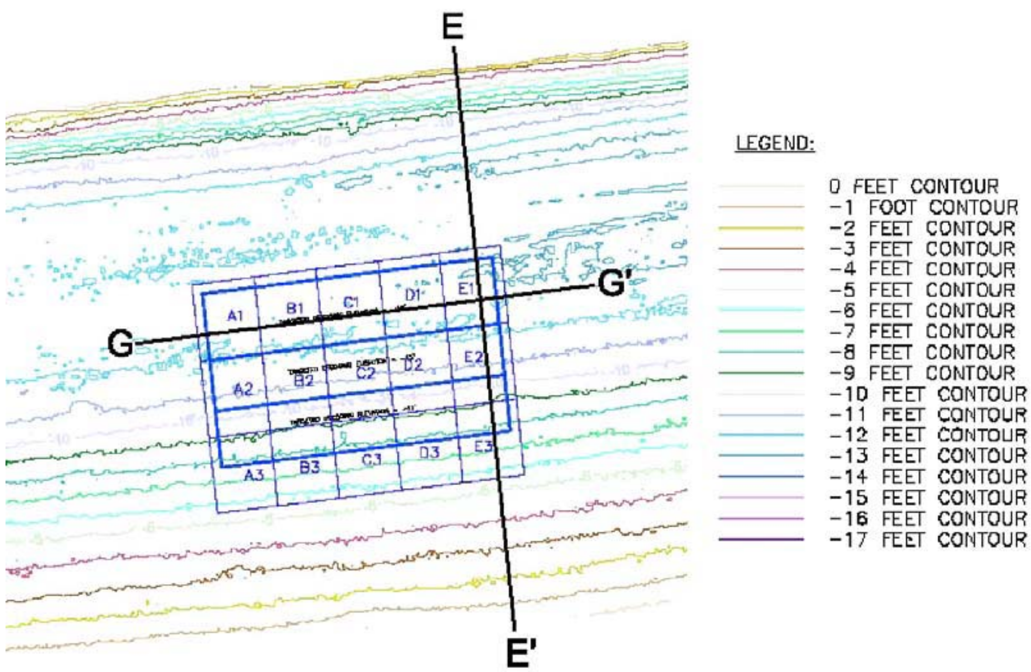

Figure 3. Dredging Plan and Cross Section Locations (E-E' and G-G')

(1 foot = 0.3m)

Figure 3 shows the sampling grid (with cells A1 through E3), the limits of dredging (smaller area outlined in dark blue) and the locations of cross-channel section E-E' and along-channel section G-G' within the dredging area. It also shows the bathymetry with one-foot contour intervals.

Volume of Dredge Prism

In order to allow for sediment to accumulate in the area to be dredged in the time between the design (initiated in 2004) and execution of the work, less than 5000 cy [3,825 m^3] were targeted. The design plans show 4700 cy [3,595 m^3] targeted for removal, based on a March 2004 bathymetric survey conducted during the planning and design phase. The contractor's pre-dredge survey conducted in late November 2005 (approximately 1 week prior to dredging) indicated approximately 4300 cy [3,290 m^3] in-situ was targeted for removal. This difference in volume between the March 2004 and November 2005 surveys is possibly a result of scour (there were significant storm events in the spring and fall of 2005 with river flows over 12,000 cubic feet per second [340 m^3/sec.]) in the area. However, it was assumed most likely a result of differing surveying techniques: the March 2004 survey was performed using single beam techniques while the November 2005 survey was performed using more accurate multi-beam techniques. All construction phase bathymetric surveys were performed using multi-beam survey techniques.

Payment and Procurement

Contractor payment was on a fixed price (lump sum) basis. Based on experience with other similar dredging projects, a sliding scale for payment was developed. The purpose of this sliding scale was to provide an incentive to the contractor to dredge as rapidly as possible with the given constraint of a + / - vertical accuracy tolerance. The dredging contractor was to be paid in full if 90% of the dredged area was within a specified tolerance, was to be paid 90% if 80% of the dredged area was within the tolerance, and was to be deemed incomplete if less than 80% of the dredged area was within the tolerance. This approach was developed to encourage normal productive environmental dredging, not slow, precision (cleanup) dredging. The contractor was procured by NJDOT through a competitive process and was selected by evaluating cost and other factors. The winning contractor, Jay Cashman, Inc., of Quincy, MA was the lowest responsive bidder.

