Dredging Research

Vol 4, No. 1 Information from the Engineer Research and Development Center Mar. 2001

Assessment of contaminant isolation at Duwamish, Wash., capping site verifies RECOVERY prediction strength

by Drs. Carlos E. Ruiz and Paul R. Schroeder, Environmental Laboratory

Subaqueous capping is a remediation technique for contaminated sediments in an aquatic environment. The technique physically isolates contaminants through a layer of clean material placed over the contaminated sediments. Field measurements at the Duwamish River dredged material disposal site in Seattle, Wash., were made to evaluate movement of contaminants from the contaminated dredged material deposit into the cap material. These measurements were made at three representative locations and at depths that included the cap and extended well into the contaminated deposit. The U.S. Army Corps of Engineers RECOVERY Model, Version 3.0, was used to predict contaminant migration and distribution in the cap as a function of time. Vertical contaminant concentration profiles from monitoring data and computer simulation indicate that a very slight movement of the contaminants has occurred and that the cap has performed as expected. In addition, comparison of measured data to numerical simulation results verified the applicability of the RECOVERY model in predicting contaminant migration in the system.

Capping

During disposal operations in ocean waters or waterways, contaminated dredged material is placed to form a mound on the bottom of the disposal site that is subsequently capped with clean material to form a larger mound. It has been shown that the presence of a stable 50-cm cap of sand, silt, or clay is often sufficient to prevent the migration of contaminants from dredged material into biota. Cap thickness is considered one of the most important factors in cap design. Proper cap designs account for the effect of bioturbation, erosion, consolidation, sediment mixing, and other operational constraints to prevent the migration of contaminants to the water column and the biologically active surficial sediment. Proper capping effectively reduces, and possibly prevents, negative ecological impacts by restricting the migration of contaminants into the biologically active surficial sediment and the water column.

Contaminant flux from the contaminated sediments into the water column results from the presence of a concentration gradient between the water column and the sediment pore water. Additionally, settling of suspended sediments, as well as resuspension of bottom sediments, affect contaminant flux between the water column and the sediment bed. A cap reduces or prevents the direct exchange between the water column and the contaminated sediment by acting as a buffer.

Field Application

In March 1984, the U.S. Army Corps of Engineers, Seattle District, created a confined

In this issue . . .

aquatic disposal site in the Duwamish Waterway. The project was conducted to demonstrate the feasibility of subaqueous capping technology. The Corps dredged sediment contaminated with metals and PCBs from a shoaling area of the Duwamish River and placed the material in a depression of the West Waterway in 22 m of water. The 30-m-wide, 91-m-long, and 1.8-m-deep depression is located in an area where about 0.5 m of deposition occurred between 1968 and 1984. The newly deposited material was capped with generally clean sand dredged from an upstream settling basin that was known to have clay balls. These clay balls have higher contaminant concentration than the clean sand. The Duwamish mound had the initial cross-sectional configuration of a truncated cone 93 m in diameter, with side slopes of approximately 1:20. The center of the mound was composed of 0.9 m of contaminated dredged material overlain by the sand cap. The cap was typically 0.3-0.61 m deep across most of the disposal site, with the central portion of the site showing a cap thickness of at least 0.91 m (Fig. 1.)

Sediment cores were taken from the contaminated shoal and at the disposal sites before capping using a vibracore sampler with a 76.2-mm diameter and 6.1-m-long core barrel. Additional borings were made at the disposal site following placement of the contaminated dredged material and then at intervals of 2 weeks, 6 months, 18 months, 5 years and 11 years. The 18-month, 5-year and 11-year samples were taken as close as practically possible to the same locations to minimize variability in sediment samples. Data taken prior to capping indicate higher levels of Cu, Zn, Pb, and PCBs than the capped material. After capping, sediment core samples were collected at three locations labeled as VDQ, VDR, and VDS, which are shown on the elevation contour plot of the site in Figure 2. At each sampling location, a core sample was collected through the sandy cap material into the underlying contaminated sediment.

