

Soils Handling Techniques and Equipment for Wetlands Restoration and Establishment

PURPOSE: This technical note provides guidance on soils handling methods and equipment needed if earthwork, i.e., excavation and/or fill, is required for the establishment or restoration of a wetland. It supplements the information available from other WES programs and is an extension of the soils handling requirements of the design sequence contained in WRP Technical Note WG-RS-3.1 (USAEWES 1992). Emphasis is placed on criteria for selecting suitable soils handling equipment and methods.

BACKGROUND: If the substrate, size, depth and/or shape of a wetland being restored or established is unsuitable, soils handling may be necessary to: (1) excavate upland soils down to wetland elevation, (2) place fill material to raise the submerged bottom up to wetland elevation, and/or (3) to place fill in dikes to retain water. Soils handling methods developed at WES are based on lessons learned in programs dealing with soft soils such as the Dredged Material Research Program (DMRP) (Willoughby 1978), the Dredging Research Program (DRP), and the Environmental Effects of Dredging Program (EEDP).

USE OF CONSISTENT TERMINOLOGY: Because of the diverse backgrounds of persons describing and classifying soils for a wetland project, it is vital that consistent terminology and classification methods be understood and used. The U.S. Army Corps of Engineers describes and classifies soils by the Unified Soil Classification System (USCS). This system (Casagrande 1948, USAEWES 1953, ASTM 1992) uses gradation and Atterberg limits to rate soils for use in airfield base courses. Corps geotechnical engineers also use the USCS for general soil description. The USCS is a disturbed soil material-based descriptor system and descriptions must be supplemented with additional terms to describe other important material descriptors and the dynamic behavior properties of the in-situ soil. When describing the shear strength of soils, the following terms are generally used:

<u>Relative Consistency of Cohesive Soils</u>	<u>Relative Compactness of Cohesionless Soils</u>
Fluid	Very Loose
Very Soft	Loose
Soft	Medium Dense
Medium Soft	Dense
Stiff	Very Dense
Very Stiff	
Hard	

Each of these terms is defined in terms of tests of the in-situ material except in the case of Fluid consistency. Relative consistency of cohesive (clayey) soils is based on the unconfined compressive strength test. The Fluid consistency occurs when a cylindrical test specimen of cohesive material will not stand unconfined under its own weight and, therefore, may be considered to have a negative unconfined compressive strength. Relative compactness of cohesionless (clean granular) soils is defined by the relative density and measured in the field using; (1) the Standard Penetration Test (SPT) (recording blow counts obtained while driving a sample tube into the soil), or (2) the Cone

Penetrometer Test (CPT) (recording force required to push a cone of a certain cross sectional area into the soil).

Trafficability of construction vehicles on soft soils has received considerable attention at WES in studies of dredged material containment sites in the DMRP and EEDP. Recent methods for assessing equipment mobility have been summarized by Poindexter-Rollings (1990) in Technical Note EEDP-O9-5. They include work by Willoughby (1978) for modifying a model for evaluating strength variation with depth. Field data for the model are obtained by pushing a hand-held cone penetrometer into in-situ dredged/fine-grained material and a remolded sample to determine a cone index (CI) and a remolded index (RI), respectively, for the soil. The product of the CI and the RI yields the rating cone index (RCI), a measure of soil strength that can be used with a ground pressure versus RCI curve to predict the number of passes specified equipment can be expected to make on a site before soil failure. Other studies of near-surface shear strength (a rut is a bearing capacity failure of a moving footing) involve the use of a hand-held vane shear device for use in cohesive soils. Strengths obtained with the vane shear device can be correlated with bearing pressure associated with earth moving equipment.

SOIL PROPERTIES IMPORTANT TO SOILS HANDLING: The engineering behavior of a soil in earthwork (soils handling) is a function of its geotechnical properties, i.e., the properties of the soil materials, the properties of the soil mass, or the dynamic behavior properties (Spigolon 1992). All of the soil properties may be directly evaluated, or reasonably estimated, by field or laboratory tests. Trafficability of the soil and its ability to support the operation of site specific equipment is also an important property.

