Environmental Effects of Dredging Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--DATA ANALYSIS

PURPOSE: The following series of technical notes described the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during dredging operations.*

EEDP-04-1	General
EEDP-04-2	Test Procedures
EEDP-04-3	Data Analysis
EEDP-04-4	Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle associated. The modified elutriate tests was developed for use in predicting

* The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

ADDITIONAL INFORMATION: Contact the author, Dr. Michael R. Palermo (601) 634-3753 (FTS 542-3753), or the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

Data Analysis

The results of the column settling tests are used to determine the concentrations of suspended solids in the effluent from a confined disposal site.

Sedimentation of freshwater slurries with solids concentrations of less than 100 g/ℓ are generally characterized by flocculent settling properties. When solids concentrations exceed 100 g/ℓ, the sedimentation process may be characterized by zone settling properties in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling properties also govern when the sediment/water salinity is greater then 3 ppt. Recent studies have shown that flocculent settling governs behavior of the suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface.

For the flocculent case, the procedures for data analysis given in Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) may be used. For the zone settling case, flocculent settling behavior governs in the supernatant water above the interface. Therefore, a modified flocculent data analysis procedure as outlined in the following paragraphs is required. Example calculations are given in Technical Note EEDP-04-4.

Step 1. Compute values of z, the depth of sampling below the fluid surface as shown in Figure 1. In computing ϕ , the fraction remaining, the highest concentration of the first port samples is considered the initial concentration SS_0 .

COLUMN SETTLING DATA				
(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/ℓ	(4) PERCENT OF INITIAL CONCENTRATION ϕ	
3	0.2	93		
	1.0	169	100	
7	1.0	100	59	
	2.0	105	62	
14	1.0	45	27	
	2.0	43	25	
	3.0	50	30	
24	1.0	19	11	
	2.0	18	11	
	3.0	20	12	
48	1.0	15	9	
	2.0	7	4	
	3.0	14	8	

NOTES: COLUMNS 1 AND 2 - RECORD FOR EACH PORT SAMPLE.
COLUMN 3 - COMPLETE FROM TEST RESULTS.
COLUMN 4 - COMPUTE USING THE HIGHEST SUSPENDED SOLIDS CONCENTRATION OF THE FIRST PORT SAMPLE AS THE INITIAL CONCENTRATION SS_0.

Figure 1

Step 2. Plot the values of fractions remaining ϕ and z using column settling data to form a concentration profile diagram (Figure 2). Concentration profiles should be plotted for each time of sample extraction.