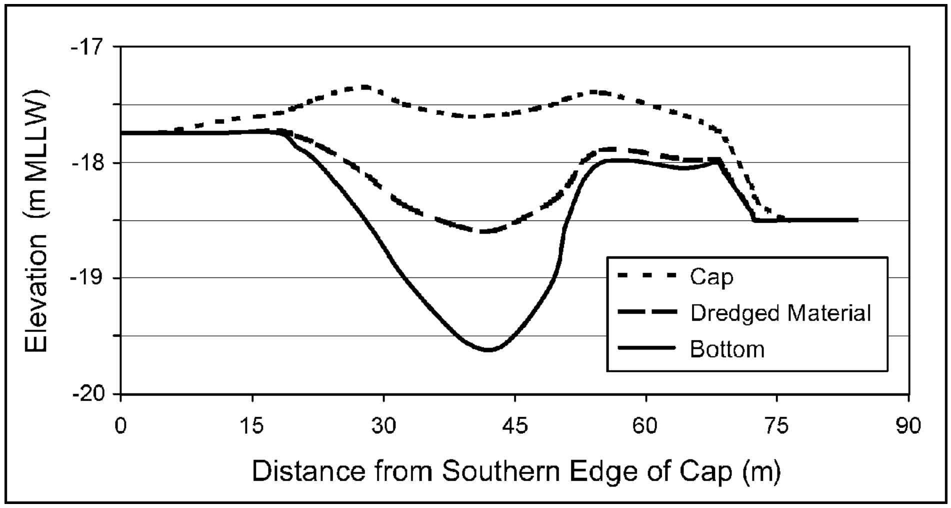


Figure 1. Representative cross section of the Duwamish Disposal Area with cap

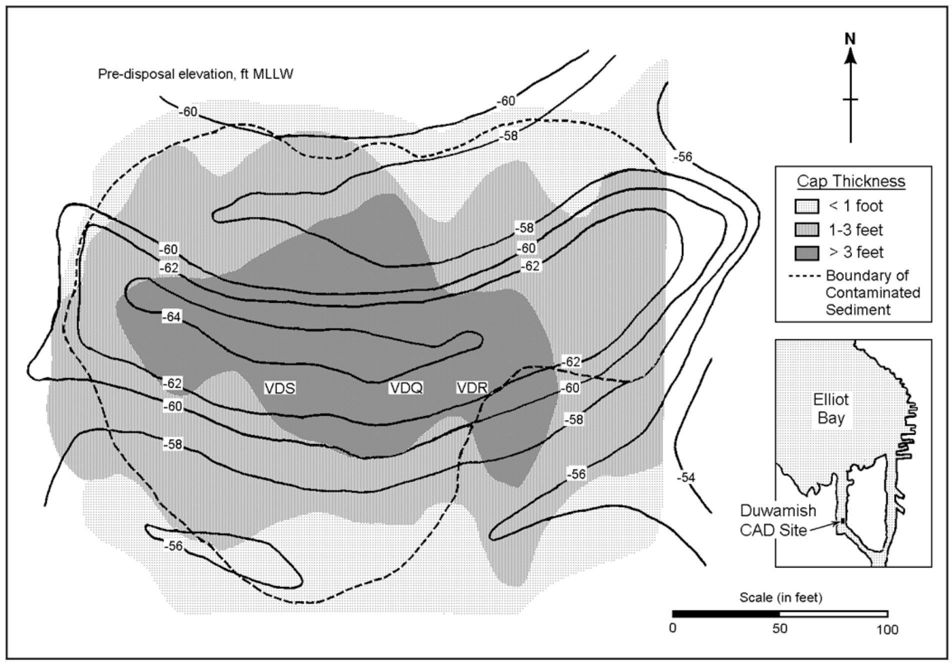


Figure 2. Elevation contour plot of the Duwamish Project showing three sample locations, VDQ, VDR, and VDS

In the 1995 investigation, subsamples were collected from each vibracore 15 cm below the sand cap/contaminated sediment interface, 15 cm above the interface, as well as 30 cm and 45 cm above the interface. A total of 10 cm of material was retained for each interval to provide adequate material for the required analysis (i.e., the +15-cm interval was collected from +10 cm to +20 cm of the core sample). However, the 1989 samples were collected at intervals smaller than 10 cm. The +45-cm samples were archived from each station pending the results of the initial chemical analysis. In addition, a surface sample (top 10 cm) was collected at station VDQ and analyzed for the full Puget Sound Dredged Disposal Analysis (PSDDA) conventionals and chemicals of concern. Three cores were collected at station VDQ to obtain enough surface sediment for all analyses.

