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Geotechnical Properties and Sediment Characterization for Dredged Material Models

PURPOSE: This technical note provides an overview of geotechnical engineering properties of dredged materials and input requirements for selected fate of dredged material models. There are numerous models that have been developed or are being developed that require information regarding geotechnical properties and material characteristics for dredged material.

BACKGROUND: The U.S. Army Corps of Engineers (USACE) is responsible for maintaining navigation on 25,000 miles (40,234 km) of waterways that serve about 400 ports in the United States. Billions of tax dollars have funded the USACE civil works mission to maintain and operate these waterways, including dredging activities. The U.S. Army Engineer Research and Development Center (ERDC) has been tasked to provide enhanced planning and operational tools for helping the USACE Districts more effectively accomplish the various dredging tasks.

A priori numerical modeling of a particular dredging operation provides a cost-effective tool to establish operational parameters and forecast optimum dredging scenarios prior to actual dredging operations. Once dredging has started, analytical models are available or are being developed to track operational dredging status to allow feedback into the dredging management process as a compliance monitoring tool. On a broader scale, numerical models allow for effective and economical regional dredging and sediment management planning, including project design.

In general, numerical dredging models require input data on the dredged material sediment characteristics, the water body characteristics, the biological and chemical parameters, the environmental forcing functions, and the dredging operations. This technical note addresses the model input requirements for dredged material sediment characteristics and engineering properties.

GEOTECHNICAL ASPECTS OF DREDGED MATERIAL ENGINEERING PROPERTIES: Dredging project designs generally do not require knowledge of the in situ soil or rock engineering properties to the detail needed for foundation engineering projects (Spigolon 1995a). The spatial area encountered in a typical dredging project is much larger than that of an underwater or onshore foundation project, where detailed site investigation and characterization information are needed. In areas of highly variable geotechnical properties, increased spatial resolution is needed to properly characterize the sediment properties, especially when determining the possibility of an area being dredged (Spigolon 1995b) or when designing contaminated sediment confined aquatic disposal sites (Rollings 2000). Because of the large costs and time duration required for conducting detailed geotechnical site investigations over such spatially large dredging areas, geotechnical properties are typically estimated or average values are assigned. Inherent uncertainty results from assigning estimates for material characteristic values.

Dredged Material Fate. In addition to the influence of spatial variability in the geotechnical properties of in situ undisturbed sediments, the problem of assigning accurate properties becomes greater when considering the dredging cycle and processes involved in sediment disturbance. Disturbed or remolded geologic materials exhibit different engineering properties when compared to their undisturbed state (Scott 1963), and dredged materials undergo significant remolding during transition from their in situ to final disposal states. Figure 1 illustrates the material remolding cycle during material removal and placement phases of a typical dredging project.