Results

Dredging Execution

Dredging was performed from the upper three feet of a 1.5 acre [6,070 m^2] area in the Harrison Reach just west of the New Jersey Turnpike Bridge. The dredge prism consisted of three cut lines approximately 300 feet [91.5 m] long at elevations of 11 feet, 13 feet, and 15 feet [3.3 m, 4.0 m, and 4.6 m] below mean low water (MLW). The dredging was conducted in 10 to 15 feet [3.0-4.6 m] of water at low tide. Dredging required five days of operation over the six day period of December 5-10, 2005. Dredging was suspended on December 9th due to poor weather conditions (heavy snow, ice, and gale force winds) that impacted the water quality sampling program. Based on the review of the debris survey data, the contractor chose not to perform pre-dredging debris removal, and debris was not an issue during dredging. Overall, dredging occurred at a rate of less than 1000 cy [756 m^3] per workday using an eight (8) cy [6.12 m^3] mechanical clamshell (Cable Arm®) dredge bucket. The bucket was equipped with depth penetration transducers and bucket closure sensors (the bucket closure sensors did not function properly for approximately the first day and a half of work and manual measurement techniques were employed).

The dredge was operated with average daily cycle times ranging from 1 3/4 to 2 3/4 minutes. A rinse tank was used to clean the dredge bucket between each cycle. Dredging cycle times, depth positioning technique (Cable Arm® depth transducers vs. measuring chain), equilibration holding time (i.e., length of time the bucket was held in position at the water surface to allow for pressure equilibration) and number of lifts per dredging area varied throughout the week of dredging. The effects of each of these variables on sediment resuspension and transport were tested during the study.

The ClamVision software displayed a 3D, color coded surface derived from existing hydrographic survey data. Each bucket grab was recorded and color coded based on cut depth or grabs left. An information box provided instant feedback showing current depth, final project depth, target depth, current bucket depth and an indication that the bucket was closed and sealed. Figure 4 illustrates the cumulative area dredged over the course of the five days. The 13 ft [4.0 m] cut was dredged on December 5, 2005, the 11 ft [3.3 m] cut was dredged on December 6, 2005 and the 15 ft [4.6 m] cut was dredged on December 7, 8, and 10, 2005. The duration of dredging the 15 ft [4.6 m] cut was spread over three days in order to allow the resuspension monitoring to occur over several ebb and flood tides. The portion of Figure 4 shown in yellow (all of the 13 ft [4.0 m] cut and a large portion of the 11 ft [3.3 m] cut) was dredged without the aid of the Cable Arm® depth sensors. On December 5 and up to 4:20 PM on December 6, 2005, paint marks on the chains holding the bucket were used to assist the dredge operator. From that time onwards until the end of the dredging on December 10, 2005 the Cable Arm® depth sensors were utilized. The areas dredged with the Cable Arm® depth sensors functioning are shown in red on Figure 4. These differences in dredge operation did affect the dredging accuracy as shown in the results discussed below.

