US Army Corps of Engineers

MISCELLANEOUS PAPER EL-87-9

DISPOSAL ALTERNATIVES FOR PCB CONTAMINATED SEDIMENTS FROM INDIANA HARBOR, INDIANA

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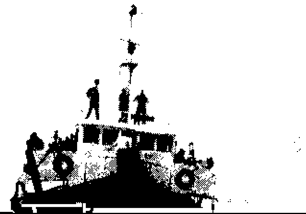


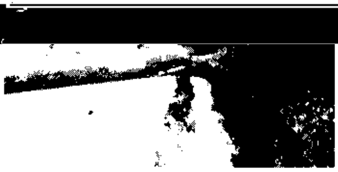
by

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
[illegible]

[illegible]

August 1987
Final Report



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Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana;
Volume I: Main Text

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See reverse.

identified by the International Joint Commission on the Great Lakes as a major area of con-

The purpose of this study was to evaluate alternative methods for dredging and dis-

☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

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19. ABSTRACT (Continued).

evaluation of disposal alternatives and a decisionmaking framework for logical application

[redacted]

material confined disposal facilities (CDFs), research was conducted to develop a leaching

[redacted]

EXECUTIVE SUMMARY

[redacted]

Indiana Harbor and Canal are part of a small, highly industrialized watershed in northwestern Indiana. The Grand Calumet River discharges into [redacted]

Corps of Engineers is authorized to maintain a deep-draft navigation project [redacted]

sediments with concentrations of polychlorinated biphenyls (PCBs) above [redacted]

and other organic contaminants.

[redacted]

US Environmental Protection Agency (USEPA) Regional Administrator. The [redacted]

the Corps' navigation maintenance authority. Alternative methods of disposal approved by the USEPA Regional Administrator appear to be the only feasible [redacted]

[redacted]

Experiment Station (WES) has developed a management strategy for disposal of [redacted]

work (Peddicord et al. 1986) has also been developed to provide a logical [redacted]

framework provides a basis for comparison of test results with standards or [redacted]

this study.

Sampling and testing

[redacted]

form the composite material used for testing. State-of-the-art testing [redacted]

[redacted]

operational controls are applied, a number of dredging and dredged material disposal options are available.

[redacted]

problems were evaluated using appropriate testing protocols. These protocols included those for effluent quality, surface runoff quality, leachate quality, and direct uptake by plants or animals. Since there was no routinely applied laboratory testing protocol to predict leachate quality from dredged material confined disposal facilities, research was conducted to develop a leaching [redacted]

in confined disposal sites. Tests were conducted for use in evaluating the thickness of cap required to isolate contaminated sediments from the overlying [redacted]

appropriate contaminant control measures for the disposal alternatives con- [redacted]

Three disposal alternatives were identified (contained aquatic disposal and two confined disposal alternatives) for the PCB-contaminated sediments and evaluated to determine technical feasibility and control measures required for implementation. Information and data were compiled and evaluated to provide [redacted]

[redacted]

of Indiana Harbor that were capable of handling the required volumes

[redacted]

should be arranged in a manner to seal the PCB-contaminated sediments sub-

[redacted]

quantity of PCBs expected to be released from an in-lake CDF during the dis-

[redacted]

disposal alternative. The actual quantity of PCBs released through the filter

[redacted]

very hydrophobic and are adsorbed very easily. Design and operational considerations for the in-lake CDF should also include chemical clarification, and control of oils.

An upland CDF for the disposal of PCB-contaminated sediments was evaluated, though no specific site has been identified. Control measures would be required to reduce the release of contaminants in effluent, surface [illegible] parameters, even with treatment controls (filtration and carbon adsorption). [illegible] would require control measures similar to the effluent, until a surf[illegible] tion and prevent surface runoff and plant and animal uptake. Volatile loss could be reduced [illegible] treatment could enhance liner performance.

[illegible]

Demonstrations of a clamshell dredge, a cutterhead suction dredge, the Dutch matchbox dredge, and a submerged diffuser were conducted dredging [illegible] during dredging and disposal.

The suspended sediment concentrations observed in the cutterhead and matchbox plumes were generally less than 20 mg/ℓ at distances of 100 ft or greater from the dredges. Based on the results of the field studies, both the matchbox and cutterhead dredges are capable of [illegible]

[redacted]

Conclusion

The feasible disposal alternatives identified for the PCB-contaminated sediments included CAD, in-lake CDF disposal, and upland confined disposal. With appropriate dredging equipment, disposal site designs, and contaminant [redacted]

PREFACE

[redacted]

The studies described in this report were conducted to evaluate the [redacted] Abou-El-Seoud.

[redacted] Paul R. Schroeder, Bobby L. Folsom, Jr., Tom L. Hart, James M. Brannon, Douglas L. Gunnison and Mr. Tommy E. Myers, all of EL, and Mr. Miller. [redacted]

The WES Study Manager was Dr. Raymond L. Montgomery, Chief, Environmental [redacted] studies by Dr. Robert M. Engler, Manager, Environmental Effects of Dredging [redacted] Harrison, Chief, EL, WES.

COL Dwayne G. Lee, CE, was the Commander and Director of WES. Dr. Robert W. Whalin was the Technical Director.

This report should be cited as follows:

Environmental Laboratory. 1987. "Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana; Vol I: Main Report," Miscellaneous Paper EL-87-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI

[redacted]

Multiply	By	To Obtain
[redacted]	[redacted]	[redacted]
		Kelvins*
feet	0.3048	metres
gallons	3.785412	cubic decimetres
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	2.54	centimetres
knots (international)	0.5144444	metres per second
[redacted]	[redacted]	[redacted]
square inches	6.4516	square centimetres
[redacted]	[redacted]	[redacted]

---

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain Kelvin (K) readings, use K = (5/9) (F - 32) + 273.15.

[redacted]

PART I: INTRODUCTION

Background

1. Indiana Harbor and Canal are part of a small, but highly industri-

[redacted]

Calumet River (GCR)/Indiana Harbor Canal (IHC) has a long history of water

[redacted]

2. The Indiana Harbor deep-draft navigation project, shown in Figure 1,

[redacted]

Federal navigation channels are from 22 to 29 ft*. Channel widths range from 160 to 800 ft. The Chicago District, US Army Corps of Engineers (CE), maintains the navigation channel by periodic dredging. Prior to 1968, dredged material from the project was placed in the open waters of Lake Michigan. After 1968, Federal environmental regulations prohibited the unconfined disposal of contaminated dredged material. The CE has been unable to maintain

[redacted]

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page x.

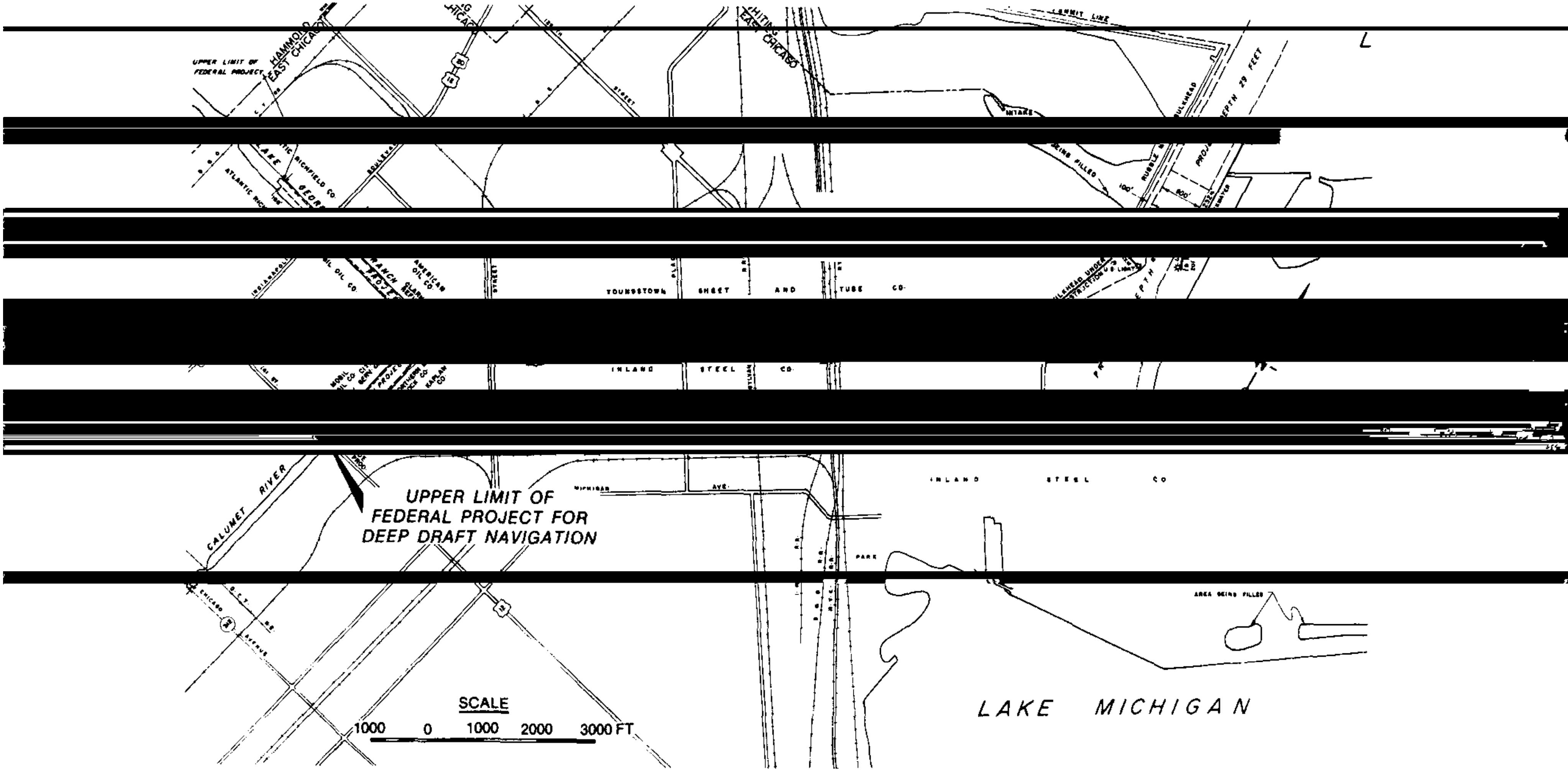


Figure 1. Project location

disposal site was available. The CE could not locate a site or local sponsor for over 10 years.

3. The bottom sediments in Indiana Harbor and Canal contain a variety of contaminants, including oil and grease, nutrients, heavy metals, and organics. [redacted] ments in the navigation channel are heavily-polluted according to these crite- [redacted] contains about 150,000 cu yd.

4. Because of the contaminated nature of the sediments and the fact that municipal drinking water intakes are located in the lake near the Indiana Harbor mouth, special precautions are required during dredging and ultimate [redacted]

** For purposes of this report, the term "PCB-contaminated sediments," refers [redacted]

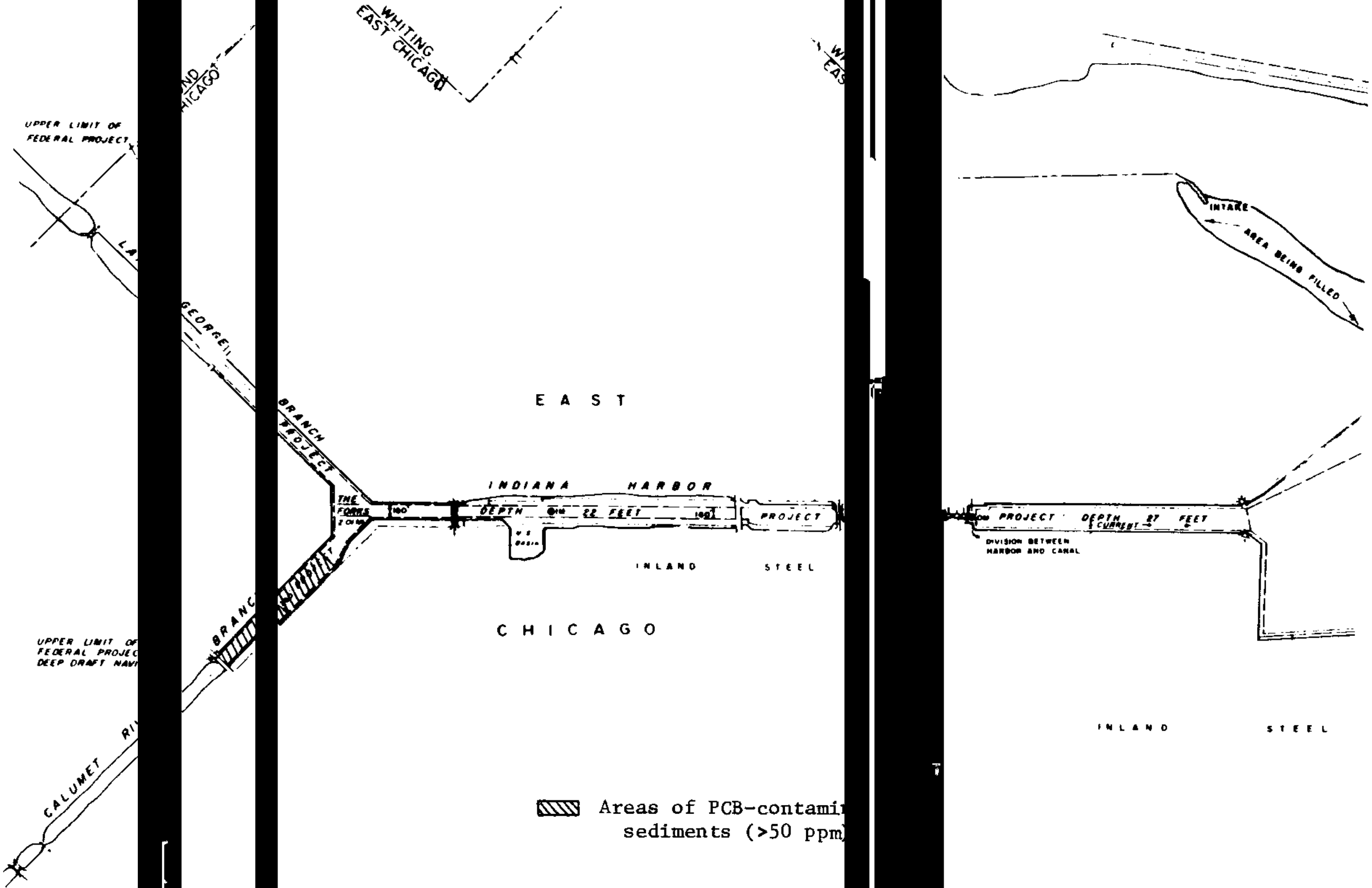


Figure 2. Locations of contamina ments

[redacted]

was prepared for this disposal facility (USACE 1986). Public opposition and

[redacted]

examining the feasibility of an alternate CDF site recommended by the State of

[redacted]

accomplishing this task in an environmentally acceptable manner. Therefore,

[redacted]

Objective

[illegible] dredged material disposal requirements for approximately 200,000 cu yd of PCB-contaminated sediment for Indiana Harbor. Appropriate testing protocols (existing and being developed) were used to identify environmentally sound [illegible]

Scope

9. The diversity of disposal alternatives and techniques required for management of highly contaminated dredged material requires that detailed evaluations be made based on testing protocols developed specifically for dredged material. This report presents the results of studies and testing [illegible] provides a framework for decisionmaking to select appropriate disposal alternatives and to identify control measures required to resolve potential envi- [illegible]

[illegible]

b. Evaluation of potential disposal alternatives.

[illegible]

d. Assessment of the need for disposal restrictions.

e. Identification of available control options.

[redacted]

lem assessment were conducted. Since there was no routinely applied labora-

[redacted]

confined disposal facilities, research was conducted to develop a leaching

[redacted]

in confined disposal sites. Tests were conducted for use in designing con-

[redacted]

under consideration. Innovative disposal alternatives and management tech-

[redacted]

capping of the contaminated sediments after controlled placement in the

[redacted]

Volume I presents the detailed evaluations of dredging and dredged material

[redacted]

c. Appendix C: Results from Previous Settling and Filtering Tests.

[redacted]

[redacted]

j. Appendix J: Contained Aquatic Disposal: Site Location and Cap Material Investigations for Outer Indiana Harbor and Southern Lake Michigan.

[redacted]

[redacted]

[redacted]

[redacted]

No-action alternative

12. Obviously, one alternative is to leave the sediments in-place. However, the sediments are known to exert a long-term impact on water quality and

[redacted]

[redacted]

[redacted]

[redacted]

and maintain the Federal navigation project. This is not a "cleanup" author-

[redacted]

only proceed with a project under this authority if a local governmental

[redacted]

14. The second authority is Section 115 of the Federal Water Pollution

[redacted]

15. The third authority is under the Comprehensive Environmental

[redacted]

using the Hazardous Ranking System (HRS). If the ranking exceeds specified

[redacted]

fund cleanup on the National Priorities List. Once finalized, a site is

[redacted]

the CE, which is responsible for contracting design and construction. To date, Indiana Harbor has not been considered for listing as a Superfund site.

[illegible]

The USEPA's Final Rule for Polychlorinated Biphenyls (PCBs) [illegible]

the Federal Register (40 CFR, Part 761) on 31 May 1979. Disposal alternatives [illegible] chemical waste landfill, or a disposal method approved by the USEPA Regional Administrator.

17. A conceptual evaluation of TSCA-approved disposal alternatives was [illegible] Indiana Harbor Canal by TSCA-approved methods of incineration and chemical [illegible]

	total cost (millions)	Cost per cubic yard	frame (years)
Incineration onsite	$205-305	$1030-1540	17
Incineration offsite	$277-7352	$1385-1760	8
TSCA landfill	$ 74- 92	$ 370- 460	6-8

The above costs are in sharp contrast to the estimated costs of the proposed confined disposal facility for the bulk of contaminated sediments from Indiana Harbor and Canal. The CDF, designed to receive about 1,300,000 cu yd of [illegible] construction, dredging, operation, and maintenance. The conceptual evaluation of TSCA-approved alternatives which serves as the basis of the above cost [illegible]

18. The estimated costs of the above TSCA-approved disposal alternatives for PCB-contaminated sediments are far beyond the limits which could be

justified under the Corps' navigation maintenance authority. Alternative methods of disposal approved by the USEPA Regional Administrator appear to be the only feasible option available to the Corps under the presently available funding authority.

[illegible]

[illegible] of alternative methods to be approved by the USEPA Regional Administrator, [illegible]

[illegible] Corps to serve as a decisionmaking framework will be described in Part II and [illegible]

PART II: DISPOSAL PROBLEM DEFINITION

[redacted] presented. The magnitude and possible impacts of dredging and disposal opera- [redacted] potential solutions, and determine what controls are needed for each disposal alternative.

General

[redacted] affinity for many pollutants. Hydrophobic contaminants, such as PCBs, have an especially high affinity for sediments containing organic matter. As a result, deposited sediments have been a significant sink for pollutants discharged to waterways. [redacted]

22. Federal and state regulations of the past twenty years have sought to [redacted] [redacted] [redacted] cleanups, generally associated with spills or specific point dischargers have [redacted] maintenance dredging may represent the only means by which in-place polluted sediments can be removed.

23. Nationwide, over 300 million cu yd of sediments are dredged by the [redacted] [redacted]

Polychlorobiphenyl Chemistry and Properties

Description and nomenclature

24. Polychlorinated biphenyls (referred to collectively as PCBs) are the contaminant of most concern which are found in the Indiana Harbor sediments. PCBs consist of two benzene rings joined at two of their apices to form

[redacted]

differentiate rings (Kornreich et al. 1976). Numbering from the ring junction

[redacted]

word Aroclor followed by a four-digit number. The first two digits of the four digit identification number can be either 12, which identifies biphenyl, or a

[redacted]

which does not follow the nomenclature rules. Aroclor 1016 is similar to

[redacted]

relatively insoluble in water, with solubility tending to decrease with

[redacted]

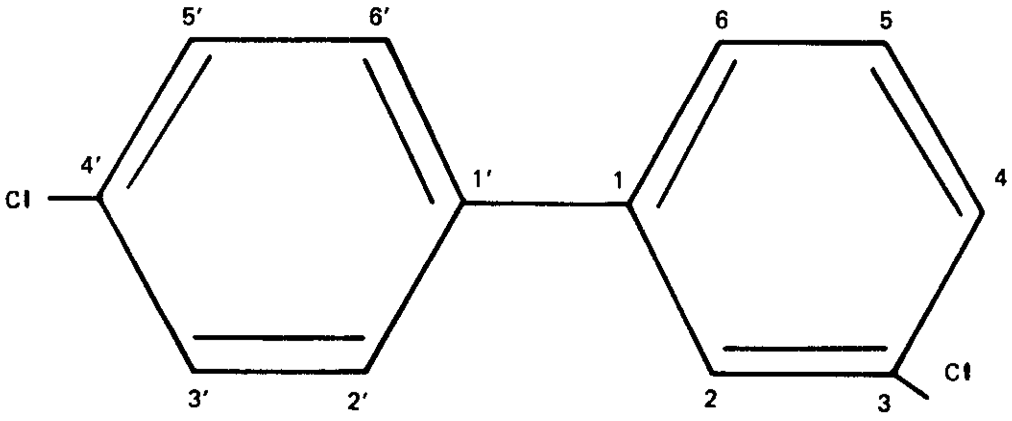


Figure 3. 3,4'-dichlorobiphenyl

[redacted]

transfer operations, also make them resistant to degradation in the environment.

Significance of Aroclors, isomer groups, and congeners

[redacted]

[redacted]

[redacted]

1975, Tucker et al. 1975, Furukawa and Matsumura 1976) have shown that the PCBs [illegible]

variations among different commercial batches of the Aroclor, differing solubility in water, and irreversible adsorption of some PCB congeners (i.e., individual chlorobiphenyl compound) in the environment. These problems are further complicated if more than one Aroclor residue is present in the environmental [illegible] sample or if the PCBs were not introduced into the environment as Aroclors.

28. In addition to the analytical difficulties [illegible]

many environmental samples, determination of a particular Aroclor or mixture of Aroclors will not yield particularly useful information. For example, calculations relying on equilibrium partitioning theory are difficult to conduct using Aroclor analysis because Aroclors are a mixture of compounds having widely differing octanol-water partitioning coefficients. Information on the potential toxicity of PCB compounds is also not provided by analysis of Aroclors because only a few of the PCB congeners constituting an Aroclor may be toxic and of concern.

29. Other means of quantifying PCB concentrations in sediments are as isomer groups (by number of chlorine atoms) or as [illegible] quantitation of PCBs has been used at the US Army Engineer Waterways Experiment Station (WES) in lieu of Aroclor analysis. This method of analysis avoids many of the difficulties inherent in Aroclor analysis [illegible] group analyses has not proved to be substantially more useful than that obtained from Aroclor analysis. Congener analysis appears to be the method- [illegible]

promulgated Method 680 for determination of PCB congeners in water and sediment [illegible]

30. [illegible] sediments of any water body must be viewed as the largest sink-source for PCBs. Other workers (Steen, Paris, and Baughman 1978; Hiraizumi, Takahashi, and Nishimura 1979) have demonstrated that particle-size distribution and total [illegible] (1983) later showed that the extent of solute insolubility in water is the primary factor affecting the partitioning of nonionic organic compounds, such as PCBs, onto soil organic matter.

31. There has not been as much work conducted on desorption of PCBs as on [illegible]

organic carbon normalized adsorption partition coefficient. Adsorption and [redacted] laboratory studies.

Application of Management Strategy for Contaminant Testing and Controls

[redacted] or potentially contaminated dredged material is required. The CE has recently [redacted] determining what contaminant control measures are appropriate. This strategy [redacted] taminated sediments (Kelly 1985). This strategy was applied in evaluating [redacted] purposes of simplicity, they are herein referred to as the Management Strategy [redacted]

[redacted] selecting alternatives for the disposal of dredged material with any level of contamination. The Management Strategy is based on findings of research conducted by the CE, USEPA, and others over the past 15 years and on experience in [redacted] manage specific problems associated with the presence or mobility of contami- [illegible]

[illegible]

impacts. Technical feasibility, economics, and other socioeconomic factors [illegible]

[illegible]

steps for managing dredged material disposal consist of the following:

a. Evaluate contamination potential.

b. Consider potential disposal alternatives.

c. Identify potential problems.

d. Apply appropriate testing protocols.

e. Assess the need for disposal restrictions.

f. Select an implementation plan.

g. Identify available control options.

h. [illegible]

These steps are graphically presented in Figure 4.