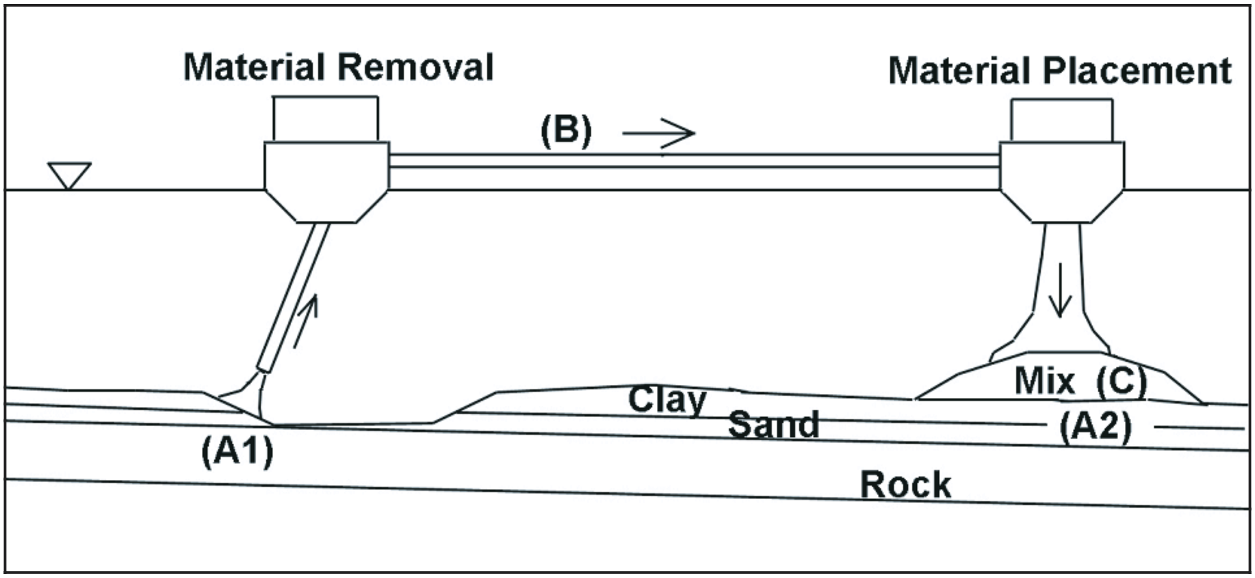

Figure 1. Illustration of dredged material fate

Native or recently deposited in situ geologic material, natural sediment, or contaminated sediment (A1) is mechanically or hydraulically dredged from its location below the mudline in a fresh, brackish, or saltwater environment. The material is mixed with water in varying proportions depending on the type of dredging equipment. The in-transit remolded material (B) is either transported directly to the disposal site or transported indirectly in intermediate steps, such as transfer to a dump scow or pipeline. At the disposal site, the material is placed onto another subsurface material (A2) via a number of methods to form yet another remolded material (C). Additional materials may be added to (C), such as encapsulation with overlying sand or rock. In Figure 1, the in situ material is remolded at least twice during the transit stages between material dredging and material disposal. Although the disposed material (C) may have the same general grain size distribution as the original material (A1), the engineering behavior and material characteristics of material (C) likely will be different. Quantifying the material characteristics and behavior of material (B) or (C), based on predredging site investigations of material (A1), involves a high degree of uncertainty. Inputting engineering property information at various material transit stages into a numerical dredged material fate model provides a challenge to the modeler, since in most cases, accurate material property information is not readily available.

Dredged Material Models. Numerous models of dredging operation and dredged material fate have been designed by the ERDC, and some of these models are listed below. The ERDC website *http://www.wes.army.mil/el/elmodels/index.html* provides a comprehensive list of dredging models developed for the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS).

Onshore placement models. Models have been developed to assist with dredged material management and design of confined disposal facilities. These include the integrated confined disposal facility (CDF) design module, which allows modeling of suspended solids retention, initial storage requirements, and hydraulic retention aspects of storage facility design. The Primary Settlement and Desiccation of Dredged Fill (PSDDF) model allows evaluation of sediment consolidation for determining the long-term storage requirements of a CDF.

Nearshore and open water placement models. Models have been developed to track the fate of dredged material operations and disposal in open water. Short-term Fate of Dredged Material Disposed in Open Water (STFATE) predicts sediment deposition and water quality effects from a single placement of dredged material. Long-term Fate of Dredged Material Disposed in Open Water (LTFATE) predicts long-term erosional stability of underwater sediment mounds. Multiple-Disposal Fate of Dredged Material Disposals in Open Water (MDFATE) bridges the gap between STFATE and LTFATE to simulate multiple disposal events at one open water disposal site and erosion from the mound as a result of current and waves. The Suspended Sediment Fate model (SSFATE) numerically computes the fate of sediment plumes generated at a dredging site for up to several tidal cycles. Computation of Mixing Zone Size or Dilution for Continuous Discharges (CDFATE) predicts water column and fluid mud impacts from pipeline placement of dredged material in shallow estuaries. The Sediment Resuspension and Contaminant Release by Dredge (DREDGE) model analytically computes suspended sediment concentrations from a dredging operation.

Engineering Properties of Dredged Materials. Engineering properties and material characteristics are assigned, depending on the model's goal, because of the complex modeling scenarios involving dredged material. For example, when modeling contaminated sediment concentration during sediment freefall through the water column, the model input would not require geotechnical engineering consolidation properties but would require information regarding the physical grain size distribution.

