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Dredging Research Technical Notes

Geotechnical Factors in DREDGeABiLity (DREDGABL)

Purpose

This technical note describes a knowledge-based expert system (KBES) computer program, "Geotechnical Factors in **DREDGeABiLity**" (DREDGABL), which was developed as part of the U.S. Army Engineer Waterways Experiment Station's (WES) Dredging Research Program (DRP). The program is intended to serve the dredging community as a geotechnical engineering consultant. DREDGABL provides guidance in the suitability of various types of dredging equipment for specific sediment types whose properties are described in the contract documents. Sediment descriptions are assumed to be available in the Unified Soil Classification System (USCS) and American Society for Testing and Materials (ASTM) format.

Background

The KBES computer program described herein was developed as part of a DRP work unit to develop standard dredging-related geotechnical descriptors for indicating, or inferring, the dredgeability of sediments.

Geotechnical engineers typically describe the physical properties of the sediments that appear to be present within the dredging prism using the USCS. Dredging-related personnel use the geotechnical information furnished to estimate and plan dredging projects.

Dredging personnel often do not fully understand the geotechnical information in the manner that it has been presented, and its limitations. In addition, the expertise of those persons who do is often lost through turnover or retirement. Geotechnical engineering descriptions of sediments do not indicate dredgeability properties directly—any more than they indicate foundation or earthwork behavior properties directly. All require analysis and interpretation. This leads to possible misinterpretation of sediment-related risks, with resulting higher bid costs, and is often a cause of costly claims.

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There is, then, a continuing need for the guidance and training of those persons lacking knowledge and experience in the dredgeability analysis of geotechnical data. For this reason, it is desirable to retain the expertise of the capable persons involved in dredging-related fields and make it available for use by the less experienced workers. Also, knowledgeable and experienced personnel can derive considerable benefit from consultation with their peers for review and as a check on their own work. One very effective manner for retaining this knowledge and making it available to prospective users is a computerized knowledge-based expert system.

Additional Information

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Objective of DREDGABL

The objective of DREDGABL is to provide guidance for dredging estimators and planners, from geotechnical and dredging experts, for the interpretation of geotechnical site investigation data in terms of dredgeability. Expert systems are computer programs capable of providing the necessary vehicle for recording the accumulated knowledge and experiences of experts, in any specific discipline, in a knowledge base and providing for interaction between the user and the knowledge base. This program can utilize geotechnical information provided by the user or can evaluate the dredgeability of samples described and recorded in a project database.

Knowledge-Based Expert Systems

A KBES uses expertly derived rules for its solutions. The rules can incorporate and process judgment, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. The knowledge base contains a database of IF - THEN rule statements that includes all of the questions a typical user may ask and that will guide the system to reach the appropriate solution for a given problem. The control system (inference engine) for DREDGABL is independent of the knowledge base, permitting simple modifications and additions to the answers contained in its knowledge base without modifying the program.

During a guidance session, a KBES such as DREDGABL searches the knowledge base through the chain of IF - THEN rule statements. The logic of the IF statements may include such modifiers as AND, OR, or

NOT, and the arguments may be either English words or phrases or numbers. For each question posed by DREDGABL, the user selects from a menu of possible answers. The menu may even include a term such as "Unknown." The path through the matrix of rules is not predetermined; rather, the path depends on the specific questions and on the user's replies, which lead to the next question and the next list of possible replies.

When all of the prerequisite IF questions have been asked, the answers are used to search the knowledge base, ruling out all inapplicable IF - AND - OR - NOR statements, searching for the appropriate THEN solution or group of solutions. The net effect in DREDGABL is one of having a geotechnical engineering expert in the dredging field answering the questions, each answer leading the user to the next question until the appropriate solution is reached. At any time during a session, the user can view an explanation of the reasoning for the solution.

Two equivalent versions of DREDGABL have been developed, both operating within the Microsoft FoxPro 2.5 Relational Database Management System. The knowledge base, the content of the user interface screens, and the inference engine (control programs) for both versions are identical. The DOS version operates in the conventional MS-DOS character-based environment. The Windows version runs in the Microsoft Windows or OS/2 graphical environment. Both versions are user friendly and support mouse input. This practically eliminates the need for the user to type words for data input during guidance sessions; only numbers and mouse-pointer selections from input menus are needed. This should greatly facilitate the use of the system by nontypists.

