
**APPENDIX B
GUIDANCE FOR EVALUATION
OF EFFLUENT DISCHARGES
FROM CONFINED DISPOSAL
FACILITIES**

TABLE OF CONTENTS

	<u>Page No.</u>
Table of Contents	i
List of Tables	iii
List of Figures	iv
APPENDIX B - GUIDANCE FOR EVALUATION OF EFFLUENT DISCHARGES FROM CONFINED DISPOSAL FACILITIES B-1	
B1.0 INTRODUCTION	B-1
B1.1 Background	B-1
B1.2 Purpose and Scope	B-3
B1.3 Regulatory Considerations	B-3
B1.4 Applicability	B-4
B1.4.1 Hydraulic Filling	B-4
B1.4.2 Flow Through Dikes	B-4
B1.4.3 Mechanical Filling	B-5
B1.4.4 Surface Runoff and Leachate	B-5
B2.0 OVERVIEW OF EVALUATIONS FOR EFFLUENT DISCHARGES	B-5
B2.1 Water Quality Standards	B-6
B2.2 Mixing Zones	B-6
B2.3 Basis of Evaluations	B-6
B2.4 Contaminant Controls	B-7
B2.5 Tiered Approach	B-7
B2.6 Tier II: Water Quality Evaluations	B-9
B2.6.1 Screen Relative to WQS	B-9
B2.6.2 Testing for Evaluation of Effluent Water Quality	B-9
B2.7 Tier III: Toxicity Evaluations	B-10
B3.0 TESTING PROCEDURES FOR EFFLUENT DISCHARGES	B-11
B3.1 Data Requirements	B-11
B3.1.1 Disposal Area Design	B-12
B3.1.2 Sampling Requirements	B-12
B3.2 Column Settling Tests	B-12
B3.2.1 Apparatus	B-14
B3.2.2 Test Procedure	B-14
B3.2.3 Data Analysis	B-18
B3.2.4 Determination of Effluent Suspended Solids Concentration	B-21
B3.2.5 Determination of Field Mean Retention Time	B-22
B3.3 Effluent Elutriate Test Procedure	B-23
B3.3.1 Apparatus	B-23
B3.3.2 Test Procedure	B-24

B3.3.3	Chemical Analyses	B-26
B3.3.4	Dissolved Concentrations of Contaminants	B-26
B3.4	Water Column Toxicity Test Procedure	B-26
B3.4.1	Apparatus	B-26
B3.4.2	Test Procedure	B-27
B4.0	EXAMPLE CALCULATIONS	B-28
B4.1	Example 1: Evaluation of Effluent Water Quality For an Existing Disposal Area	B-28
B4.1.1	Project Information	B-28
B4.1.2	Effluent Elutriate Testing	B-29
B4.1.3	Column Settling Tests	B-30
B4.1.4	Prediction of Effluent Suspended Solids Concentration	B-31
B4.1.5	Prediction of Contaminant Concentrations	B-31
B4.2	Example 2: Determination of Disposal Area Requirements to Meet a Given Effluent Quality Standard	B-31
B4.2.1	Project Information	B-31
B4.2.2	Column Settling Tests	B-32
B4.2.3	Determination of Allowed Effluent Suspended Solids Concentration	B-32
B4.2.4	Determination of Poned Volume and Surface Area	B-33
B5.0	REFERENCES	B-35

LIST OF TABLES

	<u>Page No.</u>
Table B1. Summary of Data Requirements for Prediction of the Quality of Effluent from Confined Dredged Material Disposal Areas.	B-13
Table B2. Observed Flocculent Settling Data.	B-19
Table B3. Percentage of Initial Concentration and Suspended Solids Concentrations vs. Time, Assumed Depth of Influence of 2 ft.	B-20
Table B4. Recommended Resuspension Factors for Various Poned Areas and Depths.	B-22

LIST OF FIGURES

	<u>Page No.</u>
Figure B1. Schematic of Supernatant Water Interaction in an Active Confined Disposal Facility.	B-2
Figure B2. Flowchart Illustrating Approach for Evaluating Potential Effluent Impacts from Confined Dredged Material Disposal Areas.	B-8
Figure B3a. Specifications for Settling Column and Plan for Sedimentation Column.	B-15
Figure B3b. Plans for Top and Bottom Columns.	B-16
Figure B4. Concentration Profile Diagram.	B-19
Figure B5. Plot of Supernatant Suspended Solids Concentration vs. Time from Column Settling Tests.	B-20

**APPENDIX B - GUIDANCE FOR EVALUATION OF EFFLUENT DISCHARGES FROM
CONFINED DISPOSAL FACILITIES****B1.0 INTRODUCTION****B1.1 Background**

Dredged material may be placed in diked disposal areas sometimes called confined disposal facilities (CDFs). CDFs may be considered as an alternative for contaminated dredged material that is unsuitable for disposal in open water. Possible contaminant migration pathways for confined disposal facilities include effluent discharges to surface water during filling operations, surface runoff due to precipitation, leachate into groundwater, volatilization to the atmosphere, and direct uptake by plants and animals. Subsequent cycling through food webs to animal populations living in close association with the dredged material should also be considered. Each pathway may have its own standards and criteria defined by the water quality certification or other applicable laws and regulations. If standards or criteria are not met, management options may be considered including operational modifications, treatment or containment options such as covers or liners.

This appendix provides technical guidance for evaluation of the effluent pathway. Guidance for evaluation of other pathways and for management actions and control measures for CDFs is found in USACE/EPA (1992).

Dredged material may be placed in CDFs in several ways. The most common method of filling is by direct hydraulic pipeline from cutterhead dredges. Pumpout operations from hopper dredges or hydraulic reslurry from barges results in intermittent hydraulic filling. Direct mechanical placement of dredged material from barges (or possibly from trucks) can be done with equipment located at the CDF. All of these operations result in some sort of effluent discharge, defined for purposes of this manual as that material discharged directly to receiving waters during the filling operation (this would include water discharged directly over weir structures or through filter cells or retaining dikes).

A schematic of an active hydraulically filled CDF is shown in Figure B1. Dredged material hydraulically placed in a confined disposal area settles, resulting in a thickened deposit of material overlaid by a clarified supernatant. The supernatant waters are discharged from the site as effluent during active dredging operations. The effluent may contain both dissolved contaminants and suspended solids.

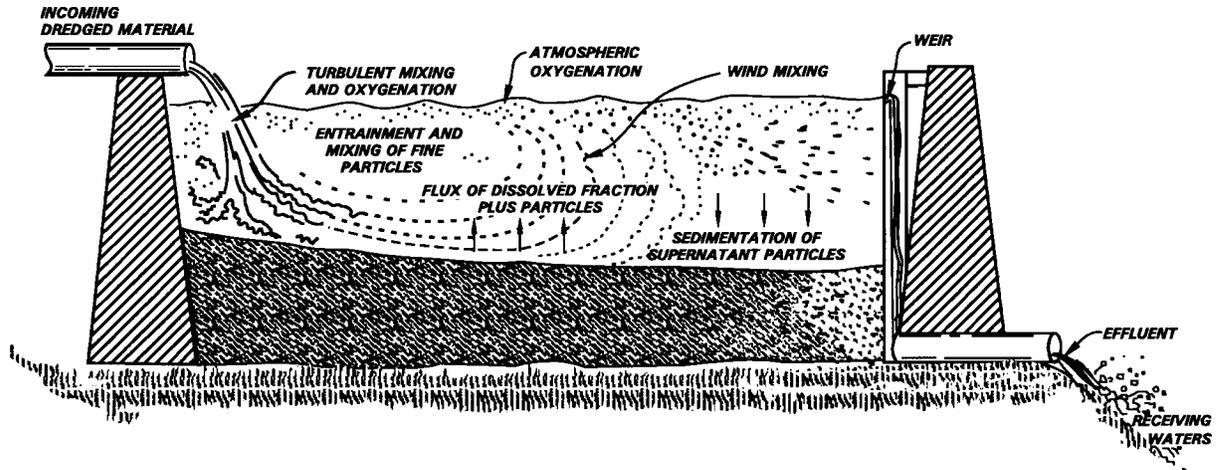


Figure B1. Schematic of Supernatant Water Interaction in an Active Confined Disposal Facility.

Supernatant waters from confined disposal sites are discharged after a retention time of up to several days. Furthermore, actual withdrawal of the supernatant is governed by the hydraulic characteristics of the ponded area and the discharge weir. Several factors influence the concentration of suspended particles present in supernatant waters. Fine particles become suspended in the disposal area water column at the point of entry due to turbulence and mixing. The suspended particles are partially removed from the water column by sedimentation. However, particle concentrations may be maintained by flow of water through the slurry mass during settling. Wind and/or surface wave action may also resuspend additional particles.

B1.2 Purpose and Scope

The purpose of this appendix is to describe procedures for evaluation of effluent discharges from CDFs. The procedures provide an estimation of potential contaminant release and/or biological effect under laboratory-simulated confined disposal conditions and consider the sedimentation behavior of dredged material, the retention time of the proposed containment area, and the physicochemical environment in ponded water during active disposal into the containment area.

B1.3 Regulatory Considerations

The quality of effluent discharged from these sites is an environmental concern and is regulated as a discharge under Section 404 of the Clean Water Act. In addition, Section 401 provides the States a certification role as to project compliance with applicable State water quality standards; effluent standards may be set as a condition of the certification.

