Second LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCEI'2004)
"Challenges and Opportunities for Engineering Education, Research and Development"
2-4 June 2004, Miami, Florida, USA

Design of CAD Pits in San José Lagoon, San Juan, Puerto Rico

Susan E. Bailey
Research Civil Engineer, US Army Engineer R&D Center, Vicksburg, MS, USA

Paul R. Schroeder, PhD, P.E.
Research Civil Engineer, US Army Engineer R&D Center, Vicksburg, MS, USA

Carlos E. Ruiz, PhD, P.E.
Research Civil Engineer, US Army Engineer R&D Center, Vicksburg, MS, USA

Abstract
The USACE ERDC has prepared a capping design for disposal of dredged material from two projects in San Juan Bay Estuary, San Juan, PR. Approximately 200,000 cubic yards failed bioassay testing for disposal in the San Juan Ocean Dredged Material Disposal Site (ODMDS). These sediments are to be hydraulically dredged and placed in the largest of the San José Lagoon pits. Plans are to cap the deposit with "clean" sediment that passed bioassay testing. In the other project, the Martín Peña Canal will be widened to improve water quality by increasing the flushing of San José Lagoon into San Juan Bay. The eastern half of the canal is polluted and has restricted flow due to siltation and accumulation of trash and debris. The channel will be mechanically dredged, resulting in approximately 750,000 cubic yards of sediment, upland fill, and debris. The dredged material will be dumped by barge into three of the San José Lagoon pits and capped with clean sand. Consolidation, erosion, and contaminant transport analyses for both projects were done to determine site capacity for dredged material storage and cap design requirements for contaminant isolation. Results determined that pit capacity would be sufficient to accommodate both projects.

Keywords
Dredging, CAD, Capping, Sizing, Consolidation

1. Introduction

Several areas of the Federal Navigation Channels in San Juan Harbor require maintenance dredging. About 200,000 cubic yards of sediment failed bioassay testing for disposal in the San Juan Ocean Disposal Site. The preferred alternative disposal scheme includes hydraulic excavation and pipeline pumping via the Martín Peña Canal into one of several existing deep holes in the eastern end of San José Lagoon. Material from San Juan Harbor that passed bioassay testing is proposed as cap material.

In a second area of the harbor system, the 3.8-mile channel of Martín Peña Canal, which connects the San Juan Bay with San José Lagoon, is highly polluted with solid wastes and debris. The resulting limited tidal exchange between the San José Lagoon and San Juan Bay has contributed to poor water quality. The proposed channel restoration would improve flushing of the San José Lagoon.

The recommended project, as described in the Draft Project Design Report and Environmental Impact Statement (USACE-DNER 2001), consists of dredging approximately 750,000 cubic yards of mixed material (sediment, upland fill, debris) to deepen and widen the existing channel, providing a depth of 10 feet. The channel will be mechanically excavated by clamshell/barge. The dredged material will be placed in existing deep pits in the San José and Los Corozos Lagoons and capped with clean sand. SJ Pit 1, SJ Pit 2 and LC Pit, shown in Figure 1, are proposed for use as CAD sites for this project.