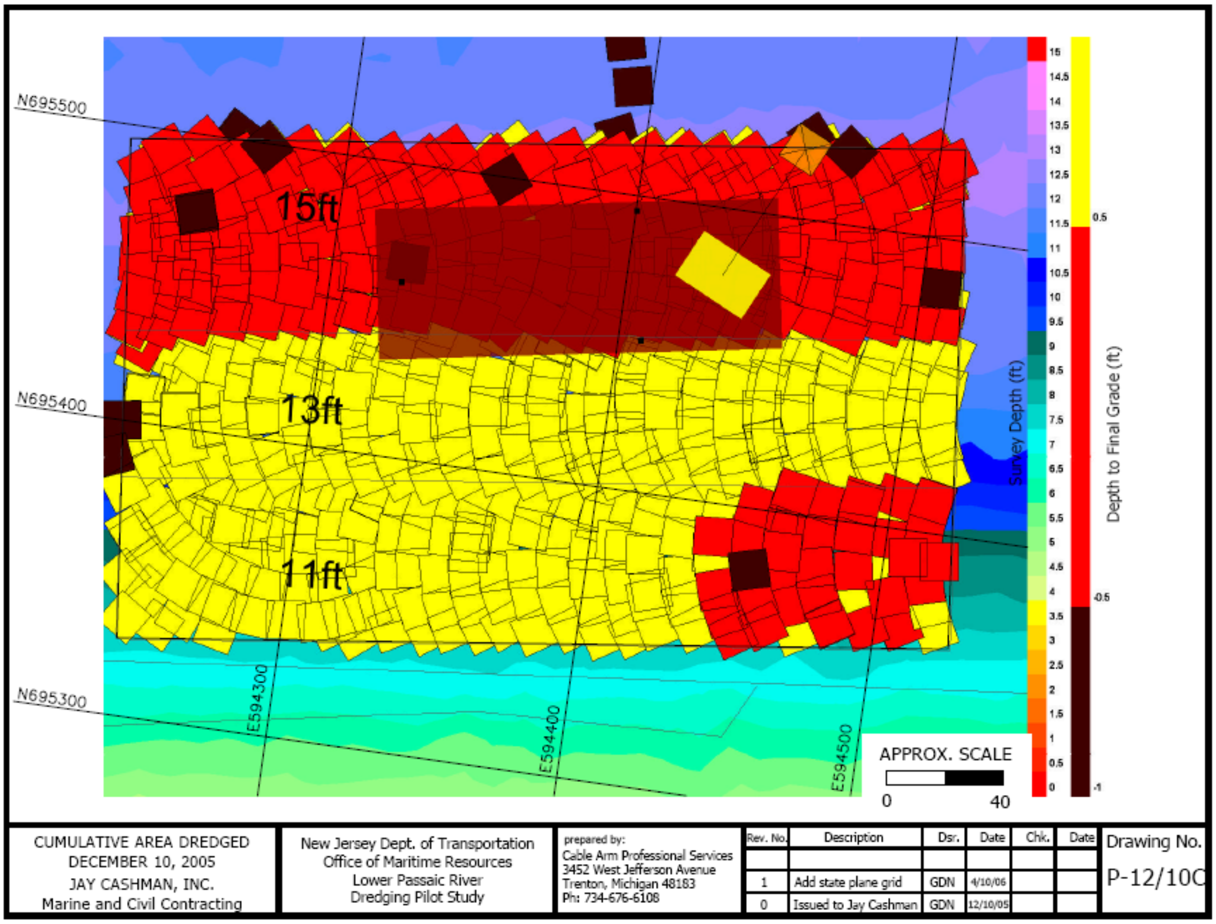

Figure 4. Clam Vision, Cumulative Area Dredged Over the 5 Day Pilot Program

(1 foot = 0.3m)

Following dredging, the sediment was transported in 3000 cy [2,295 m^3] scows to the Bayshore Recycling Inc. (Bayshore) facility located on the Raritan River in Keasbey, NJ. There the sediment was off-loaded to the Valgocen, a 730-foot [249 m] bulk carrier vessel owned by Bayshore to await decontamination treatment.

Below is a discussion of the preliminary data collected for the dredging pilot for dredging volumes, dredging accuracy, working time, and productivity calculations.

Volumes

Table 1 presents a summary of the quantities dredged during the project, the location of the dredging (e.g., which cut elevation), and the typical operational characteristics for that day's work. A total of 4,150 cy [3,175 m^3] were dredged, with an average of 830 cy [635 m^3] per day. The quantities presented are in-situ volumes and determined using the contractor's daily multi-beam bathymetric surveys.

Table 1. Dredging Volume and Work Summary
(1 cy = 0.765 m^3; 1 in. = 2.5 cm; 1 foot = 0.3 m)

Date	Volume Dredged (cy)	Dredging Time (hours)	Location of Dredging	Operational Characteristics
Dec 5	942	7.25	-13 ft MLW Cut	Cable Arm sensors not working used bucket chain method, single lift per area, no extended equilibration time.
Dec 6	1367	6.6	-11 ft MLW Cut	Cable Arm sensors not working until 4:20 PM, used bucket chain method, single lift per area, no extended equilibration time.
Dec 7	834	7.17	-15 ft MLW Cut	2 lifts per area
Dec 8	486	5.58[6]	-15 ft MLW Cut	2 lifts per area
Dec 9	No dredging due to weather			
Dec 10	522	5.25	-15 ft MLW Cut	2 lifts per area, extended bucket equilibration time
TOTAL	4,150	38.12		
AVERAGE	830 cy/day	6.27		