The discharge of effluent from a CDF is defined as a dredged material discharge in 33 CFR 323.2 (d):

...the term "discharge of dredged material" means any addition of dredged material into, including any redeposit of dredged material within, the waters of the United States. The term includes, but is not limited to, the following: ...the runoff or overflow from a contained land or water disposal area...

Nationwide general permit 16 (33 CFR 330, Appendix A, part B (16)) authorizes the return water from an upland, contained dredged material disposal area, where the quality of the return water is controlled by the State through Section 401 Certification procedures. For all non-upland CDFs, and for all CDFs in which contaminated sediments may be discharged, an evaluation of potential contaminant impacts of the discharge will be necessary.

General permits are not intended to apply to projects involving the dredging or the discharge of contaminated material. In addition, Section 230.10 (c)(1) of the Guidelines states that no discharge of dredged material shall be permitted which will result in significant adverse impacts on municipal water supplies. Section 230.50 (a) defines municipal water supplies as surface or groundwater directed to the intake of any municipal or private water supply system. Therefore, the potential impacts of leachate into groundwater must also be considered.

There are three types of general permits issued by the USACE, nationwide permits, regional general permits and programmatic general permits. Nationwide permits are issued by the Chief of Engineers

and apply nationwide. Regional permits are issued by district and division engineers and are applicable on district or State-wide basis. Programmatic permits are issued (by the Chief of Engineers, as well as district and division engineers) to other federal, State or local agencies with the intention of providing the appropriate level of environmental protection and avoiding unnecessary duplication of effort with the agency regulatory activities at issue.

There are currently four nationwide permits that pertain to dredging and the discharge of dredged material. One authorizes the discharge and return water from confined disposal areas (provided the associated dredging is authorized pursuant to Section 10 of the River and Harbor Act of 1899); two other nationwide permits authorize the dredging and discharge, respectively, of up to 25 cubic yards of material; and a fourth authorizes maintenance dredging of existing marina basins (provided that the dredged material is deposited on uplands; return water from a confined disposal area requires separate authorization pursuant to section 404 of the Clean Water Act). As stated in the preamble to the nationwide permit regulations (FR56, 226, November 22, 1991), the USACE depends on its districts' knowledge of potentially contaminated areas and on the discretionary authority of district and division engineers to develop special conditions and/or require individual permits where contaminated sediments are present. General permits are not intended to apply to projects involving the dredging or the discharge of contaminated materials.

B1.4 Applicability

B1.4.1 Hydraulic Filling

The techniques for evaluation of effluent discharges described in this appendix are specifically designed for the case of hydraulic placement of material into CDFs with the effluent discharge occurring from an outlet pipe or weir structure or structures. Hydraulic placement can be in the form of direct pipeline inflow from cutterhead or similar hydraulic suction dredges, intermittent hydraulic placement from hopper dredge pumpout operations, or intermittent hydraulic placement by reslurrying material from barges (which may have been filled by mechanical dredges). Such placement operations would normally have an effluent discharge flowrate roughly equal to that of the inflow.

B1.4.2 Flow Through Dikes

Some CDFs may be designed to allow flow of effluent water through filter cells or permeable dike sections. The techniques described in this appendix may be applied to this case, but the influence of the filter media in adsorption of contaminants from the effluent discharge should be considered (Krizek et al., 1976).

B1.4.3 Mechanical Filling

Dredged material may be placed in some CDFs by direct mechanical means such as rehandling from barges or by truck. Although such filling operations normally involve handling relatively little free water, there may still be an effluent discharge. Also, there may be ponded water in the CDF before filling begins, especially for CDFs constructed in water. For the case of mechanical filling, the effluent discharge involves the free water which is released during the mechanical placement operation or the existing pond water which is displaced by the operation. No laboratory-developed and field-verified techniques now exist for the case of direct mechanical placement of materials in CDFs, however the procedures described here may be used in the interim for the case of mechanical placement and are considered conservative for such evaluations.

B1.4.4 Surface Runoff and Leachate

Long-term geochemical changes may occur following disposal, site dewatering, and subsequent drying of the dredged material. The quality of the surface runoff or leachate to surface water or groundwater from disposal sites after these long-term changes occur may be markedly different from that of the effluent discharged during active disposal. The techniques described in this appendix apply only to conditions during active filling of the site and do not account for long-term geochemical changes. Therefore, they should not be used to evaluate the quality of surface runoff or leachate. In accordance with 33 CFR 336.1 (b)(8) and Corps Regulatory Guidance Letter 87-8, the technical procedures contained in USACE/EPA (1992) should be used as a guide for developing the appropriate tests and evaluating surface runoff and leachate and possible management options.

B2.0 OVERVIEW OF EVALUATIONS FOR EFFLUENT DISCHARGES

The discharge of effluent from CDFs has the potential for water column effects only. Any solids in the effluent would be dispersed and mixed. Because CDFs are designed to retain virtually all of the solid fraction of dredged material, the evaluation of benthic effects is usually not applicable.

The evaluation of water column effects resulting from effluent discharges uses a tiered approach generally patterned after that for discharges of material into open water. General guidance in the main body of this manual [pertaining to Tier I evaluations (Sections 4.0 and 4.1), selection of contaminants of concern (Section 4.2), sample collection and preservation (Section 8), analytical procedures (Section 9) and general procedures for toxicity tests (Section 10)] is applicable for evaluation of effluent discharges.

B2.1 Water Quality Standards

Section 401 of the CWA requires that all Federal permits and licenses, including those for effluent or other discharges into waters of the United States, authorized pursuant to Section 404 of the CWA, must be certified as complying with applicable State water quality standards (WQS). Violations of any applicable State water quality standard apply at the edge of a State designated mixing zone.

The process for adoption of State WQS is prescribed at 40 CFR 131. States must issue, condition, deny, or waive a Water Quality Certification for activities permitted or conducted by USACE, certifying that no adverse water quality impacts will occur based on determinations of compliance with applicable State WQS which have been adopted in accordance with the above regulation. State water quality standards consist of designated uses, narrative and numeric criteria designed to support those uses, and anti-degradation provisions.

B2.2 Mixing Zones

The evaluation of effluent discharges must consider the effects of mixing and dispersion. Section 230.3(m) of the Guidelines defines the mixing zone:

The term "mixing zone" means a limited volume of water serving as a zone of initial dilution in the immediate vicinity of a discharge point where receiving water quality may not meet quality standards or other requirements otherwise applicable to the receiving water. The mixing zone should be considered as a place where wastes and water mix and not as a place where effluents are treated.

Mixing zones are normally defined by the State regulatory agency as part of the 401 water quality certification. Detailed procedures for evaluation of mixing zones for CDF discharges are found in Appendix C.

B2.3 Basis of Evaluations

Chemical analyses are performed for contaminants that may be released from dredged material placed in CDFs and the results are compared to water quality standards for these contaminants after allowance for mixing. This provides an indirect evaluation of potential biological impacts. If water quality standards are met for all contaminants of concern, the material discharged as effluent in the water column may also be evaluated for toxicity after mixing. Toxicity tests provide information on the toxicity of contaminants not included in the water quality standards, and indicate possible

interactive effects of multiple contaminants. Bioaccumulation from the material discharged as effluent in the water column is typically considered to be of minor concern due to the short exposure time and low exposure concentrations resulting from rapid dispersion and dilution.

B2.4 Contaminant Controls

If the testing and associated analysis of the effluent pathway indicates applicable water quality standards will not be met after consideration of mixing, appropriate contaminant controls may be considered to reduce impacts to acceptable levels. Controls for effluent may include modification of the operation (e.g., use of a smaller dredge with reduced inflow rate, providing increased ponded area and depth of the CDF, or relocation of the inflow and effluent discharge points), or treatment of effluent to remove contaminants. Additional information on contaminant controls is found in USACE/EPA (1992).

B2.5 Tiered Approach

The tiered approach for evaluation of water column effects for effluent discharges from CDFs is generally patterned after that for discharges of material into open water (Section 3.1). The Tier I evaluations should be conducted as described in Section 4.0. Procedures in this appendix for evaluation of effluent discharges are performed in Tiers II and III. A flowchart illustrating the approach for evaluating potential effluent impact is shown in Figure B2. Detailed descriptions of the test procedures are given in Section B3.0. Tier IV evaluations for effluent discharges, if deemed required, would be performed considering the guidance in Section 11.3.

Tier II evaluations for effluent discharges consist of determinations of a screen relative to WQS compliance and perhaps conduct of additional water column testing. Water column testing should be conducted only if shown by the evaluation to be necessary. Water column impacts are evaluated (if necessary) by comparison of applicable water quality standards to the contaminant concentrations in the effluent discharge after consideration of mixing. Water column impact must also be evaluated by toxicity testing in Tier III when there are contaminants of concern for which applicable WQS are not available or where interactive effects are of concern.

