# ASSESSMENT OF PHYSICAL SEPARATION PROCESSES FOR RECOVERY OF BEACH SAND FROM A MAINTENANCE DREDGING PROJECT FOR MARINA DEL REY, CALIFORNIA

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## ABSTRACT

Beneficial use of dredged material often requires separation of coarse and fine-grained sediment particles. The coarser sandy fraction is generally cleaner from a contamination perspective than the finer silts and clays. Sandy material offers a wider range of potential uses, such as beach nourishment and construction. The U. S. Army Engineer District, Los Angeles, recently demonstrated physical separation technologies to reclaim clean sand from its maintenance dredging project at Marina del Rey Harbor. This project hydraulically dredged approximately 8,000 cubic meters of sediment from the harbor area and processed the dredged material through a treatment system consisting of scalping screen, hydrocyclones, settling tanks, and a belt filter. Since the sediment was primarily sandy material and disposal options were limited, reclamation of the sand for nourishment of a nearby beach provided both economical and environmental benefits. Dredged material was pumped across a scalper to remove larger organic material and debris. Under flow from the screen fed a package physical separation unit that included a settling chamber, hydrocyclones, and screens to dewater the clean sand exiting the bottom of the hydrocyclones. The sand is suitable for placement on the beach. Overflow from the hydrocyclones, potentially contaminated with heavy metals, pesticides, and PCBs, was further treated to remove the solids and contaminants. After concentrating the fine-grained solids and conditioning with flocculants, the fine-grained sediment was dewatered with a belt filter press or in a geobag. The fine-grained sediment was designated for landfill disposal. The effectiveness of the physical separation technology to produce a clean material suitable for beach nourishment is reviewed.

**Keywords:** Treatment, contaminated sediment, beneficial use, screens, hydrocyclones

## INTRODUCTION

Marina del Rey Harbor, California, is located on the Pacific coast 2 miles north of Los Angeles International Airport and is noted for being the Nation's largest small-craft harbor. More than 5,000 recreational boats are berthed at this facility. Congress authorized Marina del Rey as a Federal navigation project in 1954, but its current configuration with an outer breakwater was not completed until 1965. Since that time, periodic maintenance dredging has been required to remove shoals and maintain navigational depths. In 2008, the Los Angeles District, in cooperation with the Los Angeles County Beaches and Harbors Commission, awarded a contract to dredge portions of the harbor's entrance and main channel where shoaling had reduced water depths from an authorized 6.1 meters to less than 3 meters in some places. Figure 1 shows the Marina del Rey Harbor entrance and breakwater.

Marina del Rey sediment is relatively coarse-grained material with generally less than 30 percent passing a No. 200 sieve (75 microns). Contaminants of concern in the sediment include polychlorinated biphenyls (PCBs), pesticides, and heavy metals. These contaminants are primarily transported into the harbor by Ballona Creek, which empties into the Pacific alongside the marina channel and inside the breakwater. These contaminants prevent the sediment from being disposed in the open water and require consideration of other options. One such option is beneficial use whereby the sandy material in the sediment could be used for beach nourishment. There are a number of sand beaches and recreational areas adjacent to the harbor, and there is a recurring need to replace sand that erodes along the shoreline.

Physical separation technologies are designed to split soil or sediment into different fractions based on their physical characteristics. For sediments, the separation is usually by particle size or particle density. In some cases, physical separation produces the additional advantage of separating contaminants attached to sediment particles into a clean and a dirty fraction. Sediment contaminants are generally expected to be associated with the fine-grained (clay)

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fraction and with the organic material, which is often less dense and larger in size than the sand fraction. On the other hand, the coarser sand fraction is expected to have a lower affinity for contaminants and, also, often offers more potential for beneficial use such as beach nourishment. For physical separation to be economically favorable, the contaminated fraction, which will likely require subsequent treatment or disposal, must be relatively small by weight or volume compared to the reusable uncontaminated fraction. Through laboratory experiments on the sediment and review of other physical separation projects, the Los Angeles District discovered that the Marina del Rey sediment represented an excellent opportunity for application of physical separation technology.