The vibracore subsamples collected from the Duwamish CAD site were analyzed for Cu, Pb, Zn, and PCBs (Aroclors 1242 and 1254). In addition, samples VDQ-1, VDQ-2, and

VDQ-5 were analyzed for PSDDA conventionals, and VDQ-5 was also analyzed for the PSDDA chemicals of concern. The 1989 and 1995 sediment chemistry results are summarized in Table 1.

Table 1. Concentrations of DDE in the Water Column

Sampling Day	DDE in $\mu g/m^3$ X + SD
1	44.420 + 16.335
5	14.994 + 3.429
10	4.270 + 2.066
21	3.520 + 1.768
42	3.311 + 1.324
60	2.132 + 0.613
81	2.006 + 0.163
102	1.466 + 0.163
123	0.988 + 0.220
144	0.789 + 0.171
173	0.958 + 0.163
242	0.952 + 0.103

SD = standard deviation, X = mean

Model description

The RECOVERY Version 3.0 was applied to simulate contaminant migration into the capped dredged material deposit in the subaqueous depression at the Duwamish Waterway project. Pollutants in bottom sediments can be released by resuspension of particles, mixing by benthic organisms, and diffusion from the sediment pore water. On the other hand, pollutants in the water column can be transferred to the sediment layer by settling and to the atmosphere by volatilization. RECOVERY was used to assess the impact of the clean material capping project and migration of contaminants from bottom sediments.

RECOVERY modeling assumes the overlying water is well mixed, and that the contaminant follows reversible linear equilibrium sorption and first-order decay kinetics. The system is idealized as a well-mixed surface water layer underlain by a vertically stratified sediment column. The sediment is well mixed horizontally but segmented vertically into a well mixed surface layer and deep sediment. The latter is segmented into layers of varying thickness, porosity, and contaminant concentrations.

The discrete sediment layer configuration permits modeling situations in which contamination is also layered. Hence, it is ideal for capping scenarios and for sites where contamination occurred over a long period of time. A “mixed surface layer” accounts for the unconsolidated layer that is observed at the surface of sediments due to bioturbation and mechanical mixing.

Analysis of results

The measured data shown in Table 1, in general, indicate that there was a slight increase in metal concentrations above the interface between cap and contaminated sediments at stations VDQ and VDR from 1989 to 1995. However, PCB concentrations have changed little between sampling events at these stations. The overall distribution of metals and PCB concentrations at stations VDQ and VDR does not indicate significant upward migration of contaminants into the cap sediments. The difference in metal concentrations may be due to differences of sample collection methods between surveys.

At station VDS, metals and PCBs appear to have increased significantly above the interface between contaminated and cap material. The highest concentrations were found within the 30-cm depth interval. However, metals and PCBs in the cap material above and below this depth interval were found to be lower in concentration. The distribution of contaminants at station VDS suggests that the core may have contained a lens of contaminated material or clay balls in the sand cap located approximately 30 cm above the contaminated dredged material. This thin deposit of contaminated material would have occurred during cap placement and not from migration above or below this depth. Clay balls of higher contamination were also known to exist in the capping material. Outlier tests on the data presented in Table 1 indicate that the majority of the data collected 30 cm above the interface at location VDS were outliers.

The physical and chemical data described above were used to simulate contaminant migration at the Duwamish site. Simulation results (solid lines) are shown in Figures 3 through 6 for the 5- and 11-year post-capping concentration profiles along with the measured data (symbols) excluding the outliers. The figures also include a dashed line indicating the initial concentrations in the cap and dredged material. The simulation results and the data indicate a slight migration of contaminants from the contaminated dredged material into the cap material. Furthermore, the effect of sediment burial over the period of simulation is clearly shown by the accumulation of material above the cap (above 61 cm from the interface). In all cases presented, contaminants have moved slightly into the accumulated sediments.