The engineering property descriptors match the model input requirements accordingly. As an example, when the sediment has a water content greater than its geotechnical Atterberg liquid limit, the sediment property descriptors may more closely match those used by chemical engineers for suspension slurries. The sediment mass concentration may be defined instead of the geotechnical void ratio. Terminology and definition differences between various engineering and physical properties must be recognized and input accordingly to achieve consistency. To achieve compatibility between models, each material property must be singularly defined and appropriately applied. Table 1 lists some engineering properties and descriptors applicable for dredged material characterization.

Material weight-volume relationships. Figure 2 illustrates the soil sample weight-volume relationships which provide a standard (American Society for Testing and Materials (ASTM) D653) definition basis for geotechnical parameters.

Table 1
Engineering Properties and Descriptors for Dredged Material Characterization

Description[1]	Measurement Method or ASTM Standard[2]	Measurement Location[3] Pre-dredge	In-dredge	Post-dredge
Bulk Properties				
Appearance (consistency, smell, and color)	Visual, D3441 (in situ), D3213, D2488	✓	✓	✓
Slump (change in height)	Experimental		✓	✓
Slurry percentage consistency Ws/W	E300		✓	
Suspended sediment concentration (mg/l)	Various	✓	✓	
Bulk density or unit weight (assumes 100-percent water saturation typically)	D653	✓	✓	✓
Specific density (tons dry solids)	Calculated		✓	
In situ compactness	PIANC, BS1377	✓	✓	
Bulking percent (change in volume or mass as a result of material disturbance by dredge)	Estimated		✓	✓
Clump volume percent (mechanical dredging)	Estimated		✓	
Clump bulk density or unit weight	Estimated		✓	
Nonclump volume percent	Estimated		✓	
Nonclump bulk density or unit weight	D653		✓	
Solids fraction (percent solids by weight)	Experimental	✓	✓	
Weight fraction (percent sand, etc., by weight)	D422	✓	✓	✓
Volume fraction (percent sand, etc., by volume)	D2488[4]		✓	
Water Properties				
Density (or unit weight γ_w)	D653	✓	✓	
Pore water salinity	D4542	✓	✓	
Solids Properties				
Organic content percent	D2974, BS1377	✓	✓	✓
Calcium carbonate (lime) percent	D4373, PIANC	✓		✓
Mineralogy	X-ray diffraction, electron microscopy, etc.	✓	✓	✓
Specific gravity of solids Gs	D854	✓	✓	✓
Dry density (or dry unit weight γ_d)	D653	✓		✓
Dry particle density (or dry particle unit weight γ_s)	D653	✓	✓	

(Sheet 1 of 3)

[1] Mass and weight descriptors are used interchangeably with applicable conversion factors.
[2] In situ methods include data acquisition by cone penetrometer, vane shear, pressuremeter, density profilers, or other sensors. Laboratory methods include sample testing, analysis, indexing, and correlation methods that may not be standardized by the USACE, ASTM, see Appendix I, American Association of State Highway Transportation Officials (AASHTO), International Navigation Association (PIANC), British Standard (BS), German Standard (DIN), or others.
[3] Predredged material is the in situ or native material on the seabed or river bottom. In-dredge material has been mechanically or hydraulically dredged and is in transit prior to final disposal. This material is in a barge, dump scow, hopper, or pipeline. Postdredged material has been disposed or placed at an upland site, nearshore site, or open water site, and may include a capping system.
[4] ASTM D2488 provides suggestions for estimating the relative percentages of sands and fines by volume.

Table 1 (Continued)