36. The first step in the application of the Management Strategy is an initial evaluation of whether or not there is reason to believe the sediments [illegible]

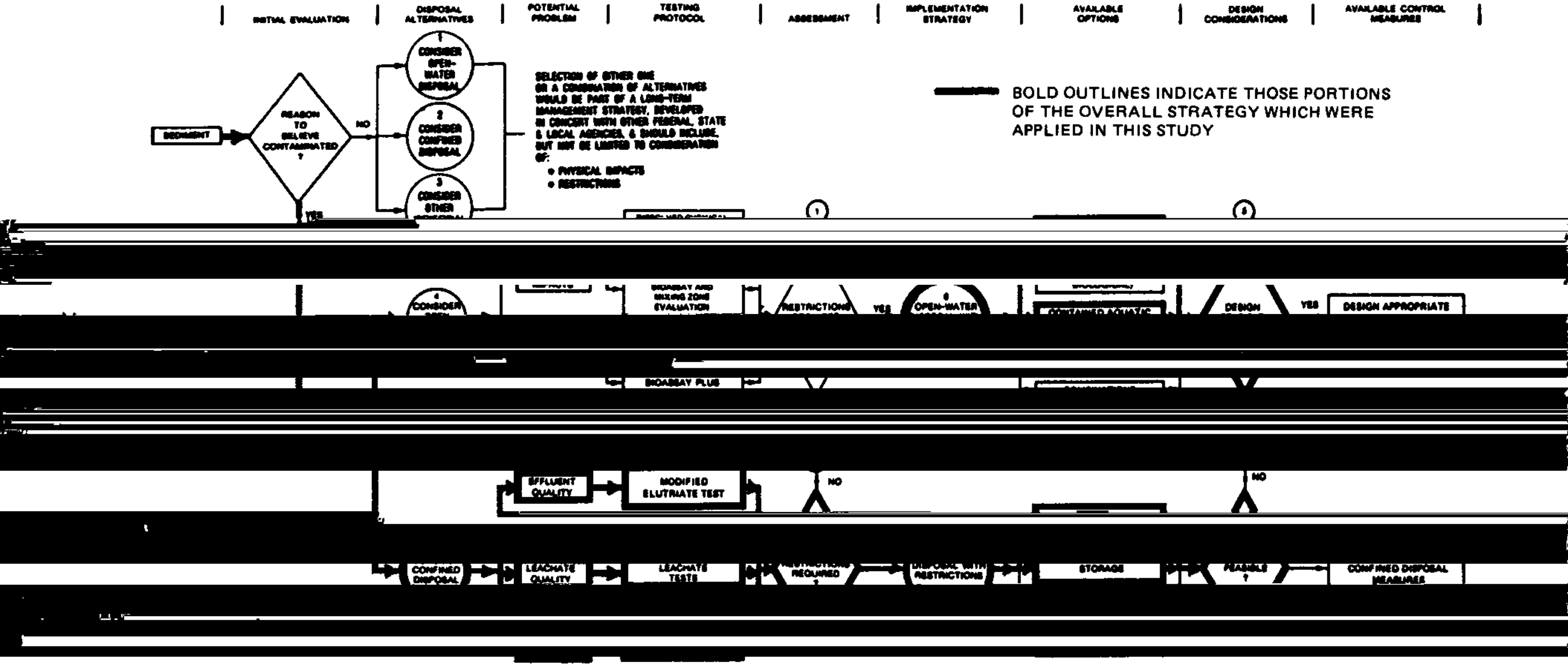


Figure 4. Management strategy flowchart

[redacted]

not performed. This leaves two general disposal alternatives available; open-water disposal with restrictions, and confined disposal. Three specific alternatives for the disposal of PCB-contaminated sediments from Indiana Harbor were considered in detail:

a. Contained aquatic disposal (CAD).

b. Confined disposal in an in-water facility.

c. Confined disposal in an upland facility.

[redacted]

these testing procedures are standardized and have been used widely for evalu-

[redacted]

protocols used in assessing the disposal alternatives. In Part III, testing protocols developed as part of this research study are described and results with Indiana Harbor sediments presented.

Criteria for Selection of Controls

[redacted] state or Federal regulatory criteria to determine where control measures [redacted] discharge of dredged material to navigable waters is regulated under Section 404 of the Clean Water Act (CWA). For disposal of maintenance dredgings, the Corps of Engineers will seek approval from the appropriate state reg- [redacted] posal facility to navigable waters. For the disposal of dredged material from [redacted] responsible for issuance of certification under Section 401.

[redacted] River. Results from effluent and runoff tests were compared with these Indiana [redacted] cussion of appropriate contaminant control measures for the disposal alter- [redacted] agreed upon by the concerned regulatory agencies. [redacted]

Table 1

Summary of Water Quality Standards

	Drinking Water	USEPA Maximum	Indiana Harbor	Lake Michigan
Cadmium	0.01	0.0015-0.0024	-	0.010
Chromium	0.05	2.2-9.9	-	0.050
Copper	1.0	0.012-0.043	-	-
Lead	0.05	0.074-0.400	-	0.050
Mercury	0.002	0.0017	0.0005	0.00005
Nickel	-	1.1-3.1	-	-
Zinc	5.0	0.18-0.57	-	-
Iron	0.3	-	0.300	0.150
Manganese	0.05	-	-	-
Total phosphorus	-	-	0.1	0.03
NH3-N	-	-	1.5	-
PCB-1248	-	0.014	0.000001	0.000001
Phenol	-	-	0.01	0.001
Dissolved solids	-	-	500	172

Sediment Collection and Preparation

Sediment collection

[redacted]

indicated the sediments had very high PCB concentrations (>50 ppm). An additional site in Lake Michigan was selected for collection of an uncontaminated [redacted]

collected from the uncontaminated site. The drums were new and had been steam- [redacted]

42. The sediments were mixed at WES. Each drum (from the PCB- [redacted]

ment poured into a previously washed and cleaned concrete mixer. When the last of the drums had been poured into the mixer, the sediment was mixed for 30 min [redacted]

were also removed from the truck and given to the appropriate investigator.

[redacted]

[redacted]

specific gravity. The grain-size distribution is shown in Figure 5. Approxi-

[redacted]

respectively. The specific gravity was 2.71. The Unified Soil Classification

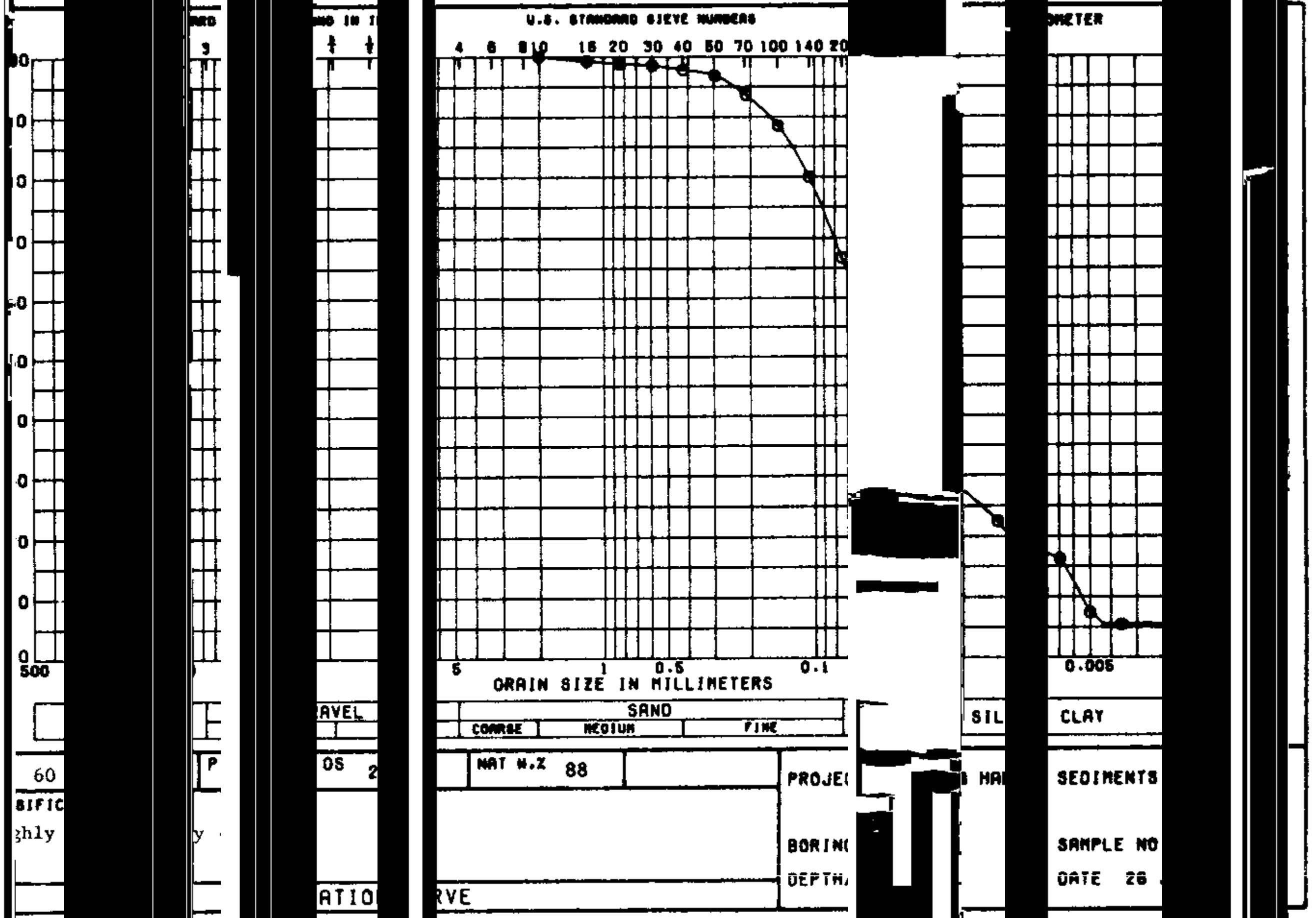
[redacted]

sample previously taken from nearby channel area in 1979 (Environmental Laboratory (EL) 1979).

Chemical characterization

44. Separate determinations of bulk sediment chemistry of the Indiana

[redacted]



5 in s distribution for Indiana sed ent

Table 2

[redacted]

	Concentration in Sediment, mg/kg dry weight	
[redacted]	[redacted]	[redacted]
Cadmium	20.0	0.1
Chromium	650.0	4.4
Lead	879.0	11.9
Mercury	0.5	BD*
Zinc	4,125.0	54.1
Pesticides		
Aldrin	2.55	0.0006
Polyaromatic hydrocarbons		
Acenaphthene	96	BD
Acenaphthylene	22	BD
Anthracene	62	BD
Benzo(a)anthracene	86	BD
Benzo(b)fluoranthene	140	BD
[redacted]	[redacted]	[redacted]
Indeno(1,2,3-c d)pyrene	50	BD
Naphthalene	2,000	0.46
Phenanthrene	200	BD
[redacted]	[redacted]	[redacted]
Total organic carbon	7.59% of sediment weight	1.83% of sediment weight
[redacted]	[redacted]	[redacted]
Oil and grease	3.88% of sediment weight	1.71% of sediment weight
[redacted]	[redacted]	[redacted]

* BD = below detection.

[redacted]

the Lake Michigan material. The remaining PAH compounds found in Indiana Harbor sediment were not detected in Lake Michigan sediment.

46. Sediment from Indiana Harbor was found to contain PCB-1248, which was not detected in Lake Michigan sediment (Table 2). By contrast, Lake Michigan sediment contained a trace amount of PCB-1254, a compound not found in the material from Indiana Harbor. Indiana Harbor sediment also contained substan- [redacted] phenol (Table 2); these were either not present or present in much smaller [redacted]

Water Quality Evaluations

47. Water quality evaluations were conducted for the upland and in-lake CDF alternatives. These included evaluations of effluent (water discharged [redacted] groundwater).

[redacted]

[redacted]

fined disposal sites that influence contaminant release. A modified elutriate

[redacted]

dicted contaminant concentrations with applicable water quality criteria while considering an appropriate mixing zone.

50. Results. The prediction of the effluent requires interpretation and

[redacted]

settling test results, and design information. Based on results of the mod-

[redacted]

dredge using a matchbox type dredgehead, and mechanical placement. For upland disposal, effluent quality following suspended solids (SS) removal is considered equal to dissolved concentrations as determined by the modified elutriate test. Additional contaminant removals could be achieved by other processes such as carbon adsorption. The results for parameters above

[redacted]

following filtration contains 0.5 mg/ℓ suspended solids, and the concentration

[redacted]

depending on the sequencing of the disposal projects, the volume of water

[redacted]

culating the effluent quality.

[redacted]

alternative are about twice as large as by the watchbox dredge alternative and

[redacted]

adsorption is also expected since it is also hydrophobic.

Table 3

[redacted]

	Modified Elutriate	In-Lake CDF Hydraulic	 Matchbox	 Mechanical
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cadmium	0.0023 ± 0.0005 ppm	0.0080	0.0015	0.00005
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Lead	0.064 ± 0.031 ppm	0.224	0.041	0.052
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Aldrin	0.00011 ± 0.00003 ppm	0.00039	0.00007	0.000002
Heptachlor epoxide	0.00004 ± 0.00006 ppm	0.00014	0.00003	<0.000001
PCB-1248	0.0034 ± 0.0017 ppm	0.0238	0.0051	<0.00001
Total organic	44.5 ± 3.7 ppm	156	28.6	1.
carbon	0.037 ± 0.004 ppm	0.130	0.024	0.0008
Phenol	-	0.5	0.5	0.5
Suspended Solids	-	347,000	1,070,000	260,000
Discharge volume		cu yd	cu yd	cu yd

---

* Assuming that the water in the CDF has no contaminants prior to disposal, that the water available for dilution is the volume for initial storage for the new lift of material plus the ponded volume for a 1-ft ponding depth, [redacted]

[redacted]

sibly total organic carbon for the matchbox dredging alternative barely exceed the water quality standards without considering a mixing zone. Detailed

[redacted]

Surface runoff quality

[redacted]

rial (Lee and Skogerboe 1983). This test protocol involves taking a sediment sample from a waterway and placing it in a soil-bed lysimeter. At intervals during the drying process, rainfall events are applied to the lysimeter, and

[redacted]

[redacted]

would still be of concern when compared with the USEPA Maximum Criteria for the

[redacted]

decrease significantly. Results of the lysimeter tests represented the worst possible case that would occur during the wet, anaerobic stage. Control mea-

[redacted]

sures during this period should concentrate on control of the SS in the surface

[redacted]

site. If an appropriate mixing zone does not exist, control measures such as the use of sedimentation basins, control structures, filters, or chemical floc-

[redacted]

57. After the sediment dried and oxidized, the surface runoff water quality constituents of concern changed. Organic compounds were present in low

[redacted]

extent of the other metals. Filtered concentrations of cadmium, copper, zinc, and lead were high enough to be of concern as they were greater than or equal to the USEPA criteria. As the sediment continues to age, hard aggregate chunks [redacted] of filtered and unfiltered metals should increase by similar amounts. There- [redacted]

[redacted] Part III and in Appendix E. A testing program aimed at developing a simplified screening test for surface runoff was conducted as a part of the research [redacted] effort described in Part III.

Leachate quality

58. Procedures. Subsurface drainage from confined disposal sites in an [redacted]

[redacted]

[redacted]

59. An appropriate leachate quality testing protocol was needed to pre- [redacted] leachate quality from dredged material disposal sites. Therefore, an evalua- [redacted]

leaching test protocol for confined dredged material. These evaluations were [redacted]

release characteristics of dredged material. Probably the most important [redacted]

[redacted]

60. The leach tests showed the majority of the contaminants in Indiana Harbor sediment to be tightly bound to sediment particles. The results showed [redacted]

[redacted]

Engineering Evaluations

[redacted]

These tests included settling and consolidation tests for the homogenized [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

zone settling instead of flocculent settling. Under this condition, the loadings for hydraulic transfer and hydraulic dredging would be about 250 and 400 mg/ℓ, respectively. Results are presented in Appendix A.

Consolidation tests

64. Consolidation tests were required to define the consolidation prop-

[redacted]

[redacted]

[redacted]

Biological Evaluations

[redacted]

was turned daily to facilitate drying. The air-drying process was conducted

[redacted]

sediment was subsequently ground to pass a 2-mm screen. Samples of air-dried

[redacted]

drilled in the bottom of the inner container, and a polyurethane sponge overlaid with a layer of washed quartz sand was placed on the sponge. The sand and sponge acted as a filter to keep the sediment from draining out the bottom of

[redacted]

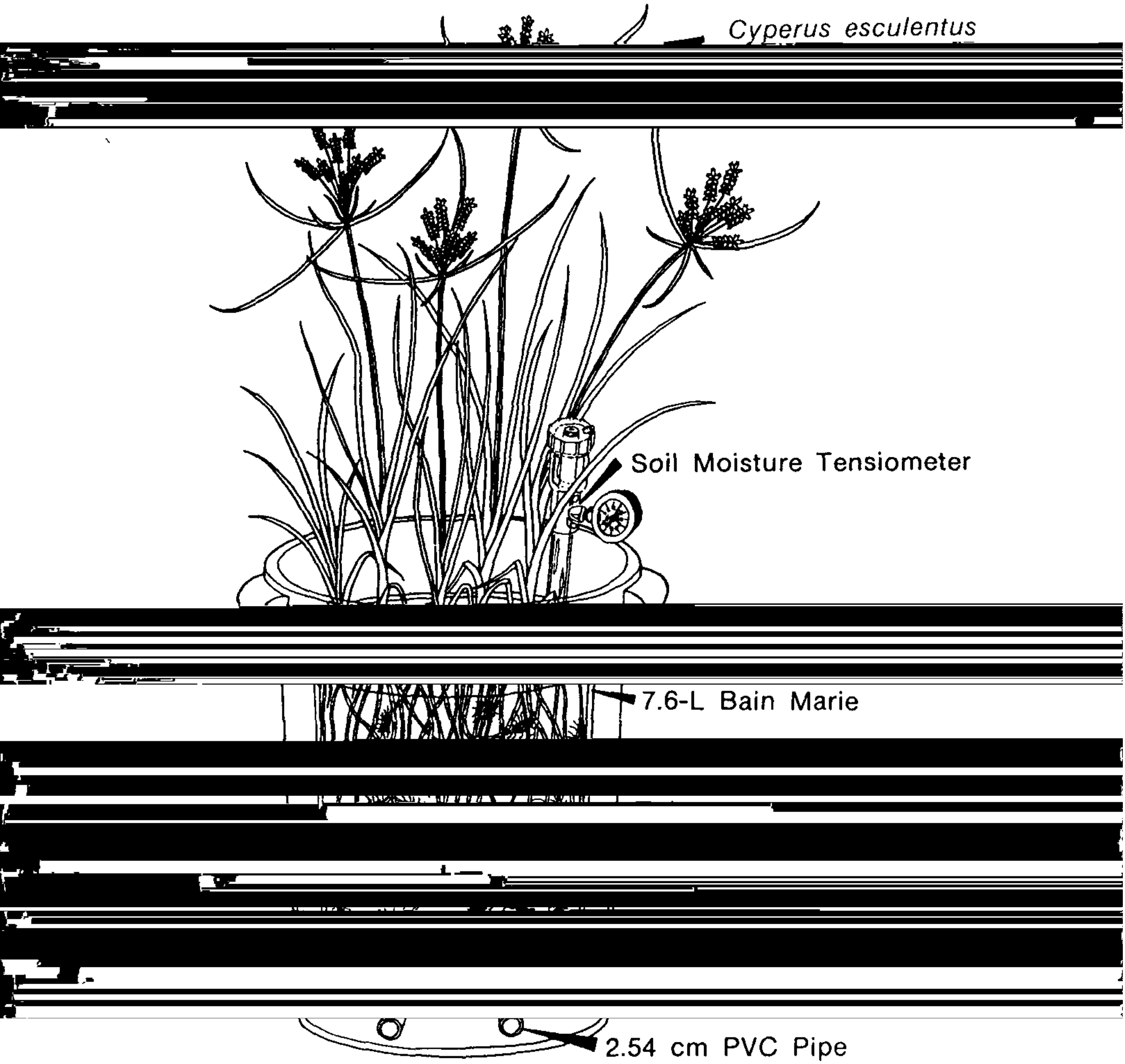


Figure 6. Plant bioassay experimental unit.

67. After the sediment has been placed into the container, a soil-

[redacted]

between 0.03-0.05 Megapascal (MPa) (a reading between 30 and 50 percent on the

[redacted]

the flooded treatment by addition of water as needed.

[redacted]

[redacted]

[redacted]

[redacted]

69. Plants in the upland EU were watered when the reading on the tensiometer was greater than 0.05. The tensiometers were monitored daily; all upland EU were maintained between 0.03 and 0.05 MPa. Temperature of the green-

[redacted]

[redacted]

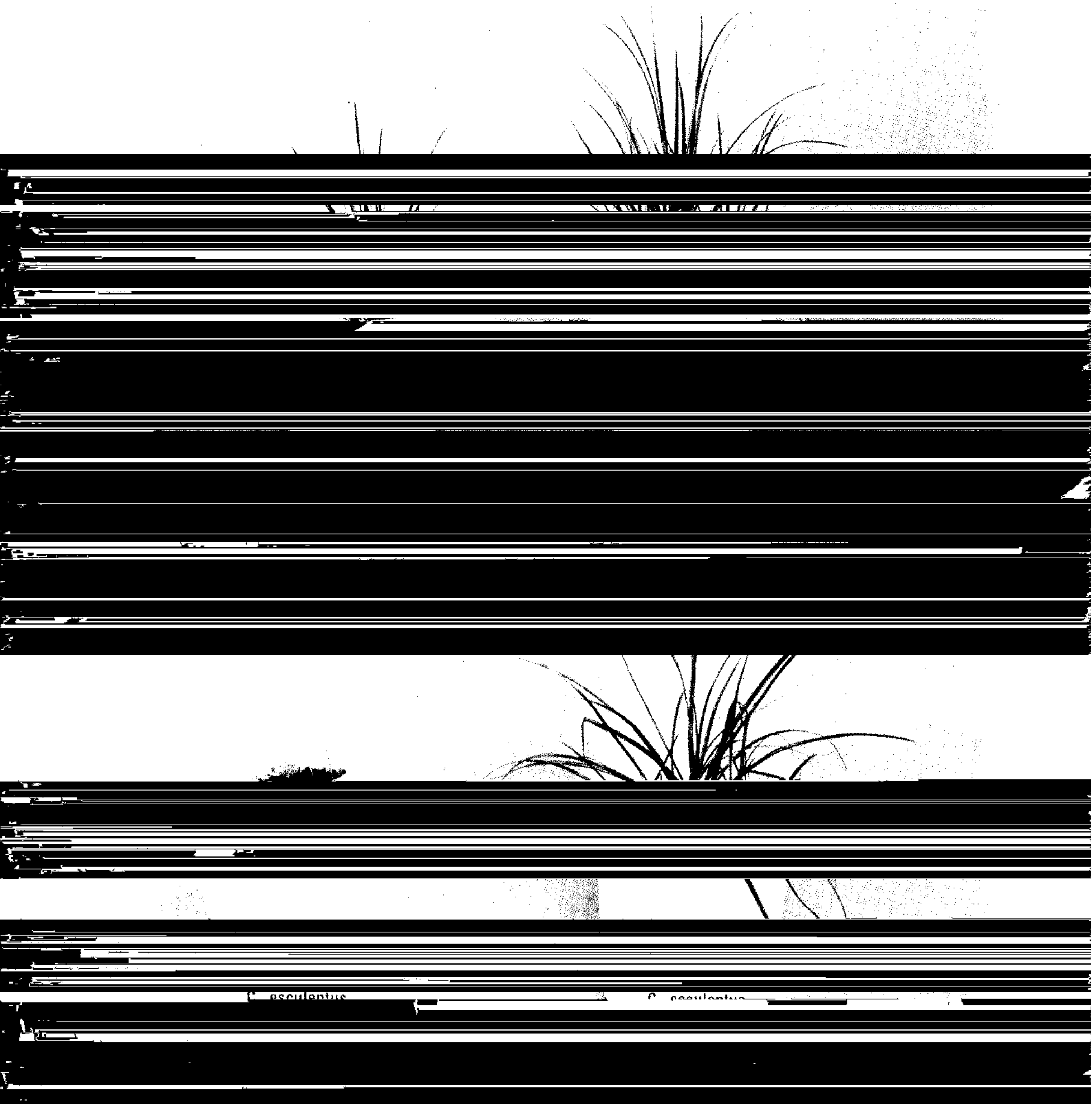


Figure 7. Plant growth of *Cyperus esculentus* on sediments

[redacted] (this tissue was to be used for heavy metal analysis) was placed into a paper [redacted] repeated for each EU.

70. The upland EUs did not have sufficient plant growth in each [redacted] a composite sample was made by combining the plant tissue from all four [redacted] analyzed for pH, lime requirement, particle size, cation exchange capacity, and [redacted] plant tissues and sediments were analyzed for the metals zinc, cadmium, copper, iron, manganese, arsenic, mercury, nickel, chromium, and lead. Plant tissue [redacted]

[redacted] the sediment analysis also indicated a fairly high electrical conductivity, potentially low available nitrogen and phosphorus, and very low concentrations [redacted] flooded sediments resulted in reduced levels of organic matter and several of the PAH compounds. Volatile organics, such as napthalene, acenaphthalene, and acenaphthene showed over a 50 percent loss by air drying.

72. Plant growth (Figure 7) on the flooded sediments was greater than [redacted]

[redacted]

should be cause for concern if the sediments were allowed to drain and dry out

[redacted]

74. Procedures. An earthworm bioassay test was conducted on Indiana

[redacted]

extremely toxic to earthworms. Various treatments were conducted on the

[redacted]

results are described in Appendix D.

75. Results. The 6-month aging process resulted in substantial changes in the concentrations of organic compounds present in the original Indiana Harbor sediment but had relatively little effect on the metals. The concen-

[redacted]

[redacted]

lyzed dropped an entire order of magnitude, largely as the result of the loss of naphthalene.

[redacted]

der and were not balled up in a state of inactivity within the cracks and air

[redacted]

increased significantly in earthworm tissues during the 28-day exposure

[redacted]

tration factors (ratios of metal concentrations in bioassay worms to those in

[redacted]

[redacted]

heptachlorinated biphenyl congener. Bioaccumulation was marginally significant (p > F = 0.0754) in one additional tetrachlorinated congener. Other congeners

[redacted]

limits in the worms, except chrysene, which also showed marginally significant (p > F = 0.0701) bioaccumulation. All PAHs which bioaccumulated significantly

[redacted]

80. Very little is known about bioaccumulation and effects of chemicals

[redacted]

the Indiana Harbor sediment apparently was the result of high concentrations of

[redacted]

cantly to the observed worm mortality, as the concentrations of metals in both the sediments and earthworms were generally below the levels demonstrated to be toxic or to inhibit growth and reproduction of earthworms (Migula et al. 1977;

[redacted]

reported to reduce reproduction by earthworms (Neuhauser et al. 1984). The presence of substantial concentrations of copper and zinc in the earthworms

[redacted]

literature indicates that metals, PCBs, and some PAHs are bioaccumulated from sediments by earthworms (Marquenie and Simmers 1984; Simmers, Lee, and Marquenie 1984; Simmers, Wilhelm, and Rhett 1984; Marquenie, Simmers, and Kay, in preparation).

[redacted] material would be the potential for acute toxicity to soil invertebrates due to [redacted] activity, and photodegradation. Following the loss of the more labile organic compounds, the sediments possibly would be colonized by earthworms and other [redacted] soil-dwelling invertebrates. Bioaccumulation of metals and the less labile [redacted]

82. The results from the 6-month aging of the Indiana Harbor sediment [redacted] York (Marquenie, Simmers, and Kay, in preparation), as well as elsewhere in the [redacted] mulation as the site became biologically productive.