It is important to note that the field data were collected at different times. The initial concentrations used in the simulation were measured before the contaminated dredged material and the cap material were placed at the Duwamish depression. In the numerical simulation, uniform initial contaminant concentrations in the cap and the dredged material were used. Furthermore, the 5- and 11- year sampling events did not necessarily reflect the concentrations at the same locations and depths. Therefore, the simulation results provided good agreement with the modeled situation and indicated only a slight migration of the contaminants into the cap. The simulation results also showed that the newly deposited sediment on top of the cap provided additional isolation of the contaminants from the water column.

Summary

The assessment of behavior of the cap at the Duwamish site indicates that the contaminants in the capped sediments are restricted from migrating into the relatively clean cap.

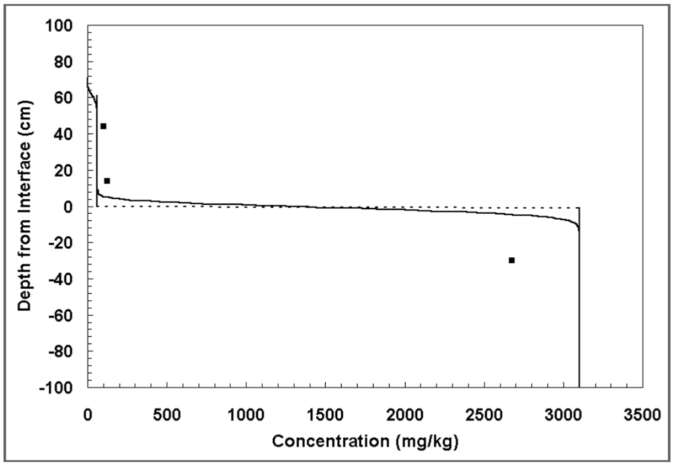


Figure 3. Simulation results, Aroclor 1254 - 5 year

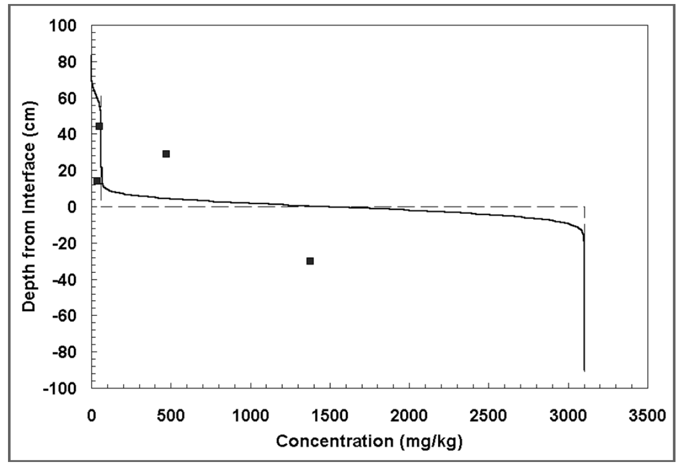


Figure 4. Simulation results, Aroclor 1254 - 11 year

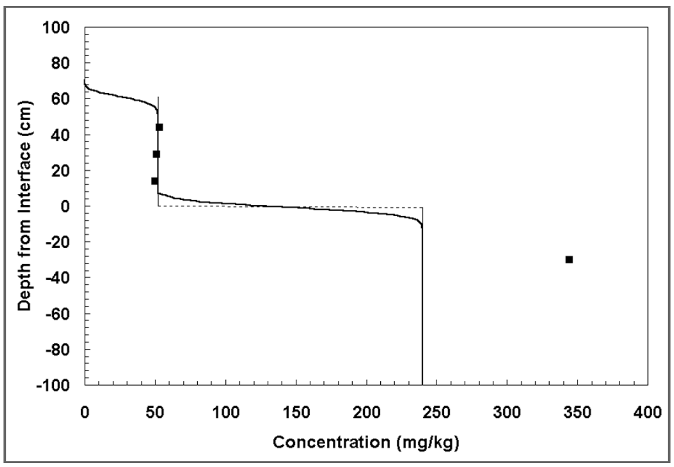


Figure 5. Simulation results, Zinc - 5 year

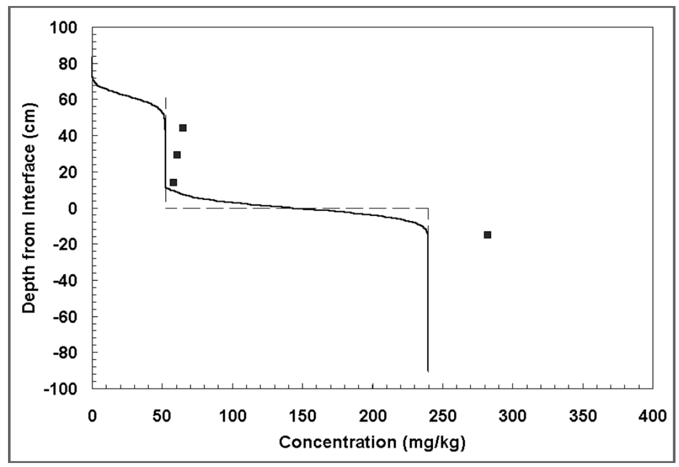


Figure 6. Simulation results, Zinc - 11 year

Comparison of the chemical data collected at the site with RECOVERY model results confirms that the cap has effectively isolated the contaminants from biota in the water column and surface sediments. In summary, this study verifies the applicability of the model in evaluating subaqueous capping scenarios and in assessing the long-term effectiveness of the cap.

Additional information on the RECOVERY model is available from Dr. Carlos E. Ruiz *(ruizc@wes.army.mil)* and Dr. Paul R. Schroeder *(schroep@wes.army.mil)*. The RECOVERY model and documentation are available for downloading at *http://www.wes.army.mil/el/*

Articles for *Dredging Research* requested:

***Dredging Research* is an information exchange bulletin for publication of ERDC-generated dredging research results. Included are articles about applied research projects. The bulletin serves all audiences and is accessible on the World Wide Web in addition to a paper circulation of 2,800.**

Articles from non-ERDC authors are solicited for publication, especially if the work described is tied to the use of ERDC-generated research results. Research articles that complement ERDC research or cover wide field applications are also accepted for consideration. Manuscripts should use a nontechnical writing style and should include suggestions for visuals and an author point of contact. Point of contact is Elke Briuer, APR, at *Elke.Briuer@erdc.usace.army.mil*.

Model upgrade allows improved simulation of bottom surges caused by open-water placement of dredged material

by Dr. Billy Johnson, Coastal and Hydraulics Laboratory

During open-water placement of dredged material, two issues are normally of concern: water column effects and effect of the falling material as it impacts with the sea-floor. In this second effect, after impact, energy within the disposed material drives a lateral movement of material that is still in suspension along the seafloor. The resulting bottom surge continues until all the energy is dissipated. The surge can continue for distances of hundreds of meters, depending on the slope of the seafloor.

Predicting the extent of such surges, and the resulting distribution of deposited material, is important to open-water disposal site management and capping project design. For example, if contaminated material is placed in under-water pits or depres-sions during a capping project, an important question is "will the material run up the side of the pit or depression and deposit material outside?" Likewise, in the manage-ment of an open-water site where material is disposed on mounds or natural topography containing slopes, it is important to be able to estimate the extent of the deposition of material contained in the bottom surge.

As illustrated in Figure 1, regard-less of the disposal method, field evaluations and laboratory tests have shown that the placement of dredged material follows a three-step process:

➢ convective descent during which the material falls under the influ-ence of gravity,
➢ dynamic collapse or surge when the material impacts the bottom, and
➢ passive transport-diffusion by ambient currents and turbulence when the material transport is determined more by ambient currents and turbulence than by the dynamics of the disposal operation.