Description	Measurement Method or ASTM Standard	Measurement Location		
		Pre-dredge	In-dredge	Post-dredge
Solids Properties (Continued)				
Grain size analysis (sieve and hydrometer)	C117, C136, D421, D422, D1140, D2217, D4822	✓	✓	✓
Classification (gravels, sands, silts, clays) by weight (sieve and hydrometer)	C117, D1140, D2487, D2488, PIANC	✓	✓	✓
Grain size frequency distribution (weight)	C136	✓		✓
Median grain size D50 (by weight)	C136, D422	✓	✓	✓
Grain angularity and shape	D2488	✓	✓	
Grain size frequency distribution (particle counting)	D4822		✓	
Classification (gravels, sands, silts, clays) from particle size volume distribution	Particle counting		✓	
Median particle size (by volume)	Particle counting		✓	
Atterberg limits (PI, LL) for cohesive materials	D421, D4318, BS1377	✓		
Water/Solids/Gas Phase Relationships				
Saturated unit weight γ_{sat}	D653	✓	✓	✓
Submerged (buoyant) unit weight γ'	D653	✓	✓	✓
Water content by solids weight (Ww/Ws)	D2216, D4643, D653	✓	✓	✓
Water content by weight (Ww/W)	Calculated	✓		
Water content by volume (Ww/V)	Calculated	✓		
Porosity (Voids volume/total volume)	D653	✓	✓	✓
Void ratio (Voids volume/solids volume)	D653	✓	✓	✓
Clump void ratio	Estimate		✓	
Nonclump void ratio	Estimate		✓	
Gas volume fraction (Vg/ V)	D5314		✓	✓
Dissolved salt phase relations[5]	Calculated	✓		✓
Engineering Behavior				
Structure (penetration resistance)	PIANC	✓		
Shear strength of soft cohesive materials	D4767, D4648, D2850, D2573(in situ), PIANC	✓	✓	✓
Relative density of cohesionless materials	D4253, D4254, PIANC	✓		✓
Rock properties	D653, PIANC, BS5930	✓		
Critical shear ("yield") stress for erosion initiation, erosion rate, and shear stress relationships	Experimental	✓		✓
Cohesion	D653	✓		✓
Friction angle phi	D653	✓		✓
Angle of repose for slope stability	D653	✓		✓

(Sheet 2 of 3)

[5] Dissolved salt phase relations take into account the effect of salinity in the pore water and solid fractions. A small error is introduced into the phase relationship calculations (water content, void ratio, etc.) when salinity is not accounted for (Noorany 1984).

Table 1 (Concluded)

Description	Measurement Method or ASTM Standard	Measurement Location		
		Pre-dredge	In-dredge	Post-dredge
Engineering Behavior (Continued)				
Self-weight consolidation of soft cohesive materials	Experimental	✓		✓
Fixed-ring (oedometer) consolidation	D2435, D4186, D4546	✓		✓
Permeability	D6527, D2434	✓		✓
Viscosity	Experimental	✓	✓	
Particle settling velocity, W_s	Calculated		✓	✓
				(Sheet 3 of 3)

