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Dredging Research Technical Notes

Analysis of Dredged Material Deposition Patterns

Purpose

This technical note presents an analysis of dredged material deposition patterns in the Puget Sound using the latest version of the dredged material disposal model SSTFATE being developed by the Dredging Research Program (DRP).

Background

In 1985, the Puget Sound Dredged Disposal Analysis (PSDDA) Program was initiated to establish long-term disposal sites for material dredged within the confines of Puget Sound. The study was cosponsored by the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency (EPA), and the Washington State Departments of Ecology and Natural Resources.

To assist in determining the appropriate size and location of the disposal sites, a numerical model, originally developed for the EPA and later refined by the U.S. Army Engineer Waterways Experiment Station (WES), was used to estimate the depositional pattern caused by the disposal of a single barge load of dredged material (Trawle and Johnson 1986). The model was used to simulate the behavior of dredged material disposed in several combinations of water depth and current speed.

Model results for dredged material that was believed to represent the worst case (greatest spread) situation (5 percent sand, 16 percent clay/silt, and 79 percent water by volume) indicated that the impact of any one barge load of material would be confined to a relatively small area. In a simulation of a 1,500-cu-yd disposal with a 400-ft water depth, stationary barge, and negligible current speed, the descending cloud of material was approximately 250 ft in diameter when it hit the bottom, approximately 30 sec after the disposal was initiated. The collapsing cloud then spread out in all directions. Ten minutes later, essentially all of the material had been deposited on the bottom within a 1,000-ft radius of the disposal point. Therefore, if a disposal were made at the edge of the 900-ft-radius disposal zone, material could be deposited up to 1,900 ft from the center of the disposal site.

Final delineation of the disposal sites included accommodation for bottom topography and tidal currents. The disposal site at Port Gardner, Washington, is located in 400 ft of water on a large flat plane where tidal currents are minimal. No modification to the circular geometry of the site was made except to add a 200-ft safety factor to create a 2,100-ft-radius site that was expected to be large enough to contain all types of sediment suitable for open-water disposal (Figure 1).

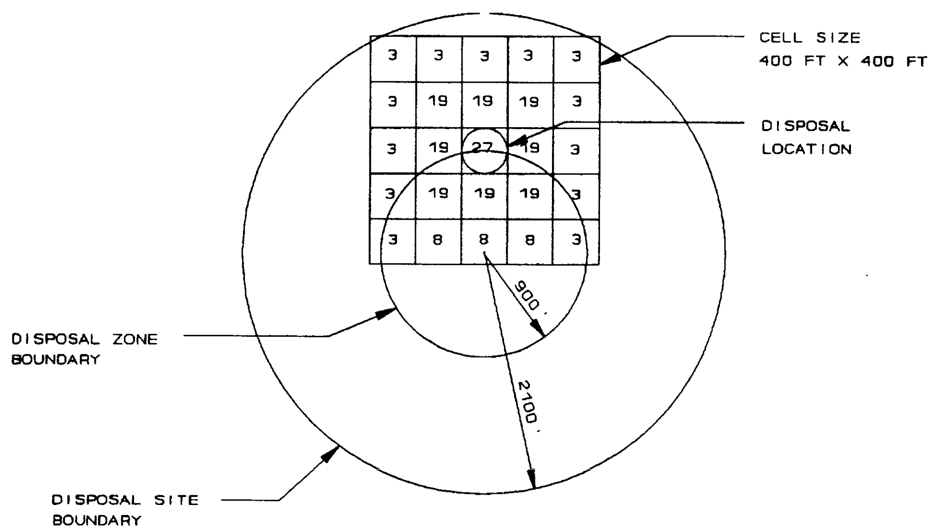

Figure 1. Deposition pattern calculated for 1,500 cu yd of PSDDA dredged material and resulting disposal site delineation; thickness in thousandths of a foot

Additional Information

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Navy Homeport Project

Shortly after the PSDDA disposal sites had been established, the first phase (Element I) of the Navy's Homeport Project at Everett, Washington, required dredging and disposal of approximately 1 million cu yd of material at the Port Gardner site (Figure 2) (Nelson and Johnson 1992). Dredging was begun on November 1, 1989, using a 15-cu-yd capacity clamshell dredge. Disposal of the material was accomplished using four sizes of split-hull scows, with capacities that varied from approximately

500 to 3,000 cu yd. The track of the tug and barge was monitored for each disposal, and the locations and times when the barge was opened and closed as well as the barge volume were recorded. These records show that 956,000 cu yd were disposed in 581 trips. Barge loads varied from 400 to 3,000 cu yd, and all disposals were made within a 600-ft-radius target area located at the center of the 900-ft-radius disposal zone. The final load of dredged material was taken to the disposal site on March 13, 1990.