Summary

83. The Indiana Harbor sediments are contaminated with PCBs, an organic contaminant which is highly insoluble in water and tends to be closely bound to sediment particles. The problems associated with dredging and disposal of the

PCB-contaminated sediments were evaluated using a Management Strategy which incorporates testing protocols designed especially for dredged material. [redacted] rated in the evaluation of disposal alternatives presented in Part IV.

PART III: APPLICATION OF RESEARCH TECHNOLOGY

84. The processes involved with release or immobilization of most sediment-associated contaminants are regulated to a large extent by the physicochemical nature of the disposal environment and the related biological activity associated with the dredged material at the disposal site. Where the [redacted] [redacted] release.

[redacted] data for decisionmaking in the selection of appropriate disposal alternatives and identify control measures, evaluations of leachate and surface runoff water quality were conducted. In addition, dredged material treatment alternatives in conjunction with confined disposal were evaluated. [redacted] [redacted]

[redacted]

sediments from Indiana Harbor.

b. A total application of the Management Strategy for a specific case.

[redacted]

leachate and surface runoff evaluations.

The results of this dredged material research are summarized in Part III, and the control measures for each disposal alternative discussed in Part IV.

[redacted]

Background

[redacted]

[redacted]

than necessary, resulting in greatly increased costs.

87. Confined disposal is one option for Indiana Harbor dredged material. However, when contaminated dredged material is placed in a CDF, the potential

[redacted]

capable of predicting, or even approximating, leachate quality from confined

[redacted]

[redacted]

[redacted]

Objective and approach

[redacted]

tests considered appropriate for the prediction of both short- and long-term leachate quality were conducted. These laboratory evaluations included

[redacted]

[redacted]

[redacted]

current application of the laboratory procedures and the mass transport equations to a specific sediment.

Results

90. A thorough analysis of the data from all the tests conducted in this

[redacted]

questions regarding the pollutant potential of Indiana Harbor sediment via leaching. Only the highlights are discussed. For a more detailed analysis of the data and an evaluation of the testing protocol, the reader is referred to Appendix G.

91. Batch testing. The intrinsic release characteristics of Indiana Harbor sediment for arsenic, cadmium, chromium, lead, zinc, PAHs, and PCBs

[redacted]

dation status of the sediment.

[redacted]

because of the oil content in the sediment. During batch testing, this oil

[redacted]

fugation. The lower the liquid-solids ratio, the more centrifugation was required to break the emulsion. For example, nine centrifugations were required to completely remove oil from the anaerobic interstitial water sample

[redacted]

93. Desorption isotherms were developed using data from the sequential batch leaching tests. The sequential batch leaching tests involved exposing

[redacted]

[redacted]

been exposed to air for 6 months. From the desorption isotherms, the leach-

[redacted]

a. Category I. q_L is very small, i.e., $q_L < 1\%$ of the bulk sediment concentration, and $1 < K_d < 10$ (ℓ/kg).

[redacted]

centration is so small that a distribution coefficient is difficult to measure.

[redacted]

the leachate concentrations were near or below the detection limits. Cate-

[redacted]

Table 4

[illegible]

Sediment for Metals and Organic Contaminant

[illegible] contaminants. Add sufficient water to each tube to bring final water-to-sediment ratio to 4:1. Sufficient stainless steel tubes must be loaded to obtain enough leachate for [illegible]

STEP 2 Shake mixtures horizontally at 160 cycles per minute for 24 hr.

STEP 3 Centrifuge for 30 min at 6500 X g for organics and 9000 X g for metals. Prior to filtering, centrifuged leachate is passed through acid-washed glass wool for metals and acetone-washed glass wool for organics. Samples for organic analysis [illegible]

STEP 4 [illegible]

STEP 5 Set aside a small amount of leachate for analysis of pH and conductivity, then acidify leachate for organic analysis with [illegible] bottles and leachate for metals analysis in plastic bottles.

[illegible]

[redacted]

[redacted]

not change appreciably following exposure to unleached anaerobic sediment. Exposure of leachate from aerobic sediment to unleached anaerobic sediment resulted in marginally higher distribution coefficients for arsenic, chromium, [redacted]

[redacted]

[redacted]

96. A permeant-porous media equation was used to predict permeameter leachate quality as a function of volume throughput. The source term in the [redacted]

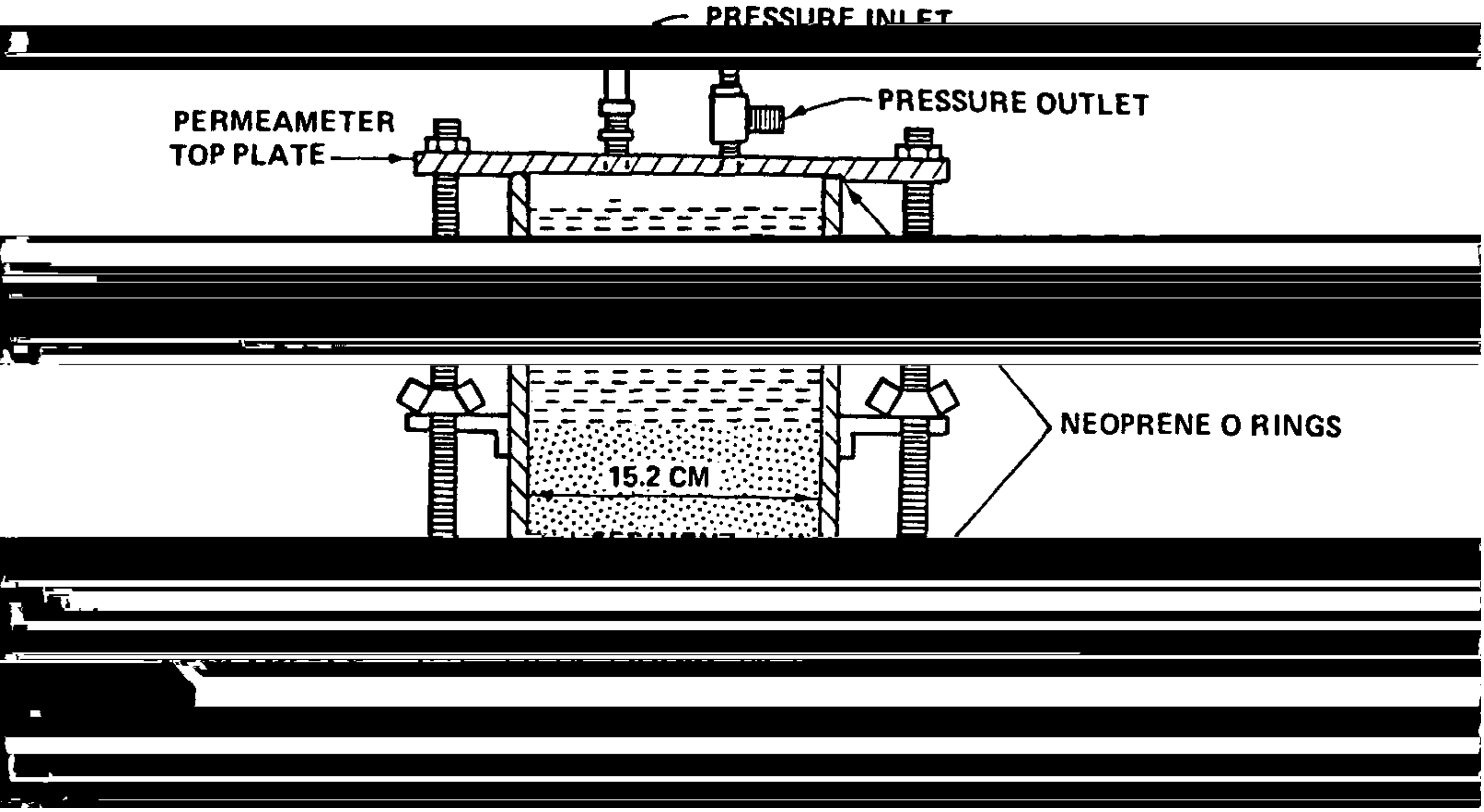


Figure 8. Divided-flow permeameter

material solids to the leachate was modeled as equilibrium-controlled, linear desorption. Details of this approach are presented in Appendix G.

97. Figure 9 shows arsenic and cadmium concentrations in leachate from [redacted]

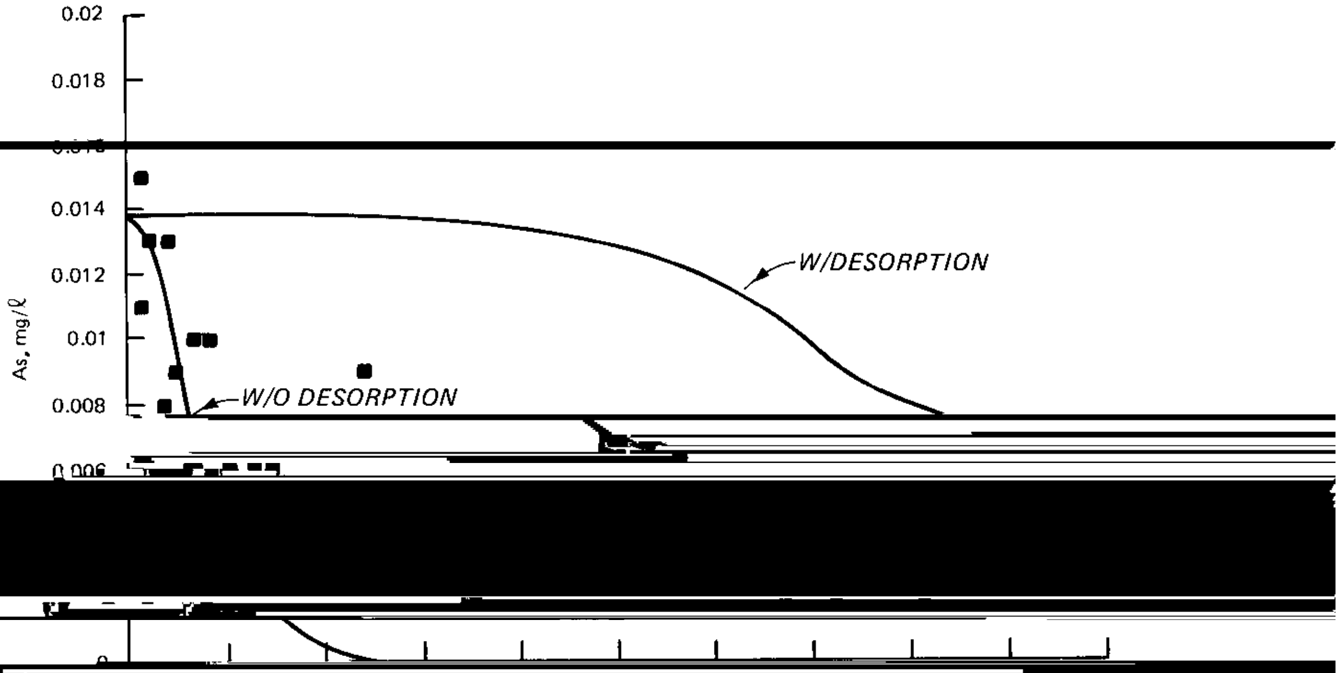
batch coefficients.

98. The results presented in Figure 9 are representative of the observed and predicted anaerobic permeameter leachate concentrations for the other con- [redacted]

These data are too close to the detection limit to be considered significant. [redacted]

chromium most of the observed values are just above the detection limit and below those predicted. The dissolved organic carbon values also indicate that [redacted]

for compare leerobic below.



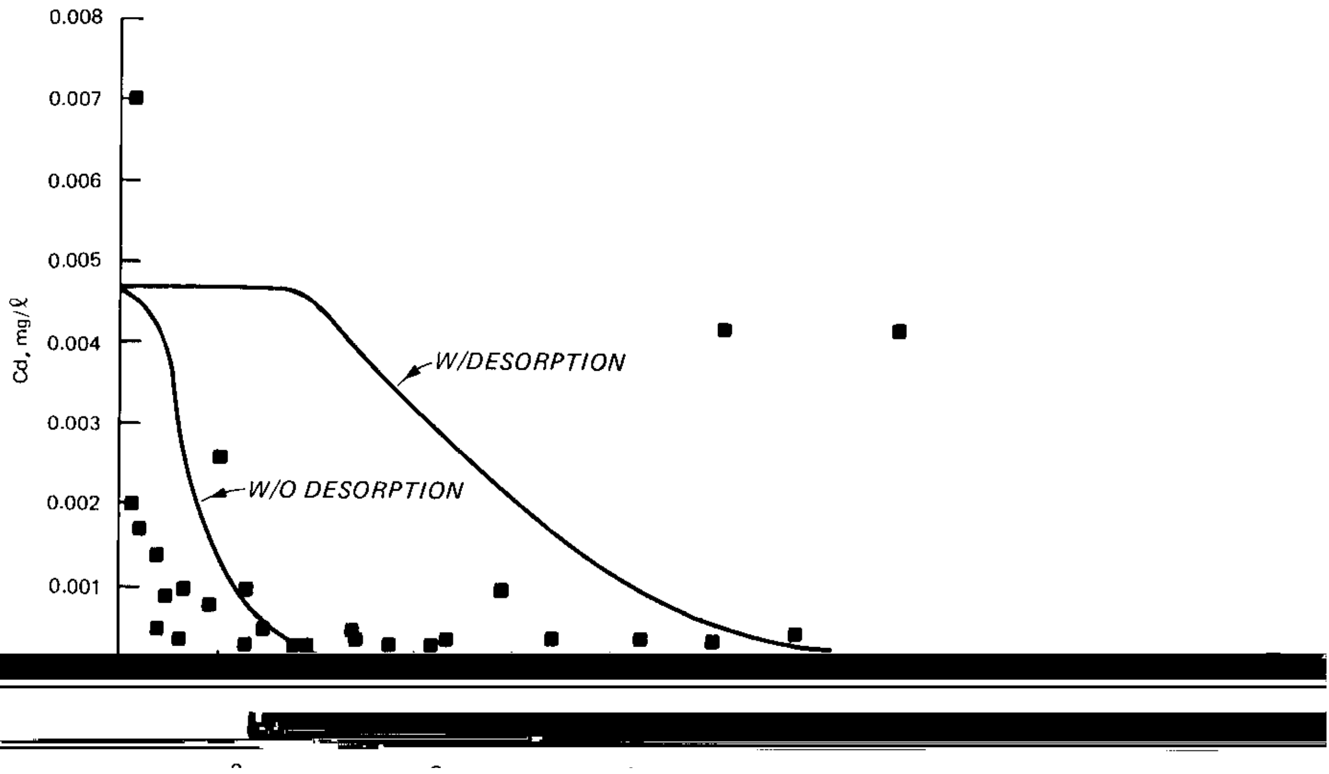


Figure 9. Comparison of arsenic and cadmium concentrations in anaerobic permeameter leachate with predicted values

100. PAHs in the permeameter effluent for anaerobic sediment were below the detection limit (0.005 mg/ℓ) in practically all of the samples analyzed. PCBs were usually below the detection limit (0.00001 mg/ℓ), but not always. Trace amounts of PCB congeners were usually present. The sequential batch [illegible] phase. When the distribution coefficient determined in the batch tests is [illegible] initially take on some very low concentration and then to persist at this value. The PCB curve was somewhat nonideal in that a tendency for concentrations to decrease or wash out was observed.

101. The effluent curves from the aerobic permeameters were not compared [illegible] the effluent curves from a partially oxidized sediment that has gone anaerobic. [illegible] "aerobic" permeameters simulate. When compared with the effluent concentra- [illegible] carbon were consistently higher in the leachate from the aerobic permeameters.

Summary

102. [illegible] Predicted and observed permeameter effluent concentrations for anaerobic metals were reasonably close (within an order of magnitude). The batch and

permeameter data showed that linear, equilibrium controlled desorption is a conservative assumption for anaerobic sediment. The fraction of metals resis- [illegible] leaching was generally greater than 99 percent for both anaerobic and [illegible] the PAHS and most of the PCB congeners. A summary of probable maximum leachate contaminant concentrations is presented in Table 5.

Surface Runoff Evaluations

Background

103. Dredged material removed from [illegible] may contain high concentrations of contaminants such as heavy metals, PCBs, PAHs, and pesticides. [illegible] tities of these contaminants may be discharged from the site through surface [illegible]

[illegible] Most contaminants are tied up in the sediment solids [illegible]

Table 5

Summary of Probable Maximum Leachate Contaminant Concentrations for Indiana Harbor Sediment

Contaminant	Concentration (mg/ℓ)	
	Anaerobic	Aerobic
Arsenic	0.034	0.016
Cadmium	0.009	0.0995
Chromium	0.195	0.013
Lead	0.370	0.055
[redacted]	[redacted]	[redacted]
Total PAH	1.82	0.0674

Erosion can result in suspended solids concentrations ranging from 5,000 to 50,000 mg/ℓ [illegible] runoff could be very high during this period, but dissolved concentrations in filtered runoff may be very low.

104. When material is placed in a confined upland disposal site, physicochemical changes occur as the wet, anaerobic material dries and oxidizes. The extent to which these changes occur may significantly affect the surface runoff water quality, particularly the dissolved portion. As the sediment dries and oxidizes, it becomes more resistant to erosion, with suspended solids decreasing to 10 to 1,000 mg/ℓ. Unfiltered concentrations of contaminants will be several orders of magnitude less than during the wet stage. If high [illegible] formation of sulfuric acid lowering the sediment pH to 4.0 where contaminants [illegible]

[illegible] rainfall. Calibration tests showed the WES Rainfall Simulator to be extremely effective at simulating the kinetic energy (95 percent) of natural rain over a standard plot area of 5.5 sq m (4.6 m X 1.2 m). The soil lysimeters used in the WES Rainfall Simulator [illegible] in increments of 15 cm to a total depth of 1.2 m. The lysimeter slope could [illegible] initiated immediately after placing the dredged material in the greenhouse lysimeters using a 5 cm/hr, 30 min storm event. A second series of surface [illegible]

Table 6

Lysimeter Surface Runoff Water Quality During Early, Wet, Unoxidized Stage

Parameter	Mean Unfil. Runoff Conc. mg/ℓ	Mean Filt. Runoff Conc. mg/ℓ	USEPA Maximum Criteria
pH	7.64	7.66	NA*
[redacted]	[redacted]	[redacted]	[redacted]
SS	6,600	NA	NA
DDE	<0.00001	0.00004	NA
PCB-1248	0.096	0.0015	0.014
PAHs	18.03	0.148	NA
Naphthalene	6.91	0.115	NA
Acenaphthylene	0.212	<0.005	NA
[redacted]	[redacted]	[redacted]	[redacted]
Phenanthrene	1.67	0.0097	NA
[redacted]	[redacted]	[redacted]	[redacted]
Chrysene	0.853	<0.005	NA
[redacted]	[redacted]	[redacted]	[redacted]
anthracene			
Benzo(G H) perylen	0.124	<0.005	NA
Heavy Metals			
Cadmium	0.134	0.0021+	0.0015-0.0024
Copper	1.79	0.0237+	0.012-0.043
Nickel	0.707	0.0297	1.1-3.1
Zinc	30.9	0.360 +	0.180-0.570
Manganese	9.04	0.0170	NA
Chromium	4.06	0.0567	2.2-9.9
Lead	6.80	0.0670	0.074-0.400
Iron	627	1.39	NA
Mercury	0.0037	<0.0002	0.0017
Arsenic	0.232	<0.005	0.440

[redacted]

Protection of Aquatic Life.

[redacted]

Table 7

Lysimeter Surface Runoff Water Quality During Dry, Oxidized Stage

Parameter	Mean Unfil. Runoff Conc. mg/ℓ	Mean Filt. Runoff Conc. mg/ℓ	USEPA Maximum Criteria
pH	6.3	6.3	NA*
Conductivity Sm	4.9	NA	NA
SS	56	NA	NA
[redacted]	[redacted]	[redacted]	[redacted]
PAH			
[redacted]	[redacted]	[redacted]	[redacted]
Fluorene	<0.005	<0.005	N
Phenanthrene	0.0069 A	0.0056 A	N
Anthracene	<0.005	<0.005	N
Fluoranthene	0.0067	<0.005	N
Pyrene	0.0061	<0.005	N
Chrysene	<0.005	<0.005	N
Benzo (a)	<0.005	<0.005	N
[redacted]	[redacted]	[redacted]	[redacted]
Indeno-1,2,3,_C D pyrene	<0.005	<0.005	N
Benzo (g h i) perylene	<0.005	<0.005	N
Heavy metals			
Cadmium	0.0011	0.0026 **,+	0.0015-0.0024
[redacted]	[redacted]	[redacted]	[redacted]
Nickel	0.038	0.046 **	1.1-3.1
Zinc	0.34	0.53 **,+	0.180-0.570
Manganese	0.28	0.40 **	NA
Lead	0.032	0.008 **	0.74-0.400
Iron	5.74	0.041	NA
Mercury	<0.0002	<0.0002	0.0017
Arsenic	<0.005	<0.005	0.440

[redacted]

** Filtered concentrations are not statistically significantly different from unfiltered concentrations.

[redacted]

[redacted] soluble.

Potential problems

114. Wet, unoxidized sediment. Filtered runoff concentrations were com- [redacted] Filtered concentrations of PCBs were below USEPA criteria; however, several [redacted] teria, however, none of the contaminants were significantly greater. Any dilution of discharged runoff from the disposal site will reduce soluble concentrations of contaminants to below the USEPA criteria. Surface runoff water from Indiana Harbor dredged material was also compared to the Lake Michigan [redacted] Indiana Harbor dredged material during the wet, anaerobic stage and therefore [redacted]

115. Contaminants in surface runoff water were present in poorly soluble [redacted] exist. The USEPA Criteria for the Protection of Aquatic Life and the Lake [redacted]

concentrations of PCBs, cadmium, copper, zinc, manganese, chromium, lead, [redacted] investigated.

116. Dry, oxidized sediment. Filtered concentrations in surface runoff [redacted] zinc and manganese from the dry, oxidized dredged material.

[redacted] Harbor sediment in the dry, oxidized stage, while the sediment was hard and cracked into large blocks. With time these hard blocks could be weathered and [redacted] if they became vegetated. Dense vegetation is commonplace on dried dredged materials, and usually has to be controlled rather than promoted. Additional

[redacted]

priate mixing zone should be considered prior to the implementation of surface

[redacted]

ment of surface runoff should be investigated.

Laboratory tests as an alternative to the rainfall simulator-lysimeter tests

[redacted]

hydrogen peroxide procedure will greatly improve its accuracy and reliability. Additional verification on several different types of dredged material is

[redacted]

predicting surface runoff water quality from contaminated dredged material. These verification tests should include both freshwater and estuarine dredged material as well as dredged material with a wide range of particle size distributions and organic matter contents.

Summary

119. During the early, wet, anaerobic stages, contaminants were mostly bound to the SS in the surface runoff and occurred mostly in the unfiltered samples. Filtered concentrations during this period were low compared to the unfiltered concentrations, but would still be of concern when compared to the [redacted] decreased, thereby decreasing the unfiltered contaminant concentrations. [redacted] appropriate mixing zone does not exist, control measures such as the use of sedimentation basins, control structures, filters, or chemical flocculants should be considered.

120. After the sediment dried and oxidized, the surface runoff water [redacted] during this stage since most of the compounds had been lost from the sediment due to volatilization into the atmosphere or adsorption to soil particles. Some naphthalene was present in both the filtered and unfiltered samples, but the total PAHs were very low. No PCBs were detectable in runoff from the dry [redacted]

[redacted]

treatment.

Contaminant Immobilization Research

Background

[redacted]

to satisfy site-specific environmental constraints for disposal. One prom-

[redacted]

refers to the application of solidification/stabilization technology and this

[redacted]

122. Solidification is the process of eliminating the free water in a

[redacted]

erties to the final products. Stabilization can be both physical and chemical. Physical stabilization refers to improved engineering properties such

[redacted]

but not necessarily chemical stabilization.

123. Since physical stabilization and solidification are equivalent in terms of the end products, the terms are often used interchangeably, with

[redacted]

not without some confusion. In this report, physical stabilization and chem-

[redacted]

technology. Unless otherwise noted, the term "solidification/stabilization" refers to physical/chemical stabilization. Where appropriate, contaminant immobilization is described as primarily physical stabilization, chemical

[redacted]

sionally stable, and the solids do not move. Since most of the contaminants

[redacted]

leached.

Objective and approach

125. The objective of the contaminant immobilization research was to investigate the technical feasibility of reducing contaminant mobility in Indiana Harbor sediments using solidification/stabilization technology. The [redacted] evaluation of the solidified/stabilized products on the basis of physical and chemical properties.

Solidification/stabilization processes

[redacted]

fly ash with lime. There are several commercially available solidification/ [redacted]

Table 8

28-Day Unconfined Compressive Strength for Portland Cement

[redacted]

[redacted]

Weight Ratios	psi
PC/FA/SS/S [redacted]	1,223
PC/FA/SS/S (0.2/0.1/0.05/1)	1,662
PC/FA/SS/S (0.25/0.25/0.05/1)	1,395
PC/SS/S (0.25/0.05/1)	1,930
PC/SS/S (0.5/0.05/1)	2,070

---

* PC = portland cement.
FA = fly ash.
SS = sodium silicate.
S = Indiana Harbor sediment.
** Data provided by PQ Corporation, Valley Forge, PA.

[redacted]

[redacted]

cases actually increased the concentrations of leachable contaminants.

[redacted]

[redacted]

stabilization agents tend to increase the leachable contaminant concentration,

[redacted]

Implementation strategies

133. Disposal concepts. Solidification/stabilization technology can potentially be implemented in a variety of ways. Three concepts for implementing solidification/stabilization technology are considered applicable to confined upland disposal (Francingues 1984). These concepts are shown in Figure 10.