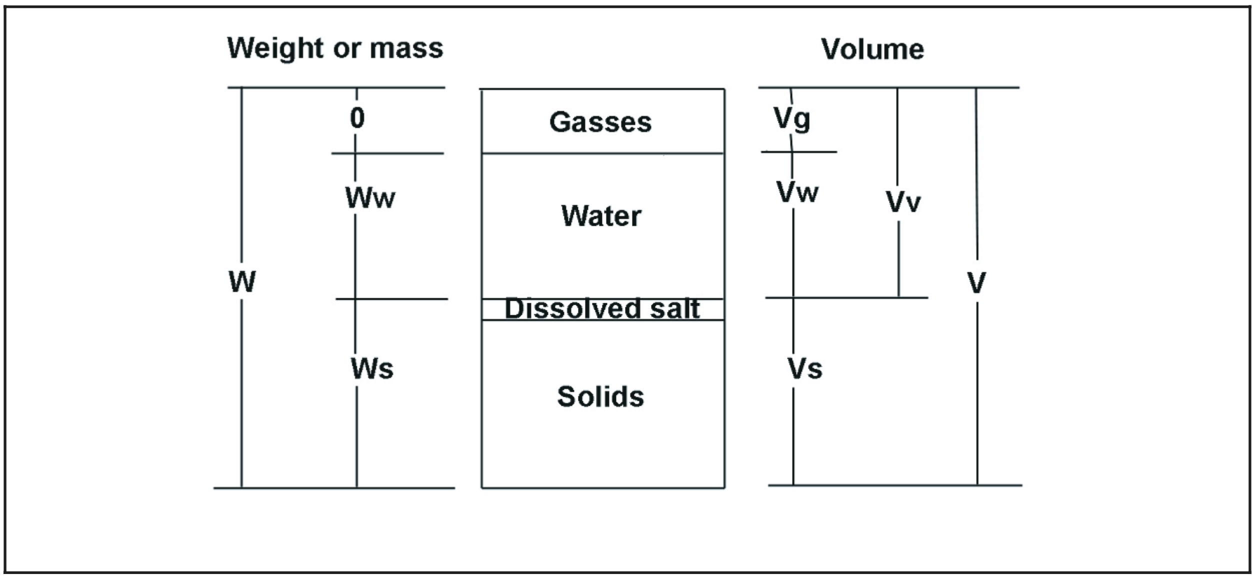

Figure 2. Illustration of weight-volume relationships in a dredged material sediment sample

W = total weight (or mass, depending on the conversion factor)

Ww = water weight (or mass)

Ws = solids weight (or mass)

V = total volume

Vg = gas volume

Vw = water volume

Vs = solids volume

Vv = voids volume (Vg + Vw)

Unit weight and density (or mass density, depending on the conversion factor) relationships:

$$\gamma = W/V \text{ (Total or bulk unit weight, or bulk density)} \tag{1}$$

$$\gamma_s = Ws/Vs \text{ (Solids unit weight or particle density)} \tag{2}$$

$$\gamma_w = Ww/Vw \text{ (Water unit weight or water density)} \tag{3}$$

$$\gamma_d = Ws/V \text{ (Dry unit weight or dry density)} \tag{4}$$

$$\gamma_{sat} = (Ws + Vv\ \gamma_w)/V \text{ (Saturated unit weight or saturated wet density)} \tag{5}$$

$$\gamma_{bouyant} \text{ or } \gamma' = \gamma_{sat} - \gamma_w \text{ (Buoyant or submerged unit weight or density)} \tag{6}$$

Other phase relationships:

$$Gs = \gamma_s/\gamma_w \text{ (Specific gravity of soil solids)} \tag{7}$$

$$e = Vv/Vs \text{ (Void ratio)} \tag{8}$$

$$n = Vv/V \text{ (Porosity)} \tag{9}$$

$$w = Ww/Ws \times 100 \text{ (Water content, percent)} \tag{10}$$

$$S = Vw/Vv \times 100 \text{ (Saturation, percent)} \tag{11}$$

$$e = (w\ Gs)/S \tag{12}$$

Phase relationships may be taken from tables listed in soil mechanics textbooks such as Bardet (1997) or Scott (1963). Figure 3 illustrates an interactive method for computing unknown components in phase relationships.

The above relationships must be modified when taking into account the presence of dissolved salt in marine soils, since the process of oven drying soil reverts the dissolved salt into solids. These additional solids are often erroneously assumed to be soil particles. Noorany (1984) showed that the weight-volume relationships in marine soils with water contents higher than about 180 percent contain a 10-percent error when the salinity is not accounted for. Particularly susceptible to the error are the water content and void ratio calculations. For marine soils with oven-dried water contents above about 180 percent, the following calculation should be performed to determine the true water content:

$$w_{true} = w/(1 - r - rw) \tag{13}$$

where w = oven-dried water content (standard method) and r = salinity (weight of salt per weight of sea water).

Dredged Material Geotechnical Volume-Mass Relations, U.S. Units

Type known or given values into the blue cells; the calculated result will be shown in the table and on the plot

62.4 lb/cu ft unit weight of fresh or salt water

Soil (or sediment) properties for typically assumed 100% water saturation:

100% Saturation assumed	**Void Ratio e**	**Porosity n**	**Specific Gravity Gs**	**Water Content ω (%)***	**Volumetric Water Cont. θ**	**Solids(or Dry) Density γd or Cd**	**Total Bulk Density γ**	**Solids Content by weight**
	ωGs	e/(1+e)	given	given	Se/(1+e)	Gs x pw/(1+e)	(Gs+Se)pw/(1+e)	
	Vv/Vs	Vv/Vt		Ww/Ws	Vw/Vt	Ws/Vt (lb/cu ft)	Wt/Vt (lb/cu ft)	Ws/Wt
100%	4.05	0.80	2.70	150.0%	0.802	33.4	83.4	40.0%

Soil (or sediment) properties for any water saturation %:

Saturation (%) S	**Void Ratio e**	**Porosity n**	**Specific Gravity Gs**	**Water Content ω (%)***	**Volumetric Water Cont. θ**	**Solids(or Dry) Density γd or Cd**	**Total Bulk Density γ**	**Solids Content by weight**
given	given	e/(1+e)	given	Se/Gs	Se/(1+e)	Gs x pw/(1+e)	(Gs+Se)pw/(1+e)	
(Vw/Vv)	Vv/Vs	Vv/Vt		Ww/Ws	Vw/Vt	Ws/Vt (lb/cu ft)	Wt/Vt (lb/cu ft)	Ws/Wt
100%	4.05	0.80	2.70	150.0%	0.802	33.4	83.4	40.0%

Vt = total volume
Vs = volume of dry solids
Vv = volume of voids
Wt = total weight
Ws = weight of dry solids
* Salinity effect ignored

DredgeProp2.xls

Figure 3. Spreadsheet for computing selected weight – volume relationships

MATERIAL PROPERTY INPUT REQUIREMENTS FOR FATE MODELS: Dredged material fate models, especially STFATE, MDFATE, and LTFATE, are being used for dredging project design as well as for project planning (Clausner 2000). Improvements and new developments to these and other nearshore fate models are being developed, including users' guides and graphical users' interfaces. Obtaining accurate prediction results from the model algorithms depends to a large degree on the proper identification and selection of the material property input values.

STFATE Model. STFATE (Johnson and Fong 1995) was developed to provide water column contaminant and suspended sediment concentrations for environmental purposes. Major factors in its applicability include:

- **The placement method of disposal.** Barge or hopper dredge operations are modeled, but pipeline disposal is not presently addressed.
- **The ambient environment into which the sediment falls.** Water density and velocity are major factors, as is the bottom bathymetry.
- **The type of material.** Four sediment types included are gravel, sand, silt, and clay. In addition, the clumping of cohesive sediments (silt and clay) is a major factor.

Up to six layers of material held inside the hopper or barge prior to release into the water column are allowed. The required material properties for each layer include:

- The bulk density (determined using ASTM D653 or Equation 1). The model assumes vertical stratification of bulk density, with the highest density layer at the bottom of the barge. No allowance is presently made for self-weight consolidation of the material inside the barge.
- The solids distribution (determined using grain size analysis methods). The percentages of solid constituents (gravel, sand, silt, and clay) are required, based on volume or weight, depending on the available or estimated in-dredge sediment data. Volume fraction (percentage) of gravel, sand, silt, and clay is calculated based on solids volume of each fraction/total volume. For example, if the material contains 30 percent solids with 40 percent silt, the volume fraction of silt = 0.3×0.4 = 12 percent.
- The settling velocity Ws for each constituent fraction (determined using calculations or curves such as that illustrated in Figure 4).
- Specific gravity of each solid constituent (determined using ASTM D854).
- The percentage of silt and clay in clumps (balls), which are estimated percentages based on the amount of fines, the water content of the bulk material, and the type of dredging equipment. Knowledge of the cohesive material liquid limit (determined from the Atterberg Limits test using ASTM D421) is helpful in estimating clumping percentages.
- Void ratios of the clumped and nonclumped materials (determined using ASTM D653, Equation 8, or Equation 12).
- Critical shear strength needed to prevent sediment deposition (determined experimentally).