Under previous U.S. Army Corps of Engineers research programs, the model STFATE (Short-Term FATE) was developed. This model predicted the initial, short-term physical fate of material placed in open water as it moves through the three modes of transport. Equations expressing the conservation of mass, momentum, and solids are formulated and solved. The equations are written for ideal-ized shapes that the disposed material is assumed to take. For example, bottom surge computations assume an ellipsoidal shape and do not fully account for the influence of bottom slopes on the spreading of the surge. Thus, a more accurate approach, which allows for better physics and a full spatial representation of the bottom surge, is needed to more accurately predict the movement and resulting deposition of the material.

Proposed Model Development

A three-dimensional model containing all the basic physics re-quired to provide a more accurate tool for computing the fate of dredged material as it travels along the seafloor is currently beging developed under the Dredging Operations and Envi-ronmental Research (DOER) (*www.wes.army.mil/el/dots/doer*) Program's Nearshore/Aquatic Place-ment Focus Area. The model must compute the transport of a sediment/ water mixture as it descends through the water column, impacts the bot-tom, and is deflected laterally along the bottom. In other words, a three-dimensional, hydrodynamic model that also computes the transport of suspended sediment is required.

Numerical hydrodynamic models that assume hydrostatic pressure are usually sufficiently accurate for most water bodies where the vertical component of the velocity is small. But when vertical acceleration is

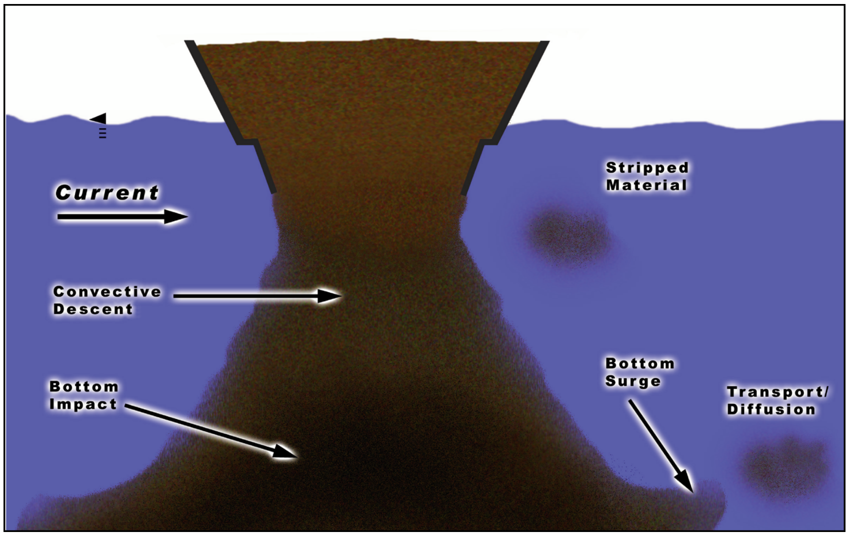


Figure 1. Description of an open-water disposal operation

important, the non-hydrostatic component of the pressure cannot be neglected. Due to the possibility of abrupt changes in bottom bathymetry and strong density gradients driving the flow of the sediment/water mixture as it descends through the water column and then moves laterally along the sea bottom, vertical accelerations are important for the problem at hand. Thus, in the development of a numerical model to accurately predict the bottom surge resulting from the open water placement of dredged material, the hydrostatic pressure assumption is not appropriate.

In addition, the numerical grid must accurately represent the bottom topography. And, since Corps Field Offices will use the model, it must be robust, run on personal computers, make rapid simulations, and display results in graphical form.

A 3D numerical hydrodynamic model called CH3D (Curvilinear Hydrodynamics in 3 Dimensions) has been developed through the joint efforts of Sheng and personnel at the Engineering Research and Development Center at Vicksburg, MS. With its ability to accurately represent bottom topography and its numerical efficiency, CH3D provides a solid framework for development of a predictive capability for the movement of bottom surges. However, CH3D assumes a hydrostatic pressure. In addition, a sediment transport capability for the transport of suspended material in the bottom surge and its ultimate deposition is required.

Modeling a non-hydrostatic pressure. CH3D is proposed for additional development to yield a bottom surge numerical model. A fractional-step scheme is proposed for incorporating the non-hydrostatic component of pressure into the existing CH3D model. The scheme involves writing the pressure as a sum of its hydrostatic and non-hydrostatic components. Since water density is variable due to salinity, temperature, and suspended sediment, the hydrostatic component is composed of both a barotropic component involving the water surface elevation and a baroclinic component related to gradients in the water density.