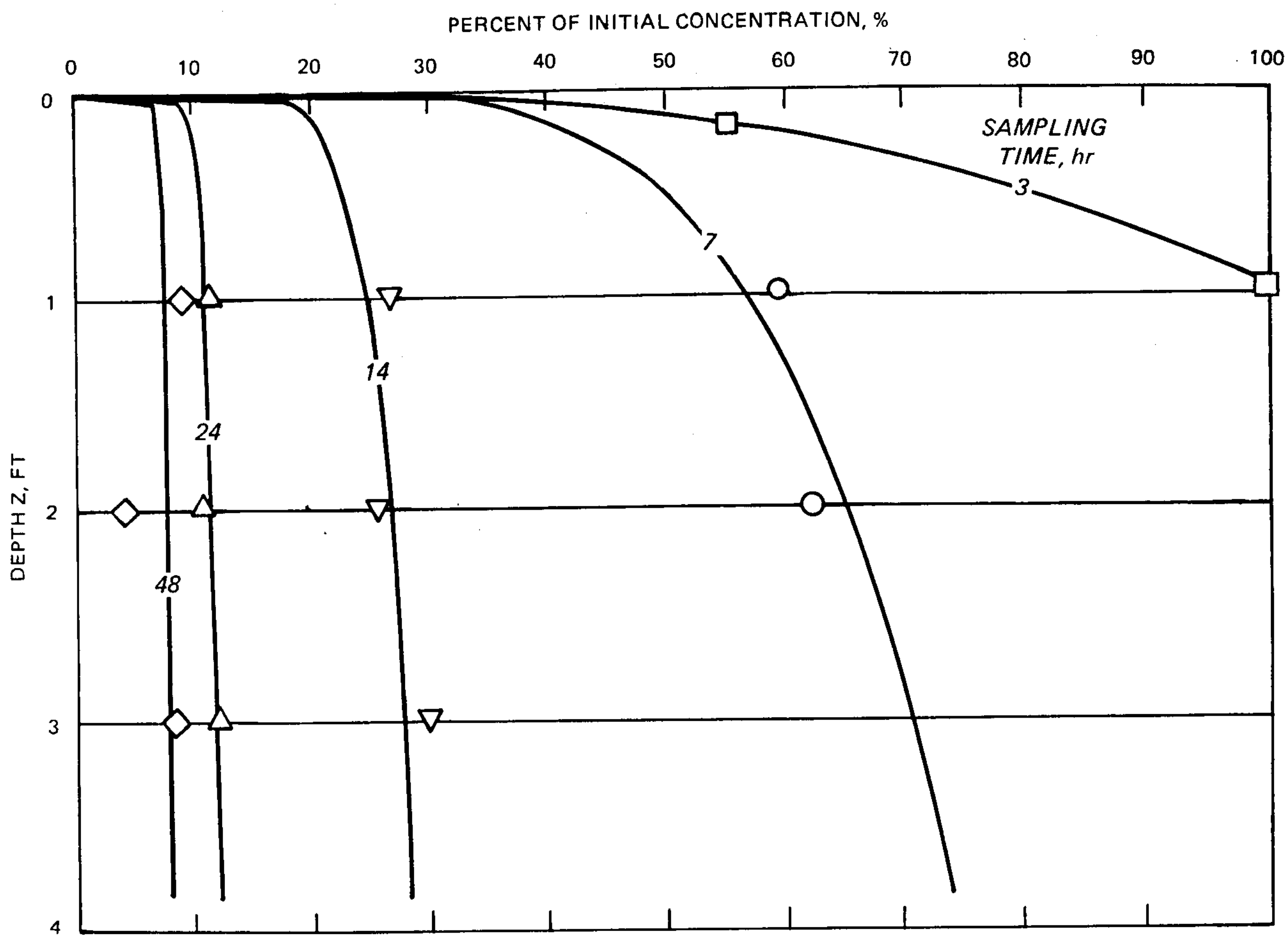

Figure 2. Concentration profile diagram

Step 3. Use the concentration profile diagram to graphically determine R, the percentages of solids removed for the various time intervals for any desired ponding depth D_{pw}. This is done by determining the area to the right of each concentration profile and its ratio to the total area above the depth D_{pw}. The removal percentage R is calculated as follows:

$$R = \frac{\text{Area Right of Profile}}{\text{Total Area}} 100 \tag{1}$$

Step 4. Compute P, the percentage of suspended solids remaining in suspension, as simply 100 minus the percentage removed as follows:

$$P = 100 - R \tag{2}$$

Step 5. Compute values for suspended solids for each time of extraction as follows:

$$SS = P \times SS_0 \tag{3}$$

Tabulate R , and P , and SS for each sampling time.

Step 6. Plot a relationship for suspended solids concentration versus time using the value for each sampling time (Figure 3). An exponential or power curve fitted through the data points is recommended.

By repeating steps 4 through 6 for each of several values of D_{pw} , a family of curves showing suspended solids versus retention time for each of several ponding depths can be developed as shown in Figure 3. These curves can be used for prediction of effluent suspended solids concentrations under quiescent settling conditions for any estimated ponding depth and field mean retention time. Simply enter a curve with the estimated field mean retention time T_d and select the value of suspended solids as estimated from the column test SS_{col} . Guidance for adjusting the value derived from the column test for anticipated resuspension and for estimated field mean retention time is given in the following paragraphs.