**Figure 1. Marina del Rey Harbor Channel**

**Status of Physical Separation for Dredged Material**

Considering physical separation technology for dredged material is not a new idea. Mallory and Nawrocki (1974) considered the feasibility of sand and gravel beneficiation using scalping pump boxes, vibrating screens, hydraulic scalpers and classifiers, hydrocyclones, and other technologies as a study topic under the Dredged Material Research Program. They suggested that these processes were feasible, but recommended demonstration for dredged material slurries. Physical separation technology demonstrations at Saginaw Bay (USEPA 1994), Erie Pier confined disposal facility at Duluth/Superior Harbor (Olin and Bowman 1996), Green Bay, WI (Olin-Estes et al. 2002), and Fort Myers, FL (Granat 1998) reported successful application of the technologies. New England District has been using physical (mechanical) separation as part of the dewatering effort for the New Bedford Harbor Superfund site, and other U.S. remediation sites have employed physical separation technologies. The first full-scale U.S. application of physical separation by mechanical means for a maintenance dredging project was recently completed for the Miami River, FL (Taylor et al. 2006). For this project, mechanically dredged sediment first passed through a grizzly to remove oversize debris, then through a trommel for additional debris removal, and finally through a hydrocyclone and screen system to capture the sand for beneficial use as landfill cover. The Miami project processed more than 400,000 cubic meters of material. In Europe, full-scale physical separation systems are more common than in the U.S. and have been used for a number of years. Despite successful demonstrations at these locations and continued interest in the technology, physical separation using mechanical equipment has not yet been implemented as a standard operational practice in the U.S.

## MARINA DEL REY PROJECT OBJECTIVES

The primary objectives of the physical separation project at Marina del Rey were:

- Increase depth in the channel and harbor for Marina del Rey
- Produce a clean sand to replenish beach sand lost to wind/wave erosion on Dockweiler State Beach
- Demonstrate application of off-the-shelf physical separation technology to a maintenance dredging project
- Evaluate contaminant removal from contaminated sediment using physical separation technologies.

## DREDGING AND PROCESSING EQUIPMENT

The Los Angeles District contracted with CJW Construction, Inc., Santa Ana, CA, to dredge up to 50,000 cubic meters of sediment from the Marina del Rey Harbor and to employ a physical separation system to recover sand for placement on the beach in Dockweiler State Beach, which is adjacent to and south of Marina del Rey. The contract allowed for a startup phase to define the operational parameters for the separation processes, followed by a production phase for treatment of the remaining material. The first phase was paid as a lump sum contract; the second phase was paid on a more typical unit cost basis.

### Dredge

The dredge selected for this project was an IMS Versi-Dredge, Model 7012, Innovative Material Systems (IMS), Prairie Village, KS. The Versi-Dredge's starwheel drive system allows the dredge to be completely self-propelled. IMS says this dredge is transportable on one truck and offers a standard dredging depth of 30 feet. The dredge head is a shrouded, horizontal cutter, 3.4 meters wide and equipped with an approximately 8-centimeter square bar grate over the intake to its 425-horsepower ladder-mounted submersible pump. Nominal production capacity for this dredge is 350 cubic yards per hour through a 25-centimeter discharge line. (http://www.imsdredge.com)

### Physical Separation Process

The overall process configuration for the Marina del Rey project is shown in Figure 2. The dredge pumped material through a floating pipeline to the shore where it emptied into a coarse screen consisting of sheet metal with 2.5 cm holes. The screen was fixed to the bottom of a basket attached to a track-mounted crane (Figure 3). This device collected mostly trash, particularly plastic bags and stringy debris, which had proved to be difficult to remove from other screening devices tested in the earliest stages of the project. Once the basket collected a thin layer of debris, the crane lifted the basket out of the flow path and emptied the material into a roll-off dumpster. Underflow from this screen was picked up by a centrifugal pump and transported two miles along the beach to the physical separation plant. A booster pump was required about halfway down the stretch.

The heart of the physical separation operation was a package unit consisting of hydrocyclones, vibrating screens, settling tank, and feed/recirculating pumps. Del Tank and Filtration Systems, Scott, LA, furnished this system, labeled the "Total Clean," to the contractor, LA. (http://deltank.com) As described on the Del Tank web site, the Total Clean "incorporates a V-shaped tank, a tilted plate baffle system, and a shaftless screw to create a clarifier." A shaftless screw at the bottom of the tank steadily moves settled solids to the suction of the hydrocyclone feed pumps. The hydrocyclones remove the heavy sands and silts, which are subsequently dewatered by vibrating linear screens. The hydrocyclone overflow containing lighter particulates and water is returned to the tank for additional settling and particulate recycle prior to overflowing the tank. Capacity of the hydrocyclones is 3 to 4 times the feed rate to the system allowing for multiple passes through the hydrocyclone separators.