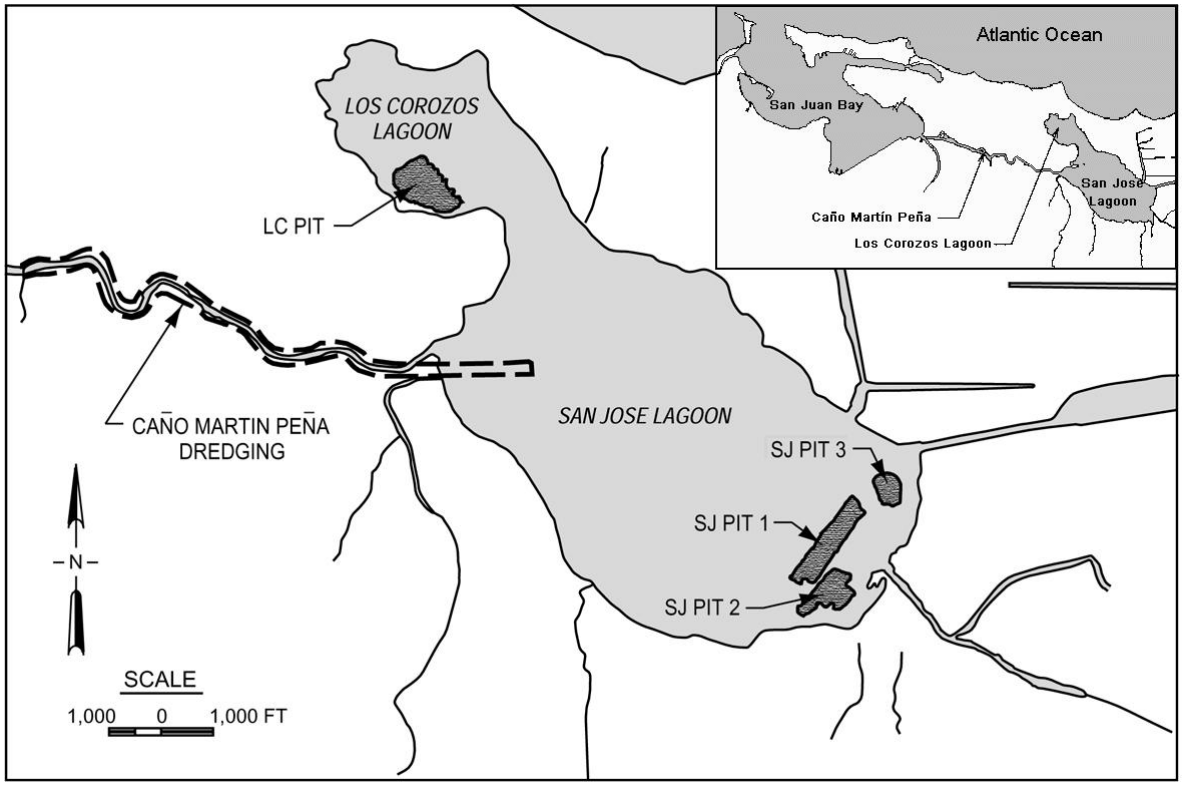

Figure 1: Existing Pits in San José and Los Corozos Lagoons

1.1 Objectives

The project objectives were to determine pit capacity and capping requirements for a range of operating conditions, as well as to determine feasibility of the two projects based on available pit capacities and environmental compliance.

1.2 Scope of Work

The scope of work consisted of physical and chemical characterizations of the dredged material; prediction of dredged material storage requirements based on settling and consolidation analyses; CAD pit cap design; evaluation of erosion; and prediction of short- and long-term water quality impacts.

2. Methodologies

2.1 Dredged Material Characterization

Physical/geotechnical characterization of the sediments consisted of measuring the following parameters in accordance with the USACE Soil Testing Guidelines (USACE 1970): grain-size distribution, liquid

limit, moisture content, specific gravity, self-weight and standard oedometer consolidations and compression settling.

2.2 Capacity Requirements

Storage requirements were predicted for the material to be hydraulically placed using the USACE ADDAMS (Schroeder and Palermo 2004) SETTLE module for compression settling. Requirements for mechanically placed materials were predicted using the ADDAMS PSDDF module for consolidation. Prediction of bulking/water entrainment during mechanical placement was predicted using the ADDAMS STFATE model.

For hydraulic placement, the volume that the dredged material and cap occupy in the pit will vary depending on the dredging rate and conditions. Since the dredge size and rate had not yet been determined, a range of possible dredging parameters was investigated as shown in Table 1.

Table 1: Range of Hydraulic Dredging Parameters Investigated

In Situ Volume (cu. yd.)	Dredge Sizes (in.)	Average Pipeline Velocities (fps)	Production Rates (%)	Solids Content (g/l)
200,000	16	10	35 %	95
225,000	18	12	50 %	115
250,000	21	15		135
300,000	24			
	27			
	30			

2.3 Cap Design

The intended function and design objectives of the cap include physical isolation of the unsuitable sediments from benthic organisms and reductions in long-term contaminant flux. The minimum thickness for cap design was evaluated based on USACE guidance (Palermo et al. 1998) using the conservative premise that the cap thickness components are additive, i.e., no dual function is performed by any cap component. The total minimum cap thickness (T) required was estimated by adding individual cap components to account for bioturbation (T_b), erosion (T_e), operational considerations (T_o), chemical isolation (T_i), and consolidation (T_c), as shown in the following equation:

$$T = T_b + T_e + T_o + T_i + T_c \quad (1)$$

Bioturbation depths are highly variable, but the active bioturbation zone with sediment mixing is assumed to be only 4-6 inches in the lagoon environment. A conservative cap thickness component for bioturbation of 1 foot was assumed reasonable to isolate underlying material from all organisms likely to recolonize the site in any significant numbers.