134. The "layered" concept (Figure 10a) involves alternating layers (thin lifts) of relatively clean dredged material and contaminated dredged material

[redacted]

a low permeability soil layer or foundation for the containment area. Once this layer has achieved the desired degree of consolidation and permeability, the contaminated material would be placed on top, dewatered, and solidified/stabilized in-situ. This layering process provides layers of clean material

Figure 10. Implementation concepts for solidification/ stabilization of Indiana Harbor sediment

that can adsorb contaminants in leachate draining from the contaminated layers during disposal. As an alternative, freshly solidified/stabilized dredged material from a processing facility would be placed on top of the clean mate- [illegible]

135. The "liner" concept (Figure 10b) incorporates soil stabilization (physical stabilization) as a treatment to produce a low permeability foundation. The low-permeability liner provided by soil stabilization is used to [illegible] dredged material to further protect against contaminant escape.

136. The final concept illustrated in Figure 10c, "secure disposal" [illegible] solidification/stabilization in a processing facility prior to placement of material in the confined disposal site. Capping would be accomplished in accordance with the intended utilization of the site.

137. Additive mixing. The implementation of onsite solidification/ [illegible] which the setting agents are added to and mixed with the dredged material. Three basic onsite methods of agent addition and mixing are available [illegible]

138. In-situ mixing is suitable for dredged slurries that have been [illegible] large volumes of low reactivity setting agents. This method incorporates the [illegible]

139. An alternative to back-hoes, clamshells, and draglines involves setting agent(s) addition and mixing by injection. Specially designed equip- [illegible]

[illegible] plant-mixing process, the dredged material is mechanically mixed with the setting agents in a processing facility prior to disposal in a prepared site. If the volume of material to be processed does not justify the expense of a mixing plant, one alternative is to mix the solidification/stabilization [illegible]

[redacted]

system. In the latter, track mounted injection equipment would move along the [redacted]

set-up before it can be removed from the scow is minimal.

141. Area-wide mixing is applicable to those confined disposal sites where high solids content slurries must be treated, and thus is not applicable [redacted] tillers to add and mix the setting agent(s) with the dredged material. Area-wide mixing is land-area intensive, requiring a relatively large land area to carry out the process. Area-wide mixing strategies present the greatest pos- [redacted] area-wide mixing strategy will require that the dredged material be suffi- [redacted]

142. Careful process selection involving laboratory tests is needed to [redacted] contaminated dredged material may interfere with the setting reactions responsible for the development of hardened mass (Jones 1985). The performance [redacted]

cost

laboratory tests. Information on several important aspects of field appli- [redacted]

practical.

Cost

[redacted]

144. Solidification/stabilization offers a variety of contaminant immobilization alternatives for the design engineer to choose. Evaluation of the [redacted] physical properties of solidified/stabilized products for selected processes showed that sediment from Indiana Harbor Canal can be physically stabilized by a variety of solidification/stabilization processes (Appendix H). There are [redacted] technology has the flexibility and versatility to meet specifications for [redacted] low strength concrete. The chemical leach data (Appendix H) showed that

solidification/stabilization of Indiana Harbor sediment reduced the mobility of some contaminants, depending on the type of setting agent(s) and additive design used. The mobility of most metals was reduced, while the mobility of organic carbon was not different from the untreated sediment. The economic feasibility of solidification/stabilization is probably affected as much by the implementation strategy that is selected as it is by the unit cost for additives and increased volume requirements.

145. The contaminant immobilization strategies discussed in this report [illegible] Due to the developmental nature of the technology, additional testing and [illegible] Additional testing and evaluation should address scale up factors, long-term [illegible] selected organic contaminants such as polychlorinated biphenyls, construction [illegible]

[redacted]

[redacted]

[redacted]

[redacted]

costs.

[redacted]

and disposal alternatives in a logical framework. Preliminary evaluation has

[redacted]

followed by a structured sequence of testing protocols. The next step in the

[redacted]

measures required for implementation. The need for control measures was

[redacted]

criteria. The selection of appropriate control measures is dependent on the

[redacted]

Evaluation of the In-Place Effects of Bottom Sediments from the

[redacted]

Background

149. Bottom sediments contaminated with organic matter, heavy metals, oil [illegible] Federal navigation channels often act as catchment basins for these polluted sediments. As a consequence, the CE must, as required by Federal statutes,

[redacted]

disposal of these materials. No effort was made to determine the environmental effects of polluted bottom sediments on the overlying water column and biota or the environmental benefits derived from the removal and confined

[redacted]

150. Many environmental groups voice strong objections to the dredging and

[redacted]

[redacted]

exert a significant oxygen demand; support few, if any, benthic organisms, and provide a long-term source of contaminants. The resuspension of contaminated

[redacted]

[redacted]

nated sediments. If the CE can demonstrate or quantify these benefits, it can

[redacted]

and disposal.

[redacted]

information on sediment-water interactions in general was analyzed, as well as

[redacted]

the GCR/IHC.

[redacted]

[redacted]

[redacted]

from suspended particulates > transport of soluble contaminants released from

[redacted]

[redacted]

species. The studies conducted at WES have shown that the high toxicity of

[redacted]

[redacted] move through the system is needed.

Wastewater reallocation

153. In order to understand the role of sediment as a source of contaminants in the GCR/IHC, it is necessary to understand the relative importance of sediment and water as contaminant sources to Lake Michigan. To accomplish [redacted]

154. Data from the National Pollution Discharge Elimination System (NPDES) on municipal and industrial point sources are available for use in calculating [redacted]

[redacted] to confirm the presence of toxic organics. Existing data will not allow separation of sediment contaminant inputs from those of point and nonpoint riverine sources.

155. Evaluation of the waste load allocation model developed for the Grand Calumet River system by the Indiana State Board of Health showed that the model simulates field water quality data for dissolved oxygen and conservative [redacted]

[redacted]

stream and harbor. Review at WES has also identified surprisingly low values [redacted] Calumet River are similar to or heavier than waste loads in other systems that have much higher sediment oxygen demands. The low levels of the sediment [redacted]

156. Waste load allocation models currently in use are of limited value [redacted]

Sediment oxygen demand

157. Sediment oxygen demand (SOD) is an important oxygen consumption [redacted] layer as a "valve" for oxidized and reduced materials. SOD is also a key [redacted] not possible to state with any degree of certainty the existing SOD values for [redacted]

values given for similarly polluted streams in the Chicago area and thus are

[redacted]

the Indiana Harbor Canal region. The reasons for this were not clear from HydroQual (1984).

[redacted]

of bioturbation, but would remain a fairly minor component of contaminant input into the overlying water.

[redacted]

conducted on compounds other than hydrophobic organics. This means that polar organic compounds and inorganic heavy metals cannot be evaluated by this

[redacted]

[redacted]

Sediment resuspension and transport

160. Under nondredging conditions, there are two major avenues for the [redacted]

equilibrium with the channel thalweg provided by passage of boat traffic. Shoaled equilibrium means that incoming sediment is equal to outgoing sedi- [redacted]

undocumented mechanisms (Lake Michigan seiches, local storm action, etc.).

161. The database for the GCR/IHC has only limited data on contaminant [redacted]

transport in the system. Additional data must also be collected before [redacted] models is not recommended.

[redacted] estimates, such as conducted by the Chicago District for the Indiana Harbor [redacted] yield, and benefits that would accrue from dredging the Indiana Harbor Canal. More detailed hydrodynamic and suspended sediment transport data are necessary to allow use of more sophisticated analytical techniques for evaluating sedi- [redacted] Canal would allow it to act as a sediment trap, retaining contaminated sedi- [redacted] hydrodynamic or contaminant models is not recommended.

[redacted] the system's hydrodynamic and sediment transport properties. The information required for an assessment of GCR/IHC system hydrodynamics and sediment transport will necessitate both short-term (on the order of a day) and longer-term (on the order of four to six days) field data sets. Following these hydrodynamic studies, one or more options presented in this report can be utilized. These include: 1) quantifying mass loadings to the water column [redacted] and nonsediment loadings to the GCR/IHC; and 3) determining the long-term fate of contaminants in the GCR/IHC system.

164. We know that in-place contaminated sediment in the GCR/IHC can exert [redacted] that the GCR/IHC could be recolonized by diverse aquatic biota so long as the contaminated sediments remain in the system.

[redacted] (Brannon et al., in preparation).

TSCA-Approved Disposal Alternatives

[redacted]

[redacted] these alternatives. Major cost items associated with a project of this nature [redacted]

[redacted]

dewatering, collect and treat the return water and runoff. A conceptual [redacted]

operation.

170. A dredged material lift (thickness) of 10 ft was assumed for the con- [redacted] "package" treatment facilities. The treated effluent would be returned to [redacted] with a moisture content of about 25 percent by weight. Although dewatering and consolidation may reduce the volume of sediments within the storage facility by about 20-30 percent, this volume will be returned due to the bulking factor from rehandling.

[redacted] are as follows:

Construction costs	$3,000,000
[redacted]	[redacted]
	$5,500,000

However, this cost could be as high as $7,500,000.

Incineration

[redacted] destroy contaminated wastes are emerging but are not in common usage at the present time.

[redacted] in the US which have been licensed by the USEPA to accept and incinerate [redacted] remaining two accept only liquid wastes. The facilities that accept solid [redacted]

[redacted] process contaminated wastes. These units can be assembled at the site and [redacted]

[redacted]

[redacted]

[redacted]

alternative was performed.

177. The major obstacles to incineration of dredged material include [redacted] interference of other contaminants. Dredged material should be dewatered to a moisture content of about 25 percent to improve burning efficiency. The sediments from Indiana Harbor Canal have a total volatile solids content of approximately 25 percent. This means that 25 percent of the solids are combustible, and that 75 percent are inert and will remain as residue or ash. This poses handling problems during incineration. In addition, the ability of [redacted] with applicable air quality standards would have to be proven with several trial burns. The interaction of the PCBs and other organic contaminants with inorganic pollutants present in the sediments could require elaborate emission controls.

[redacted]

[redacted]

[redacted]

[redacted]

179. Since a detailed analysis of the technical feasibility of incineration of Indiana Harbor Canal sediments is outside the scope and intent of

[redacted]

this report, certain assumptions had to be made in order to proceed. These

[redacted]

more than 25 percent by weight in order to improve burning efficiency in the incinerator.

[redacted]

f. The materials used in the treatment unit of the holding facility

[redacted]

be as follows:

[redacted]

d. Assemble the portable incinerator onsite (2 years).

[redacted]

ments. The specific sites in which incineration cost data were estimated by the USEPA were Waukegan Harbor in Waukegan, Illinois and Fields Brook in Ashtabula, Ohio. The local USEPA office (Region V) supplied the Chicago Dis-

[redacted]

as well as the Illinois EPA in Springfield, Illinois.

182. Previous studies by the USEPA identified costs in the range of $1,000 to $1,500 per cu yd of dredged material for incineration using a

[redacted]

project would be approximately 17 years using one incinerator. This does not include time for site layout and obtaining necessary permits. These activities could add several years to the time frame. The time frame could be

[redacted]

183. Offsite incineration. The procedure for offsite incineration would

[redacted]

[redacted]

and dispose in the storage/rehandling facility (3 months).

Dewater dredge material (1-2 years).

[redacted]

material would be transported to the offsite incinerator (approximately 30,000 to 70,000 cu yd). Assuming 20 trucks a day and 10 cu yd of material per truck and 290 working days per

[redacted]

f. Incineration at the offsite facility and disposal of the residue there.

It is assumed that the dredged material is incinerated and disposed of as soon as it arrives. If the offsite incinerator can not keep pace with this

[redacted]

18/ The costs for offsite incineration were determined by contacting the

[redacted]

Illinois. A representative of that firm supplied the Chicago District with the data necessary to determine the cost of incineration and disposal

[redacted]

tion and disposal of dredged material and liner ranges from $2[illegible] to $244 million. This figure does not include the cost of dredging, the con-

[redacted]

containerization of the sediments, and transportation to the incinerator. The [illegible]

186. PCB-contaminated materials may be disposed in an approved chemical waste landfill. The specifications of a chemical waste landfill are described [illegible] compacted clay liners, synthetic membrane liners, and leachate collection [illegible]

187. [illegible]

c. Dewater dredged material (1-2 years) [illegible]

188. The nearest approved TSCA landfill is located in Williamsburg, Ohio [illegible] Indiana Harbor. The landfill is operated by CECOS International, which has [illegible] handled in accordance with existing Federal, State and local environmental laws and all contractors and their agents will comply with these laws. Special handling and special precautions will be required at each step of the [illegible]

[redacted]

fill is estimated to include 200,000 cu yd of dredged material, 30,000 to [redacted] to 60 cu yd of filter media used in treatment processes. The transportation weight of this material (25-percent water content) is estimated to range [redacted] thus, range from $47.2 million to $57.4 million.

191. Time required to implement use of a TSCA landfill as a disposal plan [redacted] Assume that one truck can make three round trips of 540 miles each per week, [redacted] problems caused by cold weather will not impact on the schedule. It would [redacted]

The estimated costs of disposal of PCB-contaminated sediments to the closest [redacted] operation, and closure of the storage/rehandling facility. This disposal alternative would take about 6-8 years to complete.

[redacted]

authority. Based on technical considerations, it is uncertain if these sediments can be incinerated with acceptable air emissions. The ability of incineration to accommodate these high-ash materials is also uncertain. From [redacted] used to dewater the contaminated sediments represents a type of upland con- [redacted] (6-17 years), and contain state-of-the-art controls, it would have no less [redacted]

Background

193. Contained aquatic disposal was investigated in an effort to broaden [redacted]

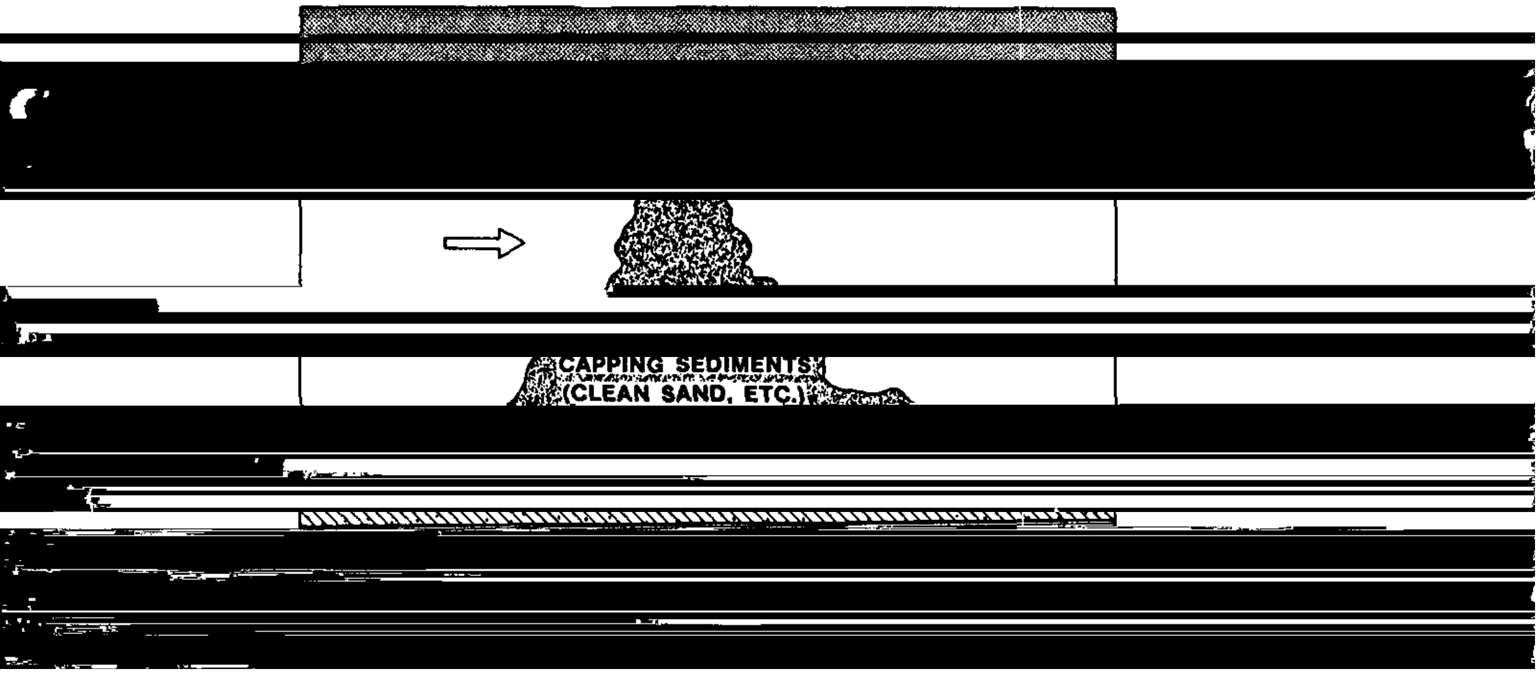


Figure 11. Schematic of typical level-bottom capping operation

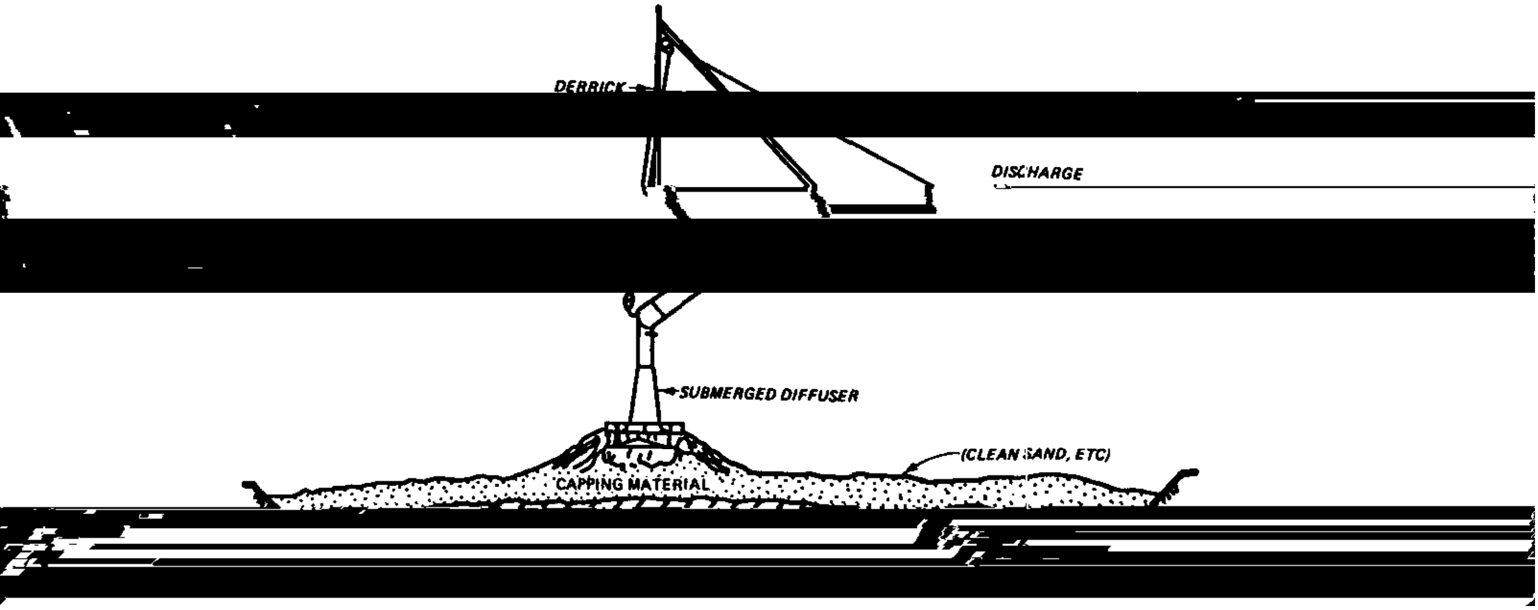


Figure 12. Schematic of CAD project also showing use of a submerged diffuser for placement

innovative approach, and the physical, chemical, and biological impacts and benefits must be understood before the project can be designed and constructed.

[redacted]

material mound. As described previously, Indiana Harbor sediments are known to be contaminated. The capping material provides the isolation necessary to control the movement of contaminants out of the dredged material and into the

[redacted]

function of stabilizing the material and protecting it from transport or dispersion away from the site. The design of the cap, therefore, requires a twofold approach. It must result in a capping layer with a grain size and

[redacted]

site.

Objectives

197. The following objectives addressed the CAD alternative:

[redacted]

[redacted]

c. Provide guidance to the District on the minimum grain size of capping material, thickness, configuration, and siting that will

[redacted]

[redacted]

construction methods, and site monitoring.

198. The remainder of this section briefly describes the approach, and

[redacted]

b. Cap materials.

[redacted]

c. Site design and construction.

d. Monitoring.

Considerable further detail on the test methods, laboratory findings, and site

[redacted]

Site selection

[redacted]

harbor itself, and/or in the more open waters of Lake Michigan. Because of the significant differences in the physical environment of these two areas and

[redacted]

[redacted]

[redacted]

Lake Michigan focused on the area between the 30- and 70-ft depth contours. The 70-ft contour was selected as corresponding to a reasonable maximum haul

[redacted]

grounding.

202. A first analysis of the bathymetric in this area together with a very

[redacted]

in this shoal zone (Figure 13) were eliminated from further consideration. No

[redacted]

study area. This simply meant that with the exception of those areas with

[redacted]

study area <u>provided</u> that the cap material was selected and the site designed considering the local shear stress at the selected location. The effects of

[redacted]

Figure 13. Area of potential CAD sites (shaded) in southern Lake Michigan

203. Although wave forecasts were extended into the outer portions of the

[redacted]

[redacted]

cap would coincide with the existing project depth. Two major problems arise

[redacted]

routinely pass at depths equal to the project depth, essentially in contact with the bottom. Armoring of the bottom could affect that practice and certainly the practice would adversely affect the cap.

Cap materials

204. As stated above, the selection of a cap material must satisfy the dual requirements of providing contaminant isolation and resistance to resuspension and transport. The two studies leading to specification of a cap design are containment isolation studies, and resuspension and transport

[redacted]

silty sand sampled from Lake Michigan. Figure 15 presents the grain-size distribution of a composite sample of the proposed cap material.

205. Contaminant isolation studies. Contaminant isolation studies were run using small column tests and large column tests.

a. The effectiveness of capping in chemically isolating Indiana Harbor sediment from the overlying water column was investigated using small- (22.6 ℓ) scale laboratory reactor units. The depth of cap material needed to accomplish this was evaluated by

[redacted]