Two primary tasks are involved in the building of a KBES. The first task is performed by the person with expertise in computerized knowledge-based expert systems, called the *expert system developer.* The second task is that of the technical experts, the contributors to the knowledge base. In this case, the technical experts would be the geotechnical engineers knowledgeable and experienced in dredging operations, simply referred to as the *knowledge-base developers.*

In the present version, the rules developed for DREDGABL (Spigolon and Bakeer 1993) represent the knowledge and expertise of the authors that was developed through professional experiences and research studies and therefore reflect their personal biases. In future upgrade versions, the present rules should again be critically reviewed by a group of geotechnical engineering and dredging experts and expanded or modified, as needed. In the ideal knowledge base, there are multiple experts who either reinforce each other or present valid alternate solutions to problems.

Geotechnical Properties Affecting Dredgeability

The following summary discussion is intended as background information, presenting terminology and concepts used in the KBES program.

Several independent, site-specific factors affect dredgeability. DREDGABL considers only the direct effect of soil type and character on dredgeability, separate from all nonsediment factors that affect dredging productivity, such as equipment characteristics, water depth, weather, tides, marine traffic, personnel problems, equipment maintenance, and so forth.

The process of dredging an underwater sediment typically occurs in four stages. *Dislodgement* is the loosening or excavation of material from its location at or below the bottom. *Removal* is the movement of the excavated material from the bottom up to the pump or transport system. *Transport* is the movement of the removed material from the dredge to the disposal site. *Disposal* is the discharge of the material within a land area or into a water disposal area. *Dredgeability* is defined as the ease with which an underwater soil sediment or rock can be excavated, removed, transported, and deposited with respect to known or assumed equipment, methods, and in situ material characteristics.

The dredgeability properties associated with each stage are:

- The dislodgement (excavation) suitability of the various dredge types is based on the suctionability, erodibility, cuttability, scoopability, and flowability (underwater slope instability) properties of the sediment.
- The removal and transport suitability of the various dredge types is based on the pumpability, abrasiveness, stickiness (affects clay balling), turbidity, sedimentation rate, and bulking properties of the sediment.
- The disposal area properties of the sediment are based on its dumpability (stickiness), turbidity, sedimentation rate, amount of bulking, and compactability.

The geotechnical properties needed for an adequate evaluation of the dredgeability properties listed above are (Spigolon 1993):

- In situ shear strength—defined in terms of relative consistency, compactness, or rock compressive strength.
- Grain size distribution—including maximum size, median size, and amount of fines.
- Angularity of coarse grains.
- Plasticity of fine grains—based on the Atterberg limits.
- Organic content—ash content or other indicator.
- Presence of shells, debris, or other nonsoil materials.

DREDGABL Expert System Program

DREDGABL is intended to serve as a geotechnical engineering expert, always available to interpret sample test and observation data for estimators and planners (whether Corps of Engineers or contractor), in terms of dredgeability. For the geotechnical engineers and geologists involved in a dredging project site investigation, DREDGABL can also identify the important sediment properties for dredgeability evaluation (Spigolon and Bakeer, in preparation).

It is assumed by DREDGABL that the user possesses a set of boring logs or a soil profile with the typical USCS or ASTM descriptors given for each stratum. In the present version, DREDGABL considers only one sediment type at a time in its evaluation of the suitability of various dredge types for that sediment.

The first question asked by DREDGABL is "What is the general sediment type?" The computer screen used to pose the question includes the following choices:

- Gravel (USCS Classification gravel-series soils).
- Sand (USCS Classification sand-series soils).
- Fines (fine-grained soils: silt, clay, peat).
- Special (rock, cemented soils, boulders, shells, fluid mud, etc.).

The user selects one from the four general sediment types shown using a mouse or the < **TAB** / **Arrow** > keys and < **Enter** >, after which the program follows with another appropriate question screen. The screens include "Alternative Choice" selector buttons for < **BACK** >, < **DISCUSSION** >, and < **QUIT** >. These buttons lead to an alternative event and are self explanatory. The choice of < **DISCUSSION** > leads to another series of screens that contain explanatory texts about the topic, including the rules and the basis for the guidance statements. Care is taken to differentiate between factual information and the experts' interpretation(s) of the facts.