Accuracy

The contractor's goal was to achieve a vertical accuracy of dredging of plus or minus six inches [15 cm]. An evaluation of the accuracy achieved was made by comparing the pre-dredging and daily post-dredging bathymetric survey data. Soundings on 3 ft by 3 ft [0.9 m by 0.9 m] horizontal grid were plotted to determine their location with respect to the dredge prism. Soundings that fell within a given design cut elevation were compared to that elevation. A summary of the findings is presented in Table 2. 66 to 72% of the area (actually the individual survey points) was dredged within 6 in [15 cm] of the design elevation, 82% to 89% of the area was dredged within 9 in [0.23 m] of the design elevation, and 92 to 94% of the area was dredged within 12 in [0.3 m] of the design elevation. Overall, the days that the Cable Arm® sensors were functioning (portion of Tuesday, Wednesday, Thursday and Saturday), demonstrate an improvement in dredging accuracy (increase of 7%) in order to achieve the targeted depth.

[6] Dredging on December 8 was restricted due to pilot's need to dredge over the course of five days in order to fulfill the requirements of the water quality monitoring program.

Table 2. Summary of Dredging Accuracy Data
(1 cy = 0.765 m^3; 1 foot = 0.3 m)

Design Cut Depth (feet below MLW)	% of Area Within 6"		% of Area Within 9"		% of Area Within 12"	
	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor	Without Cable Arm Sensor	With Cable Arm Sensor
11'	60	69	74	81	84	90
13'	65	--	85	--	95	--
15'	--	79	--	90	--	95
TOTAL	66	72	82	89	92	94

The accuracy achieved was somewhat lower than anticipated during the design preparation. After completion of the work, it was reported by the contractor that the dredge prism was not entered correctly into the dredging positioning (ClamVision) software. More specifically, where the design plans showed the bottom or toe of slope, it was configured in the ClamVision software as the top of slope. This issue caused under-dredging of 5 to 10 feet [1.5 to 3 m] on each edge of the dredge area and each transition in elevation. This was evident by viewing post-dredging cross sections (Figures 5a and 5b). Upwards of 10% of the dredging area could be affected by this issue.