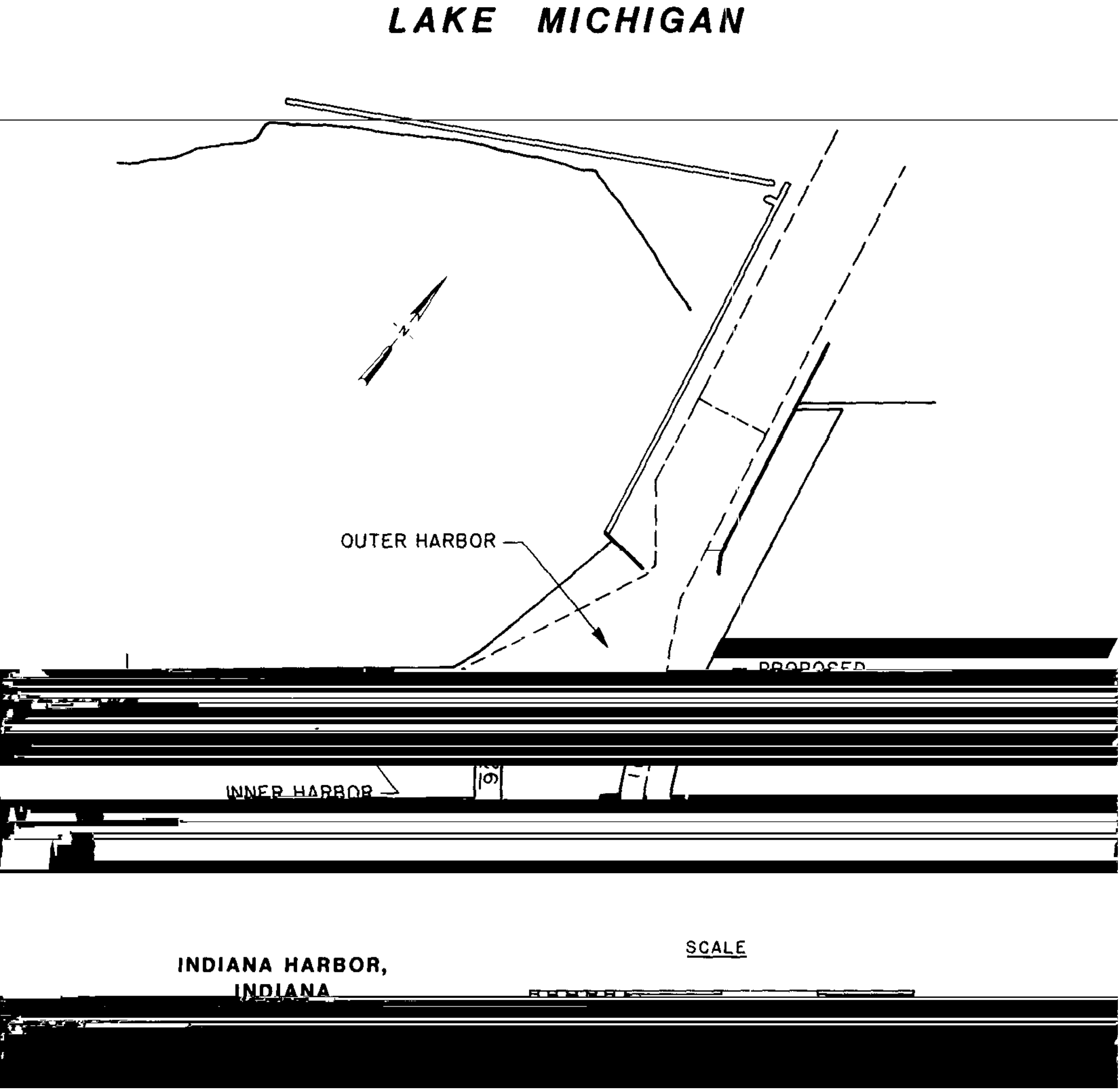
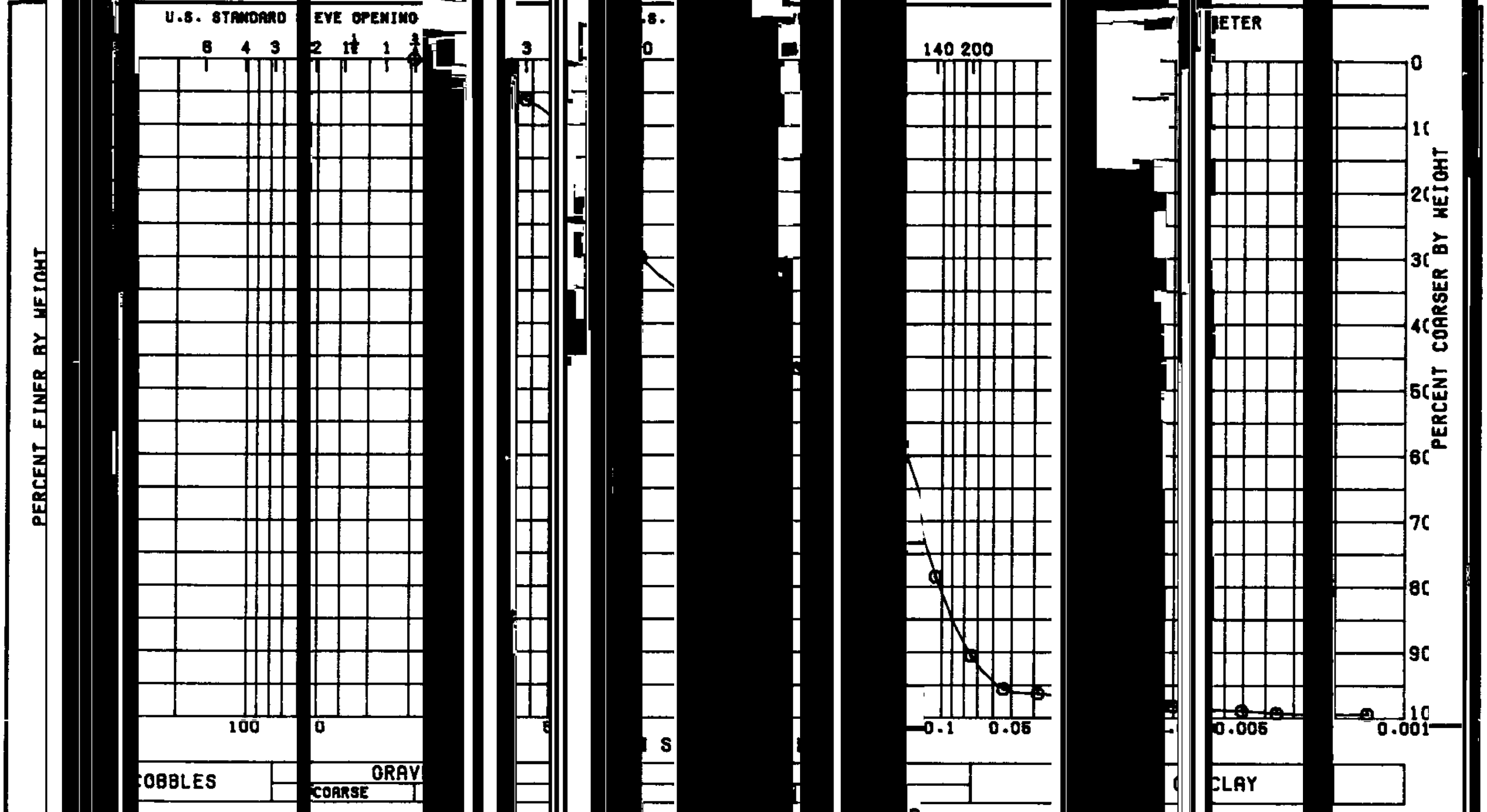


Figure 14. Proposed CAD site in outer portion of Indiana Harbor



LL	PL	PI	OS	EST	P

CLA ION

Y SAND (SP-SM, GRAY: RAV

ROJECT IN AP SEDI NT

B

BORING NO.

SAMPLE N 1

DEPTH/ELEV

ATE 13 UG 85

GRADAT RV

Fig G ze cap materi

[redacted]

are normally present in the aquatic environment. The activities of these

[redacted]

the underlying contaminated sediment to the water column, with possible resuspension of PCB-contaminated particles.

207. Many aquatic organisms are able to "process" much of the water in a

[redacted]

organisms can be used in the capping studies to trace the movement of any contaminant initially present in the test sediment, but not in the cap mate-

[redacted]

concentrate materials from their ambient environment, they can be used to keep

[redacted]

the contaminant of interest are compared with the levels of this substance

[redacted]

[redacted]

[redacted]

[redacted] and biologically isolating Indiana Harbor sediment from the overlying water column and aquatic biota was verified using 250 liter laboratory reactor [redacted] (control), Indiana Harbor sediment only, and Indiana Harbor sediment capped [redacted] contents of heavy metals and organic contaminants. Water samples were also [redacted]

[redacted]

a. Uncapped Indiana Harbor sediment was extremely toxic to the test

[redacted]

large column studies were initiated. In addition, large numbers of the fish and clams in the same units also died during and

[redacted]

causing Indiana Harbor sediment to be suspended in the water column, directly exposing fish and clams to the sediment although these organisms were well above the sediment surface.

[redacted]

survived the full 40-day exposure in the large column units con-

[redacted]

water column and aquatic biota of statistically significant levels of any of the metals or organic contaminants tested, with

[redacted]

the Lake Michigan sediment or the Indiana Harbor sediment with

[redacted]

stress are probabilistic events and must be evaluated for a particular

[redacted]

Refraction-Diffraction (RCPWAVE) model. The resulting local wave heights can be equated (using linear wave theory) to a maximum water particle velocity as

[redacted]

213. In a similar approach, the probabilistic wind speeds in the study

[redacted]

the (vector) velocity components of a bottom current in the area. The

[redacted]

able estimate of maximum water particle velocities across the study area. The

[redacted]

influence of these predicted velocities was then calculated using initiation of motion theory and empirical relationships.

[redacted]

the flow of water in the channel were evaluated in a manner similar to that

[redacted]

[redacted]

and the bottom is common.

215. Results of resuspension and transport studies were as follows:

a. Studies indicated that the deep water wave heights in

[redacted]

point. These computed velocities ranged from 6.0 to 12.9 fps.

c. As expected, bottom stresses in the lake generally increase as

[redacted]

Predicted minimum weights necessary for stability under each return period event in the lake ranged from 1 or 2 lb to as high

[redacted]

cap or that an armor layer is a necessity. As discussed in

[redacted]

d. The sheltered environment in the harbor results in reduced

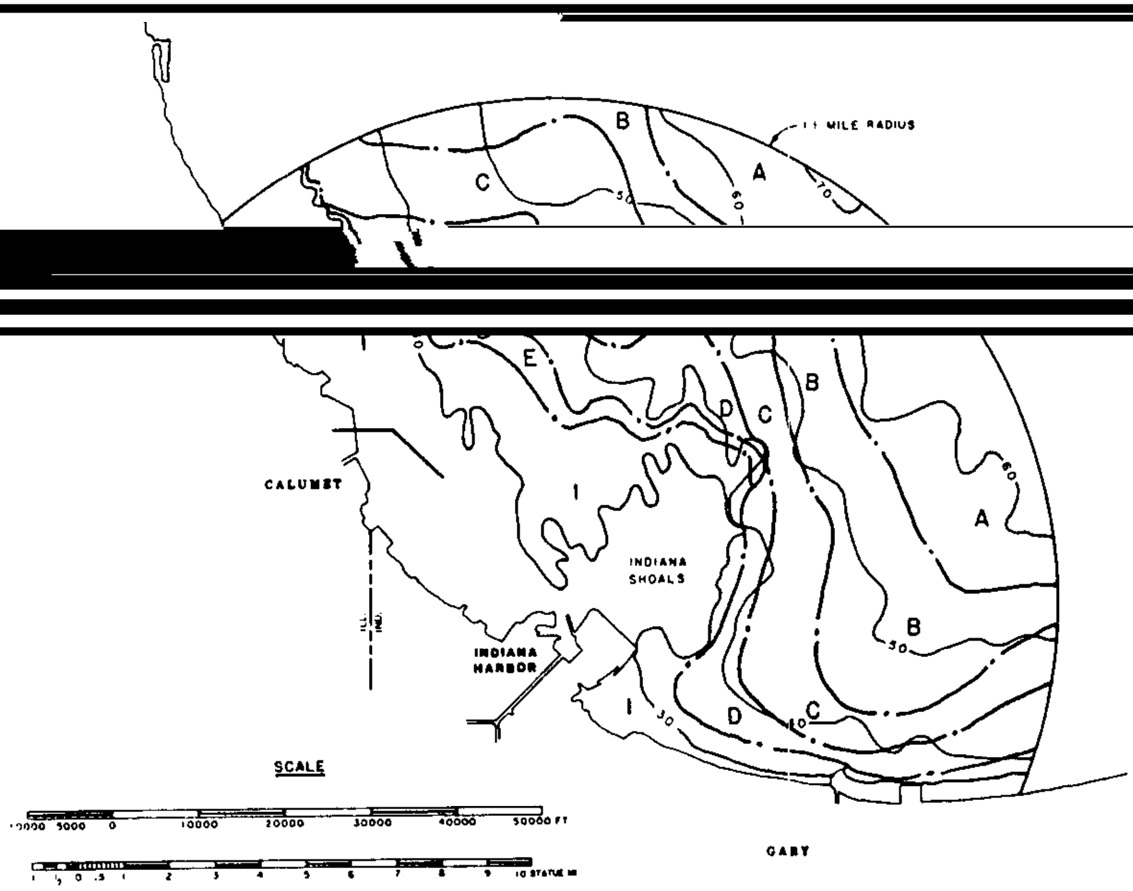
[redacted]

transported by ambient currents. However, as described above, ships using the channel frequently come into direct shear with the bottom sediment, and/or their propellers are in such

[redacted]

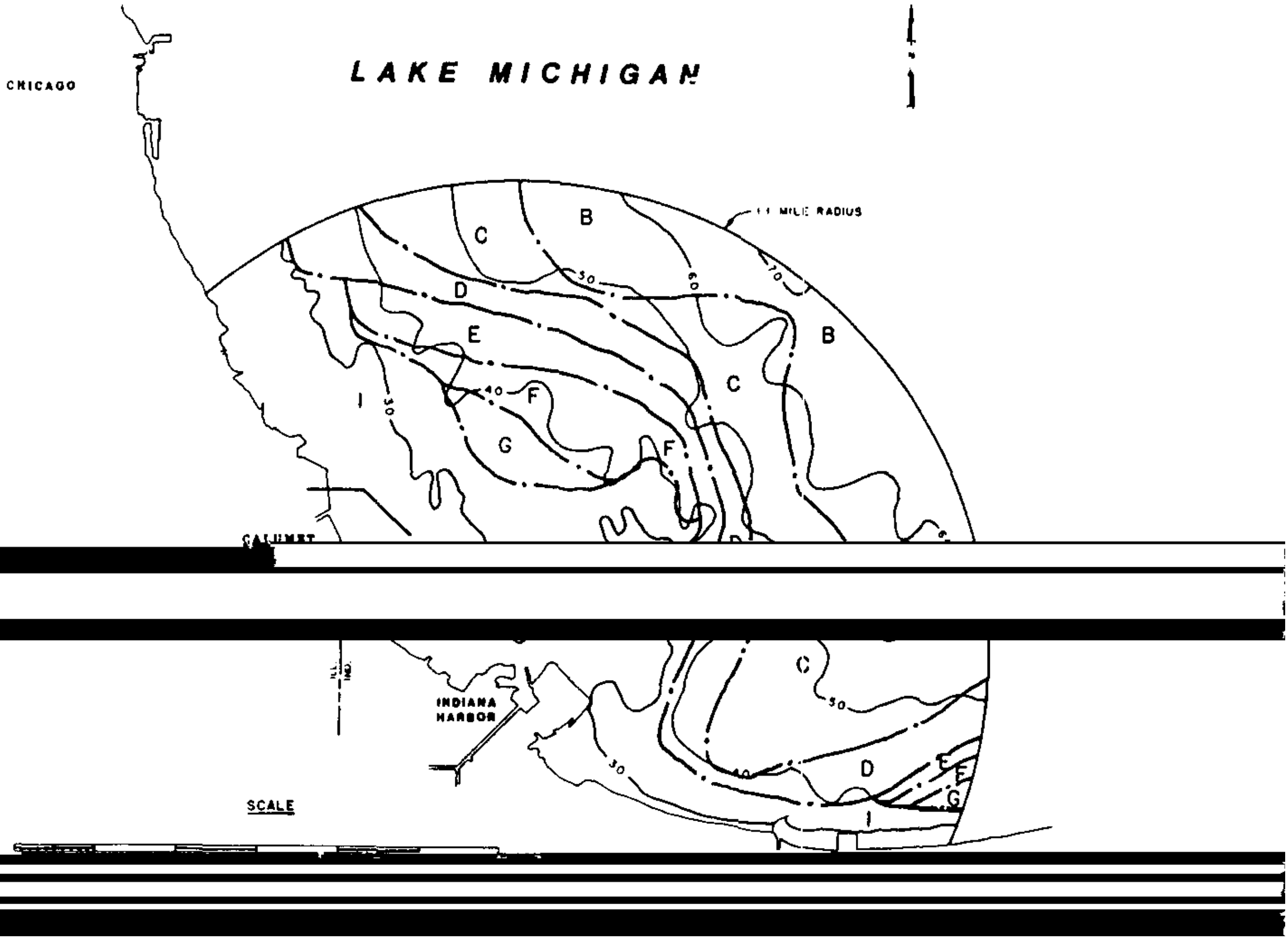
216. Recommendations for cap material. Lake Michigan sediment may be

[redacted]



AREA	PARTICLE WEIGHT (LB)
A	1-2
B	2-5
C	5-10
D	10-20
E	20-30
	AREAS OF BREAKING WAVES, SHOALS,

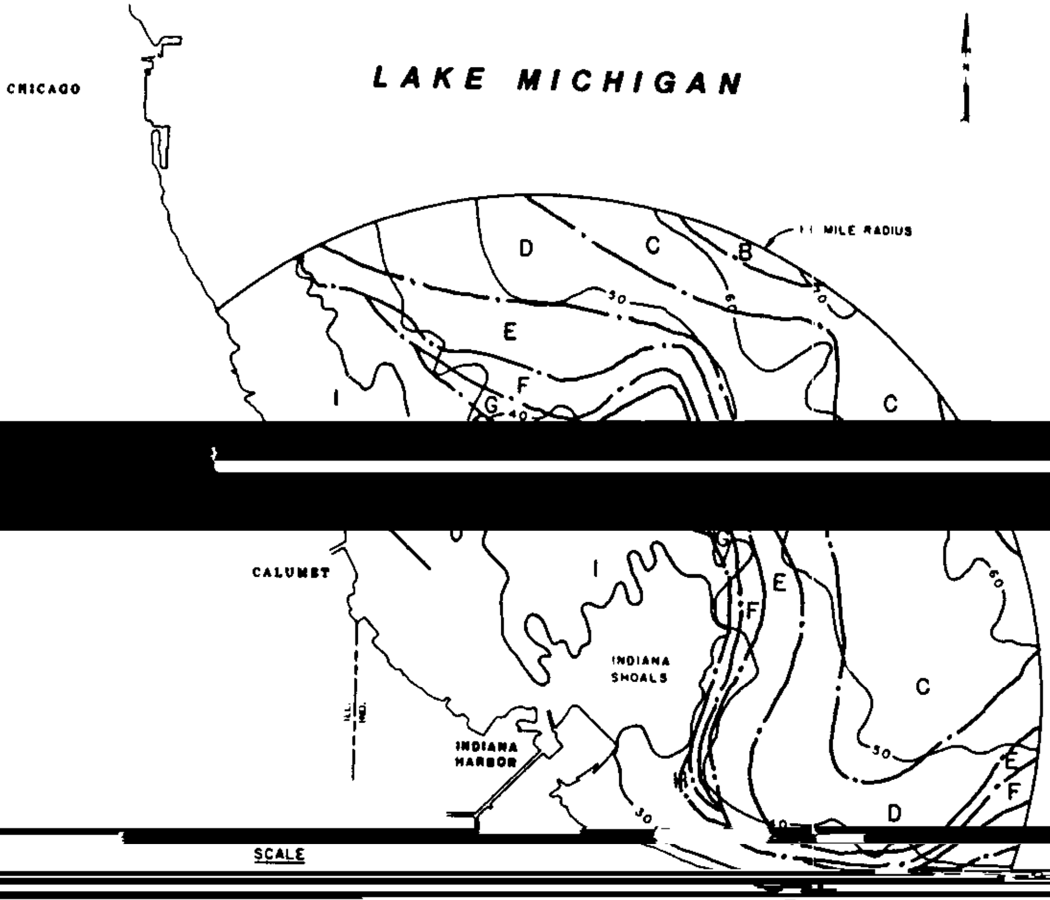
Figure 16. Armor cap material sizes based on 20-year design wave[1]



[redacted]

AREA	PARTICLE WEIGHT (LB)
[redacted]	[redacted]
C	5-10
D	10-20
E	20-30
F	30-40
G	40-60
I	AREAS OF BREAKING WAVES, SHOALS, AND SHALLOW WATER, NOT RECOMMENDED AS SITES FOR CAD

Figure 17. Armor cap material sizes based on 50-year design wage



AREA	PARTICLE WEIGHT (LB)
B	2-5
C	5-10
D	10-20
E	20-30
F	30-40
G	40-50
H	50-112
I	AREAS OF BREAKING WAVES, SHOALS, AND SHALLOW WATER, NOT RECOMMENDED AS SITES FOR CAD

[redacted]

[redacted]

217. A cap constructed of only native sandy sediment will not act as a stable armor structure under the influence of predicted storm events, and

[redacted]

isolating capability of the cap. Sediment transport is generally a continuous

[redacted]

either armoring of the cap surface (above the 20 in. minimum thickness) with a layer of stone having particle weights such that they will not be resuspended, or advance nourishment of the cap with a volume of the lighter lake sediment

[redacted]

Site design and construction

[redacted]

potential sites plays an especially crucial role in the design because of variations in bottom stress. The locations will also influence required [redacted] length (see Appendix I). Such a length is not readily available; therefore, this discussion of design will focus principally on sites in southern Lake Michigan and in the outer harbor.

220. For preliminary discussion purposes the design will assume that the [redacted] testing supporting the CDF evaluation, can be applied to hydraulically dredged sediment placed in a CAD. Therefore, sites must have a capacity approaching [redacted] 400,000 cu yd. (Actually, volumetric requirements will depend on the total time over which placement occurs since some initial consolidation will take [redacted] indicated rather than capping of a mound of material above existing contours. [redacted]

Compartmentalization is necessary to provide the maximum degree of confinement [redacted] ment of material and cap (reducing the surface area of contaminated material exposed at any one time); and to reduce the effects of erosion/breaching by storm action during or after construction.

[redacted]

depths of 40 to 60 ft. To produce a site with the recommended depth of approximately 15 ft would then require a digging depth of 55 to 75 ft. This would exceed the construction capability of a conventionally configured

[redacted]

[redacted]

begin excavation with the hopper dredge of a trench approximately 2,000 ft

[redacted]

unusual techniques except perhaps leaving three short "plugs" or cross dikes

[redacted]

Figure 19. Sequence of construction for CAD site

berm of material along the trench and some distance seaward. As soon as the dredge completed the first trench, disposal of contaminated sediment could begin in the first 500 ft section. Placement of the material would likely involve the use of a pump-out barge and the submerged diffuser to reduce resuspension and to ensure accurate placement and accounting of the contaminated sediment.

[illegible] design of a CAD option to establish the optimum method for placing the cap [illegible]

sediment. Options include the use of the submerged diffuser; direct pump-down [illegible]

[illegible] increases the internal shear strength of the contaminated sediment and reduces the chance of displacement during capping, but leaves the contaminated surface exposed to the overlying biota and to transport by sudden storm action. Additives or other forms of stabilization are possible if investigation [illegible]

225. Whatever final method is used, the operation lends itself well to sequential construction. Cap material for the first trench can come from [illegible] excavation for a second trench, parallel and shoreward of the first. (or [illegible]

[redacted]

ure 20). Positioning, timing, and traffic control at the site will be

[redacted]

volume.

226. The design of the cap section will require input from the District on economic requirements and risk analysis. The 20-in. thickness for isola-

[redacted]

approach that is warranted only as the most conservative approach. Incipient motion theory addresses only stability and not transport, especially not

[redacted]

motion although infrequently. Advanced nourishment with a greater thickness of the native material is also a possibility. Some motion will occur on a regular basis, but material will move onto the site as well as leave it. Net

[redacted]

movement onto the site that would slow loss rates.

[redacted]

tions, a cutterhead dredge could be used to excavate the disposal area. Digging depths (approximately 40 ft) may still require ladder pumps or similar equipment, but the size would be reasonable.

[redacted]

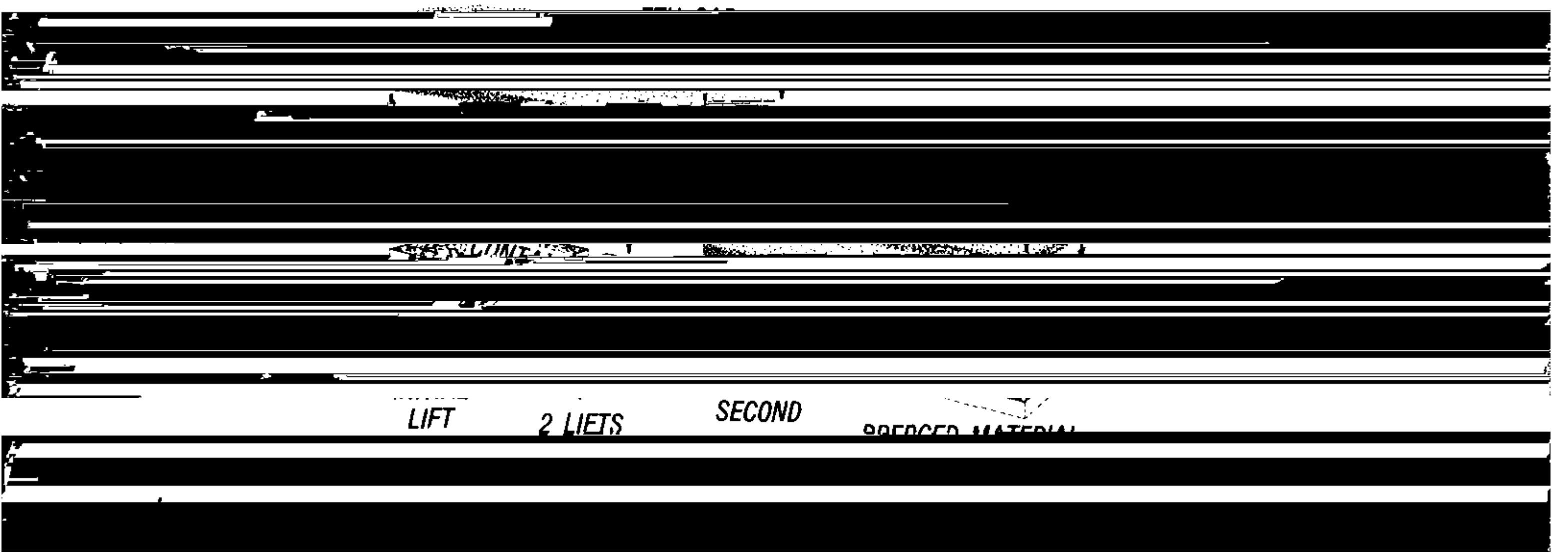


Figure 20. Section showing incremental loading resulting from sequential application of cap material

[redacted]

smaller sections in a "checkerboard" arrangement. The construction sequence previously described could still be productively employed with the added

[redacted]

Figure 21 shows this sequence applied in the harbor area. Among other assumptions, this option presumes that the native material at the outer harbor site is suitable as a capping material. Only lake bottom sediments have been tested. The contaminated sediment could also be placed directly by pipeline and diffuser if a hydraulic dredge is used for the actual removal.

229. Cap design in the harbor requires consideration of the effects of

[redacted]

detail in the appendixes. The effect of a CAD site on the future maintenance and/or improvement of the harbor is also an issue that can only be addressed

[redacted]

physical condition of the site and do so over time. Three basic categories of monitoring are suggested based on their time frames and intent.