- Soil material properties are those of the soil components, without reference to their arrangement in the soil mass:
 - Grain size distribution
 - Atterberg liquid and plastic limits (reflecting the mineralogy of the grains and the amount of clay sizes)
 - Angularity, shape, and hardness of coarse grains
 - Grain specific gravity (needed for mass-volume calculations)
 - Organic content; lime content; cementation
 - Color (often useful in identifying similar soils and in correlating strata)
- Soil mass properties are those relating to the arrangement of individual particles and other components in a soil mass:
 - In-situ density (weight per unit of volume)
 - In-situ water content (as a percentage of dry weight of solids)
 - In-situ structure of clayey soils (blocky, stratified, slickensided, etc.)
- Soil dynamic behavior properties are those that indicate the behavior of the soil under external force systems. They result from a specific combination of soil material and soil mass properties. A soil having specific material properties may be arranged with various mass properties, and a specific group of mass properties may be attained using soils of differing material properties. The dynamic behavior properties include:

- Permeability
- Shear strength (the consistency of cohesive soils, a product of the compactness of granular soils, degree of cementation of cemented soils, or the compressive strength of rock)
- Consolidation (the total volume change and time rate of compression under an external load or self weight)
- Adhesion/stickiness (of moist cohesive soils)
- Rheologic properties of a slurry (soil-water mixture), i.e., viscosity and yield stress as a function of slurry composition and density
- Bulking factors for redeposited soils.

SOIL HANDLING PROCESSES AND EQUIPMENT: Soil handling for a wetlands project is accomplished in three phases:

- Excavation or cut (loosening or dislodging the soil material from its in-situ location)
- Removal and Transport (movement of the soil from its in-situ location to the deposition area)
- Deposition or fill (placement and manipulation of the soil in a land fill or a land or water disposal area)

The equipment for performing this work may use either hydraulic or mechanical methods or a combination. The hydraulic methods use pumped fluid flow to create and move a soil-water slurry. The mechanical methods involve discrete, bulk units of soil that are excavated and moved without slurring or pumping. Equipment and methods are discussed in another section.

The mechanisms involved in the earthwork construction phases are:

- Excavation (cut) Phase--(1) cutting (ripping) with a knife, blade, or plow; (2) scooping (digging) with a bucket, shovel, or clamshell; (3) scour (erosion) from a moving water or air stream; and (4) direct hydraulic suction of extremely soft or extremely loose soils into a suction pipe.
- Removal and Transport Phase--(1) mechanical, using containers such as a land based loader-scraper, truck, or conveyor belt, or water based equipment such as a barge; or (2) hydraulic, pumping a slurry of soil particles, clumps of material, or clay balls, in a pipeline.
- Deposition Phase--(1) materials are discharged from mechanical containers by direct dumping from the transport unit; and (2) the pipeline slurry is directly discharged into a land or water disposal area. Compaction may be done by mechanical rolling or, for clean granular materials, by vibration.

Trafficability of the soils handling equipment is another major factor in earthwork. Soils handling equipment must be capable of maneuvering on the ground surface environment at the project site. Ground surfaces may range from (1) fairly dry, firm upland areas, to (2) very soft surface soils in swampy areas where the free water surface is just above or just below the ground surface, to (3) extremely soft (fluid mud) to firm soils at substantial depths below water. It is expected that most wetlands earthwork will be conducted on the type (2), soft swampy soil surfaces, or with dredging equipment in an aqueous environment.

EXCAVATION PROCESSES AND EQUIPMENT: During the excavation phase, the shear strength of the in-situ soil is the dominant behavior characteristic. The cuttability, scoopability, scourability,

and direct suctionability mechanisms all involve shearing the undisturbed soil. The adhesion or stickiness of moist clayey soils to steel cutting or scooping equipment contributes to shearing resistance. Shear strength, in turn, is a function of the externally applied loads (usually self-weight only) and the type of soil. During excavation, the rate of shear is extremely fast; therefore, there is little or no drainage of pore water. The shear strength of a clean granular soil, with little or no fines, is a direct function of its relative density, defined as relative compactness, and the angularity of the grains. With no drainage, the shear strength of a cohesive soil is its unconfined compressive strength, defined as relative consistency.