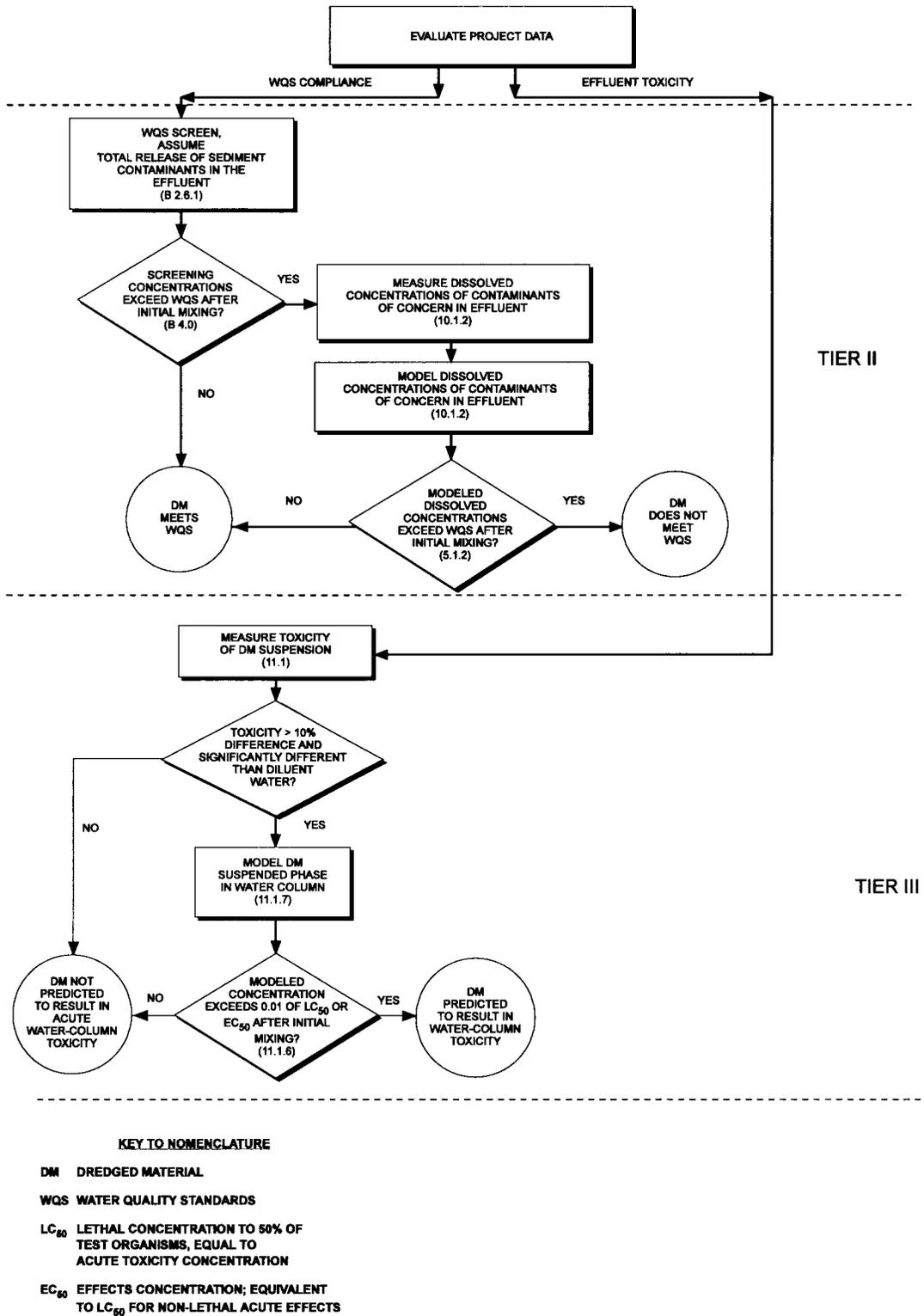


Figure B2. Flowchart Illustrating Approach for Evaluating Potential Effluent Impacts from Confined Dredged Material Disposal Areas.

B2.6 Tier II: Water Quality Evaluations

B2.6.1 Screen Relative to WQS

The screen relative to WQS determines the need for additional testing by considering the bulk concentration of contaminants in the dredged material, the mixing at the disposal site, and applicable water quality standards. If the need for additional testing is not demonstrated, the effluent discharge complies with WQS. If additional testing is needed, it is conducted according to the guidance in Section B3.0 as appropriate.

The screen involves a determination of whether the water quality standards, after consideration of mixing, would be met if the bulk concentration of contaminants present in the sediment were to be completely dissolved in the inflow water flowing into the CDF and discharged as effluent from the disposal site.

The contaminant that would require the greatest dilution is determined by calculating the dilution that would be required to meet the applicable water quality standard. To determine the dilution (D) the following equation is solved for each contaminant of concern:

$$D = [(C_s \times SS/1000) - C_{wq}] / (C_{wq} - C_{ds})$$

where

C_s	=	concentration of the contaminant in the dredged material expressed as micrograms per kilogram ($\mu\text{g}/\text{Kg}$), on a dry weight basis;
SS	=	suspended solids concentration in the CDF inflow expressed as grams per liter (g/L);
1000	=	conversion factor, g to Kg;
C_{wq}	=	WQS in micrograms per liter ($\mu\text{g}/\text{L}$); and
C_{ds}	=	background concentration of the contaminant at the disposal site in micrograms per liter ($\mu\text{g}/\text{L}$).

The mixing zone evaluation is then made for the contaminant that would require the greatest dilution. If the concentration after mixing is below the applicable water quality standard, the effluent discharge complies with WQS. If this concentration exceeds the applicable water quality standard, additional testing must be conducted according to the guidance in Sections B2.6.2 and B3.0.

B2.6.2 Testing for Evaluation of Effluent Water Quality

The Tier II water column evaluation considers concentrations of contaminants of concern released from the dredged material (in contrast to bulk concentrations used in Section B2.6.1), after allowance

for initial mixing, compared with applicable water quality standards. The evaluation therefore requires a prediction of the CDF effluent quality.

The prediction of the quality of effluent from CDFs must account for the dissolved concentration of contaminants. An effluent elutriate procedure has been developed for this purpose (Palermo, 1986, 1988; Palermo and Thackston, 1988a and b). This test defines dissolved concentrations of contaminants in milligrams per liter, and considers the geochemical changes occurring in the disposal area during active disposal operations. Refinements and extensions of column settling test procedures (Averett et al., 1988; Montgomery et al., 1983; and Palermo and Thackston, 1988c) have also been developed to define the concentration of SS in the effluent for a given operational condition (i.e., ponded area and depth, inflow rate, and hydraulic efficiency). The column test results can be used to evaluate the turbidity of the effluent if a relationship between TSS and turbidity is defined for the sediment under consideration.

Predicted contaminant concentrations based on the results of a effluent elutriate test can be used with applicable water quality standards to determine if the discharge is in compliance with the standards after consideration of mixing. To determine the dilution (D) required to meet the standards, the following equation is solved for each contaminant of concern:

$$D = (C_{ec} - C_{wq}) / (C_{wq} - C_{ds})$$

where C_{ec} = concentration of the dissolved contaminant in the effluent elutriate in micrograms per liter ($\mu\text{g/L}$). All other terms are as previously defined in Section B2.6.1.

The mixing zone evaluation is then made for the contaminant that would require the greatest dilution. If the concentration after mixing is below the applicable water quality standard, the discharge complies with WQS. Otherwise, it does not.

B2.7 Tier III: Toxicity Evaluations

Tier III testing assesses the impacts of contaminants in the dredged material on appropriate sensitive organisms to determine if there is potential for the dredged material to have an unacceptable adverse impact. The Tier III assessment methods are toxicity tests, which use lethality as the primary endpoint because the importance of this endpoint is easily interpreted. These acute tests use organisms representative of the water column at the disposal site. The recommended procedures for water column toxicity tests for evaluation of effluent discharges are conducted in generally the same manner as those for discharges of material into open water (Section 11.1). The only exception is that the toxicity test medium is prepared using an effluent elutriate procedure.

The results of the water column toxicity tests must be interpreted considering the effects of mixing. If the concentration of dissolved plus suspended contaminants, after allowance for mixing, does not exceed 0.01 of the toxic (LC50 or EC50) concentration beyond the boundaries of the mixing zone, the discharge is predicted not to be acutely toxic to water column organisms. If the concentration of dissolved plus suspended contaminants, after allowance for mixing, exceeds 0.01 of the toxic concentration, the discharge is predicted to be acutely toxic to water column organisms.

B3.0 TESTING PROCEDURES FOR EFFLUENT DISCHARGES

This section describes the data requirements, testing procedures, and evaluation techniques necessary to predict effluent contaminant concentrations for the Tier II evaluation and to conduct water column toxicity tests for the Tier III evaluation. Example calculations are presented as appropriate.

The predictive techniques can be applied to evaluate the performance of existing sites and to design new sites. For existing sites, the technique can be used to predict the effluent quality for a given set of anticipated operational conditions (known flow and containment area size). In a similar manner, the required operational conditions for a new site (size, geometry, maximum allowable dredge size, etc.) can be determined to meet a given effluent quality requirement by comparing the predicted effluent quality for a variety of assumed operational conditions. In either case evaluation of effluent quality must be considered in conjunction with a sound design of the CDF for retention of suspended solids and initial storage of the sediments to be dredged.

B3.1 Data Requirements

Data requirements for prediction of effluent quality and effluent TSS include those pertaining to operational considerations (i.e., CDF site characteristics and dredge characteristics) and those pertaining to the properties of the dredged material (i.e., contaminant release characteristics and sedimentation characteristics). Data relating to operational considerations are usually determined by the disposal area design and by past experience in dredging and disposal activities for the project under consideration or for similar projects. Data relating to the dredged material characteristics must be obtained by sampling the sediments to be dredged and testing them. A summary of the data requirements for effluent quality prediction is given in Table B1.