[redacted]

for comparisons. Water samples should be taken during the placement and capping primarily for monitoring resuspension in the area. However, the focus

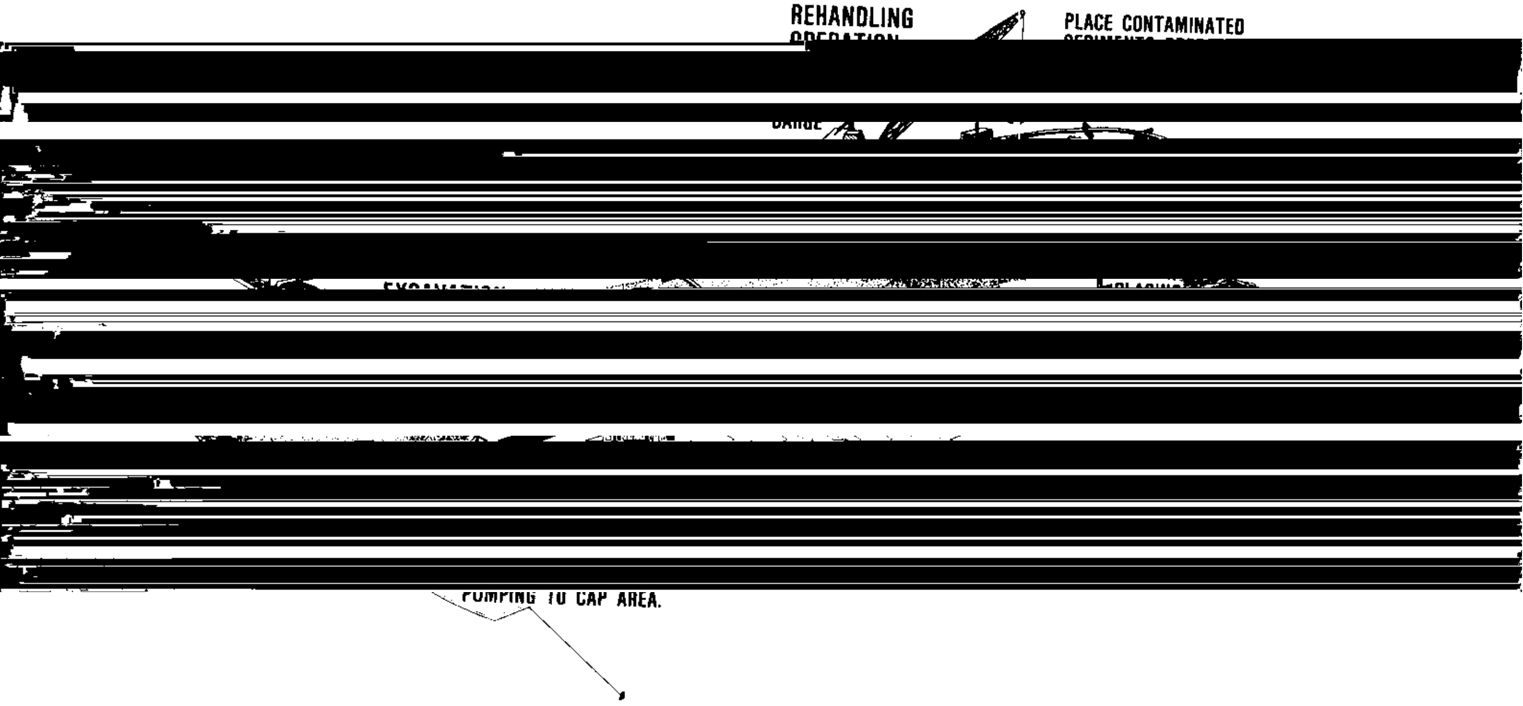


Figure 21. Sequence of construction [illegible]

[redacted]

system. Replicate soundings must be taken frequently during placement of the

[redacted]

used to verify conditions.

[redacted]

repeated at these intervals.

233. Long term. Similar water column and sediment series should be com-

[redacted]

tion should also be measured at these intervals.

234. Contingency. In addition to the above regular monitoring, specific

[redacted]

Confined Disposal Alternatives

Background

[redacted]

[redacted]

to a breakwater. Confined disposal facilities are often constructed in Europe

[redacted]

posal of dredged materials, such as marina development, shoreline protection, and creation or expansion of parks and wildlife areas.

[redacted]

238. The design of a CDF centers around engineering and environmental

[redacted]

levee. Geotechnical and structural evaluations of dike foundation and mate- [illegible]

[illegible]

239. Through the application of the management strategy, the potential routes of contaminant migration (effluent, leachate, and surface runoff) and environmental exposure (plant and animal uptake) have been examined. The [illegible] indicated in the lower portion of Figure 4.

240. The appropriate laboratory tests have been completed and the results [illegible] contaminated dredged material from Indiana Harbor. The confined disposal alterna- [illegible]

In-Lake CDF

241. [illegible] design proposed by the Chicago District to confine 1,500,000 cu yd of [illegible] provide capacity for the 200,000 cubic yards of PCB-contaminated material. [illegible] site.

[redacted]

marized below and discussed in the following paragraphs.

Possible Control Measures for In-Lake CDF

Contaminant Pathway	Control
Effluent	Settling Filter Dike Chemical Clarification
Surface Runoff	Encapsulation Place Below Lake Level
Plant/Animal Uptake	Encapsulation
Leachate (Through Dikes)	Filter Dikes Operational Controls Encapsulation
Volatilization	Encapsulation Place Below Lake Level

[redacted] additional solids removal; the filter design for filtering rate, clogging potential, removal efficiency, and design concept; the disposal operation concept; and the probable effluent quality based on results of laboratory [redacted] Additional restrictions are presented to [redacted] improve the effluent quality for both mechanical and hydraulic dredging. The evaluation of surface runoff quality summarizes the results of laboratory [redacted] on the disposal operation, and presents control [redacted]

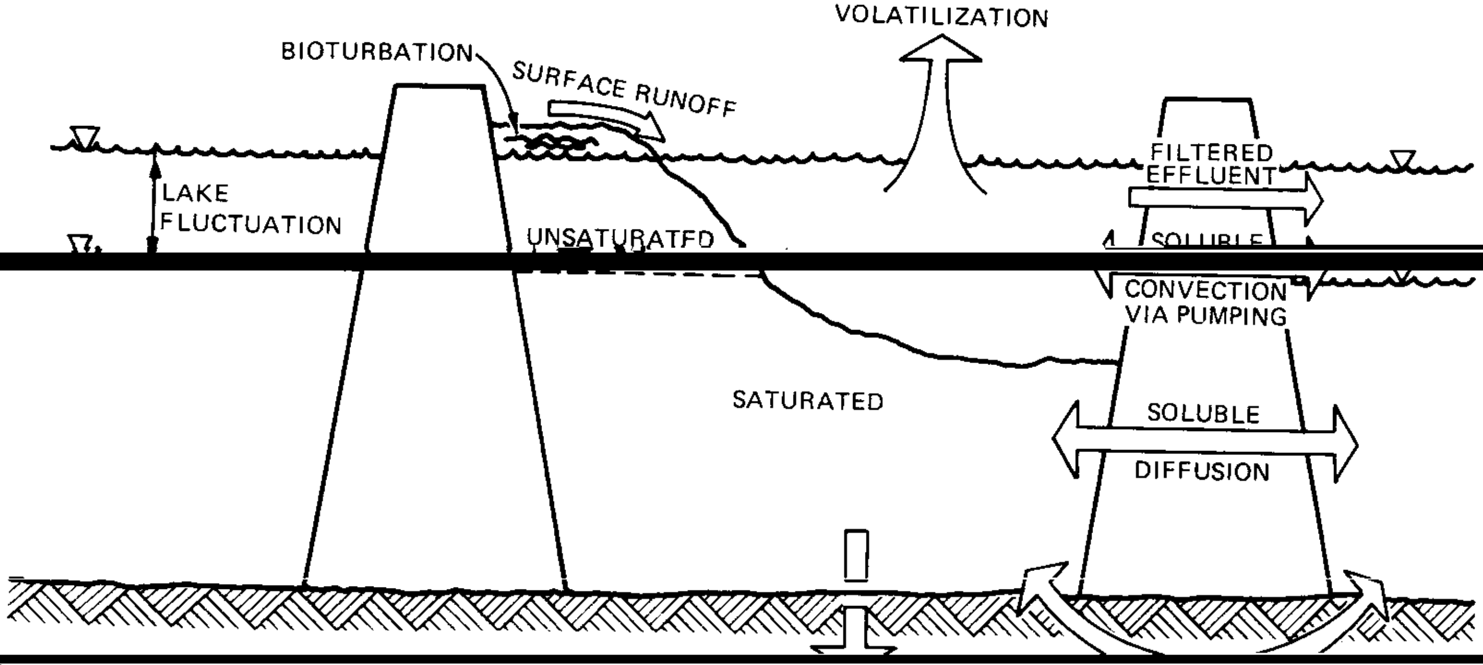
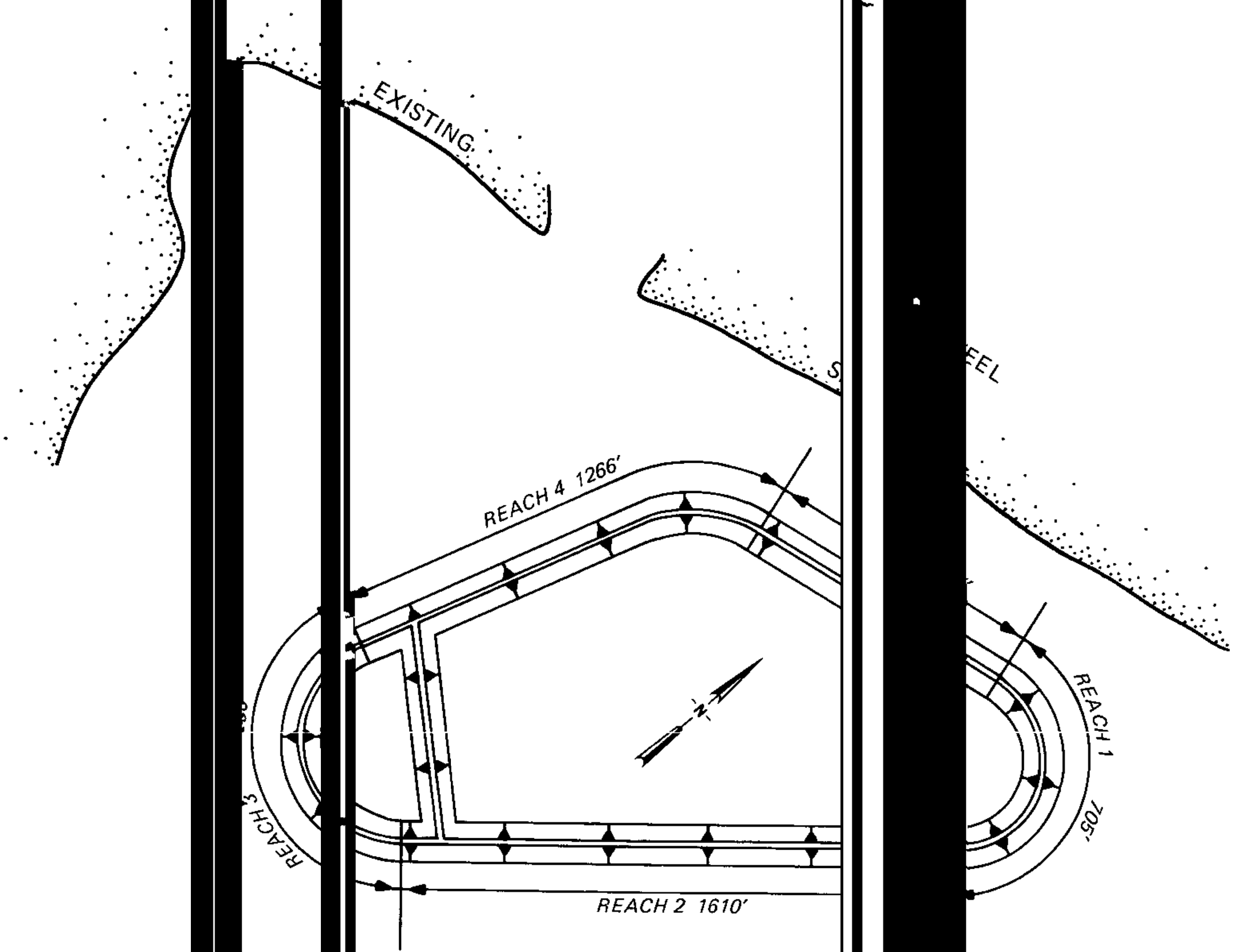


Figure 22. Contaminant pathways for an in-lake confined disposal facility

measures to reduce contaminant release by runoff. The evaluation of leachate [redacted] a function of volume of leachate produced and assesses the potential attenuation in contaminant concentration before reaching the groundwater or the [redacted] rate and contaminant concentration leaching from the site are discussed. The [redacted] contaminants in both an aerobic and anaerobic environment and presents the restrictions required for both environments. The evaluation of volatilization [redacted] to reduce it during and after dredging.

244. Proposed operation and design. The proposed CDF is located in Lake Michigan at East Chicago, Indiana, and is referred to as site 12 in US Army [redacted] The proposed CDF design includes stone-filled dikes. The dikes will be [redacted] withstand overtopping by most frequent storm events.

245. The proposed CDF is about 35 to 40 acres and has a depth of about 35 ft. The capacity of the CDF is expected to be 1,400,000 cu yd of sedi- [redacted] period. Each project will last about two months (US Army Engineer District, [redacted]



ure 23. Site plan of proposed in-la

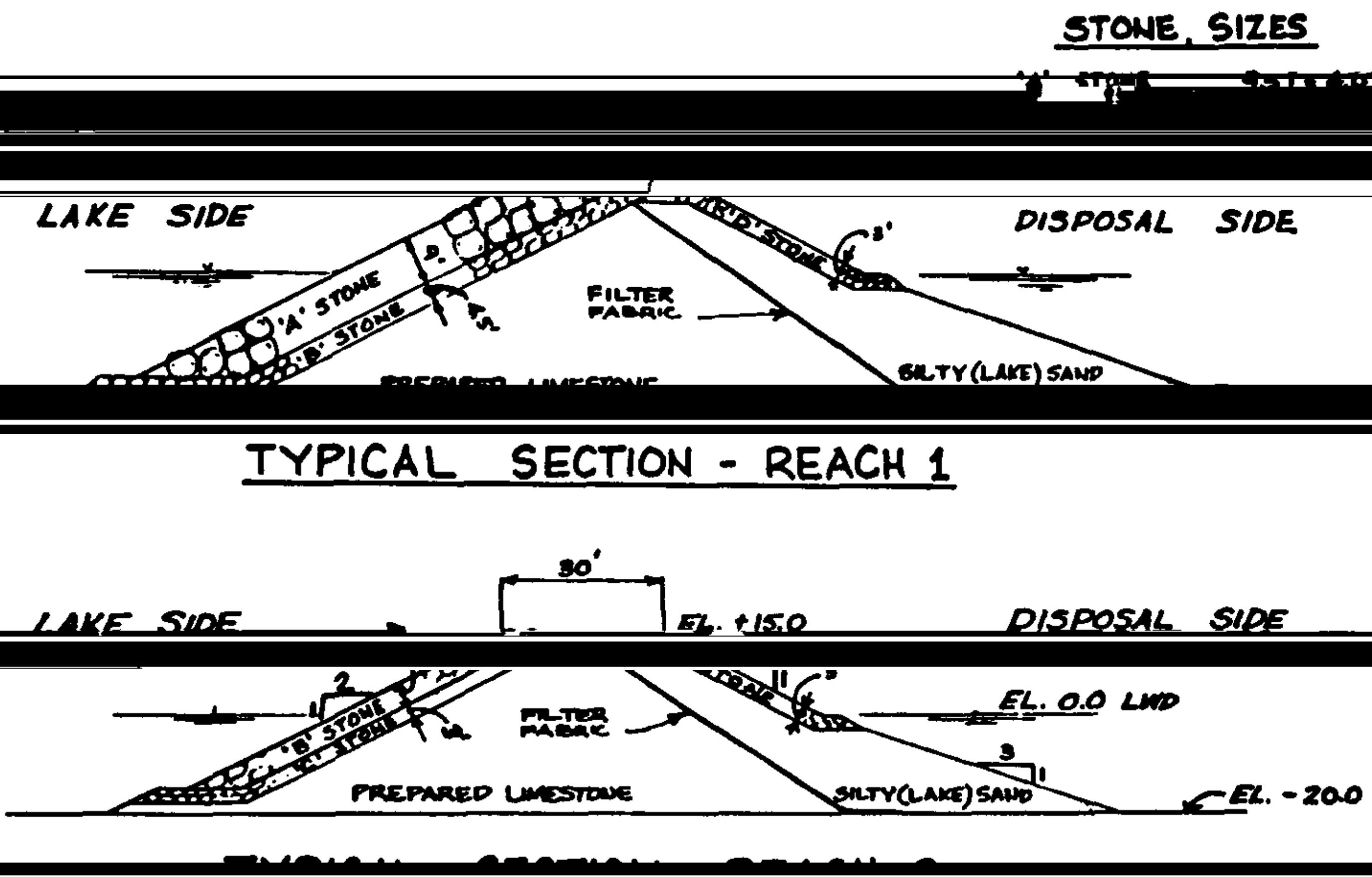


Figure 24. Typical dike cross section of proposed in-lake CDF

246. The CDF will be divided into two settling basins separated by a [illegible] and will be used for plain sedimentation and storage. The small secondary [illegible] be pumped into the secondary basin from a pumpout tank after the primary basin dikes clog. Polymeric flocculants will be added to the pumped water to enhance clarification.

247. The proposed CDF disposal operation consists of mechanically [illegible] transport material from the scows when necessary, minimizing the flow rate of [illegible]

248. The proposed CDF could be expanded to store the PCB contaminated [illegible] by a clamshell dredge or hydraulically by a matchbox dredge.

[illegible] tion is presented in Appendix A and the findings are summarized here. The effluent quality of the supernatant and the loading on the filter dikes are [illegible]

filling. As presented in Appendix A the suspended solids loading on the [illegible]

Dredging and Disposal Method	Predominant Settling Behavior in CDF	Suspended Solids Loadings to Filter Dikes Following Settling
[illegible]	[illegible]	[illegible]
Mechanical Dredging with Hydraulic Off-Loading	Flocculent Zone	1.5 g/ℓ 0.25 g/ℓ
Mechanical Dredging with Mechanical Off-Loading	-	0.020 g/ℓ

As shown in the summary, the loading for hydraulic disposal may be much lower [illegible]

250. Filter dike. The dikes (shown in Figure 24) appear to be sufficiently high to prevent overtopping by waves. Waves in the region under severe winds could be as large as 20 ft but with the breakwater the design should be adequate. The gradations and order of placement of the dike material should prevent erosion. Loss of sand by migration into the layers of larger stones should be prevented by the filter fabric. If lake sand is used [illegible] to prevent clogging and to ensure adequate seepage throughout the disposal [illegible] selection of sands with higher permeability and effective size. The filter [illegible]

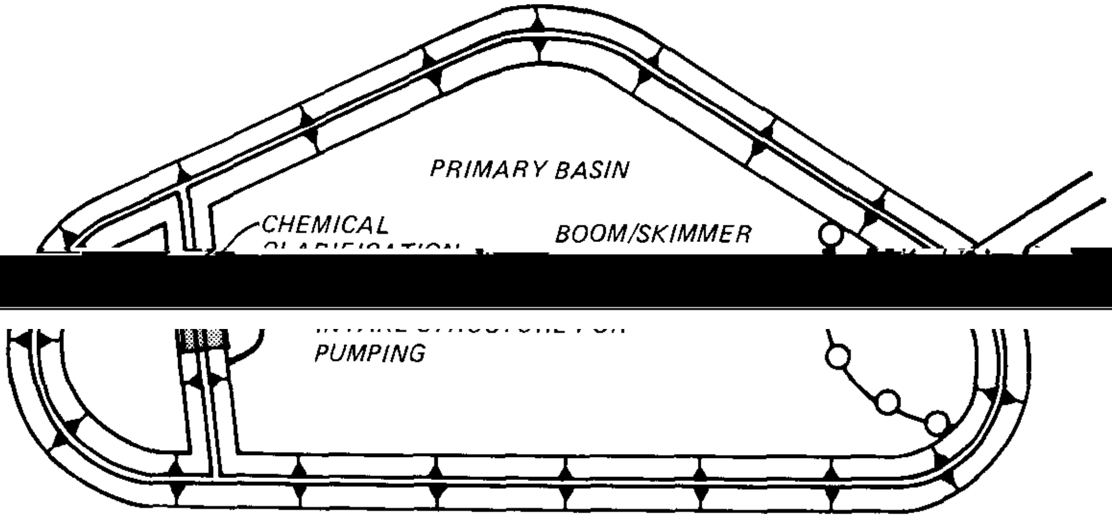
material and depth of filter sand is sufficient to remove virtually all suspended solids from the effluent.

[redacted]

[redacted] the primary cell of the CDF. If dredged mechanically, the material will be [redacted] 2 acres as shown in Figure 25. The primary cell is for plain sedimentation and storage, and the secondary cell is for additional filtration and chemical [redacted]

[redacted] through the pump intake structure will be treated prior to discharge with a polymeric flocculant to coagulate emulsified oil and rapidly settle most of [redacted]

[redacted]


PRIMARY BASIN
CHEMICAL
BOOM/SKIMMER
PUMPING

procedures. However, several operational problems may exist in the execution [redacted] which have the potential to clog the previous dikes. Oil and grease can clog [redacted] the dikes or is emulsified by turbulence. A similar device should also be placed in the primary cell where the supernatant passes through the pumpout [redacted] of the supernatant in the secondary cell. This would lead to clogging of the secondary cell's dikes. This problem as well as the problem of producing enough mixing for effective treatment could be eliminated in the proposed disposal operation by pumping the supernatant from the primary cell into a rapid [redacted] quently, the secondary cell may fill fairly soon for the hydraulic disposal alternatives. This would drastically reduce the surface area of the sand available for filtering. Therefore, settled material from the secondary cell should be periodically pumped back to the primary cell.

256. The chronological order of the dredging projects should be arranged [illegible] of less contaminated clays and silts as shown in Figure 26. The moderately [illegible] before PCB-contaminated materials are introduced into the CDF. Less con- [illegible] in the CDF. The clays and silts have low permeability which will slow any potential migration of contaminants from the CDF by leaching. The less con- [illegible] taminants which will attenuate the impact of any potential release.

257. Keeping the PCB contaminated material encapsulated in a subaqueous environment and covered by cleaner material serves several functions. It [illegible] uptake. It reduces the release of volatiles. Subaqueous confinement also [illegible] more time to be available for settling during disposal and less resuspension [illegible] potential for erosion.

258. [illegible] based on the results of the settling, filtering, and modified elutriate tests. Effluent quality for the in-lake CDF refers only to that supernatant water [illegible]

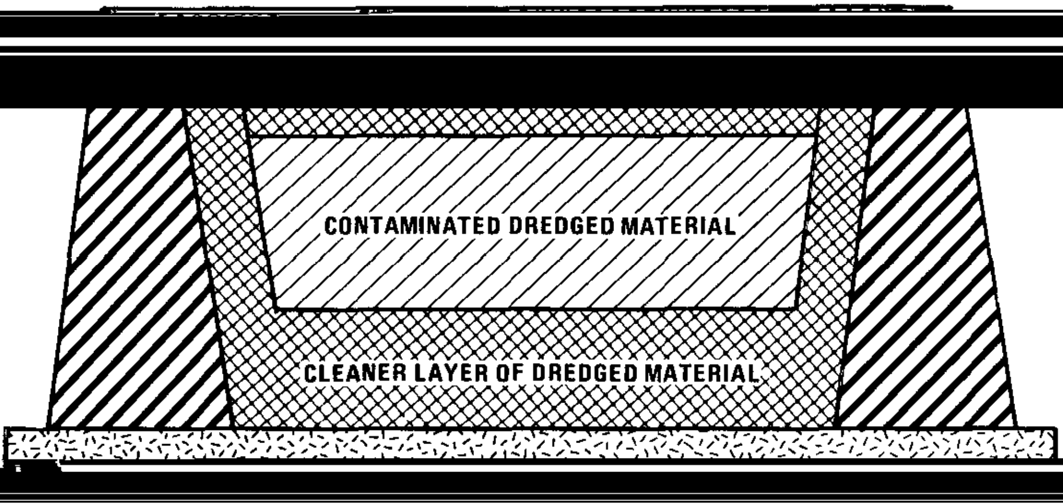


Figure 26. Disposal concept for encapsulation of PCB-contaminated

from the settled material may be drastically different. The D_{10} for the

[redacted]

the sand; therefore, using Krizek's (1976) relationships, the effluent suspended solids concentration will be less than 0.5 mg/ℓ.

[redacted]

Appendix B. Filtering is expected to remove all of the contaminants adsorbed

[redacted]

The modified elutriate test predicts dissolved contaminant concentrations in

[redacted]

which is characteristic of the influent for disposal by hydraulic means from

[redacted]

could be used to determine whether any effects on the dissolved contaminant concentrations should be expected. Significant effects are not expected for

PCBs

[redacted]

may be reduced significantly by adsorption to the fine-grained material in the dikes.

[redacted]

Appendix B. The CDF effluent with hydraulic transfer would exceed Indiana

[redacted]

were considered (less than 100 feet), the concentrations associated with matchbox dredging would fall within the standards. No mixing zone, other than the stone-filled dike, would be required if the sediments were disposed mechanically.

[redacted]

consolidates to form a layer that can virtually seal the CDF. Consolidated dredged material can have a permeability as low as 10^{-9} cm/sec. In addition

[redacted]

264. Leaching tests have been run to estimate the water quality of the

[redacted]

quantities in the leachate. The results of the leaching tests are presented in Part III and Appendix C. The concentration of contaminants would be further attenuated by adsorption on clean materials that the leachate will [illegible]

[illegible] 265. [illegible] since the quantity of water in the deposited material that will be released during consolidation is much smaller. The water content of recently [illegible] mechanically deposited material would be about 130 percent. In addition, the permeability of the mechanically deposited material is smaller since the material is more consolidated. The only drawback of mechanical disposal is that the material does not spread as well and, consequently, may not seal the [illegible] the dikes where the PCB-contaminated sediments are to be disposed by either mechanical means or with a submerged diffuser should be lined to be relatively impermeable.

266. Runoff quality. Runoff should not pose a problem since the PCB- [illegible] should occur. Additional less contaminated material should be placed above the PCB-contaminated material to encapsulate the contaminants and prevent

runoff from contacting PCB-contaminated materials. In addition, all runoff will be filtered by the dikes before leaving the CDF and entering the lake.

267. Contaminant uptake. Encapsulating the PCB-contaminated dredged [illegible] under water in an enclosed area offshore. Consequently, plant and animal [illegible] was insignificant for sediments under water. The same sediment was toxic in the animal uptake test until sufficiently oxidized; consequently, there was no [illegible]

268. Volatilization. The PCB-contaminated materials, if hydraulically [illegible] CDF through a submerged inlet to minimize splashing and turbulence at the surface thereby minimizing stripping of [illegible] wetting would significantly release volatiles from the dredged material (Thibodeaux 1979, and Chiou and Shoup 1985). Therefore, it is important to [illegible]

269. Summary. The proposed in-water CDF appears to mitigate the poten- [illegible] cell. Several design and operational considerations need to be made regarding chemical clarification, oil removal, and sequencing the disposal projects.

particularly if a small mixing zone is permitted. The concentrations of iron, lead, phenol, PCBs, ammonia, and total phosphorus are likely to be somewhat higher than the standards if hydraulic disposal is used. Only the concentration of PCBs is expected to exceed the water quality standards when mechanical disposal is used.