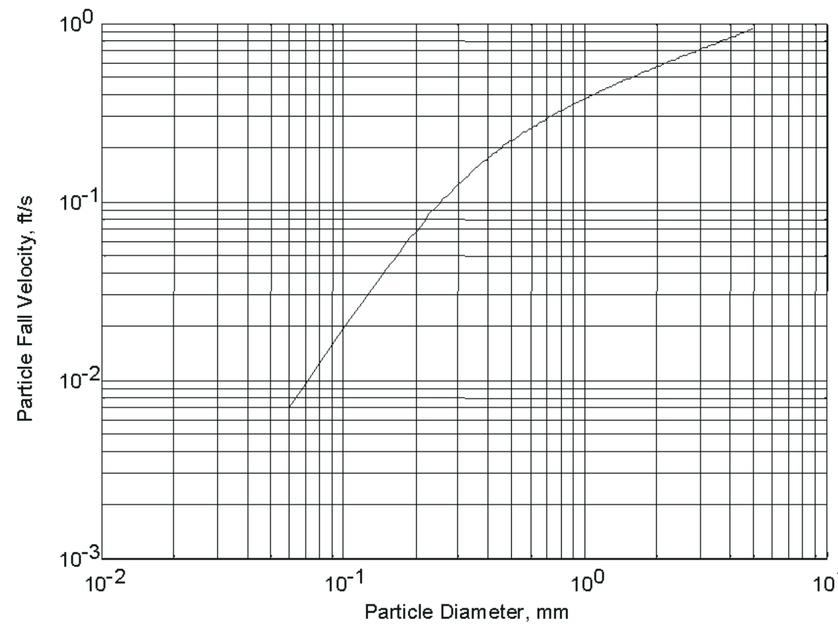

Figure 4. Relationship between grain diameter for natural sands and fall velocity, applicable for sea water at 35 °C and 35 ppt salinity (after Soulsby 1997)

SSFATE Model. The SSFATE model computes suspended sediment fields within the water column resulting from dredging operations (Johnson et al. 2000). Introduction of suspended sediments into the water column is the result of modeled cutterhead dredging, hopper dredging, or clamshell dredging. For each type of dredging operation, the suspended sediment may be introduced at the near-surface, at the near-bottom, or anywhere between. The resulting transport and fate of each sediment particle size class (sands, silts, or clays) may then be predicted. The required material properties may be input, although user-friendly pull-down menus are available for property selections.

Material database properties for input includes specifying up to five components which are elements of the released material with a single bulk density. Settling velocities are computed internally for each size class. Input requirements are:

- Sediment bulk density (determined using ASTM D653 or Equation 1).
- Sediment mass percentages of clay, fine silt, medium fine sand, fine sand, and coarse sand (determined using grain size analysis methods).
- Density of each released material component.
- Bottom shear stress ranges for each grain size class allowing deposition for that grain size class (determined experimentally).

LTFATE Model. The LTFATE model was originally developed as a site analysis tool for the dispersion of sediment from dredged material mounds in open water (Scheffner et al. 1995). Enhancements including a cohesive sediment transport submodel (Gailani 1998) and a graphical user interface (Gailani et al. 2001) have since been developed. Since the model looks at erosional stability of dredged material mounds, the following inputs are required:

- Sediment type. Four sediment class choices are pure sand, clay/sand mixture, inorganic clays, and organic clays. Layering of sediment types within the mound is allowed.
- Median grain size (determined from grain size analysis).
- Angle of initial yield (degrees), and the residual angle after shearing (determined experimentally or estimated using slope stability analysis).
- Bulk density profile of the sediment for cohesive erosion.
- Erosion parameters for cohesive erosion processes (developed from site-specific laboratory or field tests).

MDFATE Model. The MDFATE model uses modified versions of STFATE and LTFATE to simulate multiple open-water dredged material disposal events at a single site. Cohesionless material transport, cohesive material consolidation, and cohesionless material "avalanching" or lateral spreading may be predicted using MDFATE (Clausner, Gailani, and Allison 1999). The cohesive material consolidation is predicted using a subroutine from the PSDDF model. MDFATE has the same sediment data input requirements as STFATE and LTFATE but allows only a single sediment layer in the dredge instead of six.

SUMMARY: Material property input parameters for dredged material fate models include:

- Water content.
- Specific gravity.
- Bulk density.
- Void ratio.
- Percentages based on grain size analysis (percent gravel, sand, silt, and clay).
- Median grain size of each sediment component to predict settling velocities.
- Clumping percentages based on grain size analysis and Atterberg limits.
- Slope stability angles.
- Erosion shear stress.
- Erosion parameters.

Many of these are common geotechnical parameters with standardized measurement and reporting methodologies. Others are not, and they require estimation or experimental measurement methods. Assigning and defining phase relationships (weight-volume relationships) between the water, solids, and air constituents of dredged material may be challenging because of differences in terminology, nonstandardized measurement methods, and lack of predredged, in-dredge, or postdredged material property information.