B3.1.1 Disposal Area Design

When the quality of the effluent from a CDF is of concern, the design, operation, and management of the site should be carefully controlled. This includes aspects relating to both the volume required for effective sedimentation and the storage capacity of the site. Procedures for such evaluations are presented in Engineer Manual 1110-2-2-5027 (USACE, 1987), and should be considered prior to the prediction of the quality of the effluent for the project. These design procedures will determine the surface area and ponding depth required to achieve effective sedimentation, the required containment volume for storage (including required freeboard), and the proper sizing of weir structures. The prediction of the quality of the effluent described in this appendix is an extension and refinement of the design procedures. A list of data items required from the design evaluation is shown in Table B1.

The process described in Section 4.2 should identify which contaminants are of concern and which therefore should be considered for subsequent analysis in the effluent elutriate testing. The effluent elutriate tests and the column settling tests provide the remaining data required for prediction of the quality of the effluent.

B3.1.2 Sampling Requirements

Samples of channel sediment and water from the dredging site are required for conducting effluent elutriate tests and column settling tests, and toxicity tests, and for characterizing the sediment to be dredged. The level of effort, including number of sampling stations, quantity of material, and any schemes used for compositing samples, is highly project-specific. If at all possible, the sampling operations required for sediment characterization (both physical and chemical), design and evaluation of the disposal site, and conducting the effluent elutriate tests or toxicity tests should be conducted simultaneously to avoid duplication of effort. Note that water from the dredging site is used in tests for evaluation of effluent discharges. Dredging site water is used since the effluent discharge only involves a small fraction of dredged material solids and the fractionation of contaminants to the dissolved phase will be influenced primarily by that water. Note that disposal site water samples must also be taken and analyzed for evaluation of mixing. The guidance in Section 8 should be used for obtaining samples.

B3.2 Column Settling Tests

Settling tests are necessary to provide data for design or evaluation of disposal areas for retention of suspended solids. These tests are designed to define the settling behavior of a particular sediment and to provide information concerning the volumes occupied by newly placed layers of dredged material.

Table B1. Summary of Data Requirements for Prediction of the Quality of Effluent from Confined Dredged Material Disposal Areas.

<u>Data Required</u>	<u>Symbol</u>	<u>Source of Data</u>
Dredge inflow rate	Q_i	Project information; site design
Dredge inflow solids concentration	C_i	Project information; site design
Ponded area in disposal site	A_p	Project information; site design
Average ponding depth in disposal site and at the weir	D_p, D_{pw}	Project information; site design
Hydraulic efficiency factor	HEF	Dye tracer or theoretical determination
Effluent total suspended solids concentration	SS_{eff}	Laboratory column settling tests
Dissolved concentration of contaminant in effluent	C_{diss}	Effluent elutriate tests

* This summary includes only those data required for effluent quality prediction. It is assumed that the disposal area under consideration is designed for effective sedimentation and storage capacity. Data requirements for such design or evaluation are found in EM 1110-2-5027 (USACE, 1987).

For purposes of effluent water quality prediction, the column setting tests need only be performed if there are water quality standards for total suspended solids or turbidity. If standards exist for turbidity, a sediment-specific correlation of suspended solids and turbidity must be developed.

Sedimentation of freshwater slurries of concentration less than 100 g/L can generally be characterized as flocculent settling. As slurry concentrations are increased, the sedimentation process may be characterized as a zone settling process, in which a clearly defined interface is formed between the clarified supernatant water and the more concentrated settled material. Zone settling also occurs when the sediment/water salinity is approximately 3 ppt or greater. Flocculent settling also describes the behavior of residual suspended solids in the clarified supernatant water above the sediment/water interface for slurries exhibiting an interface. The procedures described below define the sedimentation of suspended solids under flocculent settling conditions or above the settled material/water interface under zone setting conditions. The settling test procedures consist of withdrawing samples from the settling column at various depths and times and measuring the concentrations of suspended solids.

B3.2.1 Apparatus

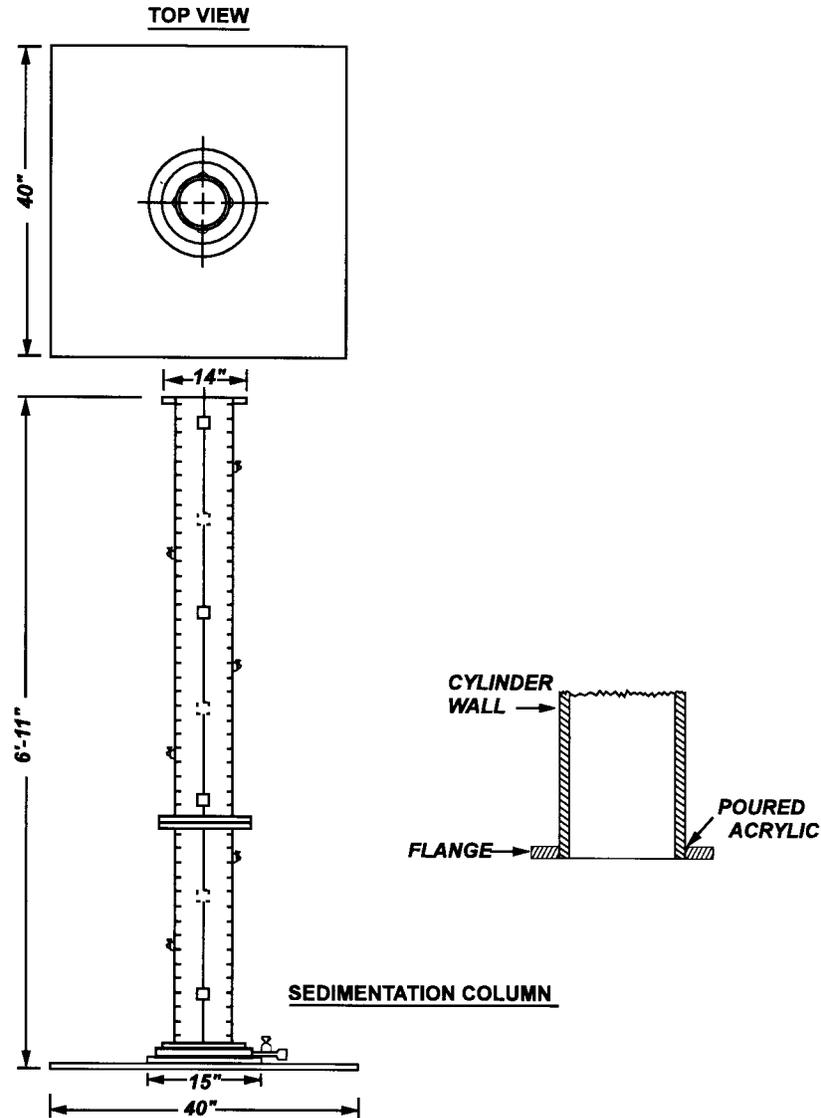
An 8-inch diameter settling column such as shown in Figure B3 is used. The test column depth should approximate the effective settling depth of the proposed disposal area. A practical limit on the depth of the test is 6 ft. The column should be at least 8 in. in diameter with interchangeable sections and with sample ports at 1/2-ft or closer intervals. The column should have provisions to bubble air from the bottom to keep the slurry mixed during the column filling period.

B3.2.2 Test Procedure

The following test procedure should be used:

Step 1. Mix the sediment slurry to a suspended solids concentration C equal to the expected concentration of the dredged material influent C_i . The slurry should be mixed in a container with sufficient volume to fill the test column. Field studies indicate that for maintenance dredging of fine-grained material, the disposal concentration will average about 150 grams per liter. This concentration should be used in the test if better data are not available.

Step 2. Pump or pour the slurry into the test column using compressed air or mechanical agitation to maintain a uniform concentration during the filling period. Any coarse material which settles to the



BILL OF MATERIAL		
QTY	MATERIAL	SIZE
1	AIR COUPLER	1/4" I.D.
1	BALL VALVE (STAINLESS STEEL)	1/4" I.D.
1	BALL VALVE (STAINLESS STEEL)	3/4" I.D.
13	SAMPLING VALVE ASSEMBLIES (STAINLESS STEEL)	3/8" I.D.
2	PIPE (STAINLESS STEEL)	1/4" I.D., 2" LONG
1	SINTERED STEEL FILTER DISK 50-80 MICRON PORE DIAMETER	1/4" THICK 8.23 DIAMETER
1	MATERIAL FOR AT LEAST 2-10" DIAMETER O-RINGS	1/4" DIA, 12" LONG
1	WATERPROOF PLYWOOD	4' x 4' x 1/2"
1	WATERPROOF PLYWOOD PLATE FOR COLUMN BASE	16" DIAMETER
8	HEX HEAD BOLT W/WASHER AND NUT	1/4" - 20 UNC x 1-1/2"
8	CARRIAGE HEAD BOLT W/WASHER AND NUT	1/4" x 3"
14	PLEXIGLASS REINFORCEMENT FOR COLUMN HOLES	3" x 3" x 1/4"
2	PLEXIGLASS FLANGE FOR BOTTOM COLUMN	1/2" THICK, 14" O.D. 8-1/2" I.D.
2	PLEXIGLASS FLANGE FOR TOP COLUMN	1/2" THICK, 14" O.D. 8-1/2" I.D.
1	PLEXIGLASS PLATE FOR COLUMN BOTTOM	1" THICK, 14" DIA
1	PLEXIGLASS CYLINDER	27" LONG, 1/4" THICK 8" I.D., 8-1/2" O.D.
1	PLEXIGLASS CYLINDER	54" LONG, 1/4" THICK 8" I.D., 8-1/2" O.D.