When a general sediment type is selected, the next screen asks "What is the main name of the sediment?" For *Fines*, if the consistency is known, the liquidity index question is bypassed to prevent conflict.

IF	sediment type is "Gravel"
OR	sediment type is "Sand"
AND	name of the sediment is:
AND	USCS classification is:
AND	gradation fineness of the gravel or sand is:
AND	relative compactness of a granular soil is:
AND	grain angularity is:

THEN	dredgeability conclusions are:

IF	sediment type is "Fines"
AND	name of the sediment is:
AND	USCS classification is:
AND	relative consistency of the inorganic or organic soil is:
OR	liquidity index is:
AND	plasticity index is:
THEN	dredgeability conclusions are:

IF	sediment type is "Special"
AND	name of the sediment is:
THEN	dredgeability conclusions are:

After the appropriate entry of the required geotechnical data, DREDGABL evaluates the data for each of the dredgeability properties listed above. The rules for evaluation operate internally in the expert system program to consider all of that sediment's known geotechnical properties that affect each of the specific dredgeability mechanisms. In this version of DREDGABL, there are 1,010 unique combinations of antecedents, each resulting from one complete set of the IF - AND - OR antecedents given above.

After all of the needed antecedents are requested and answered, an evaluation menu screen is presented that contains the following choices:

Hoppers (suitability of hopper dredges).

Pipeline (suitability of pipeline dredges).

Mechanical (suitability of mechanical dredges).

Disposal (disposal area properties).

Following selection of any one of these topics, DREDGABL displays its evaluation of the suitability of generic dredge types, along with a brief explanation for each evaluation. Depending on the choice, the suitability is displayed on screens containing the information of Table 1, 2, 3, or 4. Each unique set of antecedent options leads to a single conclusion about a dredgeability property. DREDGABL reaches 27 dredgeability conclusions for each unique set of antecedents, for a total of 27,270 possible conclusions.

Table 1
Evaluation of the Suitability of Hopper Dredges

IF AND	main sediment name is: needed sediment geotechnical information is:
THEN AND AND	suitability of a trailing suction hopper dredge is: suitability of a plain suction hopper dredge is: suitability of a bucket-type hopper dredge is:
BECAUSE AND AND AND AND AND AND AND AND	estimated relative suctionability is: estimated relative scourability is: estimated relative cuttability is: estimated relative flowability (underwater slope stability) is: estimated relative turbidity is: estimated relative pumpability is: estimated relative clay balling capacity is: estimated relative sedimentation rate in a hopper is: estimated relative bulking rate in a hopper is:

Table 2
Evaluation of the Suitability of Pipeline Dredges

IF AND	main sediment name is: needed sediment geotechnical information is:
THEN AND AND AND	suitability of a bucketwheel suction pipeline dredge is: suitability of a cutterhead suction pipeline dredge is: suitability of a plain suction pipeline dredge is: suitability of a dustpan suction pipeline dredge is:
BECAUSE AND AND AND AND AND AND AND AND	estimated relative suctionability is: estimated relative scourability is: estimated relative cuttability is: estimated relative scoopability (diggability) is: estimated relative flowability (underwater slope stability) is: estimated relative turbidity is: estimated relative pumpability is: estimated relative pipeline abrasiveness is: estimated relative clay balling capacity is:

Table 3 Evaluation of Suitability of Mechanical Dredges	
IF AND	main sediment name is: needed sediment geotechnical information is:
THEN AND AND AND AND	suitability of a backhoe mechanical dredge is: suitability of a bucket ladder mechanical dredge is: suitability of a clamshell mechanical dredge is: suitability of a dragline mechanical dredge is: suitability of a power shovel mechanical dredge is:
BECAUSE AND AND AND AND AND AND	estimated relative suctionability is: estimated relative erodibility is: estimated relative cuttability is: estimated relative scoopability (diggability) is: estimated relative flowability (underwater slope stability) is: estimated relative turbidity is: estimated relative stickiness is:

Table 4 Evaluation of Disposal Properties of a Sediment	
IF AND	main sediment name is: needed sediment geotechnical information is:
THEN AND AND AND	sedimentation rate in disposal area is: expected turbidity during disposal is: probable bulking rate in the disposal area is: mechanical compactability in the disposal area is:

References

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