Equipment for mechanical excavation includes cutting devices (dozers, loader-scrappers) and scooping systems (backhoes, shovels, bucket ladder, draglines, and clamshells). Hydraulic excavation equipment includes various types of equipment for dislodging the soil for inclusion in a slurry to be removed by suction (direct suction, cutter suction, bucketwheel suction).

The suitability of an excavation device depends on the trafficability of the surface and the characteristics of the soil to be excavated. Mechanical cutting devices depend on traction from wheels or tracks for reaction to cutting forces; therefore, they are generally limited to firm surfaces. The working platform for scooping systems may vary from (1) wheels or tracks on dry, firm ground, to (2) very low pressure carriages such as pontoons or very large wheels or tracks (Willoughby 1978, Poindexter-Rollings et al. 1990) in soft swampy soils (Figures 1, 2, and 3), to (3) barges or self-propelled vessels for dredging work. Hydraulic slurry systems require large quantities of water and are generally (but not necessarily) mounted on floating platforms, such as barges or self-propelled vessels (Figure 4).

TRANSPORTATION PROCESSES AND EQUIPMENT: Once the soil has been excavated, its in-situ mass and dynamic properties are destroyed. However, the soil material properties remain unchanged and are still relevant. Water content may be less due to drying upon excavation or greater because of slurring.

Mechanical equipment for transporting soils generally consists of containers such as loader-scrappers, wheeled trucks, conveyor belts, or barges. Trafficability of the excavation site and of haul roads will determine the necessary type and contact pressure of the hauling equipment. Hydraulic equipment generally consists of a slurry pipeline.

Soil properties affecting the transportation equipment are: bulking, pumpability, and abrasiveness. Bulking is the general increase in volume of a soil compared to its in-situ volume; this affects planning for required container volumes and measurement of production based on volume. Pipeline pumpability is a function of the median (50%) grain size (Herbich 1992); the larger the median size, the greater the pumping energy required. Abrasion of pump parts and of the pipeline depends on grain size and the angularity and hardness of coarse grains. The larger, more angular and harder the grain size, the greater the abrasion.

DEPOSITION SITE PROCESSES AND EQUIPMENT: Deposition at a fill site may be mechanical or hydraulic, depending on the transport method. If the excavated and transported soil is to be simply discarded, then mechanical dumping or hydraulic slurry placement on a land or water disposal site without manipulation is suitable. The only geotechnical concern will be the possible sticking of moist clayey soils to the container and the turbidity of the water for underwater disposal. If, however, the soil is to be graded, used for a structure, or a fill is to be made, then the amount and type of compaction to be used will determine the type of processing methods and equipment.