SUPPLIES	
MATERIAL	COMPANY
FILTER DISK	MOTT METALLURIGICAL CORPORATION FARMINGTON INDUSTRIAL PARK FARMINGTON, CT 06032
O-RING	MISSISSIPPI RUBBER AND SPECIALITY COMPANY 819 SOUTH CONGRESS JACKSON, MS 39201
PLEXIGLASS	CADILLAC PLASTIC COMPANY/FAULKNER PLASTICS, INC. 4504 E. HILLSBORO AVE. P.O. BOX 1126 TAMPA, FL 33601

Figure B3a. Specifications for Settling Column and Plan for Sedimentation Column.

bottom of the mixing container during transfer of the slurry to the test column need not be added to the column.

Step 3. When the slurry is completely mixed in the column, cut off the compressed air or mechanical agitation and immediately draw off samples at each sample port and determine their suspended solids concentration. Use the average of these values as the initial slurry concentration at the start of the test. The test is considered initiated when the first samples are drawn.

Step 4a. If an interface has not formed during the first day, flocculent settling is occurring in the entire slurry mass. Allow the slurry to settle and withdraw samples from each sampling port at regular time intervals to determine the suspended solids concentrations. Record the water surface height and time at the start of the sampling period. Analyze each sample for total suspended solids. Substantial reductions of suspended solids will occur during the early part of the test, but reductions will decrease with longer retention times. Therefore, the intervals can be extended as the test progresses. Recommended sampling intervals are 1, 2, 4, 6, 12, 24, 48 hours, etc., until the end of the test. As a rule, a 50-milliliter sample should be taken from each port. Continue the test until either an interface can be seen near the bottom of the column and the suspended solids concentration in the fluid above the interface is less than 1 gram per liter or until the suspended solids concentrations in extracted samples shows no decrease.

Step 4b. If an interface forms the first day, zone settling is occurring in the slurry below the interface, and flocculent settling is occurring in the supernatant water. For this case, samples should be extracted from all side ports above the falling interface. The first of these samples should be extracted immediately after the interface has fallen sufficiently below the uppermost port to allow extraction or sufficient sample can be withdrawn from the surface without disturbing the interface. This sample can usually be extracted within a few hours after the beginning of the test. Record the time of extraction, water surface height, and port height for each port sample taken and analyze each sample for suspended solids. As the interface continues to fall, extract samples from all ports above the interface at regular time intervals. As before, a suggested sequence of sampling intervals would be 1, 2, 4, 6, 12, 24, 48, 96 hours, etc. The samples should continue to be taken until either the suspended solids concentration of the extracted samples shows no decrease or for a maximum time of 15 days. For this case, the suspended solids in the samples should be less than 1 gram per liter, and filtration will be required to determine the concentrations. The data should be expressed in milligrams per liter for these samples. In reducing the data for this case, the concentration of the first port sample taken above the falling interface is considered the initial concentration SS_0 .

B3.2.3 Data Analysis

A flocculent data analysis procedure, as outlined in the following paragraphs, is required. Example calculations are also shown in Section B3.4.

Step 1. Arrange the flocculent settling test data from the laboratory test as shown in Table B2 and compute values of the depth of sampling below the fluid surface, z . In computing the fractions of suspended solids remaining ϕ , the highest concentration of the first port samples taken is considered the initial concentration SS_0 .

Step 2. Plot the values of ϕ and z using the data from the table as shown in Figure B4, forming a concentration profile diagram. Concentration-depth profiles should be plotted for each time of sample extraction.

Step 3. Use the concentration profile diagram to graphically determine percentages of suspended solids removed R for the various time intervals for the anticipated ponding depth D_{pw} (the minimum recommended ponding depth is 2 feet). This is done by graphically determining the area to the right of each concentration-depth profile and its ratio to the total area above the depth D_{pw} . The removal percentage is:

$$R = \frac{\text{Area to right of profile}}{\text{Total area}} (100)$$

Step 4. Compute the percentage P remaining as simply 100 minus the percentage removed, or:

$$P = 100 - R$$

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

$$SS_t = P_t(SS_0)$$

Arrange the data as shown in Table B3.

Step 6. Plot a relationship for suspended solids concentration versus time using the value for each time of extraction, as shown in Figure B5. An exponential or power curve fitted through the data points is recommended.

Table B2. Observed Flocculent Settling Data.

Sample Extraction Time t (h)	Depth of Sample Extraction z (ft)	Suspended Solids SS (mg/L)	Fraction of Initial SS ϕ (percent)
3	0.2	93	55
3	1.0	169	100
7	1.0	100	59
7	2.0	105	62
14	1.0	45	27
14	2.0	43	25
14	3.0	50	30
24	1.0	19	11
24	2.0	18	11
24	3.0	20	12
48	1.0	15	9
48	2.0	7	4
48	3.0	14	8

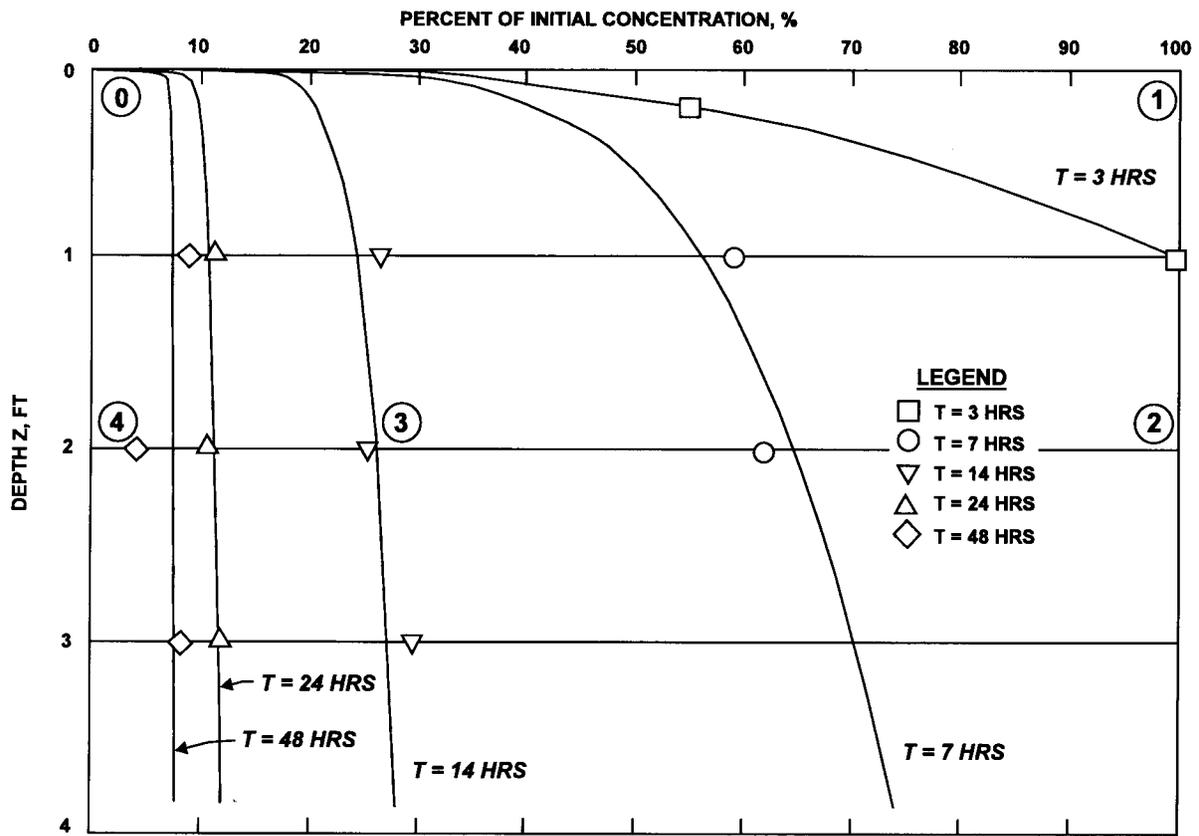


Figure B4. Concentration Profile Diagram.

Table B3. Percentage of Initial Concentration and Suspended Solids Concentrations vs. Time, Assumed Depth of Influence of 2 ft.

Sample Extraction Time t (h)	Removal Percentage, R_t	Remaining Percentage, P_t	Suspended Solids SS (mg/L)
3	14	86	145
7	47	53	90
14	78	22	37
24	90	10	17
48	94	6	10