Upland CDF

270. No specific upland CDF site or design was specified by the Chicago District for consideration, but it was assumed that such a site could be [redacted] dredged material.

[redacted] dredged material containment area. Each control measure is evaluated for its ability to fulfill the intent of TSCA land disposal regulations. As in the evaluation of the proposed in-lake CDF, effluent quality, leachate quality, [redacted] disposal methods are also included in the evaluation. Possible contaminant control measures for the upland site are summarized below and discussed in the following paragraphs.

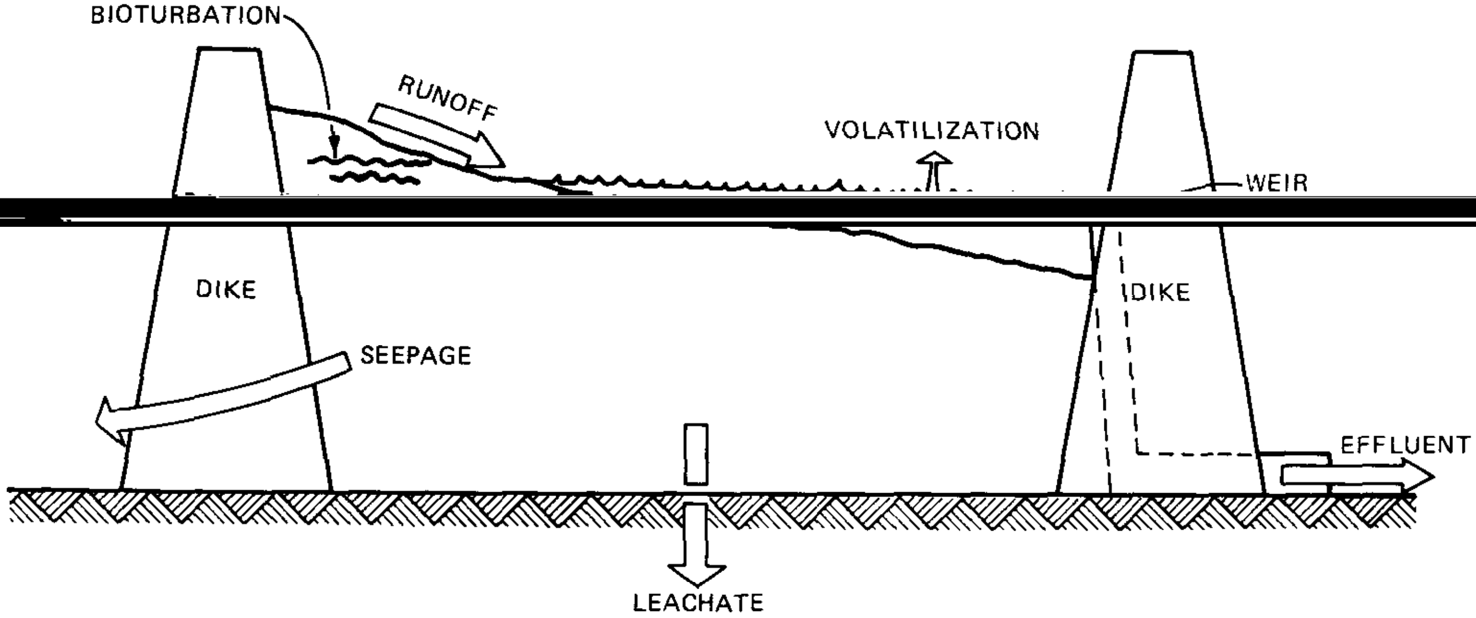


Figure 27. Contaminant pathways for an upland confined disposal facility

Possible Control Measures for Upland CDF

[redacted]

	Carbon Adsorption
Runoff	Filtration Carbon Adsorption Surface Cover
Volatilization	Surface Cover
Plant/Animal Uptake	Surface Cover
Leachate	Surface Cover Liner Leachate Collection and Treatment

272. Disposal in an upland site differs from disposal in the proposed in-lake CDF in numerous ways. Material in an upland site becomes aerobic and oxidized upon drying, while material placed below the lake level in an in-lake [redacted] aerobic, oxidized environment. During dewatering and drying at an upland site, volatile contaminants are released with the evaporation of site water. [redacted] surrounding environment is greater. In the in-lake CDF, it is proposed that

measures for maintaining effluent quality would be a major part of the design. If mechanical filling were used, effluent would be only a minor concern.

[redacted]

polymeric flocculant followed by secondary settling) is required for hydraulically handled sediments. Chemical clarification can reliably reduce the suspended solids concentration to about 20 mg/ℓ in a dredged material con-

[redacted]

tion is probably not needed to further reduce the suspended solids concentration for mechanical disposal. The concentration of contaminants associated

[redacted]

clarification (hydraulic dredging), or primary settling (mechanical dredging)

[redacted]

278. Filtration is required to remove additional suspended solids and produce an effluent essentially free of suspended solids. To employ filtration effectively, the influent to the filters should have a suspended solids concentration of less than 50 mg/ℓ to ensure a high quality effluent and to lessen maintenance and operational problems. The effluent quality following

[redacted]

[redacted]

Filtrate for sediments mechanically dredged and disposed is expected to have

[redacted]

lically handled sediments. Consequently, the mass of contaminant loss in the effluent is much smaller for mechanically handled sediments.

279. The effluent quality from the upland CDF, using hydraulic dredging/disposal would exceed most of the Indiana water quality standards for

[redacted]

the Indiana Harbor/Grand Calumet River (iron, phosphorus, ammonia, phenol, and

[redacted]

of site water collected from Indiana Harbor Canal for the analysis (0.3 µg/ℓ).

280. Carbon adsorption may be used to provide additional removal of the

[redacted]

tests were not run to evaluate this control measure, but based on the results

[redacted]

adsorption. Additional tests are needed to determine the probable effluent concentration for this measure and to evaluate the cost effectiveness of this control measure.

[redacted]

Runoff from the upland CDF following disposal of PCB-contaminated sediments would have high concentrations of suspended solids and attached contaminants (Table 6). After the sediments have dried and became oxidized, surface runoff [redacted]

It is assumed that the runoff would be contained within the diked area of the [redacted] before discharge. Filtration, as used for the CDF effluent, can remove most suspended solids from surface runoff, producing a discharge water quality as shown in Tables 6 and 7 (filtered runoff).

283. Filtered surface runoff from wet, anaerobic sediments has a quality [redacted]

[redacted]

[redacted]

after the sediments have been dewatered and consolidated sufficiently to allow access by heavy equipment. The time required for drying and consolidation of dredged material will depend on sediment characteristics, the method of dredging and disposal, the thickness of the dredged material lift, and

[redacted]

codisposal with less contaminated sediments, which could be placed on top of the PCB-contaminated sediments hydraulically. This would require an increase in the size (capacity) of the upland CDF.

[redacted]

tion (see discussion in Appendix G).

286. Controls for volatile loss from an upland CDF are more limited than

[redacted]

[redacted]

associated with surface runoff and contaminant uptake by plants and animals

[redacted]

Cover 1 consisted of only an 18-in. layer of clay loam topsoil on top of the graded surface of the partially dewatered dredged material. Cover 2 contained the same topsoil layer but it was underlain by a 24-in. compacted clay liner having a hydraulic conductivity of 1 X 10**(-7) cm/sec. The topsoil and dredged material were assumed to have a hydraulic conductivity of 1.38 X 10**(-4) cm/sec and 2.25 X 10**(-5) cm/sec, respectively. Cover 3 consisted of an 18-in. layer of topsoil covering a 12-in. drain layer of sand overlying the 24-in. clay liner described above. The sand had a hydraulic

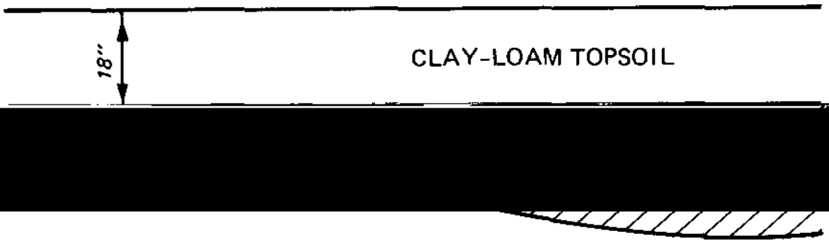
[redacted]

isolating the PCB-contaminated material from plants and animals. The thicker covers obviously provide better isolation and the hard, compacted, clay liner restricts root penetration and animal burrowing.

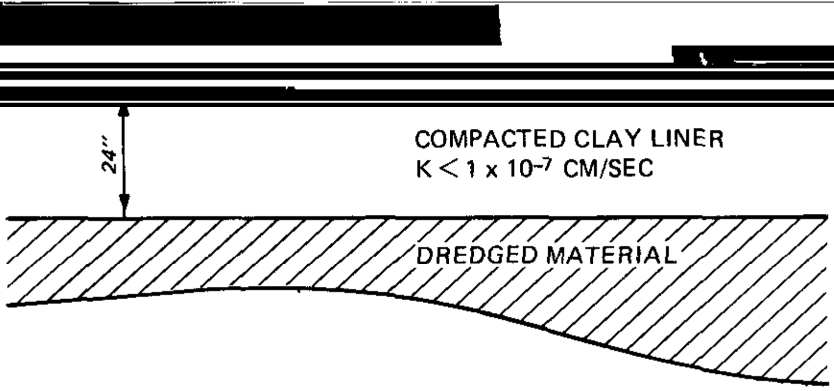
288. Infiltration through the cover and into the dredged material was

[redacted]

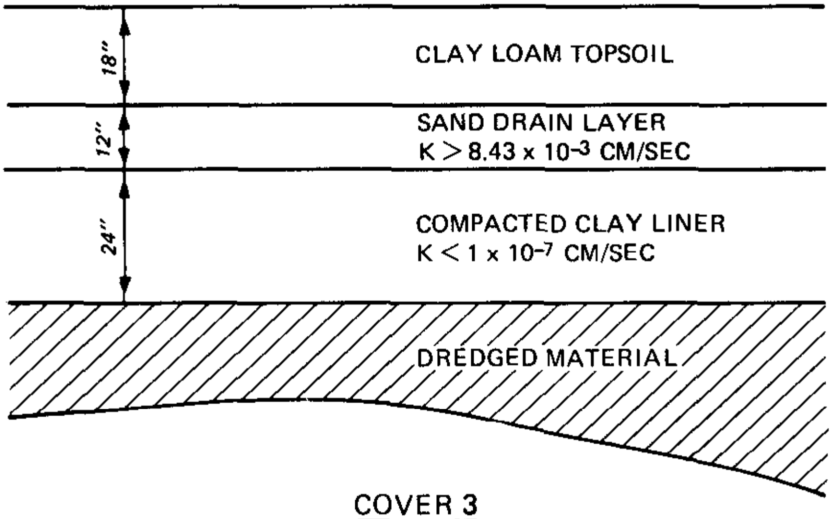
(Schroeder et al. 1984a and Schroeder et al. 1984b). Several assumptions were made to apply the model to the containment area design conditions. The HELP model's default climatic data base for Chicago, Illinois was assumed to be representative of climatic conditions at the upland site. The physical properties of the cover materials and the dredged material such as their



COVER 1



COVER 2



COVER 3

Figure 38. Typical [illegible]

porosities and saturated hydraulic conductivities were assumed to remain essentially unchanged during the five year modeling period. This assumption is not very good since significant consolidation of the dredged material is [illegible] have properties similar to that of the in-situ sediment. The topsoil was assumed to be vegetative with a fair stand of grass.

289. The precipitation averaged 34.08 in. per year during the modeling [illegible] is tabulated below for the various covers.

[illegible]

Cover Type	(in./year)	(Percent of Precipitation)
[illegible]	[illegible]	[illegible]
Cover 2	1.65	4.84
Cover 3	1.36	3.98

These results suggest that a drain layer in the cover does not substantially improve the performance of the cover and is probably unnecessary. The clay liner provides a very substantial reduction in the percolation besides additional protection against plant and animal uptake.

290. Additional reductions in percolation are practicably attainable only [illegible] 30 in. of drainable water for approximately an 11-ft depth of dredged

material. This corresponds to the volume of percolation through Cover 2

[redacted]

tion occurs, the leachate production rate will decrease. In the leaching permeameters, the hydraulic conductivity decreased drastically as the pore water leached out the bottom and the material consolidated. The hydraulic

[redacted]

potential for leachate production is largely controlled by the water content and consolidation of the dredged material, and the impact of percolation through the cover is small when a clay liner is used.

[redacted]

placed on the material by the weight of the cover. The drainage from this

[redacted]

tain contaminated pore water from the PCB-contaminated dredged material.

292. In summary, a cover composed of an 18-in. topsoil layer overlying a 24-in. clay liner provides excellent protection against release of contaminants by surface runoff, and uptake by plants and animals. The cover also

[redacted]

sand layer underlying the clay liner may aid the consolidation of the dredged

[redacted]

erosion. Cover maintenance should include a program to cut out woody species

[redacted]

bottom of the upland dredged material containment area were evaluated for

[redacted]

loam having a hydraulic conductivity of 1.45 X 10**(-6) cm/sec. Liner 2 con-

[redacted]

contained the same clay liner but it was overlain by a 12-in. sand layer. The sand layer was identical to that used in Cover 3 and had a hydraulic con-

[redacted]

294. The liners were evaluated using the HELP model to estimate percola-

[redacted]

model. The 20 years of climatic data were prepared by using the 5 years of

[redacted]

sufficient to observe the leachate production from draining the initially

[redacted]

evaluation was performed for each liner overlain by 10 ft of saturated dredged

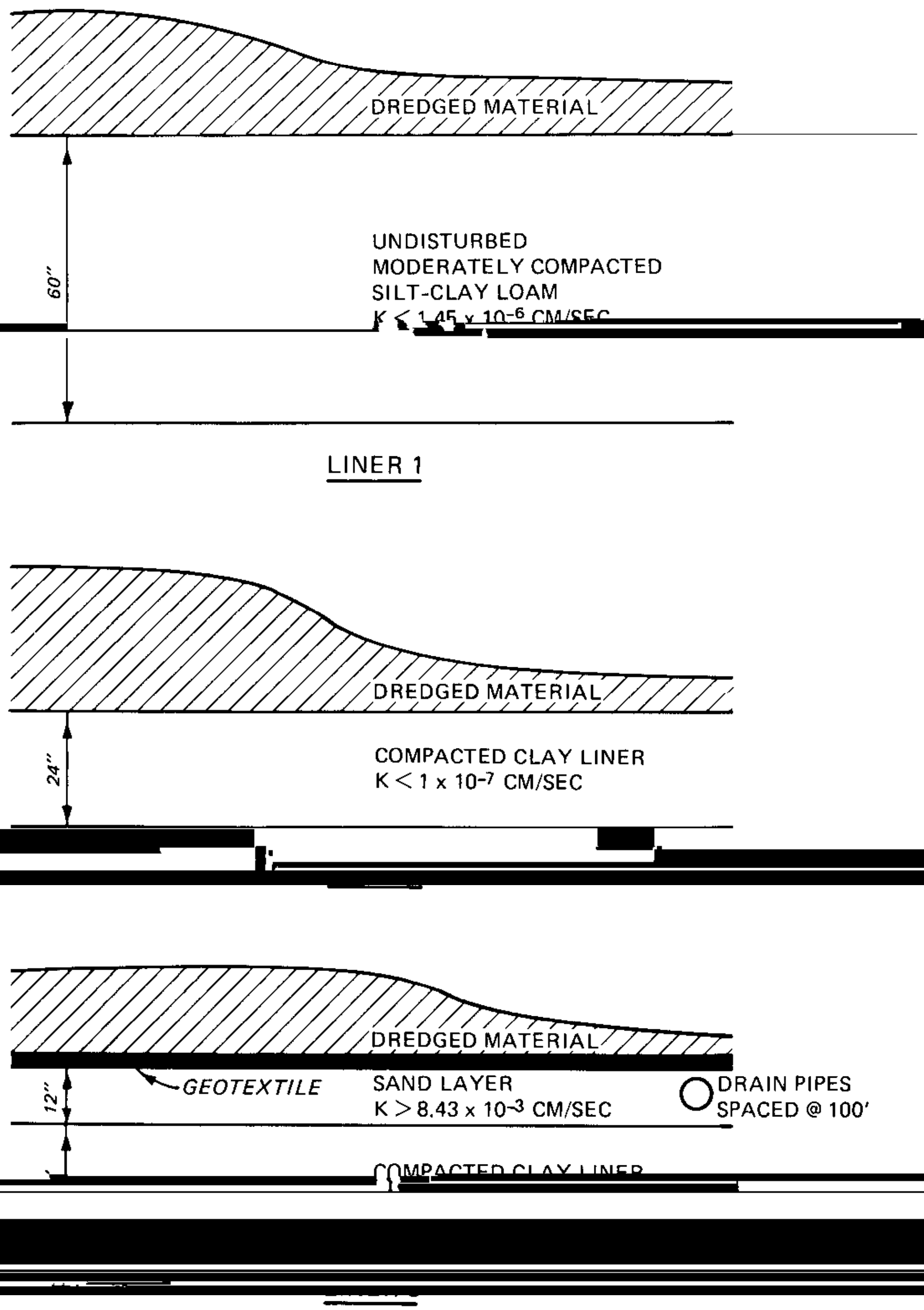


Figure 29. Typical liner designs

[redacted]

0.72 in./in. and 0.42 in./in., respectively. Its saturated hydraulic conduc-

[redacted]

the dredged material is expected as pore water leaches from the dredged

[redacted]

liner is greater than the rate at which water can move through the dredged

[redacted]

expected when a sand drainage layer for leachate collection is used.
Consequently, the leachate production rate is expected to decrease and be

[redacted]

in-place dredged material was assumed to have properties similar to that of the in-situ sediment.

295. The precipitation averaged 34.08 in. per year during the 20-year modeling period. Results of the model runs are summarized in Table 9. For

[redacted]

and 4.23 in. per year with Cover 2. The loss of leachate exceeds the infil-

[redacted]

Table 9

Summary of Liner Performance

	Percolation through Liner, in. (Average per year)*		Leachate Collection, in. (Average per year)*	
	Cover 1	Cover 2	Cover 1	Cover 2
Liner 1	10.20	4.23	-	-
Liner 2	7.10	[illegible]	[illegible]	[illegible]
Liner 3	1.28	1.26	8.88	2.94

---

* Values for each year decreased exponentially during the 20 year period.

saturated hydraulic conductivity is assumed to remain constant. The percola- [illegible]

Cover 2 the percolation rate is greater than the infiltration rate and only slightly less than the natural foundation liner. However, the percolation [illegible] through the compacted clay liner with leachate collection (Liner 3) averages 1.28 in. per year with Cover 1 and 1.26 in. per year with Cover 2. The effectiveness of this liner is essentially independent of the cover design but [illegible] 2.94 in. per year with Cover 2. The drainage rate for leachate collection is [illegible] the leachate production will be significantly lower. Liner 3 performs significantly better than the other liners. Leachate collection is important to reduce the impact of leachate on groundwater.

[illegible] by the installation of a synthetic flexible membrane liner on the surface of the clay liner. The value of these additional [illegible] presently difficult to assess without additional laboratory testing but sig- [illegible] concentration of contaminants in the leachate exceeds water quality standards

[redacted]

under aerobic, oxidizing conditions and for only chromium, lead, PCBs, and

[redacted]

all of it is likely to adsorb to the clay liner as evident by the high parti-

[redacted]

in this study and in the literature. The behavior of DOC in passing through the clay liner and foundation soils is unknown since its composition is unknown. It is expected that the DOC will have some affinity for soil since

[redacted]

[redacted]

concern when Liner 3 is employed without a flexible membrane liner.

297. In summary, a leachate collection system consisting of a 12-in. sand layer to collect leachate and a 24-in. clay liner to restrict percolation of leachate to the groundwater provides good protection against release of contaminants by leaching. The system can reduce leachate losses by as much as

[redacted]

required to assess the impact of the leachate quality on potential contamination of the groundwater.

298. Leachate treatment. As stated above, only DOC and PCBs are present [illegible]

to dredging projects where the leachate quality and quantity are likely to [illegible]

be the process of choice.

299. Summary. Disposal in an upland dredged material containment area [illegible]

and leachate treatment. Since the contaminants are predominantly associated with the suspended solids in the effluent, filtration is the minimum treatment [illegible]

a 24-in. compacted clay liner to restrict infiltration, reduce potential

[redacted]

site and to decrease the seepage rate. In addition, the performance of the

[redacted]

[redacted]

contaminants to acceptable levels.

[redacted]

contaminated material in Indiana Harbor have high concentrations of PCBs and

[redacted]

tions, contaminants may be transferred for a short period of time to the water

[redacted]

gation of PCB-laden sediments, Fulk, Gruber, and Wullschleger (1975), have shown that almost all the contaminants transferred to the water column were

[redacted]

disposal operations.

[redacted]

Research Program (DMRP) and the IOMT program. This part is a review of the

[redacted]

be done in Indiana Harbor. Also presented in this part is a description of

[redacted]

Dredging Equipment

302. Selection of the proper dredging equipment for any project includes analysis of the characteristics and quantity of material, distance to and type of disposal, dredging depth, level of contamination, and several other factors. There are several different alternative types of dredges that may be

[redacted]

However, lack of maneuverability in a restricted area precludes using a hopper dredge at Indiana Harbor.

304. A cutterhead suction dredge (Figure 30), using the proper operating techniques, limits sediment resuspension to the lower portion of the water column. Indeed, the cutterhead may be the most sensitive of any dredge type to changes in operating techniques. The sediment resuspended by a cutterhead dredge is dependent on thickness of cut, rate of swing, and cutter rotation

[redacted]

production (Hayes, Raymond, and McLellan 1984).

305. <u>Operational controls</u>. Operational controls will reduce the amount

[redacted]

(Huston and Huston 1976). Based on the impact of the factors described above,

[redacted]

are recommended:

a. Large sets, very thick cuts, and very shallow cuts should be

[redacted]

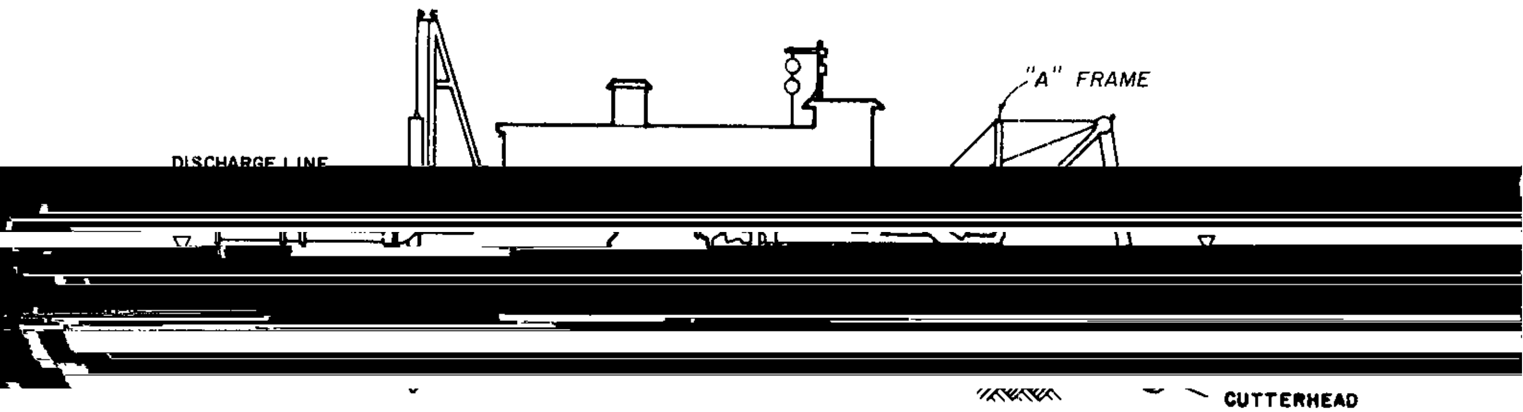


Figure 30. Cutterhead suction dredge

[illegible]

advance the dredge or using a wagger or spud carriage system.

c. Side slopes of channels are usually dredged by making a vertical box cut; the material on the upper half of the cut then sloughs to the specified slope. To minimize resuspension, the specified [illegible]

cut and remove most of the material, leaving a relatively thin [illegible]

306. The above operating techniques, properly implemented, will reduce [illegible]

the plume at Indiana Harbor. Previous studies (Hayes et al. 1984, Barnard 1978, and others) have indicated that the above-ambient concentration of suspended solids should be no greater than 500 mg/ℓ near the dredgehead, and [illegible]

307. Characteristics. The IOMT program has shown that mechanical dredges [illegible]

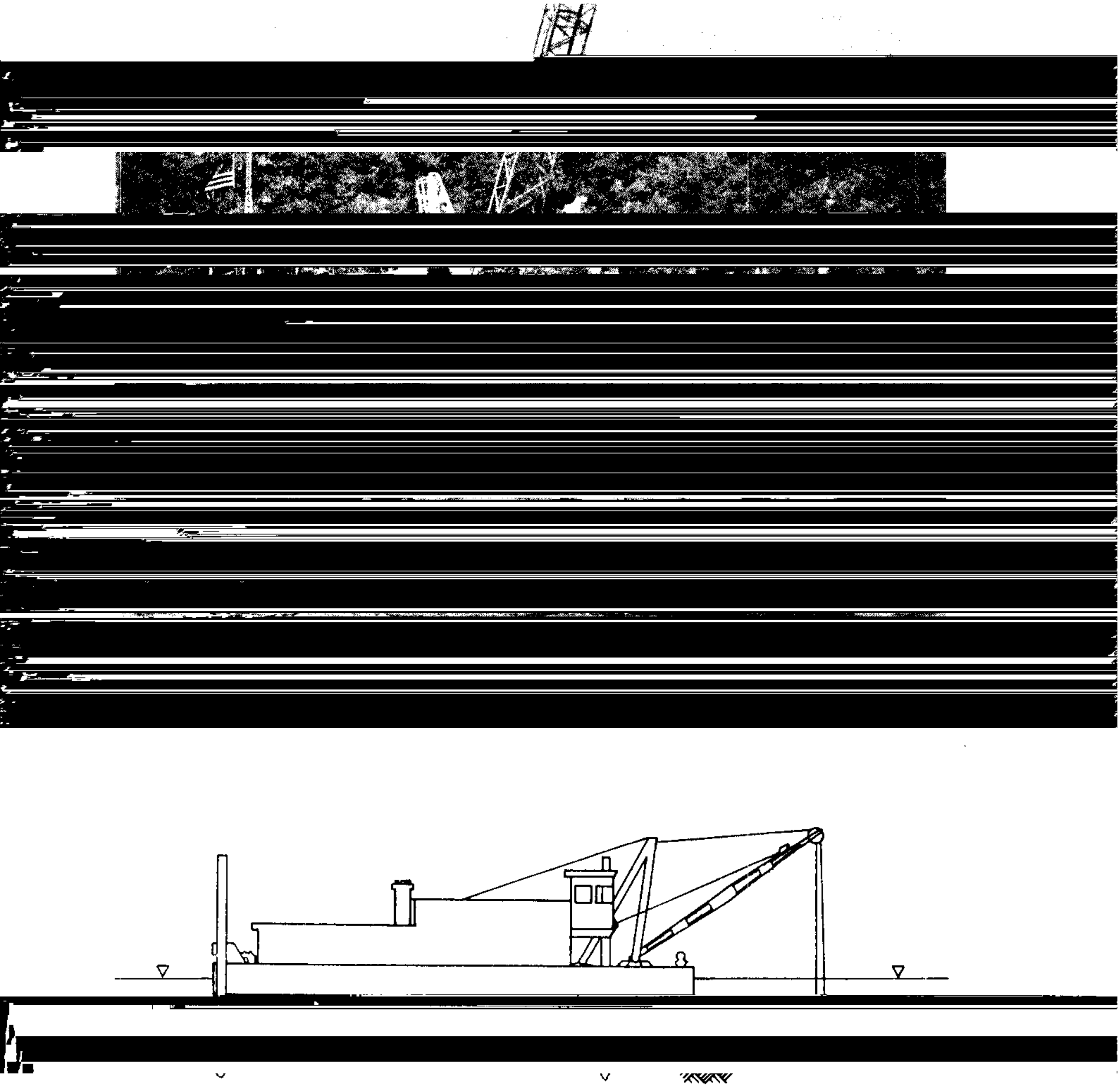


Figure 31. Clamshell dredge

[redacted]

enclosed bucket (Figure 32) has been developed in which the top is enclosed so

[redacted]

Comparisons between standard open clamshell bucket and an enclosed clamshell bucket indicate that enclosed buckets generate 30 to 70 percent less resuspension in the water column ~~than the open buckets. If a mechanical dredge is~~ used at Indiana Harbor, it should be an enclosed clamshell.