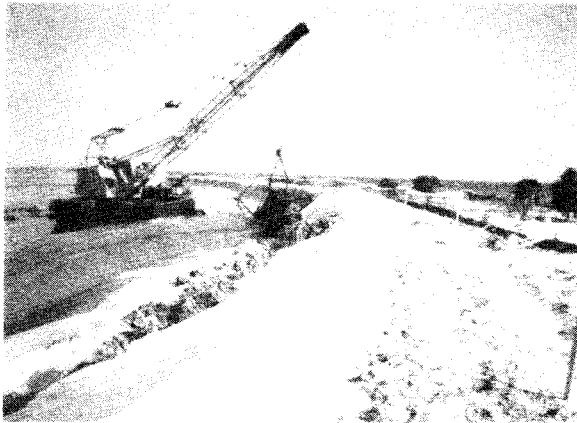


Figure 1. Quality marsh dragline

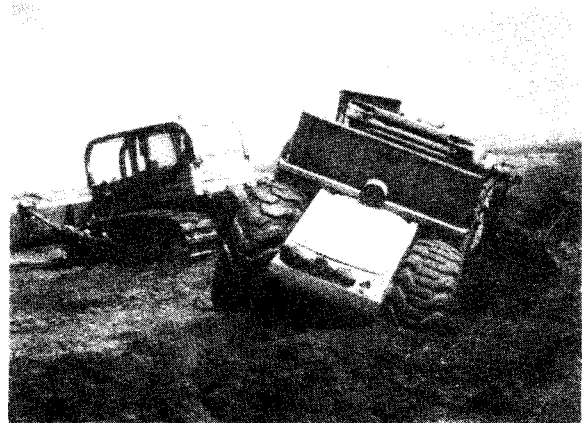


Figure 2. Bulldozer and scraper removing crust



Figure 3. Low-ground-pressure bulldozer through crust

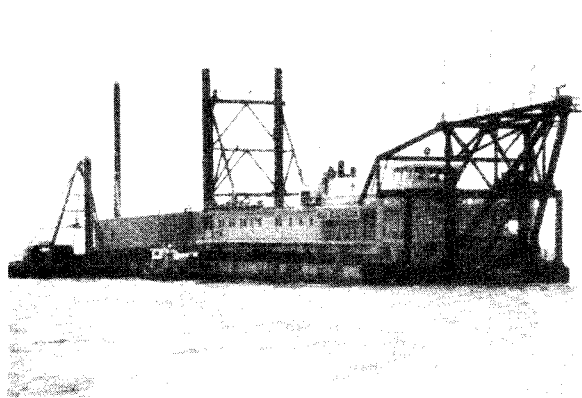


Figure 4. The Dave Blackburn dredge

There are a several methods of fill placement of soils above water level:

- Simple dumping: from the transport containers or the pipeline; minimal mechanical manipulation (grading) is used; no attempt is made at densification; excess water drains away or evaporates.
- Machine (partial) compaction: some mechanical densification (compaction) is achieved by wheels or tracks of grading machinery; no attempt is made to densify to a specification value.
- Full (specification) compaction: mechanical densification, using vibration or rollers, on thin soil layers, to achieve a specified compaction amount.

Densification methods appropriate for mechanical compaction (partial or full) depend on the soil type:

- Cohesionless (clean granular) soils: can only be densified with vibratory equipment; usually not sensitive to moisture content.
- Cohesive (clay, silty clay) and friable mixed grain soils: may only be densified using weighted rollers; vibration will not work; densification is directly dependent on water content and on the

plasticity of clay; required roller energy is directly related to water content; excess water content may prevent achievement of the desired amount of densification. "Optimum" densification occurs when the combination of water content and roller energy produce a degree of saturation in the soil of 85 to 95 percent.

SUMMARY: The suitability of various soil handling methods and equipment for use at a wetland site is determined by (1) the trafficability of the surface of the borrow area, the transport roadway, and the deposition site, (2) the quantity, location, and engineering characteristics of the soils to be moved, and (3) the location and specifications for wetland site deposition. Excavation, transportation, and deposition of a soil may be done by mechanical or hydraulic methods, or a combination of the two methods. Mechanical methods include all types of mechanical excavators and earth moving machines. Hydraulic methods typically involve forming and pumping a soil-water slurry. Virtually all soil types can be handled by either method.

REFERENCES:

ASTM. 1992. "Natural Building Stones; Soil and Rock; Geotextiles" 1992 Annual Book of ASTM Standards. Volume 04.08, American Society for Testing and Materials, Philadelphia, PA.

Casagrande, A. 1948. "Classification and Identification of Soils," Transactions of the American Society of Civil Engineers, American Society of Civil Engineers, New York, NY, Vol 113, pp 901-930.

Herbich, J. B. 1992. Handbook of Dredging Engineering, McGraw-Hill, Inc., New York, NY.

Poindexter-Rollings, M. E. 1990. "Selecting Equipment for Use in Dredged Material Containment Areas," Environmental Effects of Dredging Technical Note EEDP-09-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Spigolon, S. J. 1992. "Identification of Geotechnical Descriptors for Dredgeability of Soil Sediments: A Literature Survey," (In Publication), Dredging Research Program, USAE Waterways Experiment Station, Vicksburg, MS.

USAEWES. 1953 (Mar) (Revised Apr 1960). "The Unified Soil Classification System," Technical Memorandum No. 3-357, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

USAEWES. 1992. "Wetlands Engineering: Design Sequence for Wetlands Restoration and Establishment," Wetlands Research Program Technical Note WG-RS-3.1, Wetlands Research and Technology Center, Vicksburg, MS.

Willoughby, W. E. 1978. "Assessment of Low-Ground-Pressure Equipment for Use in Containment Area Operation and Maintenance," Technical Report DS-78-9, USAE Waterways Experiment Station, Vicksburg, MS.

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