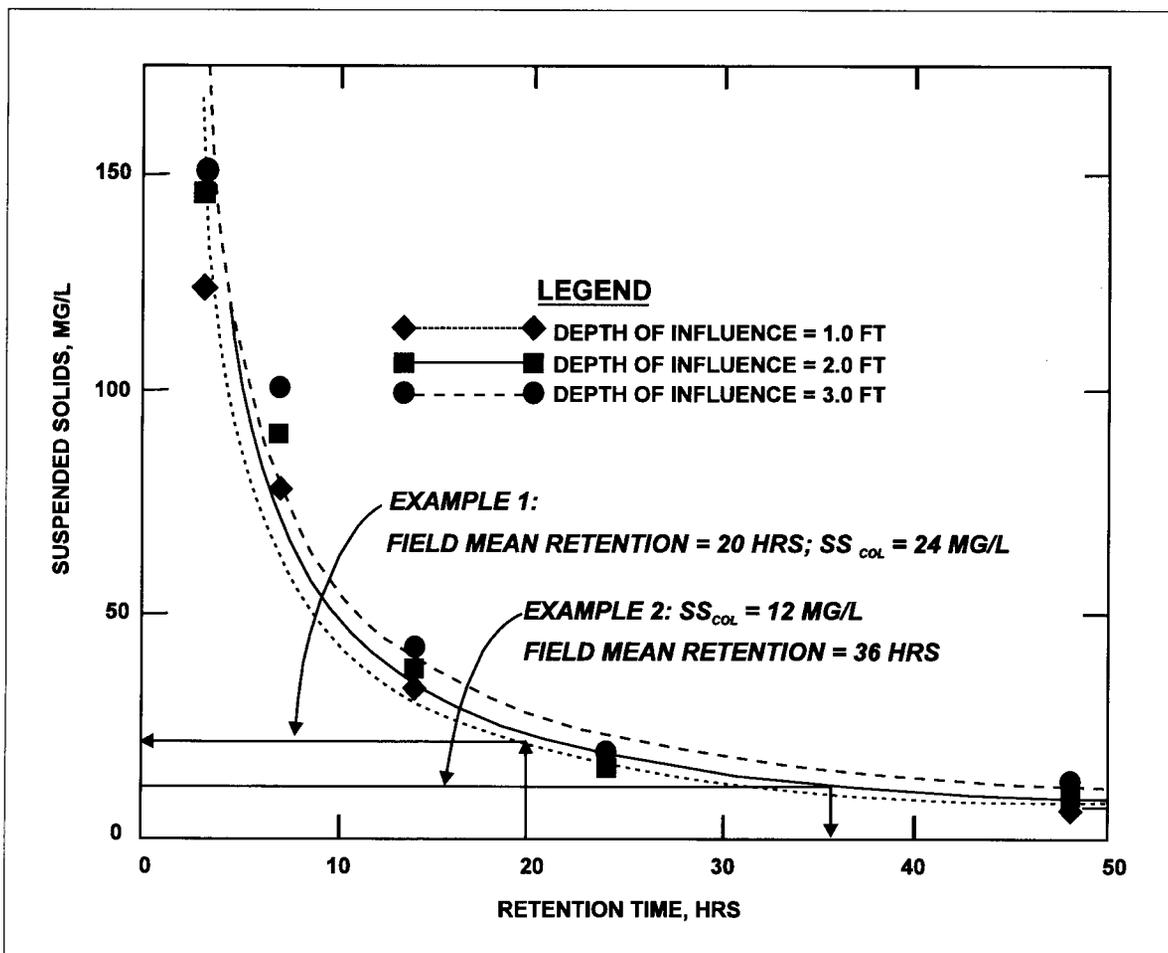


Figure B5. Plot of Supernatant Suspended Solids Concentration vs. Time from Column Settling Tests.

By repeating steps 4 through 6 for each of several values of D_{pw} , a family of curves showing suspended solids remaining versus retention time for each of several assumed ponding depths may be developed. These curves may be used for prediction of effluent suspended solids concentrations under ideal, 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 effluent suspended solids predicted by the column test SS_{col} . Guidance for determination of the field mean retention time is given in Section B3.2.5. Guidance for adjusting the value derived from the column test for anticipated resuspension is given in the Section B3.2.4.

B3.2.4 Determination of Effluent Suspended Solids Concentration

A prediction of the concentration of total suspended solids in the effluent must consider the anticipated actual mean retention time in the disposal area and must account for possible resuspension of settled material because of wind-generated turbulence. 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 actual mean 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 which could only be achieved in the field if there were little or no turbulence or resuspension of settled material. However, an adjustment for anticipated resuspension is necessary for real conditions. The minimum expected value and the value adjusted for resuspension would provide a range of anticipated suspended solids concentrations for use in predicting the total concentrations of contaminants in the effluent. The value adjusted for anticipated resuspension is:

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

where

SS_{eff} = suspended solids concentration of effluent considering anticipated resuspension, mg suspended solids/L of water

SS_{col} = suspended solids concentration of effluent as estimated from column settling tests, mg suspended solids/L of water

RF = resuspension factor selected from Table B4

Table B4 summarizes recommended resuspension factors based on comparisons of suspended solids concentrations predicted from column settling tests and field data from a number of sites with varying site conditions. For dredged material slurries 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.

Table B4. Recommended Resuspension Factors for Various Poned Areas and Depths.

Anticipated Poned Area	Resuspension Factor for Anticipated Average Poned Depth	
	Less than 2 ft.	2 ft. or Greater
Less than 100 acres	2.0	1.5
Greater than 100 acres	2.5	2.0

B3.2.5 Determination of Field Mean Retention Time

Estimates of the field mean retention time for expected operational conditions are required for selecting appropriate settling times in the effluent 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 volumetric retention time. Field mean retention time T_d can be estimated for a given flow rate and ponding conditions by applying a hydraulic efficiency correction factor (HECF) to the theoretical detention time as follows:

$$T_d = \frac{T}{(HECF)}$$

where

T_d = mean detention time, h

T = theoretical detention time, h

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

The theoretical detention time is calculated as follows:

$$T = \frac{V_p}{Q_i} \quad (12.1) = \frac{A_p D_p}{Q_i} \quad (12.1)$$

where

V_p = volume poned, acre-ft

Q_i = average inflow rate, cfs

A_p = area poned, acres

D_p = average depth of ponding, ft

12.1 = conversion factor, acre-ft/cfs to h

The hydraulic efficiency correction factor HECF can be estimated by several methods. The most accurate estimate is that made from dye tracer studies to determine T_d at the actual site under

operational conditions at a previous time, with the conditions similar to those for the operation under consideration. This approach can be used only for existing sites.

Alternatively, the ratio $T_d/T = 1/HECF$ can be estimated from the equation:

$$\frac{T_d}{T} = 0.9 \left[1 - \exp \left(-0.3 \frac{L}{W} \right) \right]$$

where L/W is the length-to-width ratio of the proposed basin. The L/W ratio can be increased greatly by the use of internal spur dikes, resulting in a higher hydraulic efficiency and a lower required total area. In the absence of dye tracer data or values obtained from other theoretical approaches, a value for HECF of 2.25 may be used based on field studies conducted at several sites (Montgomery, 1983; Montgomery et al., 1983).

B3.3 Effluent Elutriate Test Procedure

The effluent elutriate tests should be conducted, and appropriate chemical analyses should be performed, as soon as possible after sample collection. The volume of elutriate sample needed for chemical analyses will vary depending upon the number and types of chemical analyses to be conducted. The volume required for each analysis, the number of parameters measured, and the desired analytical replication will influence the total elutriate sample volume required. A 4 L cylinder is normally used for the test, and the supernatant volume available for sample extraction will vary from approximately 500 to 1,000 mL, depending on the sediment properties, settling times, and initial concentration of the slurry. It may be necessary to composite several extracted sample volumes or to use large diameter cylinders to obtain the total required volume.

B3.3.1 Apparatus

The following items are required:

- a. Laboratory mixer, preferably with Teflon shaft and blades.
 - b. Several 4 L graduated cylinders. Larger cylinders may be used if large sample volumes are required for analytical purposes. Nalgene cylinders are acceptable for testing involving analysis of inorganic compounds such as metals and nutrients. Glass cylinders are required for testing involving analysis of organic compounds.
 - c. Assorted glassware for sample extraction and handling.
-

-
- d. Compressed air source with deionized water trap and tubing for bubble aeration of slurry.
 - e. Vacuum or pressure filtration equipment, including vacuum pump or compressed air source and an appropriate filter holder capable of accommodating 47-, 105-, or 155-mm-diam filters.
 - f. Presoaked filters with a 0.45 μm pore-size diameter.
 - g. Plastic sample bottles, 500 mL capacity for storage of water and liquid phase samples for metal and nutrient analyses.
 - h. Wide-mouth, 1 gal capacity glass jars with Teflon-lined screw-type lids for sample mixing. These jars should also be used for sample containers when samples are to be analyzed for pesticides.

Prior to use, all glassware, filtration equipment, and filters should be thoroughly cleaned. Wash all glassware with detergent, rinse five times with tap water, place in a clean 10 percent (or stronger) HCl acid bath for a minimum of 4 h, rinse five times with tap water, and then rinse five times with distilled or deionized water. Soak filters for a minimum of 2 h in a 5 M HCl bath, and then rinse 10 times with distilled water. It is also a good practice to discard the first 50 mL of water or liquid phase filtered.

B3.3.2 Test Procedure

The step-by-step procedure for conducting the effluent elutriate test is outlined below.

Step 1 - Slurry preparation. The sediment and water from the proposed dredging site should be mixed to a concentration approximately equal to the expected average field inflow concentration. If estimates of the average field inflow concentration cannot be made based on past data, a slurry concentration of 150 g/L (dry weight basis) should be used. Predetermine the concentration of the well-mixed sediment in grams per liter (dry weight basis) by oven drying a small subsample of known volume. Each 4 L cylinder to be filled will require a mixed slurry volume of 3-3/4 L. The volumes of sediment and water to be mixed for a 3-3/4 L slurry volume may be calculated using the following expressions:

$$V_{\text{sediment}} = 3.75 \frac{C_{\text{slurry}}}{C_{\text{sediment}}}$$

and

$$V_{\text{water}} = 3.75 - V_{\text{sediment}}$$

where

V_{sediment} = volume of sediment, in L

3.75 = volume of slurry for 4 L cylinder, L

C_{slurry} = desired concentration of slurry, g/L (dry weight basis)

C_{sediment} = predetermined concentration of sediment, g/L (dry weight basis)

V_{water} = volume of disposal site water, in L

Step 2 - Mixing. Mix the 3-3/4 L of slurry by placing appropriate volumes of sediment and water from the proposed dredging site in a 1 gal glass jar and mixing for 5 min with the laboratory mixer. The slurry should be mixed to a uniform consistency, with no unmixed agglomerations of sediment.