Special-purpose dredges

[redacted]

having highly contaminated sediments such as in Indiana Harbor. The major drawbacks of special-purpose dredges are their limited availability and their

[redacted]

312. The matchbox suction head is designed to dredge fine-grained material as close to in-situ density as possible, keep resuspension to a

[redacted]

dredgeheads were avoided in the matchbox design.

Figure 33. Dutch Matchbox dredge (provided by U.S. Army Engineer District, Chicago)

Dredged Material Transport and Placement

315. Dredged material is normally transported to a disposal site by towed or self-propelled barges or by pipeline. Both of these transport methods can be used in placement of the dredged material in a CDF or for open-water disposal. Disposal in a CDF would consist of a reslurry and pumpout operation or [redacted] split hull barges or direct pumpout from the pipeline. DMRP studies have shown (Neal et al. 1978) that an open-water pipeline discharge would produce [redacted]

Pipelines

316. Some dredging operations, such as cutterhead, use floating pipelines to transport the dredged material from the dredge to the disposal site. These [redacted] of material quickly with no or short term environmental impacts. The pipe- [redacted] dredging location.

317. If not properly maintained, floating pipelines used in Indiana [redacted] is not washed out, material in the line will settle to the bottom with pos- [redacted]

it is thoroughly washed out, the material remaining in the line near the break [redacted] however, if the line is properly washed out, only clean water will escape when the break is made, and sediment suspension will be avoided.

318. Two types of pipelines are available for dredging discharge lines: [redacted] tions between sections of steel line are usually made with ball joints to give flexibility to the line. If the joints are old and their gaskets worn, [redacted] lighter than water and can therefore be towed in long lengths to the dredging site, and the pipe's flexibility allows it to be bent to radii approximately [redacted]

[redacted] self-propelled and can be scows, which must be pumped out, or split hull [redacted] allowed to overflow when dredging in Indiana Harbor. When using a hopper barge for disposing of the material, the hopper doors should open quickly and [redacted]

Special equipment

320. The amount of water column turbidity generated by an open-water [redacted] the slurry parallel to and just above the bottom at a low velocity. The entire discharge system is composed of a submerged diffuser and an anchored support barge attached to the end of the discharge pipeline that positions the diffuser relative to the bottom. [redacted] diffuser with a cross-sectional area ratio of 4:1 followed by a combined [redacted] prior to discharge is reduced by a factor of 16, yet the dredge's discharge [redacted] affected in any way by the diffuser. The conical and turning/radial diffuser sections are joined to form the diffuser assembly, which is flange mounted to the discharge pipeline. An abrasion-resistant impingement plate is supported from the diffuser assembly by 4 to 6 struts. The parallel conical surface of [redacted]

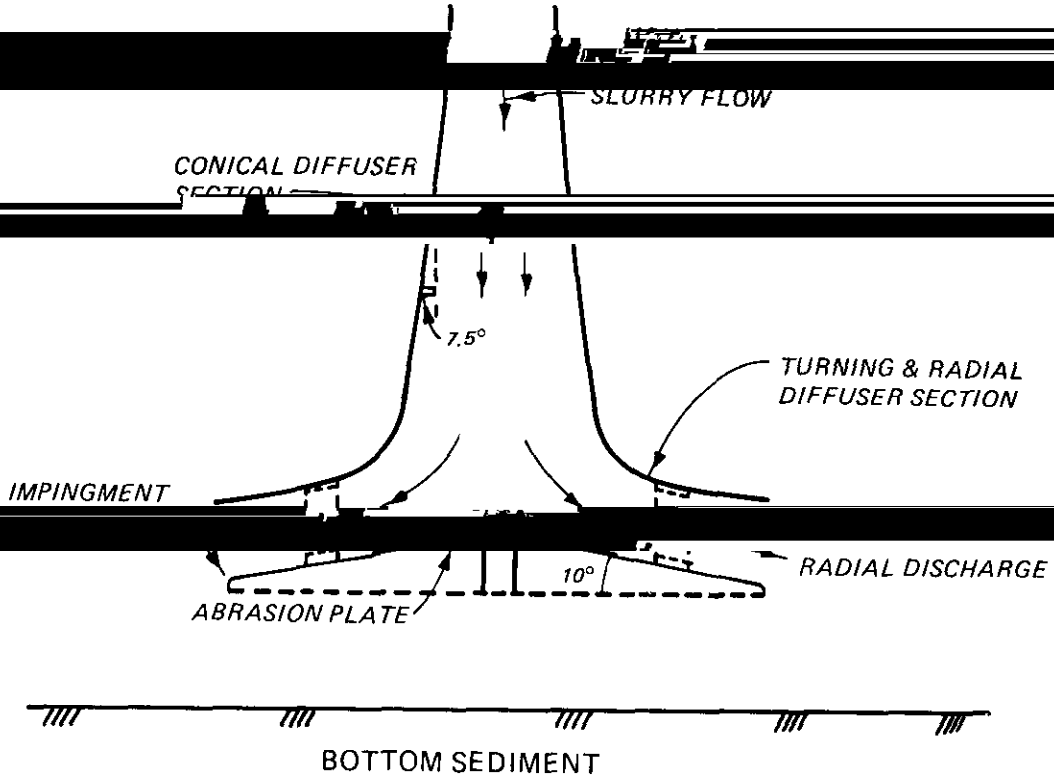


Figure 34. Submerged diffuser system

[illegible]

fuser may be adjusted by changing the length of the struts supporting the [illegible]

[illegible] can be controlled. The strut length [illegible]

[illegible] the pipe diameter.

322. [illegible] barge (Figure 35) [illegible] diffuser to provide both support and the capability for lowering the diffuser. The barge also provides a platform for the diffuser while it is being adjusted, serviced, or moved to a new site. Figure 35 also depicts the use of [illegible]

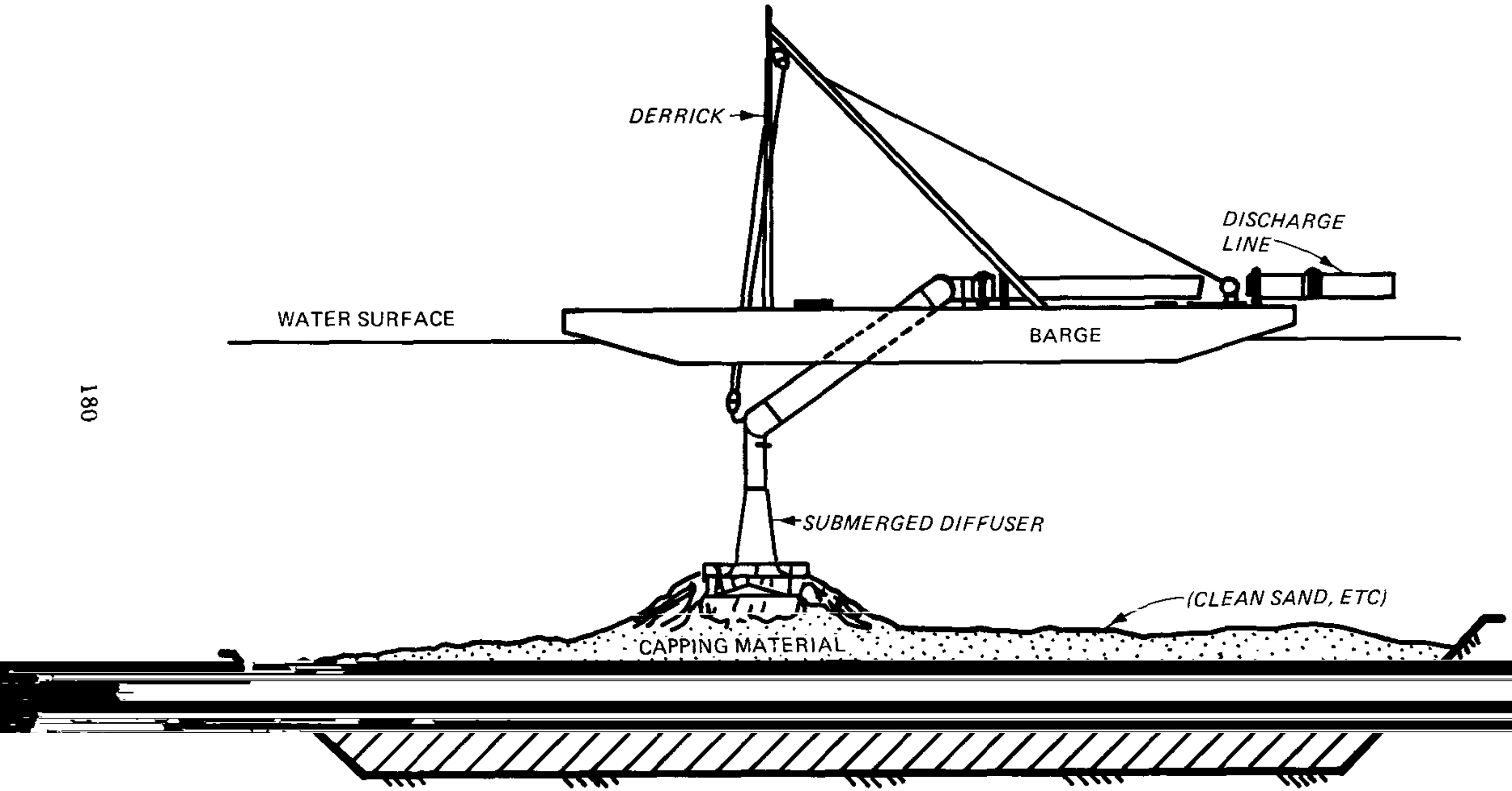


Figure 35. Submerged diffuser system, including the diffuser and discharge barge

[redacted]

323. The diffuser has a great deal of potential for eliminating turbidity [redacted] dredged material. The slurry remains in the pipeline/diffuser until it is [redacted] velocity, thus eliminating all interaction of the slurry with the water column above the diffuser.

Navigational and positioning equipment

[redacted] option of disposal is selected. The type of navigational and positioning [redacted] instruments should be accurate enough. These types of navigational aids lose their accuracy as the site moves offshore. Therefore, several different [redacted] A more detailed analysis will be performed if the CAD disposal option is chosen.

[redacted]

the Dutch matchbox dredge, and a submerged diffuser were conducted in the Chicago District in August through October of 1985. The demonstrations were

[redacted]

measure suspended solids, dredge production, and possible release of contaminants. The details and results of these equipment demonstrations will be

[redacted]

Clamshell field evaluation

326. The clamshell dredge demonstration was conducted during ongoing maintenance dredging occurring in Calumet River. This dredging was done using

[redacted]

suspended solids plume, observations of the dredge operating characteristics,

[redacted]

clamshell dredge field study incorporated one day of background sampling and two days of plume monitoring in the interior Calumet River. A total of

[redacted]
ment concentration at least 10 mg/ℓ above ambient of 3.5 acres near the bottom, 1.8 acres at middepth, and 1.7 acres near the surface. This 10 mg/ℓ level also corresponded to approximately twice the concentration of the

[redacted]
by the impact, penetration, and withdrawal of the bucket from the sediment. The highest concentrations and greatest variability of the plume were found near the bottom where samples collected within 50 ft of the dredge ranged from 540 mg/ℓ to 49 mg/ℓ.

Hydraulic dredge field evaluation

327. The cutterhead demonstration was conducted in Calumet Harbor near

[redacted]
production rate, swing speed, cutter rotational speed, and depth of each cut.

[redacted]
and 95 percent of the total water depth. The field demonstration of the Dutch matchbox dredge was also conducted at Calumet Harbor. The dredge was the same one used in the cutterhead suction demonstration, except that the cutterhead was removed and the matchbox head installed. The monitoring plan was similar

[redacted]

since the matchbox has no cutter, but the operation of both dredges was similar. The demonstration of the matchbox suction head dredge was the first use of the dredge in this country.

[illegible] 90 percent of the total depth. No plume of this concentration was identified [illegible] was identified above this depth for the cutterhead operation. The consensus [illegible] of 100 ft or greater [illegible]

Submerged diffuser field evaluation

[illegible] with the matchbox dredge demonstration (Figure 36). The demonstration site was inside the Chicago Area CDF located at Calumet Harbor. The submerged [illegible] diffuser in reducing the velocity of the dredged material and limiting the suspended solids plume to the lower portion of the water column. Velocity [illegible]

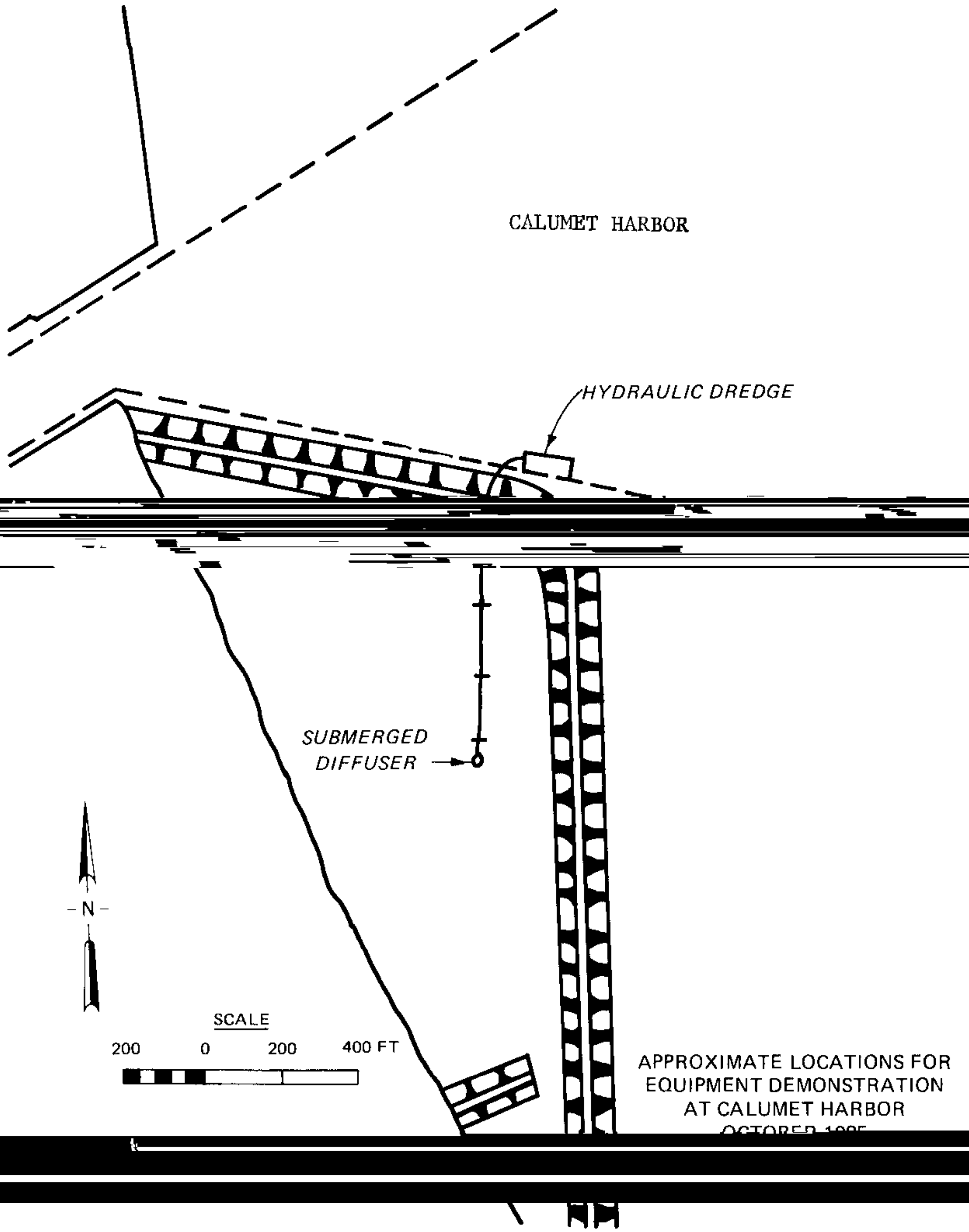


Figure 36. Submerged diff [illegible]

diffuser exit in 20 ft of water, water column samples were collected at increments of 5, 50, 80, and 95 percent total depth, every 5 minutes [illegible] 30 percent of the water column, and reduce suspended sediment effects in the upper portion of the water.

Discussion and Potential Application

330. Based on the results of these demonstrations, both cutterhead and [illegible] little resuspension when operated properly. The data for the cutterhead operation shows very low levels of resuspension near the cutterhead. Additional analysis of the cutterhead data may provide insight to the impact of operational parameters on the resuspension process.

331. [illegible] sion. However, the data for the matchbox operation reflected precise positioning problems. The operator could not determine when the top of the [illegible]

[redacted] line velocity instrumentation to control the pump speed via computer. This equipment is available (Taylor 1986) and although a properly designed system may not increase production it would optimize the efficiency, density of dredged slurry, and effectiveness, precise removal of sediment layer, of the matchbox dredge.

332. The submerged diffuser was able to reduce the pipeline exit velocity by 75 to 80 percent. However, the exit velocities were 3 to 4 times greater [redacted] column, and reduce suspended sediment effects in the upper portion of the water.

[redacted] and physical characteristics of sediment. Using the DMRP and IOMT research programs as background and the results of the demonstrations, several innovative dredging alternatives have been identified for the Indiana Harbor [redacted] bucket, a cutterhead dredge operated under specific guidelines, and a Dutch matchbox suction head dredge. Transport techniques to reduce sediment resuspension include proper care when handling, replacing and extending pipelines

[redacted]

PART VI: SUMMARY AND CONCLUSIONS

[redacted]

Summary

[redacted]

conditions of various disposal alternatives. The Management Strategy was used

[redacted]

examine the interrelationships of the problems and potential solutions, and to determine what restrictions are required for each disposal alternative under consideration. Effluent quality, surface runoff quality, leachate quality, settling, consolidation, plant contaminant uptake, and animal contaminant

[redacted]

tained aquatic disposal, confined disposal in an in-lake CDF, and confined

[redacted]

fill were also evaluated for purposes of comparison. Application of the Management Strategy identified the required contaminant control measures for each of the dredged material disposal alternatives. New emerging technologies were evaluated for application to the PCB-contaminated sediments but these technologies were limited to contaminant containment and immobilization techniques. No innovative contaminant destruction technologies were found to [redacted]

were conducted to provide information for equipment selection. Specific conclusions for each aspect of the study are given in the following [redacted] paragraphs.

Conclusions

Potential problems and testing results

336. Criteria for selection of controls. Results from effluent and runoff tests were compared with Indiana water quality standards and [redacted] for comparison with leachate test results. The comparisons of test results [redacted] measures for the disposal alternatives considered. The final design of the selected disposal alternative should be based on later comparisons of test [redacted] agencies.

[redacted] settling tests, effluent quality for the in-lake CDF and upland disposal [redacted]

ponded waters. If mixing is considered, removal of suspended solids will [redacted]

[redacted]

338. Surface runoff. The results of the surface runoff studies indicated

[redacted]

Indiana Harbor sediments were placed in the upland environment without surface capping or covering with a low permeability material. During the early, wet, anaerobic stages, contaminants were mostly bound to the suspended solids in

[redacted]

of concern when compared with the USEPA Maximum Criteria for the Protection of

[redacted]

Harbor sediments are tightly bound to the sediment solids. Metal concentra-

[redacted]

sediment. The fraction of metals resistant to leaching was generally greater

[redacted]

Harbor sediments should not be of major concern.

340. Batch testing of organic contaminant releases under anaerobic and aerobic conditions has also shown that the majority of these compounds are tightly bound to the sediment. The batch leaching data showed organic contaminant releases to be very low, and this was confirmed in the permeameter

[redacted]

release at the disposal site.

342. Solidification/stabilization of contaminated sediments. Solidification/stabilization reduced the leachability of arsenic, cadmium, chromium, lead, and zinc. Cadmium and zinc were completely immobilized by some processes. Because some solidification/stabilization tend to increase

[redacted]

the leachable metal concentration, careful process selection is needed to maximize chemical stabilization. The most effective processes for metal

[redacted]

available to evaluate the potential of solidification/stabilization technology to reduce the leachability of specific organic compounds.

[redacted]

344. Plant contaminant uptake. Plant bioassays indicated high electrical conductivity, potentially low available nitrogen and phosphorus, as well as low concentrations of unknown organics that could limit plant growth. Plant [redacted]

upland environment.

[redacted]

[redacted]

conditions may become habitable and develop into a viable, productive ecosystem. This has occurred at the Times Beach disposal site at Buffalo, NY, [redacted]

the site became biologically productive.

Disposal alternatives

[redacted]

The migration of sediment contaminants in any waterway is primarily the result

[redacted]

GCR/IHC. Existing data indicates that the Indiana Harbor navigation channel

[redacted]

otherwise have been transported to Lake Michigan. The siltation of the chan-

[redacted]

sediment trap.

349. TSCA-approved alternatives. The estimated costs of TSCA approved

[redacted]

fill for PCB-contaminated sediments are far beyond the limits which could be

[redacted]

methods of disposal approved by the USEPA Regional Administrator appear to be the only feasible option available to the Corps under this funding authority.

[redacted]

broaden the disposal options available to the Chicago District. In laboratory tests, a 12 in. layer of Lake Michigan sediment overlying Indiana Harbor sedi-

[redacted]

minimum cap depth of 20 in. is needed to maintain an effective chemical seal.

[redacted]

handling the entire volumes of PCB contaminated sediment.

[redacted]

[redacted]
the 200,000 cu yd of PCB-contaminated material.

353. Use of a two-celled CDF with filter dikes should remove virtually all suspended solids and associated contaminants from the filtered effluent. The effluent from the in-lake CDF would meet Indiana Lake Michigan water quality standards for all parameters, except PCB's which would approach ambient Lake concentrations. The effective particle size of sand used in the CDF filter dike section should be selected to prevent clogging during the life of the disposal area.

354. Design and operational controls for the CDF should also include chemical clarification, oil removal, and sequencing of dredged material disposal to provide maximum environmental protection.

355. The chronological order of the dredging projects should be arranged [redacted] and contaminant loss through volatilization.

356. Upland CDF. No specific site has been identified for an upland confined disposal facility. A number of control alternatives were evaluated for their ability to limit contaminant loss. Effluent from an upland CDF during hydraulic dredging would require chemical clarification and filtration [redacted] at a minimum. The effluent would exceed Indiana Harbor water quality [redacted]

357. Surface runoff from an upland CDF should be controlled. Filtration and carbon adsorption may be necessary for treatment of runoff until a surface

[redacted]

layer of compacted clay would restricted infiltration, reduce potential leachate, and prevent contaminant loss in surface runoff and by plant and

[redacted]

[redacted]

Dredging and disposal equipment

359. Performance of a clamshell dredge, a conventional cutterhead hydraulic dredge, and an innovative matchbox hydraulic dredge were compared in

[redacted]

[redacted]

material in open-water sites showed that the diffuser restricted material resuspension to the lower 20 to 30 percent of the water column and greatly

[redacted]

Dredging and disposal alternatives

361. The feasible dredging and disposal alternatives identified for the PCB-contaminated sediments included CAD, in-lake CDF disposal, and upland confined disposal. With appropriate dredging equipment, disposal site designs, and contaminant control measures, any of the three disposal methods

[redacted]

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