The dredge slurry pipeline initially discharges to two linear scalping screens in parallel to remove additional coarse material. These vibrating screens consisted of No. 10 mesh (2 mm) stainless steel screens with a screening surface area of 3.8 square meters each. For the much of the time only one of these shakers was required. These screens were mounted above the settling tank. The material captured on the screens was primarily vegetative debris (leaves,

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small twigs, grass, etc.) and bits of paper and other trash. This material was collected in a roll-off container for transport to a disposal site. Underflow from the screen discharged into the first compartment of the tank.

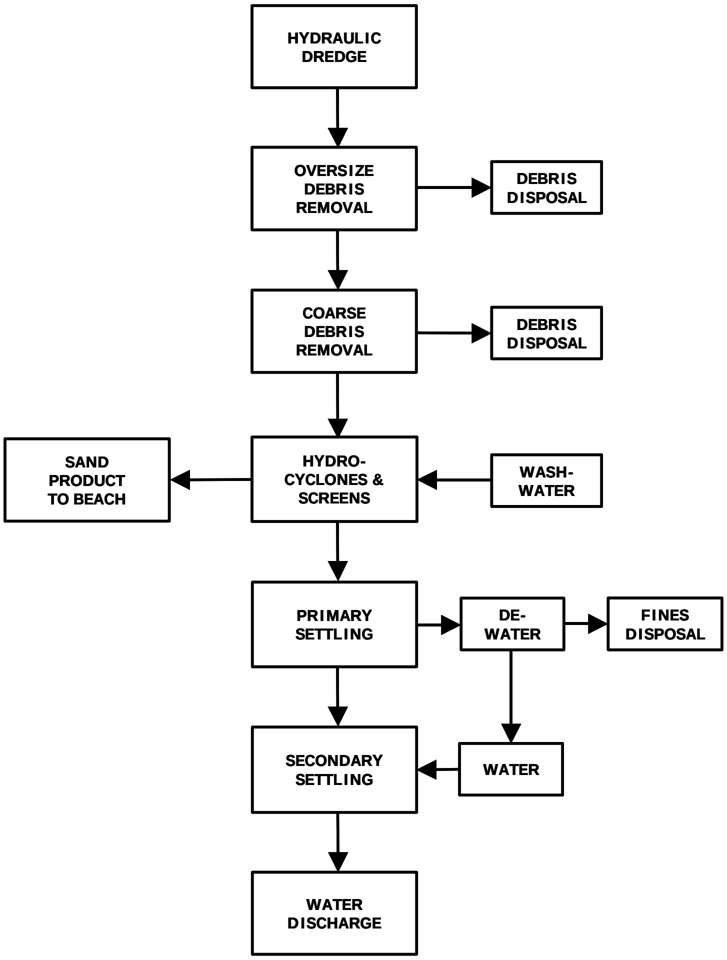


**Figure 2. Dredging and Physical Separation Project Schematic**

The tank was equipped with four pumps, one for each hydrocyclone-screening unit, and an array of valves to control flow from the bottom of the tank to the hydrocyclones and screens. Three 24-centimeter Krebs urethane cyclones in parallel were mounted above each of the four linear screens (Figure 4). Sand from the apex of the hydrocyclone cones discharged to the upstream end of the shaking screen.

Each screen was equipped with two nozzles that sprayed fresh water on the screened material to enhance the cleaning of the sand product. For this project, irrigation water not suitable for drinking was used. The mesh size for the screens varied with the upstream screens providing a coarser cut than the downstream screens. Mesh sizes for each of the four screening units and each panel for each unit are shown in Table 1.

These screens were changed out at various stages of the project depending on the physical characteristics of dredged material. In addition to adjusting wash water flow rate and screen mesh size, the inclination angle for each screening unit could be adjusted for optimum operation. Sandy material released from the end of each screening unit fell into a common conveyor belt, which moves the sand to a paved storage area where the sand stacked well with very little free water. This sand was later moved to beach areas for final disposition.


**Figure 3. Screen Basket for First Stage Debris Removal**


**Figure 4. Hydrocyclones Mounted Above Linear Vibrating Screens**

Overflow from the classification tank discharged to two Baker tanks for primary settling. Overflow from these settling tanks flowed into the eight 80-cubic meter Baker tanks for final clarification before being discharged to the adjacent Pacific Ocean. Polyelectrolyte addition to aid the primary settling step was used for the early stage of the project, but its benefits were minimal, and the point of injection was relocated to the overflow line from the primary settling tanks to the final settling tanks. Underflow from the primary settling tanks was initially pumped to a belt filter press for dewatering. However, operational problems with the belt filter and difficulties in pumping the material after it accumulated in the settling tanks resulted in switching from the belt filter press to using geobags for dewatering and consolidation of the fine-grained material. After dewatering, the fine-grained material was transported by truck to a landfill for disposal.