Step 3 - Aeration. The prepared slurry must be aerated to ensure that oxidizing conditions will be present in the supernatant water during the subsequent settling phase. Bubble aeration is therefore used as a method of sample agitation. Pour the mixed slurry into a 4 L graduated cylinder. Attach glass tubing to the aeration source and insert the tubing to the bottom of the cylinder. The tubing can be held in place by insertion through a predrilled No. 4 stopper placed in the top of the cylinder. Compressed air should be passed through a deionized water trap, through the tubing, and bubbled through the slurry. The flow rate should be adjusted to agitate the mixture vigorously for 1 h.

Step 4 - Settling. Remove the tubing, and allow the aerated slurry to undergo quiescent settling for a time period equal to the anticipated field mean retention time, up to a maximum of 24 h. If the field mean retention time is not known, allow settling for 24 h. Guidance for estimating the field mean retention is given in Section B3.2.5.

Step 5 - Sample extraction. After the appropriate period of quiescent settling, an interface will usually be evident between the supernatant water, with a low concentration of suspended solids above, and the more concentrated settled material below the interface. Samples of the supernatant water should be extracted from the cylinder at a point midway between the water surface and interface using syringe and tubing. Care should be taken not to resuspend the settled material.

Step 6 - Sample preservation and analyses. The sample should be analyzed as soon as possible after extraction. Dissolved concentrations of desired analytes in milligrams per liter should be determined. Filtration using 0.45 μm filters should be used to obtain samples for analysis of dissolved concentrations. Samples to be analyzed for dissolved pesticides or polychlorinated biphenyls (PCBs) must be free of particles but should not be filtered due to the tendency for these materials to adsorb on the filter. However, particulate matter can be removed before analysis by high-speed

centrifugation at 10,000 times gravity using Teflon, glass, or aluminum centrifuge tubes (Fulk et al., 1975).

B3.3.3 Chemical Analyses

Chemical analyses of the effluent elutriate samples should be performed according to the guidance in Section 9.

B3.3.4 Dissolved Concentrations of Contaminants

The dissolved concentrations of chemical contaminants in the effluent elutriate are compared with water quality standards after consideration of mixing.

B3.4 Water Column Toxicity Test Procedure

The procedures for performing toxicity tests to evaluate water column effects of effluent discharges from CDFs are generally the same as those for evaluation of dredged material discharges in open water (see Section 5.1). However, the preparation of the dredged material (dissolved plus suspended contaminants) should be done using the effluent elutriate procedure as described below.

The volume required for each analysis, the number of parameters measured, and the desired analytical replication will influence the total elutriate sample volume required. A 4 L cylinder is normally used for the test, and the supernatant volume available for sample extraction will vary from approximately 500 to 1,000 mL, depending on the sediment properties, settling times, and initial concentration of the slurry. It may be necessary to composite several extracted sample volumes or to use large diameter cylinders to obtain the total required volume.

B3.4.1 Apparatus

The following items are required:

- a. Laboratory mixer, preferably with Teflon shaft and blades.
 - b. Several 4 L graduated cylinders. Larger cylinders may be used if large sample volumes are required for analytical purposes. Nalgene cylinders are acceptable for testing involving analysis of inorganic compounds such as metals and nutrients. Glass cylinders are required for testing involving analysis of organic compounds.
 - c. Assorted glassware for sample extraction and handling.
-

- d. Compressed air source with deionized water trap and tubing for bubble aeration of slurry.
- e. Wide-mouth, 1-gal capacity glass jars with Teflon-lined screw-type lids for sample mixing. These jars should also be used for sample containers when samples are to be analyzed for pesticides.

Prior to use, all glassware should be thoroughly cleaned. Wash all glassware with detergent, rinse five times with tap water, place in a clean bath for a minimum of 4 h, rinse five times with tap water, and then rinse five times with distilled or deionized water.

B3.4.2 Test Procedure

The step-by-step procedure for conducting the effluent elutriate test for use in toxicity tests is outlined below.

Step 1 - Slurry preparation. The sediment and water from the proposed dredging site should be mixed to a concentration approximately equal to the expected average field inflow concentration. If estimates of the average field inflow concentration cannot be made based on past data, a slurry concentration of 150 g/L (dry weight basis) should be used. Predetermine the concentration of the well-mixed sediment in grams per liter (dry weight basis) by oven drying a small subsample of known volume. Each 4 L cylinder to be filled will require a mixed slurry volume of 3-3/4 L. The volumes of sediment and water to be mixed for a 3-3/4 L slurry volume may be calculated using the following expressions:

$$V_{\text{sediment}} = 3.75 - \frac{C_{\text{slurry}}}{C_{\text{sediment}}}$$

and

$$V_{\text{water}} = 3.75 - V_{\text{sediment}}$$

where

V_{sediment} = volume of sediment, in L

3.75 = volume of slurry for 4 L cylinder, L

C_{slurry} = desired concentration of slurry, g/L (dry weight basis)

C_{sediment} = predetermined concentration of sediment, g/L (dry weight basis)

V_{water} = volume of dredging site water, in L

Step 2 - Mixing. Mix the 3-3/4 L of slurry by placing appropriate volumes of sediment and water from the proposed dredging site in a 1-gal glass jar and mixing for 5 min with the laboratory mixer. The slurry should be mixed to a uniform consistency, with no unmixed agglomerations of sediment.

Step 3 - Aeration. The prepared slurry must be aerated to ensure that oxidizing conditions will be present in the supernatant water during the subsequent settling phase. Bubble aeration is therefore used as a method of sample agitation. Pour the mixed slurry into a 4 L graduated cylinder. Attach glass tubing to the aeration source and insert the tubing to the bottom of the cylinder. The tubing can be held in place by insertion through a predrilled No. 4 stopper placed in the top of the cylinder. Compressed air should be passed through a deionized water trap, through the tubing, and bubbled through the slurry. The flow rate should be adjusted to agitate the mixture vigorously for 1 h.

Step 4 - Settling. Remove the tubing, and allow the aerated slurry to undergo quiescent settling for a time period equal to the anticipated field mean retention time, up to a maximum of 24 h. If the field mean retention time is not known, allow settling for 24 h. Guidance for estimating the field mean retention is given in Section B3.2.5.

Step 5 - Sample extraction. After the appropriate period of quiescent settling, an interface will usually be evident between the supernatant water, with a low concentration of suspended solids above, and the more concentrated settled material below the interface.

The liquid plus the material remaining in suspension after the settling period represents the 100 percent liquid plus suspended particulate phase. Carefully siphon the supernatant, without disturbing the settled material, and immediately use it for toxicity testing. With some very fine-grained dredged materials, it may be necessary to centrifuge the supernatant for a short time. The suspension should be clear enough at the first observation time for the organisms to be visible. The general guidance in Section 10 should be followed in performing the toxicity tests.

B4.0 EXAMPLE CALCULATIONS

B4.1 Example 1: Evaluation of Effluent Water Quality For an Existing Disposal Area

This example illustrates the evaluation of a proposed effluent discharge for an existing CDF in which effluent standards exist for dissolved contaminants and total suspended solids.

B4.1.1 Project Information

Dredged material from a maintenance project will be placed in an existing disposal site. The ponded area will be approximately 35 acres. The design indicated that the surface area is adequate for sedimentation if a minimum ponding depth of 2 ft is maintained. The dredging equipment and pumping conditions anticipated will result in a flow rate of approximately 30 cfs. A dye tracer test was

previously run at this disposal site under similar operational conditions, and the field mean retention time was 20 h. Previous sampling of inflow from the dredge pipe under similar conditions indicated that the influent solids concentration was approximately 150 g/L, which is considered a conservative maximum.

The quality of effluent must be predicted and compared with applicable water quality standards so that the acceptability of the proposed discharge may be evaluated. A field evaluation of dispersion at the disposal site determined that a dilution factor of 38 would occur in the mixing zone. For purposes of this example, copper is the parameter requiring the greatest dilution and will be used to illustrate the calculations. The water quality standard for dissolved copper at the perimeter of the mixing zone was set at 0.004 mg/L, while that for total suspended solids was set at 50 mg/L. (Note that these values are for purposes of example calculations only.)

B4.1.2 Effluent Elutriate Testing

Effluent elutriate tests were conducted on samples of sediment and disposal site water from three stations at the site. The effluent elutriate tests were run at the anticipated influent concentration, in this case 150 g/L. Sediment samples for each sampling station to be tested were homogenized, and a sediment concentration of 450 g/L was determined by oven drying a sample of known volume. The volumes of sediment and water mixed for this sample for a 3-3/4 L slurry volume were determined as:

$$V_{\text{sediment}} = 3.75 \frac{C_{\text{slurry}}}{C_{\text{sediment}}} = 3.75 \frac{150}{450} = 1.25 \text{ L}$$

and

$$V_{\text{water}} = 3.75 - V_{\text{sediment}} = 3.75 - 1.25 = 2.50 \text{ L}$$

The effluent elutriate tests were completed with the retention time used in the tests equal to the anticipated field mean retention time of 20 h. Samples were extracted for the replicate tests and analyzed for dissolved concentrations of desired parameters. The mean concentration of dissolved copper was 0.06 mg/L.