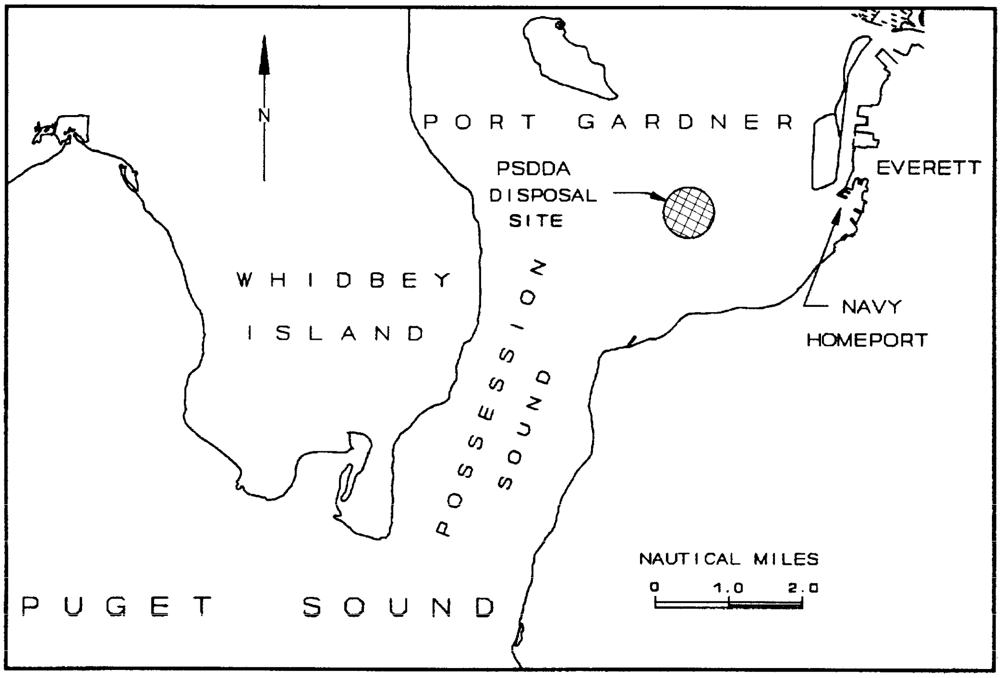

Figure 2. Port Gardner disposal site location

Monitoring

A postdisposal monitoring program began on April 30, 1990. The objective of this program was to measure the physical, chemical, and biological impacts caused by disposal of the dredged material. Sediment samples were taken and photographs made using a sediment vertical profiling system (SVPS) throughout the disposal site and surrounding area. The SVPS photographs were used to map the distribution of the dredged material (Figure 3).

Where the 0.7-ft-high camera prism penetrated the entire layer of dredged material, the thickness of the layer was estimated from the SVPS photos. If the camera penetrated only a portion of the dredged material, the measured thickness was followed by a "+." The SVPS photos indicated that over 96 percent of the disposed material was