**Table 1. Screen Mesh Sizes in Use 3 February 2009**

| Equipment | Screen Panel No. | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | Screen Mesh No.* | | | |
| Debris Screen No. 1 | 10 | 10 | 10 | 10 |
| Debris Screen No. 2 | 10 | 10 | 10 | 10 |
| Sand Dewatering Screen No. 1 | 40 | 40 | 20 | 20 |
| Sand Dewatering Screen No. 2 | 60 | 40 | 40 | 40 |
| Sand Dewatering Screen No. 3 | 325 | 250 | 210 | 140 |
| Sand Dewatering Screen No. 4 | 325 | 250 | 210 | 140 |

*U.S. Sieve No. Conversion to Nominal Sieve Opening:
No. 10 =2.00 mm; No. 20=0.841 mm; No. 40=0.420 mm;
No. 60=0.250 mm; No.140=0.105 mm; No. 230= 0.063 mm;
No. 270=0.053 mm; No. 325= 0.044 mm

Except for the oversize scalping step, all of the processing equipment was set up on a parking lot for Dockweiler State Beach (Figure 5). Areas where dredging water or process water may be released were bermed with sand bags to allow for collection of the liquids and pumping into the settling tanks. Because this is such a public area, the District continually communicated with the local sponsor and other stakeholders to maintain good community relations and support for the project. A residential area was located near the dredging site and booster pump, so noise was a concern, which limited nighttime operations. Although the timing of the project was off-season for the beach, a number of people were using the beach and walk/bike path during operations, and public safety had to be a concern. Another consideration was an environmental window for threatened bird species, which nests on the beach during the spring. The District contracted with a biologist to observe operations on the beach and to make sure the Snowy Plover was not impacted.

## PROCESS PERFORMANCE

### Process Operations

Dredged material processing began in late December 2008, and concluded in March 2009. The contractor dredged an estimated 8,000 cubic meters of sediment from the channel, and recovered about 70 percent of the dredged material as sand. While the goal was to operate on a 24-hour day, the project did not advance beyond 12 hours a day operations. The potential for complaints of noise from the local residents was one reason for restricting operations to daylight hours.

Dealing with debris was one of the major startup issues. While there were some large objects, stringy materials like plastic bags, wire, and cables tended to initially hang up or get wrapped around the dredge's horizontal cutter and the bar rack over the dredge's pump intake. Removing this material required shutting down the dredge pump and manually removing the material. Some of this material was entrained in the dredged material slurry and pumped to the processing plant. Stationary screens, requiring manual cleaning, were used at first. These were abandoned in favor of the crane-mounted basket discussed in the process description, which proved to be effective in capturing the oversize debris with limited operational difficulty.

Early operations included experimenting with different screen mesh sizes for the sand dewatering screens and modifying the partitioning of the flow among the four sand screens. The volume of wash water was also increased in an effort to further reduce the contaminants in the sandy material.


**Figure 5. Operational Physical Separation System at Dockweiler Beach**

The original plan was to dewater the separated fine-grained material with a belt filter press. However, difficulties in pumping the material after it had consolidated in the settling tank and unsatisfactory operation of the belt filter resulted in changing the process to place the fine-grained material in geobags for passive dewatering and easier handling for disposal.

**Sampling and Analysis**

Los Angeles District personnel performed sampling of the harbor/channel sediment and at various points in the treatment process with the assistance of its consultant, Anchor QEA. Calscience Environmental Laboratories, Inc performed laboratory analyses under the direction of Anchor QEA. Samples were collected, preserved, and analyzed in accordance with the methods listed in Table 2. One purpose of this sampling program was compliance with regulatory requirements for placing the recovered sand on the beach near the intertidal zone. Additional analyses were conducted to identify the boundaries for adjustment and operation of the physical separation process. Routine sampling collected material from either the dredged material slurry or the bottom sediment near the dredge and from the sand product at either the discharge from the screens or the sand stockpile. Additional samples were collected from individual screens, from the fines removed from the dredged material, and from the water discharge (effluent) from the process.

**Table 2. Analytical Procedures**

| Analysis | Method No. |
|---|---|
| Trace Heavy Metals | EPA 6020/7471A |
| Chlorinated Pesticides | EPA 8081A |
| PCB Aroclors | EPA 8082 |
| Total Organic Carbon | EPA 9060A |
| Grain Size | ASTM D4464 |

**Effectiveness of Grain-Size Separation**

The main benefit of physical separation technologies for a dredging project is separation of the dredged material by grain size to produce a product that is less contaminated than the bulk dredged material and that is more amenable to beneficial use. There are considerably more opportunities for beneficial use of sand than for fine-grained material. Such is the case for beach placement of material where there is generally an upper limit on the fraction of the material that is fine grained.