Cross Channel Section E-E

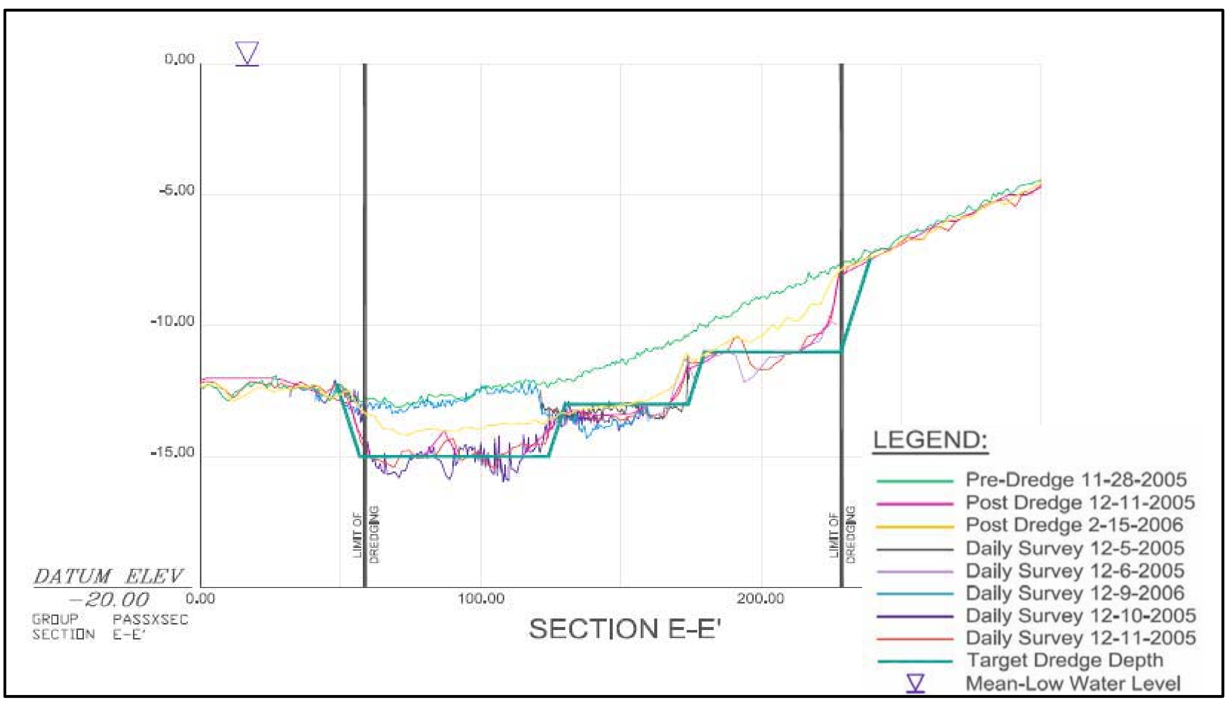

Figure 5a. Typical Post Dredging Cross Sections
(1 foot = 0.3m)

Along Channel Section G-G

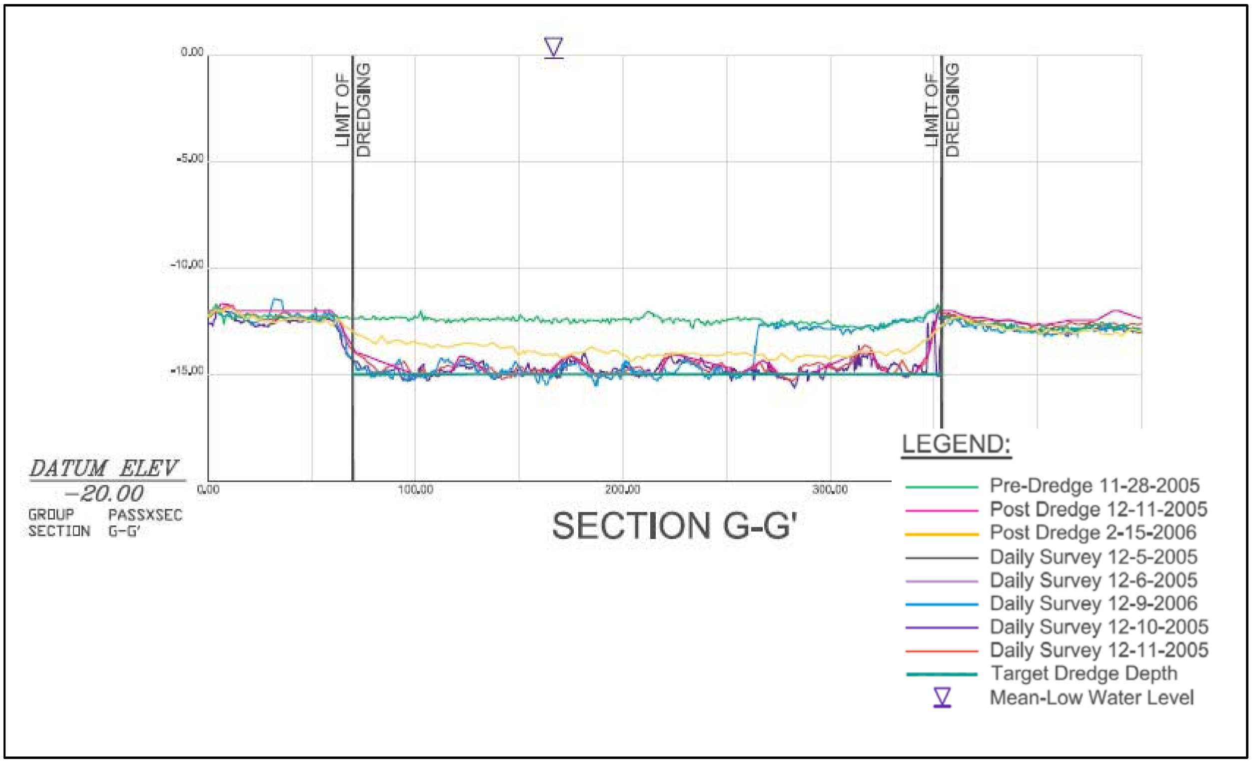

Figure 5b. Typical Post Dredging Cross Sections

(1 foot = 0.3m)

Figures 5a and 5b display cross sections E-E’ and G-G’, respectively. The different colored lines represent the various daily surveys, as well as pre- and post-dredge surveys. An additional post-dredge survey was conducted on February 15, 2006, and it shows that approximately 50% of the dredged area has already been filled in by natural deposition.