The numerical solution will involve computing the descent of the disposed material through the water column as well as the movement of the bottom surge. This will be accomplished by inserting disposal material into computational cells near the surface at some prescribed rate that represents the time required for the material to exit the disposal vessel. In addition, a vertical insertion velocity based on characteristics of the material and the disposal vessel will be prescribed in these cells. The model will then compute the descent of the material and its impact on:

- the surrounding ambient water,
- its impact with the bottom, and
- the lateral deflection of the sediment/water mixture as a surge along the bottom.

Development of a suspended sediment transport module. The descent through the water column and the bottom surge both involve transport of sediment. Thus, there is a need for computations of the ‘transport of solids’ inserted into the water column. One approach would be to solve a 3D-transport/diffusion equation for each grain size fraction of the suspended sediment. Concentrations for each size fraction would be computed and used in the ‘state’ equation to compute the water density of each computational cell. However, the approach proposed for this project will use discrete particles to represent the total mass of each ‘size’ fraction. In addition to settling, these particles are transported and diffused by the water current and turbulence.

Graphical user interface. A DOER-developed, numerical, suspended-sediment fate model called SSFATE (Suspended Sediment FATE) employs a shell-based approach. This approach consists of a color-graphics-based, menu-driven user interface; a geographic information system (GIS); environmental data management tools; and gridding software. All these attributes interface to allow data input and to supply display of output data from the model. SSFATE runs on a personal computer and makes extensive use of the mouse (point/click) and of pull-down menus. A particle-based model will predict transport and dispersion of suspended material from a sediment source, using a random-walk procedure.

Output includes animation of the particles representing each suspended sediment type in any horizontal plane or along any vertical plane of the computational domain desired; the amount of material deposited on the bed; and concentration contours in both horizontal and vertical planes.

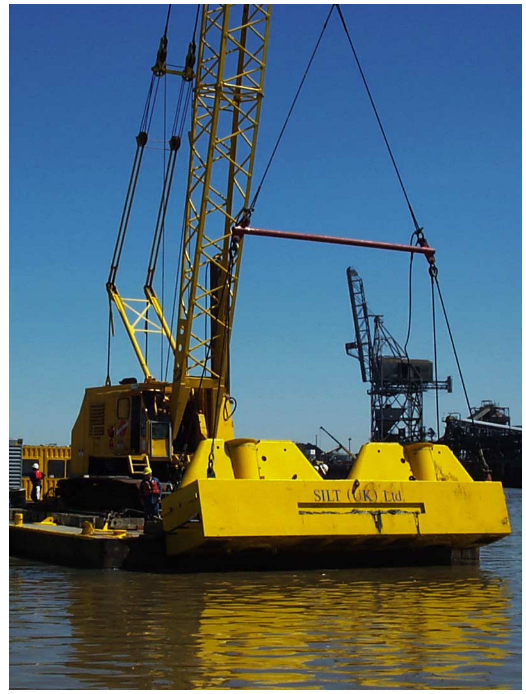
The features of the graphical user interface of SSFATE are ideal for embedding of the bottom surge computation model. The graphical user interface will allow rapid setup of problems and quick visualization of model results.

The research is expected to provide a highly accurate predictive tool to aid in the management of the disposal of dredged material. Its use should increase acceptance of both nearshore and offshore placement of dredged material by regulatory agencies during capping operations involving contaminated material. In addition, such a modeling tool will allow for better management of the placement of material on nearshore berms, and result in lower costs associated with such operations.

Additional information is available from Dr. Billy H. Johnson (601-634-3425, *johnson@wes.army.mil)* and Mr. Allen Teeter (601-634-2820, *teetera@wes.army.mil)*. Related information is available from the DOER website at *http://www.wes.army.mil/el/dots/doer*.

Wing Excavator demonstrated in Houston Ship Channel

Norman R. Francinques, Environmental Laboratory



Under the DOER Innovative Technology Focus Area, a new type of Wing Excavator was demonstrated at the mouth of Green's Bayou and the Houston Ship Channel as a Galveston District and DOER project.