One method of selecting reasonably representative material characteristics is to look at data obtained from previously completed projects in a regional geographic area. In the absence of current site-specific information, historical data may be selected for input into the fate models to allow initial simulations. Work is currently in progress to collect archived dredged material geotechnical data and establish a searchable material properties database. As new project data are input, the database may be updated on a regular basis to provide a more inclusive information source for dredged material characteristics.

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Lee, L. T. (2001). "Geotechnical properties and sediment characterization for dredged material models," *DOER Technical Notes Collection* (ERDC TN-DOER-N13), U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. *www.wes.army.mil/el/dots/doer/*

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APPENDIX I

List of applicable or potentially applicable ASTM standards for determining or testing dredged material properties:

Designation:	Standard Test Method/Practice for:
C117-95	Materials finer than 75 µm (No. 200) sieve in mineral aggregates by washing.
C136-96a	Sieve analysis of fine and coarse aggregates.
C143-00	Slump of hydraulic-cement concrete.
C172-99	Sampling freshly mixed concrete.
D421-85	Dry preparation of soil samples for particle-size analysis and determination of soil constants.
D422-63	Particle-size analysis of soils.
D653-97	Standard terminology relating to soil, rock, and contained fluids.
D854-00	Specific gravity of soil solids by water pycnometer.
D1140-00	Amount of material in soils finer than the No. 200 (75 µm) sieve.
D2166-00	Unconfined compressive strength of cohesive soil.
D2216-98	Laboratory determination of water (moisture) content of soil and rock by mass.
D2217-85	Wet preparation of soil samples for particle-size analysis and determination of soil constants.
D2434	Permeability of granular soils (constant head).
D2435-96	One-dimensional consolidation properties of soils.
D2487-00	Classification of soils for engineering purposes (Unified Soil Classification System).
D2488-00	Description and identification of soils (Visual-manual procedure).
D2573-94	Field vane shear test in cohesive soil.
D2850-95	Unconsolidated-undrained triaxial compression test on cohesive soils.
D2974-00	Moisture, ash, and organic matter of peat and other organic soils.
D3213-91	Handling, storing, and preparing soft undisturbed marine soil.
D3441	Mechanical cone penetration tests of soil.
D3975-93	Development and use (preparation) of samples for collaborative testing of methods for analysis of sediments.
D4186-89	One-dimensional consolidation properties of soils using controlled-strain loading.
D4253	Maximum index density and unit weight of soils using a vibrating table.

D4254	Minimum index density and unit weight of soils and calculation of relative density.
D4318-00	Liquid limit, plastic limit, and plasticity index of soils.
D4373-96	Calcium carbonate content of soils.
D4380-84	Density of bentonitic slurries.
D4381-84	Sand content by volume of bentonitic slurries.
D4542-95	Pore water extraction and determination of the soluble salt content of soils by refractometer.
D4546-96	One-dimensional swell or settlement potential of cohesive soils.
D4643-00	Determination of water (moisture) content of soil by the microwave oven heating.
D4648- 94	Laboratory miniature vane shear test for saturated fine-grained clayey soil.
D4767-95	Consolidated undrained triaxial compression test for cohesive soils.
D4822-88	Selection of methods of particle size analysis of fluvial sediments (manual methods).
D4823-95	Core sampling submerged, unconsolidated sediments.
D5314	Soil gas monitoring in the vadose zone.
D5387-93	Elements of a complete data set for non-cohesive sediments.
D5778	Performing electronic friction cone and piezocone penetration testing of soils.
D6024-96	Ball drop on controlled low strength material (CLSM) to determine suitability for load application.
D6067-96	Using the electronic cone penetrometer for environmental site characterization.
D6527-00	Determining unsaturated and saturated hydraulic conductivity in porous media by steady-state centrifugation.
E300-92	Sampling industrial chemicals.
E1525-94a	Designing biological tests with sediments.

British Standard BS1377 (1990) and 5930 cover test methods for soils and rocks for civil engineering purposes. German Standard ISO/DIS 14688 (2000) covers geotechnical engineering test methods. The Dutch Standards Institution (NNI) publishes Netherlands-language geotechnical standards.