Working Time

During the work, logs were kept to record the times and duration of all equipment set-up, equipment moves, equipment downtime, surveying, dredging, and client-directed standby time. A working time analysis was performed to evaluate the amount of total working time that the dredge was performing actual dredging. A summary of the weekly average working time is shown in Figure 6. This data and analysis were important in estimating the hourly production rates presented and discussed below.

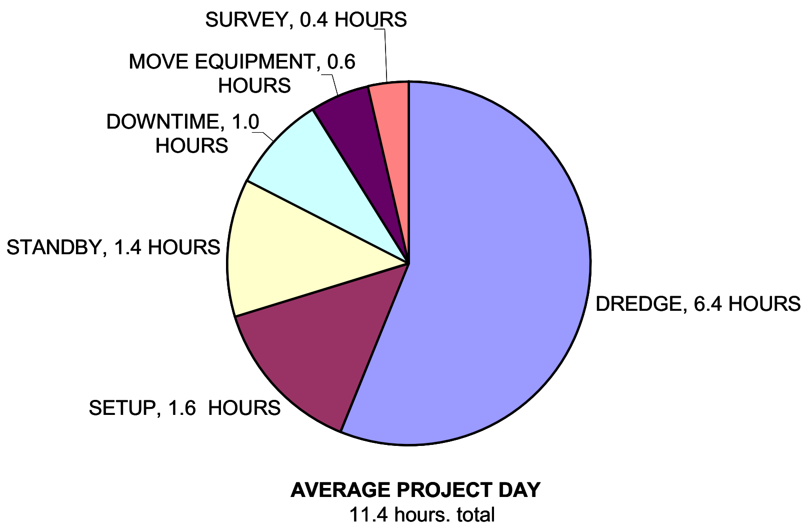

Figure 6. Summary of Weekly Average Working Time

Productivity

Average hourly production rates were calculated for each day of dredging. The average hourly production rates were calculated in three ways, for each day's given volume: (1) as a function of total hours on site (including client directed standby time); (2) as a function of total working time (e.g., total time on-site minus client-directed standby time); and (3) as a function of total dredging time. During the pilot study, client-directed standby time was used to allow for alignment of the dredging activity with the resuspension monitoring activities, and is therefore considered to be an artifact of the pilot program and not part of the actual working time. A summary of the productivity calculations is presented on Figure 7.