A thickness component to account for erosion is not considered necessary for San José Lagoon due to the low energy environment of the lagoon, and because the pit is a depression. Net deposition of material is more likely to occur than erosion.

Due to the placement accuracy of a submerged diffuser, an operational thickness component of 3 inches was used to account for mixing and thickness variation for placement of the San Juan Harbor material. A somewhat greater operational thickness of 6 inches was assumed for placement of the Martin Pena material via barge.

The thickness required to isolate all organic and heavy metal contaminants and to reduce the concentration of contaminants to an acceptable level is generally on the order of inches. The efficiency of the cap for long-term chemical isolation of the unsuitable material was evaluated using the USACE CAP model, considering addition of a minimum thickness component of 6 inches for chemical isolation.

For cap materials other than sand, the initial cap thickness will be greater than the minimum thickness to account for consolidation as predicted by the compression settling calculations.

2.4 Long-Term Consolidation and Pore Water Releases

Predictions of pore water releases and impacts on water quality were based on the consolidation analysis for each pit. The consolidation analysis of SJ Pit 1 also provided information on storage capacity available for the Martín Peña Canal project following placement of material from the San Juan Harbor project.

2.5 Erosion

To ensure there are no significant losses of contaminated slurry prior to capping, the potential erosion of the San Juan Harbor material during hydraulic filling operations was evaluated using the USACE COSED-1V-DMP model. Solids losses from mechanically placed Martín Peña Canal material was predicted by the STFATE model.

2.6 Water Quality

2.6.1 Short-term

Elutriate testing was performed to predict release of soluble contaminants from the dredged materials during placement. The ADDAMS EFQUAL computer program was used to compare the elutriate concentrations to federal marine chronic criteria and to determine if dilution is necessary to meet water quality standards. The STFATE model was used to predict mixing zone requirements to meet toxicity criteria.

2.6.2 Long-term

The long-term transport of the contaminants of concern into and through the cap was modeled using the USACE ADDAMS CAP model.

3. Results

3.1 Capacity Requirements and Operational Constraints

Results for the San Juan Harbor dredging project show the maximum solids output to avoid filling above the SJ Pit 1 lip at –12 ft is approximately 9.93, 4.17, 1.97 and 0.61 million kg/day respectively for each investigated in situ sediment volume (200,000, 225,000, 250,000, 300,000 cu. yd.). For these production constraints, the allowable operating characteristics are presented in Table 2. The results in the table indicate that significant operating constraints would need to be imposed if disposing more than 225,000 cu. yd. of in situ sediment.

Based on the STFATE results for the Martin Pena Canal dredged material, overall bulking of the in situ sediment volume during dredging and placement would be approximately 19 percent, resulting in a total bulked volume of contaminated dredged material after placement in the CAD pits of 892,340 cu. yd. prior to capping.

Table 2: Maximum Solids Output for Dredging of San Juan Harbor to Avoid Overfilling SJ Pit 1

In Situ Sediment Volume (cu. yd.)	Maximum Solids Output (million kg/day)	Maximum Dredging Rate for Graving Dock Sediment[1] (in situ cu. yd./ day)	Maximum Dredging Rate for Cruise Ship Basin Sediment[2] (in situ cu. yd./ day)	Maximum Dredge Size[3]	Minimum Time to Dredge Unsuitable Material (days)	Minimum Time to Dredge Cap Material (days)
200,000	9.928	23,960	19,573	> 30 in.	8	3
225,000	4.171	9,952	8,223	30 in.	23	7
250,000	1.972	4,705	3,887	21 in.	53	16
300,000	0.605	1,443	1,192	10 in.	208	50

[1] Assuming in situ solids content is 419.07 kg/cu. yd.
[2] Assuming in situ solids content is 507.23 kg/cu. yd.
[3] In range of parameters investigated

Leaving space for cap material, LC Pit and SJ Pit 2 will hold only 670,225 cubic yards of the estimated 892,340 cubic yards of Martín Peña bulked dredged material. This leaves 222,115 cubic yards to be placed in the SJ Pit 1 along with the necessary 2 feet of cap (described below). Assuming a maximum fill height of –12 ft, the San Juan Harbor material must consolidate to below approximately –21.2 ft to have sufficient capacity for the remaining Martín Peña Canal dredged material and cap. Thus, the feasibility of containing the material cap for both projects depends on how effectively and quickly the San Juan Harbor material consolidates.