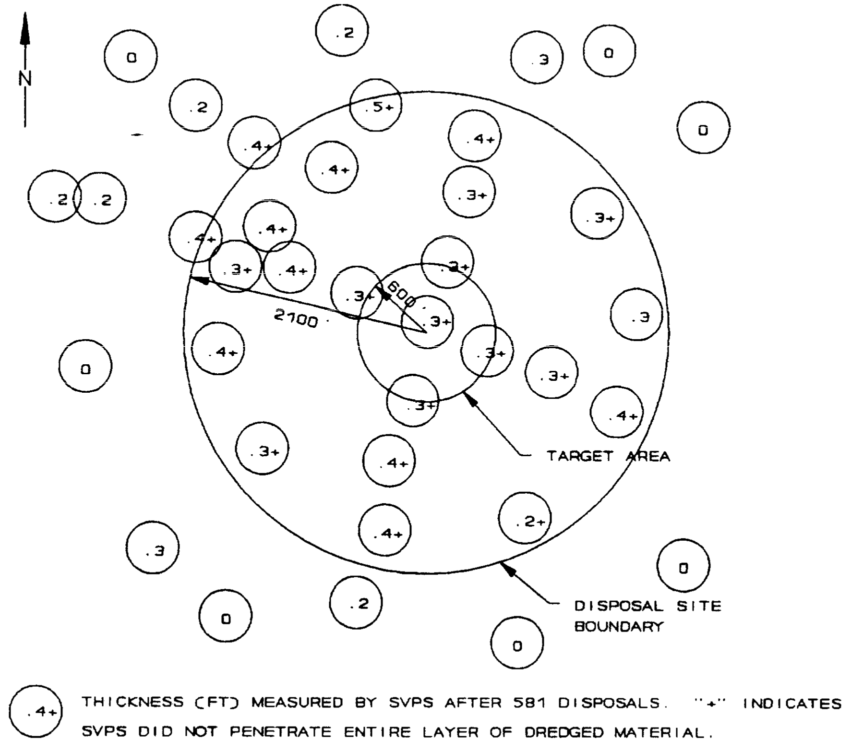

Figure 3. Distribution of 956,000 cu yd of dredged material as measured by the sediment vertical profiling system (SVPS)

deposited within the disposal site. The photos also showed, however, that some material settled as far as 1,000 ft outside the disposal site boundary. Detailed results of the monitoring studies are presented in the Final Monitoring Report by SAIC (1990).

Numerical Modeling of the Navy Project

Because the observed deposition pattern indicated that disposed material extended more widely than predicted by the PSDDA site selection process, the spread of material was reanalyzed using material characteristics and disposal parameters that were representative of the Navy's project. The sediment samples taken prior to dredging were used to characterize the material being disposed. The average in situ volumes of sand, clay, silt, and voids (water) were 15, 1, 29, and 55 percent, respectively.

Over the course of the project, four different split-hull scows were used to dispose of material, but load sizes generally fell into two categories: large (2,325 cu yd average) or small (720 cu yd average). Records indicate that the barge velocity during disposal was typically 5 ft/sec to the west and that the time required to open, empty, and close the barges was approximately 4 min in nearly all cases. However, the contractor confirmed that standard practice was to leave the barge open for approximately 4 min to reduce the possibility of debris being caught in a position to jam the barge-closing mechanism. Observers reported that from several seconds to as much as 1-1/2 min were required for the barges to discharge their loads.

The numerical model used for the PSDDA simulations has been revised and adapted to run on a personal computer by WES as part of the DRP (Johnson and Fong in preparation). The revised model (SSTFATE) was used to simulate the disposal of dredged material at the Port Gardner site and to compute the deposition patterns for the two average barge volumes of 2,325 cu yd and 720 cu yd. An additional 8 percent water was assumed to be entrained during the dredging operation to portray more accurately the dredging and disposal process. This increase corresponds to a 20 percent bulking factor, and the recomputed percents (by volume) of sand, clay, silt, and water were 12, 1, 24, and 63 percent, respectively. Simulations were made assuming an average release time of 60 sec, an average tidal current speed of 0.2 ft/sec (with a flow 50 percent of the time to the west during flood tides and 50 percent of the time to the east during ebb tides), and a barge speed of 5 ft/sec (3 knots) to the west.

Model results are displayed as solids volumes deposited throughout a specified grid cell pattern or as a material thickness within each grid cell. For the Navy project Element I, a pattern that was 20 cells on a side, with each grid cell 400 ft by 400 ft, was selected. This grid size is identical to that used in the original PSDDA site-delineation process. Results of the model simulation of one disposal (2,325 cu yd with flood tide condition and barge speed of 5 ft/sec) for the Navy's project are shown in Figure 4. Since the SSTFATE model calculates the deposition pattern for only one disposal, the final configuration of the deposited material, after numerous disposals, was calculated by multiplying the results of one disposal by the total number of disposals. The total volume of solids deposited in each cell was the result of 581 disposals (336 at 2,325 cu yd each and 245 at 720 cu yd each), with the disposal point evenly distributed among the nine 400-ft by 400-ft grid cells that represented the 1,200-ft-diam target area at the Port Gardner site. The combined results of 581 disposals using the two (ebb and flood) tidal current conditions, and disposals uniformly distributed throughout a 9-grid cell target area are shown in Figure 5. Also shown on this figure is the disposal mound boundary estimated from SVPS field measurements of the thickness of the deposited material.