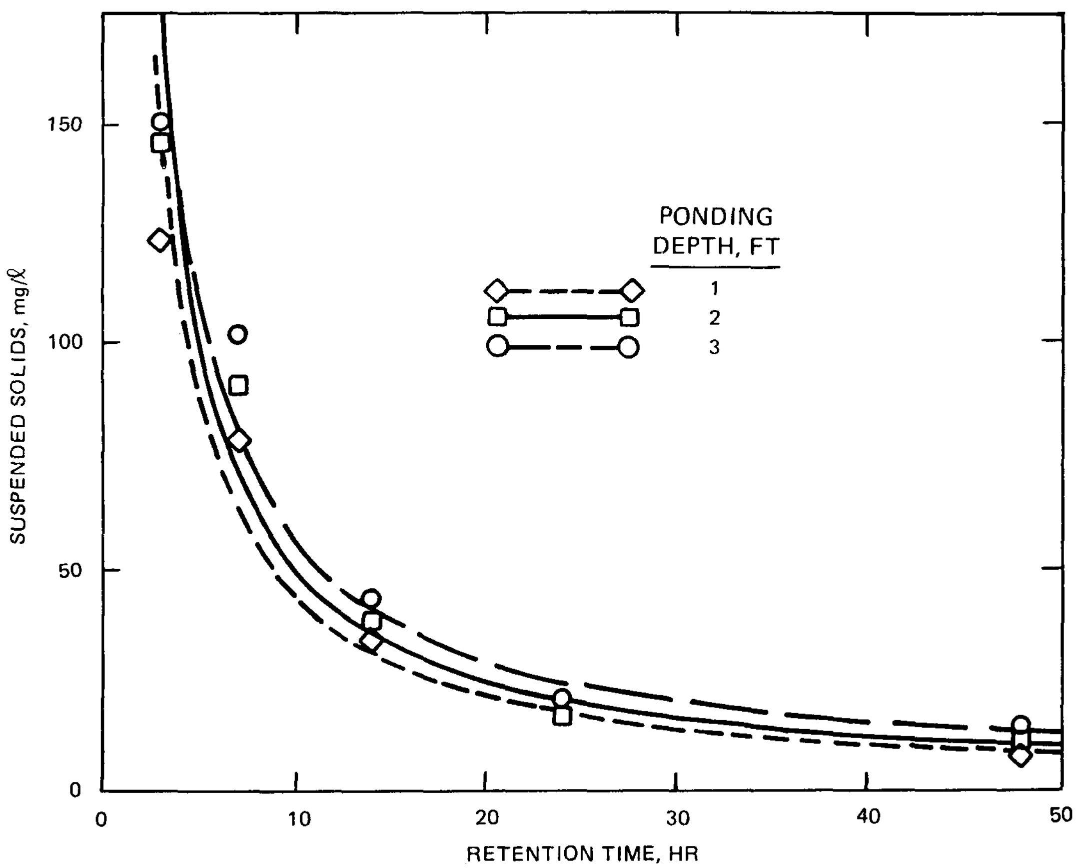

Figure 3. Supernatant suspended solids concentration versus time from column settling test

Effluent Suspended Solids Concentration

A prediction of the concentration of total suspended solids in the effluent must consider the anticipated retention time in the disposal area and must account for the possible resuspension of settled material because of wind effects. The relationship of supernatant suspended solids versus time developed from the column settling test is based on quiescent settling conditions found in the laboratory. The anticipated retention time in the disposal area under consideration can be used to determine a predicted suspended solids concentration from the relationship. This predicted value can be considered a minimum value that could be achieved in the field assuming little or no resuspension of settled material.

For dredged material exhibiting flocculent settling behavior, the concentration of particles in the ponded water is on the order of 1 g/ℓ or higher. The resuspension resulting from normal wind conditions will not significantly increase this concentration; therefore, an adjustment for resuspension is not required for the flocculent settling case.

However, an adjustment for anticipated resuspension is appropriate for dredged material exhibiting zone settling. The minimum expected value and the value adjusted for resuspension provide a range of anticipated suspended solids concentrations for use in predicting the total concentrations of contaminants in the effluent.

The following tabulation summarizes recommended resuspension factors (RF) based on comparisons of suspended solids concentrations as predicted from column settling tests and field data from a number of sites with various site conditions.