The effectiveness of the Marina del Rey system in separating silt and clay from sand is illustrated in Figure 6, which compares the fractions of medium sand, fine sand, silt, and clay in the sediment and in the recovered sand product for five sampling events. The stacked bars show that the fraction of medium and fine sand increased in the product for 4 of the 5 sampling events. On 9 March, there was a slight decrease, but the sand fraction was greater than 90% in the feed (sediment) and the differences may be due to sampling error. A similar conclusion can be reached from looking at Figure 7. This graph compares the median grain size of the sediment to that of the sand product. The physical separation process generally increased the median grain size for the samples collected.

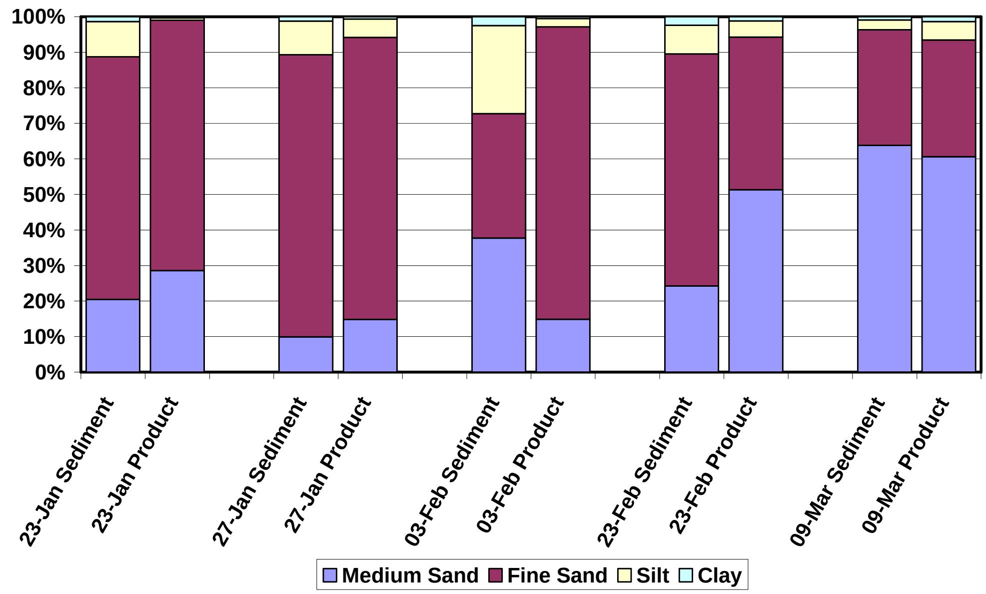


**Figure 6. Effects of Physical Separation Processing on Grain Size Classification**

**Effectiveness of Contaminant Removal**

Physical separation has been promoted as a promising technology for treatment of contaminated sediment to remove organic and inorganic contaminants. Contaminants of concern in Marina del Rey include heavy metals, pesticides, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs). The sampling program for the demonstration project included analyses for heavy metals, pesticides, and PCBs. PCBs were not found above the detection limits for any of the samples collected during the project. Heavy metals and the pesticides chlordane, dieldrin, and DDT metabolites were found in the sediment and in the sand product.

Figure 8 compares the average concentrations of arsenic, cadmium, chromium, nickel, selenium, and silver for the sediment vs. the sand product. Copper, lead, and zinc comparisons are shown in Figure 9. These figures indicate that the process slightly reduced heavy metal concentrations with the exception of lead. Average lead concentration increased, but the concentration in the sand was affected by one sample value of 200 mg/kg that appeared to be an outlier.