B4.1.3 Column Settling Tests

A column setting test was required because of the water quality standard for suspended solids. Samples from all stations were homogenized into a composite for the column settling test. The test used for prediction of effluent suspended solids was run at a slurry concentration of 150 g/L, equal to the anticipated influent slurry concentration. The interface was formed early in the test. Samples were extracted from settling column ports at 3, 7, 14, 24, and 48 h. Data for the solids concentrations and for various depths and extraction times are shown in Table B2.

The concentration-depth profile diagram was then constructed from the data, and is shown in Figure B4. Ratios of suspended solids removed as a function of time were then determined graphically using the step-by-step procedure described previously. Since an interface formed in the test, the slurry mass was undergoing zone settling. Therefore, the initial supernatant solids concentration SS_0 was assumed to be the highest concentration of the first samples taken, 169 mg/L. The concentration-depth profile diagram was therefore constructed using 169 mg/L as $\phi = 100$ percent. The lower horizontal boundaries for the area determinations corresponded to a range of assumed depths of withdrawal influence at the outlet weir, in this case 1, 2, and 3 ft. An example calculation of the removal ratio for the concentration-depth profile at $t = 14$ h and a depth of influence of 2 ft is:

$$R_{14} = \frac{\text{Area to right of the profile}}{\text{Total area}} = \frac{\text{Area 1230}^*}{\text{Area 1240}} = 0.78$$

* Areas are designated by circled numbers in Figure B5. The areas were determined by planimeter.

The portion remaining at $t = 14$ h is:

$$P_{14} = 1 - R_{14} = 1 - 0.78 = 0.22$$

The value for the suspended solids remaining is:

$$SS_{14} = P_{14} (SS_0) = 0.22 (169) = 37 \text{ mg/L}$$

Values at other times were determined in a similar manner. The summary data are shown in Table B3. Similar calculations for other assumed ponding depths were made. Curves were fitted to the data for total suspended solids versus retention time for depths of influence of 1, 2, and 3 ft and are shown in Figure B5.

B4.1.4 Prediction of Effluent Suspended Solids Concentration

A value for the estimated effluent suspended solids can be determined for quiescent settling conditions using the column test relationship. In this case, the field mean retention time of 20 h corresponds to a suspended solids concentration of 24 mg/L, as shown in Figure B5. This value should be adjusted for anticipated resuspension using the factors shown in Table B4. In this case, for a surface area less than 100 acres and an assumed average ponding depth of 2 ft, the resuspension factor is 1.5. The predicted total suspended solids concentration in the effluent is calculated as :

$$SS_{eff} = SS_{col} \times RF = 24 \text{ mg/L} \times 1.5 = 36 \text{ mg/L}$$

The acceptability of the discharge for suspended solids can be evaluated by comparing the estimated effluent concentration with the water quality standard, considering the appropriate mixing zone. For suspended solids, the estimated concentration of 36 mg/L is less than the water quality standard of 50 mg/L, therefore the discharge is acceptable for suspended solids prior to considering mixing.

B4.1.5 Prediction of Contaminant Concentrations

The acceptability of the proposed discharge for contaminants can be evaluated by comparing the estimated effluent concentrations with applicable water quality standards, considering an appropriate mixing zone. For a mixing zone dilution of 38 and a copper standard of 0.004 mg/L, the concentration of copper at the point of discharge must be less than 0.15 mg/L. The estimated concentration of 0.06 mg/L from the effluent elutriate test at the point of discharge is less than the limiting value of 0.15 mg/L. The discharge would therefore be acceptable.

B4.2 Example 2: Determination of Disposal Area Requirements to Meet a Given Effluent Quality Standard

This example illustrates the evaluation of a proposed effluent discharge for a new CDF in which effluent standards are defined in terms of total suspended solids. The required retention time of the new CDF to meet the standards is determined.

B4.2.1 Project Information

A disposal area is planned for contaminated sediment from a small maintenance dredging project. Dredging equipment traditionally used in the project area is capable of flow rates up to 15 cfs.

Available real estate in the project vicinity is scarce, with the maximum available area limited to 60 acres. The disposal area required to meet applicable water quality standards must be determined. The CDF design indicated that a minimum ponded surface area of 20 acres was required for effective sedimentation, assuming a flow rate of 15 cfs and an assumed minimum ponding depth of 2 ft. A mixing evaluation was conducted using a computer model and a dilution factor of 1.8 was estimated for the allowable mixing zone. The water quality standard for TSS is 10 mg/L (Note that this value is for purposes of example calculations only).

B4.2.2 Column Settling Tests

Column settling tests were performed, and the resulting concentration-depth profile was developed as was illustrated in Example 1. The column tests were run at a concentration of 150 g/L for this example. For simplicity, the test results from column tests used in the first example will also be used in this example (see Figures B4 and B5).

B4.2.3 Determination of Allowed Effluent Suspended Solids Concentration

Since this example requires determination of the disposal site characteristics necessary to meet a given water quality standard, the calculations would proceed in a manner similar to Example 1, but in reverse sequence. The concentration of effluent suspended solids required to meet water quality standards must first be determined. For a dilution of 1.8, the TSS concentration at the point of discharge must be less than 18 mg/L.

An appropriate value should be selected from Table B4 for the resuspension factor. The minimum ponding depth of 2 ft required by the site design was selected. A resuspension factor of 1.5 was selected, corresponding to an available area <100 acres and the selected ponding depth of 2 ft.

The value of 18 mg/L of SS which must be achieved at the point of discharge includes anticipated resuspension. The corresponding value for total suspended solids concentration under quiescent settling conditions is determined as:

$$S_{eff} = SS_{col} \times RF$$

or transposed,

$$SS_{col} = \frac{SS_{eff}}{RF} = \frac{18 \text{ mg/L}}{1.5} = 12 \text{ mg/L}$$

The disposal area must provide a retention time which will allow the necessary sedimentation. The required retention time to achieve 12 mg/L under quiescent settling conditions may be determined from the relationship of suspended solids versus retention time for the laboratory column. Using the concentration profile data and the selected depth of ponding at the weir of 2 ft, the relationship for suspended solids versus field mean retention was developed as was previously shown in Figure B5. Using Figure B5, 12 mg/L corresponds to a field mean retention time of 36 h. To determine the required disposal site geometry, the theoretical volumetric retention time should be used. Since no other data were available, the hydraulic efficiency correction factor was assumed to be 2.25. The theoretical volumetric retention time was calculated as:

$$T_d = \frac{T}{(HECF)}$$

or transposed,

$$T = T_d (HEF) = 36 (2.25) = 81 \text{ h}$$

B4.2.4 Determination of Ponded Volume and Surface Area

The required disposal area ponded volume can now be determined using data on anticipated flow rate and the theoretical volumetric retention time. Since the dredging equipment available in the project area is capable of flow rates up to 15 cfs, the high value should be assumed.

The ponded volume required is calculated as:

$$T = \frac{V_p}{Q_i} \quad (12.1)$$

or transposed,

$$V_p = \frac{TQ_i}{12.1} = \frac{81 \text{ h} \times 15 \text{ cfs}}{12.1} = 100 \text{ acre-ft}$$

A ponding depth of 2 ft is the minimum allowed. This same depth should be maintained over the entire ponded surface area and at the weir. The disposal site should therefore encompass approximately 50 acres of ponded surface area with an average depth of 2 ft if the dredge selected for the project has an effective flow rate not greater than 15 cfs. The surface area of 50 acres required to

meet the water quality standard controls the design instead of the calculated surface area of 20 acres required for effective sedimentation.

B5.0 REFERENCES

- Averett, D. E., M.R. Palermo and R. Wade. 1988. Verification of procedures for design of dredged material containment areas for solids retention. Technical Report D-88-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Fulk, R., D. Gruber and R. Wullschleger. 1975. Laboratory study of the release of pesticide and PCB materials to the water column during dredging and disposal operations. Contract Report D-75-6, prepared by Envirex, Inc., under contract to the US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Krizek, R.J., J.A. FitzPatrick and D.K. Atmatzidis. 1976. Investigation of effluent filtering systems for dredged material containment facilities. Contract Report D-76-8, prepared by Dept. of Civil Engineering, Northwestern University, under contract to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, M.S.
- Montgomery, R.L. 1983. Methodology for design of fine-grained dredged material containment areas for solids retention. Technical Report D-78-56, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Montgomery, R. L., E. L. Thackston and F. Parker. 1983. Dredged material sedimentation basin design. *J. Environ. Engineer, Am. Soc. Civil Engineers*. 109.
- Palermo, M. R. 1986. Development of a modified elutriate test for predicting the quality of effluent discharged from confined dredged material disposal areas. Technical Report D-86-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R. 1988. Field evaluations of the quality of effluent from confined dredged material disposal areas. Technical Report D-88-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R. and E. L. Thackston. 1988a. Test for dredged material effluent quality. *J. Environ. Engineer., Am. Soc. Civil Engineers* 114: 1295-1309.
- Palermo, M. R. and E. L. Thackston. 1988b. Verification of predictions of dredged material effluent quality. *J. Environ. Engineer., Am. Soc. Civil Engineers* 114: 1310-1330.
-

Palermo, M. R. and E.L. Thackston. 1988c. Refinement of column settling test procedures for estimating the quality of effluent from confined dredged material disposal areas. Technical Report D-88-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

USACE. 1987. *Confined Disposal Material*. Engineer Manual 1110-2-5027, Office, Chief of Engineers, U. S. Army Corps of Engineers, Washington, D.C.

USACE/EPA. 1992. *Evaluating Environmental Effects of Dredged Material Management Alternatives - A Technical Framework*. EPA842-B-92-008, U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, Washington, D.C.