The Wing Excavator is a water jet device that uses an axial flow system to direct and focus water currents on a submerged sediment mass for displacing the sediments some horizontal distance away from the target area. The result is similar to the action of underwater bulldozing of the sediments. This action can be termed hydro-blading. The Wing Excavator moved approximately 33,000 cubic yards of material from the shoaling area along the distance of approximately 800 feet.

Monitoring of the operation showed no visible resuspended sediment plumes in the water column. In fact, the mud flow stayed near the bottom of the channel at all times. The field observations will be confirmed in the laboratory with water samples taken at the site being analyzed for turbidity and TSS. A report will be prepared to present the results of this demonstration project.

Additional information is available from Norman Francingues, 601-634-3703 or email *Norman.R.Francingues@erdc.usace.army.mil*

Dredging Calendar

2001

April 2-5 - WODCON XXI Congress, Kuala Lumpur, Malaysia. **POC:** *www.woda.org*, click on "Congresses."

April 3-5 - Oceanology International 2001 Americas, Miami Beach Convention Center, Miami Beach, Fla. **POC:** Karl Jacobson, PGI Inc., Arlington, Va., 703-312-9129; FAX 703-528-1724; *www.oiamericas.com*

April 10-12 - Dredged Material Assessment and Management Seminar, Baltimore, Md., sponsored by U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. Register online at *www.wes.army.mil/el/dots/training.html*

April 30-May 2 - PORTS 2001, Norfolk Waterside convention Center, Norfolk, Va., sponsored by ASCE and PIANC.
POC: *www.asce.org/conferences/ports01/index.html*

May 8-9 - National Dredging Meeting 2001, Hilton Springfield, Springfield, Va.
POC: Tom Verna, 202-761-4668 or *thomas.m.verna@usace.army.mil*

May 19-21- IAPH 22nd. World Ports Conference, Montreal, Quebec, Canada; Contact: Port of Montreal, Montreal, Quebec, Canada. **POC:** 514-283-8595; FAX 514-283-0829; e-mail: *info@port-montreal.com*; *http://www.port-montreal.com*

May 30-June 1 - EPA Forum on Managing Contaminated Sediments at Hazardous Waste Sites, Hilton Alexandria Old Town, Alexandria, Va. **POC:** Joan Fisk, 703-603-8791; register at *www.epa.gov/superfund/new/sedforum.htm*

June 24-27 - XXI Western Dredging Association (WEDA) Conference; Texas A&M University's 33d Annual Dredging Seminar; and PIANC Session - Houston, Texas.
POC: 360-750-0209 or *www.wesda.org*

July 15-19 - Coastal Zone 2001, Cleveland, Ohio.
POC: *www.csc.noaa.gov/cz2001*

October 1-5 - AAPA 2001 Annual Convention, Quebec City, Canada
POC: *www.aapa-ports.org/conventions.html*

October 22-26 - Convention on the Prevention of Marine Pollution from the Dumping of Water and Other Matter, London Convention of 1972, London, UK (for Convention Members only)

2002

September 22-26 - PIANC 30th International Navigation Congress, Sydney, Australia

US Army Corps of Engineers ®

Engineer Research and Development Center

Dredging Research

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the U.S. Army Engineer Research and Development Center. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program and includes information about various dredging research areas. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Contributions are solicited from all sources and will be considered for publication. Editor is Elke Briuer, APR, *Elke.Briuer@erdc.usace.army.mil*. Mail correspondence to the Environmental Laboratory, ATTN: DOTS, Dredging Research, U.S. Army Engineer Research and Development Center, Waterways Experiment Station (CEERD-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2349. Internet address: *www.wes.army.mil/el/dots/drieb.html*.

James R. Houston, PhD
Director

CEERD-EV-I
OFFICIAL BUSINESS

DEPARTMENT OF THE ARMY
ENGINEER RESEARCH AND DEVELOPMENT CENTER
WATERWAYS EXPERIMENT STATION, 3909 HALLS FERRY ROAD
VICKSBURG, MS 39180-6199