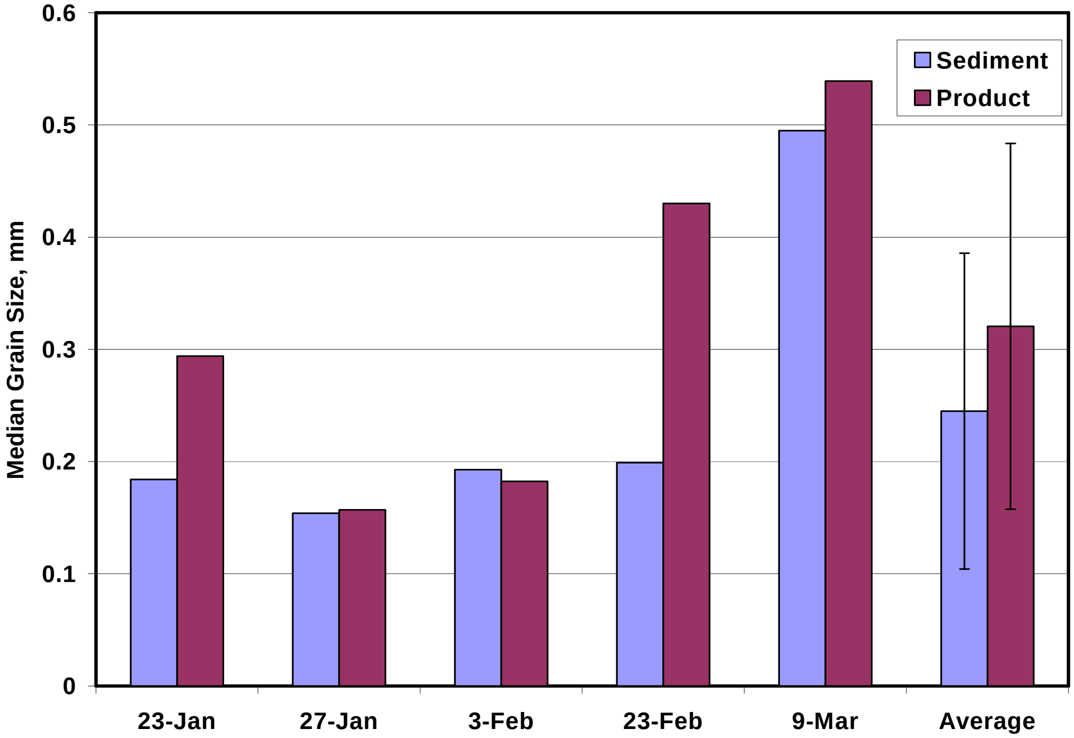


**Figure 7. Effects of Physical Separation Processing on Median Particle Size**

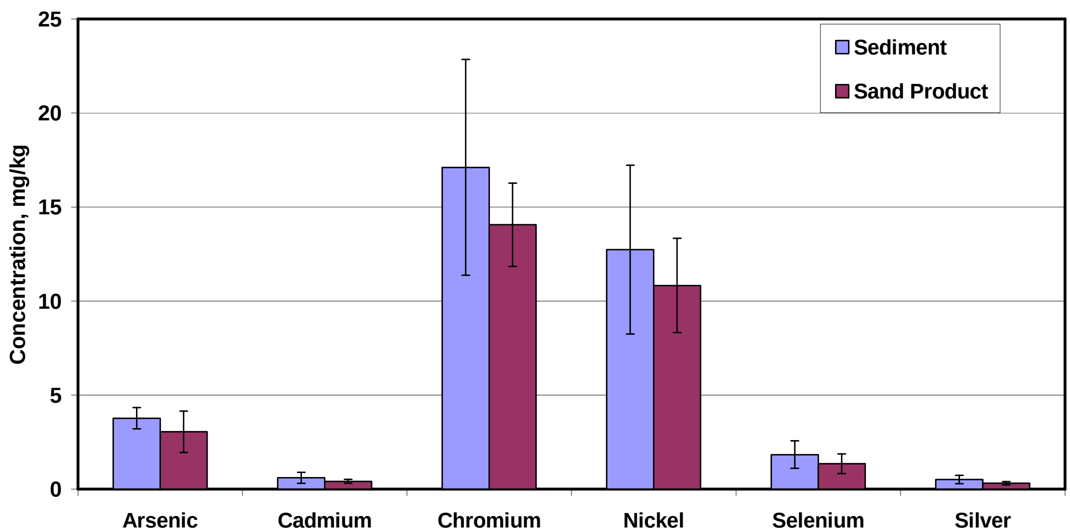


**Figure 8. Comparison of Heavy Metals (Mean ± 1 Std Dev) in Feed and Product**

The differences in pesticide concentrations are illustrated in Figure 10. Concentrations of 4,4'-DDD and 4,4'DDT appear to have been reduced by the sand recovery process, although the variance of the concentrations in the sediment weigh against the strength of this conclusion. Concentrations of 4,4'DDE, dieldrin, and total chlordane were not affected by the physical separation process. During the course of the project, chlordane became a cause of concern for placement of the sand on the beach. The concentrations found in the sand were greater than the some screening level values used by the regulatory agencies. However, toxicity tests for the sand material showed that the sand product did not exhibit toxicity to the test organisms.