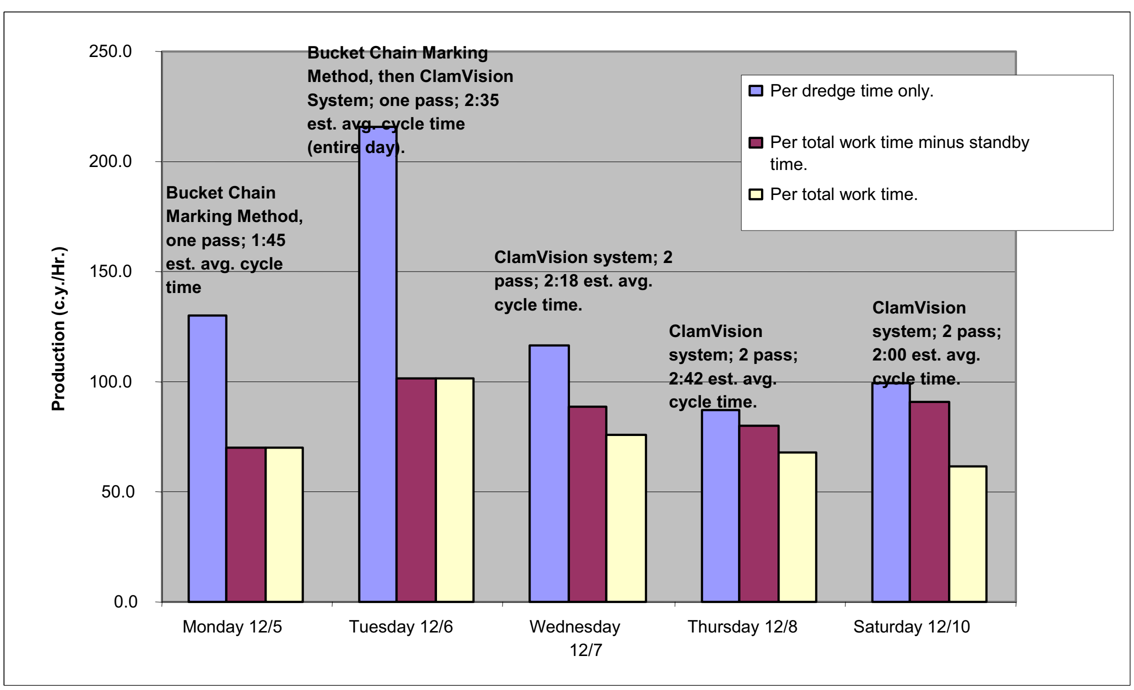

Figure 7. Daily Productivity Data

The average working day was 10 hours and the average dredging time was 6.4 hours, yielding an average up-time of 64%. Per our discussions with the USACE and other dredging contractors, this amount of up-time is typical for mechanical dredging operations. The weekly average production rates are shown on Table 3.

Table 3. Productivity Data Summary
(1 cy = 0.765 m^3)

Productivity Analysis Type	Average Hourly Production Rate (cy / hour)	Range of Daily Average Production Rate (cy / hour)	Comments Regarding Scale up
As a function of total time on site	74	61 – 101	Not representative data given that standby time was an artifact of the pilot study
As a function of total working time	84	70 – 101	Representative data given that average up-time is typical
As a function of total dredging time	130	87 – 216	Representative data

CONCLUSIONS

The Environmental Dredging Pilot Study field effort was successfully implemented in December 2005. The Environmental Dredging and Sediment Decontamination Technology Pilot Study will provide valuable site-specific information in order to evaluate the removal option as a potential remedial solution for the Feasibility Study. Findings related to the dredging accuracy, working time, and productivity analyses are as follows:

- The design called for dredging to within a + / - 6 in [15 cm] vertical accuracy. The dredging performed was considered first pass or production dredging, not precision or clean-up dredging. The contractor achieved the + / - 6 in [15 cm] accuracy over 66 to 72% of the dredging area, depending on the positioning technique employed. An issue with the set-up of the dredge positioning software could have resulted in upwards of a 10% reduction in the amount of area dredged to within the specified vertical accuracy.
- After calculating total working time and subtracting out the duration for setup, equipment moves, downtime, and surveying, the total up-time for the dredging operation was 64%. This is considered to be useful data for estimates to scale-up other data.
- During the typical 10 hours worked per day, the average hourly production rate (as a function of total working time) was 84 cy [64.3 m^3] per hour. This production rate is comparable to other full-scale environmental dredging projects and is considered useful for estimating the production rates and full-scale project timelines during the Feasibility Study analyses.

ACKNOWLEDGEMENTS

This Environmental Dredging Pilot Study was conducted by an unprecedented coordinated technical team composed of experts from multiple agencies, organizations, universities and consulting firms. The pilot was led and primarily funded by NJDOT, Office of Maritime Resources – the Local Sponsor for the overall Feasibility Study. The dredging was performed by Jay Cashman Inc., with support from Cable Arm Inc. The USACE provided the base of operations via the *SUV Hudson*, field personnel, and dredging construction oversight. USEPA provided analytical services for water quality samples and critical partnership for the decontamination pilot. USFWS provided the shuttle vessel and field staff, and US Geologic Survey (USGS) and Rutgers University led the water quality monitoring program. The consultant team included Earthtech, Inc (NJDOT's prime consultant) and Malcolm Pirnie, Inc., firms that provided the basis for the design, project specifications, and implementation of the program including dredging construction oversight with the multi-agency partnership. Aqua Survey, Inc. also conducted many of preparatory surveys and provided vessels and field personnel for pilot planning and implementation. NJDEP, Office of Dredging and Sediment Technology provided technical assistance and permits including the

Federal Consistency Determination and Water Quality Certificate. Dr. Donald Hayes from the University of Utah and Dr. Michael Palermo of Mike Palermo Consulting were key advisors to the development of the Environmental Dredging Pilot. Along with Lisa Baron (NJDOT), Scott Nicholson (USACE) and Alice Yeh (USEPA) also provided support for the Pilot as Project Managers for the overall Feasibility Study.

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