Analysis of Results

Simulation of a single disposal, using a 400-ft water depth, 0.2 ft/sec tidal current, and a 5 ft/sec barge speed, indicates that material representative of the Navy project spread about twice as far as the material originally modeled for the PSDDA site delineation. The slight tidal current, the motion of the barge, and the high proportion of solids (over

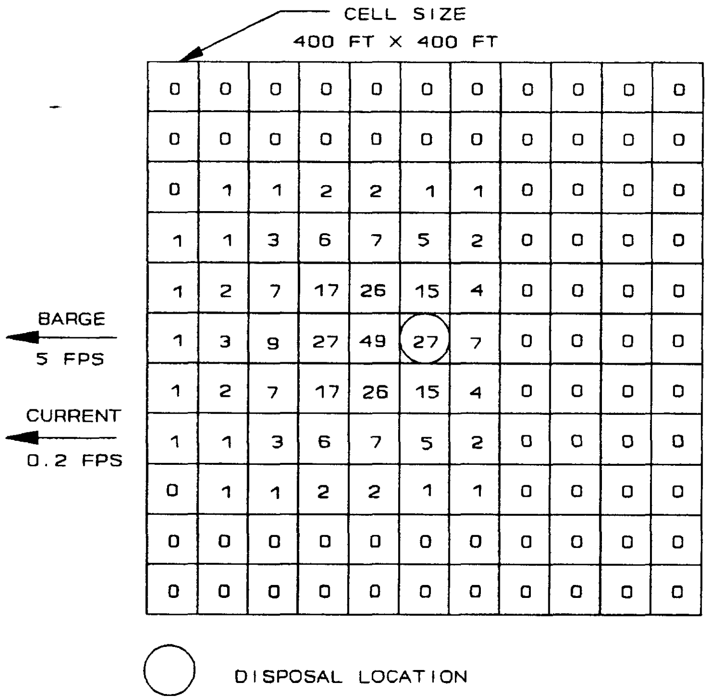

Figure 4. Deposition pattern calculated by numerical model SSTFATE for one 2,325-cu-yd load of Element I dredged material in 400 ft of water; thickness in thousandths of a foot

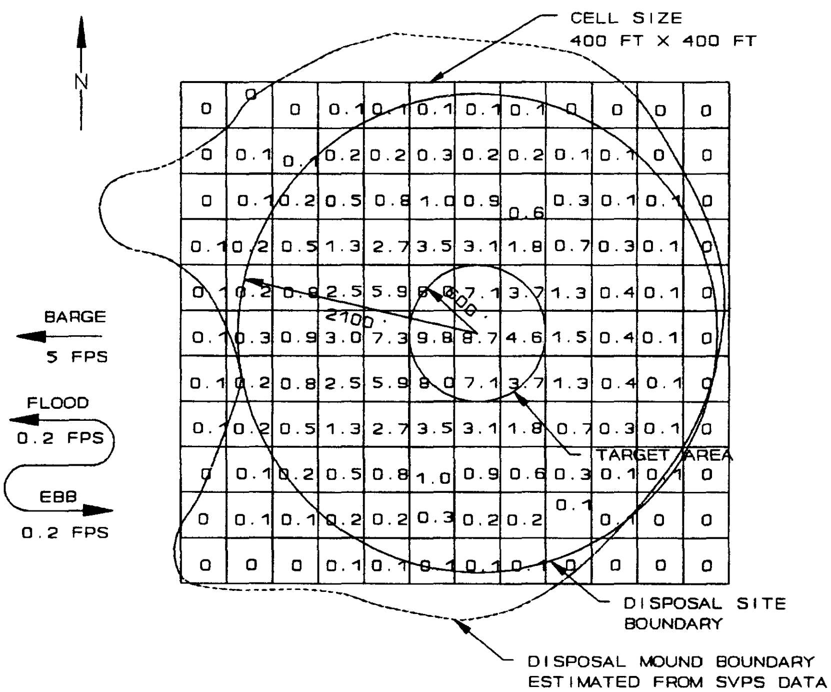

Figure 5. Comparison of measured disposals mound boundary and computed deposition pattern for 581 disposals of Element I dredged material

two times as much solids were in each cubic yard of dredged material as were in the modeled PSDDA material) are responsible for the major differences in the deposition pattern for individual disposals.

The simulation of the combined effect of all the disposals that took place during the Navy's project accurately represents the well-defined deposition pattern found at the disposal site. The simulation indicated that about 2 percent of the disposed material would be deposited outside the PSDDA disposal site boundary. Field measurements made immediately after the completion of Element I dredging found deposits outside the disposal site boundary that account for approximately 3.5 percent of the material disposed during the Navy project.