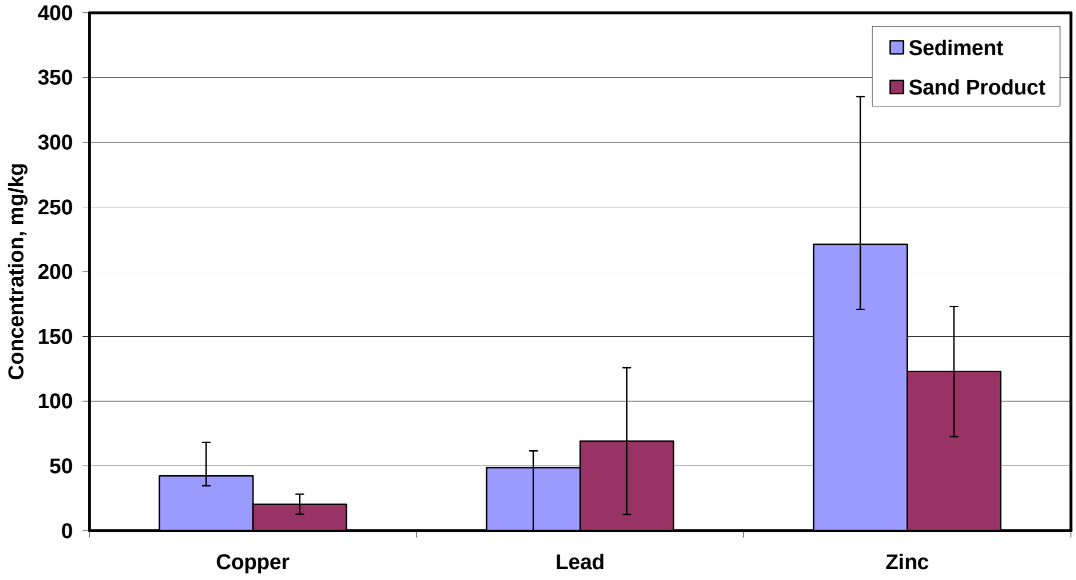


**Figure 9. Comparison of Copper, Lead, and Zinc (Mean ± 1 Std Dev) in Feed and Product**

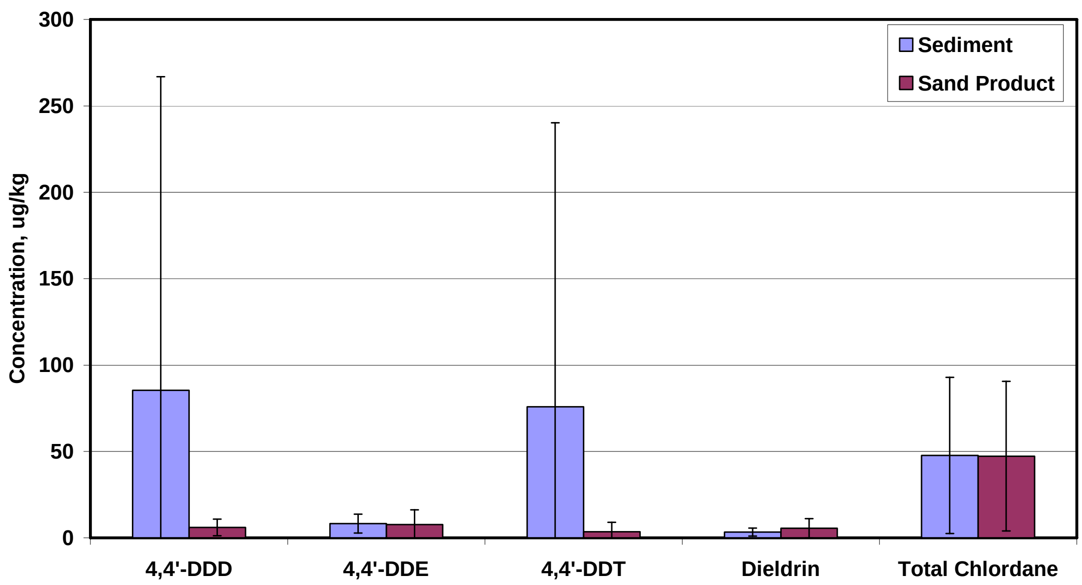


**Figure 10. Comparison of Pesticides (Mean ± 1 Std Dev) in Feed and Product**

Contaminants in sediment generally partition to the organic material in the sediment and to the fine-grained clays and silts. The effect of the process on organic carbon is shown in Figure 11. Results from these analyses are mixed, and the data limit conclusions regarding TOC removal. For the 03 Feb samples where the incoming total organic carbon (TOC) was 5.7%, the reduction through the process was notable. Considerable organic matter (leaves, grass, twigs, etc.) was removed by the screens at the beginning of the process based on visual observations and the collection of a dumpster full of this type of material. Some of this material may have been excluded in the sampling and sample preparation process prior to analysis, lowering the reported sediment concentrations. As was noted earlier, the clay and silt fractions in the sand product are less than 5% and were generally reduced by the process. The answer to the sandy material retaining contaminants is possibly the organic particles that separate with the sand fraction. If this material is black carbon (a condensed carbon phase occurring as a product of incomplete combustion, coal or similar materials), as opposed to naturally occurring amorphous carbon, the contaminants are strongly adsorbed to the carbon particles and have limited bioavailability.