Anticipated Ponded Area acres	Resuspension Factor-Average Ponded Depth	
	Less than 2 ft	2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

The value of SS_{eff}, suspended solids concentration of the effluent considering anticipated resuspension, is calculated using equation 4.

$$SS_{eff} = SS_{col} \times RF \tag{4}$$

where

SS_{eff} = suspended solids concentration of effluent considering anticipated resuspension, milligrams per liter of water

SS_{col} = suspended solids concentration of effluent estimated from column settling tests, milligrams per liter of water

RF = resuspension factor

Field Mean Retention Time

Estimates of the field mean retention time for expected operational conditions are required for selecting appropriate settling times in the modified elutriate test and for determination of suspended solids concentrations in the effluent. Estimates of the retention time must consider the hydraulic efficiency of the disposal area, defined as the ratio of mean retention time to theoretical retention time. Field mean retention time T_d can be estimated for given flowrate and ponding conditions by applying a hydraulic efficiency factor to the theoretical detention time T as follows:

$$T_d = \frac{T}{HEF} \tag{5}$$

where

T_d = mean detention time, hr

T = theoretical detention time, hr

HEF = hydraulic efficiency factor (HEF >1.0) defined as the inverse of the hydraulic efficiency

The theoretical detention time is calculated as follows:

$$T = \frac{V_p}{Q_i}\,(12.1) = \frac{A_p D_p}{Q_i}\,(12.1) \tag{6}$$

where

T = theoretical detention time, hr

V_p = volume ponded, acre-ft

Q_i = average inflow rate, cfs

A_p = area ponded, acres

D_p = average depth on ponding, ft

12.1 = conversion factor acre-ft/cfs to hr

The hydraulic efficiency factor HEF can be estimated by several methods. The most accurate estimate for existing sites is made from field dye-tracer data previously obtained at the site under operational conditions similar to those for the operation under consideration. Guidance for conducting such field tests is presented by Schroeder et al. (in preparation).

Hydraulic flow models can also be used to evaluate the effiency factor. Koussis, Saenz, and Thackston* recommended steady-state two-dimensional models for such evaluations. Development of such techniques is still under study (Schroeder et al. in preparation).

In absence of dye-tracer data or values obtained from other theoretical approaches, the HEF can be assumed based on values obtained by dye-tracer studies at similar sites and under similar conditions. Montgomery (1978) recommended at a value for HEF of 2.25 based on field studies conducted at several sites.

Total Concentrations of Contaminants

For each contaminant of interest, the modified elutriate test procedure defines the dissolved concentration and the fraction of the particle-associated contaminant in the total suspended solids under quiescent settling conditions and accounts for geochemical changes occurring in the disposal area during active disposal operations. Using these test results in conjunction with those from column settling tests, the total concentration of the contaminant in the effluent can be determined based on the estimated sedimentation condition as follows:

$$C_{total} = C_{diss.} + \frac{F_{SS} \times SS_{eff.}}{1 \times 10^6} \qquad (7)$$

where

C_{total} = estimated total concentration in effluent, milligrams per liter of water

$C_{diss.}$ = dissolved concentration as determined by modified elutriate tests, milligrams per liter of water

---

* A. D. Koussis, M. A. Saenze, and E. L. Thackston. 1982. "Evaluation of Hydraulic Models for Dredged Material Containment Areas," report prepared under contract for the US Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

F_{SS} = fraction of contaminant in the total suspended solids as calculated from modified elutriate results, milligrams per kilogram of suspended solids

$SS_{eff.}$ = suspended solids concentration of effluent as estimated from evaluation of sedimentation performance, milligrams per liter of water

1×10^6 = conversion of milligrams per milligram to milligrams per kilogram

The acceptability of the proposed confined disposal operation can then be evaluated by comparing the predicted total contaminant concentrations with applicable water quality standards, considering an appropriate mixing zone. (Environmental Effects Laboratory 1976, EPA/CE 1977).

References

Environmental Effects Laboratory. 1976. "Ecological Evaluation of Proposed Discharge of Dredged Material into Navigable Waters," Miscellaneous Paper D-76-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters, Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Environmental Protection Agency. 1980. "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Federal Register, Vol 45, No. 249, 24 December 1980, pp 85336-85358.

Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment station, Vicksburg, Miss.

Palermo, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Schroeder, P. R., et al. In preparation. "Hydraulic Efficiency of Confined Dredged Material Disposal Areas," Technical Report, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.