The small deposits detected outside the boundary were greater in thickness and distributed slightly more widely than computed by the model. These differences probably resulted from using average values for model input parameters and the averaging of the computed thickness over each 400-ft by 400-ft grid cell. More accurate computation of the thickness of the extremely small sediment deposits (0.001 ft/disposal) at the edges of the disposal site would have required a finer grid pattern and precise representation of ambient conditions, material parameters, and details of the disposal operations for each of the 581 trips to the disposal site.

Element II Predicted Pattern

The methodology developed for analyzing the Navy's Element I disposal operations was used to assist in computing the anticipated spread of disposed dredged material for the upcoming second phase of the Navy's project, Element II. The maximum Element II dredging volume is estimated at 421,000 cu yd. The material is similar in nature to that from Element I, consisting primarily of sand and silt with a very low water content. In situ sampling indicated that the material is composed of 0.6 percent gravel, 23.1 percent sand, 20.2 percent silt, 3.4 percent clay, and 52.6 percent water, by volume measurement. As for the Element I simulations, a 20 percent bulking factor was applied, resulting in a total estimated disposal volume of 505,000 cu yd. Constituent volumes were recomputed and the SSTFATE model was run for disposed material consisting of 19 percent sand, 17 percent silt, 3 percent clay, and 60 percent water. All other parameters were assumed to be the same as for Element I model runs, including the same percentage of large (2,325 cu yd) and small (720 cu yd) barge loads and the same uniform distribution of disposals in the grid cells that represent the 1,200-ft-diam target area.

The combined results of 177 loads at 2,325 cu yd and 130 loads at 720 cu yd (505,000 cu yd total) are shown in Figure 6. The numerical model simulation indicates that essentially all Element II material will be deposited within the disposal site boundaries, with a sediment thickness that is 50 to 70 percent of that predicted for the Element I disposal pattern.

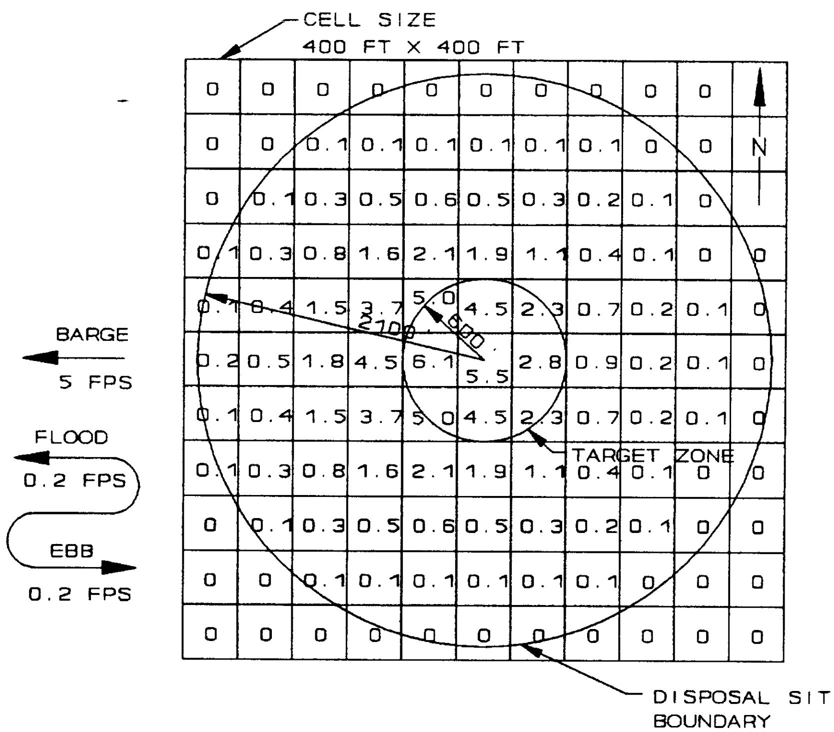

Figure 6. Deposition pattern calculated by numerical model SSTFATE for 505,000 cu yd of Element II material; thickness in feet

As in the Element I analysis, if any material is carried off site, it would be deposited at a rate of less than 0.001 ft/disposal.

Conclusion

The generally good agreement between the model results and the field measurements shows that the short-term fate model SSTFATE can be used effectively to assess the risk of dredged material being deposited outside the boundaries of an open-water disposal site. However, care must be taken to represent accurately ambient conditions, material characteristics, and disposal operations.

References

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