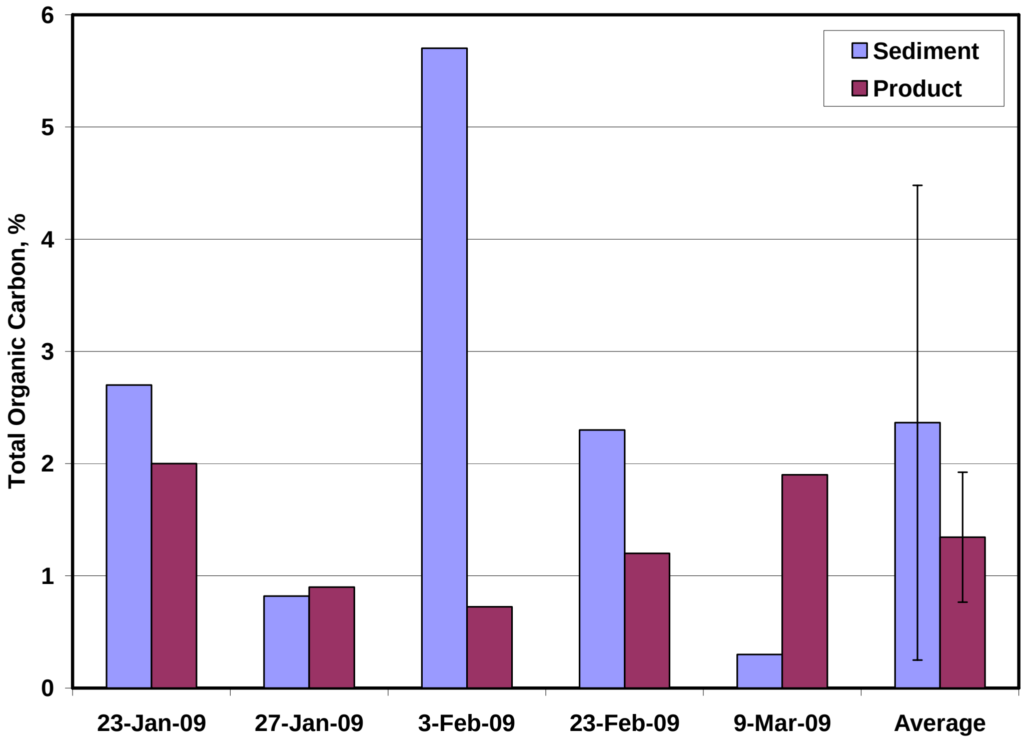


**Figure 11. Comparison of Total Organic Carbon in Feed and Product**

## SUMMARY

Commercially available physical separation processing equipment was successfully demonstrated in a sand recovery project at Marina del Rey Harbor, CA. Contaminated sediment was dredged from the harbor channel and successfully separated into coarse (sandy), fine (silt and clay), and organic fractions using a package system that included vibrating linear screens and hydrocyclones for separation of grain size fractions. The sand product from the process was physically suitable for placement on the public beach. Contaminant concentrations in the sand were somewhat reduced for selected contaminants compared to the sediment, but levels of chlordane remaining in the sand exceeded some regulatory screening levels. Toxicity testing of the sand product demonstrated no effects on the test organisms, and the plan is to place the sand on the beach.

## ACKNOWLEDGEMENTS

This paper presents results of a study conducted by the U.S. Army Corps of Engineers Los Angeles District and the U.S. Army Engineer Research and Development Center. Funds from the Dredging Operations and Environmental Research Program supported preparation of this paper. Permission to publish this material was granted by the Chief of Engineers.

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