3.2 Cap Design

For the San Juan Harbor material, the cap material will be hydraulically placed, fine-grained material. The total design minimum cap thickness is 1.75 feet, post-consolidation, but due to consolidation, the initial cap thickness will be approximately twice as thick. For the Martín Peña Canal project, the cap will be coarse-grained material, with a total cap thickness of 2 feet. Modeling of the pore water flux and contaminant flux using the USACE RECOVERY/CAP model showed the proposed cap thicknesses to be sufficient for chemical isolation.

3.3 Consolidation

Results of the PSDDF model runs for San Juan Harbor indicated the unsuitable sediment layer and cap would consolidate to nearly one half of its initial thickness within several years and that the material will completely consolidate within 15 to 20 years to approximate elevations of -24 to -22 ft. for storage of 200,000 to 300,000 cu. yd., respectively. Based on the consolidation modeling for San Juan Harbor, it appears that a lag time of anywhere from 2 to 8 years would be necessary between placement of the San Juan Harbor dredged material and the Martín Peña Canal material in order to have sufficient capacity for both projects.

3.4 Erosion During Filling

Results of the erosion modeling showed losses of the San Juan Harbor dredged slurry to be dependent on the height of the fill and would be no more than 3.6 (±0.6) percent of the placed material.

3.5 Water Quality

3.5.1 Short-term

Results of the Martín Peña standard elutriate tests indicate the presence of metals, PAHs, PCB Aroclor 1248, and some pesticides. EFQUAL results predicted that selenium (Se) is the only contaminant that

would violate water quality standards and calculated a dilution factor of 3.8 would be required to meet toxicity criteria. Based on worst-case conditions, STFATE predicted that a mixing zone extending approximately 1000 ft beyond each pit is recommended to achieve dissolved Se levels within the water quality criteria. Water column bioassay testing is recommended to verify that there are no adverse effects from contaminants without water quality criteria.

3.5.2 Long-term

Copper is the contaminant of concern for the San Juan Harbor material, requiring the greatest attenuation while showing little retardation. Modeling of the pore water flux and contaminant flux using the USACE CAP (RECOVERY and PSDDF) model predicted the water column concentration of copper to be below the Federal marine toxicity criteria at all times. The analysis shows the flux of copper from the dredged material is reduced by nearly a factor of 50 by the capping material. For the Martín Peña materials, only selenium is predicted to be transported through the cap. However, the cap retards and disperses the selenium sufficiently to decrease the pore water concentration by 90 percent in the biologically active layer reaching a concentration equal to 20 percent of the water quality standard.

4. Conclusions and Recommendations

The three proposed pits in the San José and Los Corozos Lagoons have adequate capacity to contain the contaminated material and associated caps from both the San Juan Harbor and Martín Peña Canal dredging projects, provided sufficient time is allowed for consolidation and dredging is performed within the given constraints. The proposed projects should have minimal water quality and benthic impacts.

Water column bioassay testing is recommended to ensure there will be no adverse impacts caused by release of contaminants without water quality criteria. Monitoring should be performed to ensure adequate cap placement and long-term performance. Coordination of the two projects has been advised to ensure the optimum usage of pit capacity and the associated success of both projects.

5. References

Palermo, M.R., Clausner, J.E., Rollings, M.P., Williams, G.L., Myers, T.E., Fredette, T.J., and Randall, R.E. (1998). “Guidance for subaqueous dredged material capping,” Technical Report DOER-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Schroeder, P. R. and Palermo, M. R. (2004). "The Automated Dredging and Disposal Alternatives Management System (ADDAMS)," *Environmental Effects of Dredging Technical Notes* EEDP-06-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

USACE (1970). "Laboratory Soils Testing," Engineer Manual EM 1110-2-1906, Washington, DC.

USACE – DNER. (2001). “Dredging of Caño Martín Peña Puerto Rico Draft Project Design Report and Environmental Impact Statement,” U.S. Army Corps of Engineers and Puerto Rico Department of Natural and Environmental Resources, March 2001.